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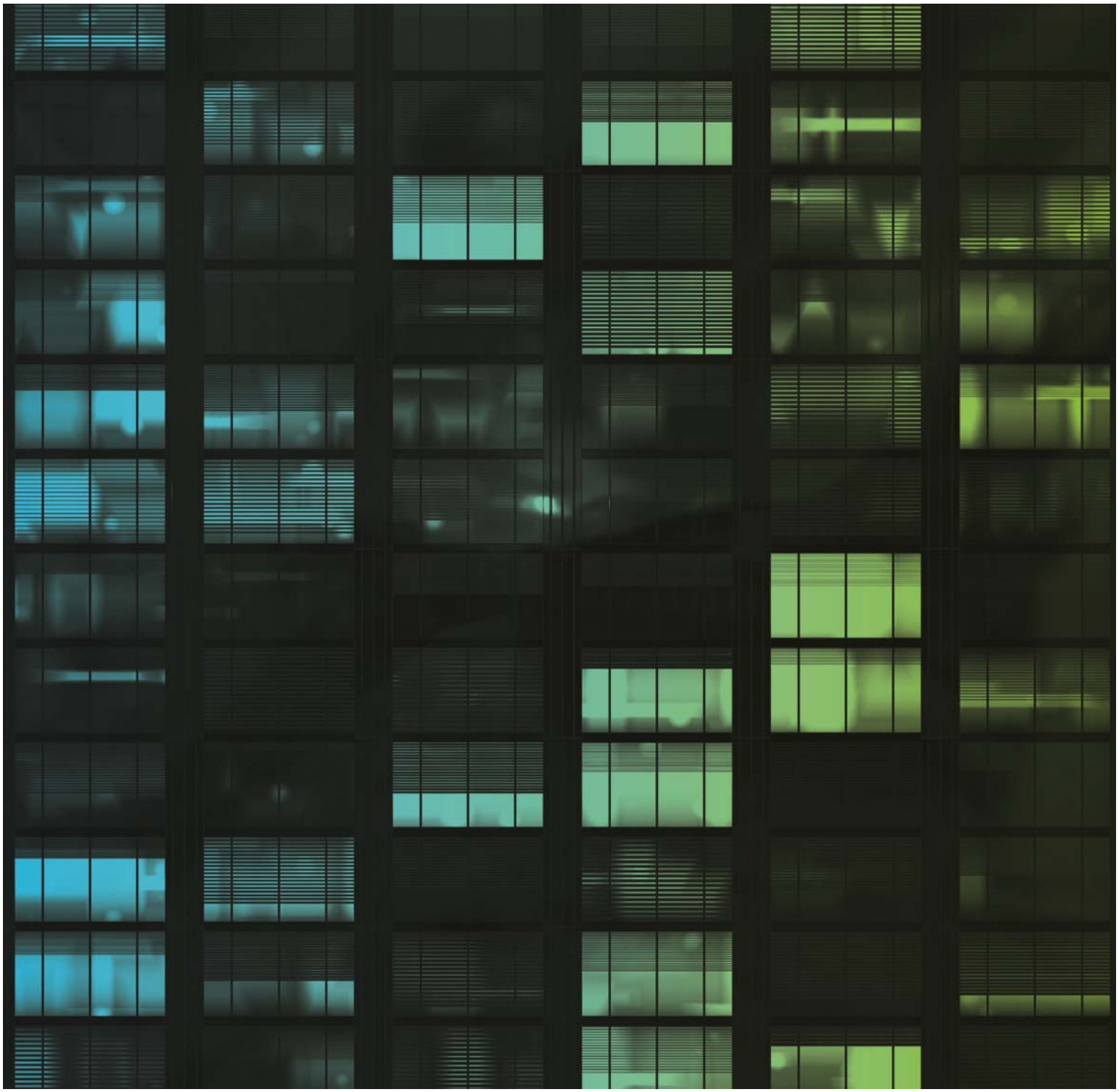
Lend Lease Buildings Pty Limited
12-Aug-2016

Air Quality Impact Assessment

One Sydney Harbour - Building R5 - State Significant Development Application



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One Sydney Harbour - Building R5 - State Significant Development Application

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Quality Information

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Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	23-Jul-2015	Draft Report	David Rollings Principal Engineer	
B	30-Oct-2015	Final Report	David Rollings Principal Engineer	
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E	12-Aug-2016	Final Report (revised)	David Rollings Associate Director Air Quality	

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Glossary of Terms

Term	Description
BTEX	Benzene, toluene, ethylbenzene and xylenes
DEC	Department of Environment and Conservation
EPA	Environment Protection Authority
EPL	Environment Protection Licence
Lendlease	Lendlease Buildings Pty Limited
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
PM_{10}	Particulate matter with an average diameter less than 10 micrometres
Site	Area associated with the Stage 1B Development Application. The Site is located on land generally known and identified in the approved Concept Plan MP06_0162 (as modified) as Blocks 4A and 4B and part of the public domain area between those blocks and Block 5.
TSP	Total suspended particulates
USEPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds

1.0 Introduction

This Air Quality Impact Assessment (AQIA) report supports State Significant Development Applications (SSD 6966) submitted to the Minister for Planning pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Development Applications (DAs) seek approval for construction of the Stage 1B Residential Building R5 and associated works at Barangaroo South as described below.

1.1 Overview of Proposed Development

The Residential Building R5 DA seeks approval for the construction and use of a 29 storey residential flat building comprising 151 apartments, ground floor retail, the allocation of car parking, services, plant and storage within the Stage 1B Basement (subject of a separate concurrent DA), and the construction of ancillary landscaping and temporary public domain.

Approval for the construction of Residential Building R5's core and associated plant and services within the basement is being sought as part of the concurrent Stage 1B Basement DA and do not form part of this DA.

1.2 Scope of Works

The Secretary's Environmental Assessment Requirements (SEARs) were issued for the project on 2 April 2015. Requirement 15 of each SEAR relates to air and odour, and specifies that an AQIA should be provided, which must:

- Be prepared in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales 2005;
- Consider the requirements of the *Protection of the Environment Operations (Clean Air) Regulation 2010*;
- Cover, where applicable:
    - The identification of the pollutants of concern (referred to in this report as chemicals of potential concern), including dust and odours;
    - The identification and assessment of all relevant fugitive and point source emissions; and
    - Proposed air quality management and monitoring procedures during the works.

This AQIA was prepared to address the above requirements.

The construction of the residential buildings of the Stage 1B development will overlap. Based on staging information provided by Lendlease, the following concurrent activities are expected to represent the worst-case emissions during the residential building construction works:

- Construction of the R4A building;
- Construction of the R4B building;
- Construction of the R5 building; and
- Operation of the on-site water treatment plant.

This will occur between August 2021 and April 2022. As such, this report presents the findings of the worst-case emissions assessment for the residential building construction for the Stage 1B development as a whole.

Dispersion modelling of the proposed overlapping activities was undertaken using the CALPUFF model. The assessment was undertaken in accordance with and/or in reference to the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales 2005* (DEC 2005)

Meteorological and terrain files and receptor locations used in the dispersion modelling were the same as those used for the assessment of the Hickson Road remediation works (AECOM, 2014) and the Stage 1B Basement works (AECOM, 2015). The location and number of sensitive receptors used in the dispersion modelling has been revised to account for the completed sections of the Stage 1A Barangaroo Development including ground level and elevated receptors located within the T1 commercial tower, residential towers R8 and R9 and childcare facilities located within the T1 podium and the AON podium. Relevant source characteristics used in previous assessments undertaken by AECOM for the Barangaroo development were used in this assessment for consistency.

2.0 Site Description

2.1 Site Location

Barangaroo is located on the north western edge of the Sydney Central Business District (CBD), bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east, and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Barangaroo Reserve, Barangaroo Central and Barangaroo South.

The R5 DA Site area is located within Barangaroo South as shown in Figure 1. The DA Site is located on land generally known and identified in the approved Concept Plan as Block 4B.

2.2 Role of Lendlease

Lendlease was contracted by the Barangaroo Delivery Authority to undertake remediation of portions of the Barangaroo site, and was appointed by the Barangaroo Delivery Authority as the Proponent to undertake the development for Barangaroo South.

2.3 Surrounding Land Use and Receptors

The Site is bordered by Sydney Harbour on the western side and by Hickson Road to the east. The closest off-site receptors are located approximately 25 m to the east of the site boundary, on Hickson Road, and consist of residential and commercial properties. A number of finger wharves containing a mixture of residential and commercial developments are located directly opposite the Site, the closest being approximately 250 m west of the site, while the residential suburb of Balmain East is located approximately 400 m to the west of the northern end of the site. The Stage 1A works are expected to be completed at the time the Stage 1B works commence; as such, receptors will also be expected to be located within that area of the Barangaroo site, which is adjacent to the Stage 1B Site. Details of the sensitive receptors considered in this assessment are provided in **Section 5.6.**

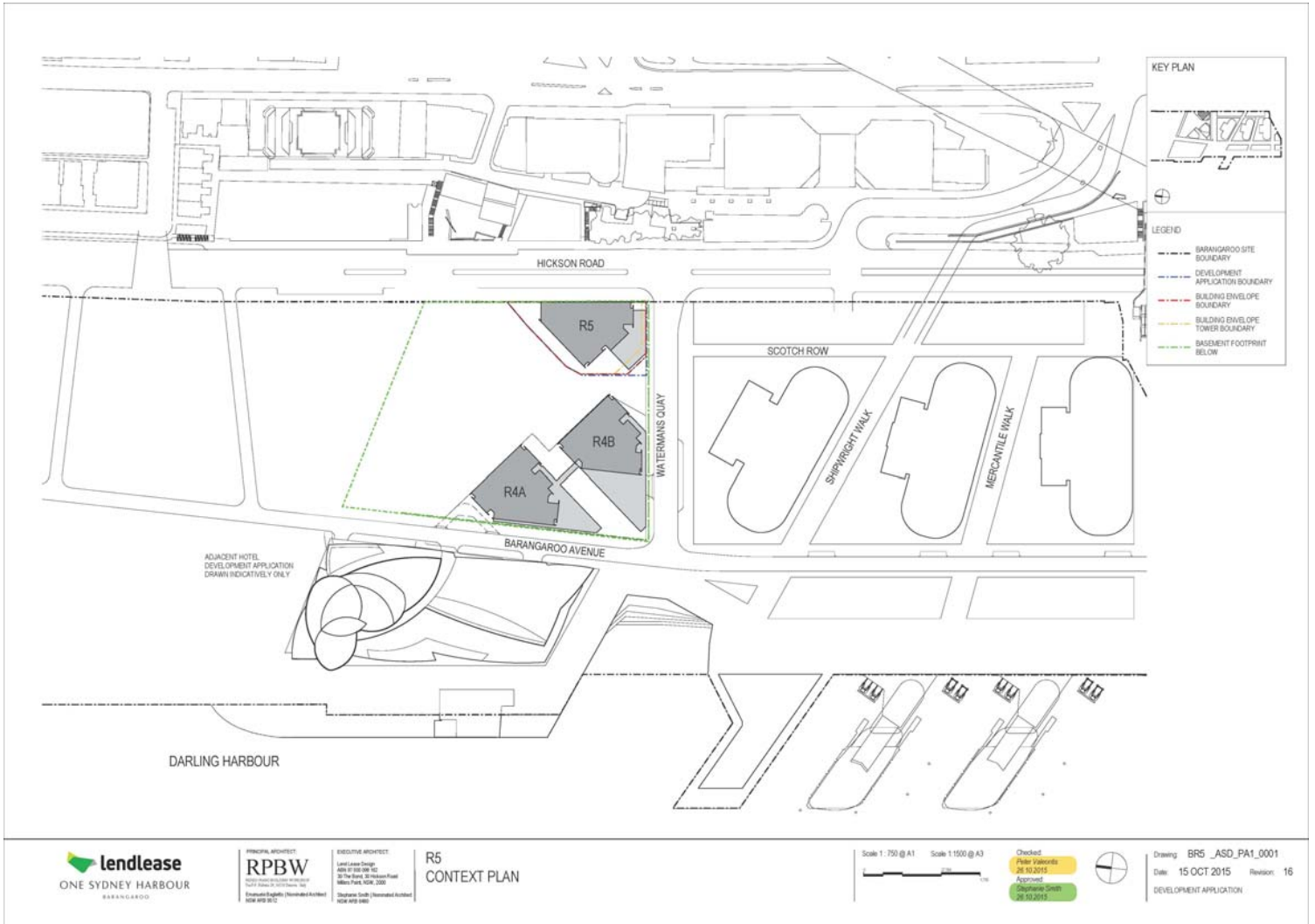

Figure 1 Stage 1B Buildings Site Location Plan

3.0 Project Description

3.1 Environmental Controls

Due to the scale of the works and proximity to sensitive receptors, the effectiveness of environmental controls and environmental management is critical to the overall success of the project. The EPA recommended that environmental management at Barangaroo should focus on source controls rather than end of pipe controls. Primary management was, therefore, the focus of proposed mitigation strategies; a number of secondary (end of pipe) controls are also recommended where necessary.

Sediment Controls

Sediment can lead to dust generation; as such, management measures for sediment are management measures for air emissions. In accordance with the EPA recommendations, the most effective sediment management measures will be based on source controls. As a contingency for the failure of source controls, a number of secondary controls should be implemented. Relevant primary (source) controls and secondary controls recommended in the *City of Sydney Guidelines to Erosion and Sediment Control on Building Sites* are provided in **Table 1.**

Table 1 Sediment Control Options

Category	Control Device	Location
Source controls	Sediment sumps	Perimeter of construction area
	Runoff diversion	Perimeter of construction area
	Tarping/mulching/gravel armouring	Material stockpiles, exposed soils, haulage trucks
Secondary controls	Wheel wash	Site exit
	Shaker grids	Site exit
	Sediment fence	Stormwater inlets, stockpile perimeters
	Sediment sock	Stormwater inlets, stockpile perimeters
	Straw bales	Stormwater inlets, stockpile perimeters

3.2 Potential Emission Sources

Emissions associated with the works assessed in this AQIA can be grouped into two categories: combustion emissions from plant and equipment (particulates, NO_2 and VOCs), and emissions from the water treatment plant. It should be noted that the water treatment plant is part of a separate, already approved, phase of the Barangaroo development.

Details of plant and equipment expected to be used during the construction works considered in this assessment were provided by Lendlease. Further emission source details are provided in **Section 5.4**.

3.3 Chemicals of Potential Concern

The combustion of diesel fuel generates a range of pollutant emissions, primarily oxides of nitrogen (NO_X) and PM_{10}, as well as volatile organic compounds (VOCs) (particularly benzene, toluene, ethylbenzene, and xylenes, which are known collectively as BTEX). These pollutants were considered in this assessment. The potential health effects of the chemicals of potential interest are summarised in **Appendix A**.

Other emissions, such as carbon monoxide and sulfur dioxide, are also emitted from combustion engines, but were not assessed as they were considered to be lower risk than particulate and NO_X emissions due to their generally higher assessment criteria. While the Stage 1B site is located within a currently contaminated area, the remediation works will be completed before the Stage 1B works commence. Emissions of contaminants, including odour, were not considered likely to occur during the construction of the Stage 1B buildings; as such, emissions of toxic pollutants and odour associated with contaminated soil were not assessed.

The potential health effects of the pollutants of interest are summarised in **Appendix C**. It should be noted that $PM_{2.5}$ was not assessed. Following discussion with the EPA, it was decided that the relative contribution of the site would be low compared to existing $PM_{2.5}$ sources in the area, specifically local traffic, and that this pollutant did not, therefore, require assessment.

Asbestos was not assessed in this AQIA nor is it expected to be encountered as part of the construction activities. Management of asbestos encountered on the site would be in accordance with the site Asbestos Management Plan to be prepared for the works, which should include monitoring works.

3.4 Impact Assessment Criteria

The EPA has specified ground level concentration criteria that are intended to minimise the adverse effects of airborne pollutants on sensitive receptors (DEC, 2005). The ambient air quality criteria for the pollutants considered in this assessment are shown in **Table 2** (combustion products, particulates and air toxics). The EPA does not have a criterion for VOCs; the criteria for the most relevant individual VOC species are presented in the table.

Table 2 EPA Impact Assessment Criteria – Combustion Products, Dust and Soil Contaminants

Pollutant	Averaging Period	Criteria (μg/m^3)
Combustion Products and Dust		
Nitrogen dioxide (NO_2)	1 hour	246
	Annual	62
Total suspended particulates (TSP)	Annual	90
Fine particulate matter (PM_{10})	24 hours	50
	Annual	30
Air Toxics		
Benzene	1 hour	29
Ethylbenzene	1 hour	8,000
Toluene	1 hour	360
Xylenes	1 hour	190
Naphthalene	1 hour	440*
*As adopted for previous Barangaroo assessments undertaken by AECOM (e.g. AECOM, 2010). Criterion is equivalent to the odour threshold for naphthalene.		

3.5 Indicative Staging

The indicative staging of the Barangaroo works, provided by Lendlease, is summarised in **Table 3**.

Table 3 Barangaroo Development Staging Summary

Project	Proposed Dates
Barangaroo Reserve Main Works	Apr 2013 – Jul 2015
T2 Commercial Building	May 2013 – Oct 2015
Concrete Batch Plant Operation	Sep 2013 – Sep 2015
T3 Commercial Building	Oct 2013 – Jun 2016
R8/R9 Residential Buildings Construction	Jan 2014 – Nov 2015
T1 Commercial Building	Mar 2014 – Oct 2016
Barangaroo Central – Waterfront Promenade	Mar 2014 – Jul 2015
Stage 1A Public Domain works	Jul 2014 – Nov 2016

Project	Proposed Dates
City Walk Link Bridge	Oct 2014 – Jun 2015
R1 Construction	Jul 2016 – Nov 2017
Crown Hotel Construction	Jul 2016 – Jan 2021
Block 5 Remediation Works	Dec 2016 – Aug 2017
R7 Construction	Dec 2015 – Oct 2016
C2/C6 Above GF Only (GF + 6 floors)	Feb 2016 – Apr 2017
C8/H2 (C1) Above GF Only (GF + 6 floors)	Feb 2018 – Aug 2019
Block 4 Remediation Works	Dec 2016 – Dec 2019
Stage 1B Basement (excavation and construction)	Jun 2018 – Mar 2021
Wynyard Walk Bridge	Apr 2013 – Dec 2016
Barangaroo Ferry Wharf	Feb 2016 – Nov 2016
R4A	Dec 2019 – Apr 2022
R4B	Jan 2021 – Jan 2023
R5	Aug 2021 – Jul 2023

This assessment considered the emissions associated with the Stage 1B Building construction works (which form part of the Stage 1B development), which, based on staging information provided by Lendlease, will commence between August 2021 and April 2022. During this period, the concurrently occurring activity would consist of construction of the R4A, R4B and R5 buildings and the operation of the water treatment plant; no other construction activities at the Barangaroo site as a whole were expected to overlap with this period.

4.0 Existing Environment

4.1 Regional Air Quality

The EPA operates a network of air quality monitoring stations around the state. The closest station to the site is located at Rozelle (approximately 3.5 km to the west). Ambient pollutant concentrations recorded at this station in 2013 were adopted for this assessment for consistency with the meteorological data.

Three exceedances of the EPA's 24 hour PM_{10} assessment criterion were recorded at Rozelle in 2013, relating to concentrations of 58.5 $\mu g/m^3$ (the maximum recorded 24 hour PM_{10} concentration as shown in **Table 4**), 57.0 $\mu g/m^3$, and 50.7 $\mu g/m^3$. As such, the cumulative concentrations predicted for this assessment will contain three exceedances due to elevated background concentrations.

Ambient TSP concentrations have not been monitored at Rozelle since 2004. The ratio of PM_{10} to TSP from Rozelle for 2004 (the last recorded year of TSP monitoring at Rozelle) was used with the ambient annual PM_{10} concentration from Rozelle in 2013 to estimate the annual TSP concentration. The ratio of PM_{10} to TSP for 2004 was calculated to be 49 % at Rozelle (i.e. 49 % of TSP in the region monitored by Rozelle was PM_{10}), which, when applied to the 2013 ambient annual PM_{10} concentration of 18.3 $\mu g/m^3$, equates to an annual TSP concentration of 37.4 $\mu g/m^3$.

The background concentrations used in the AQIA are summarised in **Table 4**.

Table 4 Ambient Pollutant Concentrations, Rozelle Monitoring Station

Pollutant	Averaging Period	Maximum Background Concentration ($\mu g/m^3$)	Assessment Criteria ($\mu g/m^3$)
NO_2 [1]	1 hour maximum	131.6	246
	Annual	21.4	62
PM_{10}	24 hour maximum	**58.5**	50
	Annual	18.3	30
TSP [2]	Annual	37.4	90
Ozone [3]	1 hour maximum	143.1	214
	Annual	33.6	-

[1] NO_2 contemporaneous background data used to predict background concentrations using the OLM detailed in **Section 5.8**.
[2] Calculated from annual PM10 concentration as described in text.
[3] Ozone concentrations used for NO_2 contemporaneous assessment calculations. Ozone was not modelled as a pollutant.

4.2 Climate

The Bureau of Meteorology (BOM) collects meteorological data from various sites in the Sydney Basin. The station at Observatory Hill is less than 200 m from the eastern boundary of the Barangaroo Site, while Fort Denison is approximately 2 km to the east of the site. The meteorological data collected from these two stations is complementary and, together, provides an indication of the climate in the immediate area around Barangaroo. Long term data averages recorded between 1859 and June 2014 are summarised in **Appendix B**.

Average maximum temperatures in summer range from 25.2 °C to 25.9 °C, while minimum temperatures range from 17.5 °C to 18.8 °C. In winter, the average maximum temperature ranges from 16.3 °C to 17.8 °C and the average minimum temperature ranges from 8.0 °C to 9.3 °C.

The annual average humidity reading collected at 9 am from the site is 69 %, and at 3 pm the annual average is 57 %. Rainfall data collected at Observatory Hill shows, on average, that the wettest months are January to June, with average rainfall of greater than 100 mm for each of the intervening months.

4.3 Terrain

The Barangaroo Site is located on Sydney Harbour. The ground surface of the entire Barangaroo Site is at an elevation of approximately 2 - 5 m (AHD). The surrounding landform (outside the bounds of the site) rises rapidly to the east, with a 10 m high sandstone cliff situated east of Hickson Road and Sussex Street. This is the most substantial natural terrain feature in the area; high rise buildings may potentially also affect wind patterns in the Site.

5.0 Dispersion Modelling Methodology

5.1 Overview

Dispersion modelling was undertaken to predict the potential effects of the worst-case construction activities associated with the Stage 1B Building Development. The following sections outline details of the dispersion model used and its inputs (specifically meteorology, terrain, modelling scenarios, source characteristics and emission rates), sensitive receptor locations, and the methodology used in the estimation of pollutant concentrations.

The modelling was conducted in accordance with and/or in consideration of the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC, 2005).

5.2 Dispersion Model

The CALPUFF dispersion model was used in accordance with the EPA Approved Methods (DEC, 2005). CALPUFF is a non steady-state, three-dimensional Gaussian puff model developed for the US Environmental Protection Agency (USEPA) for use in situations where basic Gaussian plume models are not effective, such as areas with complex meteorological or topographical conditions, including coastal areas with re-circulating sea breezes. Input parameters used in the CALPUFF dispersion modelling are summarised in **Table 5**.

Table 5 CALPUFF Input Parameters

Parameter	Input
CALPUFF version	6.42
Modelling domain	40 km x 40 km with 0.3 km spacing
Terrain data	Included in CALMET
Building wake data	Not included
Dispersion algorithm	Dispersion coeff. used turbulence computer from micrometeorology. Used PDF method for sigma-z in the convective BL.
Hours modelled	8760 hours (365 days)
Meteorological data period	1 January 2013 – 31 December 2013

Inputs to CALPUFF are discussed in the following sections.

5.2.1 Meteorology

The CALMET meteorological model uses meteorological observations to generate three dimensional wind fields on an hourly time step at a grid of points covering the area under investigation. Topographical features and land use factors are then used to further refine the wind fields, which are subsequently used in the CALPUFF dispersion model.

Local meteorological and topographical data were used to develop the CALMET wind fields to ensure the data used in the dispersion modelling were representative of local conditions. Prognostic meteorological data generated by the WRF model and the following local meteorological data recorded by the BOM were used as inputs to CALMET:

- Observatory Hill - rainfall and temperature;
- Fort Denison - wind speed and direction; and
- Sydney Airport - wind speed, wind direction, temperature, relative humidity and solar radiation.

The WRF data, which were prepared by Lakes Environmental, were used to define the upper air meteorology for the area surrounding Barangaroo, and were entered into CALMET for the site meteorological conditions together with the surface meteorological data recorded at Sydney Airport, Observatory Hill and Fort Denison. Analyses of the data are provided in **Appendix B**. The WRF data were prepared for a 50 x 50 km grid with a spacing of 4 km for the period 1 January 2013 – 31 December 2013, centred on latitude: 33.8675 S and longitude: 151.13 E with a WGS datum. The WRF file was prepared with 35 vertical levels; the lowest level was approximately 20 metres above ground level.

5.2.2 Terrain

The NASA Shuttle Radar Topographic Mission (SRTM) provides digital elevation data (DEM) for over 80 % of the globe. The SRTM data are available as 3 arc second DEMs, which provide a resolution of approximately 90 m. The vertical error of the DEMs is reported to be less than 16 m.

Digital terrain data required by CALMET were obtained from the global SRTM database for the modelling domain.

5.3 Modelling Scenarios

A single scenario was assessed, which considered the expected highest activity levels associated with the Stage 1B Building construction (post excavation works). The concurrent activities expected to occur during the period of greatest activity were:

- Construction of the R4A building;
- Construction of the R4B building;
- Construction of the R5 building; and
- Operation of the on-site water treatment plant.

All other activities on the Barangaroo site are expected to be completed when the highest level of emissions from the building construction (excluding excavation works) are expected to occur. The worst-case excavation works associated with the Stage 1B development were assessed in AECOM (2016).

5.3.1 Assumptions

Emissions associated with the water treatment plant were assumed to be the same as those used in AECOM (2011) for a water flow rate of 25 L/s.

Emissions consisted of combustion emissions from trucks, forklifts and concrete pumps, and the water treatment plant emissions. At this stage of development, all excavation works should be completed; as such, no wind erosion would be expected. Furthermore, the trafficking areas were expected to be hardstand, and not a source of wheel-generated dust.

Emission factors for specific construction plant and equipment were sourced from a report on a large construction project (Pacific Institute, 2001), which was accepted by the US EPA and references the South Coast Air Quality Management District (California Environmental Quality Act) Air Quality Handbook. Stack parameters for trucks, which were used in previous assessments (SKM, 2005), were also used for the point sources. Further assumptions are provided in the following sections.

5.4 Source Characteristics

The source characteristics used in the dispersion modelling are described in the following sections. Information regarding the type and number of plant and equipment that would be used in the works was provided by Lendlease. Emissions of all sources were assumed to occur between the hours of 7 am and 7 pm; wind erosion was assumed to occur constantly.

Emissions can be grouped into two categories: combustion emissions from plant and equipment; and emissions from the water treatment plant.

5.4.1 Combustion Emissions

Lendlease indicated that each building would use one forklift and one concrete pump for construction works; all other plant and equipment would be electrically powered. Characteristics of these sources, shown in **Table 6,** were the same as those used in previous AECOM assessments for Barangaroo (e.g. AECOM, 2014).

Table 6 Emission Source Characteristics – R4A, R4B and R5 Buildings

Source	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
Forklifts	3	0.3	14.6	624.2

Source	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
Concrete pumps	3	0.3	14.6	624.2

Trucks would deliver materials to the building sites and the water treatment plant. The following parameters, used in previous Barangaroo assessments, were used for the truck sources.

Table 7 Truck Emission Characteristics

Parameters	Value	Units
Effective stack height	4	m
Stack diameter	0.1	m
Exhaust gas temperature	349.15	K
Exhaust gas velocity	10	m/s

5.4.2 Water Treatment Plant

The on-site water treatment plant will be operational during the Stage 1B development works. The plant will have two point emission sources: the inlet tank displacement valve and the air strippers discharge stack. Details of these sources are provided in **Table 8**. It should be noted that the modelled emissions are expected to represent emissions during remediation works; at the time the Stage 1B works are undertaken, the contaminant levels in the water fed to the treatment plant are expected to be lower.

Table 8 Water Treatment Plant Stack Characteristics

Source	Stack Height (m)	Diameter (m)	Stack Velocity (m/s)	Exit Temperature (K)
Inlet tank displacement valve	2.77	0.10	3.2	288.75
Air strippers discharge stack	2.77	0.42	8.2	288.75

5.5 Emissions

Emissions from the plant and equipment to be used on site were estimated using factors published by the Australian Government for use in the National Pollutant Inventory, measured vehicle emissions from the M5 Freeway Project (SKM, 2002) and emission factors published for a large construction project (Pacific Institute, 2001).

Expected operational times for the construction works are 7 am – 7 pm Monday to Friday and 7 am – 5 pm Saturdays. No works are expected on Sundays. For modelling purposes, emission rates were entered into the model for all activities for the hours 7 am to 7 pm except for the water treatment plant, which was modelled with constant emissions.

As emission factors were not provided for TSP, TSP emissions were assumed to equal PM_{10} emissions.

5.5.1 Combustion Emissions

R4A, R4B and R5 were each assessed with a one forklift and a single concrete pump as combustion sources. The emission rates for these sources are provided in the following table.

It should be noted that forklifts and concrete pumps are not typically considered under the *Protection of the Environment (Clean Air) Regulation 2010 (NSW)*. If the general standards of concentration for scheduled premises: general activities and plant were to be applied to this equipment, however, the Group 6 limits would apply. These limits are 50 mg/m^3 for solid particles and 350 mg/m^3 for NO_2, nitric oxide or both as NO_2 equivalent. The emissions of NO_X from the concrete pumps used in this assessment are equivalent to the allowable emissions under the *Protection of the Environment (Clean Air) Regulation 2010 (NSW)*, while emissions of NO_X from the forklifts and particulates from both forklifts and concrete pumps are below the regulation limits of 0.05 g/s for solid particles and 0.36 g/s for NO_X (calculated using the diameters and velocities from **Table 6**).

Table 9 R4A, R4B, and R5 Buildings

Source	Emission Rates per Plant (g/s)

	NO_X	PM_{10}/TSP
Forklift	0.19	0.012
Concrete pump	0.36	0.001

Emission factors used for the calculation of emissions from trucks are shown in the following table. These emission rates were applied to all trucks assessed.

Table 10 Emission Factors – Combustion - Trucks

Pollutant	Emissions (g/km)
NO_X *	7.836
PM_{10} */TSP	0.523
VOCs **	0.72
*Source: SKM. (2002). M5 East Freeway Sub-Regional Air Quality Management Plan - rigid truck (diesel) emissions ** Source: NPI for Combustion Engines V3 2008, Table 21; diesel vehicle exhaust emissions (HGV), applying an assumed fuel usage value of 40L/100km	

5.5.2 Water Treatment Plant

As described in AECOM (2011), the primary pollutants of interest associated with the operation of the WTP are VOCs (BTEX) and naphthalene, which are potential contaminants located within soils on the site. Emission rates for the two associated point sources are provided in the following table. It should be noted that emissions at these rates are expected to occur when remediation activities are undertaken; as the remediation should be completed by the time the Stage 1B Building construction works are expected to occur, these emission rates represent overestimates of expected concentrations during the Stage 1B Building construction works.

Table 11 Water Treatment Plant Emission Rates

Pollutant	Emission Rate (g/s)	
	Inlet tank displacement valve	Air strippers discharge stack
Benzene	0.0010	0.009
Toluene	0.0004	0.004
Ethylbenzene	0.0001	0.001
Xylenes	0.0002	0.001
Naphthalene	0.0071	0.062

The emission rates correspond to a stripping efficiency of 99 % and a water flow rate of 25 L/s.

The water treatment plant will emit volatile organic compounds; as there will be no combustion associated with those emissions, however, the emissions are not addressed in the *Protection of the Environment (Clean Air) Regulation 2010*. Naphthalene, another pollutant that may be emitted from the water treatment plant, is similarly not addressed in that regulation.

5.6 Sensitive Receptors

The EPA considers sensitive receptors to be areas where people are likely to either live or work, or engage in recreational activities (DEC, 2005a). The receptors assessed in this report were selected to be the most representative sensitive receptors in proximity to the proposed works. A total of 116 receptors were assessed, which were primarily located along the eastern side of Hickson Road at various heights, with some located specifically on the site boundary. The receptor locations are shown in **Figure 2** and are detailed in **Appendix C**.

It should be noted that some of the buildings in Stage 1A of the Barangaroo project will be occupied at the time the Stage 1B works commence; these receptors were modelled in this assessment including:

- Sensitive receptors within the T1 commercial tower, with receptors included at ground level and open balconies located on levels 18 and 32;
- Proposed childcare centre to be located within the T1 podium;
- Sensitive receptors at ground level and various heights within the R8 and R9 residential towers; and
- New operational childcare centre located within the AON podium

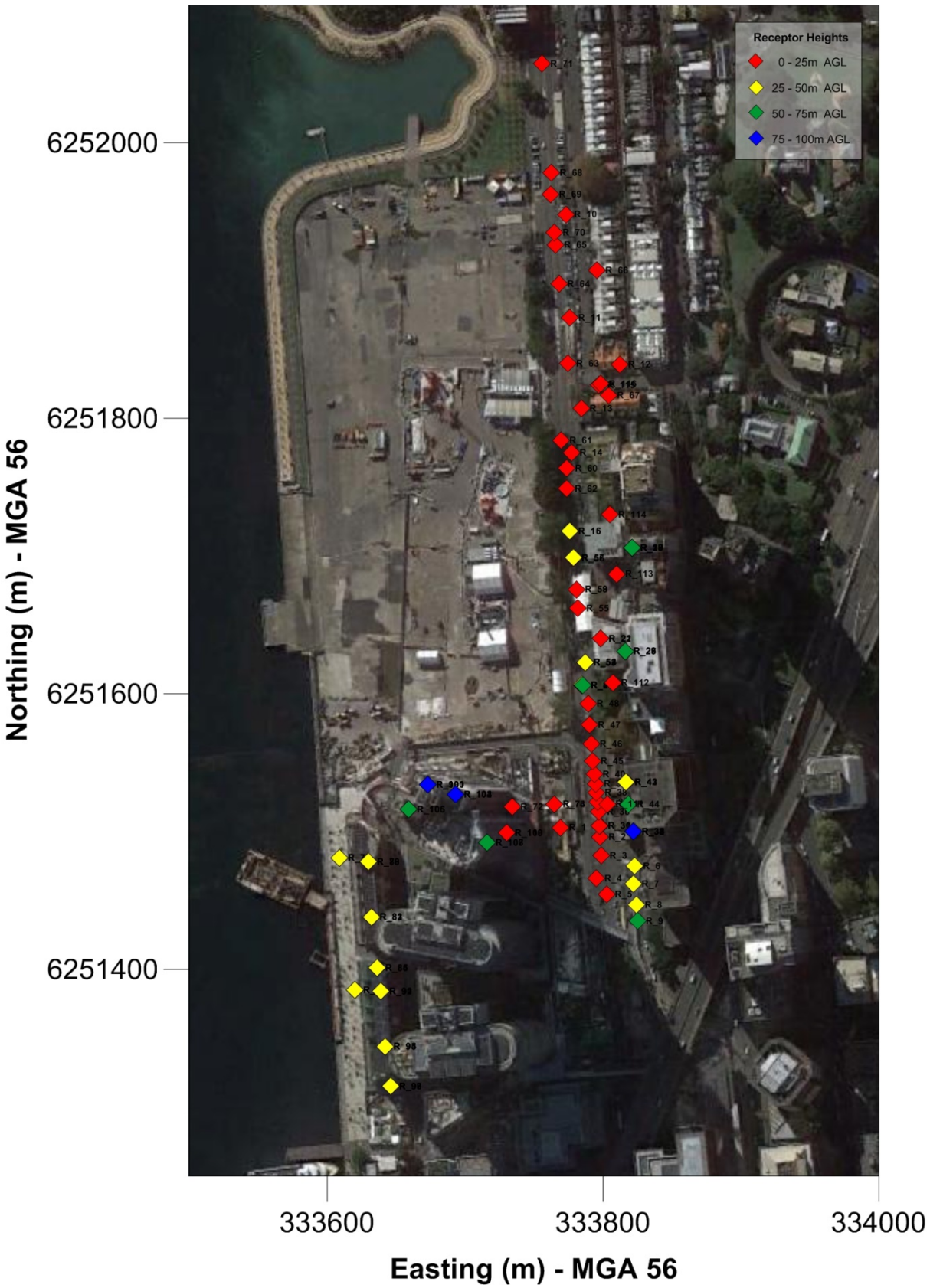

Figure 2 **Sensitive Receptor Locations – Site Boundary**

5.7 Prediction of Cumulative Impacts

For NO_2, PM_{10} and TSP, DEC (2005) specifies that AQIAs are to assess the cumulative impacts of a proposal against their impact assessment criteria. This involves adding existing background pollutant levels and expected pollutant levels from other concurrent developments to maximum pollutant concentrations of these pollutants predicted by dispersion modelling. For this assessment, all the Barangaroo works expected to occur concurrently with the Stage 1B Building construction works (excluding excavation) were included in the dispersion modelling.

The cumulative assessment comprised the addition of the maximum measured data described in **Section 4.1** (assumed ambient pollutant concentrations) for TSP and annual NO_2 and PM_{10} to predicted pollutant concentrations, and comparison of the results to the relevant criteria. Cumulative concentrations of 1 hour NO_2 and 24 hour PM_{10} were calculated contemporaneously – that is, the ambient concentrations for each hour/24 hours were added to the corresponding model predictions for those time periods.

No other works associated with the Barangaroo development are expected to occur at the same time as the activities that were modelled in this assessment. No other potential development in the area that might occur at the same time was known at the time of preparation of this assessment.

5.8 Conversion of NO_X to NO_2

Nitrogen oxides are produced in most combustion processes and are formed during the oxidation of nitrogen in fuel and nitrogen in the air. During high-temperature processes, a variety of oxides are formed including nitric oxide (NO) and NO_2. NO will generally comprise 95 % of the NO_X by volume at the point of emission. The remaining NO_X will consist of NO_2. Ultimately, however, all nitric oxides emitted into the atmosphere are oxidised to NO_2 and then further to other higher oxides of nitrogen.

The USEPA's Ozone Limiting Method (OLM) was used to predict ground-level concentrations of 1 hour NO_2. The OLM is based on the assumption that approximately 10 % of the initial NO_X emissions are emitted as NO_2. If the ozone (O_3) concentration is greater than 90 % of the predicted NO_X concentrations, all the NO_X is assumed to be converted to NO_2,otherwise NO_2 concentrations are predicted using the equation $NO_2 = 46/48 * O_3 + 0.1 * NO_X$. This method assumes instant conversion of NO to NO_2 in the plume, which overestimates concentrations close to the source since conversion usually occurs over periods of hours. This method is described in detail in DEC (2005). Background O_3 data from the Rozelle monitoring station (refer to **Section 5.1**) were used to convert the modelled NO_2 concentrations in accordance with the EPA approved OLM.

6.0 Results

6.1 Modelling Predictions

The results of the dispersion modelling are shown in **Table 12**. The results show the total cumulative pollutant concentrations of the construction of the R4A, R4B and R5 buildings and the operation of an on-site water treatment plant.

The highest project contributions (pollutant concentrations associated with the project) predicted at any sensitive receptor assessed are shown. These contributions represent the 100th percentile for NO_2, PM_{10} and TSP and the 99.9th percentile for benzene, ethylbenzene, toluene and xylenes. Cumulative pollutant concentrations, which represent the project contribution plus background pollutant concentrations, are provided for NO_2, PM_{10} and TSP as required by the EPA. For TSP, the ambient concentration was estimated from the PM_{10} concentration as described in **Section 4.1**.

The EPA criteria for air toxics apply at and beyond the boundary of the facility. The concentrations reported below represent the highest 99.9th percentile concentrations for any sensitive receptor assessed, which include receptors located on the boundary and the Barangaroo Stage 1A receptors.

As shown, exceedances of the EPA criteria were predicted to occur for 1 hour NO_2 and 24 hour PM_{10}.

Table 12 Dispersion Modelling Results

Pollutant	Averaging Period	Units	Maximum Predicted Project Contribution	Total Cumulative Concentration	Criteria
NO_2*	Max 1 hour average	$\mu g/m^3$	**281.1**	**286.7**	*246*
	Annual average	$\mu g/m^3$	13.6	33.8	*62*
PM_{10}*	Max 24 hour average	$\mu g/m^3$	15	**60.3**	*50*
	Annual average	$\mu g/m^3$	3	21	*30*
TSP	Annual average	$\mu g/m^3$	7	44	*90*
Benzene	99.9th 1 hour	$\mu g/m^3$	6.79	N/A	*29*
Ethylbenzene	99.9th 1 hour	$\mu g/m^3$	0.90	N/A	*8,000*
Toluene	99.9th 1 hour	$\mu g/m^3$	3.59	N/A	*360*
Xylenes	99.9th 1 hour	$\mu g/m^3$	0.96	N/A	*190*
Naphthalene	99.9th 1 hour	$\mu g/m^3$	56.01	N/A	*440*
* Maximum cumulative concentration calculated contemporaneously. Exceedances denoted in **bold type**.					

A number of conservative assumptions were implemented in the modelling, including the assumption that the plant would be constantly operating between the hours of 7 am to 7 pm, every day of the year. This assumption is likely to lead to overestimates of short term and annual predictions, particularly as this level of concurrent work is only expected to occur for an eight month period. This conservativeness is expected to account for the predicted exceedance of short term NO_2 concentrations.

The exceedance of the 1 hour NO_2 criterion occurred at a group of receptors to the east of the Tower construction area (refer **Figure 4**), located on Hickson Road. When the annual data is examined further, the receptors with the highest number of exceedances were shown to occur at 3 receptors situated at ground level or elevated slightly above ground level immediately adjacent to the eastern boundary of the site. Exceedances are only predicted to occur for a small number of hours per year. A ranked plot of the concentration (both in isolation and cumulatively with background NO_2) is shown in **Figure 3**.

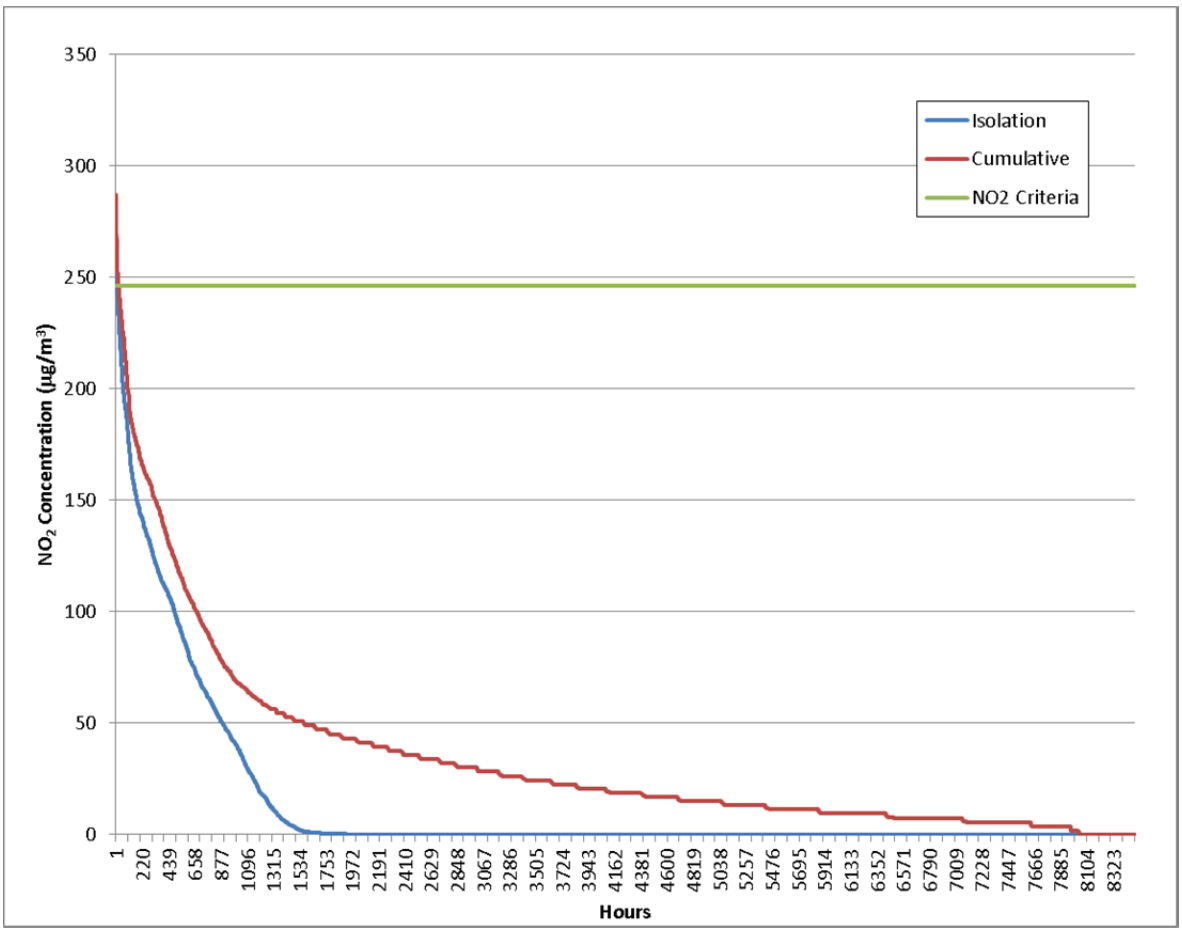

Figure 3 Ranked NO_2 Concentrations (Isolation and Cumulative)

Management of equipment to minimise the risk of cumulative impacts from engine generated air pollution e.g. only operating concrete pumps when needed, is expected to significantly reduce the potential for adverse impacts. The control of these activities will be addressed as part of the site air quality management plan component of the construction plan. The location and identification of the receptors that showed exceedances are shown in **Figure 4**.

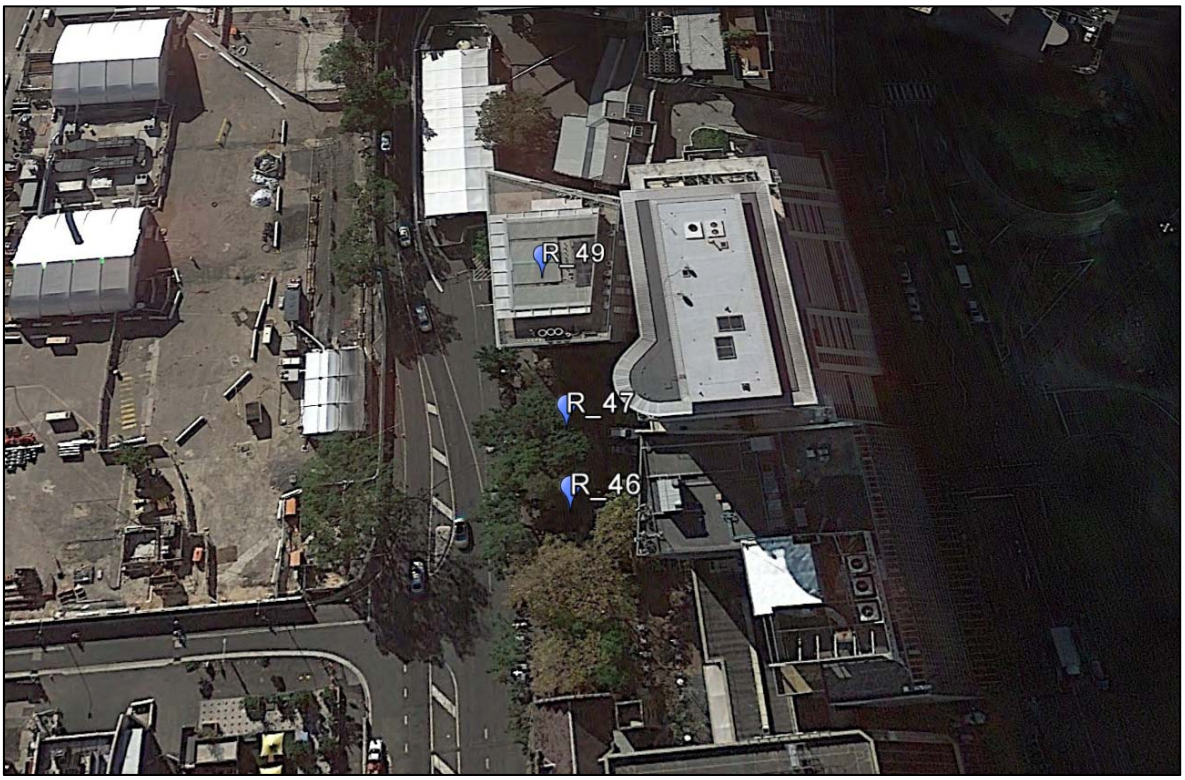

Figure 4 Sensitive receptor locations where exceedances predicted to occur

The predicted exceedances of the 24 hour PM_{10} criterion were attributable to the exceedances in the background PM_{10} concentrations – a total of three exceedances were predicted to occur at each receptor assessed, which corresponded to the three exceedances in the ambient data. The modelling predicted that no additional exceedances would occur at any receptor location assessed.

6.2 Limitations

Best efforts were made to estimate the likely numbers, operational parameters (including operational hours and handling volumes) and emissions of plant and equipment in the AQIA. The numbers used were based on information available from Lendlease at the time of preparation of this report, and may change to reflect the detailed design of the remediation activities.

If major changes are proposed to pollutant emitting activities during the excavation works, further modelling may be required to assess the effects of those changes on local air quality.

7.0 Recommended Air Quality Management and Mitigation

7.1 Mitigation Measures

Mitigation measures will be implemented based on the reactive management program and the nature of the works being undertaken on site at any time. The proposed mitigation measures are listed below:

- Mains power will be used where available and suitable.
- Vehicle engines will be turned off while parked on site.
- Vehicular access will be confined to designated access roads. Haul road lengths will be minimised.
- Equipment, plant and machinery will be appropriately tuned, modified or maintained to minimise visible smoke and emissions.
- Site speed limits will be implemented.
- Loads will be covered during transport.
- Good housekeeping practices will be implemented to minimise dust on hardstand areas.
- Spills will be immediately cleaned up.
- The complaints management system will be maintained.
- Water sprays and/or surfactants will be used wherever and whenever necessary.
- Windbreak barriers will be erected at the site boundary.
- General environmental controls will be installed for excavation works, including bunding and sediment controls.
- Exposed excavation surfaces and roads will be watered as required.

An Air Quality and Odour Management Sub-Plan would be prepared to include mitigation measures from this AQIA, and that it would include an Air Quality Monitoring Plan. The Sub-Plan would contain measures to reflect variations in cumulative emissions from construction activities across Barangaroo.

These measures are intended to reduce risks to human health and nuisance impacts. The proposed monitoring works should be undertaken for the duration of the remediation and land forming works. The management and mitigation strategies, contingency measures and monitoring works will be consistent with the requirements of Environment Protection Licence (EPL) 13336, which will be varied following the granting of project approval for the proposed remediation works.

7.2 Contingency Measures

When monitoring systems continuously measure pollutant concentrations, an early warning system based on trigger levels can be used to minimise adverse impacts on the environment. The trigger levels are generally set below a relevant assessment criterion.

A reactive management plan was developed for the site, based on a three-stage approach:

- Investigate: Identification of the likely reasons for the elevated pollutant concentration and formulation of a contingency response for the action stage;
- Action: Implementation of the measures formulated in the investigative stage and review of their effectiveness; and
- Stop Work: All air polluting works associated with the on site activities should stop at this stage until the measured pollutant levels are below the action level to avoid an exceedance of the pollutant criterion.

The reactive management procedure for PM_{10} is provided in **Table 12**.

Table 13 Reactive Management Procedure – PM_{10}

Reactive Management Procedure				
Trigger Stage	**Averaging Period**	**Trigger Value ($\mu g/m^3$)**	**Primary Responsibility**	**Action Required**
1 Investigate	1 hour	85	Environment Manager	Environmental Manager to undertake review of possible dust sources operating during the average period. Identify possible measures for these activities; action if deemed necessary.
	3 hour	80		
2 Action	1 hour	470		Environment Manager to attend site and ensure implementation of the control actions identified in stage 1. Effectiveness of control actions to be reviewed and escalate where appropriate. Identify long-term solutions to dust issues. Complete Lendlease Environmental Response Form.
	3 hour	160		
3 Stop Work	1 hour	940		Targeted shut down of dust-generating activities until the measured pollutant levels are below the stated Action period trigger value. Complete Lendlease Environmental Response Form.
	3 hour	320		

7.3 Air Quality Monitoring Program

Ambient air quality monitoring around the Barangaroo site has been undertaken by AECOM since October 2011 in accordance with the Air Quality Management Plan and EPL for the site. The monitoring has the following objectives:

- Allow a real time assessment of the various activities on the site, which can then be related back to operational changes to reduce off-site impacts; and to
- Allow reactive dust mitigation measures to be implemented based on real time monitoring data.

The monitoring is undertaken generally in accordance with the following guidelines and Australian Standards:

- The EPA's Approved Methods for Sampling and Analysis of Air Pollutants in New South Wales (DEC, 2005);
- AS/NZS 3580.9.3:2003 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - Total suspended particulate matter (TSP) - High volume sampler gravimetric method;
- AS 3580.9.8-2008 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser;
- AS/NZS 3580.1.1:2007 Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment; and
- AS 2923-1987 Ambient air - Guide for measurement of horizontal wind for air quality applications.

The monitoring works are undertaken in accordance with the site's Air Quality and Odour Management Sub-Plan.

Figure 5 Approximate Barangaroo South Monitoring Locations

8.0 Conclusion

AECOM undertook an air quality impact assessment of the proposed Stage 1B Building construction works including the R5 building. Assessment of the highest expected pollutant-generating activity on the site during the Stage 1B Building construction period (excluding excavation works) was undertaken. The worst case emissions expected during the Stage 1B excavation works were assessed in AECOM (2015).

Based on staging information provided by Lendlease, the following concurrent activities are expected to represent the worst-case building construction works, which will occur between August 2021 and April 2022:

- Construction of the R4A building;
- Construction of the R4B building;
- Construction of the R5 building; and
- Operation of the on-site water treatment plant.

These activities were assessed through dispersion modelling using the CALPUFF model. The assessment was undertaken in accordance with and/or in reference to the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales 2005, published by the Environment Protection Authority (EPA).

Exceedances of the criteria for cumulative 1 hour NO_2 and 24 hour PM_{10} were predicted to occur. The NO_2 exceedances were considered to primarily result from the assumption of continuous emissions from plant during operational hours and the assumption of works occurring for a 12 month period. The PM_{10} exceedances were found to be the result of elevated background levels of PM_{10}; no additional exceedances were predicted to occur as a result of the assessed works.

Lendlease currently operates a reactive dust mitigation system at the Barangaroo South site, which includes ambient pollution monitoring, is directly linked to real-time warnings and incorporates work procedures to ensure that action is taken to reduce dust levels when they are elevated and at risk of exceeding acceptable air pollution levels. The system has been operational on the Barangaroo South site for a few years, and will continue to operate throughout the duration of the Stage 1B remediation and basement works. Lendlease uses its existing air quality monitoring network and its operational procedures to ensure the site emissions are mitigated to an appropriate level and that adverse impacts (i.e. exceedances of ambient air quality criteria) are minimised at sensitive receptor locations as a result of site operations.

Lendlease has demonstrated that it can undertake significant materials handling and construction activities with substantial plant and equipment numbers on site while minimising emissions through this reactive management and monitoring system. As such, the Stage 1B Building construction works are not expected to result in adverse impacts on the surrounding environment.

9.0 References

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Appendix A

Chemicals of Potential Interest

Appendix A Chemicals of Potential Interest

For the purposes of this AQIA, pollutants of interest were defined as pollutants most likely to be generated by the proposed excavation and construction works, which were:

- Nitrogen dioxide (NO_2);
- Particulate matter (PM_{10} and TSP); and
- VOCs.

The potential health effects of the pollutants of interest are summarised below. Details were obtained from the National Pollutant Inventory (NPI, 2010) unless otherwise specified.

Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide. The mixture of these two gases is commonly referred to as NO_x. NO_x is a product of combustion processes. In urban areas, motor vehicles and industrial combustion processes are the major sources of ambient NO_x. NO_2 can cause damage to the human respiratory tract, increasing a person's susceptibility to respiratory infections and asthma. NO_2 can also cause damage to plants, especially in the present of other pollutants such as ozone and sulfur dioxide. NO_x are also primary ingredients in the reactions that lead to photochemical smog formation.

Particulate Matter

Suspended particulate matter may be emitted from site via combustion activities (i.e. vehicle and plant operations) and site preparation, excavation and remediation works.

Airborne particles are commonly differentiated according to size based on their equivalent aerodynamic diameter. Particles with a diameter of less than or equal to 50 micrometres (μm) are collectively referred to as total suspended particulates (TSP). TSP primarily causes aesthetic impacts associated with settling on surfaces, which also causes soiling and discolouration. Uncontrolled emissions of these large particles, however, can cause some irritation of mucosal membranes and can increase health risks from ingestion if contaminated. Particles with diameters less than or equal to 10 μm (known as PM_{10} or fine particles) tend to remain suspended in the air for longer periods than larger particles, and can penetrate into human lungs.

Exposure to particulate matter has been linked to a variety of health effects, including respiratory problems (such as coughing, aggravated asthma and chronic bronchitis) and non-fatal heart attacks.

VOCs

Organic compounds with a vapour pressure at 20 °C exceeding 0.13 kPa are referred to as VOCs. VOCs have been implicated as a major precursor in the production of photochemical smog, which causes atmospheric haze, eye irritation and respiratory problems. VOC emissions are typical for oil processing, petrochemical and chemical plants and include emissions from point sources (storage tanks and filling stations vents) and fugitive emissions from pipelines and process equipment leaks. A variety of VOCs were detected at the site, which may be released during the proposed activities.

BTEX

BTEX are a category of volatile organic compounds (VOCs). VOCs are organic compounds with a vapour pressure at 20 °C exceeding 0.13 kPa. These compounds have been implicated as a precursor in the production of photochemical smog, which may cause atmospheric haze, eye irritation and respiratory effects. VOC emissions are typical for oil processing, petrochemical and chemical plants and include emissions from point sources (storage tanks and filling stations vents) and fugitive emissions from pipelines and process equipment leaks.

Benzene

Benzene is an airborne substance that can be washed out of the air by rain, and evaporated into the air. It will decompose in soil or water when oxygen is present. Benzene exposure commonly occurs through inhalation of air containing the substance. It can also enter the body through the skin, although it is poorly absorbed this way. Low levels of benzene exposure may result from tobacco smoke and car exhaust.

Benzene is considered to be a toxic health hazard and a carcinogen. Human exposure to very high levels for even brief periods of time can potentially result in death. Lower level exposure can cause skin and eye irritation,

drowsiness, dizziness, headaches and vomiting, and over longer periods damage to the immune system, leukaemia and birth defects.

Toluene

Toluene (methylbenzene) is a highly volatile chemical that quickly evaporates to a gas if released as a liquid. After a few days, the substance breaks down in air into chemicals that are harmful to human health. Bacteria in soil and water also break down toluene. Due to relatively fast degradation, toluene emissions are typically confined to the local area in which it is emitted. Toluene is a component of petrol and paints, and is also found in tobacco smoke. Human exposure typically occurs through breathing contaminated air, but toluene can also be ingested or absorbed through the skin (in liquid form). Toluene usually leaves the body within twelve hours.

Short-term exposure to high levels of toluene can cause dizziness, sleepiness, unconsciousness and sometimes death. Long-term exposure can cause kidney damage and permanent brain damage that can lead to speech, vision and hearing problems, as well as loss of muscle and memory functions.

Ethylbenzene

Ethylbenzene is a highly volatile substance, so is typically present in air. Ethylbenzene rapidly enters the body through the lungs and digestive tract. The substance has both acute and chronic toxic effects on animals and plants, including shortened lifespan, reproductive problems and behaviour changes. Exposure to high concentrations can cause dizziness, paralysis, breathing difficulties and death. Chronic health effects in humans can last for months or years. Ethylbenzene is present in petroleum, pesticides, cleaning products and solvents.

Xylenes

Xylenes are flammable liquids that are moderately soluble in water. They are quickly degraded by sunlight when released to air, and rapidly evaporate when released to soil or water. They are used as solvents and in petrol and chemical manufacturing.

Xylenes can enter the body through inhalation or skin absorption (liquid form), and can cause irritation of the eyes and nose, stomach problems, memory and concentration problems, nausea and dizziness. Excessively high-level exposure can cause death.

Naphthalene

Naphthalene is the primary PAH of potential concern at the Barangaroo site due to its volatile nature and strong, offensive odour. It is produced from coal tar and petroleum, and is used for the production of chemicals, dyes and as a moth-repellent. It can be absorbed through inhalation, ingestion and dermal contact. Short-term exposure can cause lesions of blood cells (haemolysis), while long-term exposure can result in chronic haemolytic anaemia. Inhalation can generate symptoms such as headache, confusion, nausea, vomiting and sweating. Skin irritation and dermatitis can result from dermal contact. Naphthalene exposure can cause cataracts in the eyes, while ingestion can cause abdominal cramps, nausea, vomiting, diarrhoea and death in young infants. It is considered possible carcinogenic to humans and carcinogenic in animals. The substance is very toxic to aquatic organisms. Naphthalene may cause long-term effects in the aquatic environment[1].

[1] International Programme on Chemical Safety Poisons Information Monograph 363; http://www.inchem.org/documents/pims/chemical/pim363.htm; accessed 19 May 2010

Appendix B

Climate Averages and Meteorological Analyses

Appendix B Climate Averages and Meteorological Analyses

Average climate data recorded at the Observatory Hill meteorological station between 1859 and 2014 are shown in the following table. These data are summarised in **Section 4.2**.

Average Climate Data – Observatory Hill, 1859 – 2014 (June)

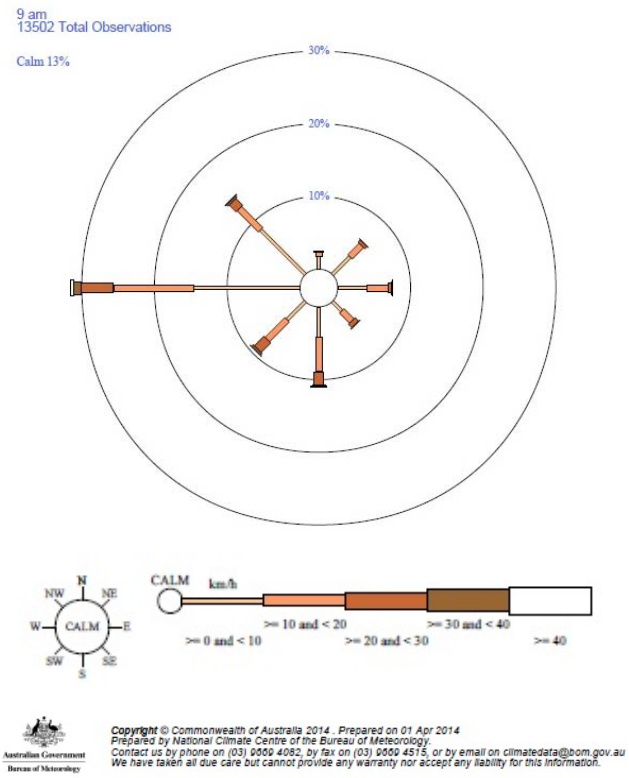
Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average temperature													
Maximum (°C)	25.9	26	24.7	22.4	19.4	16.9	16	18	20	22	24	25	21.7
Minimum (°C)	18.7	19	17.6	14.7	11.5	9.3	8	9	11	14	16	18	13.8
Rainfall													
Mean rainfall (mm)	101	118	130	127	120	132	98	80	68	77	84	77	1213
Average 9 am conditions													
Temperature (°C)	22.5	22	21.1	18.2	14.6	11.9	11	13	16	19	20	22	17.5
Relative humidity (%)	71	74	74	72	74	74	71	66	62	61	66	67	69
Wind speed (km/h)	8.6	8.2	7.9	8.8	10.5	11.9	13	13	12	12	11	9.8	10.6
3 pm conditions													
Temperature (°C)	24.8	25	24	22	19.4	16.9	16	18	19	21	22	24	21
Relative humidity (%)	62	64	62	59	57	57	51	49	51	56	58	59	57
Wind speed (km/h)	17.9	17	15.2	13.8	12.7	13.6	15	18	18	19	19	20	16.6

The following discusses the meteorological data from the CALMET data file for the year 2013 in terms of wind speed and wind direction.

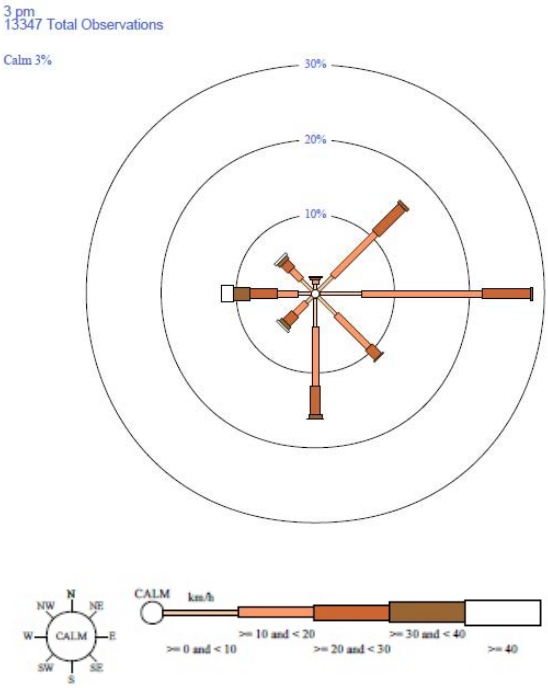
The Bureau of Meteorology (BoM) operates a network of meteorological monitoring stations around the country. The closest station to the site that measures long-term parameters is located at Observatory Hill, Sydney, approximately 200 m northeast of the Site and is considered a good representation of the regional climate.

Wind Rose

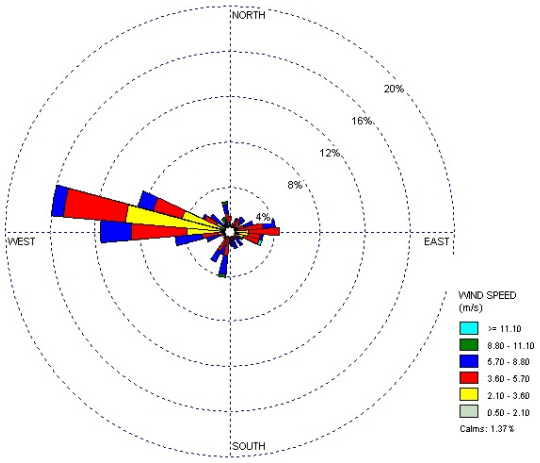
Wind speed and direction are important variables in dispersion modelling, as they dictate the direction and distance pollutant plumes travel. A comparison of wind roses from the meteorological data used in the dispersion modelling and the data from Observatory Hill was conducted. The 9 am and 3 pm wind roses for each data source are shown in the table below. The 9 am data sets were comparable in wind direction, although the prognostic data, as expected, predicted fewer calm periods than the historical measured data (1.4% vs13 %). The prognostic wind speeds were lower than the measured wind speeds. At 3 pm, again, the wind directions were similar, with a high proportion of winds from the northeast. The proportion of calm periods (0.82% vs 3%) and wind speeds were again higher in the measured data set.



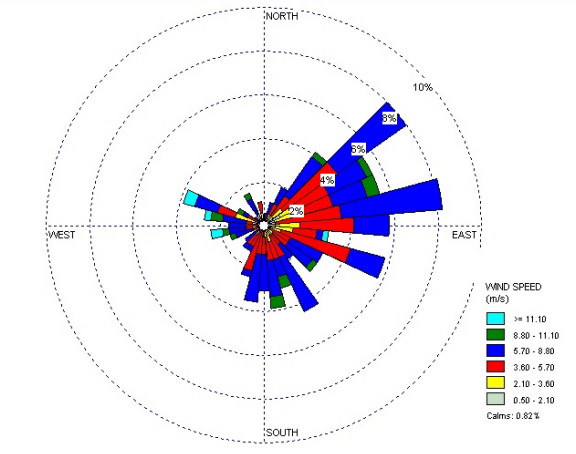
9 am wind rose – Observatory Hill (1955 – 1992)



3 pm wind rose – Observatory Hill (1955 – 1992)



9 am wind rose – CALMET, 2013



3 pm wind rose – CALMET, 2013

Wind Speed

The frequency distribution of hourly averaged wind speed values from the 2013 CALMET data generated for the assessment is shown in **Figure B1**. As shown, wind speeds in the area are medium strength, with speeds between 2 and 9 m/s occurring for around 80% of the time. The average wind speed is 4.2 m/s and the maximum wind speed is 15 m/s. Given the relative coastal location of the station, the high percentage of strong winds is expected.

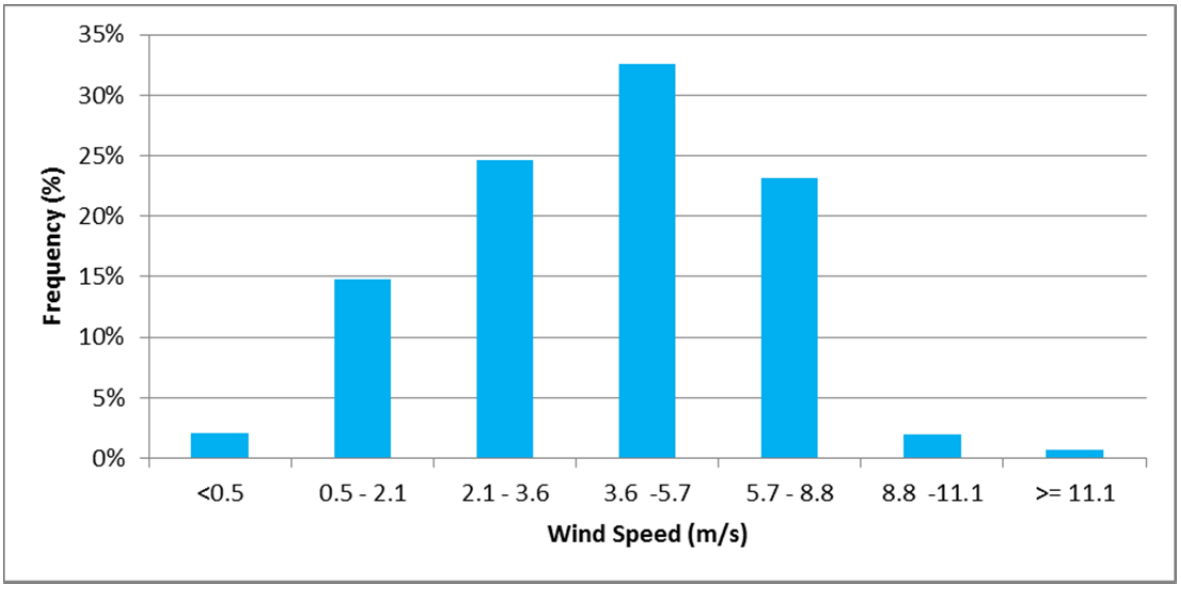


Figure B1 Frequency Distribution of Wind Speed – Barangaroo CALMET 2013

Figure B2 shows the distribution of average wind speeds by hour of day. Higher wind speeds tend to occur during the daytime between 10 am and 7 pm, with a peak around 2 pm. This is a typical diurnal pattern.

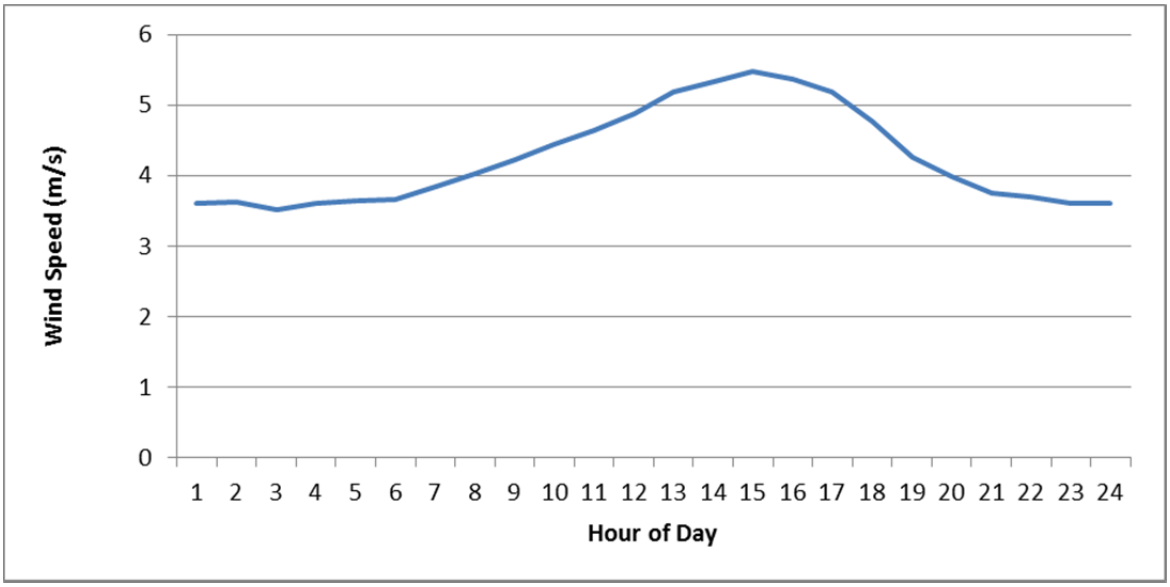


Figure B2 Wind Speed by Hour of Day – Barangaroo CALMET 2013

Appendix C

Sensitive Receptor Locations

Appendix C Sensitive Receptor Locations

The coordinates and heights of the sensitive receptors included in the dispersion modelling are provided below.

Sensitive Receptors

Receptor ID	Coordinates		Base Elevation (m)	Flagpole Height (m)	Description
	X (m)	Y (m)			
ID_Receptor	X (m)	Y (m)	Base_Elevation (m)	Flagpole_Height (m)	Description
R_1	333769	6251503	25	0	
R_2	333798	6251496	28	18	
R_3	333799	6251483	28	0	
R_4	333795	6251466	27	0	
R_5	333802	6251454	28	0	
R_6	333823	6251475	32	25	
R_7	333822	6251462	33	25	
R_8	333824	6251447	33	48	
R_9	333825	6251435	33	50	
R_10	333773	6251948	14	0	Preschool
R_11	333776	6251873	12	0	
R_12	333812	6251839	19	0	
R_13	333784	6251807	17	0	
R_14	333777	6251775	19	0	
R_15	333776	6251718	20	0	
R_16	333776	6251718	20	30	
R_17	333821	6251706	25	0	
R_18	333821	6251706	25	20	
R_19	333821	6251706	25	40	
R_20	333821	6251706	25	60	
R_21	333798	6251640	10	0	
R_22	333798	6251640	10	20	
R_23	333785	6251606	8	0	
R_24	333785	6251606	8	20	
R_25	333785	6251606	8	30	
R_26	333816	6251631	24	0	
R_27	333816	6251631	24	20	
R_28	333816	6251631	24	40	
R_29	333816	6251631	24	60	
R_30	333798	6251504	28	0	
R_31	333797	6251504	28	20	

Receptor ID	Coordinates		Base Elevation (m)	Flagpole Height (m)	Description
	X (m)	Y (m)			
R_32	333822	6251500	32	20	
R_33	333822	6251500	32	40	
R_34	333822	6251500	32	60	
R_35	333822	6251500	32	80	
R_36	333797	6251514	27	0	
R_37	333796	6251521	27	0	
R_38	333795	6251528	26	0	
R_39	333795	6251535	26	0	
R_40	333794	6251542	25	0	
R_41	333817	6251536	30	0	Stamford on kent
R_42	333817	6251536	30	20	Stamford on Kent
R_43	333817	6251536	30	40	Stamford on Kent
R_44	333819	6251520	30	60	Stamford on Kent
R_45	333792	6251551	25	0	
R_46	333792	6251564	24	0	
R_47	333790	6251577	23	0	
R_48	333789	6251593	21	0	
R_49	333785	6251606	20	10	38 Hickson Rd
R_50	333785	6251606	20	30	38 Hickson Rd
R_51	333785	6251606	20	50	38 Hickson Rd
R_52	333787	6251623	20	0	38 Hickson Rd
R_53	333787	6251623	20	20	38 Hickson Rd
R_54	333787	6251623	20	40	38 Hickson Rd
R_55	333782	6251662	19	0	
R_56	333778	6251698	20	20	30 The Bond
R_57	333778	6251699	20	40	30 The Bond
R_58	333781	6251676	20	30	30 The Bond
R_59	333781	6251676	20	10	30 The Bond
R_60	333774	6251764	19	0	
R_61	333770	6251784	18	0	
R_62	333773	6251749	20	0	
R_63	333775	6251840	15	0	
R_64	333768	6251897	12	0	
R_65	333766	6251926	13	0	
R_66	333796	6251907	15	10	Observatory Hotel
R_67	333804	6251817	20	20	Observatory Hotel

Receptor ID	Coordinates		Base Elevation (m)	Flagpole Height (m)	Description
	X (m)	Y (m)			
R_68	333763	6251978	14	0	
R_69	333762	6251963	14	10	Preschool
R_70	333765	6251935	13	0	Preschool
R_71	333756	6252057	13	0	
R_72	333734	6251518	22	0	Stage 1A receptor
R_73	333765	6251520	24	0	Stage 1A receptor
R_74	333765	6251520	24	10	Stage 1A receptor
R_75	333609	6251481	3	0	R8/R9 Ground Level
R_76	333609	6251481	3	18	R8/R9 Level 6
R_77	333609	6251481	3	32	R8/R9 Level 12
R_78	333630	6251478	4	0	RA/R9 Ground Level
R_79	333630	6251478	4	16	R8/R9 Level 6
R_80	333630	6251478	4	32	R8/R9 Level 12
R_81	333632	6251438	4	0	R8/R9 Ground Level
R_82	333632	6251438	4	18	R8/R9 Level 6
R_83	333632	6251438	4	32	R8/R9 Level 12
R_84	333636	6251401	5	0	R8/R9 Ground level
R_85	333636	6251401	5	18	R8/R9 Level 6
R_86	333636	6251401	5	32	R8/R9 Level 12
R_87	333620	6251385	4	0	R8/R9 Ground Level
R_88	333620	6251385	4	18	R8/R9 Level 6
R_89	333620	6251385	4	32	R8/R9 Level 12
R_90	333639	6251384	5	0	R8/R9 Ground level
R_91	333639	6251384	5	18	R8/R9 Level 6
R_92	333639	6251384	5	32	R8/R9 Level 12
R_93	333642	6251344	4	0	R8/R9 Ground Level
R_94	333642	6251344	4	18	R8/R9 Level 6
R_95	333642	6251344	4	32	R8/R9 Level 12
R_96	333646	6251315	4	0	R8/R9 Ground Level
R_97	333646	6251315	4	18	R8/R9 Level 6
R_98	333646	6251315	4	32	R8/R9 Level 12
R_99	333673	6251534	9	0	T1 Ground level
R_100	333673	6251534	9	54	T1 Level 18
R_101	333673	6251534	9	96	T1 Level 32
R_102	333693	6251527	12	0	T1 Ground level
R_103	333693	6251527	12	54	T1 Level 18

Receptor ID	Coordinates		Base Elevation (m)	Flagpole Height (m)	Description
	X (m)	Y (m)			
R_104	333693	6251527	12	96	T1 Level 32
R_105	333659	6251516	7	0	T1 Ground Level
R_106	333659	6251516	7	69	T1 Level23
R_107	333716	6251492	15	0	T1 Ground level
R_108	333716	6251492	15	69	T1 Level 23
R_109	333730	6251499	17	0	T1 Podium Ground level
R_110	333730	6251499	17	12	T1 Podium Childcare Centre Level 4
R_111	333803	6251520	42	0	AON Podium Childcare centre
R_112	333807	6251608	46	0	Jenkins St
R_113	333810	6251687	39	0	Jenkins Street
R_114	333805	6251730	30	0	Jenkins Street
R_115	333797	6251824	23	0	High Ln
R_116	333798	6251825	23	0	High Ln