Blackwattle Bay

State Significant Precinct

Attachment 17:

Air Quality Assessment

June 2021

NSW GOVERNMENT

BLACKWATTLE BAY

Air Quality Assessment

Prepared for:

Infrastructure NSW
Level 12, 19 Martin Place
SYDNEY NSW 2000

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BASIS OF REPORT

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

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.17553-R05-v1.0	20 May 2021	A Naghizadeh	K Lawrence	A Naghizadeh

EXECUTIVE SUMMARY

SLR Consulting was commissioned by Infrastructure NSW (INSW) to conduct an Air Quality Assessment (AQA) for the proposed rezoning and development of the Blackwattle Bay State Significant Precinct (the Study Area). 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).

Study Requirements for the Blackwattle Bay (formerly known as 'Bays Market Precinct') Study Area were issued by the Minister on 28 April 2017. The key study requirements relating to air quality are presented in the table below.

Blackwattle Bay State Significant Precinct - Study Requirements

Requirement	Section Reference
22.2 - Consider and assess potential pollution impacts from the proposed rezoning including, but not limited to, water, air, noise and light pollution.	**This Report**
22.3 - 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. These assessments should also consider other current and future local air and noise issues in the Bays area, including potential cumulative impacts from the current Sydney Fish Market and from maritime uses in the Bay.	**This Report**
22.5 - Identify and map current and proposed future sensitive receptors (eg residential uses, schools, child care centres and public open spaces)	**Section 3.3, Section 9.3**
22.6 - 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 for the Anzac Bridge approach, Western Distributor, Bank Street and Bridge Road at a minimum. Monitoring will also be required to determine current noise levels from the Sydney Fish Market (particularly from service vehicles) and maritime uses in the bay. 3D mapping to clearly communicate these impacts, including demonstrating for example how noise reduces with distance from the source, or with the use of barriers, is desirable.	**Section 5**
22.8 - Model the likely future noise, vibration and pollution scenario based on 3D block envelope diagrams prepared by the consultant appointed urban designer. This is to include noise generated by road rail and maritime uses and noise from the Sydney Fish Market, particularly from service vehicles.	**Section 9, Section 10**
22.10 - Outline the recommended measures relating to noise, vibration and pollution to minimise the nuisance and harm to people or property within / adjoining the precinct.	**Section 10.3**

The primary source of air emissions in the area immediately surrounding the Study Area was identified as vehicles travelling along the Western Distributor and other local roads, as well as the existing Hymix concrete batching facility (in the event that this land is not rezoned as part of the proposed development).

In order to gain a better understanding of the potential worst case air pollutant concentrations within the Study Area, detailed meteorological and air quality dispersion modelling of emissions from the identified sources of emissions was performed. The modelling was performed for two scenarios, namely:

- Scenario 1 – Redevelopment of the entire Study Area

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- Scenario 2 – Partial redevelopment of the Study Area with the Hymix concrete batching facility remaining in place

Emissions of NO_2 and particulate matter (as PM_{10} and $PM_{2.5}$) from vehicles travelling along the surrounding road network were estimated using the COPERT Australia software package. Particulate emissions from the Hymix facility were estimated using emission factors sourced from the US EPA AP-42 documentation. The calculated emissions from these sources were then modelled using the GRAMM/GRAL modelling system.

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) from 6 am to 10 pm every day of the year
- The 2033 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 atmospheric reaction between NOx emissions from vehicles and ozone is instantaneous.
- Background pollutant concentrations will remain at levels recorded for 2017.

The results of the cumulative impact assessment undertaken to assess the potential worst case air pollutant concentrations within the Study Area due to emissions from local traffic and activities at Hymix (for Scenario 2 only) indicate that emissions from these sources have the potential to result in exceedances of the ambient air quality criteria for PM_{10},$PM_{2.5}$ and NO_2 within the Study Area, particularly on lower floor of buildings at locations closest to the Western Distributor and Hymix. The table below summarises the extent of exceedance of the relevant air quality criteria at residential receptor locations for the two scenarios modelled (as the percentage of residential receptors modelled predicted to experience exceedances of the relevant criteria).

Summary of Exceedances at Residential Receptor Locations

Modelled Scenario	PM_{10}		$PM_{2.5}$		NO_2	
	24-hour	**Annual**	**24-hour**	**Annual**	**1-hour**	**Annual**
Scenario 1	5%	0%	1%	2%	4%	0%
Scenario 2	11%	2%	3%	7%	4%	0.5%

As outlined above, vehicle emission factors used in this study were conservatively assumed to remain at levels estimated for the 2010 NSW vehicle fleet. In order to conduct a sensitivity analysis to assess the impacts of using emission factors expected to be more representative of future emissions, incremental vehicle emissions predicted by the model for Scenario 1 (representative of complete redevelopment of the entire site) were scaled using ratios calculated from the 2016 and 2026 emissions factors derived from the Roads and Maritime air quality screening model TRAQ.

The emission factor sensitivity analysis demonstrated that:

- While exceedances of the 24-hour average PM_{10} criterion are still predicted to occur at some residential receptor locations, these will be limited to days of extremely elevated background concentrations of PM_{10};

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- Exceedances of the 24-hour average PM_{10} criterion are predicted to occur at 38% fewer residential receptor locations that those predicted using the 2010 vehicle fleet emissions;
- The incremental NO_2 impact (from vehicles travelling on the surrounding road network) on the Study Area are likely to be significantly overestimated (by 56%) by the modelling predictions using the 2010 vehicle fleet emissions; and
- Exceedances of the 1-hour average NO_2 criterion are predicted to occur at 85% fewer residential receptor locations that those predicted using the 2010 vehicle fleet emissions.

Overall, there are a higher number of residential receptors predicted to be impacted by concentrations above guideline levels for Scenario 2, in which Hymix is assumed to continue to operate as currently permitted. In order to quantify the potential risk to human health as a result of the predicted exceedances, a human health risk impact study has been completed for the proposed Precinct Plan.

The proposed Precinct Plan for the Study Area incorporates a number of mitigation measures consistent with Section 4.4 of the Guideline including:

- Minimising the formation of urban canyons by having buildings of different heights interspersed.
- No sensitive receptors (residential units) are proposed within a 20 m radius of the major roads.
- For all proposed buildings (with the exception of BLD 02) the lower eight floors are proposed to be used for commercial/retail purposes. For BLD 02, only the ground floor is proposed to be used for retail purposes, with residential uses from level 1 and above.

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 and the Hymix operations (should Hymix continue operations at the current location).

The requirement for any additional air quality mitigation for each building would be further assessed during the next stages of the project. This study has shown that from an air quality perspective, the Study Area is suitable for the intended uses within the SSP proposal, subject to the findings of the human health risk assessment study and future refinement of high-level mitigation measures summarised within this study.

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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
AQMS	Air Quality Monitoring Station
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 Department of Planning, Industry and Environment)
DPE	NSW Department of Planning and Environment (now NSW Department of Planning, Industry and Environment)
DPIE	NSW Department of Planning, Industry and Environment
EES	Environment, Energy and Science group (of NSW Department of Planning, Industry and Environment)
EETM	Emission Estimation Technique Manual
EPL	Environment Protection Licence
g	gram
GFA	Gross Floor Area
ha	Hectares
km	kilometre
IINSW	Infrastructure NSW
LGA	Local Government Area
m/s	metre per second
m^2	square metres
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 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
POEO Act	Protection of the Environment Operations Act
ppb	parts per billion (10^9)
pphm	parts per hundred million (10^8)
ppm	parts per million (10^6)
S	second
SFM	Sydney Fish Markets
SO_2	sulphur dioxide
SSP	State Significant Precinct
TSP	total suspended particulate matter
VOC	volatile organic compounds
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VKT	Vehicle kilometres travelled
WBCT	White Bay Cruise Terminal
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

Blackwattle Bay offers an extraordinary opportunity to reconnect the harbour, its surrounding neighbourhoods and the city; to showcase Sydney's living culture and stories of Country; to build an inclusive and iconic waterfront destination that celebrates innovation, diversity and community.

This air quality report has been prepared by SLR Consulting on behalf of Infrastructure NSW (INSW), to form part of the Blackwattle Bay State Significant Precinct Study (SSP Study). The SSP Study seeks a rezoning for new planning controls for Blackwattle Bay, located on the south-western side of Pyrmont.

Blackwattle Bay presents a significant opportunity for urban renewal across 10.4 hectares (ha) of predominantly government owned land located approximately 1 kilometres (km) from the Sydney CBD. NSW Government is also investigating the delivery of a Metro Station in Pyrmont and has recognised the potential to transform the Pyrmont Peninsula with a new 20-year vision and planning framework through the Pyrmont Peninsula Place Strategy.

In 2015, the NSW Government recognised The Bays Precinct as one of the highest potential urban transformation sites in Australia with the release of The Bays Precinct, Sydney Transformation Plan. Following this, the Minister for Planning identified the renewal of Blackwattle Bay and the broader Bays Precinct as a matter of State planning significance and to be investigated for rezoning through the State Significant Precinct (SSP) process. Study Requirements for the Blackwattle Bay (formerly known as 'Bays Market Precinct') Study Area were issued by the Minister on 28 April 2017.

A critical part of Blackwattle Bay's revitalisation and vision has been the NSW Government's decision to relocate the Sydney Fish Market (SFM) from its existing location on Bank Street to the head of Blackwattle Bay. This was sought through a State Significant Development Application (SSDA) process and approved in June 2020. The new SFM was designed alongside the baseline Blackwattle Bay studies to ensure that key aspects of the project are consistent with the vision and principles for Blackwattle Bay.

The outcome of the Blackwattle Bay State Significant Precinct process will be a new planning framework that will enable further development applications for the renewal of the Precinct, connected to the harbour and centred around a rejuvenated SFM. The framework will also provide for new public open spaces, including a continuous waterfront promenade, community facilities, and other compatible uses.

This report provides a comprehensive investigation of air quality impacts to address relevant parts of the Study Requirements and support the development of a new planning framework for Blackwattle Bay.

1.1 Blackwattle Bay State Significant Precinct

The Blackwattle Bay SSP Study Area ('Study Area') encompasses the land and water area, known as Blackwattle Bay, between Bank Street and the Glebe foreshore shown in **Figure 1.** The land is located within the City of Sydney local government area (LGA).

As noted above, the land within the Study Area is approximately 10.4 ha in size. It is largely government owned land containing the SFM (wholesale and retail), recreation and boating operations and facilities. There are three privately owned sites, including a concrete batching plant operated by Hymix, seafood wholesaler Poulos Brothers and private developer Celestino which owns further wholesaling facilities.

The Blackwattle Bay land area wraps around the southern and eastern edges of Blackwattle Bay and is bounded by Bridge Road to the south and Bank Street to the east. The Western Distributor motorway / Anzac Bridge viaduct is located adjacent to the eastern boundary before traversing over the northern section of the site. The water area of Blackwattle Bay is approximately 21 ha.

Figure 1 Blackwattle Bay SSP Study Area

Source: INSW

1.2 The Proposal

The SSP Study is proposing to rezone Blackwattle Bay with a new planning framework and planning controls to enable its future urban renewal.

The rezoning proposal is based on the Blackwattle Bay Precinct Plan (‘Precinct Plan’), which provides a conceptual layout to guide the development of planning controls for the precinct and has informed this report. The Precinct Plan is illustrated in **Figure 2**. The Precinct Plan provides overarching guidance about how the area should be developed based on community and stakeholder input, local character and place, current and future demographics, economic and social trends, cultural and environmental considerations, and urban renewal aspirations, as well as needs regarding land use, community recreation, transportation, housing, and jobs.

Key characteristics of the Precinct Plan include:

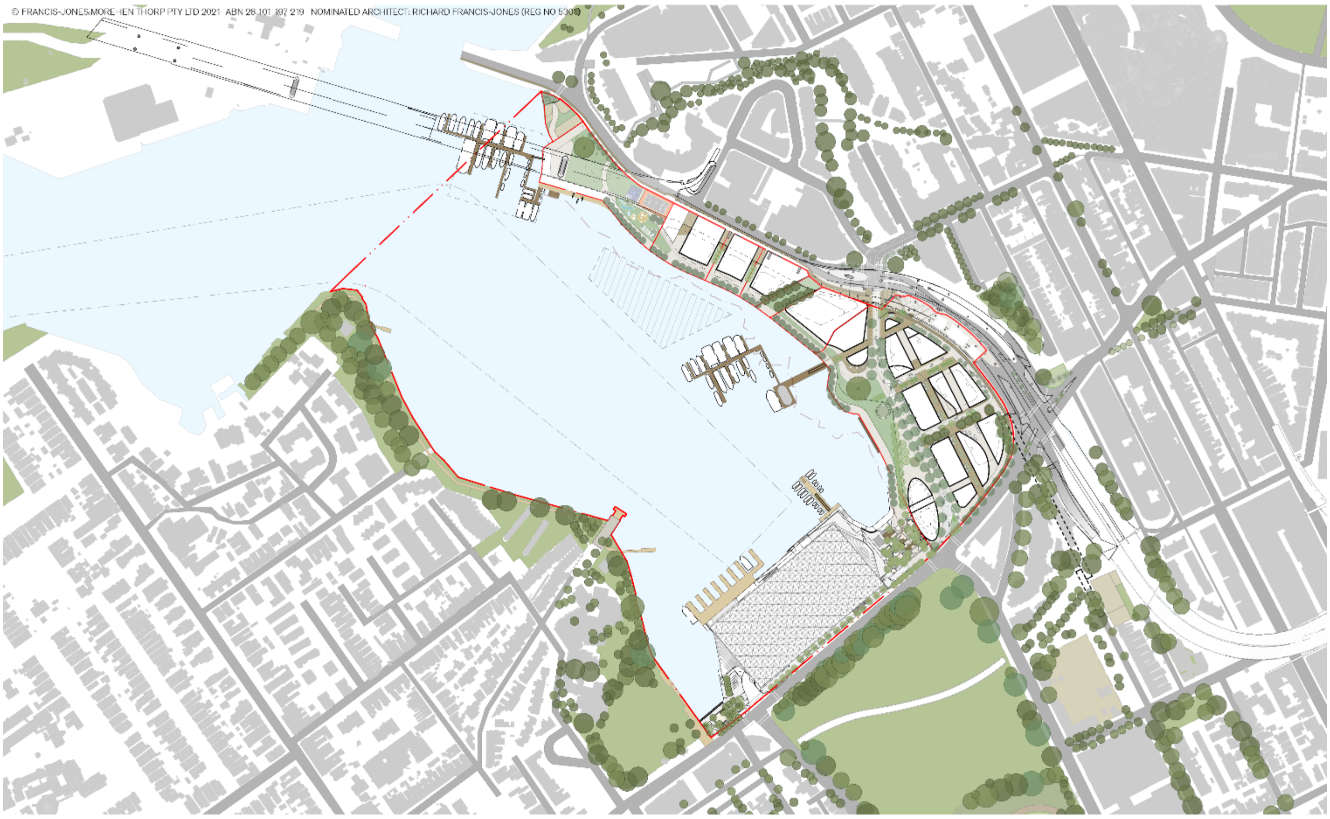
- New homes, jobs and services close to the CBD including:
  - 5,636 jobs / or approximately 5,600 jobs
  - 2,795 residents /or approximately 2,800 residents
  - 1,546 dwellings
- A continuous waterfront promenade – the missing link in an otherwise 15 km foreshore walk from Woolloomooloo to Rozelle
- New active transport connections to bring the neighbourhood closer to the harbour through new and improved pedestrian and cycling links
- Improved public transport options and minimised vehicle usage strategies including:
  - Minimising car parking spaces with limited on-street parking.
  - Ferry wharf
  - Opportunity for buses to service through site link
  - Connections to the existing light rail
  - Access to a future Sydney Metro West Station in Pyrmont
- New parks and green space with 30,000 square metres (m^2) of new open space
- An authentic, and world class new SFM at the heart of Blackwattle Bay
- An authentic place that builds on Indigenous and industrial stories and celebrating the local character.

Once the Study Area is rezoned and the new planning controls are in place, future development will need to seek development approval through the relevant approval pathway. This will include detailed development proposals and further associated environmental, social and economic assessments.

The rezoning proposal responds to the Study Requirements issued for Blackwattle Bay (formerly Bays Market District) by the Department of Planning and Environment in April 2017.

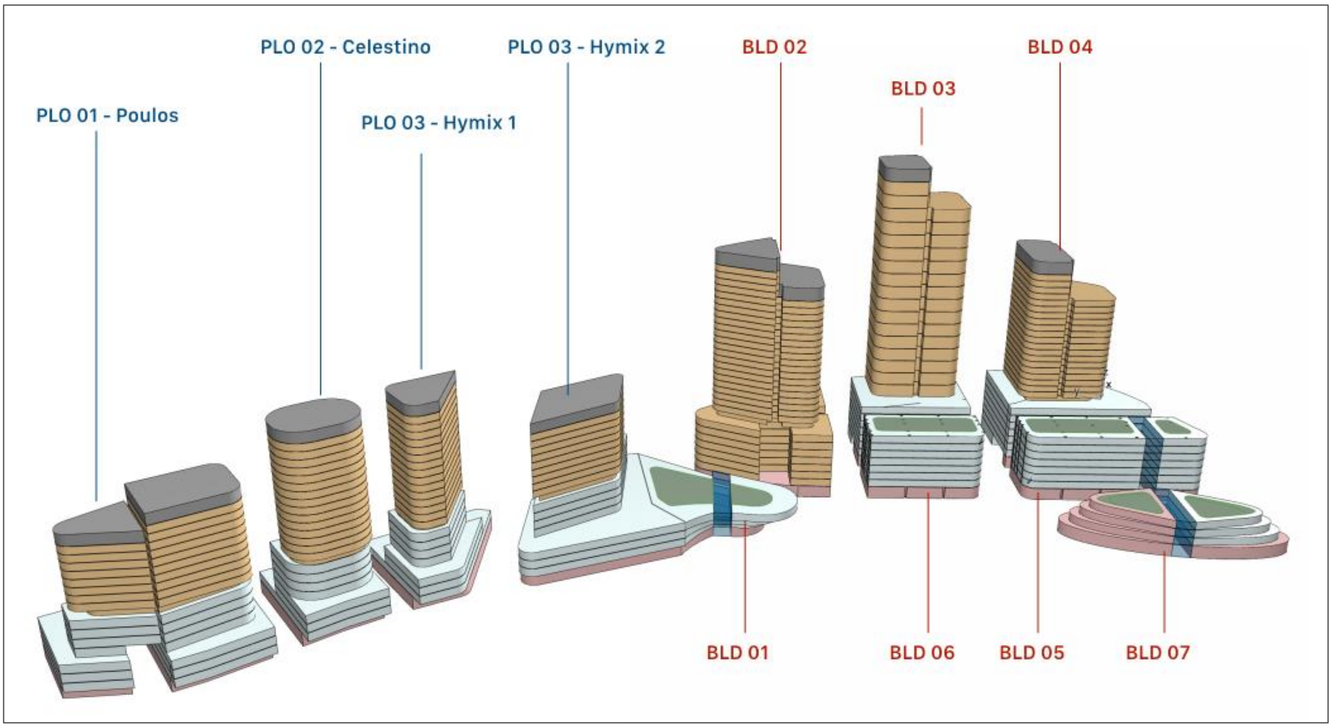
The Precinct Plan building layout used for this study is illustrated in **Figure 3**.

Figure 2 Blackwattle Bay Precinct Plan - Overview



Source: INSW

Figure 3 Blackwattle Bay Precinct Plan - Buildings



Source: INSW

1.3 Vision and Principles

Principles for a future Blackwattle Bay were formed through extensive community consultation in August 2017. These were further developed in 2019, together with a vision for the precinct. Both are provided below. These have guided the development of the Precinct Plan and will continue to guide future development proposals within the Study Area.

1.3.1 Vision

"Blackwattle Bay offers an extraordinary opportunity to reconnect the harbour, its surrounding neighbourhoods and the city; to showcase Sydney's living culture and stories of Country; to build an inclusive and iconic waterfront destination that celebrates innovation, diversity and community."

1.3.2 Principles

1. Improve access to Blackwattle Bay, the foreshore and water activities for all users.
2. Minimise additional shadowing to Wentworth Park and Glebe Foreshore (in mid-winter) and create new places with comfortable conditions for people to enjoy.
3. Pursue leading edge sustainability outcomes including climate change resilience, improved water quality and restoration of natural ecosystems.
4. Prioritise movement by walking, cycling and public transport.
5. Balance diverse traffic movement and parking needs for all users.
6. Link the Blackwattle Bay precinct to the City, Glebe Island and White Bay and other surrounding communities and attractors.
7. Mandate Design Excellence in the public and private domain.
8. Integrate housing, employment and mixed uses to create a vibrant, walkable, mixed use precinct on the city's edge.
9. Maintain and enhance water uses and activities.
10. Allow for co-existence and evolution of land uses over time.
11. A place for everyone that is inviting, unique in character, socially inclusive and affordable.
12. Expand the range of recreational, community and cultural facilities.
13. Plan for the future community's education, health, social and cultural needs.
14. Deliver development that is economically, socially, culturally and environmentally viable.
15. Embed and interpret the morphology, heritage and culture of the site to create an authentic and site responsive place.
16. Foster social and cultural understanding and respect to heal and grow relationships.

2 Study Requirements

The study requirements relevant to air quality are shown in **Table 1** and are reproduced from the Blackwattle Bay Final Study Requirements (28 April 2017).

Table 1 Study Requirements

Requirement	Section Reference
22.2 - Consider and assess potential pollution impacts from the proposed rezoning including, but not limited to, water, air, noise and light pollution.	**This Report**
22.3 - 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. These assessments should also consider other current and future local air and noise issues in the Bays area, including potential cumulative impacts from the current Sydney Fish Market and from maritime uses in the Bay.	**This Report**
22.5 - Identify and map current and proposed future sensitive receptors (eg residential uses, schools, child care centres and public open spaces)	**Section 3.3, Section 9.3**
22.6 - 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 for the Anzac Bridge approach, Western Distributor, Bank Street and Bridge Road at a minimum. Monitoring will also be required to determine current noise levels from the Sydney Fish Market (particularly from service vehicles) and maritime uses in the bay. 3D mapping to clearly communicate these impacts, including demonstrating for example how noise reduces with distance from the source, or with the use of barriers, is desirable.	**Section 5**
22.8 - Model the likely future noise, vibration and pollution scenario based on 3D block envelope diagrams prepared by the consultant appointed urban designer. This is to include noise generated by road rail and maritime uses and noise from the Sydney Fish Market, particularly from service vehicles.	**Section 9, Section 10**
22.10 - Outline the recommended measures relating to noise, vibration and pollution to minimise the nuisance and harm to people or property within / adjoining the precinct.	**Section 10.3**

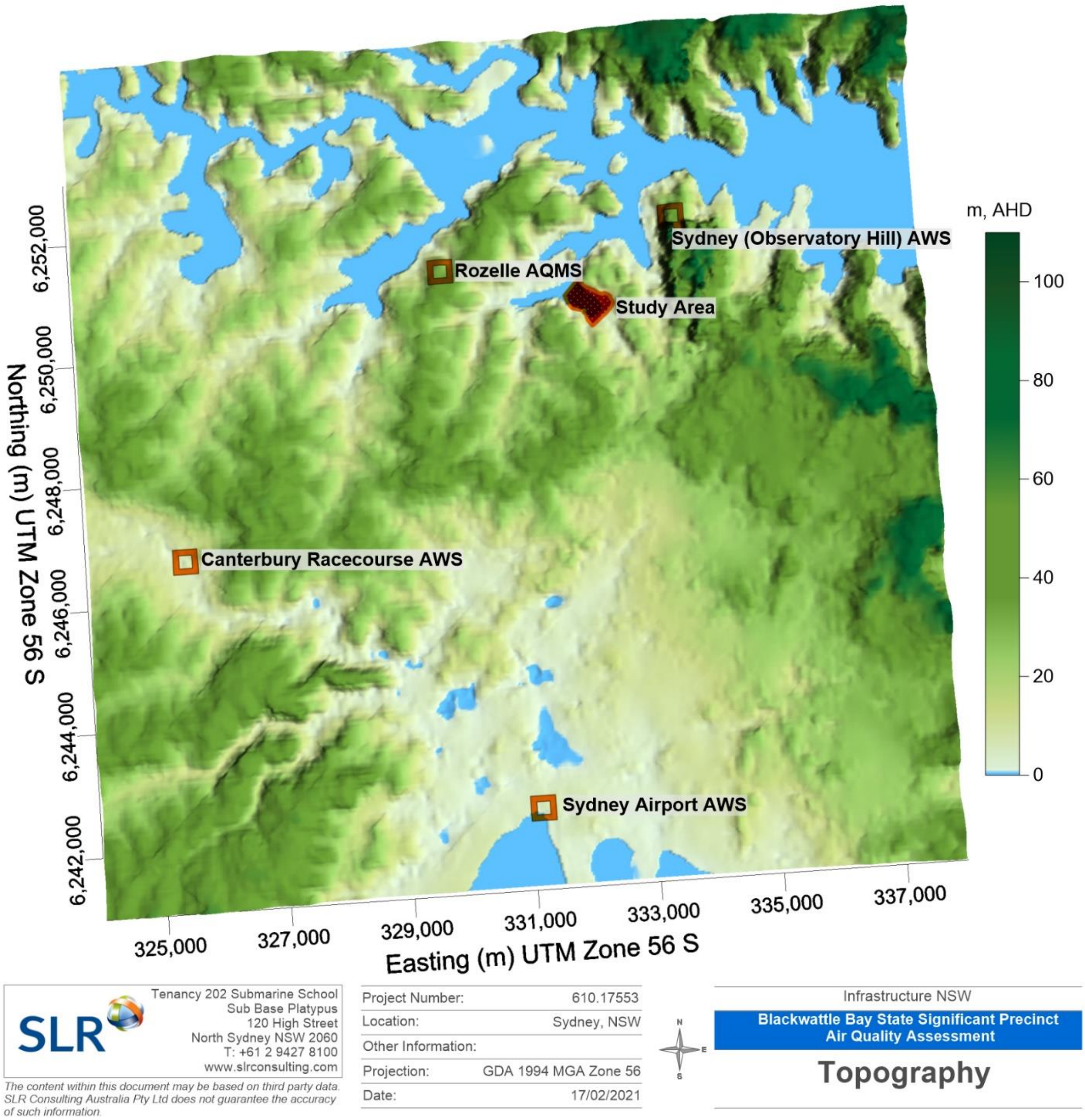
3 Project Setting

3.1 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 surrounding the Study Area is given in **Figure 4**. The topography of the local area within a 12 km radius of the Study Area ranges from an approximate elevation of -15 metres (m) to 130 m Australian Height Datum (AHD). The Study Area itself is reasonably flat and is located on the southern and eastern sides of Blackwattle Bay, with the land sloped downwards towards the bay.

Figure 4 Topography of Area Surrounding the Study Area



3.2 Climate and Meteorology

The Bureau of Meteorology (BoM) maintains and publishes data from weather stations across Australia. The closest such station to the Study Area is the Sydney Observatory Hill Automatic Weather Station (AWS) (Station ID 66062), located approximately 2 km northeast of the Study Area.

Sydney Observatory Hill AWS has data available for the following parameters:

- Temperature (°C)
- Rainfall (mm)
- Relative humidity (%)
- Wind speed (m/s) and wind direction (degrees).

A review of the long term data collected by this station is provided in the following sections.

3.2.1 Temperature

Long-term temperature statistics for the Sydney Observatory Hill AWS are summarised in **Figure 5**. Mean maximum temperatures range from 16.4°C in winter to 26°C in summer, while mean minimum temperatures range from 8.1°C in winter to around 18.9°C in summer. Maximum temperatures above 40°C and minimum temperatures below 5°C have been recorded.

3.2.2 Rainfall

Long-term rainfall statistics for the Sydney Observatory Hill AWS are summarised in **Figure 6.** The average monthly rainfall is relatively high in late-summer to early-winter, reducing from mid-winter to late-spring with the lowest average of 68.1 mm/month recorded during September. An average of over ten days of rain days per month have been recorded for all months. The highest average monthly rainfall of 133.1 mm/month occurs in June, with an average of 12.6 rain days recorded in this month. The highest monthly rainfall recorded over the time period examined was 642.7 mm recorded in August 1950.

3.2.3 Relative Humidity

Long-term humidity statistics (9 am and 3 pm monthly averages) for the Sydney Observatory Hill AWS are summarised in **Figure 7**. Morning humidity levels range from an average of around 61% in mid-spring to around 74% in winter. Afternoon humidity levels are lower, at around 64% in late summer and dropping to a low of 49% in late winter.

3.2.4 Wind Speed and Direction

Long term wind data (9 am and 3 pm) for Sydney Observatory Hill AWS are presented as wind roses in **Figure 8**. The wind roses show a strong diurnal pattern, with winds from the west quadrant dominating during the morning and winds from the east quadrant dominating in the afternoon. Winds are also stronger in the afternoon than during the morning.

Considering the topographical features of the land between the Study Area and Sydney Observatory Hill AWS (see **Figure 4**), the actual winds experienced at the Study Area may be different to those recorded by the BoM AWS. Therefore, meteorological modelling was carried out in order to predict site-representative wind conditions for the Study Area (see **Section 9.5**).

Figure 5 Long Term Temperature Data for Sydney Observatory Hill AWS

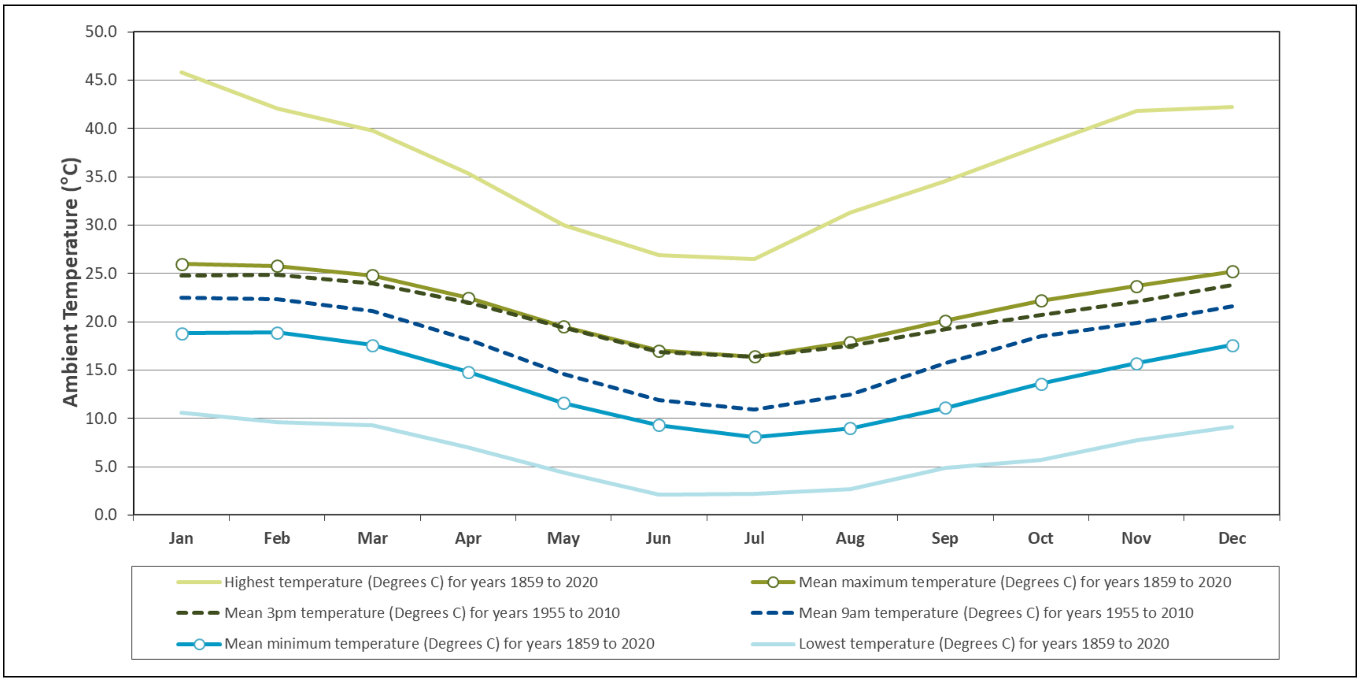


Figure 6 Long Term Monthly Rainfall Data for Sydney Observatory Hill AWS

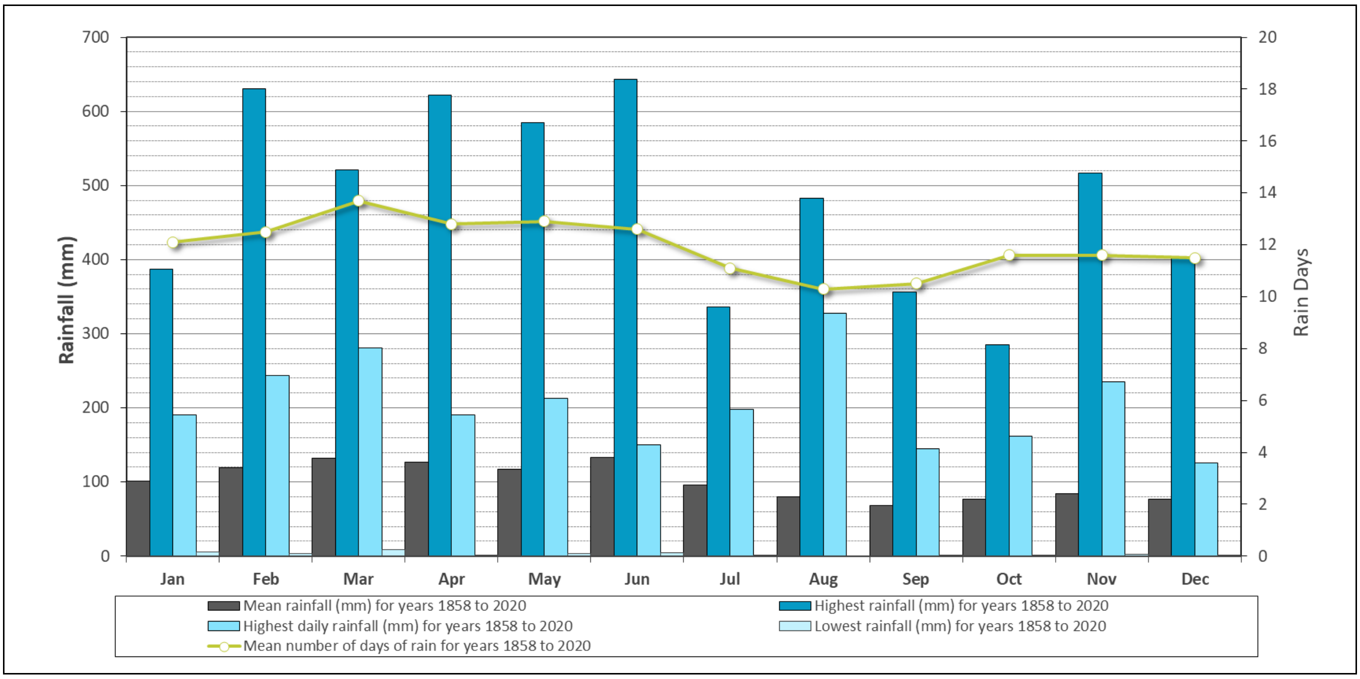


Figure 7 Long Term Humidity Data for Sydney Observatory Hill AWS

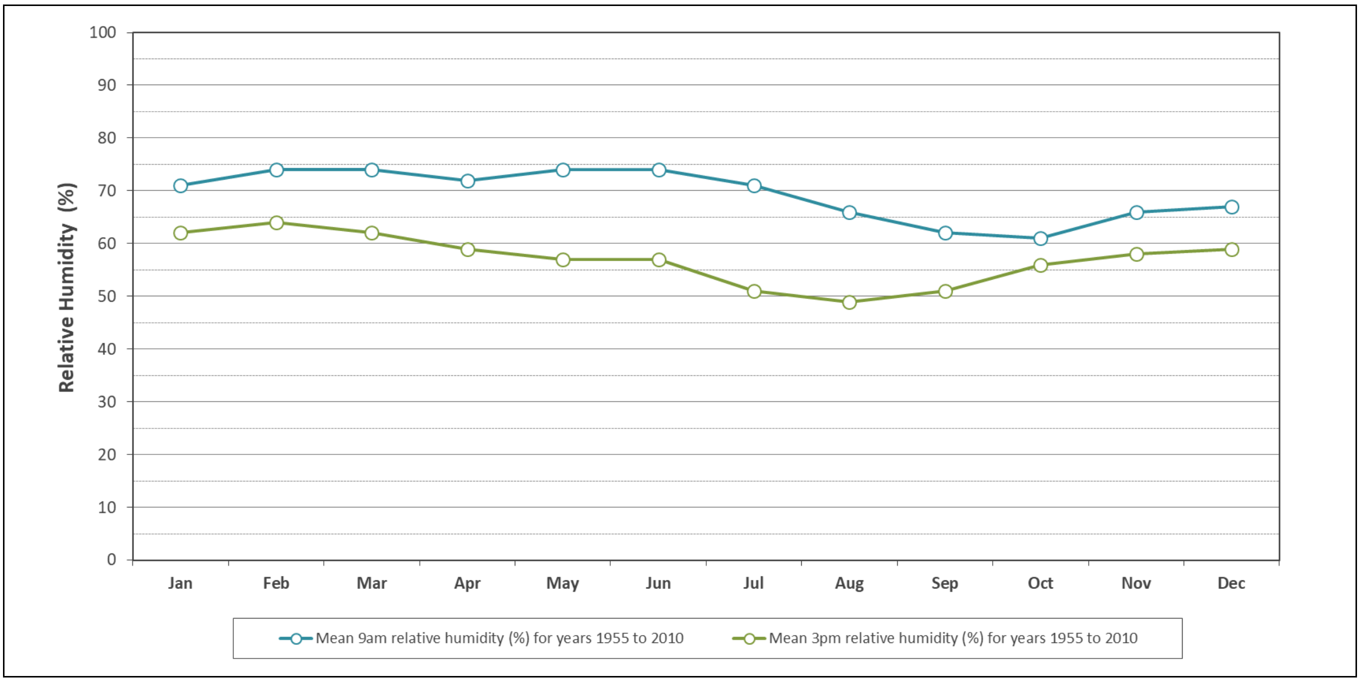
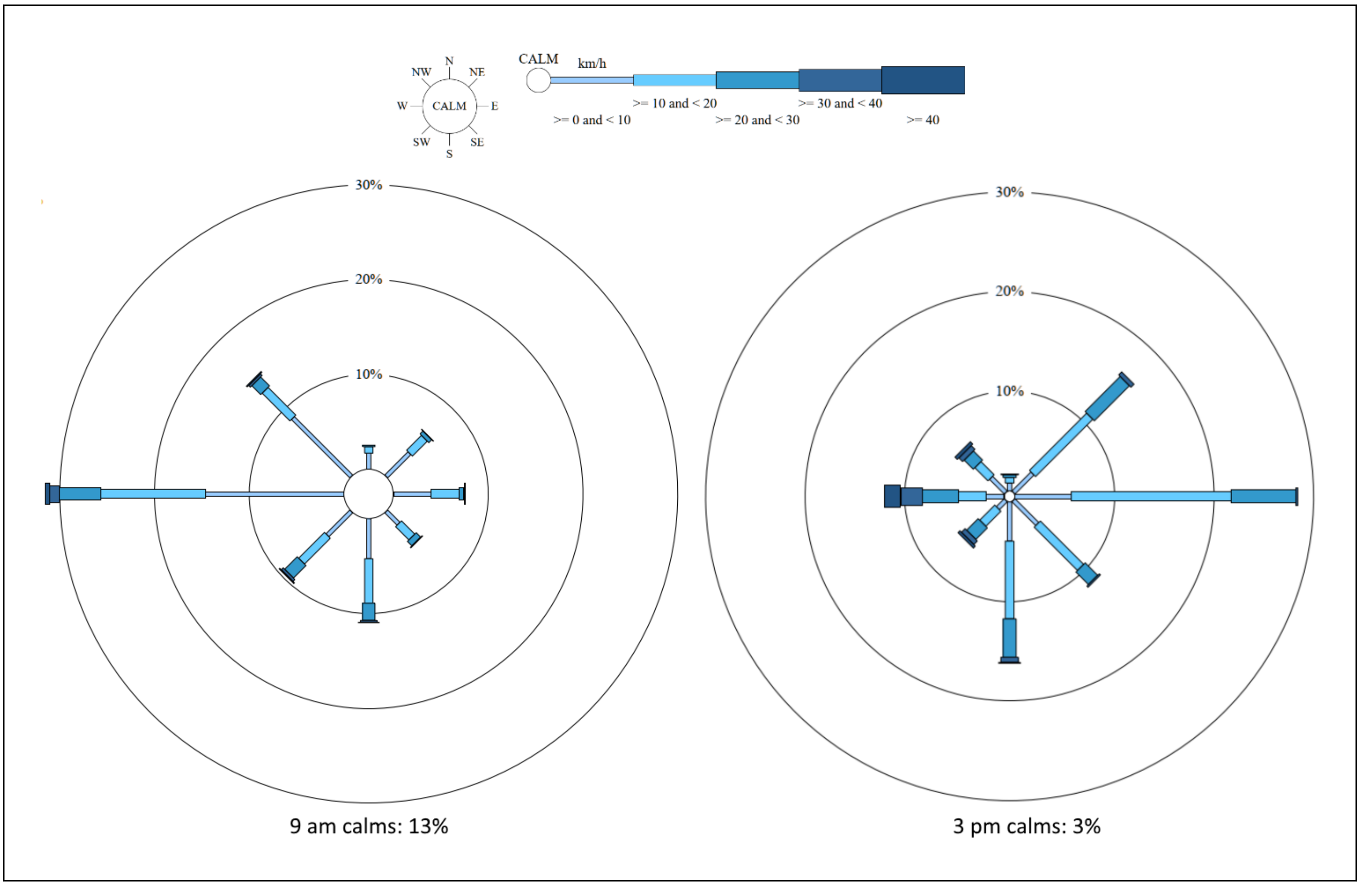


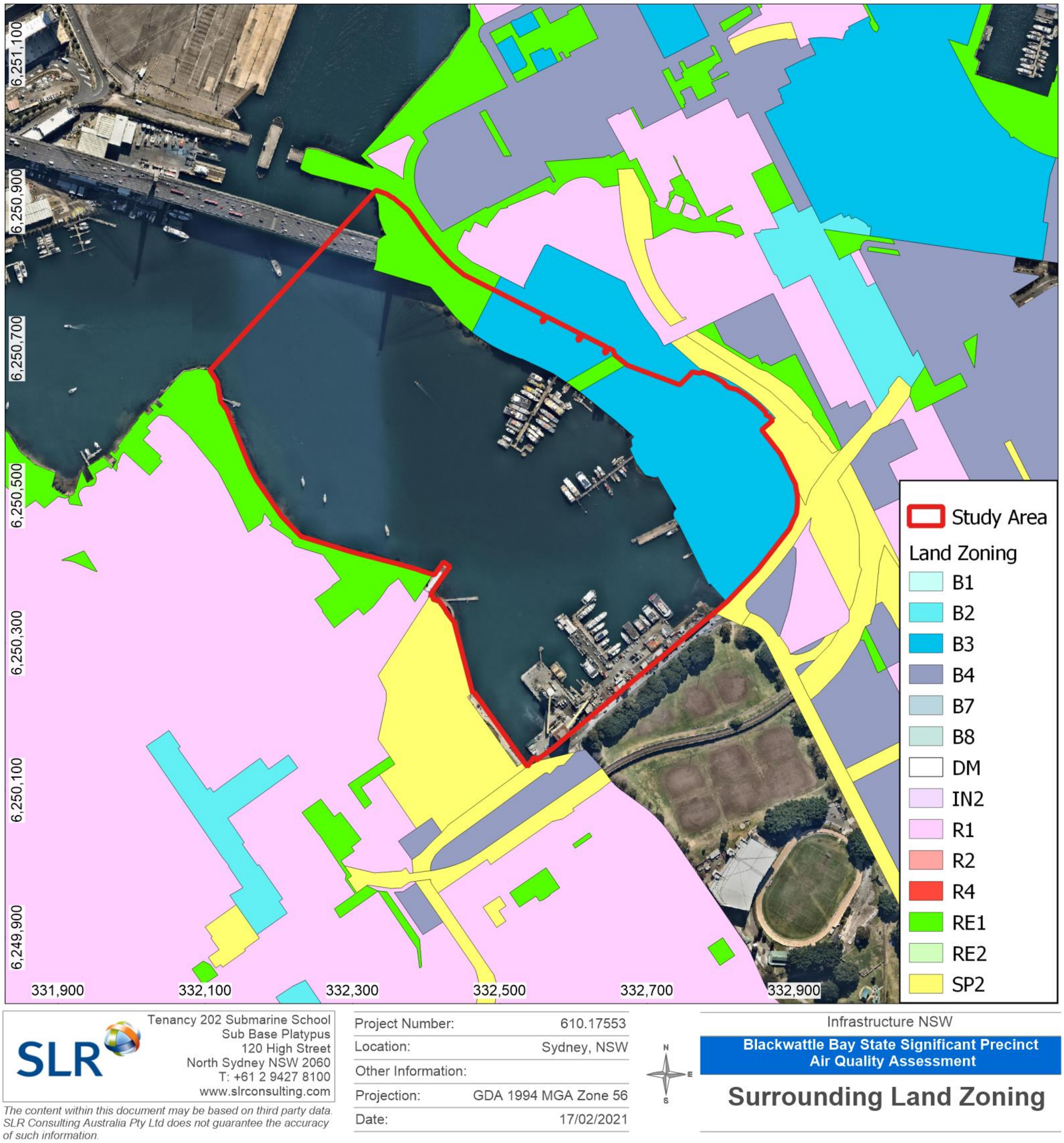
Figure 8 Rose of Wind Direction Vs Wind Speed for Sydney Observatory Hill AWS (1965 -2018)



3.3 Surrounding Land Use

The area surrounding the Study Area includes lands zoned as Local Centre (B2), Commercial Core (B3), Mixed Use (B4), General Residential (R1), Public Recreation (RE1) and Infrastructure (SP2) as seen in **Figure 9**. There are a number of existing residences located southeast, northeast, southwest and west of the Study Area.

Figure 9 Surrounding Land Use



4 Regulatory Context

4.1 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 Protection or the Environment Operations (POEO) (Clean Air) Regulation 2002 for assessment of impacts of air pollutants.

The air quality criteria set out in the Approved Methods have been reproduced and discussed in **Section 6**.

4.2 Odour Technical Framework and Notes

The EPA's Assessment and Management of Odour from Stationary Sources in NSW (Technical Framework and Technical Notes) publications provide a policy framework for assessing and managing activities that emit odour and offer guidance on dealing with odour issues. These documents are required to be referenced when assessing any odour issue in NSW.

4.3 Infrastructure SEPP

NSW State Environmental Planning Policy (Infrastructure) 2007 (the 'Infrastructure SEPP') refers to guidelines that 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. 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 of traffic noise and vehicle emission on development adjacent to classified roads.

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

An aim of the Guideline is to assist in reducing the health impacts of adverse air quality from road traffic on sensitive adjacent development and assists in the planning, design and assessment of development adjacent to busy roads.

Section 4.4 of the guideline provides the following guidance on when air quality should be a design consideration and some of the principles that should be considered at the design stage to achieve improved air quality:

When air quality should be a design consideration:

- Within 10 m of a congested collector road (traffic speeds of less than 40 km/hr at peak hour) or a road grade > 4% or heavy vehicle percentage flows > 5%;
- Within 20 m of a freeway or main road (with more than 2,500 vehicles per hour, moderate congestions levels of less than 5% idle time and average speeds of greater than 40 km/hr);

- Within 60 m of an area significantly impacted by existing sources of air pollution (road tunnel portals, major intersection / roundabouts, overpasses or adjacent major industrial sources); or
- As considered necessary by the approval authority based on consideration of site constraints, and associated air quality issues.

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 child care centres) should be as far as practicable from the major source of air pollution.
- Ventilation design and open-able windows should be considered in the design of development located adjacent to roadway emission sources. When the use of mechanical ventilation is proposed, the air intakes should be sited as far as practicable from the major source of air pollution.
- Using vegetative screens, barriers or earth mounds where appropriate to assist in maintaining local ambient air amenity. Landscaping has the added benefit of improving aesthetics and minimising visual intrusion from an adjacent roadway.

4.4 State Significant Precinct - Study Requirements

The Study Requirements for the Study Area have been prepared by the NSW Department of Planning and Environment (DPE) with the City of Sydney, in consultation with relevant State agencies and endorsed by the Project Review Panel which consists of representatives of the DPE, the City of Sydney, NSW Government Architect's Office and Transport for NSW. The key study requirements relating to air quality are outlined in **Section 2**.

5 Identified Pollutant Sources and Types

5.1 Road Traffic and Marine Vessels

The primary sources of air emissions in the area immediately surrounding the Study Area is expected to be vehicles travelling along the Western Distributer and Bridge Road. Engine exhaust emissions will also be generated by marine traffic within Blackwattle Bay and the wider Sydney Harbour, including ferries and water taxis, fishing trawlers, cruise ships visiting Darling Harbour and recreational boating.

The National Pollutant Inventory Emission Estimation Technique Manual (NPI EET) for Combustion Engines (DEWHA , 2008) identifies the primary pollutants from combustion engines as:

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

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).

The rate and composition of air pollutant emissions from road vehicles and boats is a function of a number of factors, including the type, size and age of vehicles/boats within the fleet, the type of fuel combusted, number and speed of vehicles/boats and (for road traffic) the road gradient. While boat emissions will most likely be a minor contributor to air pollutant concentrations at the Study Area, the high traffic volumes on the Western Distributor as well as the Western Distributor's elevated setting mean that road traffic emissions have the potential to result in elevated air pollutant concentrations during peak periods in areas within the Study Area closest to the Western Distributor.

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.

In relation to emissions from marine vessels, the federal government announced a new Direction in December 2016 to protect Sydney Harbour from ship emissions. The Australian Maritime Safety Authority Direction, as outlined in Marine Notice 21/2016, directs cruise vessels to limit sulphur emissions while at-berth in Sydney Harbour by using low sulphur fuel or an alternative measure that achieves an equivalent outcome. Specifically the Direction requires cruise ships to:

a. use fuel with a sulphur content not exceeding 0.1% mass per cent concentration (0.1% m/m);

b. use an exhaust gas cleaning system, certified and approved in accordance with the International Maritime Organization Guidelines for Exhaust Gas Cleaning Systems 2015;

c. use a power source external to the vessel; or

d. use a combination of any of the above measures.

5.2 Industrial Sources

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

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

Environment Protection Licences (EPL) 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 within a 3 km radius of the Study Area identified several industries which could potentially impact local air quality. Details of these facilities are presented in **Table 2** and their locations relative to the Study Area are illustrated in **Figure 10**.

In addition to the facilities identified from the search of the EPA public register and NPI database, the Hymix Australia concrete batching facility (Hymix), which is located inside the boundaries of the Study Area, is also a source of potential air pollutant emissions. According to the NSW EPA POEO Public Register, the Environment Protection Licence (EPL) for this facility has been surrendered and is no longer in force, due to changes to the POEO Regulation scheduled activities. These changes mean that concrete batch plants are no longer required to hold an EPL if they handle quantities of cement or lime that don't trigger the requirement to hold a licence under the 'cement or lime handling' activity in clause 6 of Schedule 1 of the Protection of the Environment Operations Act 1997. It is therefore understood that Hymix may remain in its existing location and continue concrete batching activities in the medium to long term, either in its existing guise or as a redeveloped/ upgraded facility.

According to the EPA website, the changes to the concrete batch plant licencing requirements have been made to reduce the administrative burden of reviewing and managing additional licences for facilities that the EPA considers to be of "*low environmental risk and are effectively regulated by the EPA outside of the licensing framework by using inspections, clean-up notices, prevention notices, penalty notices and prosecutions*."

The White Bay Cruise Terminal is also located approximately 900 m north-northeast of the Study Area (directly west of White Bay 6 Pty Ltd). Ships entering, leaving and berthed at this terminal will emit combustion products that have potential to impact on local air quality (refer to **Section 5.1**).

Figure 10 Location of Nearby Industrial Sources

Table 2 Identified Sources of Air Emissions in the Vicinity of the Study Area

Licence Holder / Facility	Type of Activity	Approximate Distance from the Study Area	Air Pollutants Potentially Emitted	Likelihood of Significant Impact
Malt Shovel Brewery	Brewing and packaging of beer	1.8 km (SW)	Odour, products of combustion	Low
Enwave Central Park Pty Ltd	Generation of electrical power from	1.4 km (SSE)	Products of gas combustion	Low
Newcastle Port Corporation	Shipping in bulk	0.5 km (N)	Particulate matter, products of combustion	Low
Sydney Ship Repair & Engineering Pty Ltd	Boat construction/maintenance (general)	1.8 km (NE)	Odour/VOCs from painting/antifouling, particulate matter from sanding/blasting	Low
Cement Australia Holdings Pty Ltd	Cement or lime handling	0.7 km (N)	Particulate matter, products of combustion	Low
Gypsum Resources Australia Pty. Limited	Shipping in bulk	0.7 km (N)	Particulate matter, products of combustion	Low
Harbour City Ferries Pty Ltd	Boat construction/maintenance (dry/floating docks)	1.4 km (N)	Odour/VOCs from painting/antifouling, particulate matter from sanding/blasting	Low
Sydney City Marine Pty Limited	Boat construction/maintenance (general)	0.4 km (N)	Odour/VOCs from painting/antifouling, particulate matter from sanding/blasting	Low
Roads And Maritime Services	Boat construction/maintenance (general)	0.5 km (NW)	Odour/VOCs from painting/antifouling, particulate matter from sanding/blasting	Low
Rozelle Bay Pty Ltd	Boat mooring and storage	0.5 km (NW)	Products of combustion, odours/VOCs from fuel storage	Low
Sugar Australia Pty Limited	General agricultural processing / Shipping in bulk	0.5 km (N)	Particulate matter, products of combustion	Low
White Bay 6 Pty Ltd	Boat construction/maintenance (general)	0.9 km (NE)	Odour/VOCs from painting/antifouling, particulate matter from sanding/blasting	Low
Hymix Australia (not currently licenced)	Concrete batch plant	0 km	Particulate matter, products of combustion	High

VOC = Volatile Organic Compounds

5.3 The New Sydney Fish Market

The new SFM (which has been approved and is currently under construction), is situated within the Study Area approximately 100 m west of the nearest future Study Area residential receptors. Potential air quality impacts from the new SFM were assessed in an air quality assessment report prepared by SLR (SLR, 2019) (the new SFM AQA). In relation to potential air quality issues, the new SFM AQA states:

> *The main potential sources of air emissions were identified as dust impacts during the construction phase and odour, VOC, products of combustion and particulates during the operational phase.*
>
> *The potential for off-site dust impacts was assessed using a qualitative risk-based approach prescribed by the Institute of Air Quality Management (IAQM). The results of this assessment indicate that dust impacts due to the construction works can be adequately managed with the implementation of site-specific mitigation measures, and that the residual impacts are likely to be low for construction and earthworks activities and negligible for trackout activities.*
>
> *The potential for off-site air quality impacts due to operation phase activities was also assessed using a qualitative risk-based approach. Although a qualitative assessment has been performed, given the nature and scale of the operations proposed, it is considered that provided appropriate mitigation measures are implemented as part of the detailed design stage the relevant air quality criteria outlined in Section 4.2 will not be exceeded as a result of the operation of the development.*

Further, the Development Consent issued for the new SFM requires that mitigation measures outlined in the new SFM AQA to be implemented thorough to the detailed design, construction and operation of the new SFM. Condition B102 of the new SFM Development consent states:

> *The mitigation measures in Part 7.4 of the Air Quality Assessment (AQA), prepared by SLR, dated April 2019 shall be implemented thorough to the detailed design, construction and operation, including exhausting, treatment of exhaust, temperature control, operational measures and monitoring. Prior to the issue of the relevant Crown Building Works Certificate, details demonstrating compliance with this requirement shalt be submitted to the Certifier.*

Given the above, the likelihood of significant incremental impacts from the operation of the new SFM is highly unlikely and construction of the new SFM would be completed before the Study Area is occupied by residents and other sensitive land uses. Potential air quality impacts within the Study Area from the new SFM are therefore not considered in detail in this report, which focuses on the master planning of Blackwattle Bay.

5.4 Other Sources

Additional industrial and commercial activities existing in the local area may 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 may still impact on air quality within the Study Area, but on a smaller scale than those that are licenced and/or are required to report under the NPI program.

During the site visit, it was observed that a number of activities, including warehousing and restaurants, exist adjacent to the Study Area. These operations would not be expected to have any significant potential for air quality impacts within the Study Area and have therefore been excluded from the dispersion modelling.

6 Relevant Air Quality Criteria

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

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

The criteria outlined in the sections below present the current ambient air quality criteria adopted by the NSW Government. It is noted that under a proposed variation to the National Environment Protection (Ambient Air Quality) Measure, supported by state Environmental Ministers, ambient air quality criteria for NO_2 and SO_2 may be amended based on the latest scientific understanding of the health risks arising from these pollutants. Recommended changes to the ambient air quality criteria for NO_2 and SO_2 include:

- The 1-hour standard for SO_2 in the AAQ NEPM should be retained, and the numerical value of the standard should be reduced to 100 ppb (currently 200 ppb).
- A future 1-hour SO_2 standard of 75 ppb is recommended for implementation from 2025.
- The 24-hour standard for SO_2 in the AAQ NEPM should be retained, and the numerical value of the standard should be reduced to 20 ppb (currently 80 ppb).
- No future target for 24-hour average SO_2 concentrations is recommended at this stage.
- The current annual mean standard for SO_2 should be removed from the AAQ NEPM.
- The form of both the 1-hour and 24-hour SO_2 standards should be the maximum value with no allowable exceedances.
- The 1-hour standard for NO_2 in the AAQ NEPM should be retained, and the numerical value of the standard should be reduced to 90 ppb (currently 120 ppb).
- The annual standard for NO_2 in the AAQ NEPM should be retained, and the numerical value of the standard should be reduced to 19 ppb (currently 30 ppb).
- The form of both the 1-hour and annual NO_2 standards should be the maximum value with no allowable exceedances.
- An exposure-reduction framework, in the form of a long-term goal for NO_2, should be established to reduce population exposure and associated health risk.
- A future 1-hour NO_2 standard of 80 ppb is recommended for implementation from 2025 as part of an exposure-reduction framework.
- A future annual NO_2 standard of 15 ppb is recommended for implementation from 2025 as part of an exposure-reduction framework.

The assessment presented in this report is based on the current ambient air quality criteria adopted by DPIE.

6.1 Particulate Matter

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

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

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

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

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

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

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

A summary of the particulate guidelines is shown in **Table 3**.

Table 3 EPA Goals for Particulates

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

6.2 Oxides of Nitrogen

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

NO is a colourless and odourless gas that does not significantly affect human health. However, in the presence of oxygen, NO can be oxidised to form NO_2 which can have significant health effects including damage to the respiratory tract and increased susceptibility to respiratory infections and asthma. Long term exposure to NO_2 can lead to lung disease. NO will be converted to NO_2 in the atmosphere after leaving a car exhaust. The goals specified within the Approved Methods for NO_2 are provided in **Table 4**.

Table 4 Assessment Criteria for Nitrogen Dioxide (NO_2)

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

Note: pphm = parts per hundred million

6.3 Carbon Monoxide

Carbon Monoxide (CO) is an odourless, colourless gas formed from the incomplete burning of fuels in motor vehicles. CO bonds to the haemoglobin in the blood and reduces the oxygen carrying capacity of red blood cells, thus decreasing the oxygen supply to the tissues and organs, in particular the heart and the brain.
It 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. CO in urban areas results almost entirely from vehicle emissions and its spatial distribution follows that of traffic flow. The goals specified within the Approved Methods for CO are provided in **Table 5**.

Table 5 Assessment Criteria for Carbon Monoxide (CO)

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

Note: ppm = parts per million

6.4 Sulphur Dioxide

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

The main sources of SO_2 in the air are industries that process materials containing sulphur (i.e. wood pulping, paper manufacturing, metal refining and smelting, textile bleaching, wineries etc.). SO_2 is also present in motor vehicle emissions, however since Australian fuels are relatively low in sulphur, high ambient concentrations are not common. The goals specified within the Approved Methods for SO_2 are provided in **Table 6**.

Table 6 Assessment Criteria for Sulphur Dioxide (SO_2)

Pollutant	Averaging Period	Criterion
SO_2	10-min	25 pphm (712 µg/m^3)
	1-hour	20 pphm (570 µg/m^3)

Pollutant	Averaging Period	Criterion
	24-hour	8 pphm (228 µg/m^3)
	Annual	2 pphm (60 µg/m^3)

6.5 Volatile Organic Compounds

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

VOCs are emitted by a variety of sources, including motor vehicles, chemical plants, automobile repair services, painting/printing industries, and rubber/plastics industries. VOCs that are often typical of these sources include benzene, toluene, ethylbenzene and xylenes (often referred to as 'BTEX'). Biogenic (natural) sources of VOC emissions are also significant (e.g. from 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 NSW OEH has established ground level air quality impact assessment criteria for BTEX as published in the Approved Methods. A summary of the relevant impact assessment criteria is given in **Table 7**.

Table 7 Air Quality Impact Assessment Criteria for BTEX

Pollutant	Averaging Period	Criterion	
		(ppm)	(µg/m^3)
Benzene	1 hour	0.009	29
Toluene	1 hour	0.09	360
Ethylbenzene	1 hour	1.8	8,000
Xylene	1 hour	40	190

6.6 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 goal 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 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 8. 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 the Study Area, the relevant criterion is 2 ou (nose-response-time average, 99th percentile).

Table 8 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

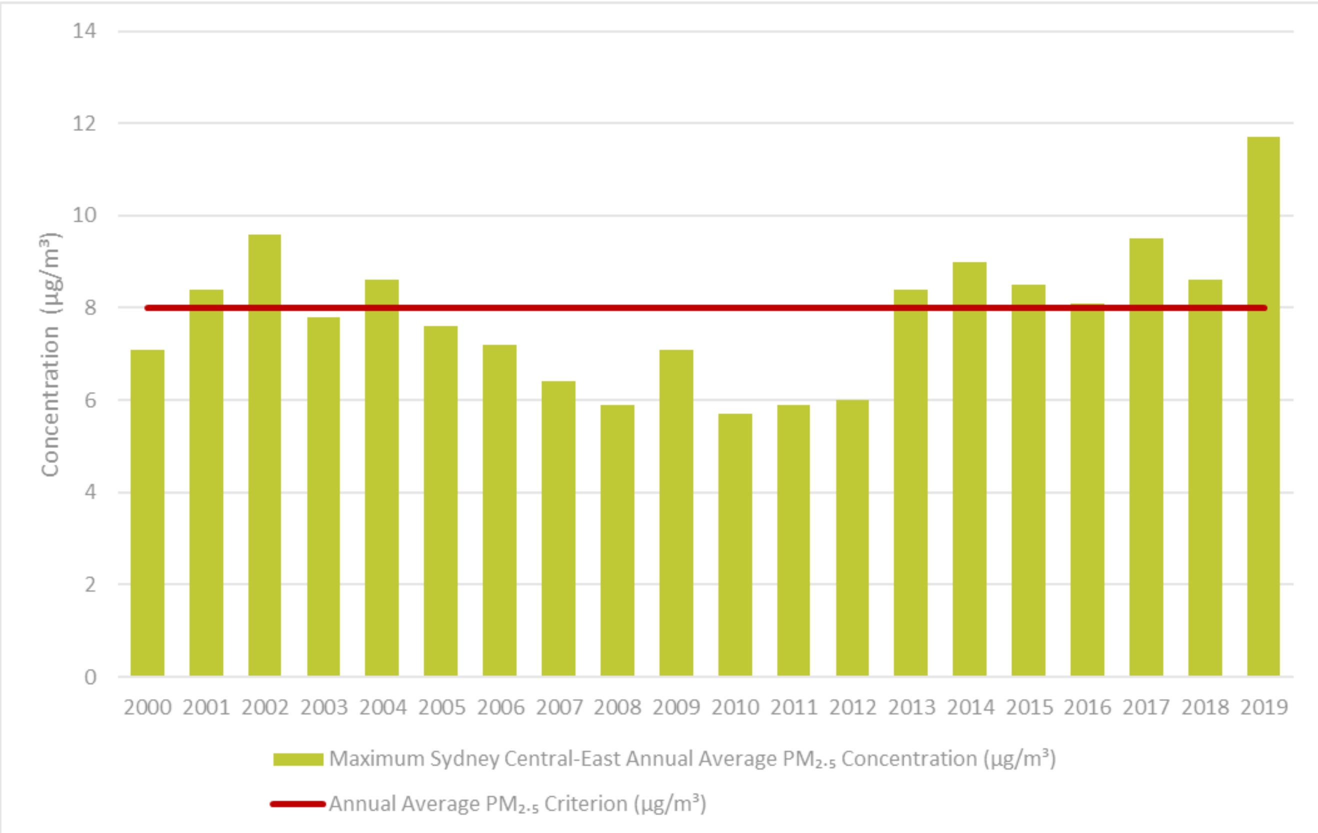
7 Characterisation of the Existing Air Environment

Air quality monitoring is performed by the NSW Department of Planning, Industry and Environment's Environment, Energy and Science (EES) group at a number of monitoring stations across NSW. Based on information from the EES Air Quality Monitoring Network, air quality is generally good in Sydney. For 2010-2019, the air quality was 'very good', 'good' or 'fair' for over 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 (8 µg/m^3) is more stringent than standards or guideline values set by the European Union (25 µg/m^3), United States (12 µg/m^3) and the WHO (10 µg/m^3). As a result, the annual average $PM_{2.5}$ guideline is frequently exceeded in the Sydney Metropolitan area. **Figure 11** illustrates the maximum annual average $PM_{2.5}$ concentrations in the Sydney central-east Region between 2000 and 2019. It is noted that exceedances were recorded for 10 of the last 20 years.

Figure 11 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 the Study Area, are exposed to, are minimised as much as practicable.

7.1 Review of EES Ambient Air Quality Monitoring Data

The closest EES Air Quality Monitoring Station (AQMS) to the Study Area is Cook and Philip Park AQMS located 1.9 km east of the Study Area. However, this station does not include long term data as it was commissioned in September 2019. The next closest AQMS to the Study Area is the Rozelle AQMS located 2.3 km to the northwest. The Rozelle AQMS station was commissioned in 1978 and is located on the grounds of Rozelle Hospital, off Balmain Road, Rozelle. It is situated in a residential area in the Parramatta River valley at an elevation of 22 m. It is part of the Sydney East air quality monitoring region.

Rozelle AQMS monitors the following air pollutants:

- Particulate matter less than 10 µm in diameter (PM_{10})
- Particulate matter less than 2.5 µm in diameter ($PM_{2.5}$)
- Nitrogen dioxide (NO_2)
- Carbon monoxide (CO)
- Sulphur dioxide (SO_2)

Air pollutant data recorded by the Rozelle AQMS were obtained for the calendar years 2015 – 2019. The data are summarised in **Table 9** (red font indicates an exceedance of the relevant criterion), and presented graphically in **Figure 12** to **Figure 16**. To be consistent with the annual NSW compliance 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.

A review of the data shows that exceedances of the 24-hour average PM_{10} criterion were recorded by the Rozelle AQMS in all five years, and exceedances of the 24-hour average and $PM_{2.5}$ criteria were recorded in all years except 2018. A review of the available compliance monitoring reports indicates that the exceedances were primarily due to exceptional events such as bushfire emergencies, dust storms and hazard reduction burns. The high number of exceedances recorded in 2019 was due to bush fire smoke that affected Sydney and the surrounding areas for a significant number of days in November and December of 2019.

Exceedances of the annual average $PM_{2.5}$ criterion were recorded in 2019. The annual average PM_{10} criterion was not exceeded for the five years reviewed.

Ambient concentrations of the gaseous pollutants NO_2, CO and SO_2 were all below the relevant criteria for all years investigated.

Table 9 Summary of Rozelle AQMS Data (2015 – 2019)

Pollutant	PM_{10}		$PM_{2.5}$		NO_2		CO	SO_2	
Averaging Period	Maximum 24-hour	Annual	Maximum 24-hour	Annual	Maximum 1-hour	Annual	Maximum 1-hour	Maximum 1-hour	Annual
Units	µg/m³	µg/m³	µg/m³	µg/m³	pphm	pphm	ppm	pphm	pphm
2015	60.3	16.7	36.0	7.2	6.0	1.1	1.6	ND	ND
2016	58.8	16.8	49.4	7.4	5.0	1.1	1.7	2.0	0.1
2017	54.1	18.1	36.3	7.2	6.1	1.1	1.2	2.4	0.1
2018	88.3*	18.4*	19.2*	7.3*	5.7*	1.0*	1.0*	3.0*	0.1*
2019	142.7	22.7	101.8	10.3	9.0	0.9	5.2	3.2	0.1
Criterion	**50**	**25**	**25**	**8**	**12**	**3**	**25**	**20**	**2**

Notes:

1 For 2015, one (1) exceedance of the 24-hour average PM_{10} and one (1) exceedance of the 24-hour average $PM_{2.5}$ were recorded.

2 For 2016, one (1) exceedance of the 24-hour average PM_{10} and five (5) exceedances of the 24-hour average $PM_{2.5}$ were recorded.

3 For 2017, one (1) exceedance of the 24-hour average PM_{10} and two (2) exceedances of the 24-hour average $PM_{2.5}$ were recorded.

4 For 2018, two (2) exceedances of the 24-hour average PM_{10} were recorded.

5 For 2019, 18 exceedances of the 24-hour average PM_{10} and 21 exceedances of the 24-hour average $PM_{2.5}$ were recorded.

ND = No Data

* The AQMS did not meet 75% data availability, due to recommissioning of the site. The AQMS was offline between 15 February 2018 and 30 May 2018. The data presented is based on available data.

Figure 12 24-Hour Average PM_{10} Concentrations at Rozelle AQMS (2015 – 2019)

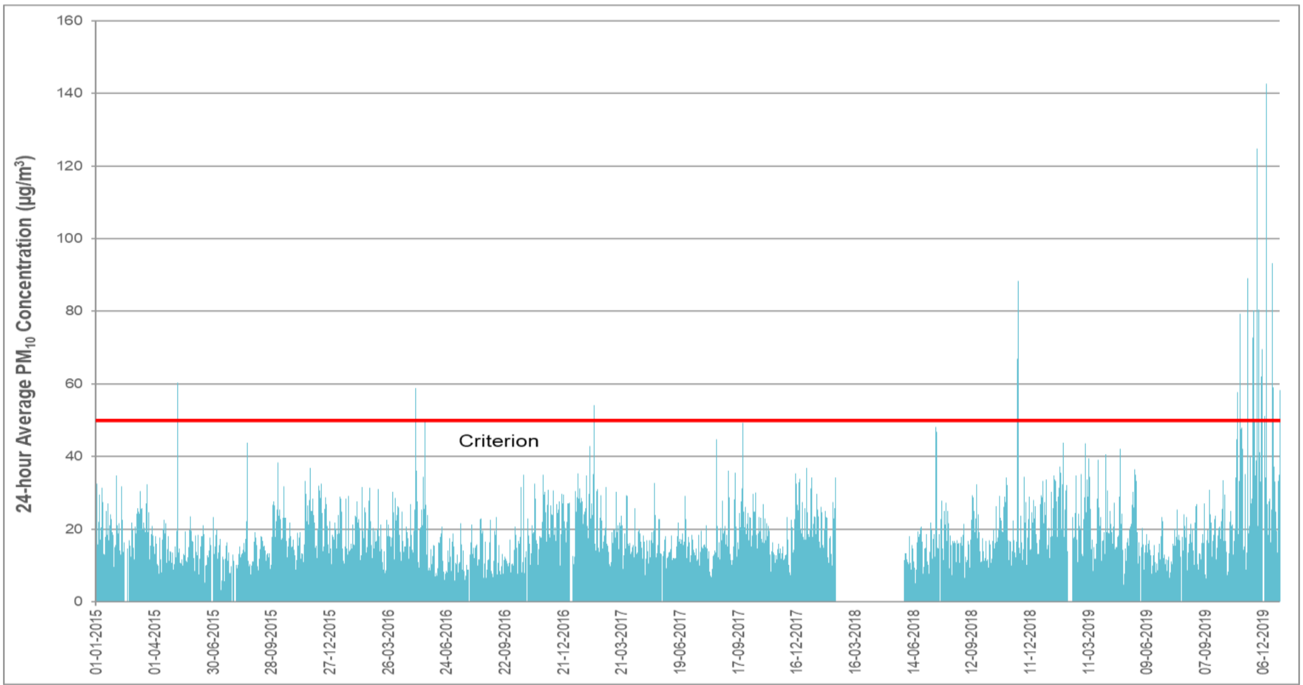


Figure 13 24-Hour Average $PM_{2.5}$ Concentrations at Rozelle AQMS (2015 – 2019)

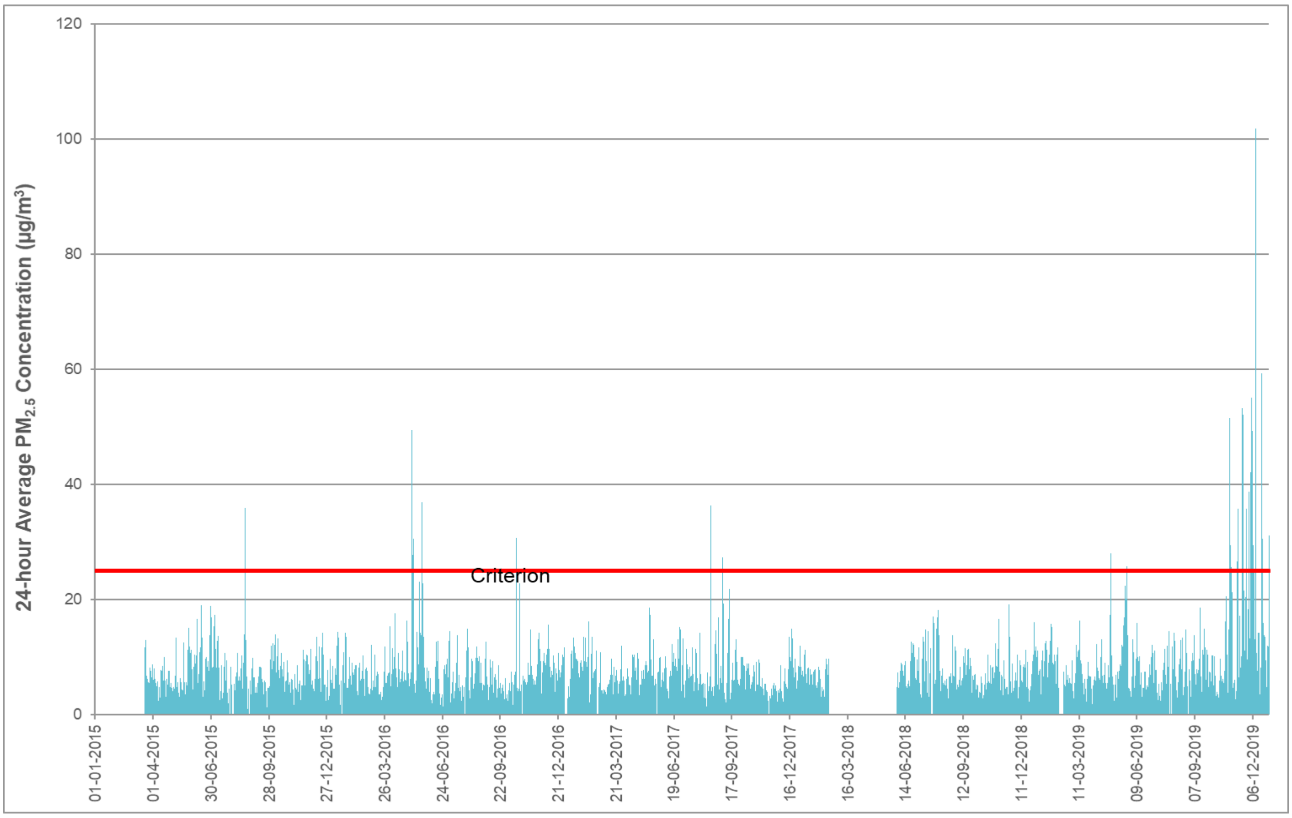


Figure 14 1-Hour Average NO_2 Concentrations at Rozelle AQMS (2015 – 2019)

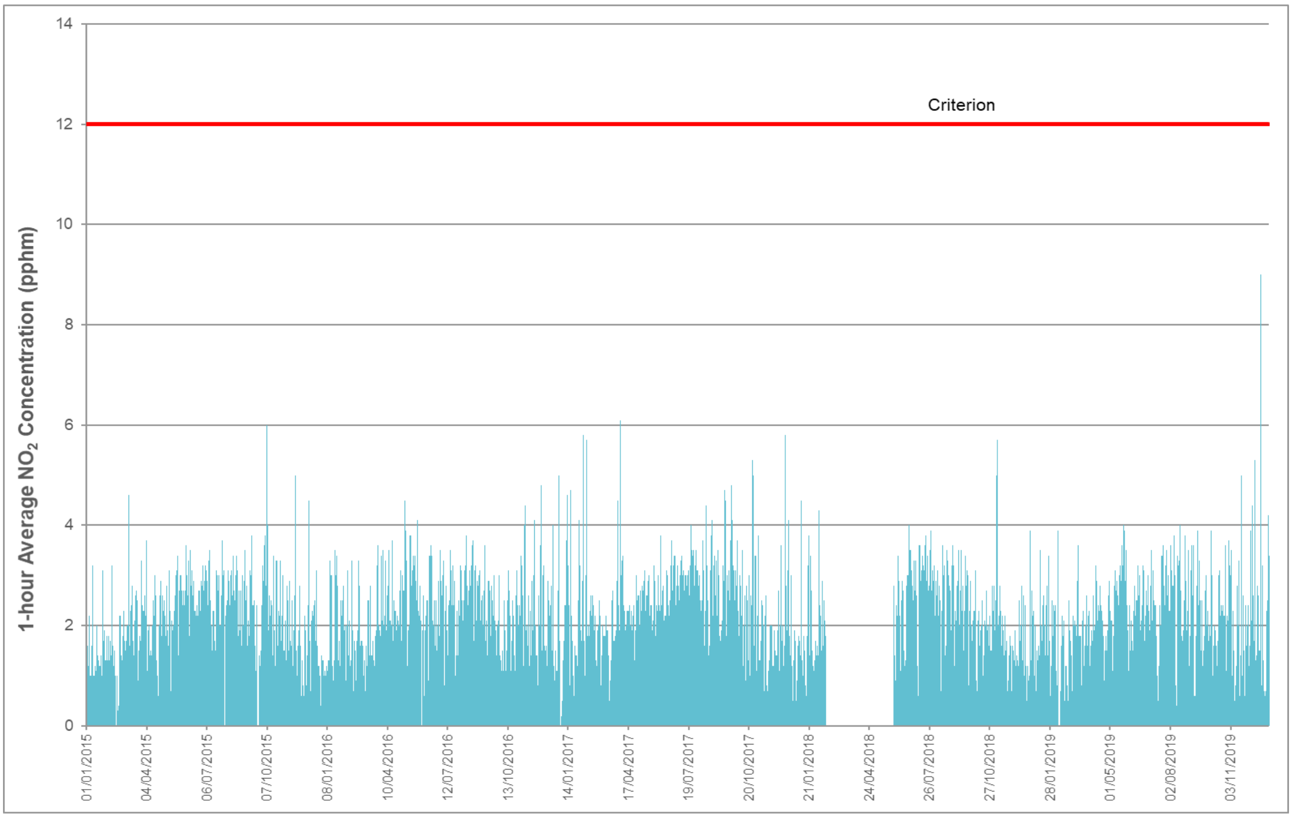


Figure 15 1-Hour Average CO Concentrations at Rozelle AQMS (2015 – 2019)

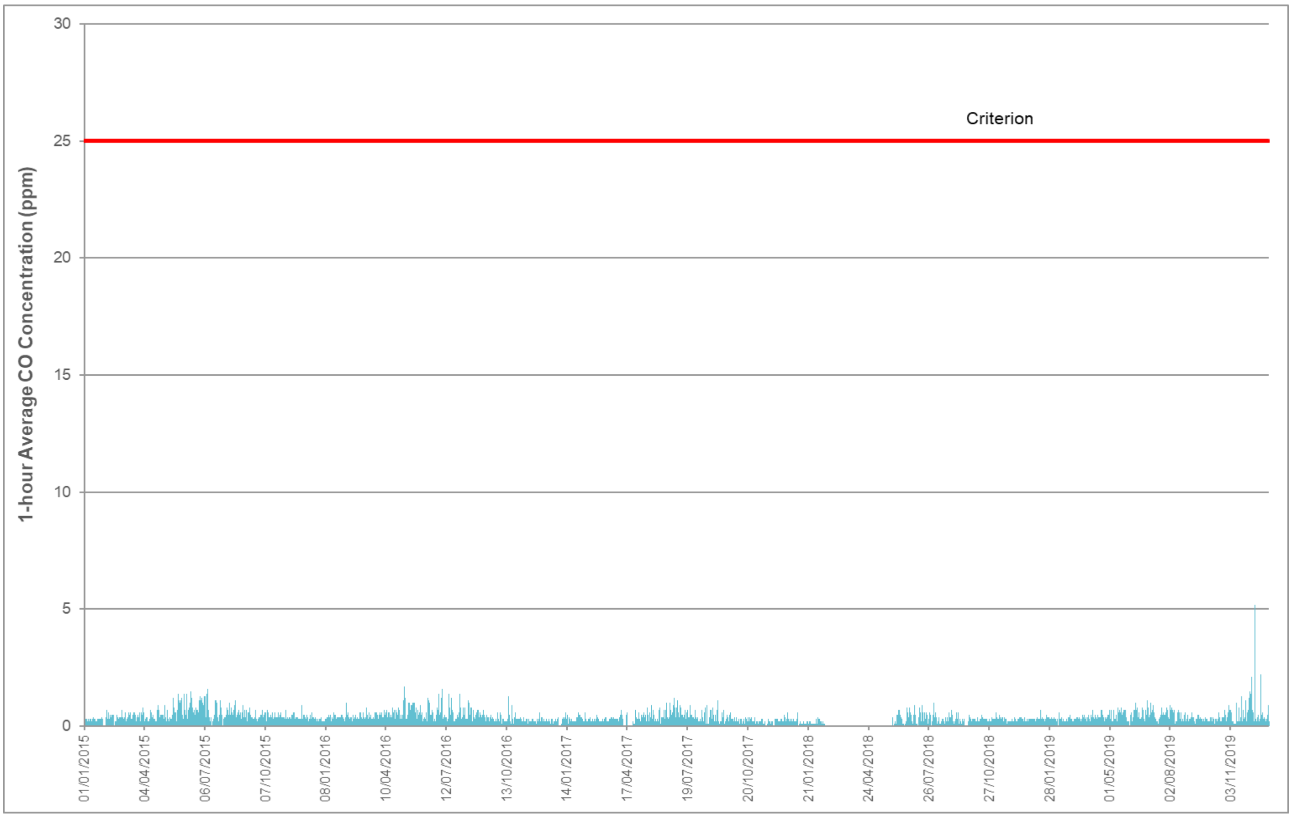
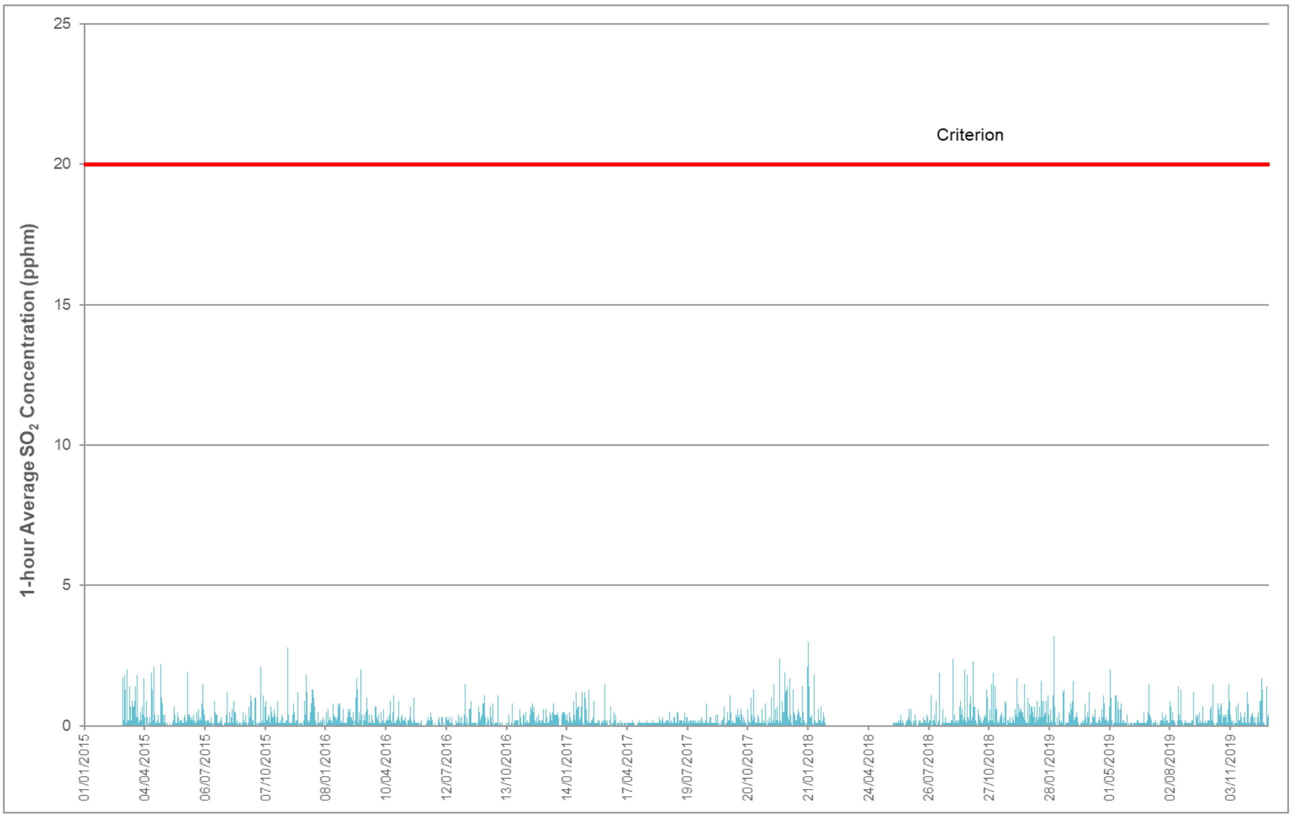


Figure 16 1-Hour Average SO_2 Concentrations at Rozelle AQMS (2015 – 2019)



7.2 Review of NSW Port Authority Ambient Air Quality Monitoring Data

The Port Authority of NSW also runs an air monitoring program at Glebe Island, approximately 1 km north of the Study Area. The pollutants monitored as part of this program are SO_2 and $PM_{2.5}$ only, in addition to meteorological parameters. The White Bay Cruise Terminal (WBCT) AQMS is located on the corner of Adolphus Street and Grafton Street approximately 100 m from WBCT.

It is noted that a complete dataset for the WBCT AQMS is not publicly available. Therefore, the presented data are based on mean and maximum concentrations presented in the monthly air quality monitoring reports for the AQMS. The number of exceedances reported in **Table 10** were derived from 24-hour average $PM_{2.5}$ concentration graphs presented in these monthly reports.

Exceedances of the 24-hour average $PM_{2.5}$ criterion were recorded by the WBCT AQMS in all years reviewed. A review of the dates the exceedances occurred identified that, with the exception of two days (19 May 2016 and 21 October 2016), the exceedances occurred on days when the nearby EES AQMSs also recorded exceedances of the criterion. This shows that the exceedances are primarily due to regional events such as bushfires, dust storms or hazard reduction burning. It is noted that ships were also berthed at the WBCT on 19 May 2016 and 21 October 2016.

The WBCT AQMS's proximity to the cruise ship terminal and berths means pollutant concentrations recorded at this monitoring station will be significantly affected by emissions from fuel combustion in cruise ships at the WBCT, which is not considered to be representative of the emission sources surrounding the Study Area. On average, the annual average $PM_{2.5}$ concentrations recorded by the WBCT AQMS are approximately 31% higher than those recorded by the Rozelle AQMS. Annual average SO_2 concentrations are approximately 25% lower than those recorded by the Rozelle AQMS, however the 1-hour average SO_2 concentrations are approximately 29% higher than those recorded by the Rozelle AQMS.

While a full statistical analysis of the WBCT AQMS data could not be carried out, a review of the concentration graphs presented in the monthly WBCT air quality monitoring reports indicates that the $PM_{2.5}$ and SO_2 concentrations recorded by the WBCT AQMS are similar to those recorded by the Rozelle AQMS on days when ships were not berthed at the WBCT. This suggests that the incremental impact from other marine vessels and industrial activities in the area (refer to **Section 5.2**) is not significant.

In addition to continuous $PM_{2.5}$ and SO_2 monitoring, two rounds of VOC sampling were conducted at three locations surrounding the WBCT in December 2015 and February 2016. The results from these monitoring campaigns indicate that the concentrations of air toxic compounds in the area are much lower than the impact assessment criteria outlined in the Approved Methods. The April 2016 WBCT Air Toxics Monitoring Report prepared by Pacific Environment (Pacific Environment, 2016) states that the majority of the suite of more than 80 VOCs analysed returned results below the limit of detection of the method. Further, the report notes that where specific VOCs were detected, these were recorded at concentrations several orders of magnitude below their relevant impact assessment criteria.

Table 10 Summary of White Bay Cruise Terminal AQMS Data (2016 – 2019)

<table>
<tr><th rowspan="2">Pollutant</th><th rowspan="2">Averaging Period</th><th rowspan="2">Criteria</th><th rowspan="2">Year</th><th colspan="2">WBCT AQMS</th><th rowspan="2">Units</th></tr>
<tr><th>Maximum Concentration</th><th>Number of Exceedances</th></tr>
<tr><td rowspan="8">$PM_{2.5}$</td><td rowspan="4">24-hour</td><td rowspan="4">25 µg/m³</td><td>2016</td><td>68.0</td><td>5</td><td>µg/m³</td></tr>
<tr><td>2017</td><td>48.0</td><td>3</td><td>µg/m³</td></tr>
<tr><td>2018</td><td>35.0</td><td>4</td><td rowspan="2">µg/m³</td></tr>
<tr><td>2019</td><td>89</td><td>5</td></tr>
<tr><td rowspan="4">Annual</td><td rowspan="4">8 µg/m³</td><td>2016</td><td>10.3</td><td>1</td><td>µg/m³</td></tr>
<tr><td>2017</td><td>9.4</td><td>1</td><td>µg/m³</td></tr>
<tr><td>2018</td><td>9.1</td><td>1</td><td rowspan="2">µg/m³</td></tr>
<tr><td>2019</td><td>11.2</td><td>1</td></tr>
<tr><td rowspan="8">SO_2</td><td rowspan="4">1-hour</td><td rowspan="4">20 µg/m³</td><td>2016</td><td>2.9</td><td>0</td><td>µg/m³</td></tr>
<tr><td>2017</td><td>2.5</td><td>0</td><td>µg/m³</td></tr>
<tr><td>2018</td><td>4.1</td><td>0</td><td rowspan="2">µg/m³</td></tr>
<tr><td>2019</td><td>2.0</td><td>0</td></tr>
<tr><td rowspan="4">Annual</td><td rowspan="4">2 µg/m³</td><td>2016</td><td>0.03</td><td>0</td><td>µg/m³</td></tr>
<tr><td>2017</td><td>0.04</td><td>0</td><td>µg/m³</td></tr>
<tr><td>2018</td><td>0.06</td><td>0</td><td rowspan="2">µg/m³</td></tr>
<tr><td>2019</td><td>0.11</td><td>0</td></tr>
</table>

7.3 Ambient Odour Field Surveys

A series of ambient odour field surveys was performed by SLR staff on three separate days over the period 25 – 29 September 2017 in order to identify sources of odour in the area and to assess the plume extent, strength and hedonic tone of odours within and surrounding the Study Area. These odour surveys were performed by staff trained in performing ambient odour surveys and whose odour sensitivity had 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*). A report summarising the methodology and findings of the odour surveys is presented in **Appendix A**.

The surveys adopted a modified approach to the *BS EN 16841-2:2016 Ambient Air – Determination of odour in ambient air by using field inspection* and the VDI 3882:1992 *Part 1 Olfactometry – Determination of Odour Intensity*. Surveys were performed on 25, 27 and 29 September 2017, with multiple surveys being performed at different times of the day on each of these days (total of nine surveys).

A desktop review of the areas surrounding the Study Area was carried out prior to the first survey to identify the main sources of odour emissions. The existing SFM was identified as the main potential source of odour. However, in order to identify any additional odours that may impact upon the Study Area, areas across the Study Area and upwind of the existing SFM were surveyed, in addition to areas downwind.

At the start of the surveys, site boundary observations were made at the existing SFM to provide an understanding of the characteristics of the odours being emitted from the site on the day and time of the survey, to enable any downwind observations to be attributed to the existing SFM, if appropriate. Publicly accessible areas across the Study Area and its immediate surrounds were surveyed (public roads and footpaths). Observations of the wind speed, wind direction were also recorded during each survey.

The results of the surveys confirmed that the most significant source of odour in the surveyed area was the existing SFM. The following observations were noted:

- 'Distinct' (intensity scale 3) odours from the existing SFM were detected in four out of the nine surveys. These odours extended approximately 430 m west, 80-105 m east and 70-120 south of the existing SFM. The hedonic tone of these 'distinct' odours ranged from +1 to -1 ('mildly pleasant' to 'mildly unpleasant').
- The predominant odour character from the existing SFM was cooked seafood odours which are attributable to the operation of food outlets and restaurants within the existing SFM. These odours could be detected at the boundary of the existing SFM site regardless of the wind direction during peak operation at these premises, but were generally only detectable within 10 to 15 m from the boundary.
- Odours from other sources, including traffic and local restaurants were also detected. However, these odours were generally weak in intensity and only detectable in close proximity to the source (typically 1-5 m).

In summary, the surveys indicate that distinct and potentially mildly unpleasant odours do occur in the areas surrounding the existing SFM on occasion. However, as discussed in **Section 5.3**, these odour sources/impacts are associated with the existing SFM which is being relocated into a new purpose-built facility. The odour controls and mitigation measures that are required to be incorporated into the new SFM are expected to significantly reduce these odour impacts.

8 Emission Estimation

Of the air pollutant emission sources identified in **Section 5**, the Hymix concrete batch plant and traffic emissions from vehicles travelling along the Western Distributer and Bridge Road were concluded to be the only sources with potential to significantly impact on air quality in the Study Area. This section describes the methods used to estimate air emissions from these two sources for use in a detailed dispersion modelling study to assess their impacts on air quality at future sensitive receptor locations within the Study Area.

8.1 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 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.

As outlined in **Section 5.1**, atmospheric pollutants emitted from road traffic include NO_X, $PM_{2.5}$, PM_{10}, SO_2 and VOCs. Given the relatively low level of CO, SO_2 and VOC emissions from vehicles and the low background concentrations (see **Section 7**), it is considered appropriate to assume that CO, SO_2 and VOC emissions from road traffic are highly unlikely to result in any exceedances of the relevant criteria (see **Section 6**). Moreover, a review of the Air Quality Impact Assessment prepared for M4 East (Pacific Environment, 2015), which will have higher traffic volumes than the roads surrounding the Study Area, 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.

A spatial emissions inventory was developed for the emissions of NO_X, PM_{10} and $PM_{2.5}$ from vehicles travelling on the main roads surrounding the Study Area using the 'Computer Programme to calculate Emissions from Road Transport' (COPERT) Australia derived emission factors.

A key input required by COPERT Australia for deriving emission factors 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 11**. 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 B**.

Table 11 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		

8.1.1 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 11**. However such detailed information on the distribution of vehicles is not publicly available for the roads surrounding the Study Area. Therefore, in order to compile the COPERT Australia input files, the following assumptions were applied:

- The annual vehicle counts were subdivided into each sub-category, fuel type and emission control standard using statistical data compiled for NSW by the National Pollutant Inventory (NPI) team of the Australian Government Department of the Environment (DSITIA, 2014), for use in preparing the Australian Motor Vehicle Emission Inventory for the NPI. These sub-categories are representative of the NSW vehicle fleet in 2010. The current and future NSW vehicle fleets will include a smaller percentage of vehicles manufactured to obsolete motor vehicle emission standards, which will add to the conservativism of this assessment.
- The emissions were estimated for a nominal 1 km length of the road.
- The emissions were estimated for two vehicle speed scenarios:
    - low vehicle speed of 10 km/hr (potential worst case emission rate that would be representative of congested traffic conditions). These emission factors were applied to vehicles travelling along all roads from 6 am to 10 pm.
    - vehicle speed of 60 km/hr (representative of non-congested traffic conditions). These emission factors were applied to vehicles travelling along all roads from 10 pm to 6 am.
- Meteorological conditions, including maximum and minimum temperature and relative humidity were estimated based on available long term average data for the Sydney region.

8.1.2 Peak Traffic Volumes

Traffic volumes forecasted for the road network surrounding the Study Area for the year 2033 (with the Study Area fully developed) were provided by the project team. The peak morning (8-9 am) traffic volumes used in the modelling are detailed in **Appendix C** and illustrated in **Figure 17**.

Given the traffic models used for the project only provide forecasts for the morning and afternoon peak periods, information on the diurnal variation in traffic flows is not available for the roads surrounding the Study Area. In order to estimate a 'diurnal multiplier' for traffic volumes in the area:

- Data available from the permanent Transport for NSW Traffic (TfNSW) traffic counter (Station ID: 20001 – 220 m West of Bowman Street, Rozelle) were obtained from the TfNSW Traffic Volume Viewer to calculate the average diurnal variation in traffic volumes for the eastbound and westbound directions separately; and
- Hourly traffic count data provided by the project team for Bank Street and Pyrmont Bridge Road were used to derive a composite diurnal multiplier for other modelled roads.

The traffic model forecasted that the total volume of vehicles during the morning peak would be greater than that of the afternoon peak. As illustrated in **Figure 18**, the diurnal multiplier for each hour of day is the ratio of traffic volume for that hour to the morning peak hour (8 - 9 am) traffic volume.

Figure 17 Morning Peak Traffic Volumes – Modelled Road Network

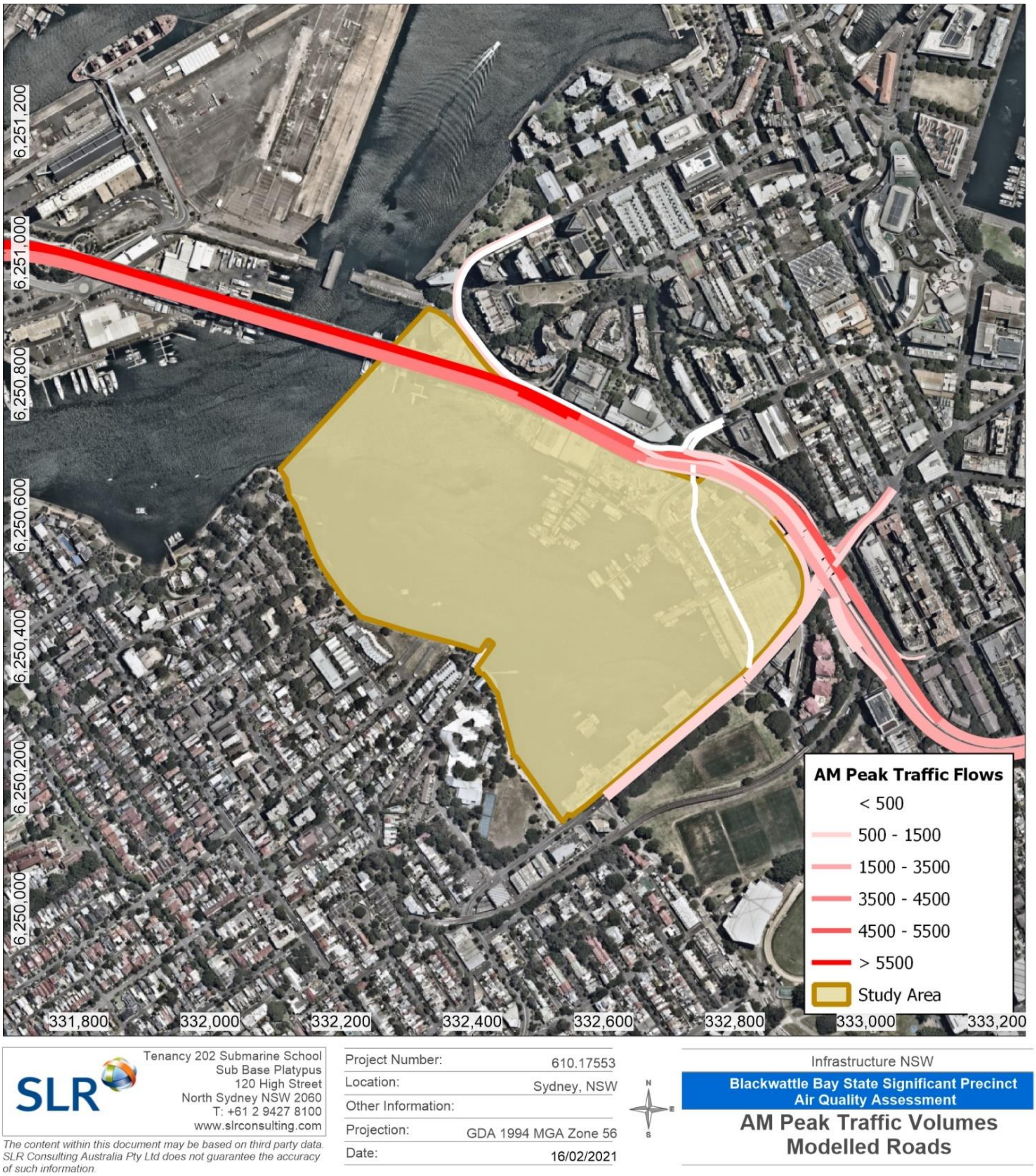
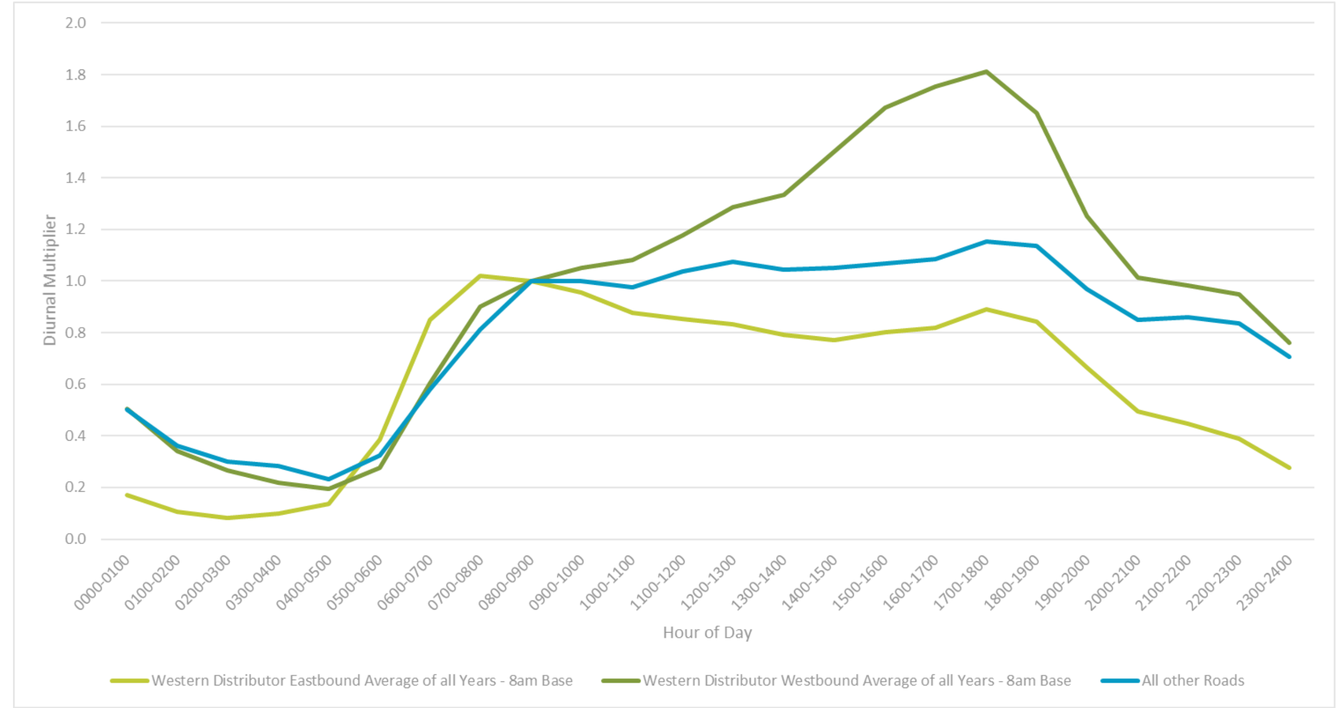


Figure 18 Diurnal Multipliers Adopted for this Study



8.1.3 Road Gradients and Lengths

The average gradient of each road link was estimated using high-resolution terrain data obtained from the Foundation Spatial Data Framework website. Elevation above sea level 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 derived using COPERT are not gradient dependent. Therefore, correction factors derived from emission factors published by PIARC (PIARC Technical Committee D.5, 2019) were applied to the COPERT emission factors. The gradient correction factors used in this assessment, which take into account the percentage of heavy and light vehicles in the surrounding road network, are presented in **Table 12** and **Table 5**. The calculated gradients were rounded to the nearest multiple of two.

Table 12 Gradient Correction Factors for COPERT Emission Factors for Vehicles Travelling at 10 km/h

Road Gradient (%)	Particulate Matter Correction Factor	NO_2 Correction Factor
-8	85%	60%
-6	85%	60%
-4	88%	69%
-2	93%	84%
0	100%	100%
2	128%	121%
4	159%	142%
6	166%	165%
8	166%	165%

Table 13 Gradient Correction Factors for COPERT Emission Factors for Vehicles Travelling at 60 km/h

Road Gradient (%)	Particulate Matter Correction Factor	NO_2 Correction Factor
-8	46%	25%
-6	46%	25%
-4	51%	39%
-2	70%	61%
0	100%	100%
2	148%	163%
4	236%	226%
6	370%	311%
8	370%	311%

8.1.4 Estimated Emission Rates

The peak hourly emission rates estimated using COPERT Australia for the key pollutants based on the methodology outlined above are presented in **Appendix C**.

8.2 Concrete Batch Plant

As outlined in **Section 4**, atmospheric pollutants likely to be generated by the activities at Hymix concrete batch plant include fugitive emissions of particulates (assessed as PM_{10} and $PM_{2.5}$) and products of fuel combustion (NO_X, SO_2, VOCs, CO, PM_{10} and $PM_{2.5}$).

It is considered appropriate to assume that combustion emissions from the Hymix operations would be negligible compared to the existing background levels, particularly from traffic on the Western Distributor. Hence, emissions of fuel combustion products from Hymix have not considered further in this assessment.

The key potential emission sources and major pollutants identified for the Concrete Batch Plants are summarised in **Table 14**.

Table 14 Summary of Potential Emission Sources – Hymix Concrete Batch Plant

Emission Source/Activity	Emission Type	Pollutants
Trucks dumping aggregates and sand	Material handling	Particulates
Front end loader on aggregates and sand	Material handling	Particulates
Miscellaneous transfer points (including conveying)	Material handling	Particulates
Mixer / weigh hopper loading	Material handling	Particulates
Road haulage	Wheel-generated dust	Particulates
Temporary overflow aggregate and sand storage bins	Wind erosion	Particulates

Particulate emissions from the emission sources listed in **Table 14** have been calculated using default emission factors sourced from the US EPA *AP-42: Compilation of Air Emission Factors* (US EPA, 2012). As no default emission factors are available for $PM_{2.5}$, the estimated PM_{10} emissions were scaled using USEPA AP-42 data in order to estimate $PM_{2.5}$ emissions.

The aggregate and sand storage bins at the two concrete batch plants appear to be either underground or enclosed and the internal surface areas of the site are paved . It was therefore assumed that emissions due to wind erosion from stockpiling of materials and road haulage within the site are minimal and have not been considered further in this assessment. Given the conservative assumptions made for other sources (e.g. uncontrolled emissions from aggregate and sand transfer and weigh hopper loading), it is considered that the total annual emissions estimated for each site will be conservative over-estimates of actual emissions.

In the absence of a current EPL or publicly available activity data for Hymix, SLR contacted Hymix through INSW to obtain activity data representative of current and future operations. Hymix provided the following information:

- The site currently operates on a 24/7 basis with no changes anticipated for future operations.
- Dust mitigation measures implemented by Hymix include: Bag filters on silos, shrouded dust extraction at the load point, paved surfaces, in ground and fully enclosed aggregate storage.
- The plant is a dry mix concrete batching facility (raw materials and water are discharged into the truck and all the material is mixed in the truck and transported to destination).

Production rates or average material compositions were not provided.

Hymix's peak daily and annual average production rates were estimated using site access survey vehicle movement data provided by the project team. The following assumptions were made in estimating Hymix's peak and annual average throughputs:

- Heavy vehicle movements recorded for the week the site access survey was completed (31st of August 2018 to 6th of September 2018) are representative of typical site operations.
- Two thirds of all heavy vehicles that enter and exit the site are concrete trucks, with the remainder being aggregate, sand and cement delivery trucks.
- Each concrete truck carries 6.5 m^3 of concrete.
- Density of concrete produced at Hymix is ,2400 kg/m^3[1]

The peak daily and annual average production rates estimated based on the assumptions above are presented in **Table 15**. The peak daily and annual average production rates were used to estimate potential site emissions to assess the short term and long term impacts from the activities at Hymix respectively.

The following average material compositions presented in the USEPA AP-42 documentation (US EPA, 2012) were adopted to estimate throughputs for the various raw materials used:

- 46.4% aggregate
- 35.5% sand
- 12.2% cement
- 1.8% cement supplement
- 4.1% water

[1] https://hypertextbook.com/facts/1999/KatrinaJones.shtml

Table 15 Estimated Hymix Production Rates

Day	Date	Total Vehicle Movements (in+out)		Production per day (tonnes/day)	Production per year (tonnes/year)
		Heavy Vehicles	Light Vehicles		
Mon	03-09-2018	452	126	2,350	857,896
Tue	04-09-2018	268	124	1,394	508,664
Wed	05-09-2018	248	110	1,290	470,704
Thu	06-09-2018	174	122	905	330,252
Fri	31-08-2018	264	182	1,373	501,072
Sat	01-09-2018	78	188	406	148,044
Sun	02-09-2018	6	162	31	11,388
Peak				**2,350**	**-**
Average					**404,003**

8.2.1 Emissions Inventory

The peak and average particulate emission inventories for the Hymix operations are shown in **Table 16** and Table 17 respectively. The $PM_{2.5}$ emissions were estimated using a $PM_{2.5}/PM_{10}$ ratio of 0.18, which was calculated based on truck mix operations equation parameters presented in Table 11.12-3 of the USEPA AP-42 documentation (US EPA, 2012).

Table 16 Emissions Inventory for Hymix Operations – Peak Operations – 2,350 tonnes/day

Process	Emission Factor (kg/tonne)	Hourly Emission Rate (kg/hr)	
	PM_{10}	PM_{10}	$PM_{2.5}$
Aggregate transfer (inground and fully enclosed 90% control)	0.0017	0.077	0.014
Sand transfer (inground and fully enclosed 90% control)	0.00051	0.018	0.0032
Cement unloading to storage silo (pneumatic)	0.00017	0.0020	0.0004
Cement supplement unloading to storage silo (pneumatic)	0.0024	0.0043	0.0008
Weigh hopper loading (enclosed and filtered – 99.9% control)	0.0013	0.0001	0.00002
Truck Loading (Truck/Dry Mix)	0.0131	0.18	0.032
Total Emissions		**0.28**	**0.051**

Table 17 Emissions Inventory for Hymix Australia Operations – Average Operations – 404,003 tonnes/year

Process	Emission Factor (kg/tonne)	Hourly Emission Rate (kg/hr)	
	PM_{10}	PM_{10}	$PM_{2.5}$
Aggregate transfer (inground and fully enclosed 90% control)	0.0017	0.036	0.0065
Sand transfer (inground and fully enclosed 90% control)	0.00051	0.0084	0.0015
Cement unloading to storage silo (pneumatic)	0.00017	0.0010	0.0002
Cement supplement unloading to storage silo (pneumatic)	0.0024	0.0020	0.0004
Weigh hopper loading (enclosed and filtered – 99.9% control)	0.0013	0.00005	0.00001
Truck Loading (Truck/Dry Mix)	0.0131	0.085	0.015
Total Emissions		**0.13**	**0.024**

9 Dispersion Model Configuration

9.1 Model Selection

The GRAL modelling system was selected for the dispersion modelling of traffic emissions from roads surrounding the Study Area and the Hymix operations 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.

9.2 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 assessment utilises the GRAL dispersion model in prognostic mode. This approach enables the representation of dynamic effects due to buildings and obstacles, and is capable of accommodating complex topography with high a horizontal resolution. The meteorological dataset was compiled using observations from nearby automatic weather stations and a five year period of meteorological data was reviewed to ensure that the year selected for use in the modelling is representative of long-term meteorological conditions.

9.3 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 grouped into three different source groups to enable the application of different diurnal patterns (see **Section 8.1.2**). Roads with significantly varying gradient were split into smaller segments as required. Emissions from the Hymix facility (Scenario 2 only) were represented by an extruded area source (ie a volume source). **Figure 19** illustrates the line and area sources modelled as part of this study.

The proposed buildings, as well as existing buildings and structures, that may affect the dispersion of pollutants through channelling and blocking effects were included in the modelling. These buildings are illustrated in **Figure 20** and **Figure 21** for Scenario 1 and Scenario 2 respectively.. The heights for all existing buildings were derived using high resolution Light Detection and Ranging (LIDAR) data. It is noted that the new SFM buildings have not been incorporated into the model. Given the location of the new SFM in relation to the proposed Study Area buildings and modelled sources, the exclusion of the SFM building(s) would not have any significant impact on the ground level pollutant concentrations within the Study Area.

Discrete receptors were distributed across the Study Area to predict the incremental impact of emissions from the surrounding road network and Hymix (for Scenario 2) on pollutant concentrations at various locations within the Study Area (including building facades from ground level to the top of all proposed buildings). 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. The location of all facade discrete receptors as well, as the proposed use at each location, is illustrated in **Figure 20** and **Figure 21** for Scenario 1 and Scenario 2 respectively.

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 2 m in the *x* and *y* directions at nine different elevations (see **Table 18**). This results in 6,131,862 grid locations across the domain.

Table 18 details the parameters used in GRAL for both modelled scenarios.

Table 18 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	2.0 m
Vertical dimension of concentration layers	1.0 m
Number of horizontal slices	9 (1 m, 8 m, 16 m, 24 m, 32 m, 40 m, 48 m, 56 m and 64 m)
Internal flow field grid	
Horizontal grid resolution	2.0 m
Vertical thickness of first layer	2.0 m
Vertical stretching factor	1.01
Number of cells in Z direction	40

Figure 19 Modelled Sources

Figure 20 Modelled Discrete Receptors – Scenario 1

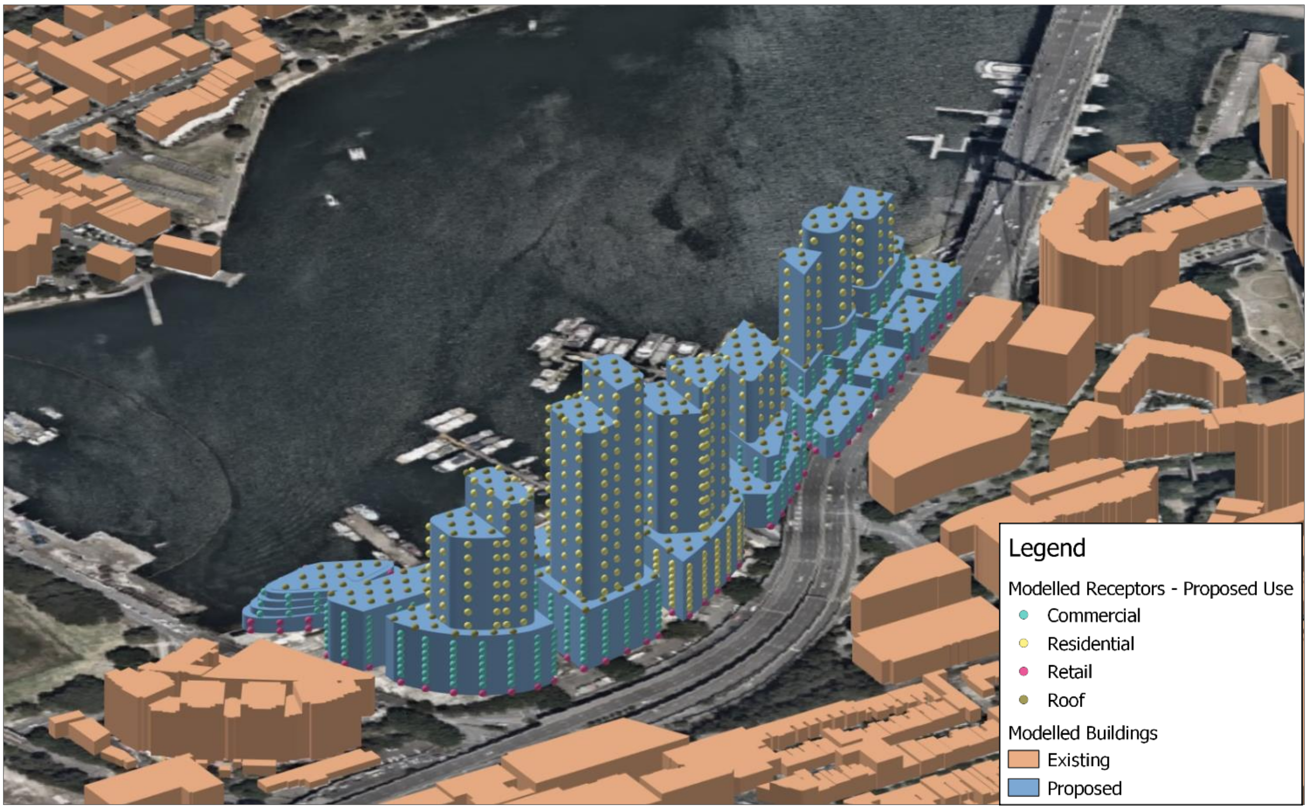
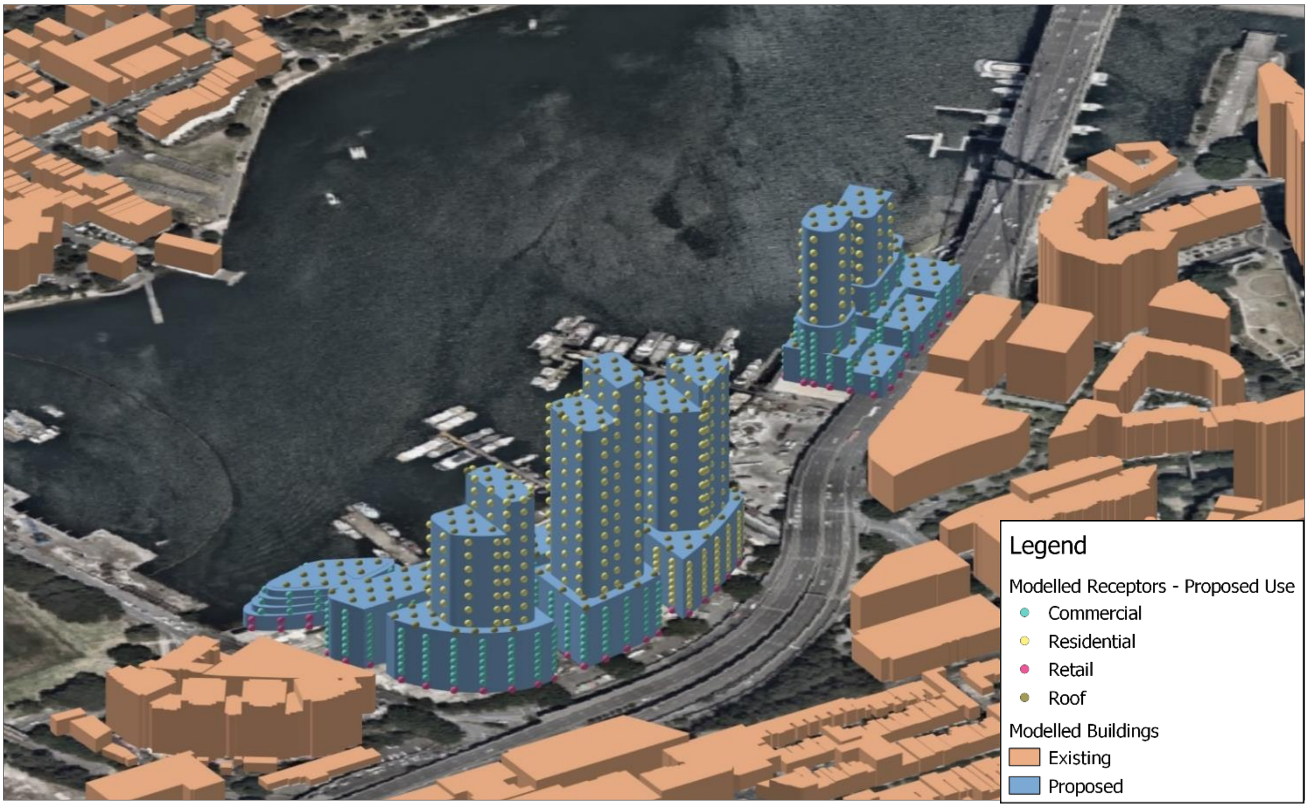


Figure 21 Modelled Discrete Receptors – Scenario 2



9.4 NO_x to NO_2 conversion

NO_x emitted from combustion processes mainly consist of NO with a small portion (approximately 10%) of NO_2. In the atmosphere however, NO emitted from the source oxidises to NO_2 in the presence of ozone (O_3) and sunlight as it travels further from the source. The rate of oxidation depends on a number of parameters, including the ambient O_3 concentration. The following methods can be applied to take account the oxidation of NO to NO_2 in estimating downwind NO_2 concentrations at receptor locations.

Method 1 – 100% Conversion

This method is usually used as a screening level assessment and assumes 100% conversion of NO to NO_2 before the plume arrives at the receptor location. Use of this method can significantly over-predict NO_2 concentrations at nearfield receptors.

Method 2 – Ambient Ozone Limiting Method (OLM)

This method assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the O_3 or all the NO is used up. NO_2 concentrations can be estimated by this method using the following equation:

$$[NO_2]_{total} = \{0.1 \times [NO_x]_{pred}\} + MIN\{(0.9) \times [NO_x]_{pred} \text{ or } (46/48) \times [O3]_{bkgd}\} + [NO_2]_{bkgd}$$

Given the close proximity of Study Area receptors to the sources of combustion gas emissions (vehicles travelling along the surrounding roads). the use of Method 1 (100% conversion) is not appropriate. Therefore Method 2 has been adopted using O_3 data from the Rozelle AQMS. This modelling approach is deemed conservative as it assumes that the atmospheric reaction is instantaneous. In reality, the reaction takes place over a number of hours. This approach will therefore provide a conservative assessment for near field locations at short transport and duration periods from the source.

9.5 Meteorological Modelling

To adequately characterise the dispersion meteorology of the Study Area, information is needed on the prevailing wind regime, mixing depth and atmospheric stability and other parameters such as ambient temperature, rainfall and relative humidity.

9.5.1 Selection of the Meteorological Year

In order to determine a representative meteorological year for use in dispersion modelling, five years of meteorological data (2015-2019) from the closest meteorological monitoring station[2] with detailed hourly data available (Sydney Airport AWS) were analysed against the five-year average meteorological conditions. Specifically, the following parameters were analysed:

- frequency and distribution of the predominant wind directions
- hourly wind speeds observed
- hourly temperature

[2] The closest BoM AWS (Sydney Observatory Hill AWS), which is located approximately 2 km to the northeast of the Study Area does not record high definition data.

Based on this analysis, it was concluded that the years 2017, 2018 and 2019 were most representative of the last five years of meteorological conditions experienced at the Study Area. Given the significant number of air quality criteria exceedances in 2019 due to bushfires and dust storms (refer **Section 7.1**) the use of this year is not deemed appropriate. Data from 2018 were also not used as the Rozelle AQMS was offline for a three month period in 2018 (refer **Section 7.1**). Given this, the year 2017 was selected for use in meteorological/dispersion modelling. A detailed analysis is presented in **Appendix D**.

9.5.2 TAPM

The TAPM prognostic model, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) was used to generate site representative data required for GRAMM modelling as outlined below.

TAPM predicts wind speed and direction, temperature, pressure, water vapour, cloud, rainwater 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 a number of BoM/EES stations in the region were incorporated into the TAPM setup. **Table 19** details the parameters used in the TAPM meteorological modelling for this assessment.

Table 19 Meteorological Parameters used for the AQIA – TAPM

Parameter	Value
Modelling Period	1 January 2017 to 31 December 2017
Centre of analysis	332,750mE 6,250,232 mS (UTM Coordinates)
Number of grid points	35 × 35 × 35
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Data assimilation	Canterbury Racecourse AWS (Station # 66194) Sydney Olympic Park AWS (Station # 66212) Sydney Airport AWS (Station # 66037) Terry Hills AWS (Station # 66059) Manly (North Head) AWS (Station # 66197)
Terrain	AUSLIG 9 second DEM

9.5.3 CALMET

In the simplest terms, CALMET is a meteorological model that develops hourly wind and other meteorological fields on a three-dimensional gridded modelling domain that are required as inputs to the CALPUFF dispersion model. 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.

The CALMET domain covered an area of 9 km by 9 km centred on the Study Area, and was modelled with a resolution of 0.1 km (i.e. 100 m). The CALMET run was performed in 'no-obs' mode (ie no surface station data included) as the five stations included in the TAPM modelling are located beyond the CALMET modelling domain. The TAPM-generated 3-dimensional meteorological data (0.3 km resolution) was used as the 'initial guess' wind field and the local topography and land use for the modelling domain were used to refine the wind field predetermined by TAPM **Table 20** details the parameters used in the meteorological modelling to drive the CALMET model.

Table 20 Meteorological Parameters used for this Study – CALMET (v 6.42)

CALMET Domain	
Meteorological grid	9.0 km × 9.0 km
Meteorological grid resolution	0.1 km
Topography	SRTM-derived 1 Second data sourced from Geosciences Australia
Initial guess filed	3D output from TAPM modelling

9.5.4 GRAMM

The GRAMM domain was defined so that it covered 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 file for the modelling domain was defined by CORINE land use categories and was created using the latest publicly available aerial imagery.

In the absence of any site specific observed meteorological data, site representative predicted meteorological data extracted from the output from the CALMET model was used as input to the GRAMM model. **Table 21** details the parameters used in the GRAMM model.

Table 21 GRAMM Meteorological Parameters

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, 6.0-7.0, >7.0
Number of wind direction sectors	36
Number of classified weather situations	758
Horizontal grid resolution (m)	100
Vertical thickness of first layer (m)	10
Number of vertical layers	15
Vertical stretching factor	1.40
Relative top layer height	3,874
Maximum time step (s)	10
Modelling time	3,600
Relaxation velocity	0.10
Relaxation scalars	0.10

9.5.5 Meteorological Data Used in Modelling

9.5.5.1 Wind Speed and Direction

A summary of the annual wind behaviour predicted by CALMET, extracted at a location within the Study Area is presented as wind roses in **Figure 22**.

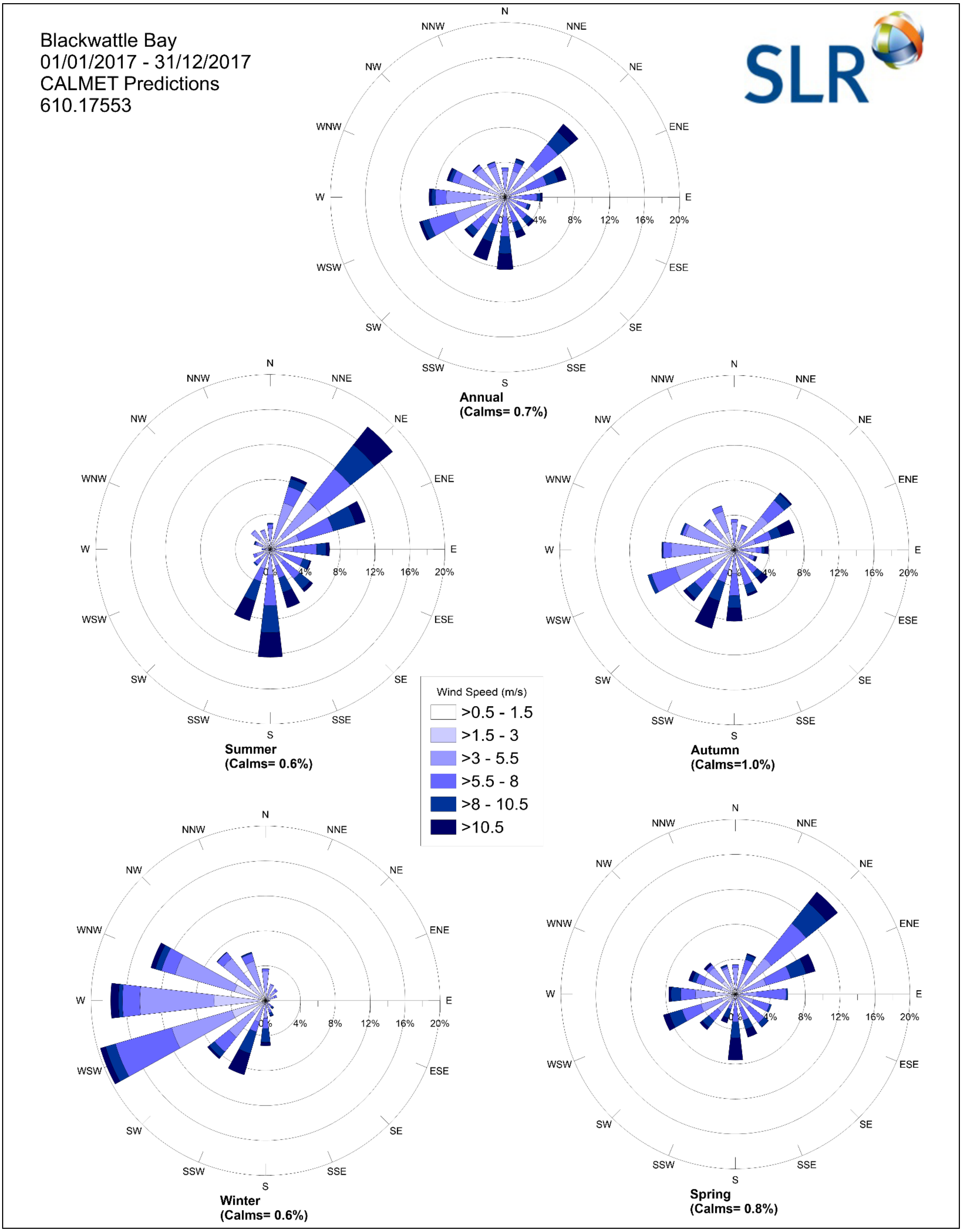
Figure 22 indicates that winds predicted at the Study Area are predominantly gentle to moderate (between 3 m/s and 8 m/s). Calm wind conditions (wind speed less than 0.5 m/s) were predicted to occur approximately 0.7% of the time throughout the modelling period.

The seasonal wind roses indicate that:

- In summer, winds are predicted to occur predominantly from the northeast, with the smallest percentage of winds blowing from the western quadrant. Calm winds were predicted 0.6% of the time during summer.
- In autumn, winds are predominantly from all directions, with the highest frequency of winds from the southwest quadrant and the lowest from the north quadrant. Calm winds were predicted 1.0% of the time during autumn.
- In winter, winds are predominantly from the western quadrant, with very few winds from the eastern quadrant. Calm winds were predicted 0.6% of the time during winter.
- In spring, winds are predominantly from the northeast, with relatively few winds from the north. Calm winds were predicted 0.8% 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 22**. Further, the GRAMM and GRAL model will further refine the CALMET predictions. The GRAL internal flow fields module takes into account the effect buildings and solid structure may have on the flow fields (refer to **Section 9.3**). The dispersion of pollutants from each source within the models will reflect the local conditions predicted by GRAL.

Figure 22 Predicted Seasonal Wind Roses for the Study Area (CALMET predictions, 2017)



9.5.5.2 Atmospheric Stability

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

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

The meteorological conditions defining each PGT stability class are shown in **Table 22**.

Table 22 Meteorological Conditions Defining PGT Stability Classes

Surface wind speed (m/s)	Daytime insolation			Night-time conditions	
	Strong	Moderate	Slight	Thin overcast or > 4/8 low cloud	<= 4/8 cloudiness
< 2	A	A - B	B	E	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

Source: (NOAA, 2018)

Notes:

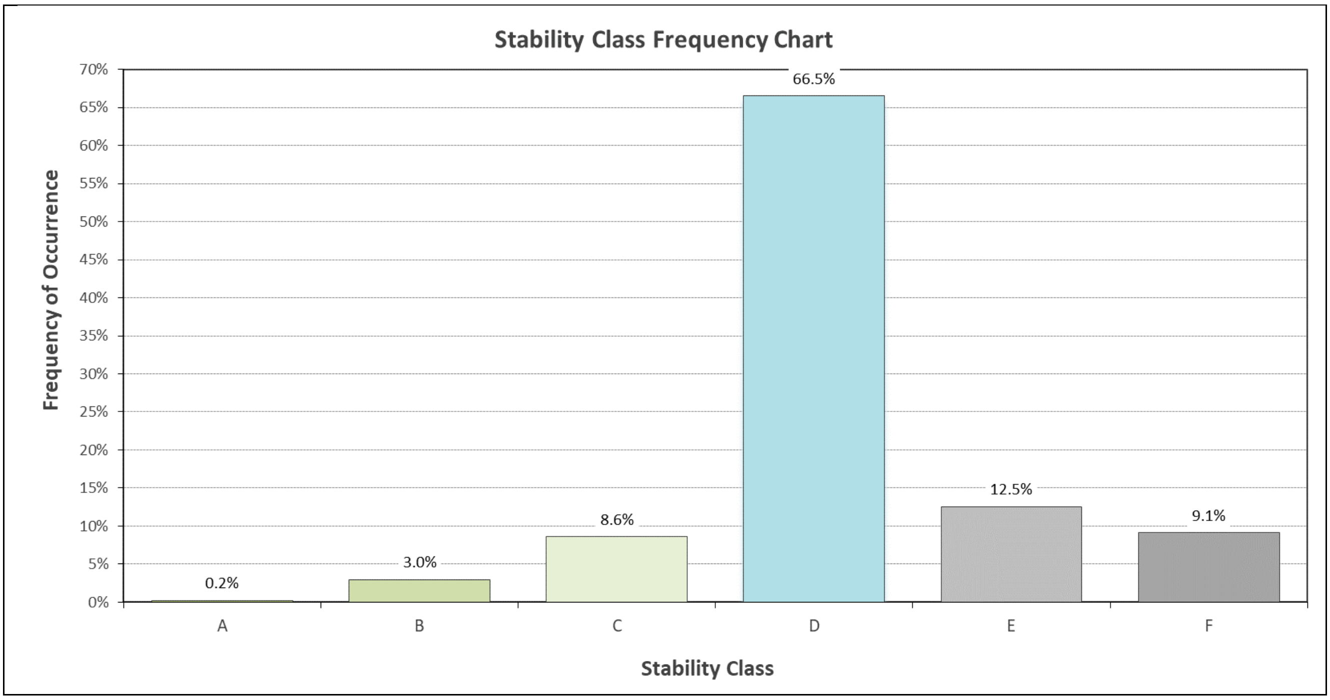
1. Strong insolation corresponds to sunny midday in midsummer in England; slight insolation to similar conditions in midwinter.

2. Night refers to the period from 1 hour before sunset to 1 hour after sunrise.

3. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

The frequency of each stability class predicted by CALMET during the modelling period, extracted at a location within the Study Area is presented in **Figure 23**. The results indicate a high frequency of conditions typical to Stability Class D, which is typical of coastal locations. Stability Class D is indicative of neutral conditions, conducive to a moderate level of pollutant dispersion due to mechanical mixing.

Figure 23 Predicted Stability Class Frequencies at the Study Area (CALMET predictions, 2017)

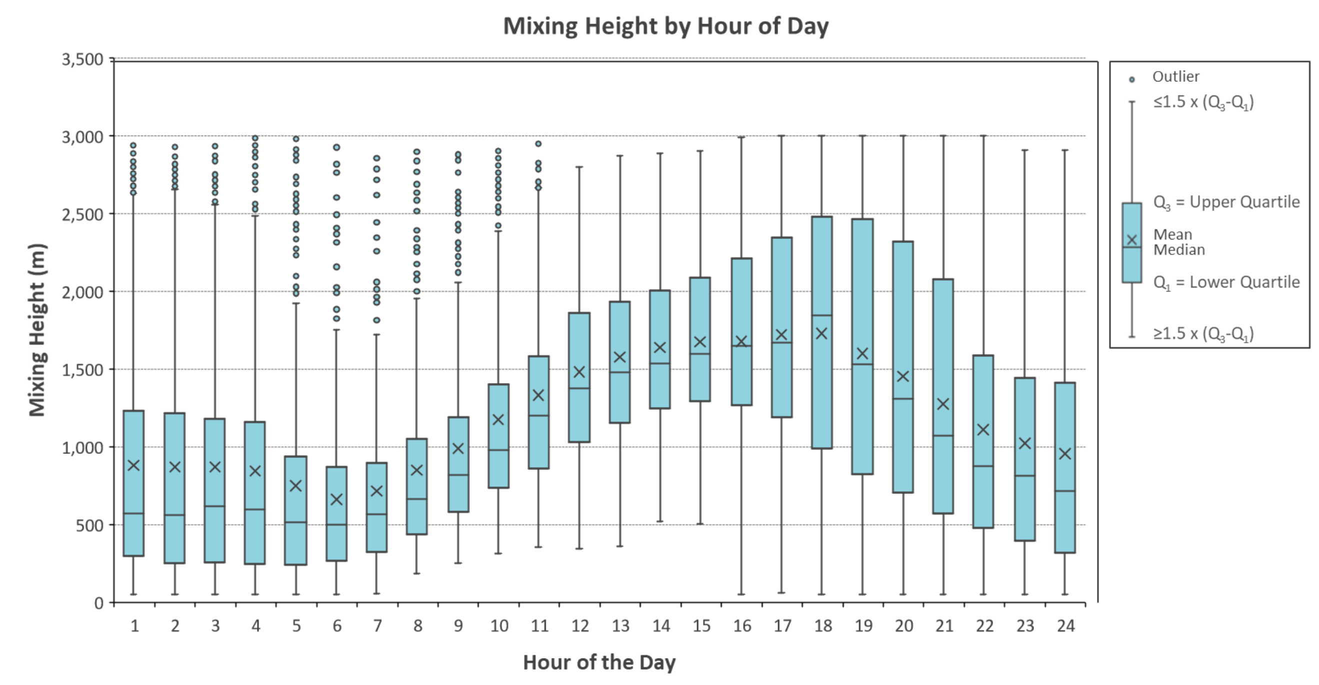


9.5.5.3 Mixing Heights

Diurnal variations in maximum and average mixing heights predicted by CALMET during the 2017 modelling period are illustrated in **Figure 24**.

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.

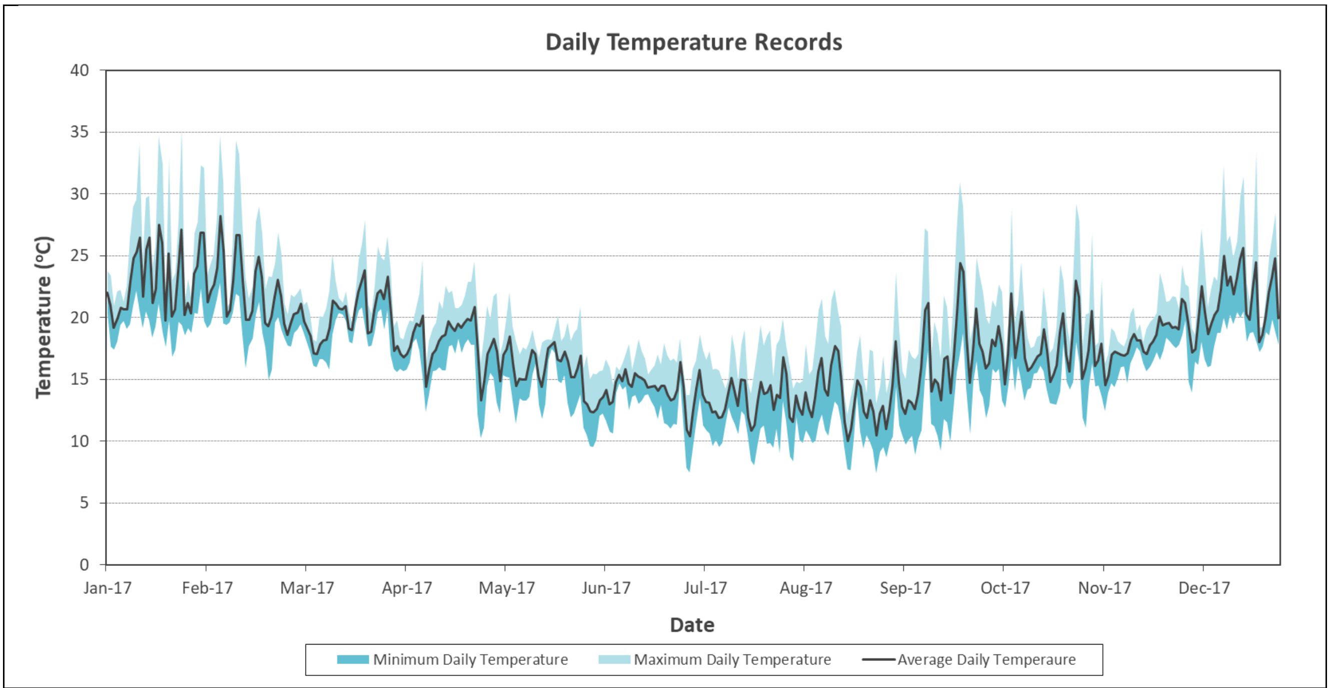
Figure 24 Predicted Mixing Heights at the Study Area (CALMET predictions, 2017)



9.5.5.4 Temperature

The modelled temperature variations as predicted at the Study Area during the year 2017 are illustrated in **Figure 25**. The maximum temperature (35.2°C) was predicted on 24 January 2017 and the minimum temperature 7.2°C) was predicted on 25 August 2017.

Figure 25 Predicted Temperatures at Study Area (CALMET predictions, 2017)



10 Assessment

10.1 Scenario 1 – Redevelopment of the Entire Study Area

This section presents a summary of the air quality impacts for a scenario in which the Study Area is fully redeveloped and Hymix ceases operations at its existing location. The emissions sources modelled for this scenario comprise vehicle emissions from the main roads surrounding the Study Area, based on projected 2033 vehicle numbers and emission factors representative of the 2010 Sydney fleet (refer **Section 8.1**). It is noted that due to improved vehicle emissions performance as outlined above, the 2033 Sydney fleet can be expected to emit less pollutants than the 2010 fleet. Improved vehicle emissions will not only have an impact on the incremental concentration of air pollutants predicted by the modelling, but will also impact background levels of air pollution. This study assumes background pollutant concentrations (for the year 2033) will remain at levels recorded for 2017.

Further, regardless of the vehicle fleet, emissions from vehicles travelling on the surrounding road network are expected to be lower than those assumed by this study as the emission inventory conservatively assumes all vehicles will be traveling at a speed of 10 km/hr on all roads for 16 hours of the day, every day of the year (refer **Section 8.1.1**).:

10.1.1 PM_{10}

The maximum incremental and cumulative 24-hour and annual average PM_{10} concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use (ie commercial, residential or retail) are presented in **Table 23**.

Figure 26 illustrates the number of exceedances predicted at the modelled discrete receptor locations for 24-hour average PM_{10}, while **Figure 27** illustrates locations where exceedances of the cumulative annual average criteria were predicted by the model. These images are taken from views looking northwest and northeast back at the Study Area (as indicated on the images), showing the building facades most affected by the emissions from the modelled sources. The spheres in these figures illustrate the locations of the discrete receptors modelled, with the white spheres showing compliance with the relevant air quality impact assessment criterion and the red spheres showing exceedance of the relevant criterion.

The modelling results presented in **Table 23** and illustrated in **Figure 26** and **Figure 27** show that exceedances of the 24-hour PM_{10} criterion are predicted along the facade of all proposed buildings. However, these exceedances predominantly affect lower floors of the proposed buildings where the proposed use is commercial or retail on facades facing the Western Distributer.

Exceedances of the 24-hour PM_{10} criterion on the facade of residential floors in limited to 5% of the modelled residential receptors. For the worst-affected residential receptor (located on the western facade of BLD 02 at an elevation of 6 m above ground level), four (4) additional exceedances of the 24-hour average PM_{10} criterion are predicted for the modelled year (January 13th, September 24th, December 14th and December 31st). These exceedances are primarily due to high background concentrations on the days the exceedances are predicted (ranging between 35.4 µg/m^3 and 49.2 µg/m^3).

Exceedances of the annual average PM_{10} criterion is limited to commercial and retail receptors of the PLO 01 – Poulos building, PLO 02 – Celestino building and PLO 03 - Hymix 1 and Hymix 2 buildings as well as a single retail receptor location on the BLD 02 building. No exceedances of the annual average PM_{10} criterion is predicted at residential receptor locations where sensitive receptors may potentially be affected.

Exceedances of the 24-hour average and annual average PM_{10} criteria at roof receptors modelled (important for determining appropriate locations for ventilation air intakes), are limited to podium roofs of the PLO 01 – Poulos, PLO 02 – Celestino, PLO 03 - Hymix 1 & Hymix 2, BLD 03 and BLD 04 buildings at locations closest to the Western Distributor.

Table 23 Predicted PM_{10} Concentrations – Scenario 1

Proposed Use	Building	Worst Impacted Receptor			
		Incremental - 24-h Average	Incremental - Annual Average	Cumulative - 24-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	22	12	58.9 (5)	29.9
	PLO 02 - Celestino	39	16	75.4 (16)	33.9
	PLO 03 - Hymix 1	31	14	64.9 (8)	32.1
	PLO 03 - Hymix 2	37	18	78.5 (9)	35.6
	BLD 01	8	3	50.8 (2)	20.9
	BLD 03	16	5	59.4 (2)	23.4
	BLD 04	12	5	55.4 (2)	23.1
	BLD 05	10	4	52.7 (1)	22.3
	BLD 06	7	3	50.8 (1)	20.7
	BLD 07	3	1	49.7	18.8
Residential	PLO 01 - Poulos	1	0	49.8	18.3
	PLO 02 - Celestino	3	0	49.3	18.4
	PLO 03 - Hymix 1	2	1	50.1 (1)	18.7
	PLO 03 - Hymix 2	6	1	49.7	18.8
	BLD 02	20	6	51.7 (4)	23.9
	BLD 03	3	1	51.1 (1)	18.6
	BLD 04	3	0	49.8	18.4
Retail	PLO 01 - Poulos	24	11	63.4 (2)	28.8
	PLO 02 - Celestino	28	16	72.3 (10)	33.6
	PLO 03 - Hymix 1	45	21	76.5 (20)	38.9
	PLO 03 - Hymix 2	40	17	79.1 (20)	35.3
	BLD 01	11	4	52.2 (2)	21.7
	BLD 02	28	7	57.1 (10)	25.4
	BLD 03	16	5	56.2 (2)	23.4
	BLD 04	14	6	55.1 (2)	24.2
	BLD 05	12	5	53.1 (2)	23.4
	BLD 06	9	3	51.1 (1)	21.1
	BLD 07	8	4	51.6 (1)	22.1
Criteria				**50**	**25**

Note 1: Red text indicates exceedance of relevant ambient air quality criterion
Note 2: Numbers in brackets indicate the number of additional exceedances of the relevant criterion

Figure 26 Predicted Exceedances of Cumulative 24-Hour Average PM_{10} – Scenario 1

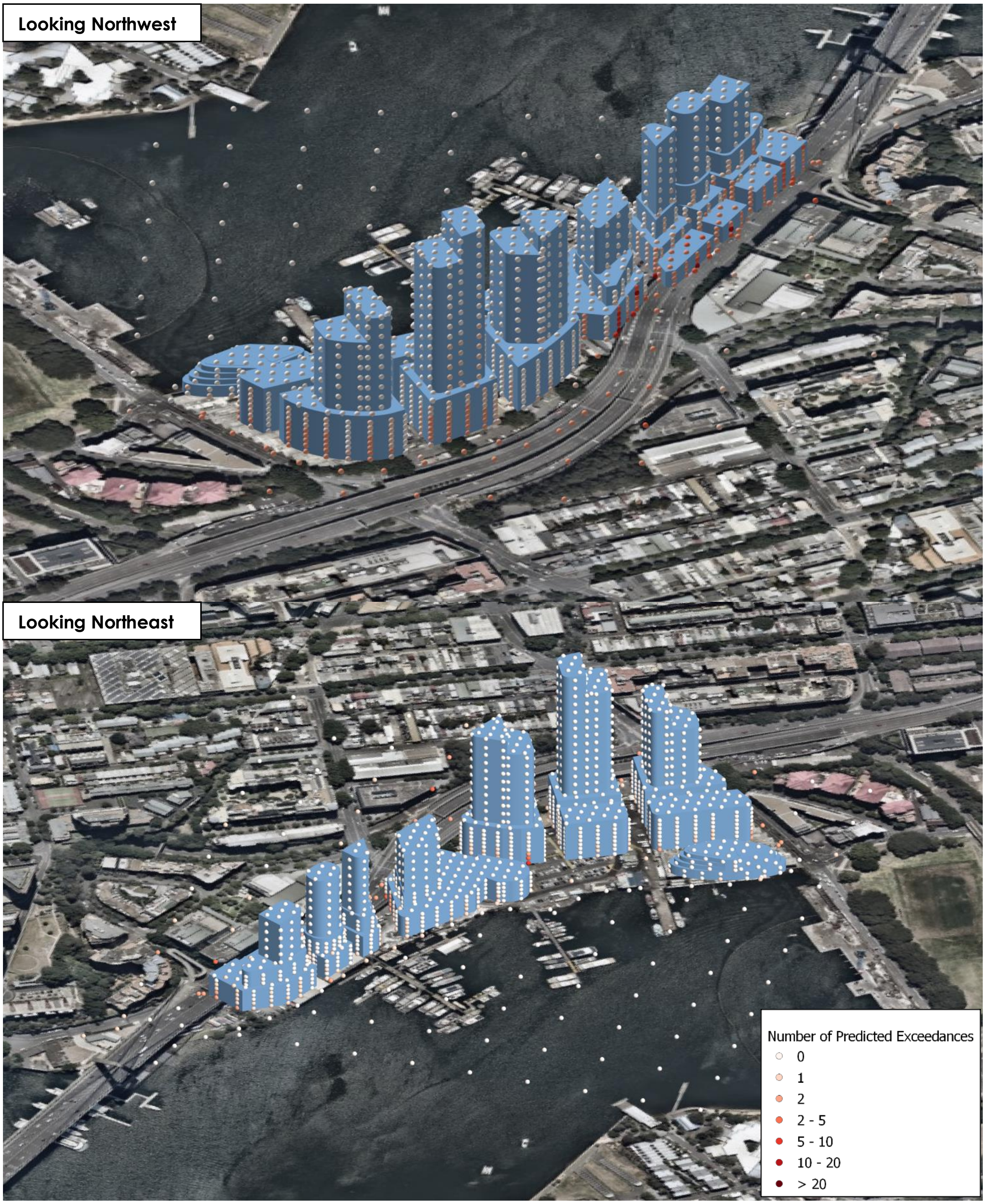
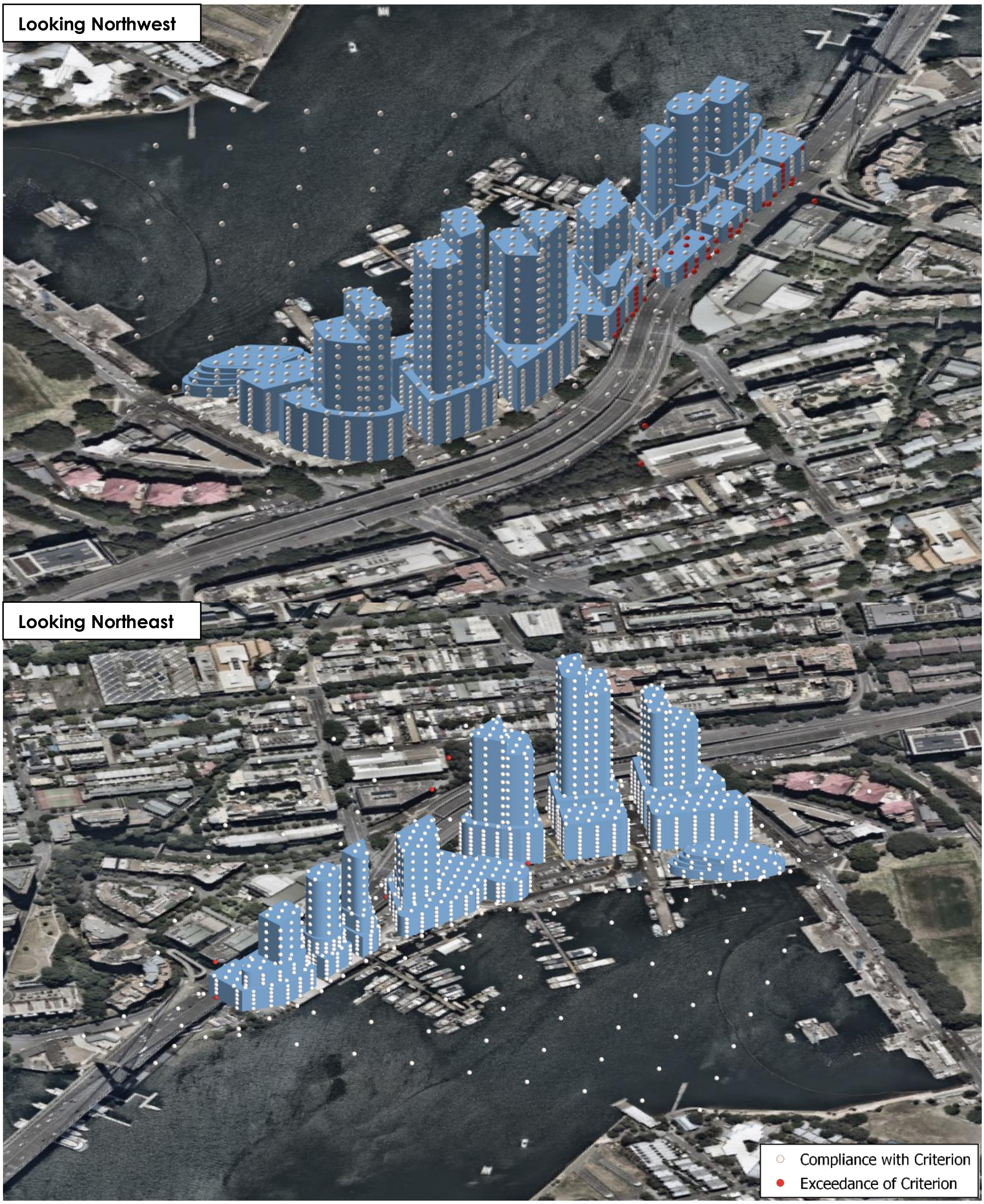


Figure 27 Predicted Exceedances of Cumulative Annual Average PM_{10} – Scenario 1



10.1.2 $PM_{2.5}$

The maximum incremental and cumulative 24-hour and annual average $PM_{2.5}$ concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use are presented in **Table 24**.

Figure 28 illustrates the number of exceedances predicted at the modelled discrete receptor locations for 24-hour average $PM_{2.5}$, while **Figure 29** illustrates locations where exceedances of the cumulative annual average $PM_{2.5}$ criterion were predicted by the model.

The modelling results presented in **Table 24** and illustrated in **Figure 28** and **Figure 29** show that exceedances of the 24-hour $PM_{2.5}$ criterion are predicted along the facade of all proposed buildings. However, these exceedances predominantly affect lower floors of the proposed buildings where the proposed use is commercial or retail on facades facing the Western Distributer.

Exceedances of the 24-hour $PM_{2.5}$ criterion on the facade of residential floors in limited to 1% of the modelled residential receptors all of which are located on the lower floors of BLD 02 (at elevations up to 14 m above ground). For the worst-affected residential receptor (located on the western facade of BLD 02 at an elevation of 6 m above ground level), 10 additional exceedances of the 24-hour average $PM_{2.5}$ criterion are predicted for the modelled year. The background 24-hour average $PM_{2.5}$ concentrations on the days the exceedances are predicted range between 8.1 µg/m^3 and 21.8 µg/m^3.

Exceedances of the annual average $PM_{2.5}$ criterion are predicted on the lower floors of all proposed buildings. A total of 17 out of the 721 residential receptors modelled exceeded the annual average $PM_{2.5}$ criterion. These receptors are all located on the facade of BLD 02 at elevations between 6 and 26 m above ground level.

As outlined in **Section 7**, exceedances of the annual average $PM_{2.5}$ criterion are frequently recorded in the Sydney metropolitan region (including in 10 of the last 20 years in the Sydney central-east Region). 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 7**) through which sources of $PM_{2.5}$ in NSW are being studied and managed to ensure that the regional background concentrations that residents within Sydney, including the Study Area, are exposed to are minimised as much as practicable.

Exceedances of the 24-hour average and annual average $PM_{2.5}$ criterion at roof receptors modelled, are limited to podium roofs of the PLO 01 – Poulos, PLO 02 – Celestino and PLO 03 - Hymix 1 & Hymix 2 buildings at locations closest to the Western Distributor.

Table 24 Predicted $PM_{2.5}$ Concentrations – Scenario 1

Proposed Use	Building	Worst Impacted Receptor			
		Incremental - 24-h Average	Incremental - Annual Average	Cumulative - 24-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	21	5	35.6 (26)	12.0
	PLO 02 - Celestino	33	6	43.2 (89)	13.6
	PLO 03 - Hymix 1	28	6	39.2 (81)	13.2
	PLO 03 - Hymix 2	33	7	39.5 (96)	14.4
	BLD 01	10	1	25.7 (1)	8.5
	BLD 03	14	2	28.7 (4)	9.6
	BLD 04	12	2	27.9 (3)	9.6
	BLD 05	12	2	26.8 (2)	9.2
	BLD 06	7	1	24.6	8.4
	BLD 07	3	0	23.2	7.7
Residential	PLO 01 - Poulos	1	0	22.1	7.3
	PLO 02 - Celestino	2	0	22.3	7.4
	PLO 03 - Hymix 1	2	0	22.1	7.5
	PLO 03 - Hymix 2	6	0	23.5	7.6
	BLD 02	19	3	30.1 (10)	9.8
	BLD 03	2	0	22.5	7.5
	BLD 04	3	0	22.8	7.4
Retail	PLO 01 - Poulos	21	4	34.9 (22)	11.5
	PLO 02 - Celestino	25	7	40.2 (25)	13.9
	PLO 03 - Hymix 1	44	9	51.1 (100)	16.3
	PLO 03 - Hymix 2	44	8	48.4 (175)	15.5
	BLD 01	14	2	28.5 (3)	9.1
	BLD 02	27	3	34.3 (41)	10.6
	BLD 03	14	2	28.8 (3)	9.6
	BLD 04	16	3	30.7 (8)	10.3
	BLD 05	19	3	30.4 (5)	9.9
	BLD 06	9	1	25.3 (1)	8.6
	BLD 07	12	2	29.9 (1)	9.4
Criteria				**25**	**8**

Note 1: Red text indicates exceedance of relevant ambient air quality criterion

Note 2: Numbers in brackets indicate the number of additional exceedances of the relevant criterion

Figure 28 Predicted Exceedances of Cumulative 24-Hour Average $PM_{2.5}$ – Scenario 1

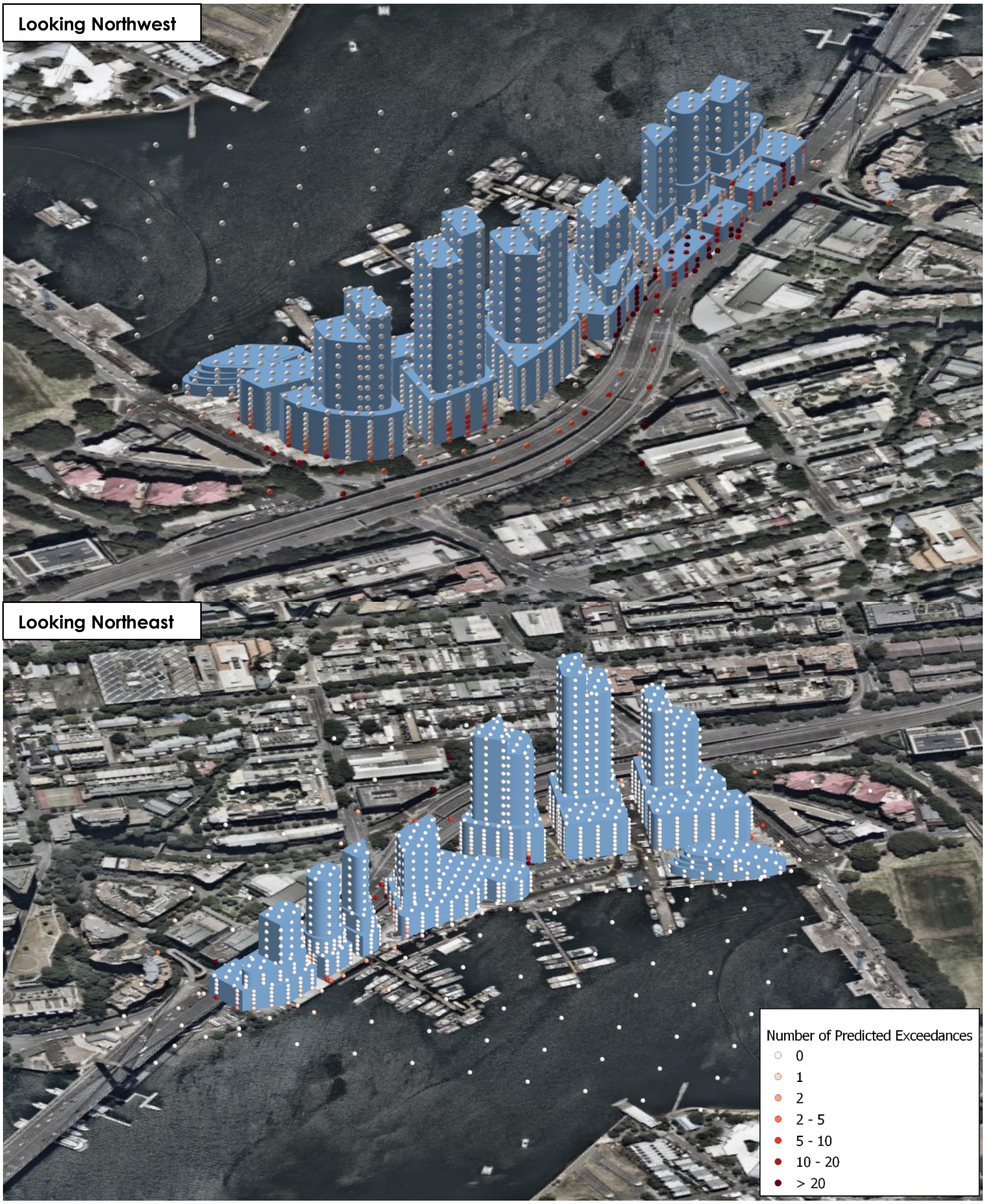
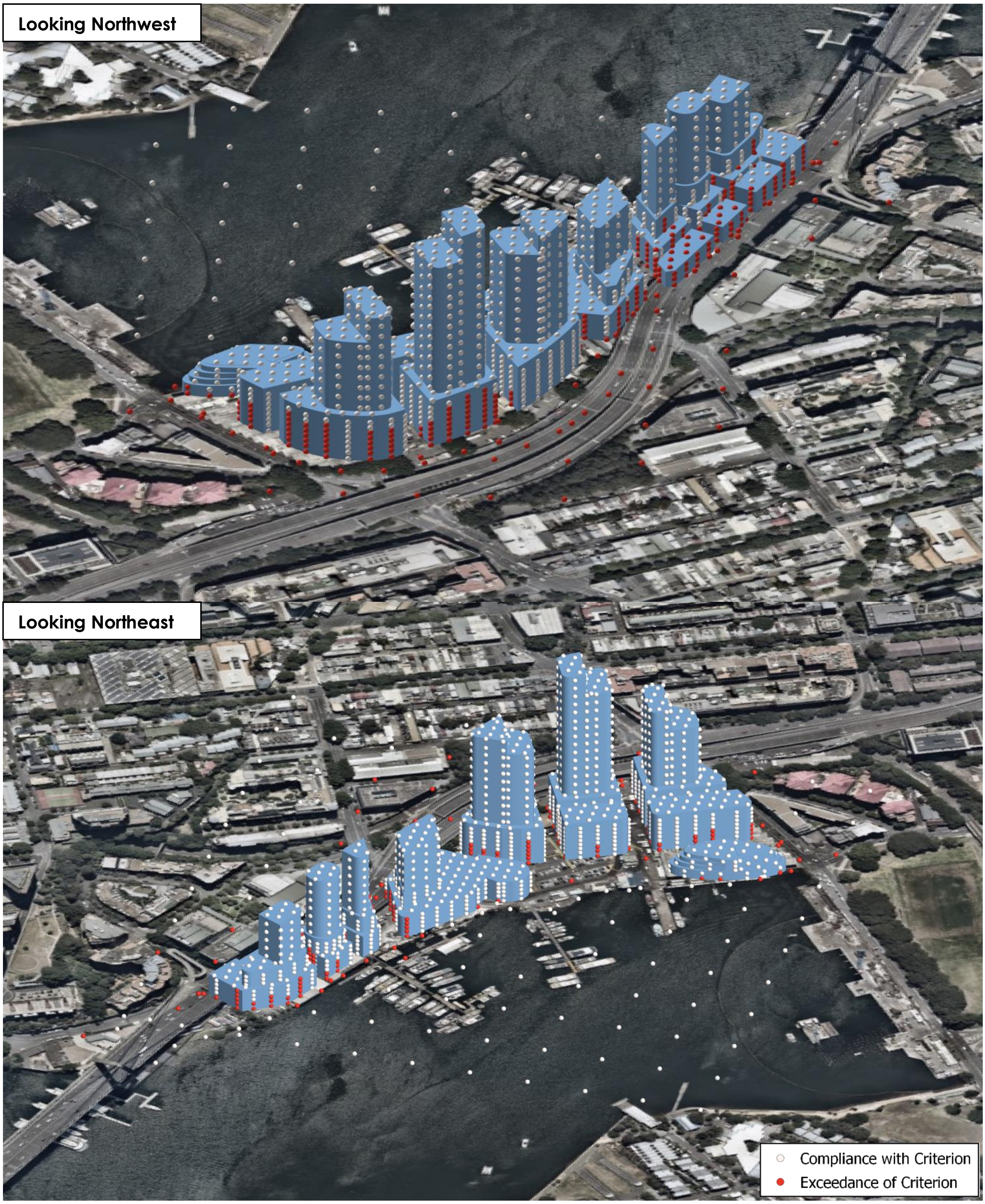


Figure 29 Predicted Exceedances of Cumulative Annual Average $PM_{2.5}$ – Scenario 1



10.1.3 NO_2

The maximum incremental and cumulative 1-hour and annual average NO_2 concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use (ie commercial, residential or retail) are presented in **Table 25**.

Figure 30 illustrates the number of exceedances predicted at the modelled discrete receptor locations for 1-hour average NO_2, while **Figure 31** illustrates locations where exceedances of the cumulative annual average criteria were predicted by the model.

The modelling results presented in **Table 25** and illustrated in **Figure 30** and **Figure 31** show that exceedances of the 1-hour NO_2 criterion are predicted along the facade of all proposed buildings. However, these exceedances predominantly affect lower floors of the proposed buildings where the proposed use is commercial or retail on facades facing the Western Distributer.

Exceedances of the 1-hour NO_2 criterion on the facade of residential floors in limited to 4% of the modelled residential receptors all of which are located on BLD 02 (at elevations up to 30 m above ground). For the worst-affected residential receptor (located on the western facade of BLD 02 at an elevation of 6 m above ground level), 2 exceedances of the 1-hour average NO_2 criterion are predicted for the modelled year.

Exceedances of the annual average NO_2 criterion is limited to commercial and retail receptors of the PLO 01 – Poulos building, PLO 02 – Celestino building and PLO 03 - Hymix 1 and Hymix 2 buildings. No exceedances of the annual average NO_2 criterion is predicted at residential receptor locations where more sensitive receptors may potentially be affected.

It is noted that the OLM method for estimating the NO_2 incremental concentrations (Section **9.4**) is considered conservative, as it assumes that NO converts to NO_2 instantaneously. In reality, this would occur over a number of hours, during which the predicted incremental NO_X concentrations (from which the NO_2 concentrations are calculated), are likely to have dissipated (reduced) substantially.

Exceedances of the 1-hour average and annual average NO_2 criterion at roof receptors modelled, are limited to podium roofs of the PLO 01 – Poulos, PLO 02 – Celestino and PLO 03 - Hymix 1 buildings at locations closest to the Western Distributor.

Table 25 Predicted NO_2 Concentrations – Scenario 1

Proposed Use	Building	Worst Impacted Receptor			
		Incremental - 1-h Average	Incremental - Annual Average	Cumulative - 1-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	263	45	338 (3)	66
	PLO 02 - Celestino	326	52	376 (26)	74
	PLO 03 - Hymix 1	251	51	323 (4)	72
	PLO 03 - Hymix 2	291	59	366 (7)	80
	BLD 01	232	23	307 (2)	44
	BLD 03	236	30	290 (1)	52
	BLD 04	238	35	288 (2)	57
	BLD 05	225	32	300 (2)	53
	BLD 06	214	24	289 (1)	45
	BLD 07	130	11	205.1	33
Residential	PLO 01 - Poulos	89	4	140.0	25
	PLO 02 - Celestino	88	4	136.9	26
	PLO 03 - Hymix 1	84	9	122.4	30
	PLO 03 - Hymix 2	131	11	209.1	32
	BLD 02	230	29	305 (2)	51
	BLD 03	111	7	171.8	29
	BLD 04	138	5	226.5	26
Retail	PLO 01 - Poulos	243	44	313 (3)	66
	PLO 02 - Celestino	257	55	328 (7)	76
	PLO 03 - Hymix 1	297	63	372 (18)	85
	PLO 03 - Hymix 2	283	62	348 (7)	84
	BLD 01	247	25	323 (2)	47
	BLD 02	276	35	318 (3)	56
	BLD 03	245	31	298 (2)	52
	BLD 04	243	39	308 (2)	61
	BLD 05	262	35	337 (7)	56
	BLD 06	226	26	301 (1)	47
	BLD 07	231	32	306 (1)	53

Note 1: Red text indicates exceedance of relevant ambient air quality criterion

Note 2: Numbers in brackets indicate the number of additional exceedances of the relevant criterion

Figure 30 Predicted Exceedances of Cumulative 1-Hour Average NO_2 – Scenario 1

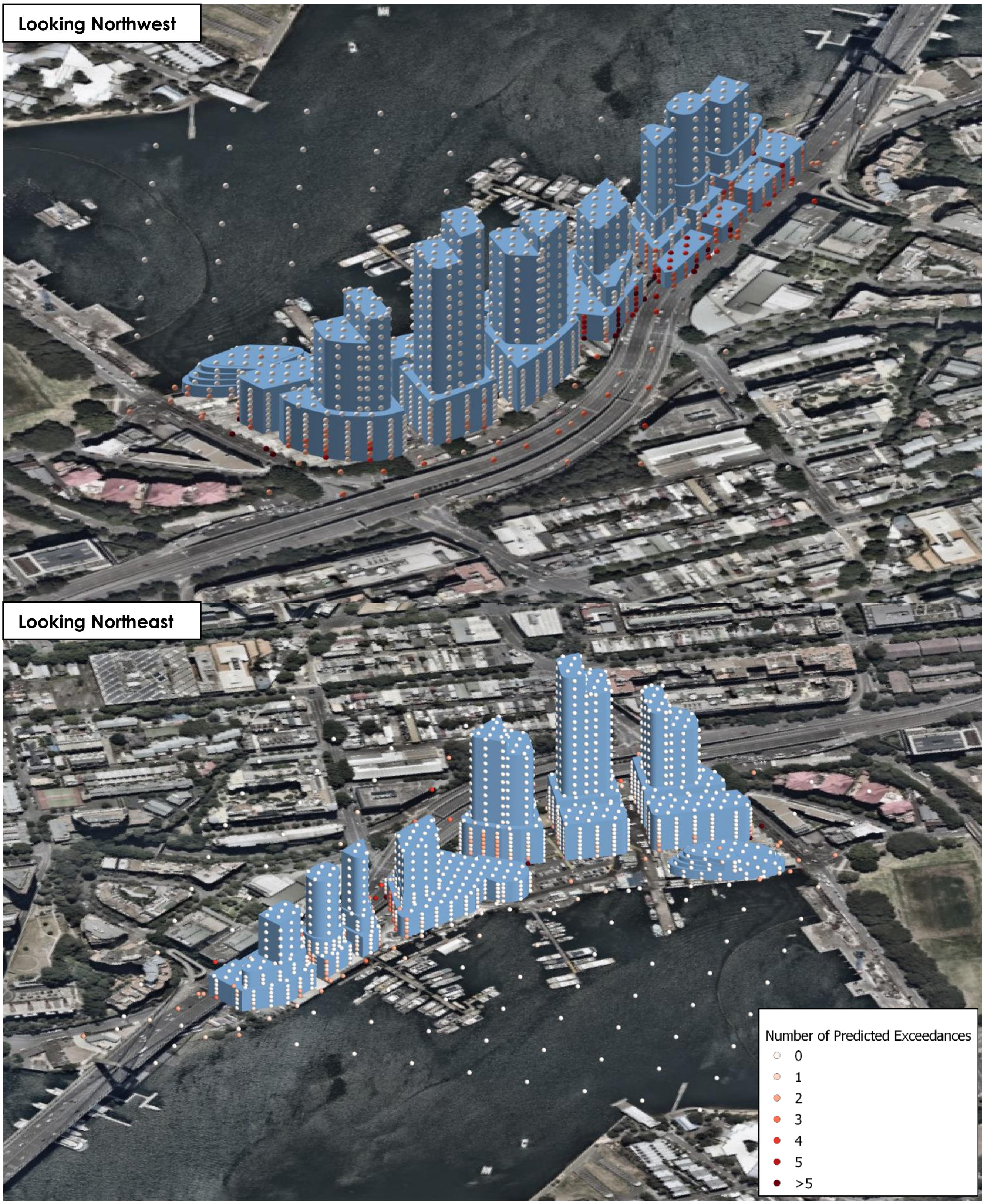
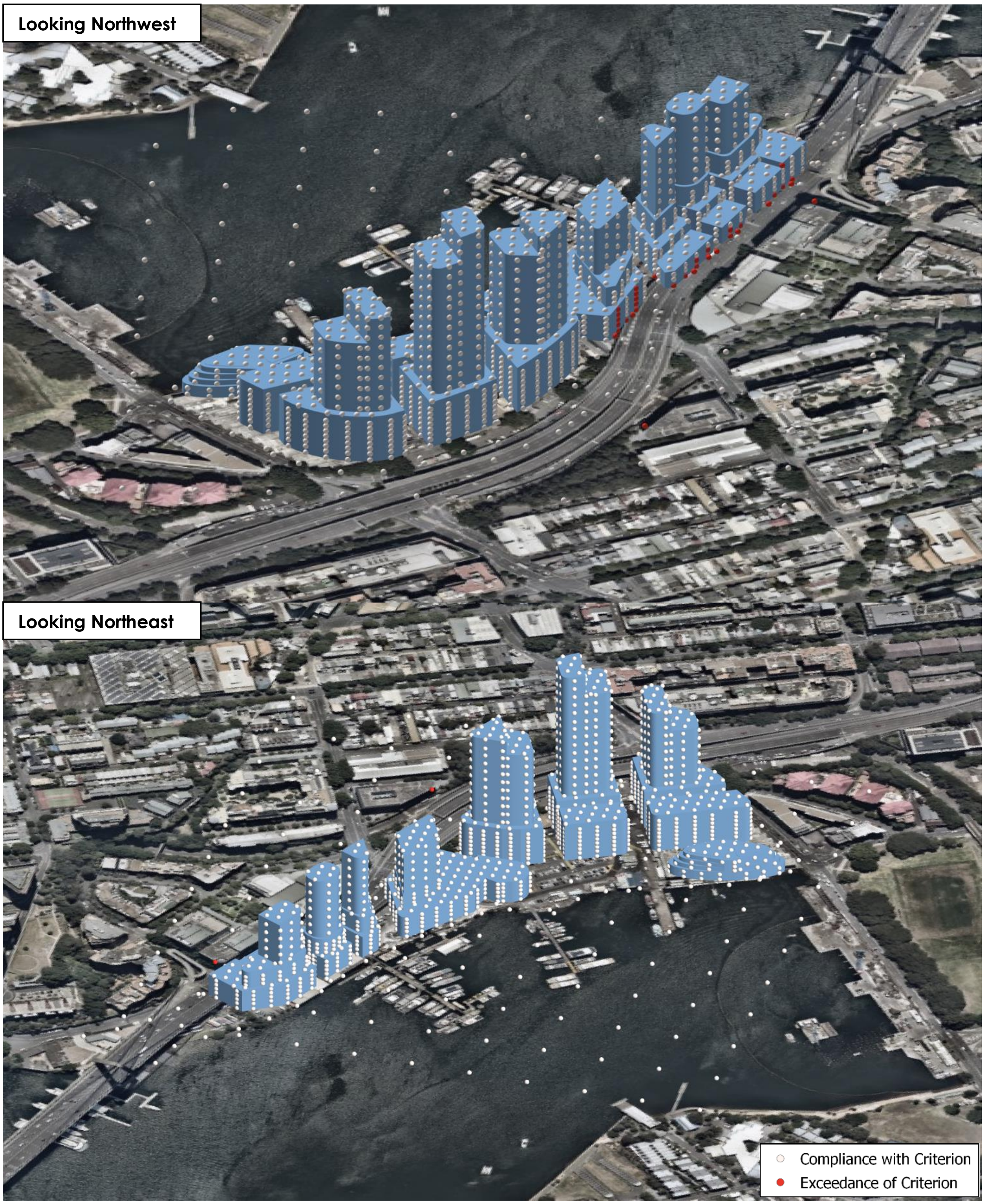


Figure 31 Predicted Exceedances of Cumulative Annual Average NO_2 – Scenario 1



10.2 Scenario 2 – Partial Redevelopment of the Study Area

This section presents a summary of the air quality impacts for a scenario in which the Study Area is only partially redeveloped and Hymix continues to operate as currently permitted. The emissions sources modelled for this scenario include vehicle emissions from the main roads surrounding the Study Area, based on projected 2033 vehicle numbers and emission factors representative of the 2010 Sydney fleet (refer **Section 8.1**) as well as fugitive particulate emissions from the concrete batching operations at Hymix (refer **Section 8.2**).

10.2.1 PM_{10}

The maximum incremental (for Hymix and vehicle emissions separately) and cumulative 24-hour and annual average PM_{10} concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use (ie commercial, residential or retail) are presented in **Table 26**.

Figure 32 illustrates the number of exceedances predicted at the modelled discrete receptor locations for 24-hour average PM_{10}, while **Figure 33** illustrates locations where exceedances of the cumulative annual average criteria were predicted by the model.

The modelling results presented in **Table 26** and illustrated in **Figure 32** and **Figure 33** show that exceedances of the 24-hour PM_{10} criterion are predicted along the facade of all proposed buildings. While these exceedances predominantly affect lower floors of the proposed buildings where the proposed use is commercial or retail on facades facing the Western Distributer, exceedances of the 24-hour PM_{10} criterion on the facade of residential floors predicted to occur at 11% of the modelled residential receptors. For the worst-affected residential receptor (located on the western facade of BLD 02 at an elevation of 6 m above ground level) only two (2) additional exceedances of the 24-hour average PM_{10} criterion are predicted for the modelled year (August 14th and September 24th). These exceedances are primarily due to high background concentrations on the days the exceedances are predicted (44.8 µg/m^3 and 49.2 µg/m^3 respectively).

Exceedances of the annual average PM_{10} criterion is predicted at lower floors of all proposed buildings, with the exception of BLD 06 for which no exceedances of the annual average PM_{10} criterion is predicted. A total of 10 out of the 629 residential receptors modelled exceed the annual average PM_{10} criterion. These receptors are all located on the facade of BLD 02 at elevations between 6 and 22 m above ground level.

Exceedances of the 24-hour average and annual average PM_{10} criterion at roof receptors modelled, are limited to the BLD 07 roof as well as podium roofs of the PLO 01 – Poulos, PLO 02 – Celestino, BLD 02, BLD 03 and BLD 04 buildings.

Table 26 Predicted PM_{10} Concentrations – Scenario 2

Proposed Use	Building	Worst Impacted Receptor -					
		Incremental - 24-h Average - Hymix	Incremental - Annual Average - Hymix	Incremental - 24-h Average - Vehicles	Incremental - Annual Average - Vehicles	Cumulative - 24-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	13	0.7	23	11	58.4 (5)	34.3
	PLO 02 - Celestiono	20	1.3	36	14	74.7 (10)	36.8
	BLD 01	32	4.5	8	3	82.0 (19)	28.2
	BLD 02	1	0.0	1	0	49.6	18.6
	BLD 03	9	0.6	14	5	63.7 (2)	23.5
	BLD 04	2	0.1	12	5	55.9 (2)	26.4
	BLD 05	4	0.4	10	4	53.6 (2)	24.1
	BLD 06	3	0.3	6	3	51.8 (2)	22.4
	BLD 07	9	0.9	5	2	54.4 (2)	21.5
Residential	PLO 01 - Poulos	0	0.0	2	0	49.9	18.3
	PLO 02 - Celestiono	1	0.0	2	0	50.3 (1)	18.3
	BLD 02	9	0.9	15	4	59.0 (2)	29.6
	BLD 03	2	0.1	3	1	52.7 (1)	18.4
	BLD 04	1	0.0	2	0	50.0 (1)	18.5
Retail	PLO 01 - Poulos	14	0.7	25	11	63.7 (3)	37.9
	PLO 02 - Celestiono	36	1.6	33	14	77.8 (15)	44.3
	BLD 01	42	5.8	9	3	92.5 (45)	30.0
	BLD 02	11	1.2	17	5	61.2 (2)	26.4
	BLD 03	7	0.5	13	5	59.6 (2)	26.9
	BLD 04	4	0.2	14	6	55.7 (2)	27.0
	BLD 05	7	0.6	12	5	55.4 (2)	28.6
	BLD 06	4	0.4	11	3	53.0 (2)	24.9
	BLD 07	12	1.0	9	4	55.5 (2)	26.1

Note 1: Red text indicates exceedance of relevant ambient air quality criterion

Figure 32 Predicted Exceedances of Cumulative 24-Hour Average PM_{10} – Scenario 2

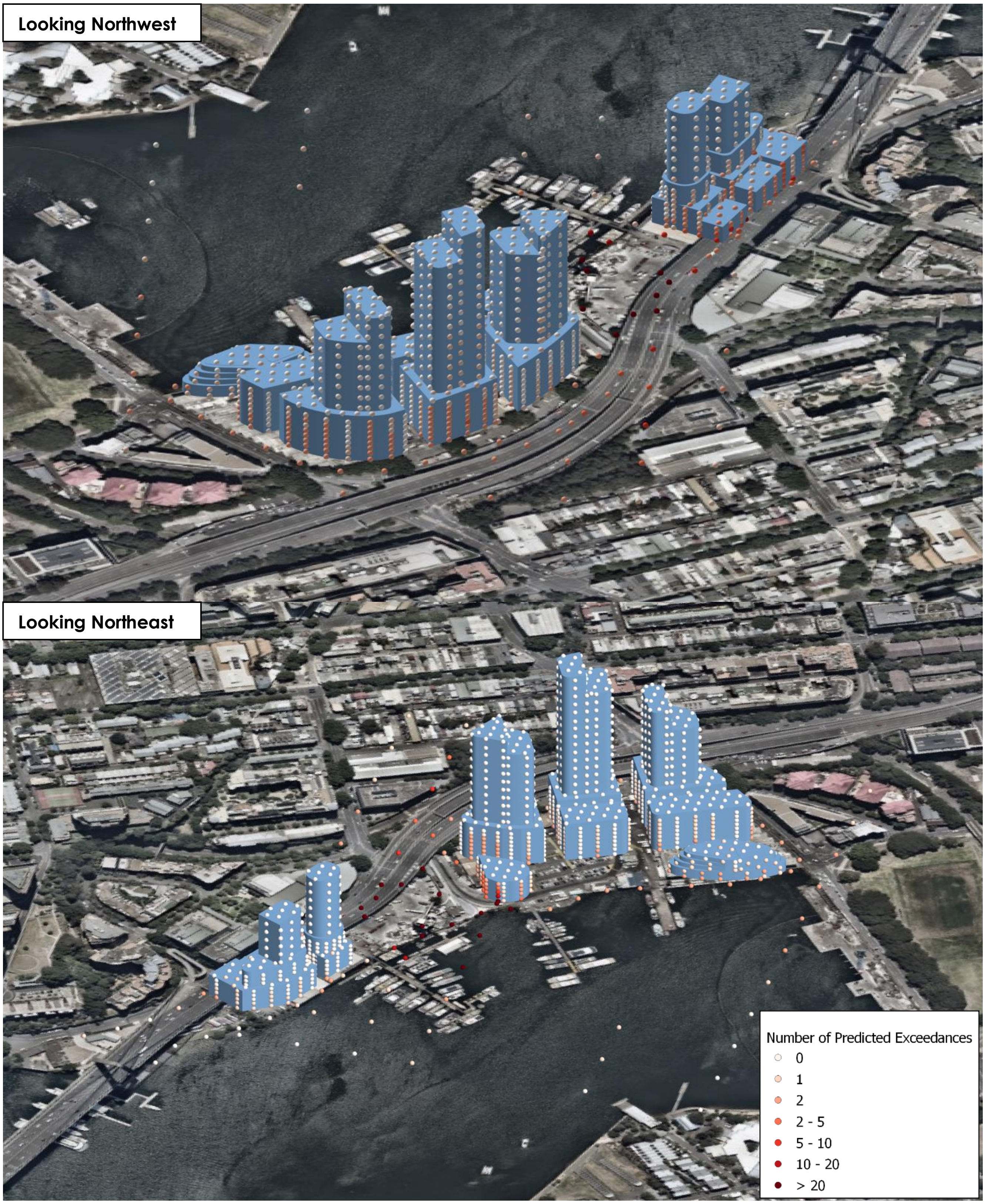
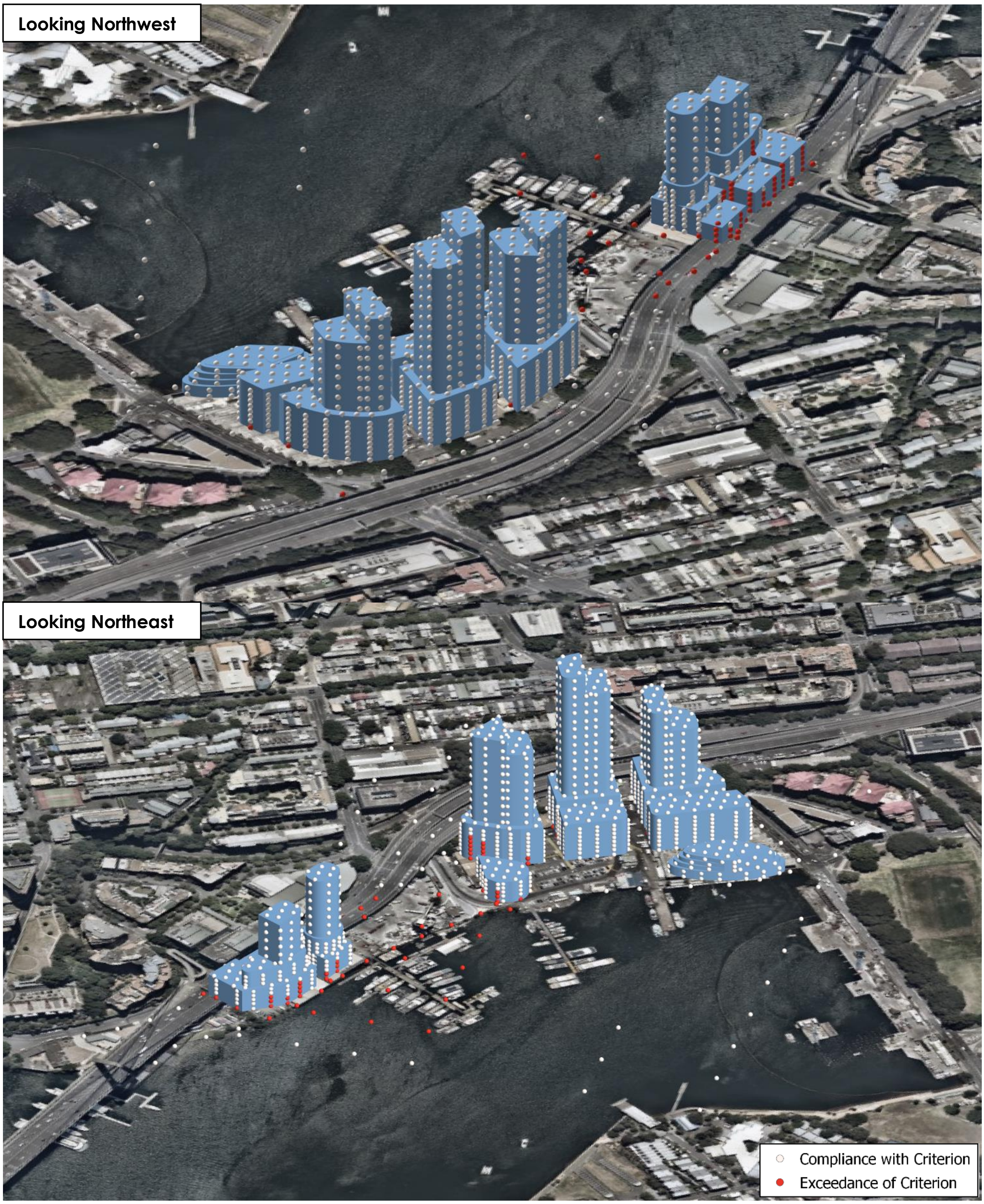


Figure 33 Predicted Exceedances of Cumulative Annual Average PM_{10} – Scenario 2



10.2.2 $PM_{2.5}$

The maximum incremental and cumulative 24-hour and annual average $PM_{2.5}$ concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use are presented in **Table 27**.

Figure 34 illustrates the number of exceedances predicted at the modelled discrete receptor locations for 24-hour average $PM_{2.5}$, while **Figure 35** illustrates locations where exceedances of the cumulative annual average $PM_{2.5}$ criterion were predicted by the model.

The modelling results presented in **Table 27** and illustrated in **Figure 34** and **Figure 35** show that exceedances of the 24-hour $PM_{2.5}$ criterion are predicted along the facade of all proposed buildings. However, these exceedances predominantly affect lower floors of the proposed buildings where the proposed use is commercial or retail on facades facing the Western Distributer.

Exceedances of the 24-hour $PM_{2.5}$ criterion on the facade of residential floors in limited to 3% of the modelled residential receptors all of which are located on the BLD 02 building (at elevations up to 30 m above ground). For the worst-affected residential receptor (located on the western facade of BLD 02 at an elevation of 6 m above ground level), one (1) additional exceedance of the 24-hour average $PM_{2.5}$ criterion is predicted for the modelled year. The background 24-hour average $PM_{2.5}$ concentration on the day the exceedance is predicted (September 19th) was 21.8 µg/m^3.

Exceedances of the annual average $PM_{2.5}$ criterion are predicted on the lower floors of all proposed buildings. A total of 41 out of the 629 residential receptors modelled (7%) exceed the annual average $PM_{2.5}$ criterion. These receptors are all located on the facade of BLD 02 at elevations between 6 and 30 m above ground level.

As outlined in **Section 7**, exceedances of the annual average $PM_{2.5}$ criterion are frequently recorded in the Sydney metropolitan region (including in 10 of the last 20 years in the Sydney central-east Region). 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 7**) through which, sources of $PM_{2.5}$ in NSW are being studied and managed to ensure that the regional background concentrations that residents within Sydney, including the Study Area, are exposed to are minimised as much as practicable.

Exceedances of the 24-hour average and annual average $PM_{2.5}$ criterion at roof receptors modelled, are limited to podium roofs of the PLO 01 – Poulos, PLO 02 – Celestino and BLD 02 buildings as well as single roof receptors on the BLD 01 and BLD 05 buildings.

Table 27 Predicted $PM_{2.5}$ Concentrations – Scenario 2

Proposed Use	Building	Worst Impacted Receptor -					
		Incremental - 24-h Average - Hymix	Incremental - Annual Average - Hymix	Incremental - 24-h Average - Vehicles	Incremental - Annual Average - Vehicles	Cumulative - 24-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	3	0.1	20	10	33.6 (19)	16.8
	PLO 02 - Celestiono	4	0.3	31	11	40.5 (61)	18.7
	BLD 01	7	0.9	8	3	30.4 (3)	10.5
	BLD 02	0	0.0	1	0	22.4	7.6
	BLD 03	2	0.2	13	5	29.7 (5)	12.3
	BLD 04	1	0.0	12	5	27.4 (2)	12.1
	BLD 05	1	0.1	13	4	27.6 (2)	11.3
	BLD 06	1	0.1	6	2	25.6 (1)	9.7
	BLD 07	3	0.2	5	2	25.0 (1)	9.3
Residential	PLO 01 - Poulos	0	0.0	2	0	22.1	7.5
	PLO 02 - Celestiono	0	0.0	2	0	22.2	7.5
	BLD 02	2	0.2	14	4	29.6 (1)	11.4
	BLD 03	0	0.0	3	1	22.5	7.8
	BLD 04	0	0.0	2	0	22.8	7.6
Retail	PLO 01 - Poulos	4	0.2	22	9	38.6 (27)	16.6
	PLO 02 - Celestiono	6	0.4	29	12	40.8 (90)	19.9
	BLD 01	11	1.3	11	3	33.2 (14)	11.8
	BLD 02	3	0.3	16	5	30.0 (3)	12.4
	BLD 03	1	0.1	13	5	29.8 (4)	12.6
	BLD 04	1	0.1	17	6	32.1 (7)	13.8
	BLD 05	2	0.2	18	6	31.6 (8)	13.1
	BLD 06	1	0.1	11	3	26.9 (1)	10.3
	BLD 07	4	0.3	12	5	30.5 (2)	12.1

Note 1: Red text indicates exceedance of relevant ambient air quality criterion

Note 2: Numbers in brackets indicate the number of additional exceedances of the relevant criterion

Figure 34 Predicted Exceedances of Cumulative 24-Hour Average $PM_{2.5}$ – Scenario 2

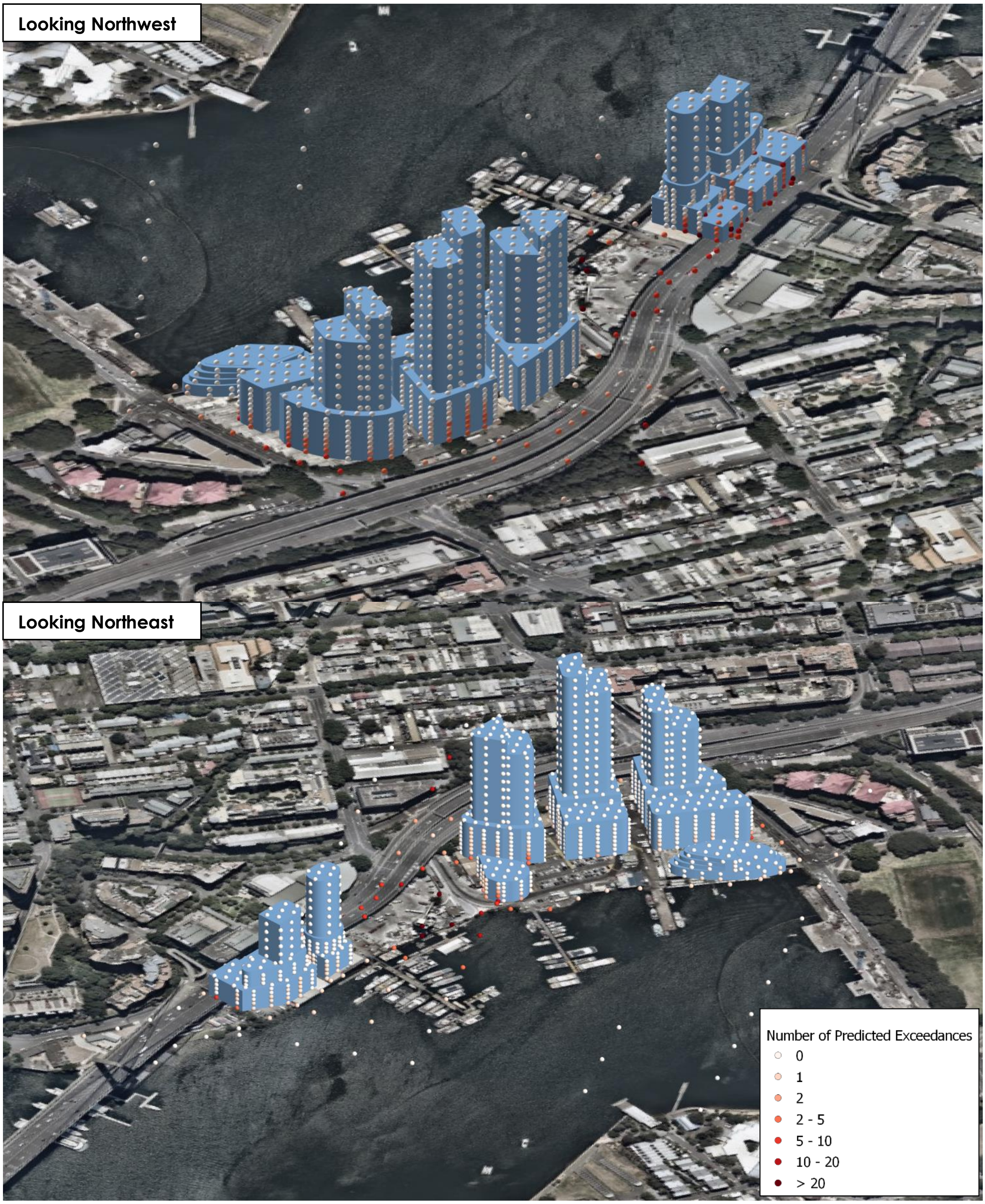
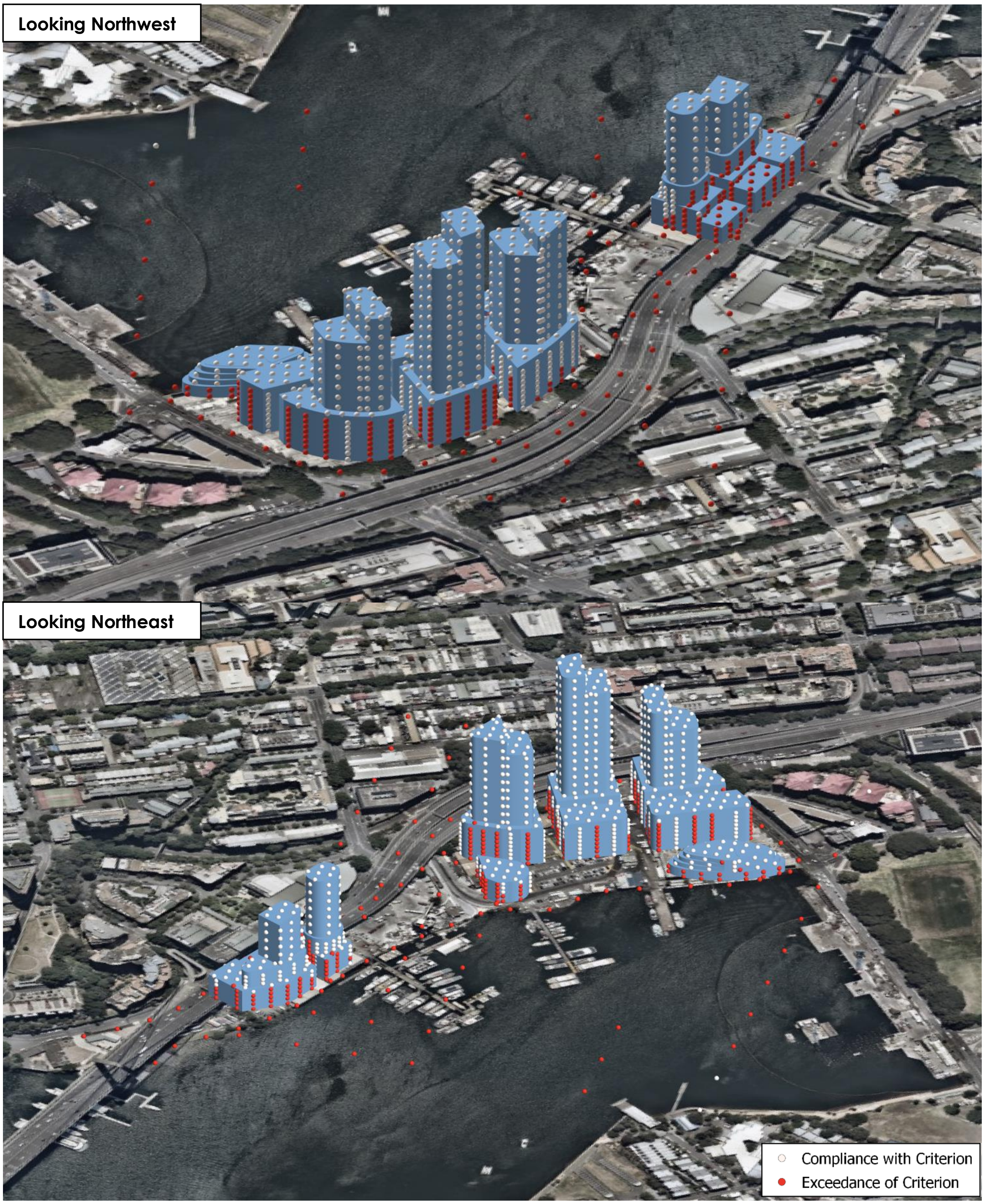


Figure 35 Predicted Exceedances of Cumulative Annual Average $PM_{2.5}$ – Scenario 2



10.2.3 NO_2

The maximum incremental and cumulative 1-hour and annual average NO_2 concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use (ie commercial, residential or retail) are presented in **Table 28**.

Figure 36 illustrates the number of exceedances predicted at the modelled discrete receptor locations for 1-hour average NO_2, while **Figure 37** illustrates locations where exceedances of the cumulative annual average criteria were predicted by the model.

The modelling results presented in **Table 28** and illustrated in **Figure 36** and **Figure 37** show that exceedances of the 1-hour NO_2 criterion are predicted along the facade of all proposed buildings. However, these exceedances predominantly affect lower floors of the proposed buildings where the proposed use is commercial or retail on facades facing the Western Distributer.

Exceedances of the 1-hour NO_2 criterion on the facade of residential floors in limited to 4% of the modelled residential receptors all of which are located on BLD 02 (at elevations up to 30 m above ground). For the worst-affected residential receptor (located on the western facade of BLD 02 at an elevation of 6 m above ground level), three (3) exceedances of the 1-hour average NO_2 criterion are predicted for the modelled year.

Exceedances of the annual average NO_2 criterion are only predicted to occur at 0.5% of the façade receptors modelled, with all these exceedances occurring at commercial and retail locations of the PLO 01 – Poulos building and PLO 02 – Celestino building. No exceedances of the annual average NO_2 criterion is predicted at residential receptor locations where sensitive receptors may potentially be affected.

Exceedances of the 1-hour average and annual average NO_2 criteria at roof receptors modelled, are limited to podium roofs of the PLO 01 – Poulos, PLO 02 – Celestino and PLO 03 - Hymix 1 buildings at locations closest to the Western Distributor.

Table 28 Predicted NO_2 Concentrations – Scenario 2

Proposed Use	Building	Worst Impacted Receptor -			
		Incremental - 24-h Average - Vehicles	Incremental - Annual Average - Vehicles	Cumulative - 24-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	240	43	314 (3)	64
	PLO 02 - Celestiono	347	48	379 (17)	69
	BLD 01	223	23	298 (2)	44
	BLD 02	94	5	156.1	26
	BLD 03	226	29	288 (1)	51
	BLD 04	232	35	295 (1)	56
	BLD 05	223	31	298 (2)	53
	BLD 06	196	22	271 (1)	44
	BLD 07	208	23	283 (1)	44
Residential	PLO 01 - Poulos	77	3	120.7	25
	PLO 02 - Celestiono	92	5	129.2	26
	BLD 02	233	28	308 (3)	49
	BLD 03	98	8	185.3	30
	BLD 04	122	4	209.9	26
Retail	PLO 01 - Poulos	243	43	299 (4)	64
	PLO 02 - Celestiono	277	50	320 (6)	72
	BLD 01	243	25	293 (3)	46
	BLD 02	284	31	307 (2)	53
	BLD 03	238	30	306 (2)	51
	BLD 04	247	39	300 (1)	60
	BLD 05	299	35	374 (7)	57
	BLD 06	239	27	315 (2)	48
	BLD 07	247	33	322 (2)	54

Note 1: Red text indicates exceedance of relevant ambient air quality criterion

Note 2: Numbers in brackets indicate the number of additional exceedances of the relevant criterion

Figure 36 Predicted Exceedances of Cumulative 1-Hour Average NO_2 – Scenario 2

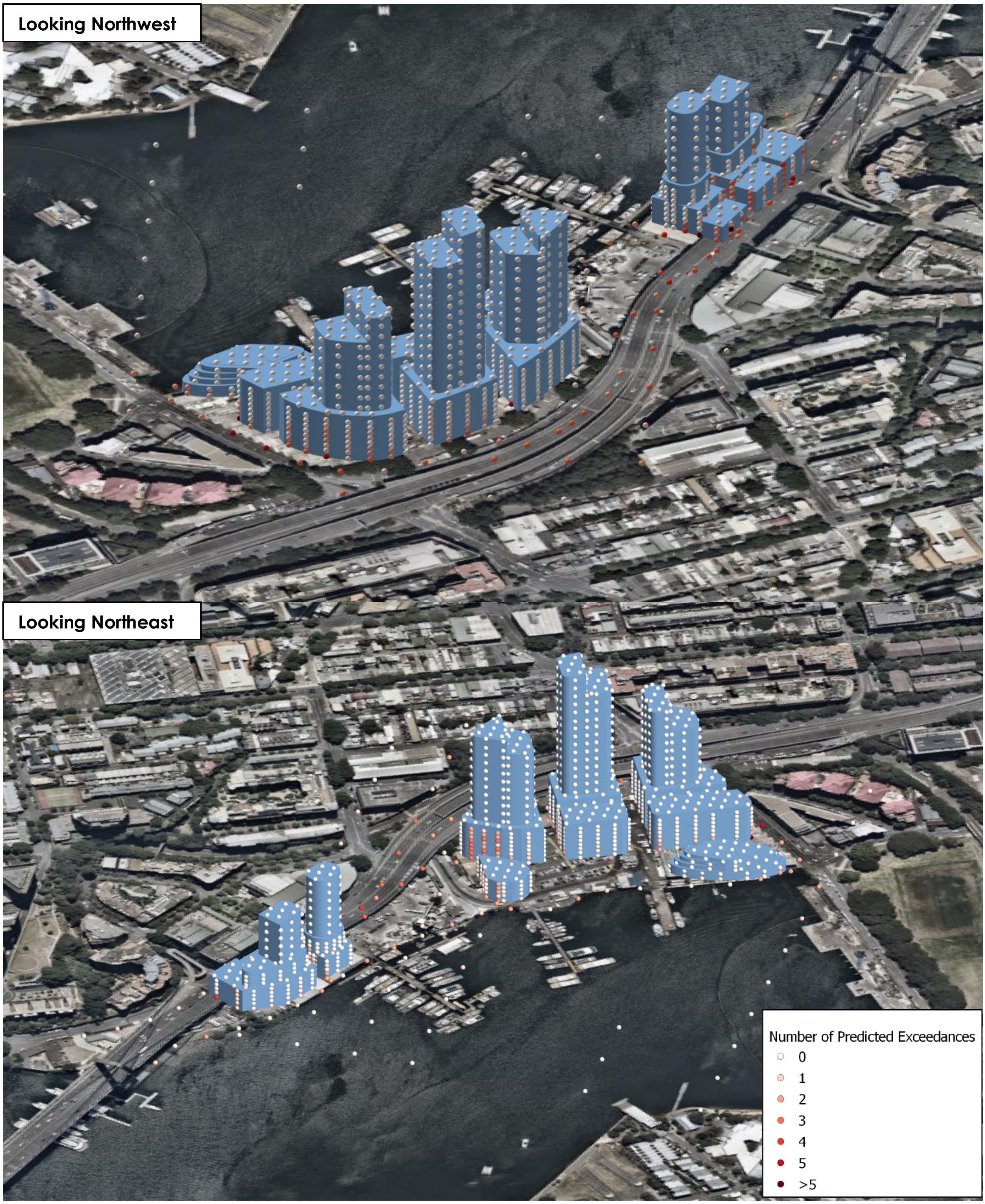
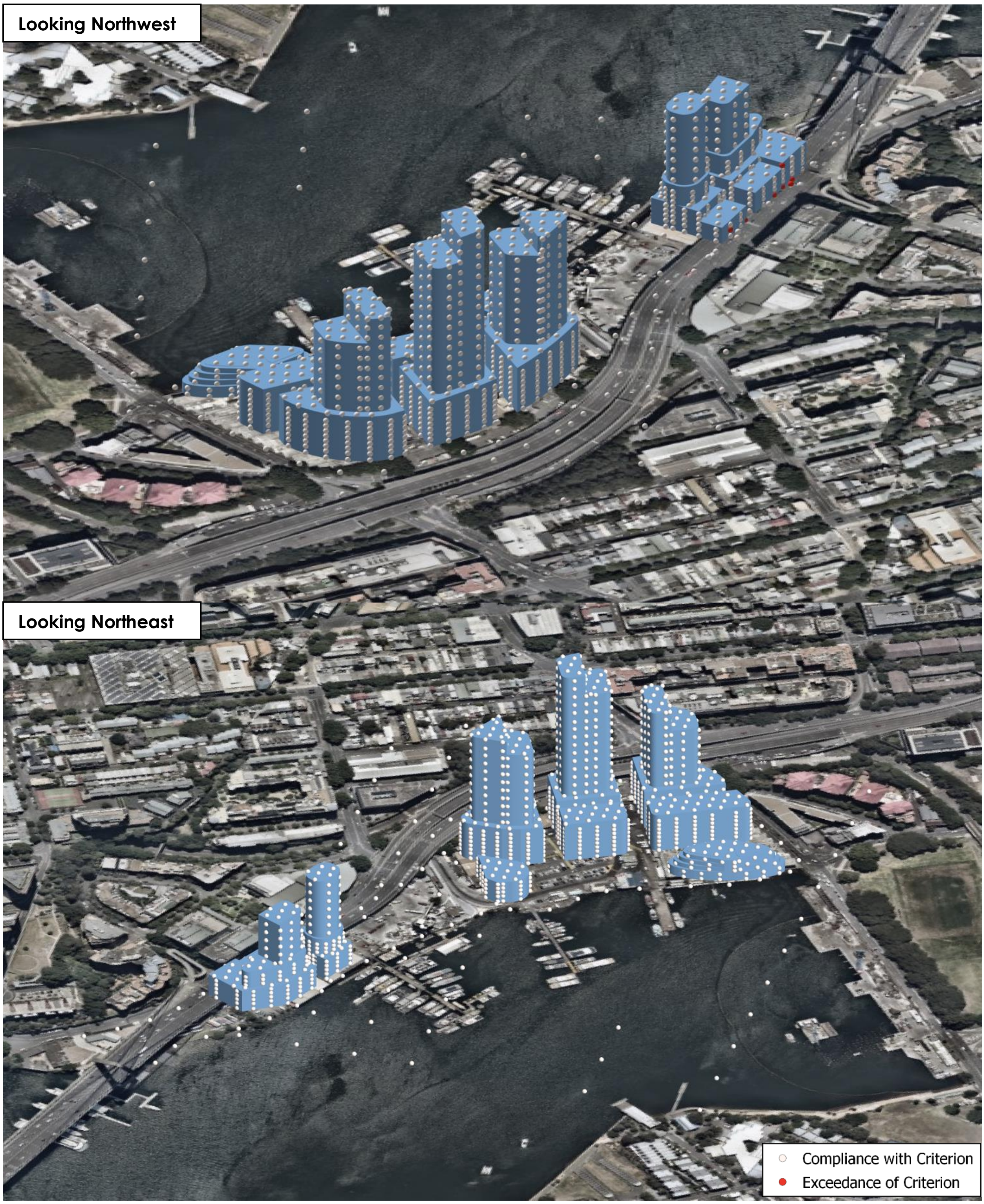


Figure 37 Predicted Exceedances of Cumulative Annual Average NO_2 – Scenario 2



10.3 Potential Future Reductions in Vehicle Emissions

As outlined in **Section 8.1,** the vehicle emission factors used in this study were conservatively derived assuming the average vehicle fleet emissions in 2033 are the same as those of 2010. This is because detailed vehicle information representative of the NSW fleet in the year 2033, in a format suitable for use in the COPERT model, was not available at the time of preparing this assessment.

In order to conduct a sensitivity analysis to assess the impacts of using emission factors expected to be more representative of future emissions, incremental vehicle emissions predicted by the model for Scenario 1 (representative of complete redevelopment of the entire site) were scaled using ratios calculated from 2016 and 2026 emissions factors derived from the Roads and Maritime air quality screening model TRAQ. It is noted that the current version of TRAQ does not estimate $PM_{2.5}$ emissions.

TRAQ, developed by NSW EPA, incorporates a simplified version of the emission model for surface roads developed by NSW EPA for the emissions inventory covering the Greater Metropolitan Region (GMR). The TRAQ model includes emission projections for several future years, taking into account anticipated improvements in the engine and emissions technology within the vehicle fleet. **Table 29** presents the emission factors estimated by TRAQ for the year 2016 and 2026 using the default fleet for NSW arterial roads, with cold start emissions included. Emission factors derived from COPERT have also been included for comparison. The numbers in brackets illustrate the percentage reduction in emissions estimated by TRAQ in future years compared to 2016.

As shown in **Table 29**, the TRAQ emission model estimates that NOx and PM_{10} emissions will drop an average of 56% and 21% respectively over the ten year period for which data is available. The actual reductions for the 23 year gap between the vehicle fleet year modelled (2010) and the year the Study Area is expected to be fully developed (2023), could be much greater. However, due to limitations in the years the TRAQ model is capable of calculating emissions for, a more precise estimate in the reduction of emissions for the time period of interest could not be estimated.

Table 29 TRAQ Emission Factors

Emission Model	Vehicle Fleet Year	Average Vehicle Speed (km/h)	NOx (g/VKT)	PM10 (g/VKT)
TRAQ	2016	10	1.26	0.08
	2016	60	0.54	0.06
	2026	10	0.55 (56%)	0.06 (25%)
	2026	60	0.24 (56%)	0.05 (17%)
COPERT	2010	10	1.25	0.07
	2010	60	0.96	0.05

10.3.1 PM_{10} - Emission Factors Sensitivity Analysis

The maximum incremental and cumulative 24-hour and annual average PM_{10} concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use (ie commercial, residential or retail) and scaled using the TRAQ 2026:2016 ratios are presented in **Table 30**.

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The incremental PM_{10} concentration at all receptors within the study area is estimated to be 22% less than that estimated using the using the 2010 vehicle fleet emissions.

Exceedances of the 24-hour PM_{10} criterion on the facade of residential floors is limited to 3% of the modelled residential receptors. For the worst-affected residential receptor, one (1) additional exceedance of the 24-hour average PM_{10} criterion is predicted for the modelled year (September 24th). This exceedance is primarily due to the high background concentration on the day the exceedance is predicted (49.2 µg/m^3).

Exceedances of the annual average PM_{10} criterion are limited to commercial and retail receptors of the PLO 01 – Poulos building, PLO 02 – Celestino building and PLO 03 - Hymix 1 and Hymix 2 buildings. No exceedances of the annual average PM_{10} criterion are predicted at residential receptor locations where sensitive receptors may potentially be affected.

10.3.2 NO_2 - Emission Factors Sensitivity Analysis

The maximum incremental and cumulative 1-hour and annual average NO_2 concentrations predicted at the worst impacted facade receptors for each building, categorised based on the proposed use (ie commercial, residential or retail) and scaled using the TRAQ 2026:2016 ratios are presented in **Table 30**.

The incremental NO_2 concentration at all receptors within the study area is estimated to be 56% less than that presented in **Section 10.1**.

Exceedances of the 1-hour NO_2 criterion on the facade of residential floors is limited to four receptor locations out of the 721 locations modelled (less than 1%), all of which are located on BLD 02 (at elevations of 6 m and 10 m above ground). For the worst-affected residential receptor (located on the western facade of BLD 02 at an elevation of 6 m above ground level), two (2) exceedances of the 1-hour average NO_2 criterion are predicted for the modelled year.

Exceedances of the annual average NO_2 criterion are limited to one receptor location out of the 1,773 facade locations modelled (less than 1%). The single exceedance is predicted to occur at a commercial receptor located on the PLO 03 - Hymix 2 facade. No exceedances of the annual average NO_2 criterion are predicted at residential receptor locations where sensitive receptors may potentially be affected.

10.3.3 Summary

The emission factor sensitivity analysis demonstrated that:

- While exceedances of the 24-hour average PM_{10} criterion are still predicted to occur at some residential receptor locations, these will be limited to days of extremely elevated background concentrations of PM_{10};
- Exceedances of the 24-hour average PM_{10} criterion are predicted to occur at 38% fewer residential receptor locations that those predicted using the 2010 vehicle fleet emissions;
- The incremental NO_2 impact (from vehicles travelling on the surrounding road network) on the Study Area are likely to be significantly overestimated (by 56%) by the modelling predictions using the 2010 vehicle fleet emissions; and
- Exceedances of the 1-hour average NO_2 criterion are predicted to occur at 85% fewer residential receptor locations that those predicted using the 2010 vehicle fleet emissions.

Table 30 Predicted PM_{10} Concentrations – Emission Factors Sensitivity Analysis

Proposed Use	Building	Worst Impacted Receptor			
		Incremental - 24-h Average	Incremental - Annual Average	Cumulative - 24-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	17	9	56.8 (3)	27
	PLO 02 - Celestino	30	12	68.6 (6)	30
	PLO 03 - Hymix 1	24	11	61.4 (4)	29
	PLO 03 - Hymix 2	28	14	72.0 (3)	32
	BLD 01	7	2	50.5 (1)	20
	BLD 03	12	4	57.2 (2)	22
	BLD 04	10	4	54.0 (1)	22
	BLD 05	8	3	51.9 (1)	21
	BLD 06	5	2	50.4 (1)	20
	BLD 07	2	1	49.6	19
Residential	PLO 01 - Poulos	1	0	49.7	18
	PLO 02 - Celestino	2	0	49.3	18
	PLO 03 - Hymix 1	1	0	49.9	19
	PLO 03 - Hymix 2	4	1	49.6	19
	BLD 02	15	5	50.4 (1)	23
	BLD 03	2	0	50.7 (1)	18
	BLD 04	2	0	49.6	18
Retail	PLO 01 - Poulos	19	8	60.2 (2)	26
	PLO 02 - Celestino	22	12	67.1 (4)	30
	PLO 03 - Hymix 1	35	16	69.4 (6)	34
	PLO 03 - Hymix 2	31	13	72.4 (6)	31
	BLD 01	8	3	50.8 (2)	21
	BLD 02	22	6	52.3 (4)	24
	BLD 03	12	4	54.7 (2)	22
	BLD 04	11	5	53.8 (2)	23
	BLD 05	10	4	51.5 (1)	22
	BLD 06	7	2	50.7 (1)	20
	BLD 07	6	3	51.1 (1)	21
Criteria				**50**	**25**

Note 1: Red text indicates exceedance of relevant ambient air quality criterion

Note 2: Numbers in brackets indicate the number of additional exceedances of the relevant criterion

Table 31 Predicted NO_2 Concentrations – Emission Factors Sensitivity Analysis

Proposed Use	Building	Worst Impacted Receptor			
		Incremental - 1-h Average	Incremental - Annual Average	Cumulative - 1-h Average	Cumulative - Annual Average
Commercial	PLO 01 - Poulos	219	32	294 (3)	53
	PLO 02 - Celestino	218	36	307 (3)	58
	PLO 03 - Hymix 1	212	34	287 (2)	55
	PLO 03 - Hymix 2	231	41	306 (3)	62
	BLD 01	205	14	280 (1)	36
	BLD 03	151	21	239	42
	BLD 04	141	24	229	46
	BLD 05	181	21	256 (1)	43
	BLD 06	130	15	210	36
	BLD 07	66	6	147	27
Residential	PLO 01 - Poulos	45	2	128	23
	PLO 02 - Celestino	68	2	124	24
	PLO 03 - Hymix 1	51	5	121	26
	PLO 03 - Hymix 2	108	6	144	27
	BLD 02	200	20	276 (1)	41
	BLD 03	66	4	125	25
	BLD 04	71	2	149	24
Retail	PLO 01 - Poulos	208	31	283 (2)	53
	PLO 02 - Celestino	207	37	287 (2)	59
	PLO 03 - Hymix 1	250	40	309 (4)	62
	PLO 03 - Hymix 2	238	40	298 (3)	62
	BLD 01	212	17	287 (2)	39
	BLD 02	210	23	285 (1)	44
	BLD 03	171	21	246	43
	BLD 04	206	28	281 (2)	49
	BLD 05	218	24	293 (2)	45
	BLD 06	184	17	260 (1)	38
	BLD 07	205	22	280 (1)	43

Note 1: Red text indicates exceedance of relevant ambient air quality criterion

Note 2: Numbers in brackets indicate the number of additional exceedances of the relevant criterion

11 Recommended Mitigation Measures

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 reported 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/retail use and residential receivers should be located on higher floors.

Should Hymix continue to operate as currently permitted, lower floors of buildings located closest to the Hymix facility should be commercial/retail use and residential receivers should be located on higher floors.

Where possible, the number of apartments facing the Western Distributor and Hymix (for Scenario 2) should be reducing by designing building cores to these directions. Additionally, wintergardens with fixed glazing could be incorporated into the design of such apartments to reduce the potential for impact.

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.

The proposed Precinct Plan for the Study Area incorporates a number of these measures including:

- Minimising the formation of urban canyons by having buildings of different heights interspersed.
- No sensitive receptors (residential units) are proposed within a 20 m radius of the major roads.
- For all proposed buildings (with the exception of BLD 02) the lower eight floors are proposed to be used for commercial/retail purposes. For BLD 02, the ground floor is proposed to be used for retail purposes.

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 The Western Distributor, 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 The Study Area due to emissions from local traffic and activities at Hymix (for Scenario 2 only) indicate that emissions from these sources have the potential to result in exceedances of the ambient air quality criteria for PM_{10},$PM_{2.5}$ and NO_2 within the Study Area, particularly on lower floor of buildings at locations closest to the Western Distributor and Hymix. **Table 32** summarises the extent of exceedance of the relevant air quality criteria at residential receptor locations for the two scenarios modelled (as the percentage of residential receptors modelled predicted to experience exceedances of the relevant criteria).

Table 32 Summary of Exceedances at Residential Receptor Locations

Modelled Scenario	PM_{10}		$PM_{2.5}$		NO_2	
	24-hour	**Annual**	**24-hour**	**Annual**	**1-hour**	**Annual**
Scenario 1	5%	0%	1%	2%	4%	0%
Scenario 2	11%	2%	3%	7%	4%	0.5%

Vehicle emission factors used in this study were conservatively assumed to remain at levels estimated for the 2010 NSW vehicle fleet. In order to conduct a sensitivity analysis to assess the impacts of using emission factors expected to be more representative of future emissions, incremental vehicle emissions predicted by the model for Scenarios 1 (representative of complete redevelopment of the entire site) were scaled using ratios calculated from the 2016 and 2026 emissions factors derived from the Roads and Maritime air quality screening model TRAQ.

The emission factors sensitivity analysis demonstrated that:

- While exceedances of the 24-hour average PM_{10} criterion are still predicted to occur at some residential receptor locations, these will be limited to days of extremely elevated background concentrations of PM_{10};
- Exceedances of the 24-hour average PM_{10} criterion are predicted to occur at 38% fewer residential receptor locations that those predicted using the 2010 vehicle fleet emissions;
- The incremental NO_2 impact (from vehicles travelling on the surrounding road network) on the Study Area are likely to be significantly overestimated (by 56%) by the modelling predictions using the 2010 vehicle fleet emissions; and
- Exceedances of the 1-hour average NO_2 criterion are predicted to occur at 85% fewer residential receptor locations that those predicted using the 2010 vehicle fleet emissions.

Overall, there are a higher number of residential receptors predicted to be impacted by concentrations above guideline levels for Scenario 2, in which Hymix is assumed to continue to operate as currently permitted. In order to quantify the potential risk to human health as a result of the predicted exceedances, a human health risk impact study has been completed for the proposed Precinct Plan.

The proposed Precinct Plan for the Study Area incorporates a number of mitigation measures consistent with Section 4.4 of the Guideline including:

- Minimising the formation of urban canyons by having buildings of different heights interspersed.
- No sensitive receptors (residential units) are proposed within a 20 m radius of the major roads.
- For all proposed buildings (with the exception of BLD 02) the lower eight floors are proposed to be used for commercial/retail purposes. For BLD 02, only the ground floor is proposed to be used for retail purposes, with residential uses form level 1 and above.

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 and the Hymix operations (should Hymix continue operations at the current location).

The requirement for any additional air quality mitigation for each building would be further assessed during the next stages of the project. This study has shown that from an air quality perspective, the Study Area is suitable for the intended uses within the SSP proposal, subject to the findings of the human health risk assessment study and future refinement of high-level mitigation measures summarised within this study.

14 References

ARUP. (2017). *Bays Precinct Data Collection Results and Findings.*

DEC. (2007). Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales.

DEWHA . (2008). *National Pollutant Inventory Emission Estimation Technique Manual for Combustion Engines.* Department of Environment, Water, Heritage and Arts.

DoP. (2008). *Development Near Rail Corridors and Busy Roads – Interim Guideline.* NSW Department of Planning.

DSITIA. (2014). Email communication with Dr Robin Smith, Science Leader, Inventory and Air Assessment. Queensland Department of Science, Information Technology and the Arts.

Environment Australia. (1999). *National Pollutant Inventory Emission Estimation Technique Manual for Concrete Batching and Concrete Product Manufacturing.* National Pollutant Inventory.

National Environment Protection Council. (2003). *Variation to the National Environment Protection (Ambient Air Quality) Measure.* Canberra: National Environment Protection Council.

National Environment Protection Council. (2016). *National Environment Protection (Ambient Air Quality) Measure.* Canberra: Department of the Environment.

NOAA. (2018, February 14). *Air Resources Laboratory*. Retrieved February 20, 2018, from National Oceannic and Atmospheric Association: https://www.ready.noaa.gov/READYpgclass.php

NSW DEC. (2006b). *Technical Notes: Assessment and management of odour from stationary sources in NSW.* Sydney: NSW Department of Environment and Conservation.

NSW EPA. (2007). Local Government Air Quality Toolkit - Construction Sites.

NSW EPA. (2007). *Local Government Air Quality Toolkit - Food Outlets.*

NSW EPA. (2008). *Environmental Action for Automotive Servicing and Repairs.*

NSW EPA. (2013). Managing particles and improving air quality in NSW.

NSW EPA. (2014). *Trends in Motor Vehicles and their Emissions.* Environment Protection Authority.

NSW EPA. (2017, January). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. Prepared by NSW Environment Protection Authority, which is part of the NSW Office of Environment and Heritage (OEH). Retrieved from http://www.environment.nsw.gov.au/resources/air/ammodelling05361.pdf

NSW Government. (2017, June). *Air Quality in NSW.* Retrieved from https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/air/Air-Quality-in-NSW.ashx

NSW OEH. (2017). *NSW Annual Compliance Report 2015.*

NSW OEH. (2017b). *Air quality statement 2016.*

NSW OEH. (2017b). *NSW Annual Air Quality Statement 2017.*

NSW OEH. (2019). *NSW Annual Air Quality Statement 2018.*

Oke, T. R. (2002). *Boundary Layer Climates.* Routledge.

Pacific Environment. (2015). *WestConnex M4 East Air Quality Assessment Report.*

Pacific Environment. (2016). *White Bay Cruise Terminal Air Toxics Monitoring Report.*

Pasquill. (1961). The estimation of the dispersion of windborne material. *The Meteorological Magazine, 90*(1063), 33-49.

PIARC Technical Committee D.5. (2019). *Road Tunnels: Vehicle Emissions and Air Demand for Ventilation.* World Road Association (PIARC).

SLR. (2019). *The New Sydney Fish Market Stage 2 - Main Works (SSD 8925) Air Quality Assessment.*

Uniquest. (2014, August 02). Australian Motor Vehicle Emission Inventory for the National Pollutant inventory (NPI). Uniquest, Prepared for Department of Environment.

US EPA. (2012). *AP-42: Compilation of Air Emission Factors - Section 11.12 Concrete Batching.* US EPA.

APPENDIX A

Odour Survey Report

23 October 2017

610.17553-L01-v1.0.docx

UrbanGrowth NSW
Level 12, MLC Centre
19 Martin Place
Sydney NSW 2000

Attention: Stephanie Ballango

Dear Stephanie

Bays Market District
Field Odour Survey Report

SLR Consulting Australia (SLR) was commissioned by UrbanGrowth NSW to conduct a series of ambient odour field surveys to assess the plume extent, intensity and hedonic tone of odours in the area surrounding potential odour sources in the vicinity of the Bays Market District, Sydney, NSW (the Investigation Area).

The purpose of the odour surveys was to identify the main sources of pollutants impacting upon the Investigation Area and assessing the baseline odour strength and hedonic tone in the areas surrounding the Investigation Area.

This letter outlines the methodology and results of the odour surveys and is accompanied by and should be read in conjunction with SLR Report 610.17553-R01, which summarises the findings of the odour surveys.

Yours sincerely

ALI NAGHIZADEH
Associate - Air Quality

Checked/
Authorised by: KL

1 Location

The Investigation Area is located at the western edge of Pyrmont, less than two kilometres from Sydney CBD. **Figure 1** illustrates the location of the Bays Market District. The existing Sydney Fish Markets (SFM) is located at the western corner of the Investigation Area and is a potentially significant source of odours in the area.

Figure 1 Bays Market District Location

2 Methodology

A series of ambient odour field surveys was performed by SLR staff on 25, 27 and 29 September 2017, with multiple surveys being performed at different times of the day on each of these days (total of nine surveys). The purpose of these surveys was to assess:

- The odour plume extent;
- The odour intensity;
- The odour hedonic tone; and
- The characteristics of the perceived odour.

Survey days and times were selected with an aim to capture peak emissions from the existing SFM. This included early morning surveys to capture potential odours associated with the auction floor activities.

Publicly accessible areas upwind and downwind of the Investigation Area were surveyed (public roads and footpaths). Observations of the wind speed, wind direction were also recorded during each survey.

It is noted that an odour survey provides only a snap shot of the odour at these locations. However, the odour surveys performed provide an indication of the likely impact under a variety of meteorological conditions.

2.1 Odour Assessor

SLR utilised personnel to conduct the odour surveys who have successfully undertaken and comply with the odour assessor sensitivity screening protocol in accordance with:

- AS/NZS 4323.3:2001 *Stationary source emissions – Part 3: Determination of odour concentration by dynamic olfactometry*.

Refer to **Appendix B** for Certificates of Analysis of the results of the odour assessor sensitivity screening.

Both of the SLR odour assessors were near the middle of the sensitivity range of the AS4323.3:2001 criterion to qualify as an odour assessor.

2.2 Odour Plume Extent

During the odour surveys, SLR adopted a modified approach to the British Standard BS EN 16841-2:2016 *Ambient Air – Determination of odour in ambient air by using field inspection* to characterise the area surrounding the identified odour sources by the presence or absence of odour, and in order to determine the likely extent of potential exposure to recognisable odours from each site.

This method uses odour assessors to determine the extent of the downwind odour plume, under specific meteorological conditions.

It is noted that the British Standard does not include the measurement of intensity of ambient odours or the hedonic tone of the ambient odours. Modified approaches to German VDI standards were adopted for the assessment of odour intensity and hedonic tone as described below.

2.3 Odour Intensity

During the odour surveys, SLR adopted a modified approach to the German VDI 3882:1992 Part 1 *Olfactometry – Determination of Odour Intensity* to record odour intensity.

This method was utilised during the odour surveys as there is currently no Australian Standard for rating odour intensity. The German VDI 3882 standard is however the most commonly referred to standard by the Environment Protection Authority (EPA).

To assess the odour intensity at each location for any discernible odours detected, the odour assessor undertaking the survey would classify their perception of the odour intensity in accordance with the scale outlined in **Table 1**.

Table 1 Summary of Odour Intensity Scale Utilised during the Field Odour Surveys

Odour	Intensity Level
Extremely Strong	6
Very Strong	5
Strong	4
Distinct	3
Weak	2
Very Weak	1
Not perceptible	0

2.4 Odour Hedonic Tone

During the odour surveys SLR adopted a nine point scale of +4 to -4 to define the hedonic tone.

To assess the hedonic tone (degree of pleasantness/unpleasantness of odour) at each location for any odours detected, the odour assessor undertaking the survey would classify their perception of the odour hedonic tone in accordance with the scale outlined in **Table 1**.

It is noted that hedonic definition is subjective, which means the results may vary from one assessor to another.

Table 2 Summary of Odour Intensity Scale Utilised during the Field Odour Surveys

Odour	Intensity Level
Very Pleasant	+4
Pleasant	+3
Moderately Pleasant	+2
Mildly Pleasant	+1
Neutral Odour / No Odour	0
Mildly Unpleasant	-1
Moderately Unpleasant	-2
Unpleasant	-3
Very Unpleasant	-4

3 Odour Survey Results

3.1 Identified Odour Sources

Prior to the surveys, the existing SFM was identified as the main potential source of odour in the area. However, in order to identify any other additional existing sources of odour that currently impact upon the Investigation Area, odour surveys were conducted upwind of the SFM and across the full extent of the Investigation Area, as well as downwind of the SFM.

Odours identified during the surveys other than those associated with activities at the SFM included:

- Vehicle exhaust odours from road traffic; and
- Food/cooking odours from restaurants and cafes.

These additional odours, which were generally described as very weak to distinct, were very localised and were only detectable within a few meters from the source.

3.2 Odour Intensity, Hedonic Tone and Plume Extent

Refer to **Appendix A** for intensity and hedonic tone plots illustrating the observations recorded across the areas surveyed during the eight survey events. **Table 3** details the character of the perceived odours and the meteorological conditions at the time of each survey and summarises the maximum intensity and hedonic tone recorded during each survey at the survey locations upwind and downwind of the Investigation Area.

Table 3 Summary of Odour Plume Survey Results – Intensity, Hedonic Tone and Character

Survey No.	Date	Start Time	Finish Time	Wind Direction	Wind Speed (km/h)	Maximum Odour Intensity	Hedonic Tone	Odour Character
						(0 to 6)	(-4 to +4)	
1	25-Sep-17	12:00	13:30	WNW	26	3	-1	Cooked food / fish
2	25-Sep-17	15:00	16:30	WNW	33	3	-1	Cooked food / fish
3	25-Sep-17	17:30	19:00	W	26	2	0	No recognisable odours
4	27-Sep-17	05:30	08:00	ENE	11	2	0	Weak fresh fish odours
5	27-Sep-17	10:00	11:30	ESE/NE	6 - 26	2	0	Weak fresh fish odours
6	27-Sep-17	13:00	14:30	NE	30	3	0	Cooked food / fish
7	29-Sep-17	06:00	08:00	W	15	2	0	Fishy
8	29-Sep-17	10:30	12:00	W	20	2	-1	Fishy, car exhaust
9	29-Sep-17	13:00	14:30	W	6 - 20	3	-1	Fishy, garbage, cooked food

Table 4 summaries the approximate extent of the 'distinct' odour plume during each of the nine (9) odour surveys performed at the Investigation Area. During the odour surveys, the predominant odour character was identified as being attributable to activities at the existing SFM, including raw and cooked fish. The plume extents have therefore been estimated from the boundary of the existing SFM. It is noted that only areas that are publicly accessible by foot were surveyed upwind and downwind of the Investigation Area. Therefore, the plume extent in some directions, specifically northwest of the Investigation Area (ie, the bay and Glebe Island) could not be determined.

It is noted that during the peak operation hours of the restaurants located within the existing SFM, cooking odours were detectable within 10 -15 m of the existing SFM (ie. on Bridge Road) regardless of wind conditions.

Table 4 Summary of Odour Plume Survey Results – Plume Extent

Survey No.	Date	Start Time	Finish Time	Wind Direction	Approximate Distinct Downwind Odour Plume Extent (m)							
					N	NE	E	SE	S	SW	W	NW
1	25-Sep-17	12:00	13:30	WNW	ND	**130**	**80**	**35**	**100**	**15**	ND	ND
2	25-Sep-17	15:00	16:30	WNW	ND	**120**	**90**	**90**	**80**	**50**	ND	ND
3	25-Sep-17	17:30	19:00	W	ND	ND	ND	ND	ND	ND	ND	ND
4	27-Sep-17	05:30	08:00	ENE	ND	ND	ND	ND	ND	ND	ND	ND
5	27-Sep-17	10:00	11:30	ESE/NE	ND	ND	ND	ND	**10**	**15**	ND	ND
6	27-Sep-17	13:00	14:30	NE	ND	ND	ND	ND	**120**	**160**	**430**	ND
7	29-Sep-17	06:00	08:00	W	ND	ND	ND	ND	ND	ND	ND	ND
8	29-Sep-17	10:30	12:00	W	ND	ND	ND	ND	**10**	**15**	ND	ND
9	29-Sep-17	13:00	14:30	W	ND	**100**	**105**	**25**	**70**	**15**	ND	ND

ND: No distinct odours detected

4 Conclusions

This report outlines the findings of the field odour survey, identifies approximate extent of the odour plume downwind of the identified sources of odour that have the potential to impact upon the Investigation Area and presents the odour character and perceived pleasantness of the odours emitted from these sources.

The conducted odour surveys found that the main source of odour in the area surrounding the Investigation Area is the existing Sydney Fish Markets and that all other odour sources (e.g. local cafes, restaurants and traffic) have a relatively insignificant impact at the Investigation Area.

Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

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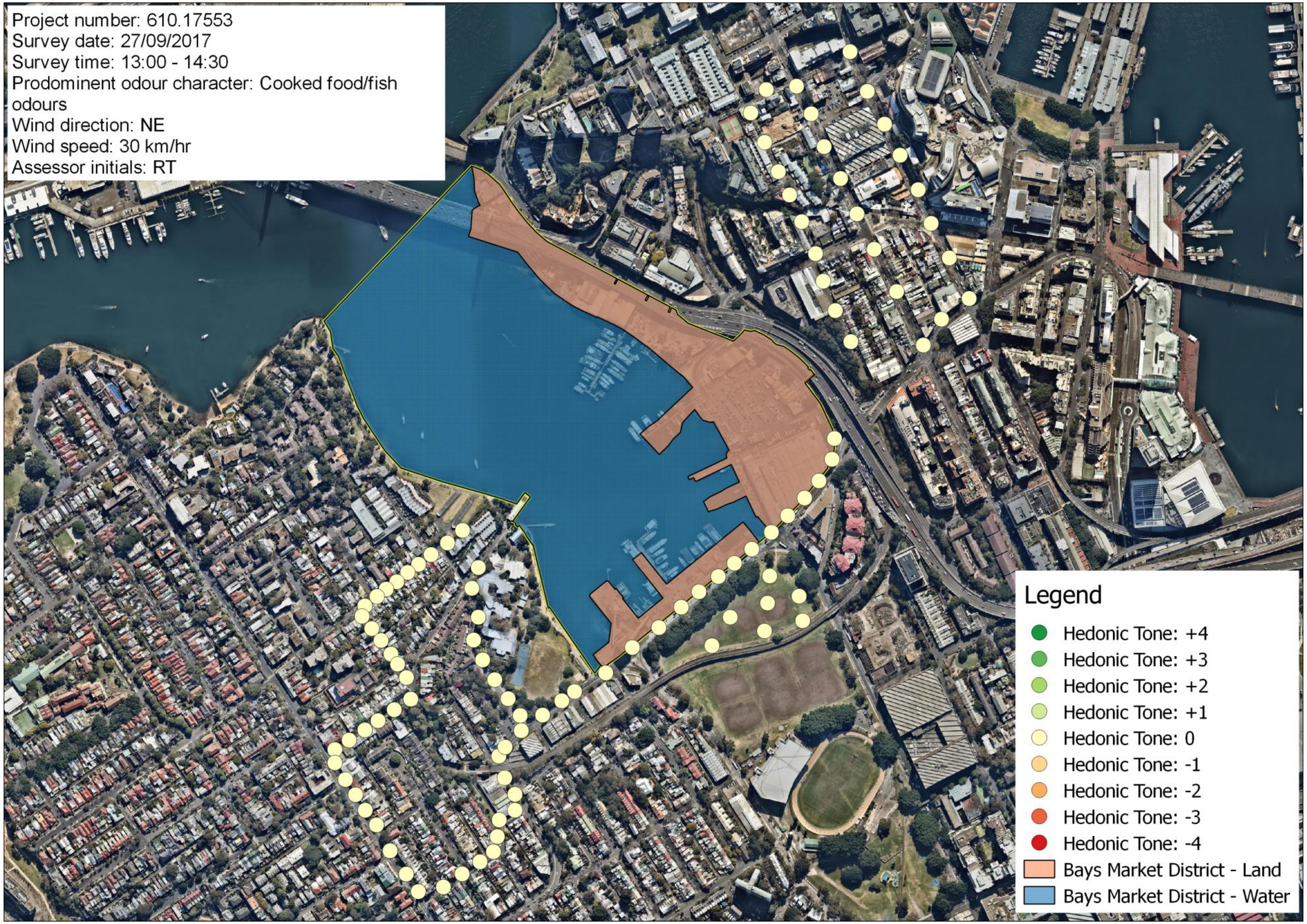
Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots



Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

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Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

Hedonic Tone and Odour Intensity Plots

Certificates of Analysis for Odour Assessor Sensitivity Screening

THE ODOUR UNIT

CERTIFICATE OF QUALIFICATION
ODOUR ASSESSOR

This certificate is awarded to

Ali Naghizadeh

Has successfully qualified as an odour assessor under the Australian Standard AS/NZS 4323.3:2001 criteria.

n-butanol threshold criteria (ppb): **$20 \le \chi \le 80$**
Assessor mean threshold (ppb): **46.9**

Standard deviation criteria: **Sr < 2.3**
Assessor standard deviation: **0.25**

The Odour Unit Pty Limited

James Schulz
NSW Coordinator

Date 25/07/2017

THE ODOUR UNIT

CERTIFICATE OF QUALIFICATION
ODOUR ASSESSOR

This certificate is awarded to

Ryan Thomsen

Has successfully qualified as an odour assessor under the Australian Standard AS/NZS 4323.3:2001 criteria.

n-butanol threshold criteria (ppb): **$20 \leq \chi \leq 80$**
Assessor mean threshold (ppb): **49.9**

Standard deviation criteria: **Sr < 2.3**
Assessor standard deviation: **0.2**

The Odour Unit Pty Limited

James Schulz
NSW Coordinator

Date 14/09/2017

APPENDIX B

COPERT Australia Input Parameters

Table A2-1 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 A2-2 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 A2-3 Distribution of Vehicles – Sectors and Subsectors

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

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

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

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

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

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

Sector	Subsector	Technology	Population (Annual)	Percentage
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 A2-4 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 C

Projected Morning Peak Traffic Volumes, Road Gradients and Estimated Emission Rates

Table C-1 Projected Morning Peak (8am – 9am) Traffic Volumes

Road Segment	Direction	Heavy Vehicles	Light Vehicles	Total
Bridge Road, Between Wentworth Park Road and Wattle Street	eastbound	27	821	848
Bridge Road, Between Wentworth Park Road and Wattle Street	westbound	27	937	964
Pyrmont Bridge Road between Wattle Street and Bank Street	eastbound	41	1,138	1,179
Pyrmont Bridge Road between Wattle Street and Bank Street	westbound	26	842	868
Pyrmont Bridge Road between Bank Street and Harris Street	eastbound	48	1,494	1,542
Pyrmont Bridge Road between Bank Street and Harris Street	westbound	28	626	654
Bank Street between Pyrmont Bridge Road and Miller Street	northbound	18	569	587
Bank Street between Pyrmont Bridge Road and Miller Street	southbound	54	496	550
Bank Street north of miller street	northbound	18	569	587
Bank Street north of miller street	southbound	11	273	284
Through Site Link	northbound	126	308	434
Through Site Link	southbound	5	90	95
WD Westbound Exit ramp to PBR	westbound	19	1,013	1,032
WD Eastbound Exit ramp to PBR	eastbound	31	778	809
Anzac Bridge, between Victoria Road and Exit to the Fish Market Pyrmont Bridge Road (PBR)	eastbound	243	5,848	6,091
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road	westbound	155	3,531	3,686
WD between Exit to Pyrmont Bridge Road and Exit to Allen Street	eastbound	221	5,214	5,435
WD between Exit to Allen Street and on ramp from PBR	eastbound	154	4,075	4,230
WD between Merge with On ramp from Druitt Street and Exit to PBR	westbound	112	3,125	3,237
WD between Exit to PBR and Merge with On ramp from PBR	westbound	109	2,524	2,632
WD Eastbound On ramp from PBR	eastbound	22	489	511
WD Westbound On ramp from PBR	westbound	37	1,133	1,170
Pyrmont Bridge Road between Wattle Street and Bank Street	westbound	26	842	868
Pyrmont Bridge Road between Wattle Street and Bank Street	eastbound	41	1,138	1,179
Miller Street	eastbound	0	105	105
Miller Street	westbound	19	231	249
Bank Street between Pyrmont Bridge Road and Miller Street	northbound	18	569	587
WD Eastbound Exit ramp to Allen Street	eastbound	50	648	698
WD between On Ramp from PBR and Exit to Bathurst Street	eastbound	117	2,862	2,979

Table C-2 Estimated Road Elevations and Gradients

Road Segment	Source Group	Elevation (m)	Lanes	Gradient (%)
Bridge Road, Between Wentworth Park Road and Wattle Street - eastbound	3	6	2	-
Bridge Road, Between Wentworth Park Road and Wattle Street - westbound	3	6	2	-
Pyrmont Bridge Road between Wattle Street and Bank Street - eastbound	3	8	2	-2.00
Pyrmont Bridge Road between Wattle Street and Bank Street - westbound	3	7	2	-
Pyrmont Bridge Road between Bank Street and Harris Street - eastbound	3	14	2	4.00
Pyrmont Bridge Road between Bank Street and Harris Street - westbound	3	13	2	-4.00
Bank Street between Pyrmont Bridge Road and Miller Street - northbound	3	11	2	-
Bank Street between Pyrmont Bridge Road and Miller Street - southbound	3	11	2	-
Bank Street between Pyrmont Bridge Road and Miller Street - Segment 2 - southbound	3	11	2	-
Bank Street north of miller street - northbound	3	14	2	-2.00
Bank Street north of miller street - southbound	3	14	2	2.00
Through Site Link - northbound	3	7	1	2.00
Through Site Link - southbound	3	7	1	-2.00
WD Westbound Exit ramp to PBR - westbound	2	12	4	-8.00
WD Westbound Exit ramp to PBR - Segment 2 - westbound	2	17	2	-6.00
WD Eastbound Exit ramp to PBR - eastbound	1	10	1	-
WD Eastbound Exit ramp to PBR - Segment 2 - eastbound	1	11	1	-4.00
WD Eastbound Exit ramp to PBR - Segment 3 - eastbound	1	17	1	-
WD Eastbound Exit ramp to PBR - Segment 4 - eastbound	1	17	1	2.00
Anzac Bridge, Btwn Victoria Road and Exit to the Fish Market Pyrmont Bridge Road (PBR) - eastbound	1	27	4	-
Anzac Bridge, Btwn Victoria Road and Exit to the Fish Market Pyrmont Bridge Road (PBR) - Segment 2 - eastbound	1	25	4	-4.00
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - westbound	2	21	4	6.00
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - Segment 2 - westbound	2	18	4	2.00
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - Segment 3 - westbound	2	22	4	-2.00
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - Segment 4 - westbound	2	25	4	-8.00
WD Btwn Exit to Pyrmont Bridge Road and Exit to Allen Street - eastbound	1	21	4	-6.00
WD Btwn Exit to Pyrmont Bridge Road and Exit to Allen Street - Segment 2 - eastbound	1	18	4	-4.00
WD Btwn Exit to Pyrmont Bridge Road and Exit to Allen Street - Segment 3 - eastbound	1	18	3	-
WD Btwn Exit to Allen Street and on ramp from PBR - eastbound	1	21	3	4.00

Road Segment	Source Group	Elevation (m)	Lanes	Gradient (%)
WD Btwn Merge with On ramp from Druitt Street and Exit to PBR - westbound	2	23	4	-2.00
WD Btwn Exit to PBR and Merge with On ramp from PBR - westbound	2	18	3	-
WD Eastbound On ramp from PBR - eastbound	1	10	2	6.00
WD Eastbound On ramp from PBR - Segment 2 - eastbound	1	19	1	6.00
WD Westbound On ramp from PBR - westbound	2	15	1	4.00
WD Westbound On ramp from PBR - Segment 2 - westbound	2	17	1	2.00
WD Westbound On ramp from PBR - Segment 3 - westbound	2	11	1	6.00
WD Westbound On ramp from PBR - Segment 4 - westbound	2	8	2	-
Pyrmont Bridge Road between Wattle Street and Bank Street - westbound	3	6	2	-
Pyrmont Bridge Road between Wattle Street and Bank Street - eastbound	3	6	3	-
Miller Street - eastbound	3	10	2	2.00
Miller Street - westbound	3	10	2	-2.00
Bank Street between Pyrmont Bridge Road and Miller Street - northbound	3	10	2	-
WD Eastbound Exit ramp to Allen Street - eastbound	3	17	1	-2.00
WD btwn On Ramp from PBR and Exit to Bathurst Street - eastbound	3	25	3	-

- Indicated gradient of less than 2%

Table C-3 Estimated Emission Rates

Road Segment	NOX (kg/km/h)		PM_{10} (kg/km/h)		$PM_{2.5}$ (kg/km/h)	
Vehicle Speed (km/h)	10	60	10	60	10	60
Bridge Road, Between Wentworth Park Road and Wattle Street - eastbound	1.061	0.814	0.063	0.042	0.053	0.035
Bridge Road, Between Wentworth Park Road and Wattle Street - westbound	1.206	0.925	0.071	0.048	0.060	0.040
Pyrmont Bridge Road between Wattle Street and Bank Street - eastbound	1.236	0.691	0.081	0.041	0.068	0.034
Pyrmont Bridge Road between Wattle Street and Bank Street - westbound	1.086	0.833	0.064	0.043	0.054	0.036
Pyrmont Bridge Road between Bank Street and Harris Street - eastbound	2.746	3.349	0.182	0.182	0.152	0.149
Pyrmont Bridge Road between Bank Street and Harris Street - westbound	0.565	0.245	0.043	0.017	0.036	0.014
Bank Street between Pyrmont Bridge Road and Miller Street - northbound	0.734	0.564	0.043	0.029	0.036	0.024
Bank Street between Pyrmont Bridge Road and Miller Street - southbound	0.688	0.528	0.041	0.028	0.034	0.023

Road Segment	NOX (kg/km/h)		PM_{10} (kg/km/h)		$PM_{2.5}$ (kg/km/h)	
Bank Street between Pyrmont Bridge Road and Miller Street - Segment 2 - southbound	0.688	0.528	0.041	0.028	0.034	0.023
Bank Street north of miller street - northbound	0.616	0.344	0.040	0.020	0.034	0.017
Bank Street north of miller street - southbound	0.430	0.446	0.027	0.021	0.023	0.017
Through Site Link - northbound	0.657	0.681	0.041	0.032	0.035	0.026
Through Site Link - southbound	0.100	0.056	0.007	0.003	0.005	0.003
WD Westbound Exit ramp to PBR - westbound	0.769	0.251	0.065	0.023	0.054	0.019
WD Westbound Exit ramp to PBR - Segment 2 - westbound	0.769	0.251	0.065	0.023	0.054	0.019
WD Eastbound Exit ramp to PBR - eastbound	1.012	0.777	0.060	0.040	0.050	0.033
WD Eastbound Exit ramp to PBR - Segment 2 - eastbound	0.699	0.304	0.053	0.021	0.044	0.017
WD Eastbound Exit ramp to PBR - Segment 3 - eastbound	1.012	0.777	0.060	0.040	0.050	0.033
WD Eastbound Exit ramp to PBR - Segment 4 - eastbound	1.224	1.269	0.077	0.060	0.064	0.049
Anzac Bridge, Btwn Victoria Road and Exit to the Fish Market Pyrmont Bridge Road (PBR) - eastbound	7.619	5.847	0.451	0.305	0.378	0.250
Anzac Bridge, Btwn Victoria Road and Exit to the Fish Market Pyrmont Bridge Road (PBR) - Segment 2 - eastbound	5.263	2.285	0.399	0.156	0.334	0.128
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - westbound	7.622	11.003	0.453	0.682	0.379	0.560
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - Segment 2 - westbound	5.577	5.782	0.350	0.273	0.294	0.224
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - Segment 3 - westbound	3.866	2.160	0.252	0.128	0.212	0.105
Anzac Bridge, Btw Merge with On ramp from PBR and Victoria Road - Segment 4 - westbound	2.748	0.898	0.231	0.084	0.193	0.069
WD Btwn Exit to Pyrmont Bridge Road and Exit to Allen Street - eastbound	4.052	1.324	0.340	0.124	0.285	0.101
WD Btwn Exit to Pyrmont Bridge Road and Exit to Allen Street - Segment 2 - eastbound	4.697	2.039	0.356	0.139	0.298	0.114
WD Btwn Exit to Pyrmont Bridge Road and Exit to Allen Street - Segment 3 - eastbound	6.799	5.218	0.402	0.272	0.337	0.223
WD Btwn Exit to Allen Street and on ramp from PBR - eastbound	7.534	9.187	0.499	0.500	0.418	0.410
WD Btwn Merge with On ramp from Druitt Street and Exit to PBR - westbound	3.394	1.897	0.222	0.113	0.186	0.092
WD Btwn Exit to PBR and Merge with On ramp from PBR - westbound	3.293	2.527	0.195	0.132	0.163	0.108
WD Eastbound On ramp from PBR - eastbound	1.057	1.526	0.063	0.095	0.053	0.078
WD Eastbound On ramp from PBR - Segment 2 - eastbound	1.057	1.526	0.063	0.095	0.053	0.078
WD Westbound On ramp from PBR - westbound	2.084	2.542	0.138	0.138	0.116	0.113
WD Westbound On ramp from PBR - Segment 2 - westbound	1.770	1.835	0.111	0.087	0.093	0.071
WD Westbound On ramp from PBR - Segment 3 - westbound	2.419	3.493	0.144	0.217	0.120	0.178
WD Westbound On ramp from PBR - Segment 4 - westbound	1.464	1.123	0.087	0.059	0.073	0.048

Road Segment	NOX (kg/km/h)		PM_{10} (kg/km/h)		$PM_{2.5}$ (kg/km/h)	
Pyrmont Bridge Road between Wattle Street and Bank Street - westbound	1.086	0.833	0.064	0.043	0.054	0.036
Pyrmont Bridge Road between Wattle Street and Bank Street - eastbound	1.475	1.132	0.087	0.059	0.073	0.048
Miller Street - eastbound	0.159	0.165	0.010	0.008	0.008	0.006
Miller Street - westbound	0.262	0.146	0.017	0.009	0.014	0.007
Bank Street between Pyrmont Bridge Road and Miller Street - northbound	0.734	0.564	0.043	0.029	0.036	0.024
WD Eastbound Exit ramp to Allen Street - eastbound	0.732	0.409	0.048	0.024	0.040	0.020
WD btwn On Ramp from PBR and Exit to Bathurst Street - eastbound	3.726	2.859	0.220	0.149	0.185	0.122

APPENDIX D

Selection of Representative Meteorological Data

D.1 SELECTION OF REPRESENTATIVE METEOROLOGICAL DATA

Once emitted to atmosphere, emissions will:

- Rise according to the momentum and buoyancy of the emission at the discharge point relative to the prevailing atmospheric conditions;
- Be adverted from the source according to the strength and direction of the wind at the height which the plume has risen in the atmosphere;
- Be diluted due to mixing with the ambient air, according to the intensity of turbulence; and
- (Potentially) be chemically transformed and/or depleted by deposition processes.

Dispersion is the combined effect of these processes.

Dispersion modelling is used as a tool to simulate the air quality effects of specific emission sources, given the meteorology typical for a local area together with the expected emissions. Selection of a year when the meteorological data is atypical means that the resultant predictions may not appropriately represent the most likely air quality impacts. Therefore, in dispersion modelling, one of the key considerations is the representative nature of the meteorological data used.

The year of meteorological data used for the dispersion modelling was selected by reviewing the most recent five years of historical surface observations at Sydney Airport AWS (2015 to 2019 inclusive) to determine the year that is most representative of average conditions. Wind direction, wind speed and ambient temperature were compared to averages for the region to determine the most representative year.

Data collected from 2015 to 2019 is summarised in **Figure D1** to **Figure D3**. Examination of the data indicates the following:

- **Figure D1** indicates relatively similar wind roses for all years analysed;
- **Figure D2** indicates that 2017, 2018 and 2019 exhibit wind speeds that are closest to the long term average; and
- **Figure D3** shows that temperatures are relatively similar for all five years analysed.

It is noted that background air quality data recorded in 2019 is not representative of typical conditions for the region due to significant bushfires and dust storms (refer **Section 7**). Further, the Rozelle AQMS was offline for recommissioning for a three month period in 2018. Thus the year 2017 was selected for use in meteorological/dispersion modelling.

Figure D1 Frequency of Winds at Sydney Airport AWS for 2015 – 2019

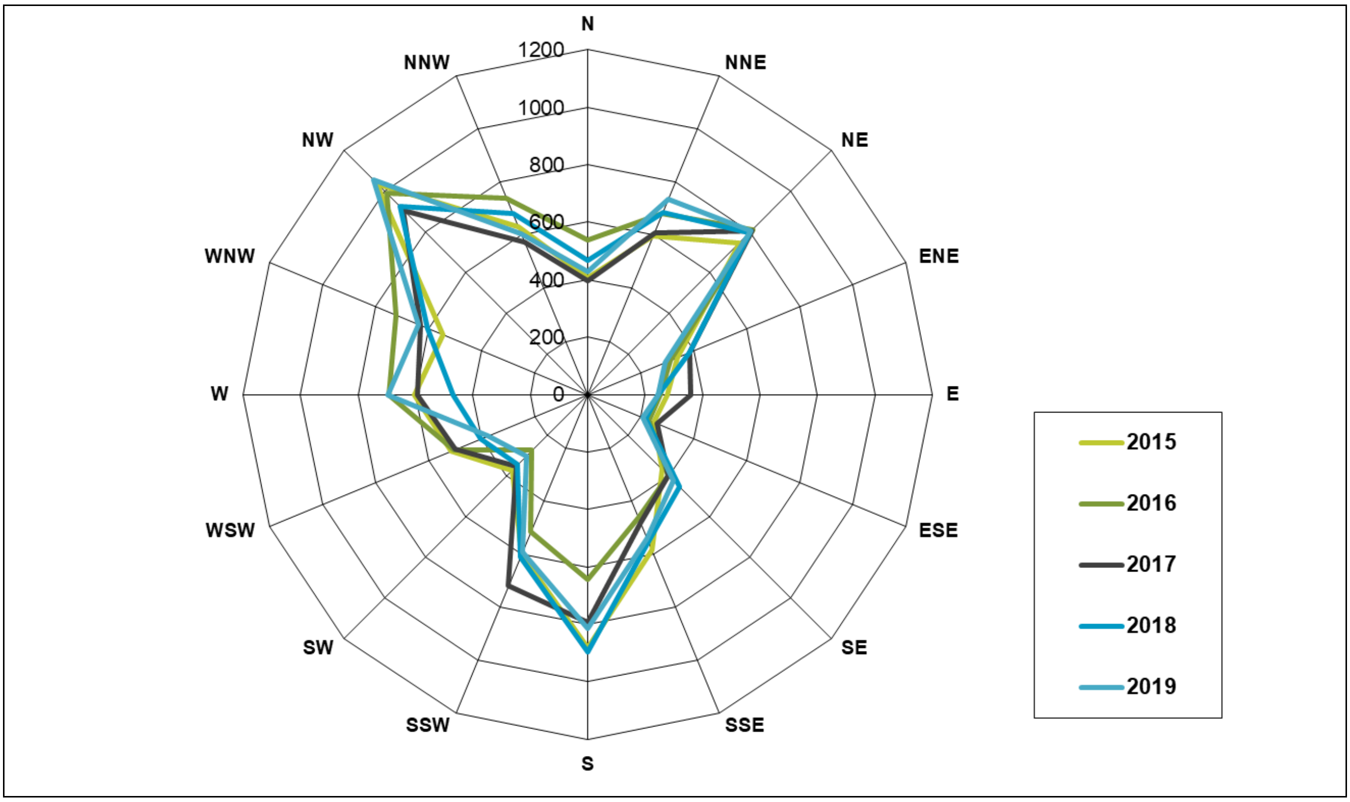


Figure D2 Monthly Average Wind Speed at Sydney Airport AWS for 2015 – 2019

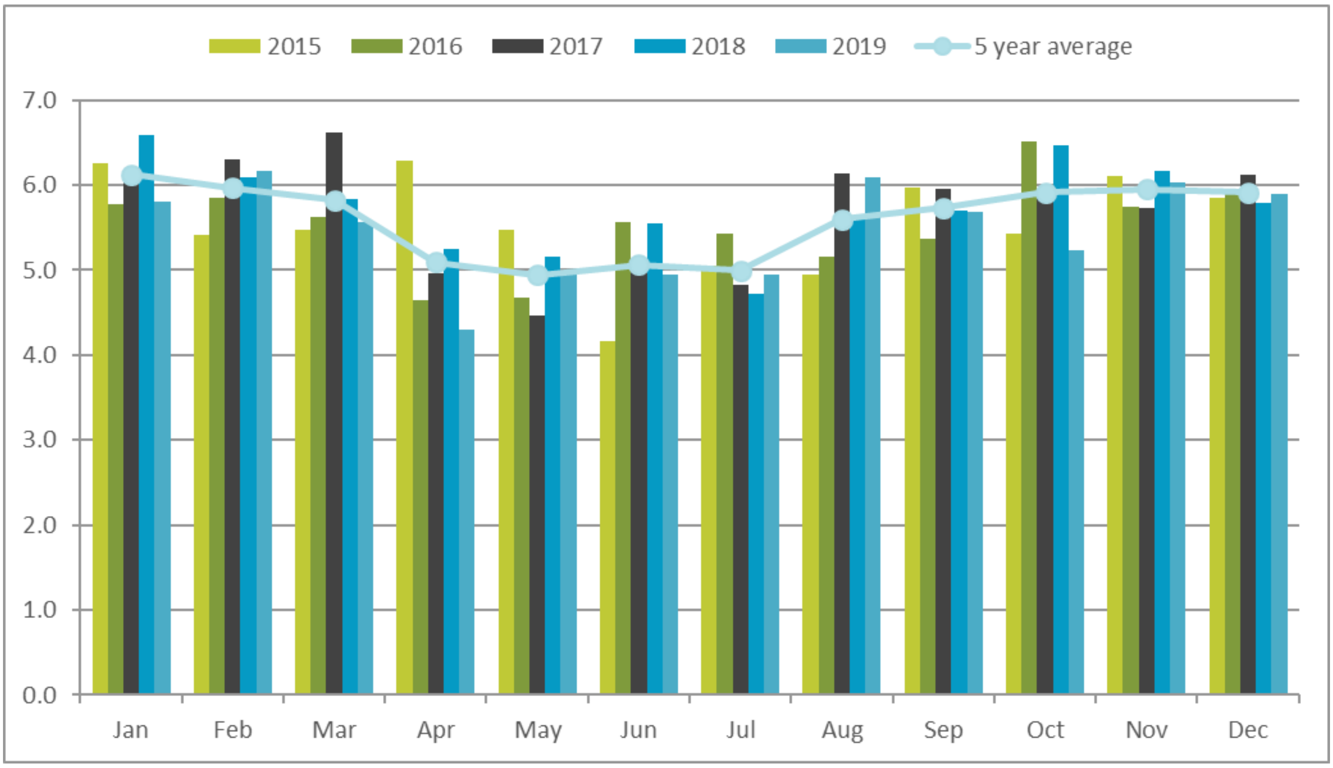
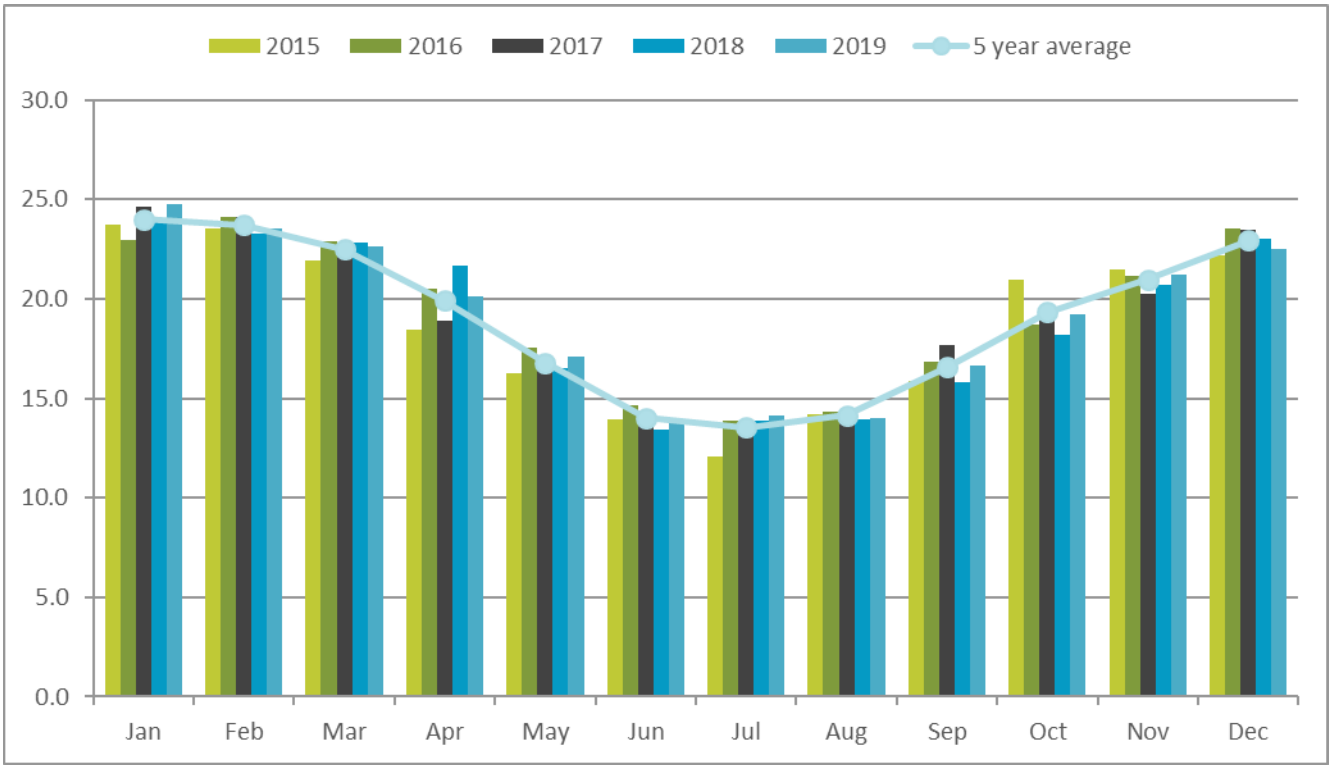


Figure D3 Monthly Average Temperature at Sydney Airport AWS for 2015 – 2019



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