Attachment B24

Air Quality Assessment – Waterloo Estate (South) – Land and Housing Corporation

WATERLOO SOUTH - AIR QUALITY ASSESSMENT

Waterloo Estate
Air Quality Assessment

Prepared for:

NSW Land and Housing Corporation
219-241 Cleveland Street
Strawberry Hills NSW 2016

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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 Waterloo South. 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).

On 19 May 2017, the Minister issued Study Requirements for the Waterloo Precinct. The key study requirements relating to air quality are presented in the table below.

Waterloo SSP - Study Requirements

Requirement	Section Reference
18.2. *Consider and assess potential pollution impacts from the proposed rezoning including, but not limited to, water, air, noise and light pollution.*	**Section 10**
18.3. *Provide an air quality assessment for the proposal. The assessment will address the relevant policies and guidelines in relation to air quality including State Environmental Planning Policy (Infrastructure) 2007 and the Development Near Rail Corridors and Busy Roads – Interim Guideline.*	**Section 5 and 10**
18.4. *These assessments should also consider other current local air and noise issues in the Waterloo area, including potential cumulative impacts from the Waterloo Estate.*	**Section 8**
18.5. *Identify and map current and proposed future sensitive receptors (e.g. residential uses, schools, child care centres).*	**Section 4.3**
18.6. *Identify current and likely future noise, vibration and pollution affecting the precinct, including sources and nature and impact. Site monitoring will be required to determine current road noise levels on Botany Road. 3D mapping to clearly communicate these impacts, including demonstrating for example how noise reduces with distance from source, is desirable.*	**Section 6**
18.7. *Model the likely future noise, vibration and pollution scenario based on 3D block envelope diagrams prepared by the urban designer. This is to include road and rail noise.*	**Section 10.1**
18.9. *Outline the recommended measures relating to noise, vibration and pollution to minimise the nuisance and harm to people or property within the precinct.*	**Section 11**

The primary source of air emissions in the area immediately surrounding Waterloo South was identified as vehicles travelling along McEvoy Street and other local roads.

In order to gain a better understanding of the potential worst case air pollutant concentrations within Waterloo South 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 PM_{10} and $PM_{2.5}$) 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.

EXECUTIVE SUMMARY

It is noted that a number of conservative assumptions have been made for the modelling including the assumption that vehicles travel at a speed of 10 km/hr (potential worst case emission rate that would be representative of congested traffic conditions) throughout the day and that the 2036 vehicle fleet emission rates are similar to that of the 2010 vehicle fleet (ie improvements in emissions performance of newer cars was not accounted for).

The results of the cumulative impact assessment indicated that traffic on the surrounding road network has potential to result in slight exceedances of the ambient air quality criteria for PM_{10} and $PM_{2.5}$ at locations within Waterloo South, particularly close to McEvoy Street. Exceedances of the 24 hour average PM_{10} and $PM_{2.5}$ ambient air quality criteria are limited to days with high regional levels of particulates due to natural causes (bushfires/hazard reduction burns/dust storms).

Mitigation measures consistent with Section 4.4 of the Guideline have been incorporated into the concept design of Waterloo South. These include:

- Minimising the formation of urban canyons by having buildings of different heights interspersed.
- For buildings along McEvoy Street:
  - Locating no sensitive receptors on the first two floors.
  - Reducing the number of south facing apartments by designing building cores to the south.
  - Provision of only corner apartments to the south.
  - Provision of wintergardens to the south facade with fixed glazing to the south and operable windows to the side facade.

The mitigation measures outlined above will minimise any potential for sensitive receptors to be exposed to high levels of pollutants emitted from vehicles travelling on the nearby road network. It is noted that annual $PM_{2.5}$ could potentially exceed its ambient air quality criterion at all locations within Waterloo South due to high background concentrations.

Other emission sources in the local area that could potentially impact on air quality within Waterloo South were identified as service stations, automotive workshops and food outlets. The potential for off-site air quality impacts due to these activities was assessed using a qualitative risk-based approach. Based on this qualitative risk-based assessment, taking into account the nature and scale of these activities and distance from Waterloo South, it was concluded that they do not have any significant potential to adversely impact on air quality within Waterloo South. No further assessment of these activities is therefore considered to be warranted.

In addition to the above, emission sources within Waterloo South (e.g. food outlets) could potentially lead to amenity/nuisance impacts at surrounding sensitive receptors or at residential locations within Waterloo South itself. The risk of any impacts would depend on the type and scale of the activities, the location of the activity relative to sensitive receptors, and any emissions controls incorporated into the design (e.g. filtration/control of emissions etc). It is therefore recommended that further assessment of any potentially air polluting activities proposed within Waterloo South 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.

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

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Abbreviations

%	percent
°C	degrees Celsius
µg	microgram
$\mu g/m^3$	microgram per cubic metre
AHD	Australian Height Datum
AQA	Air Quality Assessment
AWS	Automatic Weather Station
ANZEEC	Australian and New Zealand Environment and Conservation Council
BoM	Bureau of Meteorology
CBD	Central Business District
CO	carbon monoxide
CO_2	carbon dioxide
DoE	NSW Department of Environment (now NSW Office of Environment and Heritage)
DPIE	NSW Department of Planning, Industry and Environment
EETM	Emission Estimation Technique Manual
g	gram
GFA	Gross Floor Area
ha	Hectares
km	kilometre
LAHC	Land and Housing Corporation
LGA	Local Government Area
m/s	metre per second
m^3	cubic metre
mg/m^3	milligram per cubic metre
NEPC	National Environment Protection Council
NO	nitric oxide
NHMRC	National Health and Medical Research Council
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
NPI	National Pollutant Inventory (Australia)
NSW EES	NSW Department of Planning, Industry and Environment’s Environment, Energy and Science group
NSW OEH	New South Wales Office of Environment and Heritage
O_3	ozone
OLM	Ozone Limited Method
ou	Odour units
PM	particulate matter
PM_{10}	particular matter with an equivalent aerodynamic diameter of 10 microns or less
$PM_{2.5}$	particular matter with an equivalent aerodynamic diameter of 2.5 microns or less
pphm	parts per hundred million (10^8)
ppm	parts per million (10^6)
s	second

SO_2	sulphur dioxide
SSP	State Significant Precinct
sqm	Square metres
TSP	total suspended particulate matter
TVOC	Total volatile organic compounds
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VKT	Vehicle kilometres travelled
WHO	World Health Organization

Glossary

air dispersion model	A computer-based software program which provides a mathematical prediction of how pollutants from a source will be distributed in the surrounding area under specific conditions of wind, temperature, humidity and other environmental factors.
ambient	Pertaining to the surrounding environment or prevailing conditions.
atmosphere	A gaseous mass surrounding the planet that is retained by Earth's gravity. It is divided into five layers, with most of the weather and clouds found in the first layer.
atmospheric stability	The tendency of the atmosphere to resist or enhance vertical motion.
background	The existing air quality in the Project area excluding the impacts from the Project.
CALMET	A meteorological model that develops wind and temperature fields on a three-dimensional gridded modelling domain.
combustion	The process of burning. A chemical change, especially oxidation, accompanied by the production of heat and light.
dust deposition	Settling of particulate matter out of the air through gravitational effects (dry deposition) and scavenging by rain and snow (wet deposition).
dispersion	The spreading and dilution of substances emitted in a medium (e.g., air or water) through turbulence and mixing effects.
diurnal	Relating to or occurring in a 24-hour period; daily.
downwind	The direction in which the wind is blowing.
epidemiological	The branch of medicine that deals with the study of the causes, distribution, and control of disease in populations.
emissions inventory	A database that lists, by source, the amount of air pollutants discharged into the atmosphere from a facility over a set period of time (e.g. per annum, per hour)
fossil fuel	A natural fuel such as coal, diesel or gas, formed in the geological past from the remains of living organisms.
fugitive emissions	Pollutants which escape from an industrial process due to leakage, materials handling, transfer, or storage.
GRAL	A Lagrangian dispersion model that predicts pollutant concentrations by simulating the movement of individual ‘particles’ of a pollutant emitted from a source along trajectories in a three-dimensional wind field.
GRAMM	A Eulerian prognostic, mesoscale wind field model that is the meteorological driver for GRAL.
impact assessment criteria	The prescribed level of a pollutant in the outside air that should not be exceeded during a specific time period to protect public health.
guideline	A general rule, principle, or piece of advice. A statement or other indication of policy or procedure by which to determine a course of action.
meteorological	The science that deals with the phenomena of the atmosphere, especially weather and weather conditions.

mixing height	The height to which the lower atmosphere will undergo mechanical or turbulent mixing, producing a nearly homogeneous air mass.
modelling domain	The area over which the model is making predictions.
particulate	Of, relating to, or formed of minute separate particles. A minute separate particle, as of a granular substance or powder.
plume	A space in air, water, or soil containing pollutants released from a point source.
pollutant	A substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource.
prognostic	A prediction of the value of variables for some time in the future on the basis of the values at the current or previous times.
qualitative assessment	An assessment of impacts based on a subjective, non-statistical oriented analysis.
quantitative assessment	An assessment of impacts based on estimates of emission rates and air dispersion modelling techniques to provide estimate values of ground level pollutant concentrations.
receptor	Coordinate locations specified in an air dispersion model where pollutant concentrations are calculated by the model.
sensitive receptor	Locations such as residential dwellings, hospitals, churches, schools, recreation areas etc., where people (particularly the young and elderly) may often be present.
spatial variation	Pertaining to variations across an area.
synoptic meteorological data	A surface weather observation, made at periodic times (usually at 3-hourly and 6-hourly intervals), of sky cover, state of the sky, cloud height, atmospheric pressure reduced to sea level, temperature, dew point, wind speed and direction, amount of precipitation, hydrometeors and lithometeors, and special phenomena that prevail at the time of the observation or have been observed since the previous specified observation.
topography	Detailed mapping or charting of the features of a relatively small area, district, or locality.
volatile organic compounds	All organic compounds (substances made up of predominantly carbon and hydrogen) with boiling temperatures in the range of 50 to 260°C, excluding pesticides. This means that they are likely to be present as a vapour or gas in normal ambient temperatures.
wind direction	The direction from which the wind is blowing.
windrose	A meteorological diagram depicting the distribution of wind direction and speed at a location over a period of time.

1 Introduction

The Greater Sydney Region Plan and Eastern City District Plan seek to align growth with infrastructure, including transport, social and green infrastructure. With the catalyst of Waterloo Metro Station, there is an opportunity to deliver urban renewal to Waterloo Estate that will create great spaces and places for people to live, work and visit.

The proposed rezoning of Waterloo Estate is to be staged over the next 20 years to enable a coordinated renewal approach that minimises disruption for existing tenants and allows for the up-front delivery of key public domain elements such as public open space. Aligned to this staged approach, Waterloo Estate comprises three separate, but adjoining and inter-related stages:

- Waterloo South;
- Waterloo Central; and
- Waterloo North.

Waterloo South has been identified as the first stage for renewal. The lower number and density social housing dwellings spread over a relatively large area, makes Waterloo South ideal as a first sub-precinct, as new housing can be provided with the least disruption for existing tenants and early delivery of key public domain elements, such as public open space.

A planning proposal for Waterloo South is being led by NSW Land and Housing Corporation (LAHC). This will set out the strategic justification for the proposal and provide an assessment of the relevant strategic plans, state environmental planning policies, ministerial directions and the environmental, social and economic impacts of the proposed amendment. The outcome of this planning proposal will be a revised planning framework that will enable future development applications for the redevelopment of Waterloo South. The proposed planning framework that is subject of this planning proposal, includes:

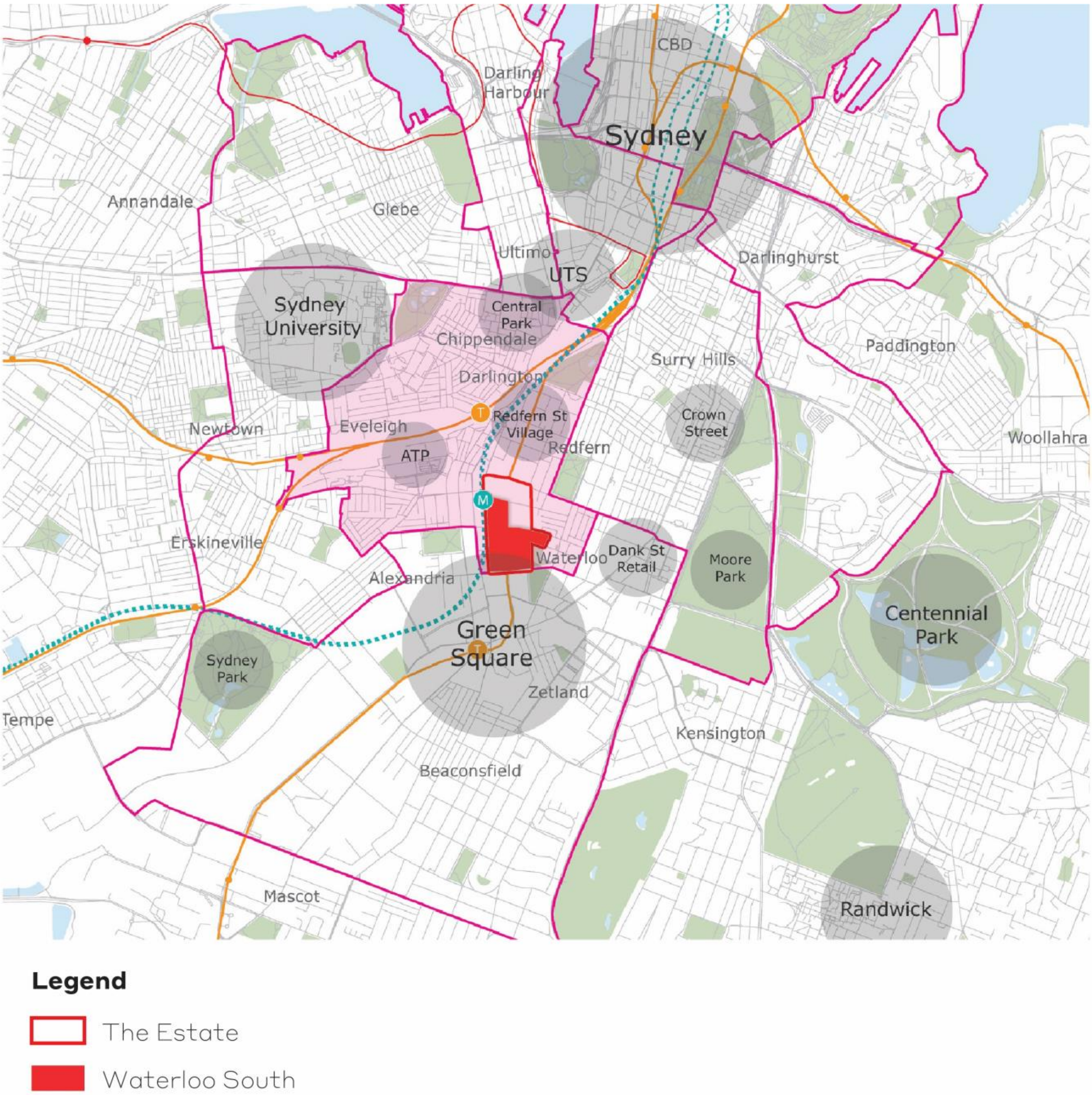
- **Amendments to the Sydney Local Environmental Plan 2012** – This will include amendments to the zoning and development standards (i.e. maximum building heights and floor space ratio) applied to Waterloo South. Precinct-specific local provisions may also be included.
- **A Development Control Plan (DCP) –** This will be a new part inserted into 'Section 5: Specific Areas' of the Sydney DCP 2012 and include detailed controls to inform future development of Waterloo South.
- **An infrastructure framework –** in depth needs analysis of the infrastructure required to service the needs of the future community including open space, community facilities and servicing infrastructure.

Waterloo Estate

Waterloo Estate is located approximately 3.3 km south-southwest of the Sydney CBD in the suburb of Waterloo (refer to **Figure 1**). It is located entirely within the City of Sydney local government area (LGA). Waterloo Estate is situated approximately 0.6km from Redfern train station and 0.5 km from Australia Technology Park. The precinct adjoins the new Waterloo Metro Station, scheduled to open in 2024. The Waterloo Metro Quarter adjoins Waterloo Estate and includes the station and over station development, and was rezoned in 2019. Waterloo Estate comprises land bounded by Cope, Phillip, Pitt and McEvoy Street, including an additional area bounded by Wellington, Gibson, Kellick and Pitt Streets. It has an approximate gross site area of 18.98 ha (14.4 ha excluding roads). Waterloo Estate currently comprises 2,012 social housing dwellings owned by LAHC, 125 private dwellings, a small group of shops and community uses on the corner of Wellington and George Streets, and commercial properties on the southeast corner of Cope and Wellington Streets.

A map of Waterloo Estate and relevant boundaries is illustrated in **Figure 2**.

Figure 1 Location plan of Waterloo Estate and Waterloo South



Source: Turner Studio

Waterloo South

Waterloo South includes land bounded by Cope, Raglan, George, Wellington, Gibson, Kellick, Pitt and McEvoy Streets, and has an approximate gross site area of 12.32 ha (approximately 65% of the total Estate).

Waterloo South currently comprises 749 social housing dwellings owned by LAHC, 125 private dwellings, and commercial properties on the southeast corner of Cope and Wellington Streets. Existing social housing within Waterloo South is predominantly walk up flat buildings constructed in the 1950s and '60s, and mid-rise residential flat buildings (Drysdale, Dobell & 76 Wellington Street) constructed in the 1980s. Listed Heritage Items within Waterloo South include the Duke of Wellington Hotel, Electricity Substation 174 on the corner of George and McEvoy Streets, the terrace houses at 229-231 Cope Street and the Former Waterloo Pre-School at 225-227 Cope Street. The State Heritage listed 'Potts Hill to Waterloo Pressure Tunnel and Shafts' passes underneath the precinct. ha A map of Waterloo South and relevant boundaries is illustrated in **Figure 2**.

Figure 2 Waterloo Precinct

Source: Ethos Urban

Renewal Vision

The transition of Waterloo Estate will occur over a 20-year timeframe, replacing and providing fit for purpose social (affordable rental) housing as well as private housing to create a new integrated and inclusive mixed-tenure community.

This aligns with Future Directions for Social Housing in NSW – the NSW Government's vision for social housing. It also aligns with LAHC's Communities Plus program, which is tasked with achieving three key objectives:

1. Provide more social housing
2. Provide a better social housing experience
3. Provide more opportunities and support for social housing tenants

The following is LAHC's Redevelopment Vision for Waterloo Estate, which was derived from extensive consultation and technical studies:

Culture and Heritage

- Recognise and celebrate the significance of Waterloo's Aboriginal history and heritage across the built and natural environments.
- Make Waterloo an affordable place for more Aboriginal people to live and work.
- Foster connection to culture by supporting authentic storytelling and recognition of artistic, cultural and sporting achievements.

Communal and Open Space

- Create high quality, accessible and safe open spaces that connect people to nature and cater to different needs, purposes and age groups.
- Create open spaces that bring people together and contribute to community cohesion and wellbeing.

Movement and Connectivity

- Make public transport, walking and cycling the preferred choice with accessible, reliable and safe connections and amenities.
- Make Waterloo a desired destination with the new Waterloo Station at the heart of the Precinct's transport network – serving as the gateway to a welcoming, safe and active community.

Character of Waterloo

- Strengthen the diversity, inclusiveness and community spirit of Waterloo.
- Reflect the current character of Waterloo in the new built environment by mixing old and new.

Local Employment Opportunities

- Encourage a broad mix of businesses and social enterprise in the area that provides choice for residents and creates local job opportunities.

Community Services, Including Support for Those Who Are Vulnerable

- Ensure that social and human services support an increased population and meet the diverse needs of the community, including the most vulnerable residents.
- Provide flexible communal spaces to support cultural events, festivals and activities that strengthen community spirit.

Accessible Services

- Deliver improved and affordable services that support the everyday needs of the community, such as health and wellbeing, grocery and retail options.

Design Excellence

- Ensure architectural design excellence so that buildings and surrounds reflect community diversity, are environmentally sustainable & people friendly – contributing to lively, attractive and safe neighbourhoods.
- Recognise and celebrate Waterloo's history and culture in the built environment through artistic and creative expression.
- Create an integrated, inclusive community where existing residents and newcomers feel welcome, through a thoughtfully designed mix of private, and social (affordable rental) housing .

Source: Let's Talk Waterloo: Waterloo Redevelopment (Elton Consulting, 2019)

Purpose of this report

This report relates to the Waterloo South planning proposal. While it provides comprehensive baseline investigations for Waterloo Estate, it only assesses the proposed planning framework amendments and Indicative Concept Proposal for Waterloo South.

The key matters addressed as part of this study, include:

- 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 area;
- Quantify air pollutant emissions from key identified sources within and surrounding Waterloo South;
- Model the dispersion of the quantified emissions in order to characterise cumulative maximum concentrations of air pollutants across Waterloo South; and
- Compare the model results against relevant guidelines to identify any constraints for the future development of Waterloo South.

2 The Proposal

The planning proposal will establish new land use planning controls for Waterloo South, including zoning and development standards to be included in Sydney LEP 2012, a new section in Part 5 of DCP 2012, and an infrastructure framework. Turner Studio and Turf has prepared an Urban Design and Public Domain Study which establishes an Indicative Concept Proposal presenting an indicative renewal outcome for Waterloo South. The Urban Design and Public Domain Study provides a comprehensive urban design vision and strategy to guide future development of Waterloo South and has informed the proposed planning framework. The Indicative Concept Proposal has also been used as the basis for testing, understanding and communicating the potential development outcomes of the proposed planning framework.

The Indicative Concept Proposal comprises:

- Approximately 2.57 hectares (ha) of public open space representing 17.8% of the total Estate (Gross Estate area - existing roads) proposed to be dedicated to the City of Sydney Council, comprising:
    - Village Green – a 2.25 ha park located next to the Waterloo Metro Station; and
    - Waterloo Common and adjacent – 0.32 ha located in the heart of the Waterloo South precinct.
    - The 2.57 ha all fall within the Waterloo South Planning Proposal representing 32.3% of public open space (Gross Waterloo South area – proposed roads)
- Retention of 52% of existing high and moderate value trees (including existing fig trees) and the planting of three trees to replace each high and moderate value tree removed.
- Coverage of 30% of Waterloo South by tree canopy.
- Approximately 257,000 square metres (sqm) of GFA on the LAHC land, comprising:
    - Approximately 239,100 sqm GFA of residential accommodation, providing for approximately 3,048 dwellings comprising a mix of market and social (affordable rental) housing dwellings;
    - Approximately 11,200 sqm of GFA for commercial premises, including, but not limited to, supermarkets, shops, food & drink premises and health facilities; and
    - Approximately 6,700 sqm of community facilities and early education and child care facilities.

The key features of the Indicative Concept Proposal are:

- It is a design and open space led approach.
- Creation of two large parks of high amenity by ensuring good sunlight access.
- Creation of a pedestrian priority precinct with new open spaces and a network of roads, lanes and pedestrian links.
- Conversion of George Street into a landscaped pedestrian and cycle friendly boulevard and creation of a walkable loop designed to cater to the needs of all ages.
- A new local retail hub located centrally within Waterloo South to serve the needs of the local community.
- A target of 80% of dwellings to have local retail services and open space within 200m of their building entry.
- Achievement of a 6 Star Green Star Communities rating, with minimum 5-star Green Star – Design & As-Built (Design Review certified).
- A range of Water Sensitive Urban Design (WSUD) features.
- The proposed land allocation for the Waterloo South precinct (the Precinct) is described in **Table 1** below.

Table 1 Breakdown of Allocation of Land within the Waterloo South

Land allocation	Existing	Proposed
Roads	3.12 ha / 25.3%	4.38 ha / 35.5%
Developed area (Private sites)	0.86 ha / 6.98%	0.86 ha / 7%
Developed area (LAHC property)	8.28 ha / 67.2%	4.26 ha / 34.6%
Public open space (proposed to be dedicated to the City of Sydney)	Nil / 0%	2.57 ha / 20.9% (32.2 excluding roads)
Other publicly accessible open space (Including former roads and private/LAHC land)	0.06 ha / 0.5%	0.25 ha / 2%
TOTAL	**12.32 ha**	**12.32 ha**

The Indicative Concept Proposal for the Waterloo South is illustrated in **Figure 3** below.

Figure 3 Indicative Concept Proposal

Source: Turner Studio

The concept design of Waterloo South incorporates a number of measures in order to reduce the likelihood of air quality impacts. These include:

- Minimising the formation of urban canyons[1] by having buildings of different heights interspersed.
- For buildings along McEvoy Street:
    - Locating no sensitive receptors on the first two floors.
    - Reducing the number of south facing apartments by designing building cores to the south.
    - Provision of only corner apartments to the south.
    - Provision of wintergardens to the south facade with fixed glazing to the south and operable windows to the side facade.

[1] A street that is flanked on either side with tall buildings creating a structure that's similar to a canyon. Within an urban canyon, air recirculation is poor and there is a risk of pollutant accumulation.

3 Study Requirements

On 19 May 2017, the Minister issued Study Requirements for the Waterloo Precinct. The key study requirements relating to air quality are presented in **Table 2**.

Table 2 Waterloo SSP - Study Requirements

Requirement	Section Reference
18.2. *Consider and assess potential pollution impacts from the proposed rezoning including, but not limited to, water, air, noise and light pollution.*	**Section 10**
18.3. *Provide an air quality assessment for the proposal. The assessment will address the relevant policies and guidelines in relation to air quality including State Environmental Planning Policy (Infrastructure) 2007 and the Development Near Rail Corridors and Busy Roads – Interim Guideline.*	**Section 5 and 10**
18.4. *These assessments should also consider other current local air and noise issues in the Waterloo area, including potential cumulative impacts from the Waterloo Estate.*	**Section 8**
18.5. *Identify and map current and proposed future sensitive receptors (e.g. residential uses, schools, child care centres).*	**Section 4.3**
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18.7. *Model the likely future noise, vibration and pollution scenario based on 3D block envelope diagrams prepared by the urban designer. This is to include road and rail noise.*	**Section 10.1**
18.9. *Outline the recommended measures relating to noise, vibration and pollution to minimise the nuisance and harm to people or property within the precinct.*	**Section 11**

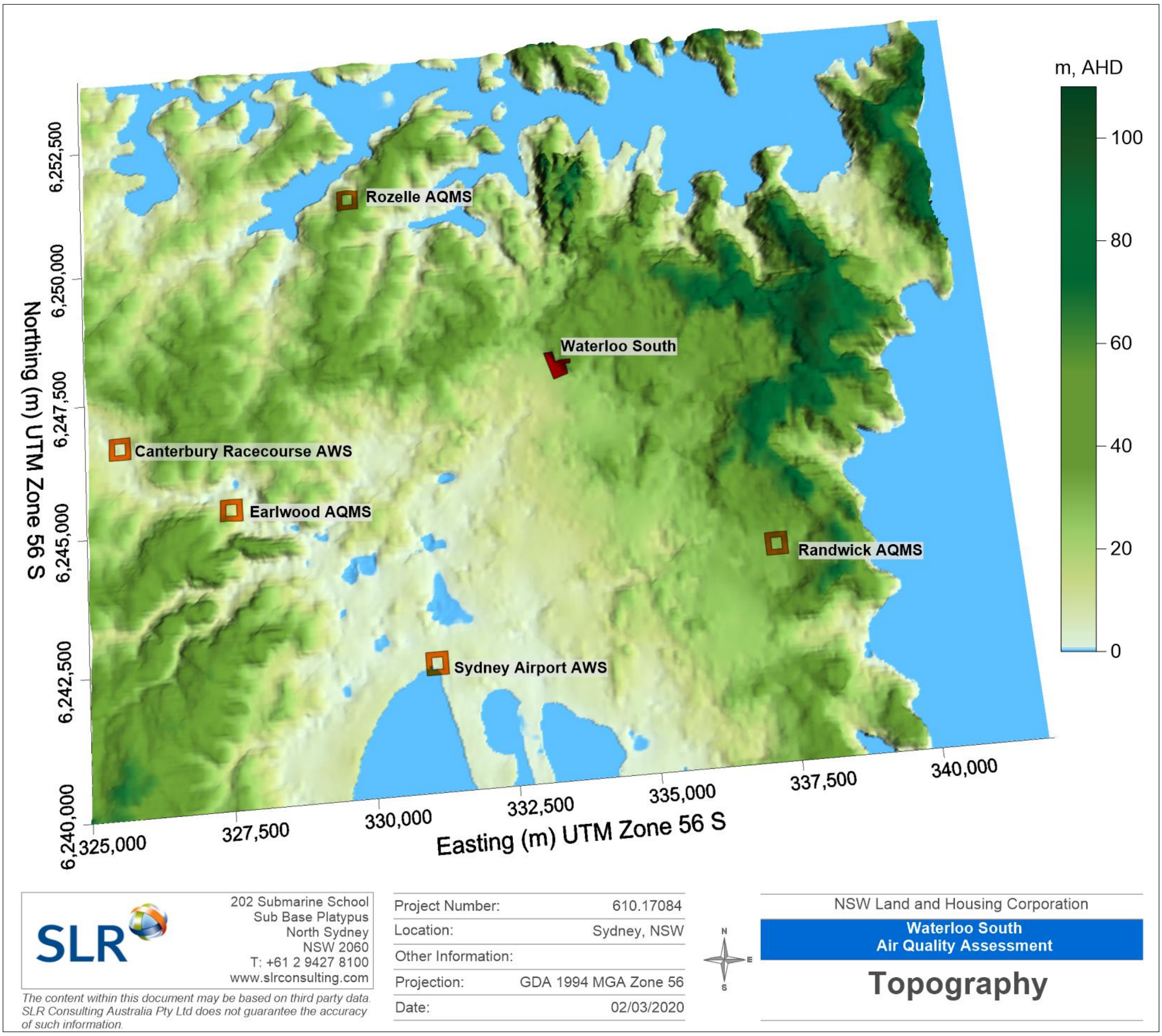
4 Project Setting

4.1 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.

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

Figure 4 Topography of Area Surrounding Waterloo South



The area immediately surrounding Waterloo South is currently relatively open, which will facilitate the dispersion of air emissions and prevent 'pooling' of air pollutants.

4.2 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 Waterloo South) and Canterbury Racecourse AWS (approximately 8 km west of Waterloo South) (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

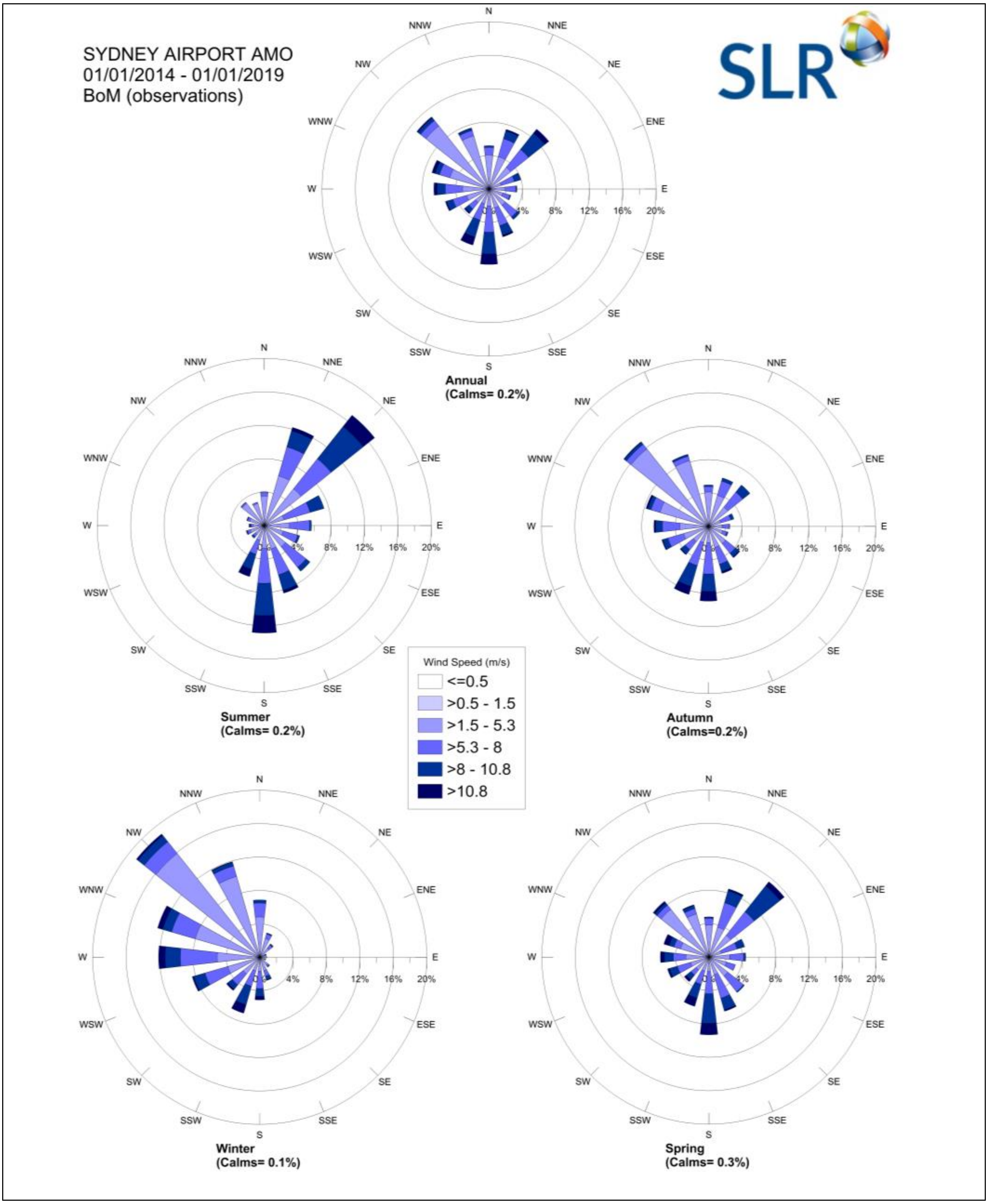


Figure 6 Canterbury Racecourse AWS Annual and Seasonal Wind Roses, 2014-2018

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 Waterloo South, it can be concluded that Waterloo South is likely to be subjected to winds from all directions, with the lowest frequency of winds from the east and southwest quadrants.

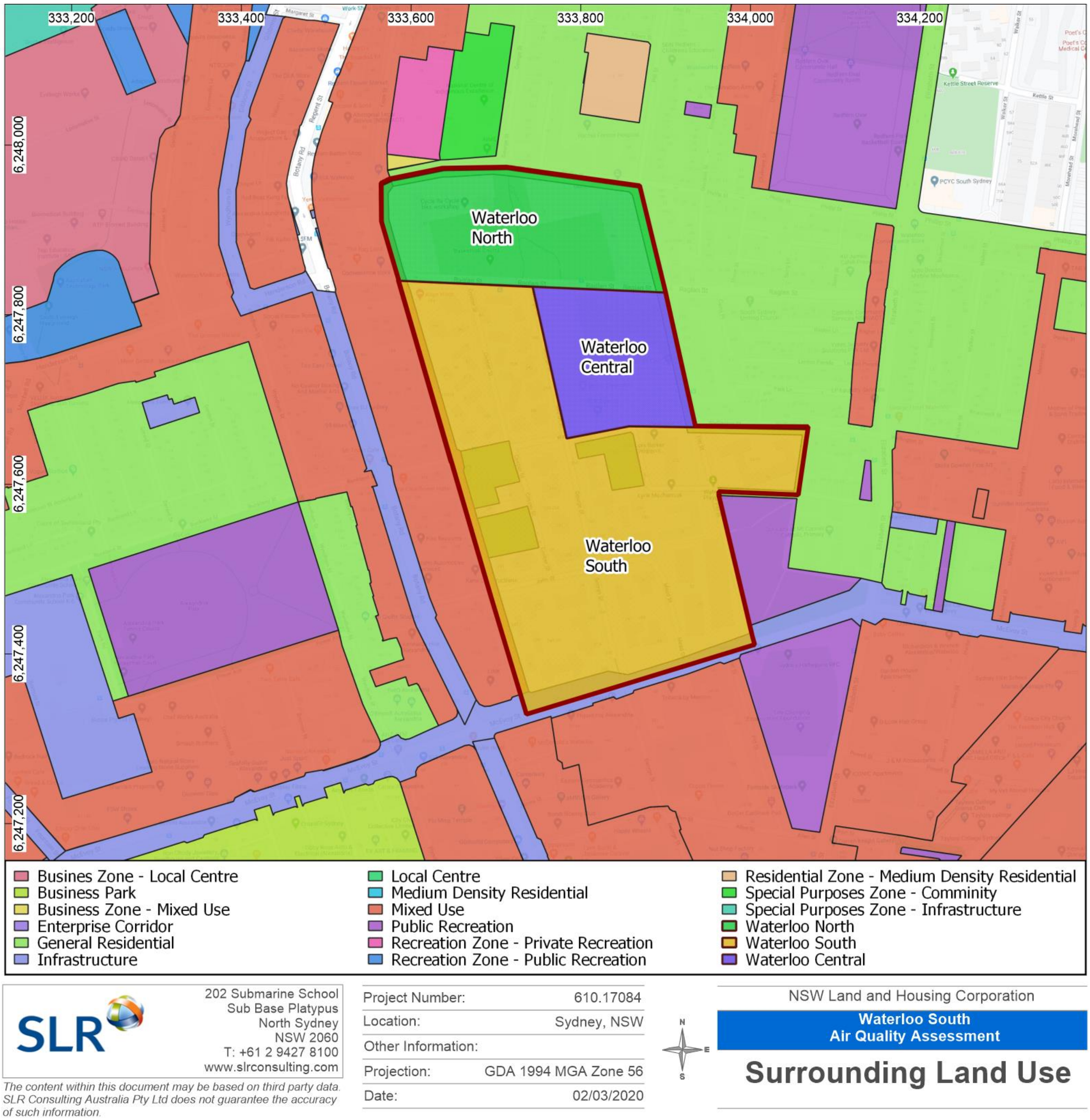
Considering the relatively complex topographical features of the land between Waterloo South and the two BoM weather stations (see **Figure 4**), the actual winds experienced at Waterloo South may be different to those recorded by the BoM stations. Therefore, meteorological modelling was carried out to provide site-representative wind data for Waterloo South (see **Section 9.2**).

4.3 Surrounding Land Use

As illustrated in **Figure 7**, the lots immediately surrounding Waterloo South are zoned as Mixed Use, General Residential and Public Recreation by the *Sydney Local Environment Plan 2012*. Within a 500 m radius of Waterloo South, the land is predominantly zoned as General Residential, Mixed Use, Public Recreation, Local Centre, Business Park and Infrastructure.

Some commercial and light industry uses are located within the Mixed Use zones to the south and west. Potential air emissions from these activities are addressed in **Section 9.4**.

Figure 7 Surrounding Land Use



5 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 7**).

5.1 Approved Methods

State air quality guidelines adopted by the NSW EPA are published in the NSW EPA's *Approved Methods for Modelling and Assessment of Air Pollutants in NSW* publication (NSW EPA, 2017), hereafter referred as the 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 Waterloo South are reproduced and discussed in **Section 7**.

5.2 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*[2]. 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 congestion 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

2 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.

- As considered necessary by the approval authority based on consideration of site constraints, and associated air quality issues.

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 openable 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.

5.3 Local Air Quality Toolkit

The Local Government Air Quality Toolkit (AQ Toolkit) has been developed by the EPA to assist local government in their management of air quality issues and provides guidelines for air quality management and for the use of air pollution control techniques. Relevant AQ Toolkit air quality guidance notes include Food Outlets (NSW EPA, 2007).

6 Identified Pollutant Sources and Types

6.1 Road Traffic

The primary source of air emissions in the area immediately surrounding Waterloo South is expected to be vehicles travelling along McEvoy Street as well as Botany Road which is classified as a "Main Road" under the *NSW Roads Act 1993* (Gazetted Road Number: 170). A review of the *National Pollutant Inventory Emission Estimation Technique Manual* (NPI EETM) for Combustion Engines (DEWHA , 2008) identifies the primary pollutants from combustion engines as:

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

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 Waterloo South means that road traffic emissions have the potential to result in elevated air pollutant concentrations during peak periods in areas within Waterloo South closest to McEvoy Street and Botany Road.

6.2 Industrial Sources

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

- A 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.

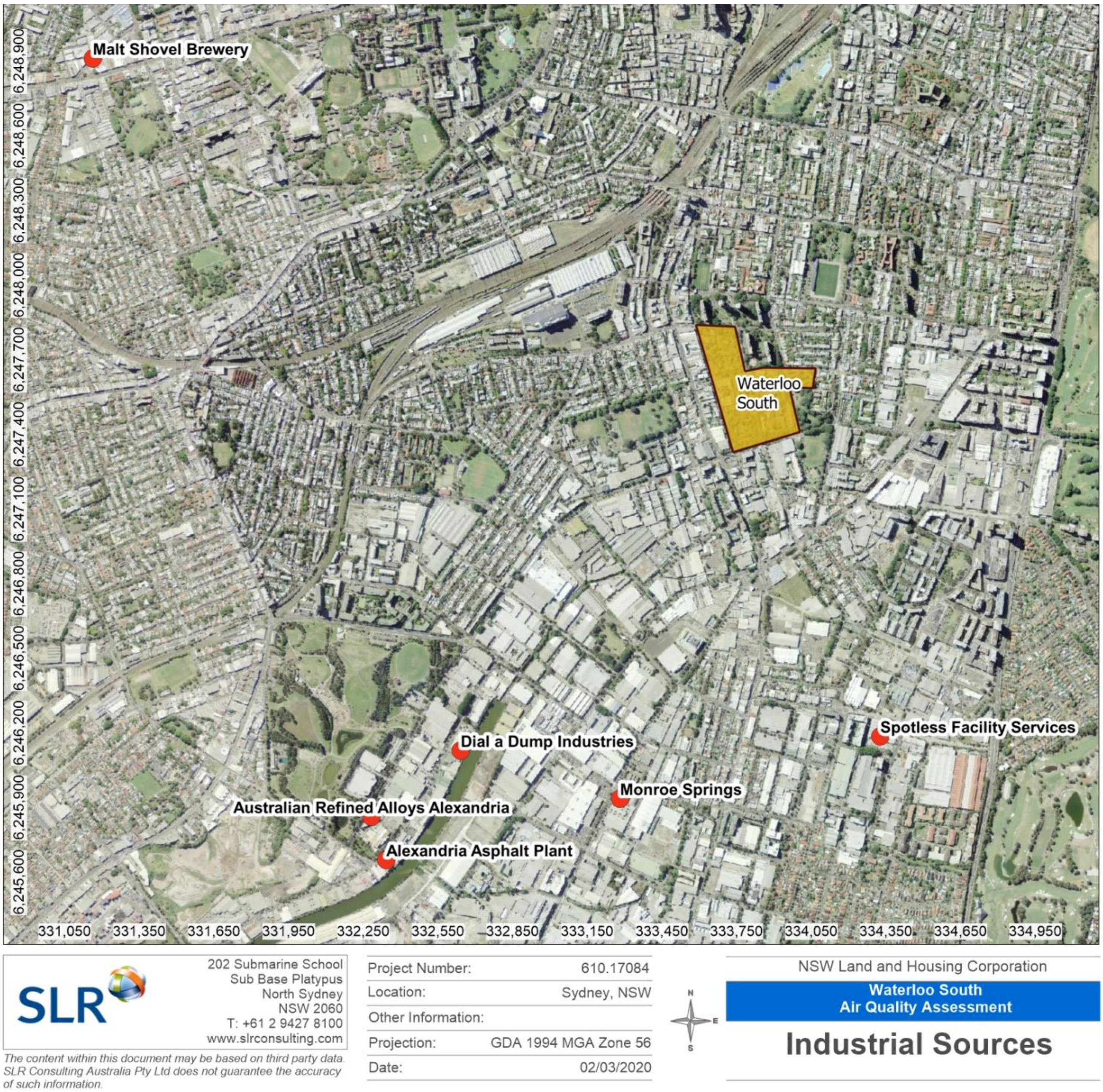
A search of the EPA public register and NPI database for the project area returned several records of industries in the vicinity of the Precinct which could potentially be a source of air pollutant emissions. The locations of these facilities relative to Waterloo South is illustrated in **Figure 8** with further details presented in **Table 3**.

As outlined in **Table 3**, considering the separation distances and activity types associated with the identified emission sources, significant air quality impacts at Waterloo South due to air emissions from these facilities are considered unlikely.

Table 3 Identified Sources of Air Emissions in the Vicinity of Waterloo South

Facility Name	Type of Activity	Approximate Distance from Waterloo South	Likelihood of Significant Impact
Alexandria Asphalt Plant	Petroleum and coal product manufacturing	2.1 km (SW)	Low
Australian Refined Alloys Alexandria	Basic non-ferrous metal manufacturing	2.1 km (WSW)	Low
Monroe Springs	Metal product manufacturing	1.5 km (SSW)	Low
Spotless Facility Services	Laundry and dry-cleaning services	1.3 km (SSE)	Low
Dial a Dump Industries	Waste processing (non-thermal treatment)	1.4 km (SW)	Low
Malt Shovel Brewery	Brewing and packaging of beer	2.6 km (NW)	Low

Figure 8 Location of Nearby Industrial Sources



6.3 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 Waterloo South, 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 service stations, automotive workshops and food and beverage outlets were identified within 250 m of the Waterloo South boundary. Details of these facilities are presented in **Table 4**. It is noted that the distances specified in **Table 4** indicate the distance between the identified source and the Waterloo South boundary. Given the setback of the buildings proposed within Waterloo South and the elevated location of sensitive receptors, the actual distance may be greater. Potential emissions from these facilities are discussed in the following sections.

In addition to the existing sources identified in **Table 4**, emissions from activities within Waterloo South itself (e.g. food outlets) may lead to potential amenity/nuisance impacts at nearby sensitive receptors. Depending on the type and scale of the activities, emitted pollutant concentrations could range from very low to very high. However, emissions from any activity (including food outlets) can be controlled and concentrations reduced to very low levels if appropriate emissions controls are put in place.

In the absence of detailed information in relation to the type and scale of any potentially polluting activities within Waterloo South, potential impacts have not been assessed further in this assessment. It is recommended that once the final design is available and tenants/activity types have been identified, additional air quality assessment(s) be carried out to ensure sufficient control measures have been adopted and that no nuisance or loss of amenity is anticipated due to dust, odour or fumes from these activities.

Table 4 Identified Small Scale Sources of Air Emissions in the Vicinity of Waterloo South

Facility Name	Type of Activity	Approximate Distance from the Waterloo South Boundary
Abbotts Hotel	Food Outlet	75 m (W)
Daily French Hot Bread	Food Outlet	60 m (W)
Eddy's Bakery	Food Outlet	50 m (NW)
John Smith Specialty Coffee	Food Outlet	65 m (W)
Lord Raglan	Food Outlet	150 m (W)
McDonalds Alexandria	Food Outlet	50 m (S)
Mr Toast	Food Outlet	95 m (W)
Thai Thai Restaurant	Food Outlet	110 m (W)
The Cauliflower Hotel	Food Outlet	60 m (W)
The Rag Land	Food Outlet	45 m (W)
Waterloo Cafe Pizzeria	Food Outlet	75 m (W)
Wildcockatoo Bakery	Food Outlet	100 m (W)
Yens Vietnamese Restaurant	Food Outlet	80 m (W)
Yum Yai	Food Outlet	95 m (W)
Yellow Fever Cafe	Food Outlet	360 m (N)
Chocolait Cafe and Restaurant	Food Outlet	85 m (E)
George Hotel	Food Outlet	100 m (E)
Baby Coffee Co.	Food Outlet	150 m (E)
Indian Leaf Restaurant	Food Outlet	200 m (E)
Pizza:Deli	Food Outlet	170 m (S)
Cuppa Flower Cafe	Food Outlet	170 m (S)
Social Hideout Waterloo	Food Outlet	200 m (S)

Facility Name	Type of Activity	Approximate Distance from the Waterloo South Boundary
All Spice Thai Kitchen	Food Outlet	200 m (S)
B & B Mechanical Repairs	Automotive Workshops	230 m (NW)
Hahn Automotive Services	Automotive Workshops	75 m (W)
Hargrave Motor Repairs	Automotive Workshops	95 m (W)
BP Service Station	Service Station	330 m (N)
Caltex Service Station	Service Station	190 m (WSW)

6.3.1 Food Outlets

The main air emission from food and beverage outlets (including bakeries and restaurants) is odour, primarily generated from the cooking process. Studies (including analysis of cooking fume emissions) have shown that many odorous hydrocarbons or Volatile Organic Compounds (VOCs), such as alkenes, aromatics, aldehydes and organic acids are formed in the cooking process as breakdown products of natural fats and oils (NSW EPA, 2007). The strength and offensiveness of the odours varies widely, depending on what is being cooked and the manner of cooking.

The potential air quality impacts from these food outlets have been assessed in **Section 10.2.1**.

6.3.2 Service Stations and Automotive Workshops

Emissions of VOCs from service stations occur due to evaporative losses during filling as well as working and standing losses from the fuel storage tanks.

As described in the National Pollutant Inventory's *Emission Estimation Technique Manual for Fuel and Organic Liquid Storage* (Environment Australia, 2012), working losses are the combined loss from filling and emptying a tank containing hydrocarbon liquids. As the liquid level increases, the pressure inside the tank increases and vapours containing VOCs are expelled from the tank. A loss during emptying occurs when air drawn into the tank becomes saturated with organic vapour and expands, thus exceeding the capacity of the vapour space. In addition to losses from the underground storage tanks, working losses can occur from the vehicle fuel tanks being filled at the bowser.

Standing losses occur through the expulsion of vapour from a tank due to the vapour expansion and contraction as a result of changes in temperature and barometric pressure. This loss occurs without any change in the liquid level in the tank.

Emissions of VOCs also occur at automotive workshops, albeit to a lesser degree. *The Environmental Action for Automotive Servicing and Repairs* document published by the NSW EPA (NSW EPA, 2008) identifies the potential emissions to atmosphere from automotive workshops as:

- Vapours released by volatile fluids (eg. solvents, petrol and paints)
- Dust generated from friction materials in brakes and clutches
- Release of LPG from vehicles and storage tanks
- Ozone depleting substances found in air conditioning units.

Other emissions to air that will occur at both service stations and automotive workshops will be emissions of products of fuel combustion from vehicle exhausts as they enter and exit the site. Given all engines will most likely be switched off once the vehicles are parked within these facilities, emissions from idling vehicles will be minor.

The potential air quality impacts from these facilities have been assessed in **Section 10.2.2**.

6.3.3 Waterloo Metro Station

Waterloo South is situated over and adjacent to the Sydney Metro City & Southwest project including Waterloo Station. Potential air quality impacts from the future metro station were assessed by Transport for NSW and presented in *the Sydney Metro Chatswood to Sydenham Environmental Impact Statement* (TfNSW, 2016). In relation to potential air quality issues, the EIS states:

> *As the project would be powered by electricity, local emissions generated during operation are expected to be minimal and highly dispersed.*
>
> *The project would include a ventilation system to circulate fresh air through the tunnels and underground stations and prevent the build-up of heat. Fresh air would be drawn into the tunnels and air would be extracted from the tunnels through the portals by the piston effect of the trains, and by mechanical ventilation at the stations.*
>
> *Air would be discharged from the tunnel portals and through ventilation outlets integrated into each station. The stations would also provide separate fresh air ventilation systems to draw fresh air in and extract air from the station environment. Air discharged from the tunnels and stations would be well diluted and dispersed into the outdoor air.*
>
> *Minor quantities of particulate matter (PM_{10}) emissions would be generated in the tunnels, mainly due to wear of the train brake pads, vaporisation of metals due to sparking, wear of steel due to friction between wheels and rail, and recirculation of particulates from tunnel walls. Most of these emissions would be vented through the fresh air ventilation system in very low concentrations.*
>
> *Vented air is also likely to comprise minor concentrations of carbon dioxide, volatile organic compounds and oxides of nitrogen as well as ash and soot particulates generated during maintenance. The ventilation outlet air would contain small quantities of particulates at low concentrations due to the large volumes of exhaust air. Given the low concentrations of particulates, it is very unlikely that the project would have air quality impacts on the surrounding environment, including sensitive receivers.*
>
> *The fresh air ventilation system would also respond to emergency conditions such as fire incidents where smoke-laden air would be discharged through the emergency ventilation system to prevent smoke entering stations or recirculating through ventilation shafts or tunnel portals. The design and location of the fresh air ventilation shafts at stations would ensure sensitive receivers were not unnecessarily affected; suitable emergency plans would be in place for these circumstances.*

Given the above, the likelihood of significant incremental impacts from the operation of the Waterloo Station is highly unlikely and further assessment is not warranted.

7 Relevant Air Quality Criteria

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

- Airborne particulate matter;
- Products of combustion such as NO_X, CO, SO_2 and VOCs; and
- Odour.

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.

7.1 Particulate Matter

7.1.1 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 impact assessment criteria for TSP recommended by the NSW EPA is 90 micrograms per cubic metre of air ($\mu g/m^3$). The TSP criteria 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} impact assessment criteria set out in the Approved Methods are as follows:

- a 24-hour maximum of 50 $\mu g/m^3$; and,
- an annual average of 25 $\mu g/m^3$.

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

- a 24-hour maximum of 25 $\mu g/m^3$; and,
- an annual average of 8 $\mu g/m^3$.

A summary of the particulate impact assessment criteria is shown in **Table 5**.

Table 5 EPA Impact Assessment Criteria for Particulates

Pollutant	Averaging Time	Impact Assessment Criteria
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

7.1.2 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 6 presents the impact assessment criteria 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 6 EPA Impact Assessment Criteria 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.

7.2 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 impact assessment criteria specified within the Approved Methods for NO_2 are provided in **Table 7**.

Table 7 Assessment Criteria for Nitrogen Dioxide (NO_2)

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

Note: pphm = parts per hundred million

7.3 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 impact assessment criteria specified within the Approved Methods for CO are provided in **Table 8**.

Table 8 Assessment Criteria for Carbon Monoxide (CO)

Pollutant	Averaging Period	Impact Assessment 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

7.4 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 9 Assessment Criteria for Sulphur Dioxide (SO_2)

Pollutant	Averaging Period	Impact Assessment 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

7.5 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 10**.

Table 10 Impact Assessment Criteria for VOCs

Pollutant	Averaging Period	Impact Assessment Criteria
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)

7.6 Odour

Impacts from odorous air contaminants are often nuisance-related rather than health-related. Odour performance goals guide decisions on odour management, but are generally not intended to achieve "no odour".

The detectability of an odour is a sensory property that refers to the theoretical minimum concentration that produces an olfactory response or sensation. This point is called the *odour threshold* and defines 1 odour unit (ou). An odour impact assessment criteria of less than 1 ou would theoretically result in no odour impact being experienced.

In practice, the character of a particular odour can only be judged by the receiver's reaction to it, and preferably only compared to another odour under similar social and regional conditions. Based on the literature available, the level at which an odour is perceived to be a nuisance can range from 2 ou to 10 ou depending on a combination of factors including population sensitivity, background level, public expectation (considered offensive or easily tolerated), source characteristics (i.e. emitted from a stack or general area) and health effects.

Odour performance goals need to be designed to take into account the range in sensitivities to odours within the community, and provide additional protection for individuals with a heightened response to odours, using a statistical approach which depends on the size of the affected population.

It is often not possible or practical to determine and assess the cumulative odour impacts of all odour sources that may impact on a receptor in an urban environment. Therefore, the proposed odour performance goals allow for population density, cumulative impacts, anticipated odour levels during adverse meteorological conditions, and community expectations of amenity.

A summary of the impact assessment criteria given for various population densities, as drawn from the Approved Methods, is given in **Table 11**. The Approved Methods states that the impact assessment criteria for complex mixtures of odorous air pollutants must be applied at the nearest existing or likely future off-site sensitive receptor(s). In an urban area such as Waterloo South, the relevant criterion is 2 ou (nose-response-time average, 99th percentile).

Table 11 Impact Assessment Criteria - Complex Mixtures of Odorous Air Pollutants

Population of Affected Community	Impact Assessment Criteria for Complex Mixtures of Odours (ou, nose-response-time average, 99th percentile)
Urban area (≥ 2000)	2
~500	3
~125	4
~30	5
~10	6
Single residence (≤ 2)	7

Source: Approved Methods, NSW EPA 2017.

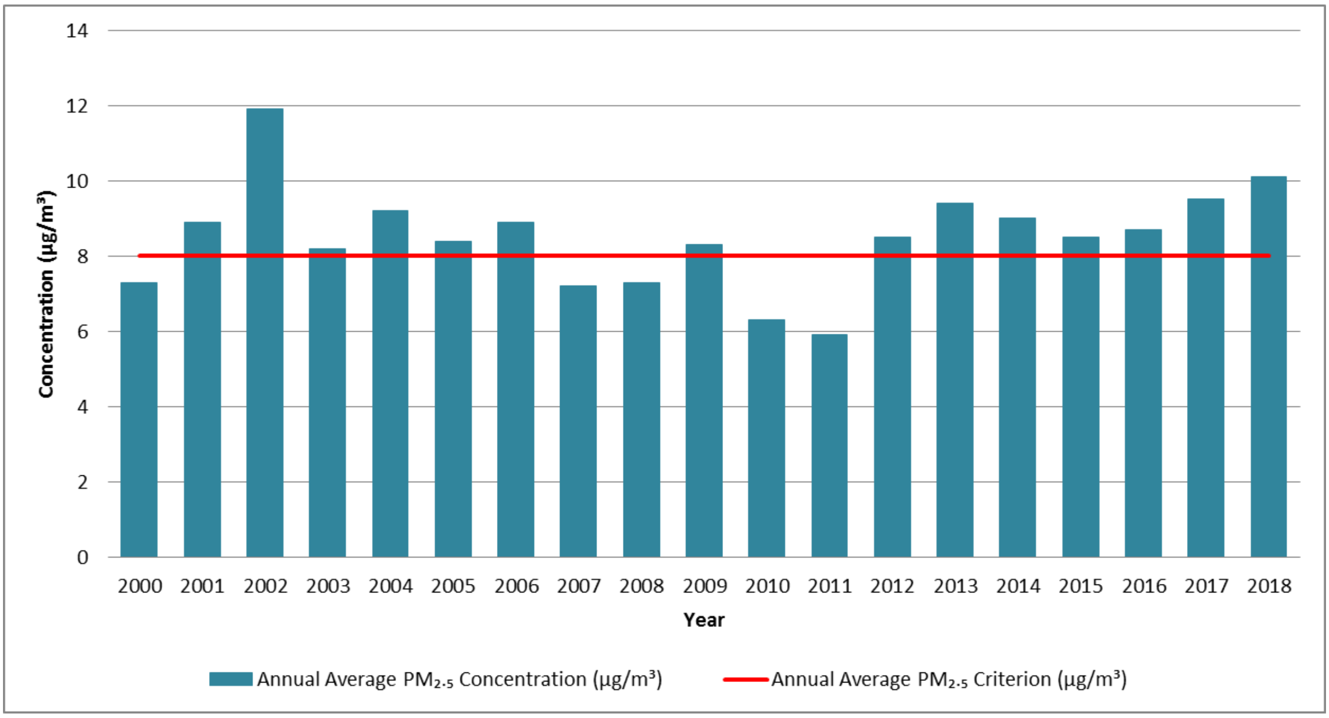
8 Background Air Quality

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 PM2.5 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. Read about other programs to reduce particle pollution.
- **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 Waterloo South, are exposed to, are minimised as much as practicable.

8.1 Review of NSW EES 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 EES station is located at Rozelle, approximately 5.0 km to the northwest of Waterloo South. Other nearby stations include Randwick and Earlwood, which are located approximately 5.2 km southeast and 6.9 km southwest of Waterloo South 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 12**.

Table 12 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 13**. To be consistent with the NSW EES monitoring reports, the data for gaseous pollutants are presented in parts per hundred million (pphm) or parts per million (ppm), rather than µg/m^3 and mg/m^3 as used in **Section 7**.

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 and the 1-hour average O_3 concentrations exceeded the 10 pphm criterion in 2015, 2017 and 2018.

Table 13 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

Pollutant	Averaging Period	Criteria	Year	Randwick AQMS		Units
				Maximum Concentration	Number of Exceedances	
PM_{10}	24-hour	50 µg/m³	2014	46	0	µg/m³
			2015	77	1	µg/m³
			2016	44	0	µg/m³
			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 EES 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 14**. 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 15**. No exceedances of the 1-hour average and 8-hour average CO criteria were recorded by the Rozelle AQMS over this period.

Table 14 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 15 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	2014	1.4	0	ppm
			2015	1.6	0	ppm
			2016	1.7	0	ppm
			2017	1.2	0	ppm
			2018	1.0	0	ppm
	8-hour	9 ppm	2014	1.1	0	ppm
			2015	1.1	0	ppm
			2016	1.2	0	ppm
			2017	0.9	0	ppm
			2018	0.7	0	ppm

9 Assessment Methodology

The key issues identified for air quality at Waterloo South 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 Waterloo South. Regional monitoring data available from the NSW EES ambient monitoring networks (see **Section 8**) were then used to assess the potential cumulative concentrations of these pollutants that future residents of Waterloo South would potentially be exposed to, and to assess compliance against relevant air quality guidelines.

As outlined in **Section 6.1**, atmospheric pollutants emitted from road traffic include NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOCs. Given the low level of CO and SO_2 emissions from vehicles and the low ambient concentrations recorded in Sydney (see **Section 8**), 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 at Waterloo South. SLR's experience in modelling VOC emissions from roads has also shown that kerbside concentration 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 Waterloo South, showed that ground level VOC concentrations at the nearest receptors were predicted to be well below the relevant assessment criteria. Hence, CO, SO_2 and VOC 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.

Other sources of air pollutants identified in the local area with the potential to impact on air quality at Waterloo South include a service station and a number of food and beverage outlets. As detailed information on the operational activities within these facilities is not available, a large number of assumptions would be required to be used as input to any quantitative (i.e. air dispersion modelling) assessment. The uncertainty associated with the output of such studies means it would be of limited value. SLR has therefore performed a qualitative (risk-based) assessment for these activities, based on the information available.

In addition to the above, emission sources within Waterloo South (e.g. food outlets) could potentially lead to amenity/nuisance impacts at surrounding sensitive receptors or at residential locations within Waterloo South itself. Considering 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 for the purpose of this assessment. However, it is recommended that assessment of any potentially air polluting activities proposed within Waterloo South 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.

9.1 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 Waterloo South 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 16**. 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 16 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		

9.1.1 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 16**. However such detailed information on the distribution of vehicles is not publicly available for the roads surrounding Waterloo South. Therefore, in order to compile the COPERT Australia input files, the following assumptions were applied:

- The modelled traffic volume predictions 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**).

9.1.2 Peak Traffic Volumes

Modelled peak 1-hour traffic volumes classified as Car, Truck (i.e. light goods vehicle) and Heavy Truck forecasted for 2036 with the full Metro Quarter and Waterloo South development 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 **Appendix B**. The location of each corridor is illustrated in **Figure 11**.

Figure 12 shows PM Peak traffic volumes for all modelled roads. As illustrated in this figure, the highest traffic volumes (for roads on the boundary and within Waterloo South) are predicted for McEvoy Street, located south of Waterloo South.

The traffic modelling performed by Jacobs covered the morning and afternoon peak periods, and information on the diurnal variation in traffic flows for the roads surrounding Waterloo South was not available. Information on the diurnal variation of traffic on Regent Street (Station ID: 02385 – 10 m north of James Street, Redfern) was therefore obtained from the Transport for NSW Traffic Volume Viewer (RMS, 2018) 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 (4 – 5 pm) traffic volume.

Figure 10 Diurnal Variation of Traffic on Regent Street

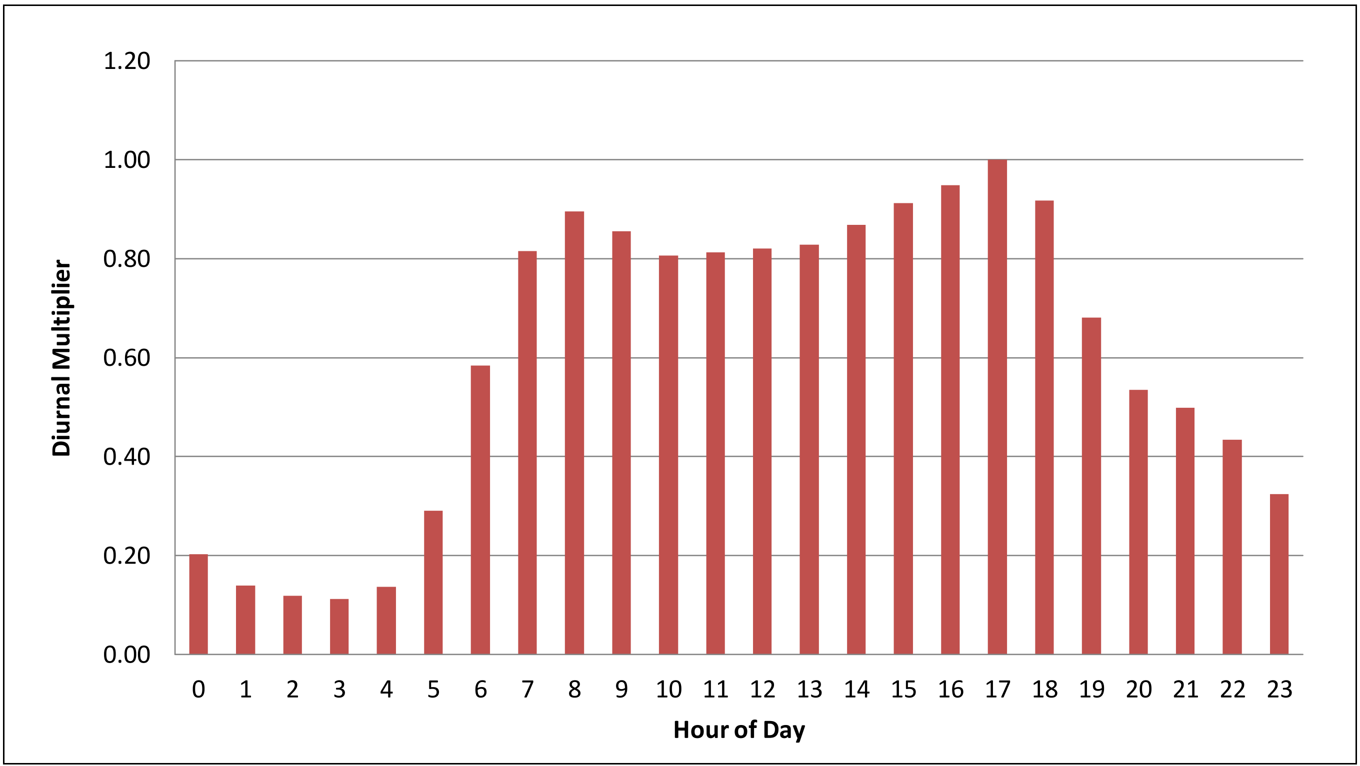
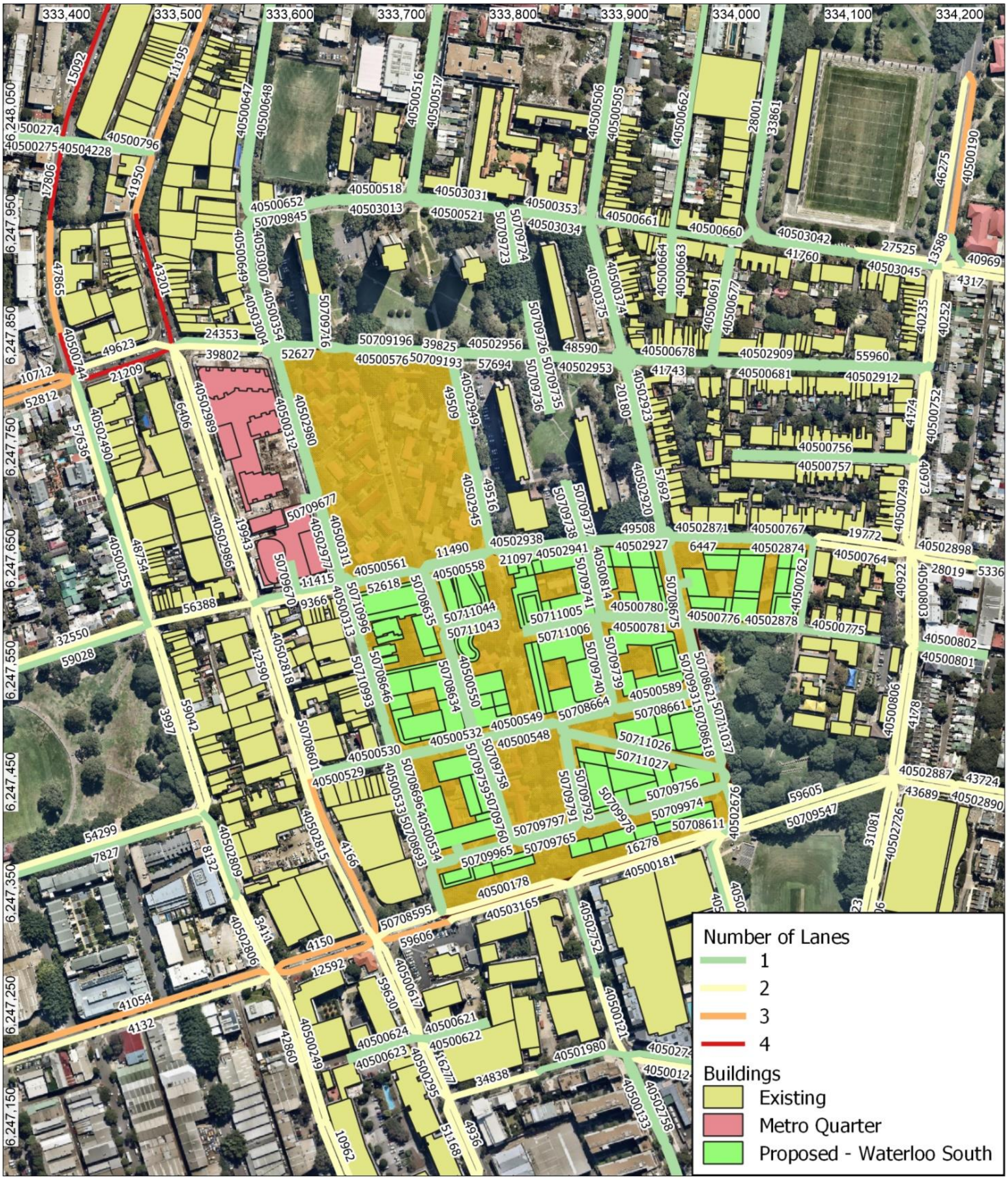


Figure 11 Modelled Road Sources and Buildings



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Location:	Sydney, NSW
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Projection:	GDA 1994 MGA Zone 56
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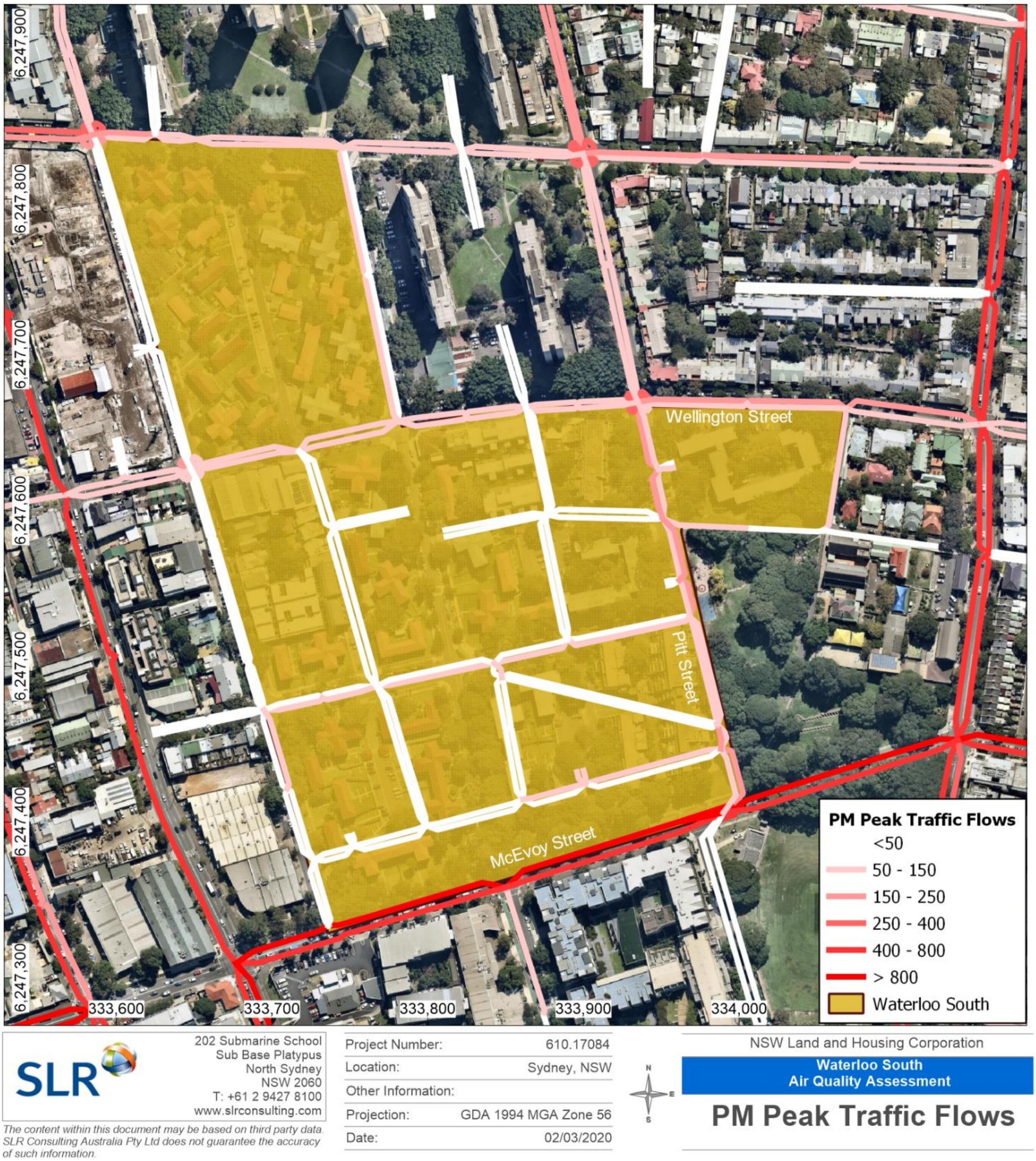
NSW Land and Housing Corporation

Waterloo South
Air Quality Assessment

Modelled Roads

Figure 12 Modelled Traffic Flows



9.1.3 Road Gradients and Lengths

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

Emission factors prepared using COPERT are not gradient dependent. Therefore, average correction factors derived from emission factors published by PIARC (PIARC Technical Committee C4, 2012) were applied to the COPERT emission factors. It is noted that this component of the assessment was completed before the 2019 version of the PIARC emission factors (PIARC Technical Committee D.5, 2019) was published. A review of the 2012 and 2019 PIARC emission factors indicates that the gradient correction factors derived from the 2012 data results in slightly higher (ie conservative) emissions from the modelled road network. The gradient correction factors used in this assessment are presented in **Table 17**.

Table 17 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%

9.1.4 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 **Appendix C**.

9.2 Meteorological Modelling

To provide the meteorological data required by GRAL, 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.

9.2.1 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 8**, the EES maintains a network of AQMSs across NSW that record wind speed and wind direction as well as air quality data. The nearest such EES stations are located at Rozelle (approximately 5 km to the northeast of Waterloo South), Randwick (approximately 5 km southeast of Waterloo South) and Earlwood approximately 7 km southwest of Waterloo South) (refer **Figure 4**).

As noted on the EES 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

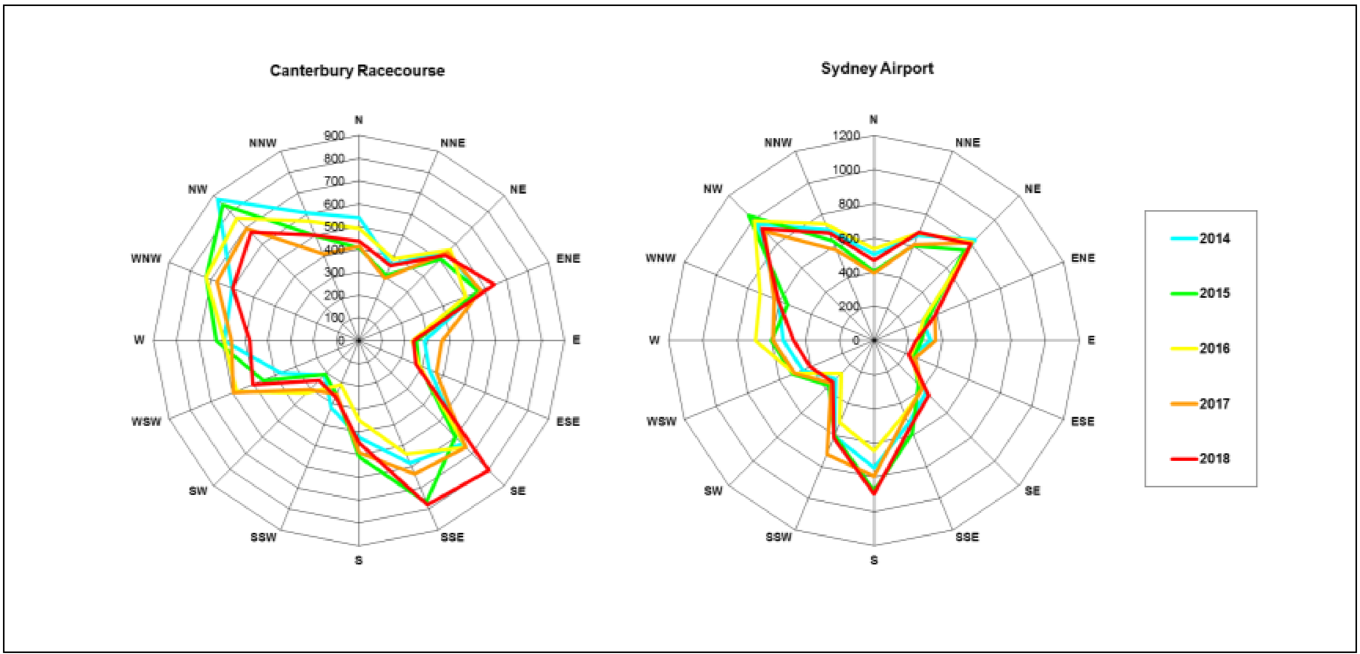
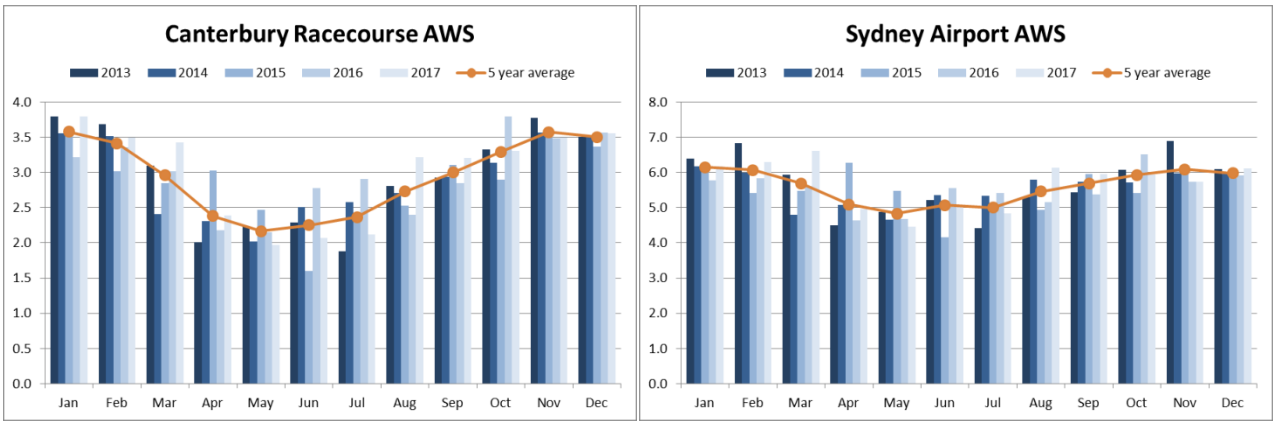


Figure 14 Sydney Airport and Canterbury Racecourse Monthly Average Wind Speeds, 2014-2018



9.2.2 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 as outlined below.

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 18** details the parameters used in the TAPM meteorological modelling for this assessment.

Table 18 Meteorological Parameters used for the AQA – TAPM

Parameter	Value
Modelling Period	1 January 2014 to 31 December 2014
Centre of analysis	332,750 mE 6,250,232 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

9.2.3 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 19** details the parameters used in the meteorological modelling to drive the CALMET model.

Table 19 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

9.2.4 GRAMM

The GRAMM domain was defined so that it covered the whole extent of Waterloo South as well as the surrounding road network, with a sufficient buffer zone. 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. **Table 20** details the parameters used in the GRAMM model.

Table 20 Meteorological Parameters used for this Study – GRAMM

Parameter	Value
Number of wind speed classes	9
Wind speed classes (m/s)	0-0.5, 0.5-1.0, 1.0-2.0, 2.0-3.0, 3.0-4.0, 4.0-5.0, 5.0-6.0, 6.0-9.0, >9.0
Number of wind direction sectors	36
Number of classified weather situations	891
Horizontal grid resolution	100 m
Vertical thickness of first layer	10 m
Number of vertical layers	15
Vertical stretching factor	1.40
Relative top layer height	3,874
Maximum time step	10 s
Modelling time	3,600
Relaxation velocity	0.10
Relaxation scalars	0.10

9.3 Meteorological Data Used in Modelling

9.3.1 Wind Speed and Direction

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

Figure 15 indicates that winds predicted at Waterloo South 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 0.4% of the time throughout the modelling period.

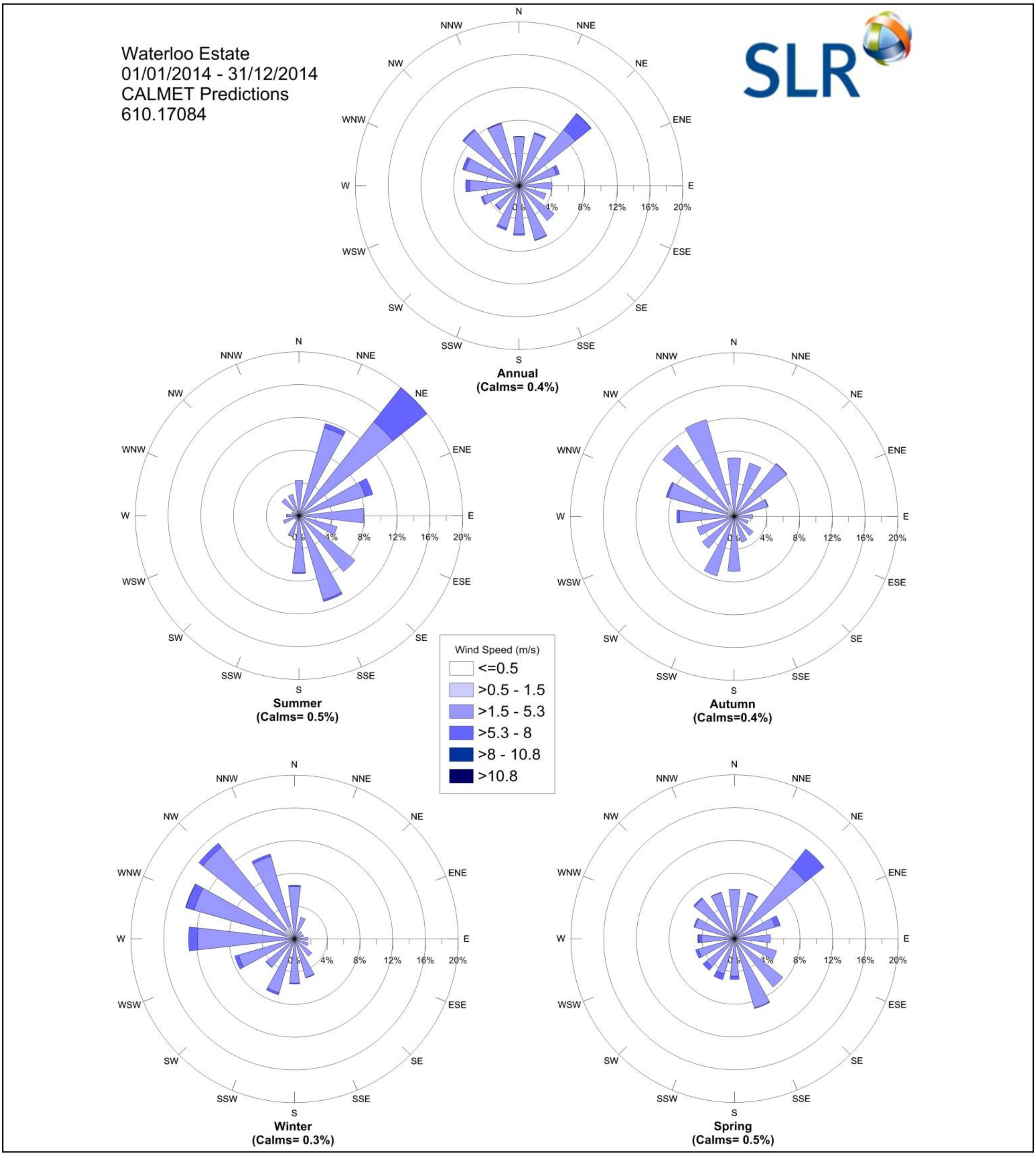
The seasonal wind roses indicate that:

- 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 0.4% 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**, which are for one point within Waterloo South. Within GRAL, the dispersion of pollutants from each source is predicted by the model based on the local conditions.

Figure 15 Predicted Seasonal Wind Roses for Waterloo South (CALMET predictions, 2014)



9.3.2 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 21**.

Table 21 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 Waterloo South 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.

9.3.3 Mixing Heights

Diurnal variations in maximum and average mixing heights predicted by CALMET at Waterloo South 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.

9.3.4 Temperature

The modelled temperature variations as predicted at Waterloo South 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 Waterloo South (CALMET predictions, 2014)

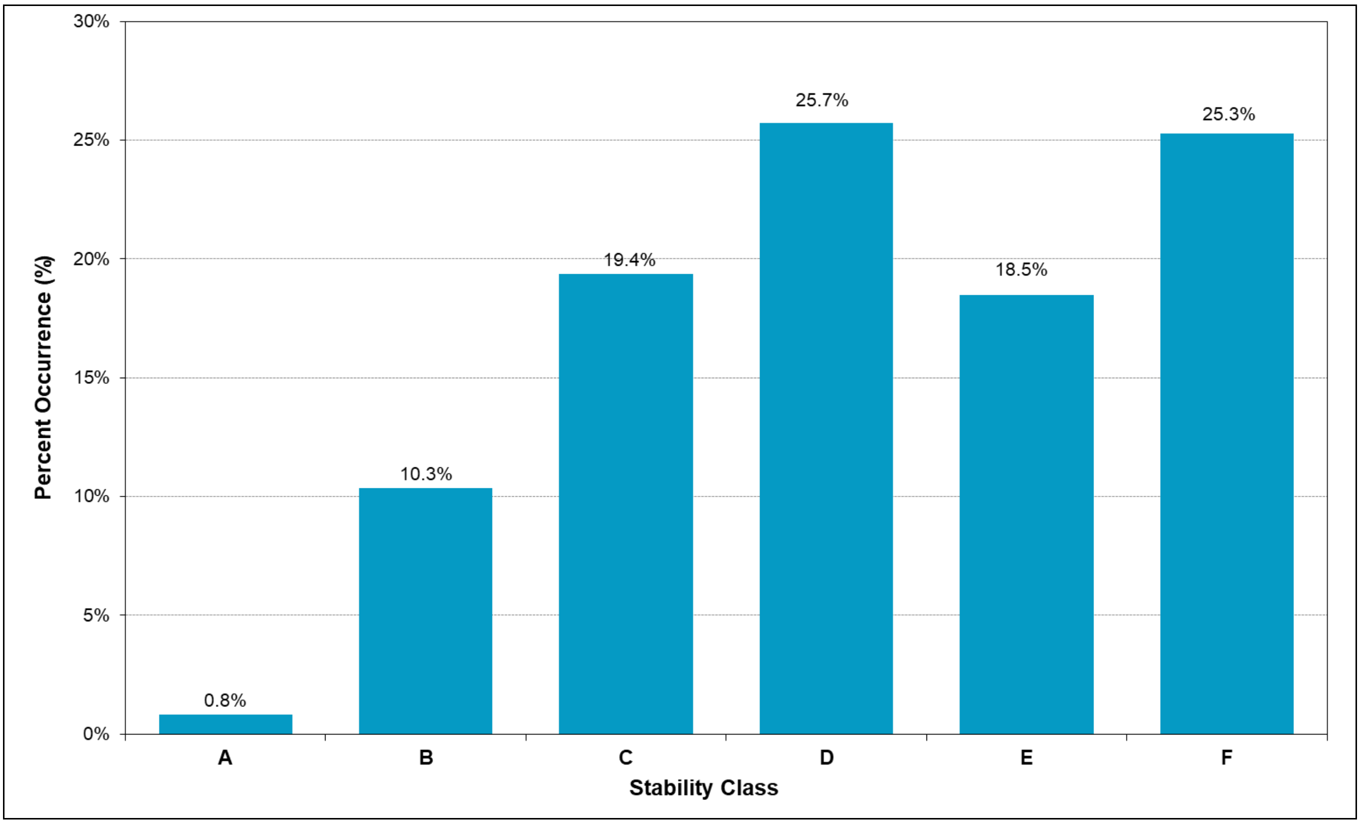


Figure 17 Predicted Mixing Heights at Waterloo South (CALMET predictions, 2014)

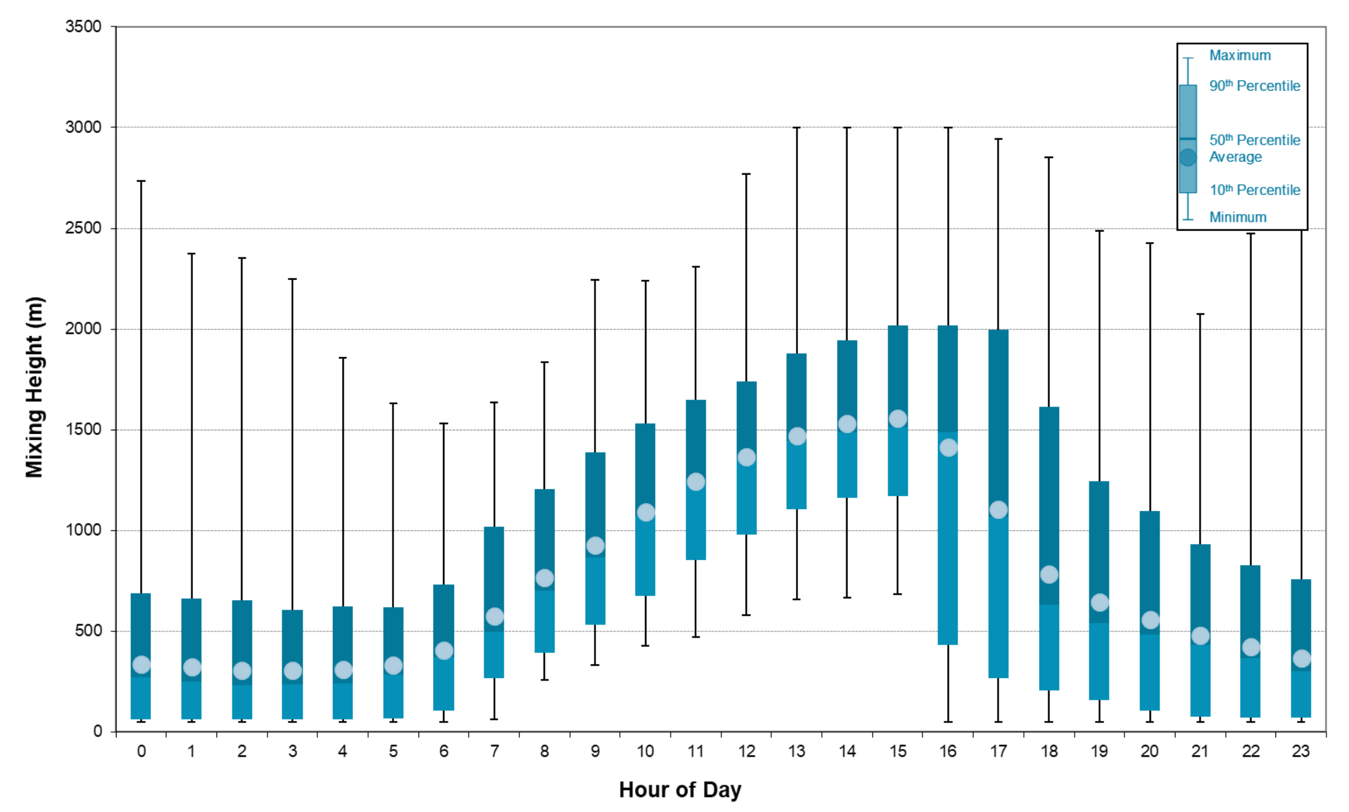
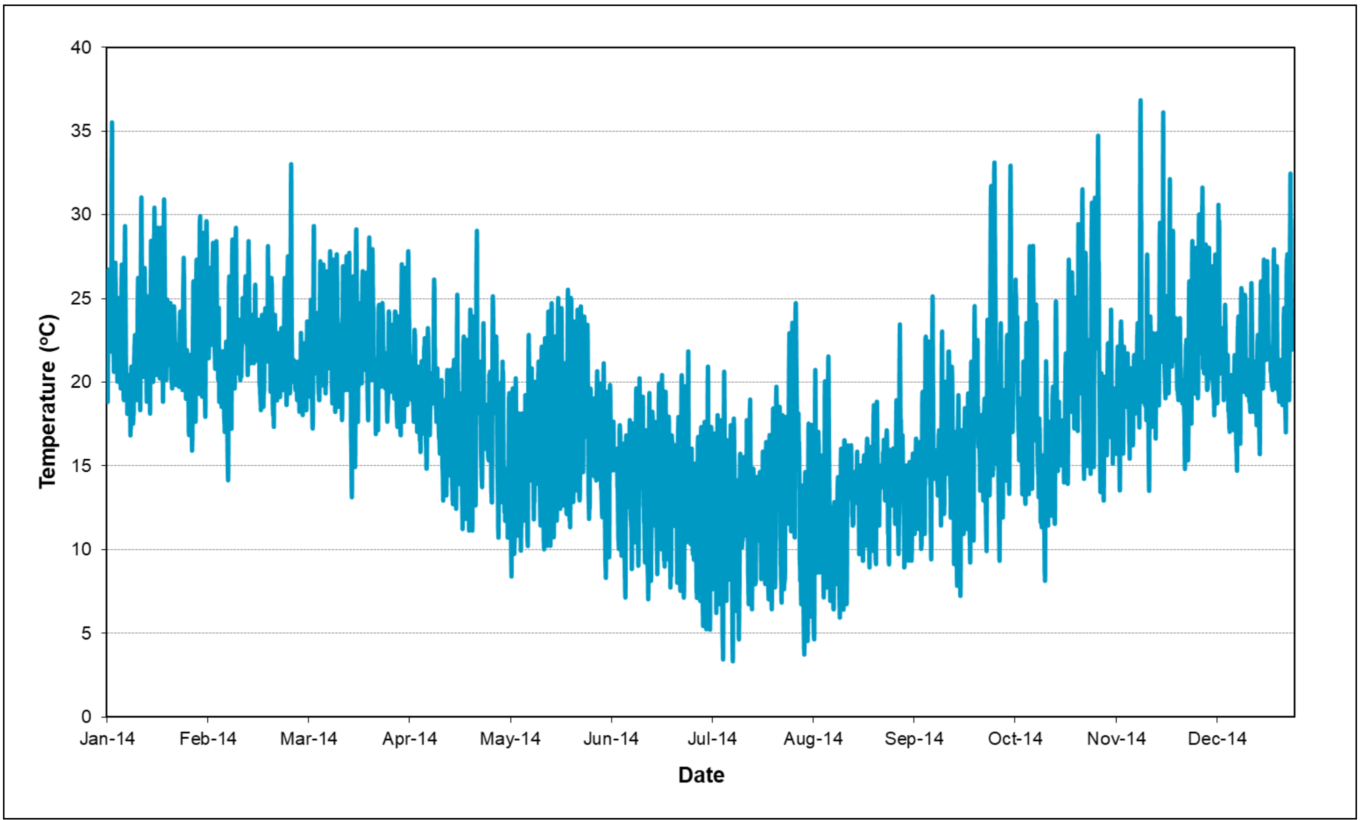


Figure 18 Predicted Temperatures at Waterloo South (CALMET predictions, 2014)



9.4 Dispersion Modelling

9.4.1 Model Selection

The GRAL modelling system was selected for the dispersion modelling of traffic emissions from roads surrounding the Estate 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, 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.

9.4.2 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 a high 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.

9.4.3 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 Waterloo South and Waterloo Metro Quarter 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. Outlines of these buildings are illustrated in **Figure 11** and the heights for all existing building were derived using high resolution Light Detection and Ranging (LIDAR) data.

A total of 2,721 discrete receptors were distributed across Waterloo South to predict the incremental impact of emissions from the surrounding roads on pollutant concentrations at potential residential areas. 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 5 m in the x and y directions. This results in 30,561 grid locations across the domain.

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). Additional discrete receptors were located at elevations up to 48 m for buildings in close proximity of roads with the highest traffic volumes (hence the highest risk for exceedances) (see **Figure 19**). It is noted that concentrations above the maximum heights modelled will be lower than the predictions presented in this report.

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.

Table 22 details the parameters used in GRAL for this assessment.

Table 22 Parameters used in GRAL for the AQA

Parameter	Value
General	
Dispersion time	3,600 seconds
Particles per second	100
Obstacles	Prognostic GRAL
Concentration Grids	
Horizontal concentration grid resolution	5.0 m
Vertical dimension of concentration layers	1.0 m
Number of horizontal slices	5 (1.0 m, 3.0 m, 6.0 m, 9.0 m and 12.0 m)
Internal flow field grid	
Horizontal grid resolution	3.0 m
Vertical thickness of first layer	1.0 m
Vertical stretching factor	1.05
Number of cells in Z direction	40

Figure 19 Modelled Discrete Receptors

9.5 Qualitative Assessment of Other Identified Sources

A risk-based qualitative assessment approach has been adopted for emission sources other than traffic that may impact Waterloo South (see **Appendix D** for full methodology). This risk-based assessment methodology takes account of a range of impact descriptors, including the following:

- **Nature of Impact**: does the impact result in an adverse or beneficial environment?
- **Sensitivity**: how sensitive is the receiving environment to the anticipated impacts? This may be applied to the sensitivity of the environment in a regional context or specific receptor locations.
- **Magnitude**: what is the anticipated scale of the impact?

The integration of sensitivity with impact magnitude is used to derive the predicted significance of that change. Given the small scale of the identified activities, and the limited operational details available, it is considered that this approach is appropriate to identify those key activities that have the potential to lead to air quality impacts at Waterloo South.

10 Assessment of Air Quality at Waterloo South

10.1 Impacts from the Surrounding Road Network

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 Waterloo South, based on projected 2036 vehicle numbers and emission factors representative of the current Sydney fleet. It is noted that due to improved vehicle emissions performance as outlined above, the 2036 Sydney fleet can be expected to emit less pollutants than the current fleet.

10.1.1 $PM_{2.5}$

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 23.**

Figure 20 illustrates the cumulative ground level 24-hour average $PM_{2.5}$ concentrations predicted within Waterloo South, while **Figure 21** 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.

Figure 22 illustrates the cumulative 24-hour average $PM_{2.5}$ concentrations predicted on the facade of the buildings most significantly impacted (buildings facing McEvoy Street), while **Figure 23** illustrates the cumulative annual average concentrations. These images are taken from a view looking northwest back at Waterloo South, with McEvoy Street in the foreground. The spheres in these figures illustrate the locations of the discrete receptors modelled, with the red spheres showing an exceedance of the relevant air quality impact assessment criterion and the green spheres showing a predicted cumulative concentration below the relevant criterion.

The predicted 24-hour average $PM_{2.5}$ concentrations exceed the relevant criterion at 28 out of over 2,700 receptors located on the building facades, all of which are located on the McEvoy Street facade (at elevations up to 15 m). However, it is noted that the southern facades of the McEvoy street buildings are not proposed to have any operable windows. As outlined in **Section 2**, it is proposed that for buildings along McEvoy Street, building cores will be located to the south.

For the worst-affected facade receptor, two (2) exceedances of the 24-hour average $PM_{2.5}$ criterion are predicted for the modelled year (August 6th and 9th). These exceedances are primarily due to high background concentrations on the days the exceedances are predicted (22.7 µg/m³ and 19.5 µg/m³ for August 9th and August 6th respectively). According to the New South Wales Air Quality Statement 2014 published by the NSW OEH (NSW OEH, 2015), the Sydney region experienced poor air quality early August 2014 due to hazard reduction burns and bush fires. As outlined in **Section 8**, in the years 2012 to 2017, Earlwood AQMS has recorded between 2 to 5 days of exceedance of the 24-hour average $PM_{2.5}$ criterion per year with the exception of 2014 when no exceedances were recorded.

Exceedances of the annual average $PM_{2.5}$ criterion are predicted at approximately 70% of the discrete receptors modelled (see **Figure 23**). This is primarily due to high background concentrations of $PM_{2.5}$ within the local airshed. 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.

As outlined in **Section 8**, exceedances of the annual average $PM_{2.5}$ criterion are frequently recorded in the Sydney metropolitan region (including in two of the last five years as recorded by the Earlwood AQMS). 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 8**) 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 Waterloo South, are exposed to are minimised as much as practicable.

Table 23 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	14.6	8.3	31.7	16.1
	Maximum at building facade	5.7	2.7	25.8	10.5
3 m Elevation	Maximum at building facade receptors	9.4	4.2	28.5	12.0
6 m Elevation	Maximum at building facade receptors	6.5	2.8	27.2	10.6
9 m Elevation	Maximum at building facade receptors	5.4	2.4	26.7	10.2
12 m Elevation	Maximum at building facade receptors	4.3	1.7	25.6	9.5
			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 criterion

Figure 20 Maximum Predicted Cumulative 24-Hour Average Ground Level $PM_{2.5}$ Concentrations

Figure 21 Predicted Cumulative Annual Average Ground Level $PM_{2.5}$ Concentrations

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Project Number:	610.17084
Dispersion Model:	GRAL
Modelling Period:	2014
Projection:	GDA 1994 MGA Zone 56
Date:	11/03/2020

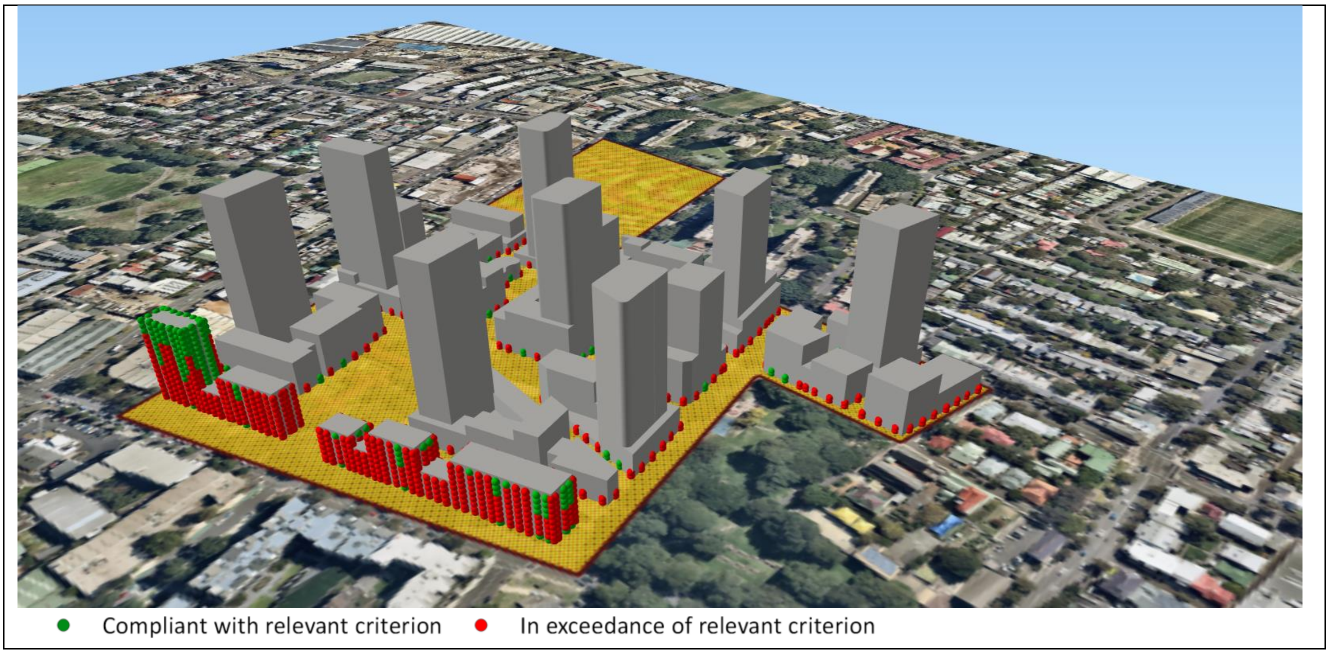
N W E S

NSW Land and Housing Corporation
Waterloo South
Air Quality Assessment
Cumulative Impact (Ground Level)

Pollutant	$PM_{2.5}$	Averaging Period	Annual	Unit	µg/m³

Figure 22 Maximum Predicted Cumulative 24-Hour Average $PM_{2.5}$ Concentrations – Facade Receptors

Figure 23 Predicted Cumulative Annual Average $PM_{2.5}$ Concentrations – Facade Receptors



10.1.2 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 24**.

Figure 24 illustrates the cumulative ground level 24-hour average PM_{10} concentrations predicted within Waterloo South, while **Figure 25** illustrates the cumulative annual average concentrations. **Figure 26** illustrates the cumulative 24-hour average PM_{10} concentrations predicted on the facade of the buildings most significantly impacted, while **Figure 27** illustrates the cumulative annual average concentrations at the facade receptors.

The modelling results presented in **Table 18** and illustrated in **Figure 26** and **Figure 27** show that while no exceedances of the annual average PM_{10} criterion is predicted for modelled facade receptors, exceedances of the 24-hour PM_{10} criterion are predicted at McEvoy Street facade locations (ground level and 3 m elevation). One (1) exceedance of the 24-hour average PM_{10} criterion is predicted per year for the worst-affected facade discrete receptors on the first two floors of buildings within close proximity of McEvoy Street (primarily due to a high background concentration of 46.1 µg/m³ on the day of the exceedance).

However, it is noted that the first two floors of the McEvoy street frontage are proposed to be used for retail/commercial use, which means no exceedances of the 24-hour PM_{10} criteria are predicted at any location on Waterloo South building facades where sensitive receptors may potentially be affected.

Table 24 Predicted PM_{10} Concentrations

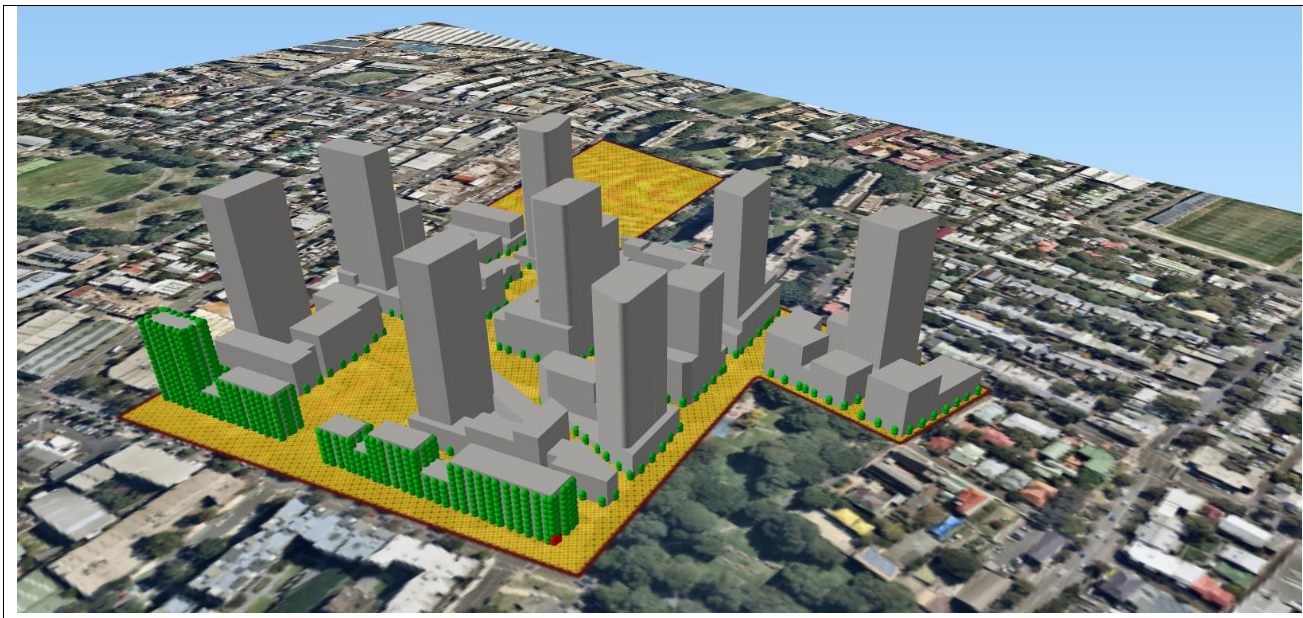
Elevation [1]	Location	Maximum Incremental Concentrations (µg/m³)		Maximum Cumulative Concentrations (µg/m³)	
		24-Hour Average	Annual Average	24-Hour Average	Annual Average
Ground Level	Maximum at boundary receptor	16.9	9.9	57.2	28.1
	Maximum at building facade	6.9	3.2	50.0	21.4
3 m Elevation	Maximum at building facade receptors	11.0	5.1	52.2	23.3
6 m Elevation	Maximum at building facade receptors	7.6	3.3	49.3	21.5
9 m Elevation	Maximum at building facade receptors	6.5	2.9	48.4	21.1
12 m Elevation	Maximum at building facade receptors	5.2	2.1	47.8	20.3
			CRITERIA	**50**	**25**

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 criterion

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

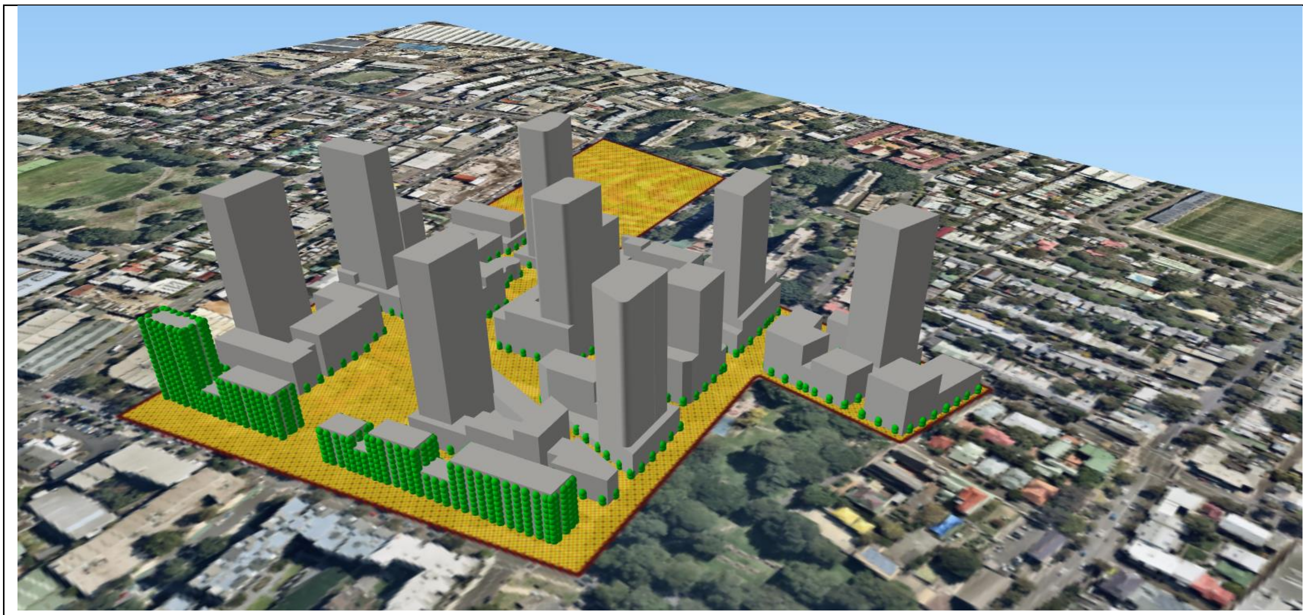
Figure 25 Predicted Cumulative Annual Average Ground Level PM_{10} Concentrations

Figure 26 Maximum Predicted Cumulative 24-Hour Average PM_{10} Concentrations – Facade Receptors



● Compliant with relevant criterion ● In exceedance of relevant criterion

Figure 27 Predicted Cumulative Annual Average PM_{10} Concentrations – Facade Receptors



● Compliant with relevant criterion ● In exceedance of relevant criterion

10.1.3 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 25**. 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 9.4.3**

Figure 28 and **Figure 29** illustrate the cumulative maximum 1-hour average and annual average ground level NO_2 concentrations predicted across Waterloo South.

The modelling results presented in **Table 25** show that while a minor exceedance of the 1-hour average NO_2 criteria is predicted at the Waterloo South boundary, no exceedances of the 1-hour or annual NO_2 criteria are predicted at building facade locations.

Table 25 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	164	48	187	68
	Maximum at building facade	110	26	153	46
3 m Elevation	Maximum at building facade receptors	140	34	170	55
6 m Elevation	Maximum at building facade receptors	116	30	162	50
9 m Elevation	Maximum at building facade receptors	116	28	151	49
12 m Elevation	Maximum at building facade receptors	113	24	142	44
			CRITERIA	**246**	**62**

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 criterion

Figure 28 Maximum Predicted Cumulative 1-Hour Average Ground Level NO_2 Concentrations

Figure 29 Predicted Cumulative Annual Average Ground Level NO_2 Concentrations

10.2 Impacts from Other Sources

This section presents a high level assessment of the potential risks of adverse air quality impacts at sensitive receptors within Waterloo South due to existing small scale activities in the surrounding area with a potential to impact upon local air quality. The impact assessment uses the methodology summarised in **Section 9.4** of this report, which integrates the receptor sensitivity with impact magnitude to derive the potential significance of that impact. Details of the qualitative risk assessment methodology used are provided in **Appendix D**.

10.2.1 Odour Emissions from Food Outlets

As discussed in **Section 6.3**, odour emissions are the main air quality issue for food and beverage outlets. As odour discharged from restaurant outlets has the potential to give rise to nuisance impacts if emitted in significant enough quantities, the nature of the impact is therefore defined as '**adverse**'.

The nearest food outlets to Waterloo South are located less than 50 m from the closest boundary. With regards to the methodology outlined in **Appendix D**, the sensitivity of the residential areas within Waterloo South to air pollutant emissions generated by these activities has been classified as ***high***.

Three site visits were conducted by SLR in April and May 2018 and February 2019 in order to better understand the extent of potential odour impacts from the identified restaurants. These site visits were conducted by staff trained in performing ambient odour surveys and whose odour sensitivity had recently (in the previous 12 months) been confirmed by a NATA-certified odour laboratory as falling within the acceptable range for odour assessors (in compliance with *AS/NZS 4323.3:2001 Stationary source emissions Part 3: Determination of odour concentration by dynamic olfactometry*). During the site visits, distinct cooking odours could only be detected from the McDonalds restaurant, which is located approximately 50 m to the south-southwest of Waterloo South (approximately 70 m to the south-southwest of the nearest proposed building). Odours from this restaurant were detectable approximately 10 m up to 100 m downwind, however these odours only carried a negative hedonic tone in close proximity of the source (within 20 m). Odours from other local restaurants were generally weak in intensity and only detectable in the immediate vicinity of the source (typically 1-5 m).

Given the above, the magnitude of odour impacts from the restaurants operating in the vicinity of Waterloo South on the proposed residential areas is concluded to be of '**negligible'** magnitude (i.e. impact is predicted to cause no significant consequences, **Table D2** of **Appendix D**).

Based on the nearest receptors having a '**high**' sensitivity to air quality impacts and the magnitude of the potential impacts from the restaurants being classified as '**negligible'**, the impact significance is concluded to be **'neutral'** (see **Table 26**).

Table 26 Risk Assessment of Odour Impacts – Food Outlets

Sensitivity		Impact Magnitude [Defined by Table D2]			
		Substantial Magnitude	Moderate Magnitude	Slight Magnitude	Negligible Magnitude
[Defined by Table D1]	Very High Sensitivity	Major Significance	Major/ Intermediate Significance	Intermediate Significance	Neutral Significance
	High Sensitivity	Major/ Intermediate Significance	Intermediate Significance	Intermediate/Minor Significance	Neutral Significance
	Medium Sensitivity	Intermediate Significance	Intermediate/Minor Significance	Minor Significance	Neutral Significance
	Low Sensitivity	Intermediate/Minor Significance	Minor Significance	Minor/Neutral Significance	Neutral Significance

10.2.2 VOC Emissions from Service Stations and Automotive Workshops

As discussed in **Section 6.3**, air quality issues associated with service stations and automotive workshops predominantly relate to emissions of volatile organic compounds (VOCs). Emissions of VOCs can give rise to both adverse health impacts due to exposure to specific hydrocarbon compounds, as well as adverse impacts on local amenity levels due to the odorous nature of some petrol and solvent vapour compounds. The nature of the impact is therefore defined as '**adverse**'.

With regards to the methodology outlined in **Appendix D**, the sensitivity of the residential areas within Waterloo South to air pollutant emissions generated by these activities has been classified as ***high***.

In order to determine the impact magnitude, reference has been made to Western Australia Environment Protection Authority (WA EPA) policy documentation for minimum recommended separation distances - *Separation distances between Industrial and Sensitive Land Uses* (WA EPA, 2005). In this document, the WA EPA makes recommendations for assessing appropriate separation distances where amenity may be reduced for sensitive or incompatible land uses. A summary of the separation distances which may be applicable to the service stations and automotive workshops located in the vicinity of Waterloo South are provided in **Table 27**. These values have been provided for guidance only and are not regulatory guideline values for NSW. The document does not include any specific separation distance between automotive workshops and sensitive land uses. The application of the service station separation distance to automotive workshops is considered to be conservative.

Table 27 Recommended Separation Distances for Industrial Residual Air Emissions

Industry Type	Description	Impacts	Recommended Separation Distance (m)
Service stations, involving vehicle cleaning/detailing facilities & the retailing of spare parts & foodstuffs	For premises operating during normal hours, i.e. Monday - Saturday from 0700-1900 hours	Gaseous Noise Odour Risk	50
	Freeway service centre (24 hour operations)		100
	All other 24 hour operations		200

The nearest service station to Waterloo South is located over 190 m from the closest boundary. The closest automotive workshop is located approximately 75 m from the closest boundary. It is noted that while the service stations operate 24/7, the nearest automotive workshop only operates Monday to Saturday from 07:00 am to 05:00 pm. It is further noted that as per NSW Government regulations, all petrol service stations located in the Sydney region supplying more than 0.5 million litres per year are required to have vapour recovery systems installed and operating.

Given the above considerations, the magnitude of impact from service stations and automotive repair shops is predicted to be '**negligible'** (i.e. impact is predicted to cause no significant consequences, **Table D2** of **Appendix D**).

Based on the nearest receptors having a '**high**' sensitivity to air quality impacts and the magnitude of the potential impacts from the service stations being classified as '**negligible'**, the impact significance is concluded to be **'neutral'** (see **Table 28**).

Table 28 Risk Assessment of VOC Impacts – Service Stations and Automotive Workshops

Sensitivity		Impact Magnitude [Defined by Table D2]			
		Substantial Magnitude	Moderate Magnitude	Slight Magnitude	Negligible Magnitude
[Defined by Table D1]	**Very High Sensitivity**	Major Significance	Major/ Intermediate Significance	Intermediate Significance	Neutral Significance
	High Sensitivity	Major/ Intermediate Significance	Intermediate Significance	Intermediate/Minor Significance	Neutral Significance
	Medium Sensitivity	Intermediate Significance	Intermediate/Minor Significance	Minor Significance	Neutral Significance
	Low Sensitivity	Intermediate/Minor Significance	Minor Significance	Minor/Neutral Significance	Neutral Significance

11 Recommended Mitigation Measures

11.1 Traffic Emissions

As air pollutant concentrations from road traffic (main source of emissions identified in the study area) tend to decrease with increasing distance from the road, it is recommended that sensitive receptors within the Precinct be located as far away from the main roads as possible. Considering the significant (75%) drop in pollutant concentrations 20 m away from the road (DoP, 2008), it is recommended that no sensitive receptors be located within a 20 m radius of the major roads.

The built environment throughout the Precinct should be designed in a way that avoids the creation of street canyons. This can be done by setting back the upper floor of buildings on roads with buildings along both sides of the road. Where street canyons cannot be avoided, it is recommended that lower floors be used for commercial use and residential receivers should be located on higher floors.

Vegetation barriers can play a significant role in mitigating urban air pollution and have many positive health benefits. Vegetation barriers force polluted air to flow either over or to pass through the vegetation; this is dependent upon porosity and physical dimensions. Low density vegetation results in the majority of air flowing through the barrier, whereas high density leads to little or no infiltration.

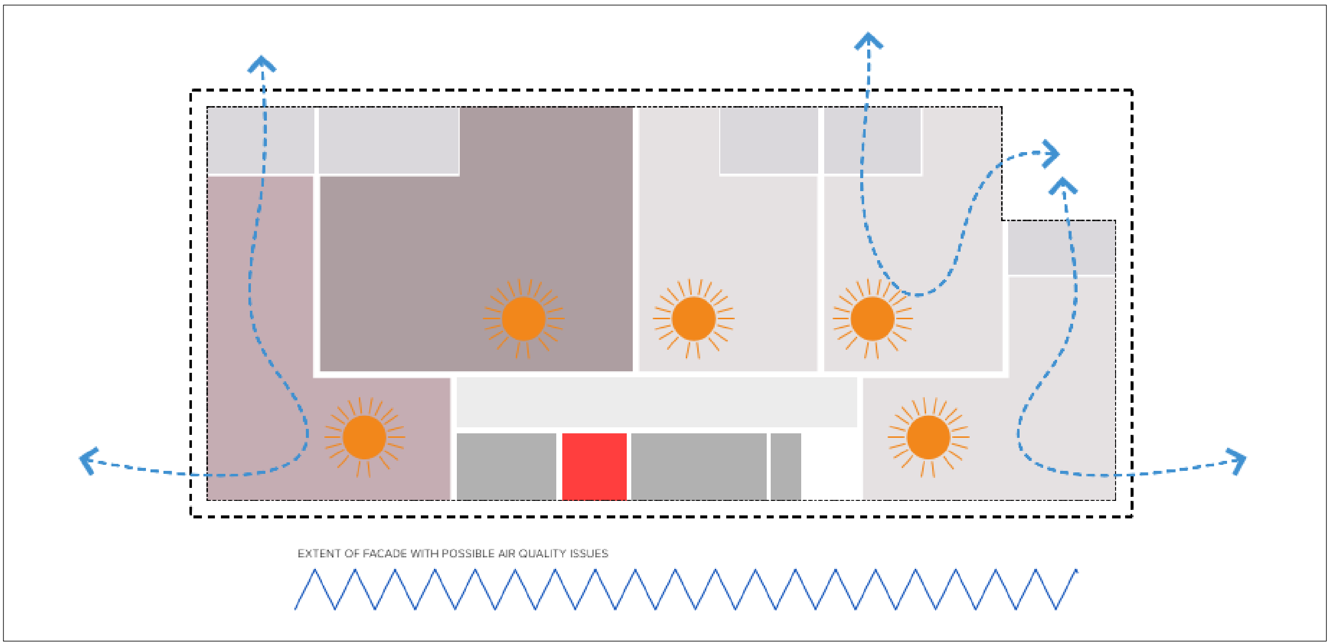
In open road environments, a mixture of trees and bushes can act as barriers to improving air quality. In street canyons however, depending on the urban and vegetation characteristics, trees may deteriorate air quality if their configuration is not planned adequately. This is because trees can reduce the wind speed in a street canyon, resulting in reduced air exchange between the air above the roof and within the canyon and hence leading to accumulation of pollutants inside the street canyon. Therefore, it is recommended that low-level hedgerows or green walls be used in street canyons.

As outlined in **Section 2**, the Indicative Concept Proposal of Waterloo South incorporates a number of these measures including:

- Minimising the formation of urban canyons by having buildings of different heights interspersed.
- For buildings along McEvoy Street:
    - Locating no sensitive receptors on the first two floors.
    - Reducing the number of south facing apartments by designing building cores to the south.
    - Provision of only corner apartments to the south.
    - Provision of wintergardens to the south facade with fixed glazing to the south and operable windows to the side facades.

Figure 30 illustrates how internal floor plates could potentially be planned to mitigate potential McEvoy street air quality impacts.

Figure 30 – Example Floorplate Showing Building Layout Limiting Exposure to McEvoy Frontage



11.2 Metro Station Emissions

According to the EIS prepared for the Sydney Metro Chatswood to Sydenham (TfNSW, 2016), only minor pollutant emissions from the Metro Station's ventilation system are likely. However, it is understood that during emergency conditions such as fire incidents, smoke-laden air would be discharged through the fresh air ventilation system. It is therefore highly recommended that sensitive receptors and ventilation intakes within Waterloo South are located away from the Waterloo Station ventilation outlet.

11.3 Other Emissions

As outlined in **Section 6.3**, emissions from future activities within Waterloo South (e.g. food outlets) may lead to potential amenity/nuisance impacts. In order to reduce impacts from such activities, suitable air extraction systems should be designed for all polluting activities to ensure air is extracted in compliance with AS 1668.2-2012 and BCA guidelines. If necessary, additional control measures can be adopted. Commonly used emission control options that may be applicable to the types of air emissions that could occur at Waterloo South include:

- Emission Height - Increasing the discharge height would improve dispersion by:
  - Allowing more dilution of the emissions by simply increasing the physical separation distance between the discharge point and the sensitive receptor (if at ground level); and
  - Reducing building wake effects. The wind flow at the point of discharge is affected by the interference that physical structures have on wind flow patterns. Buildings may cause a number of effects on air flow such that the air flow (i.e. wind) is increasingly turbulent as it passes over the building, and may lead to poor dispersion conditions through the effect of downwash. In simple terms, if the emission point is located within the turbulent flow zone, dispersion may be significantly hampered and rather than dispersing, the pollutant may be washed down preferentially towards the roof.

- Gas Momentum - A significant influencing factor on plume dispersion is gas momentum, or the velocity of the gas being discharged. The lower the discharge velocity, the less effect initial gas momentum has on the rise of the plume before dispersion via dilution effects. Dispersion of exhausts may be significantly enhanced through physical changes to the discharge dimensions or through the fitting of devices to increase the discharge velocity (e.g. dilution fans). Horizontal discharge vents or raincaps that block the upward flow of the gases should be avoided.
- Treatment
    - Cyclonic Filters - use the cyclone separation principle in order to remove large grease particles.
    - Electrostatic Precipitators (ESP) - are used to separate solid or liquid particles from ventilation air. The particles distributed in the gas are electrostatically charged so that they can be collected onto collection plates.
    - Cold Water Spray / Water Mist Systems – work by removing particulates and condensable materials by means of cold water sprays that run continuously. The cold water spray/mist causes the grease particles in the extracted air to drop in temperature, solidify and drop out of the air stream via a drain.
    - Ultraviolet (UV) Control Systems – work by breaking down organic particles and can be effective in neutralising odorous organic compounds. Due consideration needs to be given to the residual ozone that may arise from these systems.
    - Activated Carbon Adsorption - work by adsorbing odorous materials and other gaseous emissions such as VOCs into the pores of the carbon. The filters need to be replaced at appropriate intervals before they become saturated and their control efficiency begins to be compromised.
    - Wet Scrubbing - involves a mass transfer between a soluble gas and a liquid in a gas-liquid tower. This process relies on the preferential solubility of the pollutants present in the exhaust stream. Due consideration needs to be given to disposal requirements for the additional wastewater stream that would be generated by this system.

12 Recommended Controls

The proposed development is to 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 SSDA assessments for future developments across the site, particularly those fronting McEvoy Street, detailed assessments on final building configurations shall 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 surrounding the proposed construction methodology and equipment are known, a construction air quality impact assessment and Construction Air Quality Management Plan (CAQMP) shall be undertaken as part of the approval process.

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

13 Conclusions

The results of the cumulative impact assessment undertaken to assess the potential worst case air pollutant concentrations within Waterloo South due to emissions from local traffic indicate that traffic on the surrounding road network has potential to result in slight exceedances of the ambient air quality criteria for PM_{10} and $PM_{2.5}$ at locations within Waterloo South, particularly close to McEvoy Street. Exceedances of the 24 hour average PM_{10} and $PM_{2.5}$ ambient air quality criteria are limited to days with high regional levels of particulates due to natural causes (bushfires/hazard reduction burns/dust storms).

Mitigation measures consistent with Section 4.4 of the Guideline have been incorporated into the concept design of Waterloo South. These include:

- Minimising the formation of urban canyons by having buildings of different heights interspersed.
- For buildings along McEvoy Street:
    - Locating no sensitive receptors on the first two floors.
    - Reducing the number of south facing apartments by designing building cores to the south.
    - Provision of only corner apartments to the south.
    - Provision of wintergardens to the south facade with fixed glazing to the south and operable windows to the side facade.

The mitigation measures outlined above will minimise any potential for sensitive receptors to be exposed to high levels of pollutants emitted from vehicles travelling on the nearby road network. It is noted that annual $PM_{2.5}$ could potentially exceed its ambient air quality criterion at all locations within Waterloo South due to high background concentrations.

Other emission sources in the local area that could potentially impact on air quality within Waterloo South were identified as service stations, automotive workshops and food outlets. The potential for off-site air quality impacts due to these activities was assessed using a qualitative risk-based approach. Based on this qualitative risk-based assessment, taking into account the nature and scale of these activities and distance from Waterloo South, it was concluded that they do not have any significant potential to adversely impact on air quality within Waterloo South. No further assessment of these activities is therefore considered to be warranted.

In addition to the above, emission sources within Waterloo South (e.g. food outlets) could potentially lead to amenity/nuisance impacts at surrounding sensitive receptors or at residential locations within Waterloo South itself. The risk of any impacts would depend on the type and scale of the activities, the location of the activity relative to sensitive receptors, and any emissions controls incorporated into the design (e.g. filtration/control of emissions etc). It is therefore recommended that further assessment of any potentially air polluting activities proposed within Waterloo South 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.

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

14 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%

Sector	Subsector	Technology	Population (Annual)	Percentage
Passenger Cars	PC-S-petrol	ADR79-02	60,297	1.3%
Passenger Cars	PC-S-petrol	ADR79-03	0	0.0%
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%

Sector	Subsector	Technology	Population (Annual)	Percentage
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%
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%

Sector	Subsector	Technology	Population (Annual)	Percentage
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%
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%

Sector	Subsector	Technology	Population (Annual)	Percentage
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%
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%

Sector	Subsector	Technology	Population (Annual)	Percentage
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%
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%

Sector	Subsector	Technology	Population (Annual)	Percentage
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%
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	

APPENDIX B

Projected Traffic Volumes

ID	Name	Car	Truck	Heavy Truck	Total
3411	N19985_N13478	202	0	1	203
3997	N19985_N14630	747	12	4	763
4132	N13478_N12139	1590	22	2	1614
4134	N13480_N12161	686	6	1	693
4146	N13480_N12175	1279	13	1	1293
4150	N13478_N12160	1017	4	4	1025
4166	N13476_N12160	1109	13	2	1124
4174	N13474_N12151	895	4	3	902
4178	N13474_N12159	1339	15	2	1356
4317	N13448_N12149	525	0	0	525
4799	N13480_N13479	452	5	4	461
4936	N19997_N16728	821	15	1	837
5336	N13474_N14629	71	0	0	71
6406	N13476_N16799	628	8	6	642
6447	N13474_N16839	277	0	0	277
6554	N19997_N20012	53	0	0	53
7827	N19985_N22129	0	0	0	0
8132	N13478_N19985	747	12	4	763
9366	N25154_N13476	198	0	0	198
10712	N25280_N16800	691	2	4	697
10962	N13478_N24369	394	3	1	398
11195	N13440_N24371	1819	27	9	1855
11415	N13476_N25154	230	0	0	230
11490	N25154_N16842	96	0	0	96
11829	N12164_N12163	969	26	0	995
12590	N12160_N13476	571	8	6	585
12592	N12160_N13478	1646	27	3	1676
13327	N12172_N14762	1035	17	5	1057
13588	N24372_N12149	900	14	2	916
15092	N24370_N14565	1191	12	10	1213
16277	N12160_N19997	738	12	1	751
16278	N12160_N20003	814	1	2	817
17806	N12144_N24370	1174	13	10	1197
19772	N16839_N13474	213	0	0	213
19943	N16799_N13476	1054	13	2	1069
20180	N16839_N14624	149	0	0	149
21097	N16839_N16842	231	0	0	231
21209	N16799_N16800	1689	23	9	1721

ID	Name	Car	Truck	Heavy Truck	Total
24353	N16799_N25155	460	0	0	460
27525	N14631_N12149	27	0	0	27
28001	N14631_N13443	136	0	0	136
28019	N14629_N13474	234	0	0	234
31081	N20012_N12159	904	4	1	909
31084	N20012_N12163	879	7	0	886
32543	N13479_N12161	373	2	0	375
32550	N19956_N14630	173	0	0	173
32558	N13479_N12177	265	16	0	281
33134	N13479_N13480	354	0	1	355
33861	N13443_N14631	2	0	0	2
34838	N20012_N19997	139	5	0	144
39288	N13479_N24369	916	9	4	929
39802	N25155_N16799	381	0	0	381
39825	N25155_N16840	166	0	0	166
40174	N12163_N12161	1595	33	0	1628
40175	N12163_N12164	640	4	0	644
40191	N12161_N12163	696	4	0	700
40235	N12151_N12149	886	4	3	893
40252	N12149_N12151	1236	14	2	1252
40837	N12177_N13479	362	0	0	362
40846	N12175_N13480	1131	11	5	1147
40916	N12161_N13479	477	15	0	492
40917	N12161_N13480	923	13	0	936
40922	N12159_N13474	930	4	3	937
40969	N12149_N13448	438	0	0	438
40973	N12151_N13474	1240	14	2	1256
41054	N12139_N13478	849	7	5	861
41743	N12151_N14624	171	0	0	171
41760	N12149_N14631	136	0	0	136
41765	N12161_N14762	1008	22	1	1031
41950	N24371_N12145	1842	28	8	1878
42860	N24369_N13478	1065	8	3	1076
42861	N24369_N13479	416	3	1	420
42972	N17982_N12163	652	0	0	652
43060	N12161_N16728	672	11	5	688
43201	N12145_N16799	1861	28	6	1895
43689	N17864_N12159	573	18	1	592

ID	Name	Car	Truck	Heavy Truck	Total
43724	N12159_N17864	717	5	2	724
43770	N12163_N17982	486	0	0	486
44523	N24369_N16728	86	1	0	87
44672	N12163_N20012	973	6	1	980
44679	N12159_N20003	1014	24	1	1039
44681	N12159_N20012	891	7	0	898
46275	N12149_N24372	685	4	2	691
47865	N16800_N12144	1166	13	10	1189
48147	N16728_N12161	604	14	1	619
48590	N16840_N14624	160	0	0	160
48754	N16800_N14630	162	0	1	163
49508	N16842_N16839	75	0	0	75
49509	N16842_N16840	0	0	0	0
49516	N16840_N16842	0	0	0	0
49623	N16800_N16799	350	0	0	350
51168	N16728_N19997	623	10	5	638
52618	N16842_N25154	209	0	0	209
52627	N16840_N25155	132	0	0	132
52767	N16728_N24369	188	2	0	190
52812	N16800_N25280	1259	24	6	1289
54299	N22129_N19985	0	0	0	0
55490	N14762_N12161	1029	16	5	1050
55492	N14762_N12172	999	22	1	1022
55960	N14624_N12151	107	0	0	107
56388	N14630_N13476	139	0	0	139
57636	N14630_N16800	596	12	4	612
57692	N14624_N16839	349	0	0	349
57694	N14624_N16840	126	0	0	126
59028	N14630_N19956	159	0	0	159
59042	N14630_N19985	176	0	1	177
59605	N20003_N12159	711	1	2	714
59606	N20003_N12160	1058	21	1	1080
59630	N19997_N12160	685	12	5	702
40500082	N12177_N13479	192	4	0	196
40500085	N12177_N13479	561	4	0	565
40500088	N13479_N24369	726	5	4	735
40500095	N16728_N12161	754	15	1	770
40500098	N12161_N12163	1191	10	1	1202

ID	Name	Car	Truck	Heavy Truck	Total
40500101	N16728_N12161	146	1	0	147
40500105	N12161_N12163	1202	10	1	1213
40500108	N12161_N12163	506	6	1	513
40500112	N24369_N16728	129	0	0	129
40500113	N16728_N24369	102	2	0	104
40500121	N19997_N20012	41	4	0	45
40500124	N20012_N19997	120	0	0	120
40500132	N19997_N20012	110	0	0	110
40500133	N19997_N20012	36	1	0	37
40500140	N12161_N12163	1337	11	1	1349
40500143	N12163_N12161	1606	33	0	1639
40500147	N19997_N20012	188	0	0	188
40500153	N19997_N20012	28	2	0	30
40500154	N20012_N19997	65	1	0	66
40500161	N19997_N20012	33	0	0	33
40500162	N19997_N20012	156	1	0	157
40500167	N19997_N20012	33	0	0	33
40500170	N20012_N19997	201	1	0	202
40500178	N12160_N20003	875	4	2	881
40500181	N20003_N12160	1133	25	1	1159
40500190	N24372_N12149	1063	13	2	1078
40500193	N12149_N13448	281	0	0	281
40500196	N24372_N12149	157	0	0	157
40500201	N13474_N16839	204	0	0	204
40500202	N16839_N13474	253	0	0	253
40500220		260	0	0	260
40500221		462	0	0	462
40500222		486	0	0	486
40500223		438	0	0	438
40500238	N12177_N13479	560	4	0	564
40500241	N13479_N12177	263	16	0	279
40500246	N24369_N13478	1016	8	3	1027
40500249	N13478_N24369	399	3	1	403
40500255	N14630_N16800	611	12	4	627
40500274	N14630_N16800	19	0	0	19
40500275	N14630_N16800	2	0	0	2
40500295	N19997_N12160	673	12	5	690
40500303	N16840_N16842	0	0	0	0

ID	Name	Car	Truck	Heavy Truck	Total
40500304	N16840_N16842	0	0	0	0
40500311	N16840_N16842	43	0	0	43
40500312	N16842_N16840	135	0	0	135
40500313	N16840_N16842	20	0	0	20
40500314	N16840_N16842	40	0	0	40
40500335		256	0	0	256
40500336		160	0	0	160
40500337		245	0	0	245
40500338		224	0	0	224
40500353	N16842_N16840	139	0	0	139
40500354	N16840_N16842	151	0	0	151
40500356		559	0	0	559
40500357		579	0	0	579
40500358		423	0	0	423
40500359		483	0	0	483
40500374	N14624_N16839	359	0	0	359
40500375	N16839_N14624	157	0	0	157
40500485		326	0	0	326
40500486		529	0	0	529
40500487		553	0	0	553
40500488		355	0	0	355
40500505	N14624_N16839	374	0	0	374
40500506	N16839_N14624	217	0	0	217
40500516	N16842_N16840	121	0	0	121
40500517	N16840_N16842	206	0	0	206
40500518	N16842_N16840	170	0	0	170
40500521	N16840_N16842	84	0	0	84
40500529	N25154_N13476	0	0	0	0
40500530	N13476_N25154	8	0	0	8
40500531	N25154_N13476	80	0	0	80
40500532	N13476_N25154	5	0	0	5
40500533	N25154_N13476	0	0	0	0
40500534	N13476_N25154	0	0	0	0
40500548	N25154_N13476	122	0	0	122
40500549	N13476_N25154	67	0	0	67
40500550	N16840_N16842	96	0	0	96
40500558	N16842_N25154	231	0	0	231
40500561	N25154_N16842	123	0	0	123

ID	Name	Car	Truck	Heavy Truck	Total
40500564	N16840_N16842	49	0	0	49
40500572	N16840_N16842	140	0	0	140
40500576	N16840_N25155	126	0	0	126
40500579	N25155_N16840	292	0	0	292
40500587	N16840_N16842	0	0	0	0
40500588	N16840_N16842	0	0	0	0
40500589	N13476_N25154	61	0	0	61
40500590	N25154_N13476	155	0	0	155
40500604	N19997_N20012	67	0	0	67
40500605	N20012_N19997	84	0	0	84
40500606	N12159_N20012	892	7	0	899
40500609	N20012_N12159	892	4	1	897
40500617	N12160_N19997	762	12	1	775
40500621	N19997_N20012	35	0	0	35
40500622	N20012_N19997	25	0	0	25
40500623	N20012_N19997	3	0	0	3
40500624	N19997_N20012	0	0	0	0
40500642	N24371_N12145	1839	28	8	1875
40500647	N16842_N16840	7	0	0	7
40500648	N16840_N16842	6	0	0	6
40500649	N16842_N16840	133	0	0	133
40500652	N16840_N16842	145	0	0	145
40500660	N16842_N16840	20	0	0	20
40500661	N16840_N16842	22	0	0	22
40500662	N16840_N16842	42	0	0	42
40500663	N16840_N16842	0	0	0	0
40500664	N16840_N16842	0	0	0	0
40500677	N16840_N16842	0	0	0	0
40500678	N14624_N12151	147	0	0	147
40500681	N12151_N14624	171	0	0	171
40500691	N16840_N16842	0	0	0	0
40500744	N16800_N12144	1187	13	10	1210
40500749	N13474_N12151	906	4	3	913
40500752	N12151_N13474	1238	14	2	1254
40500756	N14624_N12151	0	0	0	0
40500757	N12151_N14624	11	0	0	11
40500762	N16839_N13474	61	0	0	61
40500764	N13474_N16839	290	0	0	290

ID	Name	Car	Truck	Heavy Truck	Total
40500767	N16839_N13474	264	0	0	264
40500775	N16839_N13474	0	0	0	0
40500776	N16839_N13474	60	0	0	60
40500780	N16839_N13474	27	0	0	27
40500781	N16839_N13474	85	0	0	85
40500787	N16842_N16839	95	0	0	95
40500790	N16839_N16842	252	0	0	252
40500796	N14630_N16800	0	0	0	0
40500797	N14630_N16800	0	0	0	0
40500801	N16839_N13474	11	0	0	11
40500802	N16839_N13474	13	0	0	13
40500803	N13474_N12159	1343	15	2	1360
40500806	N12159_N13474	927	4	3	934
40500814	N16839_N13474	19	0	0	19
40500818		0	0	0	0
40501980	N20012_N19997	64	5	0	69
40502490	N16800_N14630	155	0	1	156
40502676	N16839_N13474	124	0	0	124
40502677	N16839_N13474	171	0	0	171
40502696	N12175_N13480	1120	11	5	1136
40502699	N13480_N12175	1276	13	1	1290
40502705	N17982_N12163	649	0	0	649
40502708	N12163_N17982	491	0	0	491
40502716	N19997_N20012	74	0	0	74
40502719	N20012_N19997	76	0	0	76
40502723	N20012_N12159	903	4	1	908
40502726	N12159_N20012	892	7	0	899
40502734	N19997_N20012	129	1	0	130
40502737	N19997_N20012	36	0	0	36
40502740	N19997_N20012	60	0	0	60
40502743	N20012_N19997	85	0	0	85
40502752	N19997_N20012	87	7	0	94
40502755	N19997_N20012	62	1	0	63
40502758	N19997_N20012	70	0	0	70
40502766	N12161_N16728	659	11	5	675
40502769	N16728_N12161	793	15	1	809
40502779	N24369_N16728	85	1	0	86
40502782	N16728_N24369	153	2	0	155

ID	Name	Car	Truck	Heavy Truck	Total
40502793	N13479_N24369	919	9	4	932
40502796	N24369_N13479	416	3	1	420
40502806	N13478_N19985	756	12	4	772
40502809	N19985_N13478	176	0	1	177
40502815	N12160_N13476	570	8	6	584
40502818	N13476_N12160	1102	13	2	1117
40502828	N16840_N16842	138	0	0	138
40502833	N16840_N16842	0	0	0	0
40502836	N16840_N16842	0	0	0	0
40502844	N13476_N25154	5	0	0	5
40502847	N25154_N13476	80	0	0	80
40502871	N16839_N13474	256	0	0	256
40502874	N13474_N16839	276	0	0	276
40502878	N16839_N13474	37	0	0	37
40502887	N12159_N17864	720	5	2	727
40502890	N17864_N12159	566	18	1	585
40502898	N13474_N14629	86	0	0	86
40502901	N14629_N13474	206	0	0	206
40502909	N14624_N12151	147	0	0	147
40502912	N12151_N14624	117	0	0	117
40502920	N16839_N14624	148	0	0	148
40502923	N14624_N16839	349	0	0	349
40502927	N16839_N16842	252	0	0	252
40502930	N16842_N16839	75	0	0	75
40502938	N16842_N16839	95	0	0	95
40502941	N16839_N16842	231	0	0	231
40502945	N16842_N16840	0	0	0	0
40502949	N16840_N16842	0	0	0	0
40502953	N14624_N16840	188	0	0	188
40502956	N16840_N14624	167	0	0	167
40502968	N16840_N16842	77	0	0	77
40502971	N16840_N16842	158	0	0	158
40502977	N16842_N16840	139	0	0	139
40502980	N16840_N16842	70	0	0	70
40502986	N13476_N16799	611	8	6	625
40502989	N16799_N13476	1050	13	3	1066
40503004	N16842_N16840	132	0	0	132
40503007	N16840_N16842	145	0	0	145

ID	Name	Car	Truck	Heavy Truck	Total
40503013	N16840_N16842	180	0	0	180
40503016	N16842_N16840	169	0	0	169
40503020	N25155_N16840	284	0	0	284
40503023	N16840_N25155	144	0	0	144
40503031	N16842_N16840	157	0	0	157
40503034	N16840_N16842	116	0	0	116
40503042	N14631_N12149	22	0	0	22
40503045	N12149_N14631	138	0	0	138
40503165	N20003_N12160	1081	21	1	1103
40504228	N14630_N16800	0	0	0	0
50708595	N12160_N20003	873	4	2	879
50708601	N13476_N12160	1110	13	2	1125
50708611	N20003_N12159	814	1	2	817
50708618	N16839_N13474	176	0	0	176
50708621	N16839_N13474	223	0	0	223
50708634	N16840_N16842	32	0	0	32
50708635	N16840_N16842	26	0	0	26
50708646	N16840_N16842	40	0	0	40
50708649	N16840_N16842	20	0	0	20
50708661	N25154_N13476	158	0	0	158
50708664	N13476_N25154	61	0	0	61
50708672	N16839_N13474	253	0	0	253
50708675	N13474_N16839	204	0	0	204
50708686	N25154_N13476	103	0	0	103
50708689	N13476_N25154	0	0	0	0
50708693	N25154_N13476	0	0	0	0
50708696	N13476_N25154	1	0	0	1
50709193	N16840_N25155	126	0	0	126
50709196	N25155_N16840	165	0	0	165
50709547	N12159_N20003	993	22	1	1016
50709669	N16840_N16842	5	0	0	5
50709670	N16842_N16840	28	0	0	28
50709671	N13476_N25154	253	0	0	253
50709676	N16840_N16842	13	0	0	13
50709677	N16842_N16840	45	0	0	45
50709715	N25155_N16840	102	0	0	102
50709716	N16840_N25155	95	0	0	95
50709721	N25155_N16840	40	0	0	40

ID	Name	Car	Truck	Heavy Truck	Total
50709722	N16840_N25155	39	0	0	39
50709723	N25155_N16840	6	0	0	6
50709724	N16840_N25155	50	0	0	50
50709725	N16840_N25155	19	0	0	19
50709726	N25155_N16840	48	0	0	48
50709735	N16840_N25155	43	0	0	43
50709736	N25155_N16840	6	0	0	6
50709737	N16840_N25155	18	0	0	18
50709738	N25155_N16840	42	0	0	42
50709739	N16840_N25155	6	0	0	6
50709740	N25155_N16840	9	0	0	9
50709741	N16839_N13474	2	0	0	2
50709756	N13476_N25154	1	0	0	1
50709757	N25154_N13476	0	0	0	0
50709758	N25154_N13476	58	0	0	58
50709759	N13476_N25154	17	0	0	17
50709760	N13476_N25154	6	0	0	6
50709761	N25154_N13476	0	0	0	0
50709762	N13476_N25154	0	0	0	0
50709765	N25154_N13476	6	0	0	6
50709789	N25154_N13476	68	0	0	68
50709790	N13476_N25154	29	0	0	29
50709791	N13476_N25154	29	0	0	29
50709792	N25154_N13476	1	0	0	1
50709797	N13476_N25154	0	0	0	0
50709800	N25154_N13476	35	0	0	35
50709842	N16840_N16842	180	0	0	180
50709845	N16842_N16840	132	0	0	132
50709870	N16839_N13474	210	0	0	210

APPENDIX C

Estimated Emission Rates – Traffic

Table 29 Estimated Road Gradients and Emission Rates

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
3411	N19985_N13478	158	-0.3	0.198	0.012	0.010
3997	N19985_N14630	675	1.1	1.101	0.071	0.059
4132	N13478_N12139	1626	-0.2	2.034	0.120	0.101
4134	N13480_N12161	704	2.8	1.149	0.074	0.062
4146	N13480_N12175	1309	0.0	1.638	0.097	0.081
4150	N13478_N12160	1028	2.7	1.677	0.108	0.090
4166	N13476_N12160	1257	-1.5	0.992	0.050	0.042
4174	N13474_N12151	766	0.2	0.958	0.057	0.047
4178	N13474_N12159	1300	-4.0	0.864	0.045	0.037
4317	N13448_N12149	426	-1.8	0.336	0.017	0.014
4799	N13480_N13479	444	3.1	0.890	0.060	0.050
4936	N19997_N16728	1019	0.2	1.275	0.075	0.063
5336	N13474_N14629	51	2.7	0.083	0.005	0.004
6406	N13476_N16799	760	0.3	0.951	0.056	0.047
6447	N13474_N16839	122	-4.5	0.081	0.004	0.004
6554	N19997_N20012	38	2.0	0.062	0.004	0.003
7827	N19985_N22129	0	0.2	0.000	0.000	0.000
8132	N13478_N19985	675	1.9	1.101	0.071	0.059
9366	N25154_N13476	238	0.1	0.298	0.018	0.015
10712	N25280_N16800	629	1.1	1.026	0.066	0.055
10962	N13478_N24369	317	-0.6	0.397	0.023	0.020
11195	N13440_N24371	1894	3.0	3.798	0.255	0.214
11415	N13476_N25154	103	0.1	0.129	0.008	0.006
11490	N25154_N16842	70	1.1	0.114	0.007	0.006
11829	N12164_N12163	1056	1.0	1.723	0.111	0.093
12590	N12160_N13476	610	0.0	0.763	0.045	0.038
12592	N12160_N13478	1667	-2.7	1.316	0.066	0.055
13327	N12172_N14762	899	0.0	1.125	0.067	0.056
13588	N24372_N12149	941	0.3	1.177	0.070	0.058
15092	N24370_N14565	1233	1.9	2.012	0.129	0.108
16277	N12160_N19997	961	-1.4	0.758	0.038	0.032
16278	N12160_N20003	748	2.7	1.221	0.078	0.066
17806	N12144_N24370	1235	3.6	2.477	0.166	0.139
19772	N16839_N13474	173	0.4	0.216	0.013	0.011

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
19943	N16799_N13476	1208	0.0	1.511	0.089	0.075
20180	N16839_N14624	159	1.0	0.259	0.017	0.014
21097	N16839_N16842	136	-3.8	0.090	0.005	0.004
21209	N16799_N16800	1671	0.1	2.090	0.124	0.104
24353	N16799_N25155	396	-0.2	0.495	0.029	0.025
27525	N14631_N12149	36	1.0	0.059	0.004	0.003
28001	N14631_N13443	137	0.5	0.171	0.010	0.008
28019	N14629_N13474	196	-1.5	0.155	0.008	0.007
31081	N20012_N12159	861	4.0	1.727	0.116	0.097
31084	N20012_N12163	824	-0.2	1.031	0.061	0.051
32543	N13479_N12161	158	3.5	0.317	0.021	0.018
32550	N19956_N14630	142	0.2	0.178	0.011	0.009
32558	N13479_N12177	422	0.3	0.528	0.031	0.026
33134	N13479_N13480	336	2.8	0.548	0.035	0.030
33861	N13443_N14631	5	0.5	0.006	0.000	0.000
34838	N20012_N19997	97	1.0	0.121	0.007	0.006
39288	N13479_N24369	1048	0.0	1.311	0.078	0.065
39802	N25155_N16799	298	-0.4	0.373	0.022	0.018
39825	N25155_N16840	130	1.9	0.212	0.014	0.011
40174	N12163_N12161	1641	1.0	2.678	0.172	0.144
40175	N12163_N12164	564	1.0	0.706	0.042	0.035
40191	N12161_N12163	626	0.6	0.783	0.046	0.039
40235	N12151_N12149	838	0.8	1.048	0.062	0.052
40252	N12149_N12151	1172	0.7	1.466	0.087	0.073
40837	N12177_N13479	126	2.5	0.206	0.013	0.011
40846	N12175_N13480	1156	2.2	1.886	0.121	0.102
40916	N12161_N13479	536	3.6	1.075	0.072	0.060
40917	N12161_N13480	971	2.5	1.584	0.102	0.085
40922	N12159_N13474	814	2.2	1.328	0.085	0.072
40969	N12149_N13448	374	2.0	0.610	0.039	0.033
40973	N12151_N13474	1172	0.4	1.466	0.087	0.073
41054	N12139_N13478	787	0.2	0.985	0.058	0.049
41743	N12151_N14624	102	9.5	0.223	0.017	0.014
41760	N12149_N14631	137	-0.9	0.171	0.010	0.008
41765	N12161_N14762	1032	0.4	1.291	0.076	0.064

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_x	$PM_{2.5}$	PM_{10}
41950	N24371_N12145	1904	0.2	2.382	0.141	0.118
42860	N24369_N13478	1054	0.9	1.319	0.078	0.065
42861	N24369_N13479	451	0.8	0.564	0.033	0.028
42972	N17982_N12163	543	1.2	0.886	0.057	0.048
43060	N12161_N16728	639	1.4	1.043	0.067	0.056
43201	N12145_N16799	1924	1.1	3.139	0.202	0.169
43689	N17864_N12159	582	-5.2	0.372	0.019	0.016
43724	N12159_N17864	632	2.0	1.031	0.066	0.056
43770	N12163_N17982	435	2.0	0.710	0.046	0.038
44523	N24369_N16728	191	1.6	0.312	0.020	0.017
44672	N12163_N20012	842	-0.3	1.053	0.062	0.052
44679	N12159_N20003	1162	-2.7	0.917	0.046	0.039
44681	N12159_N20012	841	-0.7	1.052	0.062	0.052
46275	N12149_N24372	662	-0.4	0.828	0.049	0.041
47865	N16800_N12144	1236	3.1	2.479	0.166	0.139
48147	N16728_N12161	665	0.0	0.832	0.049	0.041
48590	N16840_N14624	156	5.7	0.342	0.026	0.022
48754	N16800_N14630	90	-0.1	0.113	0.007	0.006
49508	N16842_N16839	72	5.4	0.158	0.012	0.010
49509	N16842_N16840	69	0.2	0.086	0.005	0.004
49516	N16840_N16842	59	-0.4	0.074	0.004	0.004
49623	N16800_N16799	298	0.1	0.373	0.022	0.018
51168	N16728_N19997	633	-0.1	0.792	0.047	0.039
52618	N16842_N25154	168	-0.2	0.210	0.012	0.010
52627	N16840_N25155	57	0.1	0.071	0.004	0.004
52767	N16728_N24369	246	-1.1	0.194	0.010	0.008
52812	N16800_N25280	1242	1.2	2.027	0.130	0.109
54299	N22129_N19985	0	0.1	0.000	0.000	0.000
55490	N14762_N12161	900	0.6	1.126	0.067	0.056
55492	N14762_N12172	1029	0.0	1.287	0.076	0.064
55960	N14624_N12151	151	5.2	0.331	0.025	0.021
56388	N14630_N13476	37	0.4	0.046	0.003	0.002
57636	N14630_N16800	560	1.4	0.914	0.059	0.049
57692	N14624_N16839	187	-1.3	0.148	0.007	0.006
57694	N14624_N16840	90	5.4	0.197	0.015	0.013

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_x	$PM_{2.5}$	PM_{10}
59028	N14630_N19956	168	0.1	0.210	0.012	0.010
59042	N14630_N19985	128	-1.2	0.101	0.005	0.004
59605	N20003_N12159	666	2.7	1.087	0.070	0.059
59606	N20003_N12160	1133	-2.7	0.894	0.045	0.038
59630	N19997_N12160	673	1.3	1.098	0.071	0.059
40500082	N12177_N13479	397	0.8	0.497	0.029	0.025
40500085	N12177_N13479	524	1.1	0.855	0.055	0.046
40500088	N13479_N24369	651	1.7	1.062	0.068	0.057
40500095	N16728_N12161	910	-0.3	1.138	0.067	0.056
40500098	N12161_N12163	912	1.3	1.488	0.096	0.080
40500101	N16728_N12161	242	1.4	0.395	0.025	0.021
40500105	N12161_N12163	1127	0.1	1.410	0.083	0.070
40500108	N12161_N12163	501	0.2	0.627	0.037	0.031
40500112	N24369_N16728	122	0.5	0.153	0.009	0.008
40500113	N16728_N24369	92	-0.6	0.115	0.007	0.006
40500121	N19997_N20012	54	1.1	0.088	0.006	0.005
40500124	N20012_N19997	59	0.8	0.074	0.004	0.004
40500132	N19997_N20012	107	0.1	0.134	0.008	0.007
40500133	N19997_N20012	12	0.4	0.015	0.001	0.001
40500140	N12161_N12163	1154	1.0	1.444	0.085	0.072
40500143	N12163_N12161	1656	0.3	2.072	0.123	0.103
40500147	N19997_N20012	125	1.5	0.204	0.013	0.011
40500153	N19997_N20012	39	1.4	0.064	0.004	0.003
40500154	N20012_N19997	53	-1.6	0.042	0.002	0.002
40500161	N19997_N20012	21	-1.6	0.017	0.001	0.001
40500162	N19997_N20012	29	1.9	0.047	0.003	0.003
40500167	N19997_N20012	23	0.9	0.029	0.002	0.001
40500170	N20012_N19997	51	-1.8	0.040	0.002	0.002
40500178	N12160_N20003	825	0.8	1.032	0.061	0.051
40500181	N20003_N12160	1168	-2.7	0.922	0.046	0.039
40500190	N24372_N12149	1055	-0.3	1.320	0.078	0.065
40500193	N12149_N13448	263	1.1	0.429	0.028	0.023
40500196	N24372_N12149	111	-0.1	0.139	0.008	0.007
40500201	N13474_N16839	216	6.0	0.473	0.036	0.030
40500202	N16839_N13474	116	5.7	0.254	0.019	0.016

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
40500220	0	275	3.7	0.552	0.037	0.031
40500221	0	303	2.2	0.494	0.032	0.027
40500222	0	225	-4.0	0.150	0.008	0.006
40500223	0	310	-2.3	0.245	0.012	0.010
40500238	N12177_N13479	525	0.1	0.657	0.039	0.033
40500241	N13479_N12177	423	1.9	0.690	0.044	0.037
40500246	N24369_N13478	1007	1.1	1.643	0.106	0.089
40500249	N13478_N24369	317	-0.9	0.397	0.023	0.020
40500255	N14630_N16800	574	0.1	0.718	0.042	0.036
40500274	N14630_N16800	10	9.5	0.022	0.002	0.001
40500275	N14630_N16800	2	9.7	0.004	0.000	0.000
40500295	N19997_N12160	671	1.3	1.095	0.070	0.059
40500311	N16840_N16842	26	0.3	0.033	0.002	0.002
40500312	N16842_N16840	11	0.1	0.014	0.001	0.001
40500313	N16840_N16842	43	-0.1	0.054	0.003	0.003
40500314	N16840_N16842	11	0.3	0.014	0.001	0.001
40500335	0	104	0.0	0.130	0.008	0.006
40500336	0	121	-0.4	0.151	0.009	0.008
40500337	0	207	0.1	0.259	0.015	0.013
40500338	0	239	0.0	0.299	0.018	0.015
40500353	N16842_N16840	122	3.9	0.245	0.016	0.014
40500354	N16840_N16842	96	-0.2	0.120	0.007	0.006
40500356	0	408	0.2	0.510	0.030	0.025
40500357	0	415	0.0	0.519	0.031	0.026
40500358	0	325	0.5	0.407	0.024	0.020
40500359	0	310	0.2	0.388	0.023	0.019
40500374	N14624_N16839	258	0.2	0.323	0.019	0.016
40500375	N16839_N14624	195	0.4	0.244	0.014	0.012
40500485	0	355	3.8	0.712	0.048	0.040
40500486	0	417	4.7	0.836	0.056	0.047
40500487	0	341	4.1	0.684	0.046	0.038
40500488	0	313	4.3	0.628	0.042	0.035
40500505	N14624_N16839	201	-1.6	0.159	0.008	0.007
40500506	N16839_N14624	220	1.7	0.359	0.023	0.019
40500516	N16842_N16840	75	3.1	0.150	0.010	0.008

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_x	$PM_{2.5}$	PM_{10}
40500517	N16840_N16842	129	-3.1	0.086	0.004	0.004
40500518	N16842_N16840	102	4.6	0.205	0.014	0.012
40500521	N16840_N16842	48	-2.5	0.038	0.002	0.002
40500529	N25154_N13476	0	0.9	0.000	0.000	0.000
40500530	N13476_N25154	33	0.5	0.041	0.002	0.002
40500531	N25154_N13476	113	0.2	0.141	0.008	0.007
40500532	N13476_N25154	22	0.5	0.028	0.002	0.001
40500533	N25154_N13476	4	0.3	0.005	0.000	0.000
40500534	N13476_N25154	0	1.0	0.000	0.000	0.000
40500548	N25154_N13476	131	1.0	0.164	0.010	0.008
40500549	N13476_N25154	26	1.0	0.033	0.002	0.002
40500550	N16840_N16842	43	0.8	0.054	0.003	0.003
40500558	N16842_N25154	156	-1.1	0.123	0.006	0.005
40500561	N25154_N16842	82	0.1	0.103	0.006	0.005
40500576	N16840_N25155	72	-0.7	0.090	0.005	0.004
40500579	N25155_N16840	131	0.3	0.164	0.010	0.008
40500589	N13476_N25154	14	11.3	0.031	0.002	0.002
40500590	N25154_N13476	95	5.8	0.208	0.016	0.013
40500604	N19997_N20012	69	1.7	0.113	0.007	0.006
40500605	N20012_N19997	72	0.4	0.090	0.005	0.004
40500606	N12159_N20012	848	-3.9	0.563	0.029	0.024
40500609	N20012_N12159	847	0.7	1.060	0.063	0.053
40500617	N12160_N19997	985	-1.3	0.777	0.039	0.033
40500621	N19997_N20012	47	0.1	0.059	0.003	0.003
40500622	N20012_N19997	25	0.2	0.031	0.002	0.002
40500623	N20012_N19997	0	0.4	0.000	0.000	0.000
40500624	N19997_N20012	0	0.3	0.000	0.000	0.000
40500642	N24371_N12145	1904	0.4	2.382	0.141	0.118
40500647	N16842_N16840	7	3.3	0.014	0.001	0.001
40500648	N16840_N16842	5	-3.4	0.003	0.000	0.000
40500649	N16842_N16840	89	0.0	0.111	0.007	0.006
40500652	N16840_N16842	83	-1.3	0.066	0.003	0.003
40500660	N16842_N16840	18	2.4	0.029	0.002	0.002
40500661	N16840_N16842	25	2.8	0.041	0.003	0.002
40500662	N16840_N16842	43	0.1	0.054	0.003	0.003

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
40500663	N16840_N16842	0	-2.2	0.000	0.000	0.000
40500664	N16840_N16842	0	1.8	0.000	0.000	0.000
40500677	N16840_N16842	0	-3.9	0.000	0.000	0.000
40500678	N14624_N12151	178	9.7	0.390	0.030	0.025
40500681	N12151_N14624	102	-2.2	0.081	0.004	0.003
40500691	N16840_N16842	0	3.8	0.000	0.000	0.000
40500744	N16800_N12144	1249	2.0	2.038	0.131	0.110
40500749	N13474_N12151	772	0.2	0.966	0.057	0.048
40500752	N12151_N13474	1171	0.5	1.465	0.087	0.073
40500756	N14624_N12151	0	2.0	0.000	0.000	0.000
40500757	N12151_N14624	6	-1.8	0.005	0.000	0.000
40500762	N16839_N13474	112	11.5	0.245	0.019	0.016
40500764	N13474_N16839	204	0.7	0.255	0.015	0.013
40500767	N16839_N13474	203	4.6	0.407	0.027	0.023
40500775	N16839_N13474	0	3.1	0.000	0.000	0.000
40500776	N16839_N13474	123	11.7	0.269	0.021	0.017
40500780	N16839_N13474	43	11.3	0.094	0.007	0.006
40500781	N16839_N13474	91	11.5	0.199	0.015	0.013
40500787	N16842_N16839	40	4.9	0.080	0.005	0.005
40500790	N16839_N16842	107	-5.1	0.068	0.004	0.003
40500796	N14630_N16800	0	5.4	0.000	0.000	0.000
40500797	N14630_N16800	0	5.4	0.000	0.000	0.000
40500801	N16839_N13474	17	0.7	0.021	0.001	0.001
40500802	N16839_N13474	12	0.4	0.015	0.001	0.001
40500803	N13474_N12159	1300	-1.0	1.026	0.052	0.043
40500806	N12159_N13474	808	4.7	1.620	0.109	0.091
40500814	N16839_N13474	13	0.9	0.016	0.001	0.001
40500818	0	0	2.7	0.000	0.000	0.000
40501980	N20012_N19997	25	2.6	0.041	0.003	0.002
40502490	N16800_N14630	80	-1.5	0.063	0.003	0.003
40502676	N16839_N13474	152	-3.3	0.101	0.005	0.004
40502677	N16839_N13474	126	1.7	0.206	0.013	0.011
40502696	N12175_N13480	1162	0.0	1.454	0.086	0.072
40502699	N13480_N12175	1309	2.3	2.136	0.137	0.115
40502705	N17982_N12163	540	2.0	0.881	0.057	0.047

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
40502708	N12163_N17982	438	1.1	0.715	0.046	0.039
40502716	N19997_N20012	73	0.5	0.091	0.005	0.005
40502719	N20012_N19997	66	1.7	0.108	0.007	0.006
40502723	N20012_N12159	855	3.8	1.715	0.115	0.096
40502726	N12159_N20012	848	-4.0	0.563	0.029	0.024
40502734	N19997_N20012	24	1.5	0.039	0.003	0.002
40502737	N19997_N20012	22	-2.0	0.017	0.001	0.001
40502740	N19997_N20012	42	0.7	0.053	0.003	0.003
40502743	N20012_N19997	33	0.9	0.041	0.002	0.002
40502752	N19997_N20012	120	0.8	0.150	0.009	0.007
40502755	N19997_N20012	33	0.1	0.041	0.002	0.002
40502758	N19997_N20012	60	0.4	0.075	0.004	0.004
40502766	N12161_N16728	616	0.1	0.771	0.046	0.038
40502769	N16728_N12161	987	-1.4	0.779	0.039	0.033
40502779	N24369_N16728	189	0.7	0.236	0.014	0.012
40502782	N16728_N24369	233	-1.6	0.184	0.009	0.008
40502793	N13479_N24369	1047	-0.1	1.310	0.077	0.065
40502796	N24369_N13479	451	-0.1	0.564	0.033	0.028
40502806	N13478_N19985	701	0.3	0.877	0.052	0.043
40502809	N19985_N13478	133	-0.7	0.166	0.010	0.008
40502815	N12160_N13476	609	1.5	0.994	0.064	0.054
40502818	N13476_N12160	1245	0.0	1.557	0.092	0.077
40502828	N16840_N16842	61	-0.3	0.076	0.005	0.004
40502844	N13476_N25154	22	0.2	0.028	0.002	0.001
40502847	N25154_N13476	113	0.5	0.141	0.008	0.007
40502871	N16839_N13474	202	4.5	0.405	0.027	0.023
40502874	N13474_N16839	122	-4.8	0.081	0.004	0.004
40502878	N16839_N13474	64	9.0	0.140	0.011	0.009
40502887	N12159_N17864	637	5.1	1.395	0.106	0.089
40502890	N17864_N12159	572	-1.9	0.451	0.023	0.019
40502898	N13474_N14629	72	1.6	0.117	0.008	0.006
40502901	N14629_N13474	168	-2.7	0.133	0.007	0.006
40502909	N14624_N12151	178	2.2	0.290	0.019	0.016
40502912	N12151_N14624	79	-5.1	0.051	0.003	0.002
40502920	N16839_N14624	159	1.3	0.259	0.017	0.014

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
40502923	N14624_N16839	187	0.9	0.234	0.014	0.012
40502927	N16839_N16842	107	5.5	0.234	0.018	0.015
40502930	N16842_N16839	72	5.1	0.158	0.012	0.010
40502938	N16842_N16839	40	3.9	0.080	0.005	0.005
40502941	N16839_N16842	136	-4.9	0.090	0.005	0.004
40502945	N16842_N16840	69	0.4	0.086	0.005	0.004
40502949	N16840_N16842	59	-0.3	0.074	0.004	0.004
40502953	N14624_N16840	113	5.7	0.247	0.019	0.016
40502956	N16840_N14624	159	5.3	0.348	0.027	0.022
40502977	N16842_N16840	10	-0.3	0.013	0.001	0.001
40502980	N16840_N16842	26	-0.1	0.033	0.002	0.002
40502986	N13476_N16799	744	-0.2	0.931	0.055	0.046
40502989	N16799_N13476	1202	-0.3	1.504	0.089	0.075
40503004	N16842_N16840	89	0.3	0.111	0.007	0.006
40503007	N16840_N16842	86	-0.1	0.108	0.006	0.005
40503013	N16840_N16842	73	-4.5	0.049	0.003	0.002
40503016	N16842_N16840	102	2.2	0.166	0.011	0.009
40503020	N25155_N16840	146	-0.2	0.183	0.011	0.009
40503023	N16840_N25155	72	-0.2	0.090	0.005	0.004
40503031	N16842_N16840	128	2.4	0.209	0.013	0.011
40503034	N16840_N16842	59	-4.0	0.039	0.002	0.002
40503042	N14631_N12149	23	0.5	0.029	0.002	0.001
40503045	N12149_N14631	138	-1.2	0.109	0.005	0.005
40503165	N20003_N12160	1127	-2.7	0.889	0.045	0.037
40504228	N14630_N16800	0	8.1	0.000	0.000	0.000
50708595	N12160_N20003	825	2.7	1.346	0.087	0.073
50708601	N13476_N12160	1256	-1.0	0.991	0.050	0.042
50708611	N20003_N12159	748	2.7	1.221	0.078	0.066
50708618	N16839_N13474	127	4.6	0.255	0.017	0.014
50708621	N16839_N13474	129	-2.2	0.102	0.005	0.004
50708634	N16840_N16842	56	0.7	0.070	0.004	0.003
50708635	N16840_N16842	62	-0.3	0.078	0.005	0.004
50708646	N16840_N16842	11	0.3	0.014	0.001	0.001
50708649	N16840_N16842	42	0.3	0.053	0.003	0.003
50708661	N25154_N13476	56	11.0	0.123	0.009	0.008

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
50708664	N13476_N25154	8	5.9	0.018	0.001	0.001
50708672	N16839_N13474	132	6.2	0.289	0.022	0.018
50708675	N13474_N16839	186	5.3	0.407	0.031	0.026
50708686	N25154_N13476	0	0.6	0.000	0.000	0.000
50708689	N13476_N25154	33	0.6	0.041	0.002	0.002
50708693	N25154_N13476	0	1.0	0.000	0.000	0.000
50708696	N13476_N25154	98	0.2	0.123	0.007	0.006
50709193	N16840_N25155	72	-2.0	0.057	0.003	0.002
50709196	N25155_N16840	130	0.7	0.163	0.010	0.008
50709547	N12159_N20003	1108	-2.7	0.874	0.044	0.037
50709669	N16840_N16842	14	1.3	0.023	0.001	0.001
50709670	N16842_N16840	3	1.2	0.005	0.000	0.000
50709671	N13476_N25154	92	-0.1	0.115	0.007	0.006
50709676	N16840_N16842	5	0.1	0.006	0.000	0.000
50709677	N16842_N16840	5	-0.1	0.006	0.000	0.000
50709715	N25155_N16840	30	5.3	0.066	0.005	0.004
50709716	N16840_N25155	0	5.5	0.000	0.000	0.000
50709721	N25155_N16840	29	0.8	0.036	0.002	0.002
50709722	N16840_N25155	0	0.8	0.000	0.000	0.000
50709723	N25155_N16840	0	2.8	0.000	0.000	0.000
50709724	N16840_N25155	17	-2.3	0.013	0.001	0.001
50709725	N16840_N25155	18	1.0	0.029	0.002	0.002
50709726	N25155_N16840	0	1.1	0.000	0.000	0.000
50709735	N16840_N25155	44	1.1	0.072	0.005	0.004
50709736	N25155_N16840	0	0.5	0.000	0.000	0.000
50709737	N16840_N25155	63	-2.2	0.050	0.002	0.002
50709738	N25155_N16840	0	2.2	0.000	0.000	0.000
50709739	N16840_N25155	50	0.6	0.063	0.004	0.003
50709740	N25155_N16840	7	0.8	0.009	0.001	0.000
50709741	N16839_N13474	11	0.2	0.014	0.001	0.001
50709756	N13476_N25154	98	7.0	0.215	0.016	0.014
50709757	N25154_N13476	0	0.7	0.000	0.000	0.000
50709758	N25154_N13476	13	0.1	0.016	0.001	0.001
50709759	N13476_N25154	12	0.1	0.015	0.001	0.001
50709760	N13476_N25154	12	-0.3	0.015	0.001	0.001

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
50709761	N25154_N13476	13	-0.3	0.016	0.001	0.001
50709762	N13476_N25154	18	-0.2	0.023	0.001	0.001
50709765	N25154_N13476	2	0.9	0.003	0.000	0.000
50709789	N25154_N13476	65	0.5	0.081	0.005	0.004
50709790	N13476_N25154	70	0.6	0.088	0.005	0.004
50709791	N13476_N25154	4	-0.1	0.005	0.000	0.000
50709792	N25154_N13476	65	0.2	0.081	0.005	0.004
50709797	N13476_N25154	21	1.0	0.026	0.002	0.001
50709800	N25154_N13476	5	3.2	0.010	0.001	0.001
50709842	N16840_N16842	73	-2.5	0.058	0.003	0.002
50709845	N16842_N16840	83	1.2	0.135	0.009	0.007
50709870	N16839_N13474	176	2.3	0.287	0.018	0.015
50709929	N16839_N13474	9	5.2	0.020	0.002	0.001
50709930	N16839_N13474	9	5.0	0.018	0.001	0.001
50709931	N16839_N13474	124	1.6	0.202	0.013	0.011
50709934	N16839_N13474	131	-2.5	0.103	0.005	0.004
50709944	N16839_N13474	30	4.2	0.060	0.004	0.003
50709945	N16839_N13474	44	6.8	0.096	0.007	0.006
50709956	N25154_N13476	18	1.1	0.029	0.002	0.002
50709957	N13476_N25154	0	0.7	0.000	0.000	0.000
50709962	N13476_N25154	0	0.1	0.000	0.000	0.000
50709965	N25154_N13476	0	0.1	0.000	0.000	0.000
50709971	N13476_N25154	85	3.5	0.170	0.011	0.010
50709974	N25154_N13476	5	6.8	0.011	0.001	0.001
50709977	N25154_N13476	88	0.9	0.110	0.007	0.005
50709978	N13476_N25154	75	1.7	0.122	0.008	0.007
50709988	N16839_N13474	112	5.6	0.245	0.019	0.016
50710984	N25154_N13476	0	0.3	0.000	0.000	0.000
50710985	N13476_N25154	0	0.8	0.000	0.000	0.000
50710993	N16840_N16842	42	0.5	0.053	0.003	0.003
50710996	N16840_N16842	11	0.0	0.014	0.001	0.001
50711005	N16839_N13474	58	6.3	0.127	0.010	0.008
50711006	N16839_N13474	65	6.3	0.142	0.011	0.009
50711026	N13476_N25154	22	5.7	0.048	0.004	0.003
50711027	N25154_N13476	101	5.7	0.221	0.017	0.014

Corridor ID	Corridor Name	Vehicles/hour (PM Peak)	Gradient (%)	Emission Rates (kg/km/h)		
				NO_X	$PM_{2.5}$	PM_{10}
50711028	N13476_N25154	4	0.7	0.005	0.000	0.000
50711031	N25154_N13476	52	0.5	0.065	0.004	0.003
50711034	N16839_N13474	228	6.7	0.499	0.038	0.032
50711037	N16839_N13474	90	-4.4	0.060	0.003	0.003
50711043	N16839_N13474	6	1.3	0.010	0.001	0.001
50711044	N16839_N13474	13	1.3	0.021	0.001	0.001

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
3411	N19985_N13478	0.25	0.01	0.02
3997	N19985_N14630	0.95	0.05	0.06
4132	N13478_N12139	2.02	0.10	0.12
4134	N13480_N12161	0.87	0.04	0.05
4146	N13480_N12175	1.62	0.08	0.10
4150	N13478_N12160	1.28	0.06	0.08
4166	N13476_N12160	1.41	0.07	0.08
4174	N13474_N12151	1.13	0.06	0.07
4178	N13474_N12159	1.70	0.08	0.10
4317	N13448_N12149	0.66	0.03	0.04
4799	N13480_N13479	0.58	0.03	0.03
4936	N19997_N16728	1.05	0.05	0.06
5336	N13474_N14629	0.09	0.00	0.01
6406	N13476_N16799	0.80	0.04	0.05
6447	N13474_N16839	0.35	0.02	0.02
6554	N19997_N20012	0.07	0.00	0.00
7827	N19985_N22129	0.00	0.00	0.00
8132	N13478_N19985	0.95	0.05	0.06
9366	N25154_N13476	0.25	0.01	0.02
10712	N25280_N16800	0.87	0.04	0.05
10962	N13478_N24369	0.50	0.03	0.03
11195	N13440_N24371	2.32	0.12	0.14
11415	N13476_N25154	0.29	0.01	0.02
11490	N25154_N16842	0.12	0.01	0.01
11829	N12164_N12163	1.24	0.06	0.07
12590	N12160_N13476	0.73	0.04	0.04

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
12592	N12160_N13478	2.10	0.10	0.12
13327	N12172_N14762	1.32	0.07	0.08
13588	N24372_N12149	1.15	0.06	0.07
15092	N24370_N14565	1.52	0.08	0.09
16277	N12160_N19997	0.94	0.05	0.06
16278	N12160_N20003	1.02	0.05	0.06
17806	N12144_N24370	1.50	0.07	0.09
19772	N16839_N13474	0.27	0.01	0.02
19943	N16799_N13476	1.34	0.07	0.08
20180	N16839_N14624	0.19	0.01	0.01
21097	N16839_N16842	0.29	0.01	0.02
21209	N16799_N16800	2.15	0.11	0.13
24353	N16799_N25155	0.58	0.03	0.03
27525	N14631_N12149	0.03	0.00	0.00
28001	N14631_N13443	0.17	0.01	0.01
28019	N14629_N13474	0.29	0.02	0.02
31081	N20012_N12159	1.14	0.06	0.07
31084	N20012_N12163	1.11	0.06	0.07
32543	N13479_N12161	0.47	0.02	0.03
32550	N19956_N14630	0.22	0.01	0.01
32558	N13479_N12177	0.35	0.02	0.02
33134	N13479_N13480	0.44	0.02	0.03
33861	N13443_N14631	0.00	0.00	0.00
34838	N20012_N19997	0.18	0.01	0.01
39288	N13479_N24369	1.16	0.06	0.07
39802	N25155_N16799	0.48	0.02	0.03
39825	N25155_N16840	0.21	0.01	0.01
40174	N12163_N12161	2.04	0.10	0.12
40175	N12163_N12164	0.81	0.04	0.05
40191	N12161_N12163	0.88	0.04	0.05
40235	N12151_N12149	1.12	0.06	0.07
40252	N12149_N12151	1.57	0.08	0.09
40837	N12177_N13479	0.45	0.02	0.03
40846	N12175_N13480	1.43	0.07	0.09
40916	N12161_N13479	0.62	0.03	0.04

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
40917	N12161_N13480	1.17	0.06	0.07
40922	N12159_N13474	1.17	0.06	0.07
40969	N12149_N13448	0.55	0.03	0.03
40973	N12151_N13474	1.57	0.08	0.09
41054	N12139_N13478	1.08	0.05	0.06
41743	N12151_N14624	0.21	0.01	0.01
41760	N12149_N14631	0.17	0.01	0.01
41765	N12161_N14762	1.29	0.06	0.08
41950	N24371_N12145	2.35	0.12	0.14
42860	N24369_N13478	1.35	0.07	0.08
42861	N24369_N13479	0.53	0.03	0.03
42972	N17982_N12163	0.82	0.04	0.05
43060	N12161_N16728	0.86	0.04	0.05
43201	N12145_N16799	2.37	0.12	0.14
43689	N17864_N12159	0.74	0.04	0.04
43724	N12159_N17864	0.91	0.05	0.05
43770	N12163_N17982	0.61	0.03	0.04
44523	N24369_N16728	0.11	0.01	0.01
44672	N12163_N20012	1.23	0.06	0.07
44679	N12159_N20003	1.30	0.06	0.08
44681	N12159_N20012	1.12	0.06	0.07
46275	N12149_N24372	0.86	0.04	0.05
47865	N16800_N12144	1.49	0.07	0.09
48147	N16728_N12161	0.77	0.04	0.05
48590	N16840_N14624	0.20	0.01	0.01
48754	N16800_N14630	0.20	0.01	0.01
49508	N16842_N16839	0.09	0.01	0.01
49509	N16842_N16840	0.00	0.00	0.00
49516	N16840_N16842	0.00	0.00	0.00
49623	N16800_N16799	0.44	0.02	0.03
51168	N16728_N19997	0.80	0.04	0.05
52618	N16842_N25154	0.26	0.01	0.02
52627	N16840_N25155	0.17	0.01	0.01
52767	N16728_N24369	0.24	0.01	0.01
52812	N16800_N25280	1.61	0.08	0.10

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
54299	N22129_N19985	0.00	0.00	0.00
55490	N14762_N12161	1.31	0.07	0.08
55492	N14762_N12172	1.28	0.06	0.08
55960	N14624_N12151	0.13	0.01	0.01
56388	N14630_N13476	0.17	0.01	0.01
57636	N14630_N16800	0.77	0.04	0.05
57692	N14624_N16839	0.44	0.02	0.03
57694	N14624_N16840	0.16	0.01	0.01
59028	N14630_N19956	0.20	0.01	0.01
59042	N14630_N19985	0.22	0.01	0.01
59605	N20003_N12159	0.89	0.04	0.05
59606	N20003_N12160	1.35	0.07	0.08
59630	N19997_N12160	0.88	0.04	0.05
40500082	N12177_N13479	0.25	0.01	0.02
40500085	N12177_N13479	0.71	0.04	0.04
40500088	N13479_N24369	0.92	0.05	0.05
40500095	N16728_N12161	0.96	0.05	0.06
40500098	N12161_N12163	1.50	0.08	0.09
40500101	N16728_N12161	0.18	0.01	0.01
40500105	N12161_N12163	1.52	0.08	0.09
40500108	N12161_N12163	0.64	0.03	0.04
40500112	N24369_N16728	0.16	0.01	0.01
40500113	N16728_N24369	0.13	0.01	0.01
40500121	N19997_N20012	0.06	0.00	0.00
40500124	N20012_N19997	0.15	0.01	0.01
40500132	N19997_N20012	0.14	0.01	0.01
40500133	N19997_N20012	0.05	0.00	0.00
40500140	N12161_N12163	1.69	0.08	0.10
40500143	N12163_N12161	2.05	0.10	0.12
40500147	N19997_N20012	0.24	0.01	0.01
40500153	N19997_N20012	0.04	0.00	0.00
40500154	N20012_N19997	0.08	0.00	0.01
40500161	N19997_N20012	0.04	0.00	0.00
40500162	N19997_N20012	0.20	0.01	0.01
40500167	N19997_N20012	0.04	0.00	0.00

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
40500170	N20012_N19997	0.25	0.01	0.02
40500178	N12160_N20003	1.10	0.06	0.07
40500181	N20003_N12160	1.45	0.07	0.09
40500190	N24372_N12149	1.35	0.07	0.08
40500193	N12149_N13448	0.35	0.02	0.02
40500196	N24372_N12149	0.20	0.01	0.01
40500201	N13474_N16839	0.26	0.01	0.02
40500202	N16839_N13474	0.32	0.02	0.02
40500220		0.33	0.02	0.02
40500221		0.58	0.03	0.03
40500222		0.61	0.03	0.04
40500223		0.55	0.03	0.03
40500238	N12177_N13479	0.71	0.04	0.04
40500241	N13479_N12177	0.35	0.02	0.02
40500246	N24369_N13478	1.28	0.06	0.08
40500249	N13478_N24369	0.50	0.03	0.03
40500255	N14630_N16800	0.78	0.04	0.05
40500274	N14630_N16800	0.02	0.00	0.00
40500275	N14630_N16800	0.00	0.00	0.00
40500295	N19997_N12160	0.86	0.04	0.05
40500303	N16840_N16842	0.00	0.00	0.00
40500304	N16840_N16842	0.00	0.00	0.00
40500311	N16840_N16842	0.05	0.00	0.00
40500312	N16842_N16840	0.17	0.01	0.01
40500313	N16840_N16842	0.03	0.00	0.00
40500314	N16840_N16842	0.05	0.00	0.00
40500335		0.32	0.02	0.02
40500336		0.20	0.01	0.01
40500337		0.31	0.02	0.02
40500338		0.28	0.01	0.02
40500353	N16842_N16840	0.17	0.01	0.01
40500354	N16840_N16842	0.19	0.01	0.01
40500356		0.70	0.04	0.04
40500357		0.72	0.04	0.04
40500358		0.53	0.03	0.03

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
40500359		0.60	0.03	0.04
40500374	N14624_N16839	0.45	0.02	0.03
40500375	N16839_N14624	0.20	0.01	0.01
40500485		0.41	0.02	0.02
40500486		0.66	0.03	0.04
40500487		0.69	0.03	0.04
40500488		0.44	0.02	0.03
40500505	N14624_N16839	0.47	0.02	0.03
40500506	N16839_N14624	0.27	0.01	0.02
40500516	N16842_N16840	0.15	0.01	0.01
40500517	N16840_N16842	0.26	0.01	0.02
40500518	N16842_N16840	0.21	0.01	0.01
40500521	N16840_N16842	0.11	0.01	0.01
40500529	N25154_N13476	0.00	0.00	0.00
40500530	N13476_N25154	0.01	0.00	0.00
40500531	N25154_N13476	0.10	0.01	0.01
40500532	N13476_N25154	0.01	0.00	0.00
40500533	N25154_N13476	0.00	0.00	0.00
40500534	N13476_N25154	0.00	0.00	0.00
40500548	N25154_N13476	0.15	0.01	0.01
40500549	N13476_N25154	0.08	0.00	0.01
40500550	N16840_N16842	0.12	0.01	0.01
40500558	N16842_N25154	0.29	0.01	0.02
40500561	N25154_N16842	0.15	0.01	0.01
40500564	N16840_N16842	0.06	0.00	0.00
40500572	N16840_N16842	0.18	0.01	0.01
40500576	N16840_N25155	0.16	0.01	0.01
40500579	N25155_N16840	0.37	0.02	0.02
40500587	N16840_N16842	0.00	0.00	0.00
40500588	N16840_N16842	0.00	0.00	0.00
40500589	N13476_N25154	0.08	0.00	0.01
40500590	N25154_N13476	0.19	0.01	0.01
40500604	N19997_N20012	0.08	0.00	0.01
40500605	N20012_N19997	0.11	0.01	0.01
40500606	N12159_N20012	1.12	0.06	0.07

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
40500609	N20012_N12159	1.12	0.06	0.07
40500617	N12160_N19997	0.97	0.05	0.06
40500621	N19997_N20012	0.04	0.00	0.00
40500622	N20012_N19997	0.03	0.00	0.00
40500623	N20012_N19997	0.00	0.00	0.00
40500624	N19997_N20012	0.00	0.00	0.00
40500642	N24371_N12145	2.35	0.12	0.14
40500647	N16842_N16840	0.01	0.00	0.00
40500648	N16840_N16842	0.01	0.00	0.00
40500649	N16842_N16840	0.17	0.01	0.01
40500652	N16840_N16842	0.18	0.01	0.01
40500660	N16842_N16840	0.03	0.00	0.00
40500661	N16840_N16842	0.03	0.00	0.00
40500662	N16840_N16842	0.05	0.00	0.00
40500663	N16840_N16842	0.00	0.00	0.00
40500664	N16840_N16842	0.00	0.00	0.00
40500677	N16840_N16842	0.00	0.00	0.00
40500678	N14624_N12151	0.18	0.01	0.01
40500681	N12151_N14624	0.21	0.01	0.01
40500691	N16840_N16842	0.00	0.00	0.00
40500744	N16800_N12144	1.51	0.08	0.09
40500749	N13474_N12151	1.14	0.06	0.07
40500752	N12151_N13474	1.57	0.08	0.09
40500756	N14624_N12151	0.00	0.00	0.00
40500757	N12151_N14624	0.01	0.00	0.00
40500762	N16839_N13474	0.08	0.00	0.01
40500764	N13474_N16839	0.36	0.02	0.02
40500767	N16839_N13474	0.33	0.02	0.02
40500775	N16839_N13474	0.00	0.00	0.00
40500776	N16839_N13474	0.08	0.00	0.00
40500780	N16839_N13474	0.03	0.00	0.00
40500781	N16839_N13474	0.11	0.01	0.01
40500787	N16842_N16839	0.12	0.01	0.01
40500790	N16839_N16842	0.32	0.02	0.02
40500796	N14630_N16800	0.00	0.00	0.00

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
40500797	N14630_N16800	0.00	0.00	0.00
40500801	N16839_N13474	0.01	0.00	0.00
40500802	N16839_N13474	0.02	0.00	0.00
40500803	N13474_N12159	1.70	0.08	0.10
40500806	N12159_N13474	1.17	0.06	0.07
40500814	N16839_N13474	0.02	0.00	0.00
40500818		0.00	0.00	0.00
40501980	N20012_N19997	0.09	0.00	0.01
40502490	N16800_N14630	0.20	0.01	0.01
40502676	N16839_N13474	0.16	0.01	0.01
40502677	N16839_N13474	0.21	0.01	0.01
40502696	N12175_N13480	1.42	0.07	0.08
40502699	N13480_N12175	1.61	0.08	0.10
40502705	N17982_N12163	0.81	0.04	0.05
40502708	N12163_N17982	0.61	0.03	0.04
40502716	N19997_N20012	0.09	0.01	0.01
40502719	N20012_N19997	0.10	0.01	0.01
40502723	N20012_N12159	1.14	0.06	0.07
40502726	N12159_N20012	1.12	0.06	0.07
40502734	N19997_N20012	0.16	0.01	0.01
40502737	N19997_N20012	0.05	0.00	0.00
40502740	N19997_N20012	0.08	0.00	0.00
40502743	N20012_N19997	0.11	0.01	0.01
40502752	N19997_N20012	0.12	0.01	0.01
40502755	N19997_N20012	0.08	0.00	0.01
40502758	N19997_N20012	0.09	0.00	0.01
40502766	N12161_N16728	0.84	0.04	0.05
40502769	N16728_N12161	1.01	0.05	0.06
40502779	N24369_N16728	0.11	0.01	0.01
40502782	N16728_N24369	0.19	0.01	0.01
40502793	N13479_N24369	1.17	0.06	0.07
40502796	N24369_N13479	0.53	0.03	0.03
40502806	N13478_N19985	0.97	0.05	0.06
40502809	N19985_N13478	0.22	0.01	0.01
40502815	N12160_N13476	0.73	0.04	0.04

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
40502818	N13476_N12160	1.40	0.07	0.08
40502828	N16840_N16842	0.17	0.01	0.01
40502833	N16840_N16842	0.00	0.00	0.00
40502836	N16840_N16842	0.00	0.00	0.00
40502844	N13476_N25154	0.01	0.00	0.00
40502847	N25154_N13476	0.10	0.01	0.01
40502871	N16839_N13474	0.32	0.02	0.02
40502874	N13474_N16839	0.35	0.02	0.02
40502878	N16839_N13474	0.05	0.00	0.00
40502887	N12159_N17864	0.91	0.05	0.05
40502890	N17864_N12159	0.73	0.04	0.04
40502898	N13474_N14629	0.11	0.01	0.01
40502901	N14629_N13474	0.26	0.01	0.02
40502909	N14624_N12151	0.18	0.01	0.01
40502912	N12151_N14624	0.15	0.01	0.01
40502920	N16839_N14624	0.19	0.01	0.01
40502923	N14624_N16839	0.44	0.02	0.03
40502927	N16839_N16842	0.32	0.02	0.02
40502930	N16842_N16839	0.09	0.01	0.01
40502938	N16842_N16839	0.12	0.01	0.01
40502941	N16839_N16842	0.29	0.01	0.02
40502945	N16842_N16840	0.00	0.00	0.00
40502949	N16840_N16842	0.00	0.00	0.00
40502953	N14624_N16840	0.24	0.01	0.01
40502956	N16840_N14624	0.21	0.01	0.01
40502968	N16840_N16842	0.10	0.01	0.01
40502971	N16840_N16842	0.20	0.01	0.01
40502977	N16842_N16840	0.17	0.01	0.01
40502980	N16840_N16842	0.09	0.00	0.01
40502986	N13476_N16799	0.78	0.04	0.05
40502989	N16799_N13476	1.33	0.07	0.08
40503004	N16842_N16840	0.17	0.01	0.01
40503007	N16840_N16842	0.18	0.01	0.01
40503013	N16840_N16842	0.23	0.01	0.01
40503016	N16842_N16840	0.21	0.01	0.01

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
40503020	N25155_N16840	0.36	0.02	0.02
40503023	N16840_N25155	0.18	0.01	0.01
40503031	N16842_N16840	0.20	0.01	0.01
40503034	N16840_N16842	0.15	0.01	0.01
40503042	N14631_N12149	0.03	0.00	0.00
40503045	N12149_N14631	0.17	0.01	0.01
40503165	N20003_N12160	1.38	0.07	0.08
40504228	N14630_N16800	0.00	0.00	0.00
50708595	N12160_N20003	1.10	0.05	0.07
50708601	N13476_N12160	1.41	0.07	0.08
50708611	N20003_N12159	1.02	0.05	0.06
50708618	N16839_N13474	0.22	0.01	0.01
50708621	N16839_N13474	0.28	0.01	0.02
50708634	N16840_N16842	0.04	0.00	0.00
50708635	N16840_N16842	0.03	0.00	0.00
50708646	N16840_N16842	0.05	0.00	0.00
50708649	N16840_N16842	0.03	0.00	0.00
50708661	N25154_N13476	0.20	0.01	0.01
50708664	N13476_N25154	0.08	0.00	0.01
50708672	N16839_N13474	0.32	0.02	0.02
50708675	N13474_N16839	0.26	0.01	0.02
50708686	N25154_N13476	0.13	0.01	0.01
50708689	N13476_N25154	0.00	0.00	0.00
50708693	N25154_N13476	0.00	0.00	0.00
50708696	N13476_N25154	0.00	0.00	0.00
50709193	N16840_N25155	0.16	0.01	0.01
50709196	N25155_N16840	0.21	0.01	0.01
50709547	N12159_N20003	1.27	0.06	0.08
50709669	N16840_N16842	0.01	0.00	0.00
50709670	N16842_N16840	0.04	0.00	0.00
50709671	N13476_N25154	0.32	0.02	0.02
50709676	N16840_N16842	0.02	0.00	0.00
50709677	N16842_N16840	0.06	0.00	0.00
50709715	N25155_N16840	0.13	0.01	0.01
50709716	N16840_N25155	0.12	0.01	0.01

Corridor ID	Corridor Name	Emission Rates (kg/km/h)		
		NO_X	$PM_{2.5}$	PM_{10}
50709721	N25155_N16840	0.05	0.00	0.00
50709722	N16840_N25155	0.05	0.00	0.00
50709723	N25155_N16840	0.01	0.00	0.00
50709724	N16840_N25155	0.06	0.00	0.00
50709725	N16840_N25155	0.02	0.00	0.00
50709726	N25155_N16840	0.06	0.00	0.00
50709735	N16840_N25155	0.05	0.00	0.00
50709736	N25155_N16840	0.01	0.00	0.00
50709737	N16840_N25155	0.02	0.00	0.00
50709738	N25155_N16840	0.05	0.00	0.00
50709739	N16840_N25155	0.01	0.00	0.00
50709740	N25155_N16840	0.01	0.00	0.00
50709741	N16839_N13474	0.00	0.00	0.00
50709756	N13476_N25154	0.00	0.00	0.00
50709757	N25154_N13476	0.00	0.00	0.00
50709758	N25154_N13476	0.07	0.00	0.00
50709759	N13476_N25154	0.02	0.00	0.00
50709760	N13476_N25154	0.01	0.00	0.00
50709761	N25154_N13476	0.00	0.00	0.00
50709762	N13476_N25154	0.00	0.00	0.00
50709765	N25154_N13476	0.01	0.00	0.00
50709789	N25154_N13476	0.09	0.00	0.01
50709790	N13476_N25154	0.04	0.00	0.00
50709791	N13476_N25154	0.04	0.00	0.00
50709792	N25154_N13476	0.00	0.00	0.00
50709797	N13476_N25154	0.00	0.00	0.00
50709800	N25154_N13476	0.04	0.00	0.00
50709842	N16840_N16842	0.23	0.01	0.01
50709845	N16842_N16840	0.17	0.01	0.01
50709870	N16839_N13474	0.26	0.01	0.02

APPENDIX D

Qualitative Assessment Methodology

The risk-based assessment takes account of a range of impact descriptors, including the following:

- **Nature of Impact**: does the impact result in an adverse or beneficial environment?
- **Sensitivity**: how sensitive is the receiving environment to the anticipated impacts? This may be applied to the sensitivity of the environment in a regional context or specific receptor locations.
- **Magnitude**: what is the anticipated scale of the impact?
- The integration of receptor sensitivity with impact magnitude is used to derive the predicted **significance** of that change.

Nature of Impact

Predicted impacts may be described in terms of the overall effect upon the environment:

- **Beneficial**: the predicted impact will cause a beneficial effect on the receiving environment.
- **Neutral**: the predicted impact will cause neither a beneficial nor adverse effect.
- **Adverse**: the predicted impact will cause an adverse effect on the receiving environment.

Receptor Sensitivity

Sensitivity may vary with the anticipated impact or effect. A receptor may be determined to have varying sensitivity to different environmental changes, for example, a high sensitivity to changes in air quality, but low sensitivity to noise impacts. Sensitivity may also be derived from statutory designation which is designed to protect the receptor from such impacts.

Sensitivity terminology may vary depending upon the environmental effect, but generally this may be described in accordance with the broad categories outlined in **Table D1**, which has been used in this assessment to define the sensitivity of receptors to air quality impacts.

Table D1 Methodology for Assessing Sensitivity of a Receptor to Air Quality Impacts

Sensitivity	Criteria
Very High	Receptors of very high sensitivity to air pollution (e.g. dust or odour) such as: hospitals and clinics, retirement homes, painting and furnishing businesses, hi-tech industries and food processing.
High	Receptors of high sensitivity to air pollution, such as: schools, residential areas, food retailers, glasshouses and nurseries, horticultural land and offices.
Medium	Receptors of medium sensitivity to air pollution, such as: farms, outdoor storage, light and heavy industry.
Low	All other air quality sensitive receptors not identified above.

Magnitude of Impact

Magnitude describes the anticipated scale of the anticipated environmental change in terms of how that impact may cause a change to baseline conditions. **Table D2** outlines the methodology used in this assessment to define the magnitude of the identified potential air quality impacts.

Table D2 Methodology for Assessing Magnitude of Impacts

Magnitude	Description
Substantial	Impact is predicted to cause significant consequences on the receiving environment (may be adverse or beneficial)
Moderate	Impact is predicted to possibly cause statutory objectives/standards to be exceeded (may be adverse)
Slight	Predicted impact may be tolerated.
Negligible	Impact is predicted to cause no significant consequences.

Significance of Impact

The risk-based matrix provided below illustrates how the definition of the sensitivity and magnitude interact to produce impact significance.

Table D3 Impact Significance Matrix

Magnitude / Sensitivity		[Defined by Table D2]			
		Substantial Magnitude	Moderate Magnitude	Slight Magnitude	Negligible Magnitude
[Defined by Table D1]	Very High Sensitivity	Major Significance	Major/ Intermediate Significance	Intermediate Significance	Neutral Significance
	High Sensitivity	Major/ Intermediate Significance	Intermediate Significance	Intermediate/Minor Significance	Neutral Significance
	Medium Sensitivity	Intermediate Significance	Intermediate/Minor Significance	Minor Significance	Neutral Significance
	Low Sensitivity	Intermediate/Minor Significance	Minor Significance	Minor/Neutral Significance	Neutral Significance

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