

# Air Quality Impact Assessment

*Pacific Environment*

# Final Report

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## 21532 Cockle Bay Wharf Air Quality Assessment

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Document Control Number: AQ-NW-001-21532

Date: 25 October 2016

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**Project Name:** 21532 Cockle Bay Wharf Air Quality Assessment

**Document Control Number:** AQ-NW-001-21532

**Prepared For:** DPT Operator Pty Ltd and DPPT Operator Pty Ltd

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*Document Control*

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## Executive Summary

The Minister for Planning's Approval Condition 274 for the Cross City Tunnel (CCT) states that any development in the vicinity of the CCT stack requires an air quality assessment of potential impacts from the stack plume. The development at Cockle Bay Wharf, Sydney is within 300 metres of the CCT stack and therefore triggers the requirement to undertake an air quality assessment.

Pacific Environment have completed an air quality assessment of the CCT ventilation stack and nearby Western Distributor roadway to determine the potential air quality impact of these sources on the proposed development.

The assessment concludes that the emissions from the CCT stack and Western Distributor are not anticipated to result in any exceedances of the NSW EPA criteria for the air quality metrics assessed in the vicinity of the proposed development.

The modelling completed to date indicates that higher concentrations of the air quality metrics evaluated are predicted to occur at the top of the proposed development compared with those at ground level.

It is noted however, that given the complexity of the modelled scenario, optimisation of any air intakes locations for the proposed development should necessarily occur during the detailed design stage for the development. It is recommended that this be completed using a micro-scale modelling technique such as computational fluid dynamics (CFD) or the GRAL roadway assessment modelling scheme.

# Table of Contents

Executive Summary .....	iii
1. Introduction .....	1
1.1 Background .....	1
1.2 Site Description .....	2
1.3 Overview of Proposed Development.....	4
1.4 Planning Approvals Strategy .....	5
1.5 Background to the Study .....	6
1.6 Scope of Works .....	6
2. Air Quality Criteria .....	7
2.1 Impact Assessment Criteria .....	7
3. Existing Environment .....	8
3.1 Climate Data.....	8
3.2 Meteorology.....	9
3.2.1 Wind Speed and Direction.....	9
3.2.2 Atmospheric Stability .....	11
3.3 Existing Air Quality .....	14
4. Modelling Approach .....	16
4.1 Stack Modelling System .....	16
4.2 Roadway Modelling System .....	16
5. Emissions Estimation .....	17
5.1 Stack Emissions .....	17
5.1.1 Cross City Tunnel Ventilation Outlet .....	17
5.1.2 Darling Park Tunnel Ventilation Points.....	19
5.2 Roadside Emissions .....	20
5.2.1 Western Distributor Flyover (Vehicle Emissions) .....	20
5.3 Building Wake Effects .....	21
5.3.1 Impact of Proposed Development on the CCT Plume .....	21
5.4 Nitrogen Dioxide Characterisation.....	21
6. Dispersion Modelling.....	22
6.1 CCT Stack .....	22
6.2 Vehicle Emissions .....	23
6.3 Air Quality Assessment .....	24
7. Conclusions .....	26
8. References.....	27
Appendix A .....	28



## List of Figures

Figure 1-1: Local setting .....	2
Figure 1-2: 3D representation of proposed development at Cockle Bay Wharf, Sydney, NSW .....	3
Figure 3-1: Annual and seasonal windroses representative of Darling Harbour, NSW .....	10
Figure 3-2: Annual statistics of 1/L by hour of the day .....	12
Figure 3-3: Annual distribution of stability type by hour of the day .....	13
Figure 3-4: 24-hour PM <sub>10</sub> concentrations measured at Rozelle from 2010 to 2015 inclusive..	15
Figure 5-1: Three-dimensional representation of assessment area .....	18
Figure 5-2: Darling Park Ventilation Points evaluated during site inspection (30/08/2016) .....	19
Figure 6-1: Predicted maximum 1-hour NO <sub>2</sub> concentrations at ground level associated with the operation of the CCT stack .....	22
Figure 6-2: Predicted maximum 1-hour NO <sub>2</sub> concentrations at ground level associated with vehicle movements on the Western Distributor .....	23

## List of Tables

Table 2-1: EPA Air Quality Standards/Goals for PM <sub>10</sub> and NO <sub>2</sub> concentrations ( <b>NSW DEC, 2005</b> ) .....	7
Table 3-1: Climate averages for the Sydney Observatory Hill .....	8
Table 3-2: Inverse of the Monin-Obukhov length L with respect to atmospheric stability .....	12
Table 3-3: Summary of monitoring data from OEH's Rozelle site .....	14
Table 3-4: Summary of background concentrations referenced within this assessment .....	15
Table 5-1: Stack parameters adopted for Cross City Tunnel stack .....	17
Table 5-2: Emissions from Western Distributor (g/km/hr) .....	20
Table 6-1: Predicted maximum NO <sub>2</sub> and PM <sub>10</sub> concentrations at ground level of the proposed development .....	25
Table 6-2: Concentrations of NO <sub>2</sub> and PM <sub>10</sub> at varying heights of the proposed development .....	25
Table 8-1: Model Inputs for CCT Dispersion Modelling .....	29

# 1. Introduction

This report supports a State Significant Development Application (SSDA) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) is seeking to secure approval to establish concept proposal details for the redevelopment of the Cockle Bay Wharf Building and surrounding area (Cockle Bay Wharf). The concept proposal will include:

- up to 12,000m<sup>2</sup> of publicly accessible open space;
- new retail outlets, including new food and beverage destinations;
- new cultural and entertainment destinations; and
- a new commercial office tower.

The project supports the realisation of the NSW State Government's vision for an expanded 'cultural ribbon' spanning from Barangaroo, around to Darling Harbour and Pyrmont. The project importantly will add further renewed diversity in tourism and entertainment facilities to reinforce Sydney's CBD being Australia's pre-eminent tourist destination.

## 1.1 Background

The Proponent controls the lease of the site, and also of the adjacent Darling Park site. The Darling Park site is a successful premium grade office precinct located on the west of the Sydney CBD, the associated Crescent Garden, located to the west of the three existing Darling Park towers, is a key area of open space in this part of the city.

The Proponent has recognised a number key issues with the existing layout of the Darling Park and Cockle Bay precinct, these being:

- The existing Cockle Bay Wharf building is not well integrated with the city, the Western Distributor freeway currently acts as a barrier to separate this area from the CBD;
- Despite being publicly accessible, the existing Darling Park Crescent Garden is not well utilised; and
- The existing Cockle Bay Wharf building is outdated and is not in keeping with the future of Darling Harbour area as a vibrant entertainment and tourist destination.

The Cockle Bay precinct is at risk of being left behind and undermining the significant investment being made in Darling Harbour that will see it return to the world stage as a destination for events and entertainment.

Accordingly, the Proponent is taking a carefully considered and staged approach to the complete revitalisation of the site and its surrounds. The envisaged development, which will be facilitated by the proposed building envelopes will:

- Reconnect the city with the Darling Harbour waterfront and the Darling Park Crescent Garden;



- Provide new access routes between the city and the ICC Sydney / Darling Harbour Live precinct;
- Support the Sydney economy by providing a new premium commercial building; and
- Refresh and renew an existing entertainment and tourist destination.

## 1.2 Site Description

Darling Harbour is a 60 hectare waterfront precinct on the south-western edge of the Sydney Central Business District that provides a mix of functions including recreational, tourist, entertainment and business. The Site is located to the immediate south of Pyrmont Bridge, within the Sydney CBD on the eastern side of the Darling Harbour precinct. The Cross City Tunnel (CCT) ventilation outlet is located approximately 300 m south of the Site. The Site is located within the City of Sydney local government area (LGA). A locational context area plan and location plan are provided in **Figure 1-1** below.

The Darling Harbour precinct is undergoing significant redevelopment as part of the SICEEP, Darling Square, and IMAX renewal projects. The urban, built form and public transport / pedestrian context for Harbourside will fundamentally change as these developments are progressively completed.

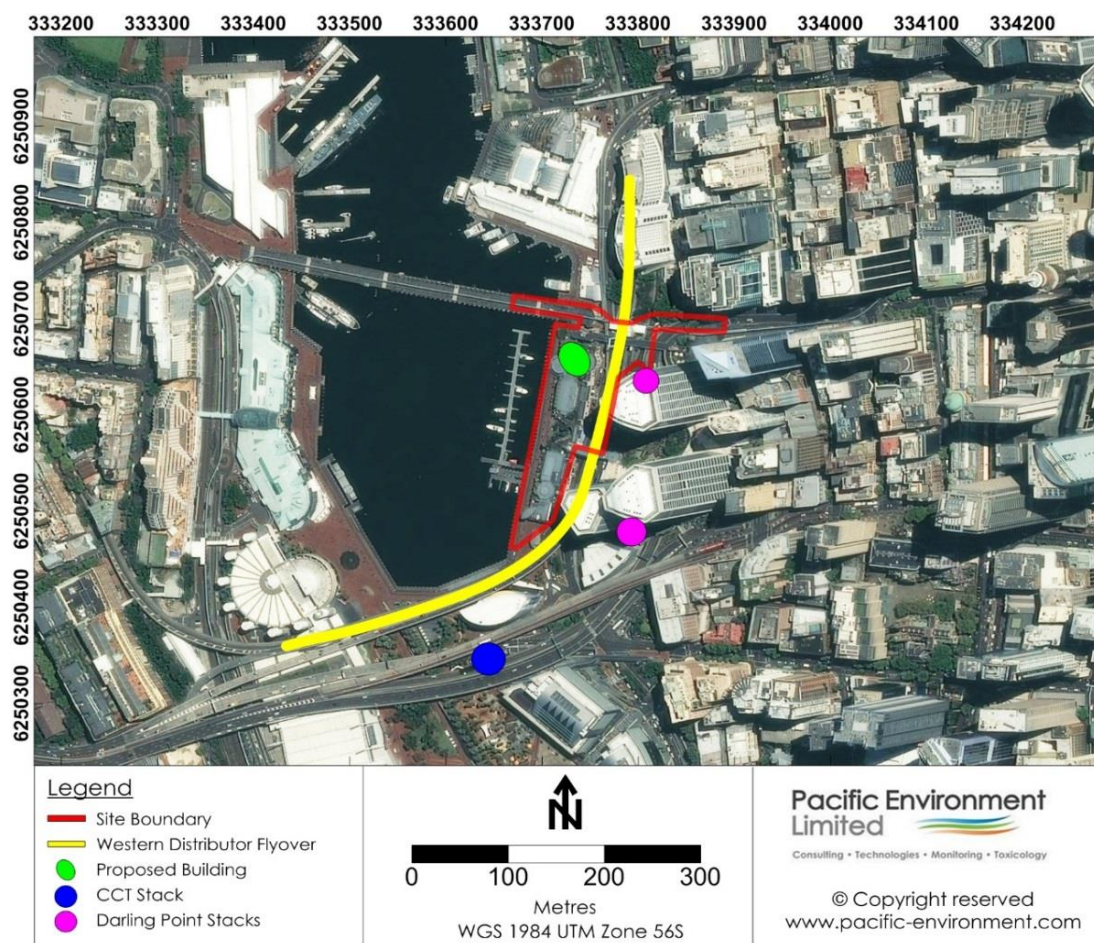


Figure 1-1: Local setting

A 3D representation of the site is presented in **Figure 1-2**.

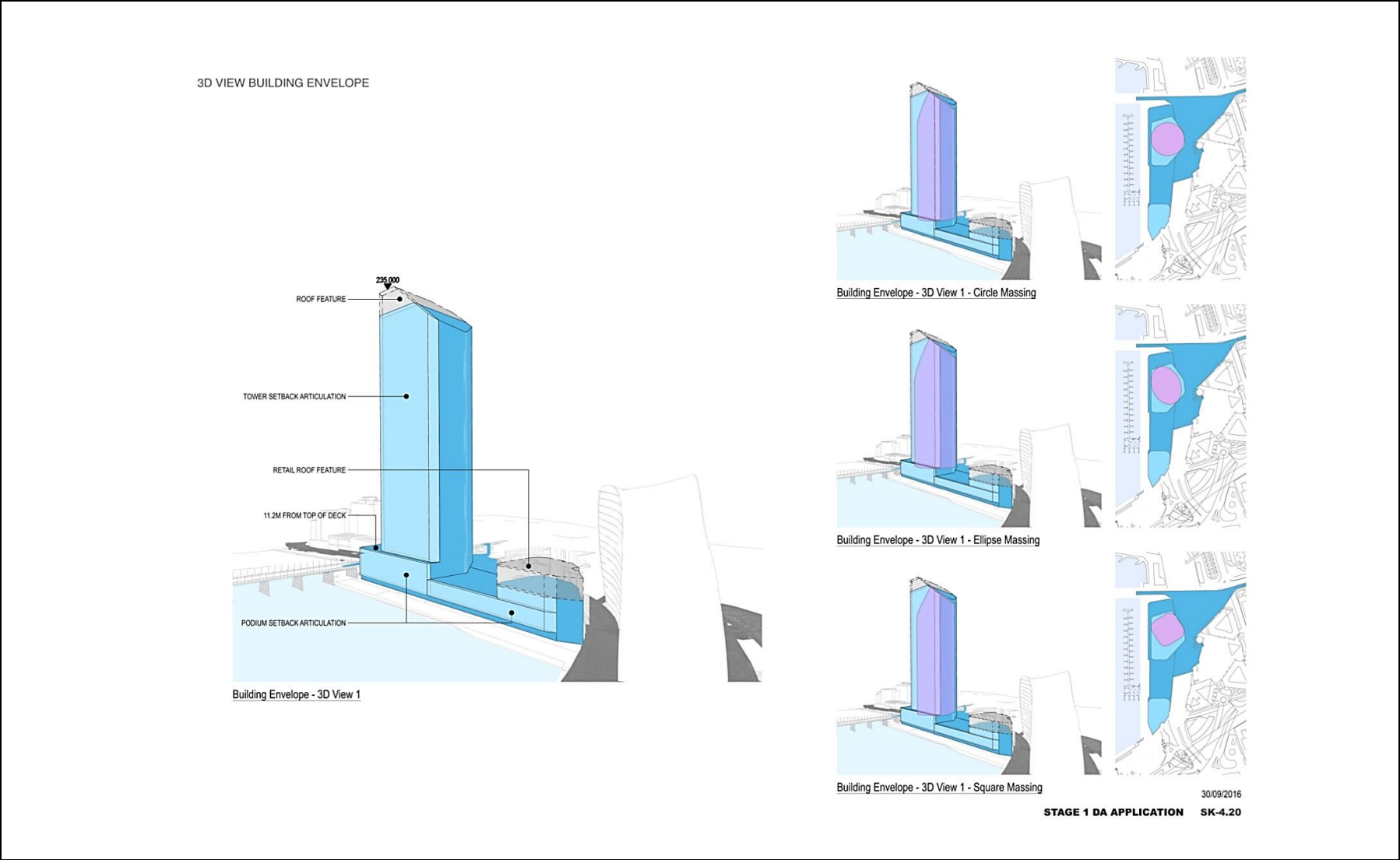


Figure 1-2: 3D representation of proposed development at Cockle Bay Wharf, Sydney, NSW

## 1.3 Overview of Proposed Development

The proposal relates to a staged development application and seeks to establish concept proposal details for the renewal and re-imagining of Cockle Bay Wharf.

The concept proposal establishes the vision and planning and development framework which will be the basis for the consent authority to assess future detailed development proposals.

The Cockle Bay Wharf site is to be developed for a mix Retail, Cultural and Commercial (Office) uses, including retail and restaurants, commercial offices, and open space.

The Concept Proposal seeks approval for the following key components and development parameters:

- Demolition of existing site improvements, including the existing Cockle Bay Wharf, pedestrian bridge links across the Western Distributor, and obsolete monorail infrastructure;
- Building envelopes;
- Land uses across the site;
- A maximum total Gross Floor Area (GFA) across the Cockle Bay Wharf of 85,000m<sup>2</sup> for commercial development and 25,000m<sup>2</sup> for retail (including food and beverage) development;
- Car parking rates to be utilised in subsequent detailed (Stage 2) Development Applications);
- Urban Design and Public Realm Guidelines to guide future development and the public domain; and
- Strategies for utilities and services provision, drainage and flooding, and ecological sustainable development.

## 1.4 Planning Approvals Strategy

The Site is located within the Darling Harbour precinct, which is identified as a State Significant Site in Schedule 2 of State Environmental Planning Policy (State and Regional Development) 2011. As the proposed development will have a capital investment exceeding \$10 million, it is declared to be State Significant Development (SSD) for the purposes of the Environmental Planning and Assessment Act 1979 (EP&A Act), with the Minister for Planning the consent authority for the project.

This State Significant Development Application (DA) is a staged development application made under section 83B of the EP&A Act. It seeks approval for the concept proposal for the entire site and its surrounds.

More specifically this staged DA includes establishing land uses, gross floor area, building envelopes, public domain concept, pedestrian and vehicle access and circulation arrangements and associated car parking provision.

Detailed development application/s (Stage 2 DAs) will accordingly follow seeking approval for the detailed design and construction of all or specific aspects of the proposal in accordance with the approved staged development application.

The Department of Planning and Environment provided the Secretary's Environmental Assessment Requirements (SEARs) to the applicant for the preparation of an Environmental Impact Statement for the proposed development on 23 June 2016. This report has been prepared having regard to the SEARs as relevant.

## 1.5 Background to the Study

An air quality assessment was undertaken during the Environmental Assessment phase of the Cross City Tunnel project and subsequently to determine the potential impact of the ventilation stack on future buildings in the vicinity of the (then proposed) stack. Part of the Minister for Planning's Approval Condition 274 for the project was that for any future building, a protocol would need to be developed to allow an assessment of the impact of both the ventilation stack plume on any proposed building and the potential for the building to affect dispersion of the plume. A Protocol has now been prepared and sets out a methodology for identifying and assessing developments which may be impacted by or impact upon the plume from the CCT ventilation stack in the vicinity of Darling Harbour.

## 1.6 Scope of Works

The following outlines the scope of work covered within this report:

- Review the preliminary project drawings and incorporate the proposed design (as accurately as possible) into the Building Profile Input Program (BPIP) for assessment of building downwash effects;
- Conduct a modelling assessment to predict pollutant concentrations from the CCT stack at a number of heights corresponding to levels of the proposed building;
- Modelling assessment to predict pollutant concentrations from the Darling Park Tunnel ventilation points;
- Assess anticipated air quality impacts with distance from the Western Distributor using a conventional roadway dispersion modelling;;
- Obtain traffic count data for the Western Distributor flyover and combine this with (NSW EPA) vehicle emission data to produce road line source emission estimates;
- Compare ground level concentrations of pollutants with and without the building, to assess any potential impact that building downwash might have on ground level concentrations;
- Use the above information to inform an air quality constraints analysis, including detail on any limitations to the siting of building air intakes; and
- Provide high level design advice in the form of a short report as to the potential for operable windows / balconies at height and setback distances from the CCT stack, Western Distributor and Darling Park Tunnel ventilation outlets.

## 2. Air Quality Criteria

The principal emissions of concern in this assessment are as follows:

- Oxides of nitrogen (NO<sub>x</sub>)
- Particulate matter (PM<sub>10</sub>)

### 2.1 Impact Assessment Criteria

**Table 2-1** summarises the air quality goals for the stated air quality metrics that are relevant to this study.

Table 2-1: EPA Air Quality Standards/Goals for PM<sub>10</sub> and NO<sub>2</sub> concentrations (**NSW DEC, 2005**)

Pollutant	Standard	Averaging Period
NO <sub>2</sub>	246 µg/m <sup>3</sup>	1-hour
	62 µg/m <sup>3</sup>	Annual
PM <sub>10</sub>	50 µg/m <sup>3</sup>	24-hour
	30 µg/m <sup>3</sup>	Annual

Notes: µg/m<sup>3</sup> – micrograms per cubic metre.



## 3. Existing Environment

### 3.1 Climate Data

The Bureau of Meteorology (BoM) collects climatic information in the vicinity of the site at Sydney Observatory Hill located approximately 1.5 km north of the site. This climatic information is presented in **Table 3-1 (BoM, 2016)**.

Table 3-1: Climate averages for the Sydney Observatory Hill

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
<b>9am Mean Dry-bulb Temperatures (°C) and Relative Humidity (%)</b>													
Dry-bulb	22.5	22.3	21.1	18.2	14.6	11.9	10.9	12.5	15.7	18.5	19.9	21.6	17.5
Humidity	71.0	74.0	74.0	72.0	74.0	74.0	71.0	66.0	62.0	61.0	66.0	67.0	69.0
<b>3pm Mean Dry-bulb Temperatures (°C) and Relative Humidity (%)</b>													
Dry-bulb	24.8	24.9	24.0	22.0	19.4	16.9	16.4	17.5	19.2	20.7	22.1	23.8	21.0
Humidity	62.0	64.0	62.0	59.0	57.0	57.0	51.0	49.0	51.0	56.0	58.0	59.0	57.0
<b>Daily Maximum Temperature (°C)</b>													
Mean	25.9	25.8	24.8	22.5	19.5	17.0	16.3	17.8	20.0	22.1	23.6	25.2	21.7
<b>Daily Minimum Temperature (°C)</b>													
Mean	18.7	18.8	17.6	14.7	11.6	9.3	8.1	9.0	11.1	13.6	15.7	17.5	13.8
<b>Rainfall (mm)</b>													
Mean	102.5	117.0	129.6	128.8	119.2	133.0	97.1	80.6	68.4	76.7	84.1	77.7	1214.6
<b>Rain days (Number)</b>													
Mean	12.2	12.5	13.6	12.9	13.0	12.5	11.2	10.4	10.6	11.6	11.7	11.5	143.7

Station number: 066062; Commenced 1858; Status: Open; Elevation: 39 m AHD  
Latitude: 33.86 °S; Longitude: 151.21 °E. Source: **BoM (2016)**

## 3.2 Meteorology

### 3.2.1 Wind Speed and Direction

Air quality impacts are influenced by meteorological conditions, primarily in the form of gradient wind flow regimes, and by local conditions that are generally driven by topographical features and interactions with coastal influences, such as the sea breeze.

As no site-specific meteorological data were available, CALMET was used to incorporate data from the surrounding weather stations<sup>1</sup> in order to provide representative meteorology for the site. Cloud cover and height were generated using The Air Pollution Model, or TAPM (a prognostic model). Model inputs and specifications are presented in **Appendix A**.

The annual and seasonal wind roses generated for the study area (representative year 2013) are presented in **Figure 3-1**. The average wind speeds for the period was determined to be 2.9 m/s. The percentage of calms (wind speeds below 0.5 m/s) for the meteorological file are relatively low at 1.7%.

The dominant winds are from the north-west, south and west quadrants on an annual basis. Typical of the Sydney basin, winter and autumn show a higher percentage of winds from the west, with summer receiving a higher percentage from the north-east.

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<sup>1</sup> BoM Sydney Olympic Park (Archery Centre), BoM Sydney Airport, BoM Bankstown Airport, BoM Canterbury Racecourse, BoM Fort Denison, EPA Chullora, EPA Earlwood and EPA Rozelle.

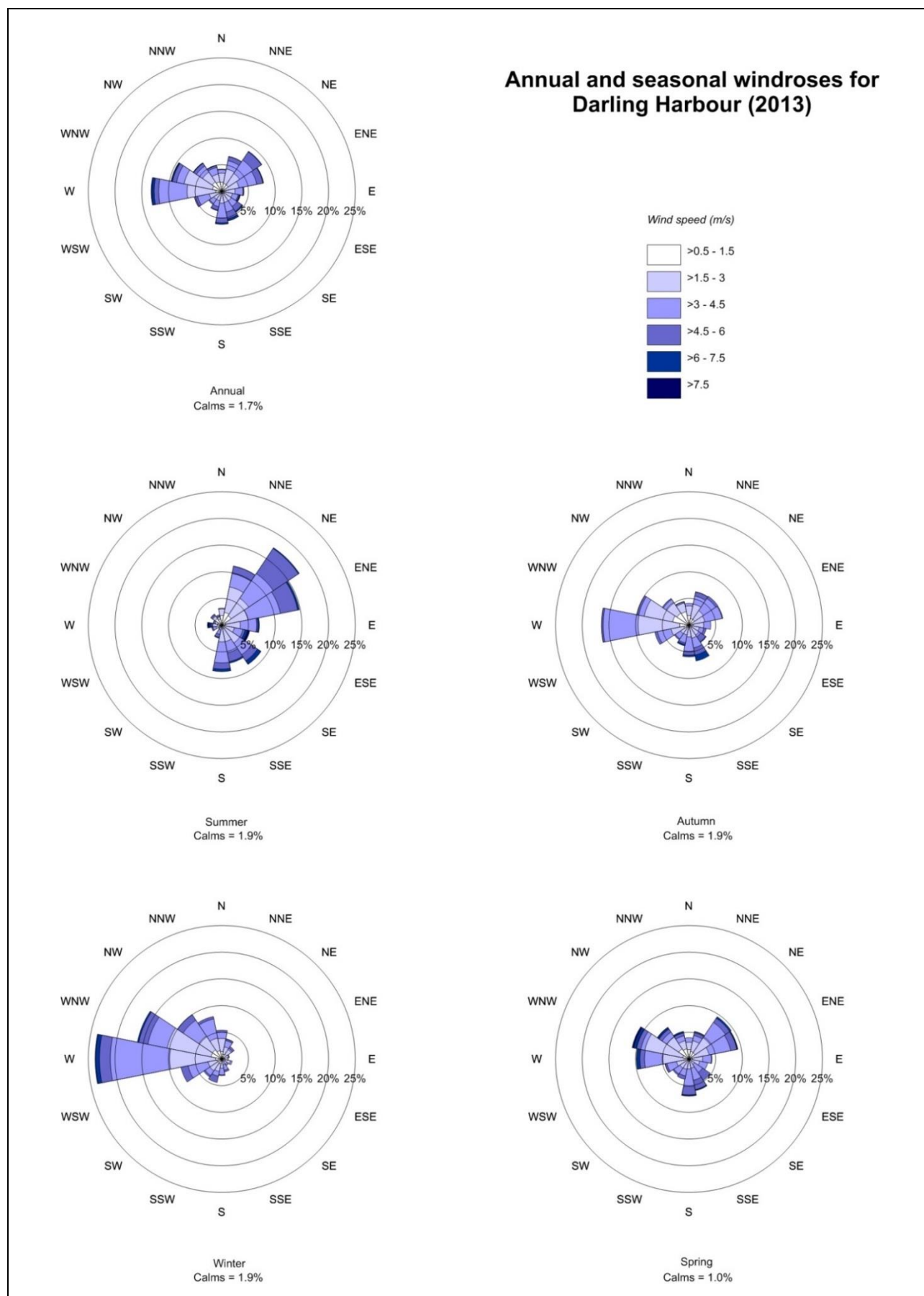


Figure 3-1: Annual and seasonal windroses representative of Darling Harbour, NSW

### 3.2.2 Atmospheric Stability

An important aspect of atmospheric dispersion is the level of turbulence in the lowest 1 km or so of the atmosphere, known as the planetary boundary layer (PBL). Turbulence controls how effectively a plume is diffused into the surrounding air and hence diluted. It acts by increasing the cross-sectional area of the plume due to random motions. With stronger turbulence, the rate of plume dispersion increases. Weak turbulence limits dispersion and contributes to high plume concentrations downwind of a source.

Turbulence is generated by both thermal and mechanical effects to varying degrees. Thermally driven turbulence occurs when the surface is being heated, in turn transferring heat to the air above by convection. Mechanical turbulence is caused by the frictional effects of wind moving over the earth's surface, and depends on the roughness of the surface as well as the flow characteristics.

Turbulence in the boundary layer is influenced by the vertical temperature gradient, which is one of several indicators of stability. Plume models use indicators of atmospheric stability in conjunction with other meteorological data to estimate the dispersion conditions in the atmosphere.

Stability can be described across a spectrum ranging from highly unstable through neutral to highly stable. A highly unstable boundary layer is characterised by strong surface heating and relatively light winds, leading to intense convective turbulence and enhanced plume diffusion. At the other extreme, very stable conditions are often associated with strong temperature inversions and light winds, which commonly occur under clear skies at night and in the early morning. Under these conditions plumes can remain relatively undiluted for considerable distances downwind. Neutral conditions are linked to windy and/or cloudy weather, and short periods around sunset and sunrise, when surface rates of heating or cooling are very low.

The stability of the atmosphere plays a large role in determining the dispersion of a plume and it is important to have it correctly represented in dispersion models. Current air quality dispersion models (such as AERMOD and CALPUFF) use the Monin-Obukhov Similarity Theory (MOST) to characterise turbulence and other processes in the PBL. One of the measures of the PBL is the Monin-Obukhov length ( $L$ ), which approximates the height at which turbulence is generated equally by thermal and mechanical effects (**Seinfeld and Pandis, 2006**). It is a measure of the relative importance of mechanical and thermal forcing on atmospheric turbulence. Because values of  $L$  diverge to  $+$  and  $-$  infinity as stability approaches neutral from the stable and unstable sides, respectively, it is often more convenient to use the inverse of  $L$  (i.e.,  $1/L$ ) when describing stability.

**Figure 3-2** shows the hourly averaged 1/L for the site computed from all data in the meteorological modelling file. Based on **Table 3-2** this plot indicates that, as to be expected, the PBL is stable overnight and becomes unstable as radiation from the sun heats the surface layer of the atmosphere and drives convection. The changes from positive to negative occur at the shifts between day and night. This indicates that the diurnal patterns of stability are realistic within the modelling.

Table 3-2: Inverse of the Monin-Obukhov length L with respect to atmospheric stability

1/L	Atmospheric Stability
Negative	Unstable
Zero	Neutral
Positive	Stable

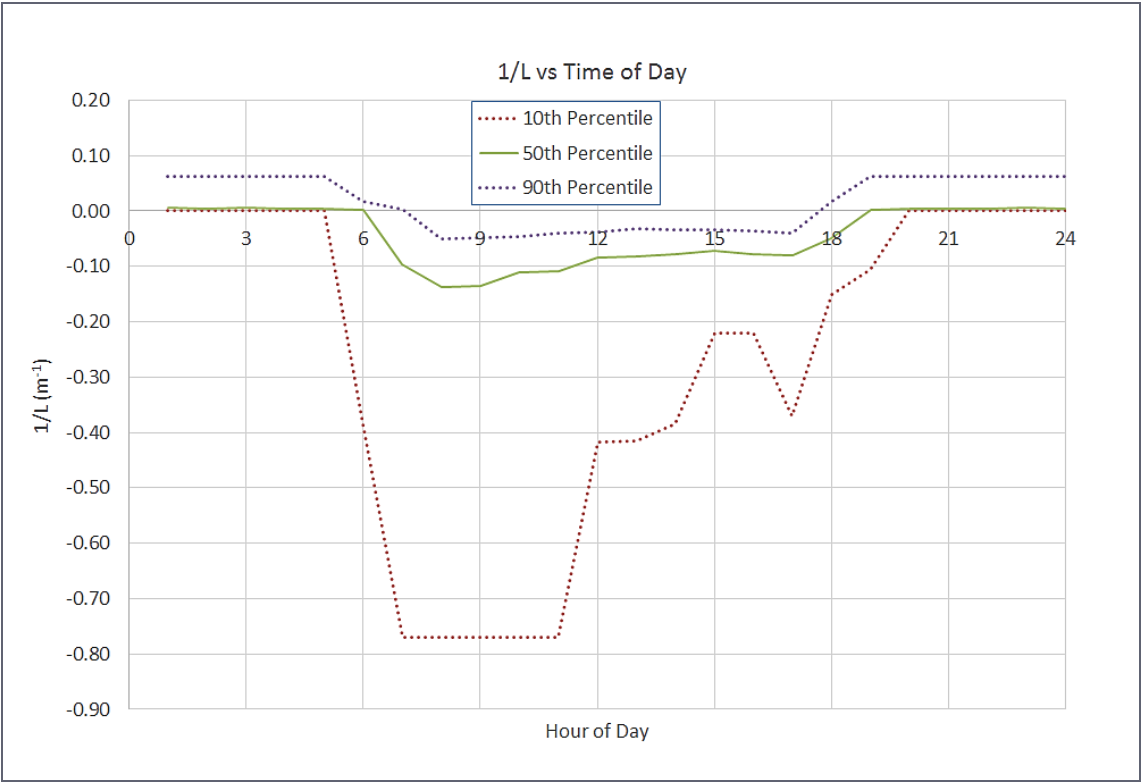


Figure 3-2: Annual statistics of 1/L by hour of the day

**Figure 3-3** shows the variations in stability over the year by hour of the day, with reference to the widely known Pasquill-Gifford classes of stability. The relationship between L and stability classes is based on values derived by **Golder (1972)** set out in **NSW DEC (2005)**. Note that the reference to stability categories here is only for convenience in describing stability. The AERMET/AERMOD modelling system uses calculated values of L across a continuum.

**Figure 3-3** shows that stable and very stable conditions occur for about 40-50% of the time, which is typical for onshore locations. Atmospheric instability increases during the morning and reaches a peak around 8 am. A stable atmosphere is prevalent during the night. These profiles indicate that pollutant dispersion is most effective during the daytime and least effective at night.

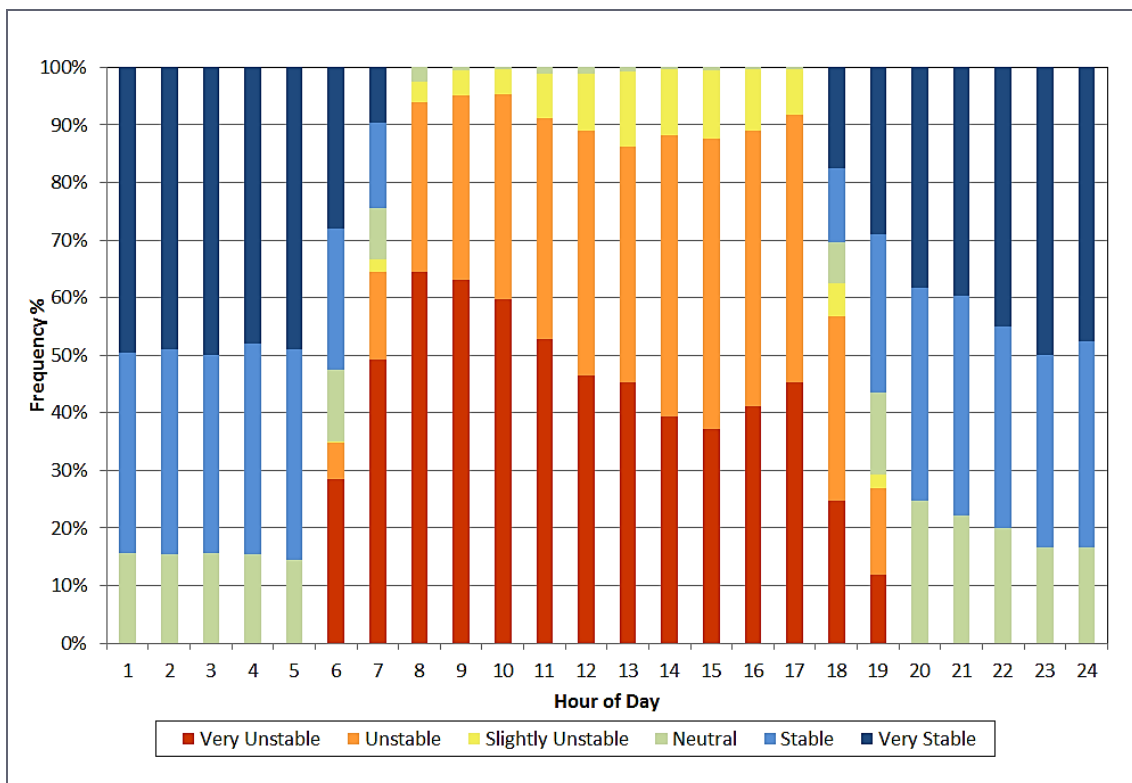


Figure 3-3: Annual distribution of stability type by hour of the day



### 3.3 Existing Air Quality

The NSW Office of Environment and Heritage (OEH) monitors air quality at several urban background locations around Sydney. The closest OEH urban background monitoring station to the site is at Rozelle. The air quality observations at Rozelle were therefore considered to be the most representative of background air quality in the study area.

**Table 3-3** summarises the NO<sub>2</sub> and PM<sub>10</sub> data from the Rozelle monitoring station for the years 2010 to 2015 inclusive.

Table 3-3: Summary of monitoring data from OEH's Rozelle site

Year	NO <sub>2</sub> (µg/m <sup>3</sup> )		PM <sub>10</sub> (µg/m <sup>3</sup> )	
	Maximum 1-hour mean	Annual Mean	Maximum 24-hour mean	Annual Mean
2010	100.5	22.6	37.6	16.1
2011	102.5	22.6	39.4	16.6
2012	127.1	24.6	40.7	16.9
2013	143.5	22.6	58.5	18.3
2014	112.8	22.6	43.8	17.9
2015	123.0	22.6	60.3	16.7

The monitoring data indicate that, with the exception of 24-hour PM<sub>10</sub>, the concentrations of NO<sub>2</sub> and PM<sub>10</sub> across the time periods presented are well below their respective NSW EPA criteria.

As shown in **Table 3-3** above, the 24 hour average PM<sub>10</sub> criterion of 50 µg/m<sup>3</sup> was exceeded at the Rozelle site in 2013 and 2015. These exceedances are anticipated to be due to regional events such as bushfires or dust storms rather than as a result of specific local sources.

For this assessment the maximum monitored concentrations have been used to represent the background air quality in the area, with the contribution of the emission sources modelled subsequently added. It must be noted that this assumption is overly conservative and unrealistic, particularly in the case of the 24-hour average PM<sub>10</sub>, where an alternative approach was taken.

**Figure 3-4** presents a time series of the 24-hour mean PM<sub>10</sub> measurements at Rozelle from 2010 to 2015. The figure demonstrates that the majority of concentrations are below 30 µg/m<sup>3</sup>, with a number of elevated observations occurring in October 2013 when severe bushfires were present in the Sydney region.

There were only 96 occasions in the six years (2,191 days) of data presented when the 24-hour mean PM<sub>10</sub> concentration exceeded 30 µg/m<sup>3</sup>. To assess the cumulative PM<sub>10</sub> impacts of the emission sources added, it was therefore deemed appropriate to remove the influence of these short-term regional peaks in the monitoring data used to represent background air quality.

For the purposes of this assessment, it was considered reasonable (yet still conservative) to take a background 24-hour mean concentration for PM<sub>10</sub> as the 99<sup>th</sup> percentile of these data (i.e. the concentration that would only be exceeded on one per cent of days) presented in **Figure 3-4**. This value was determined to be 37.6 µg/m<sup>3</sup>.

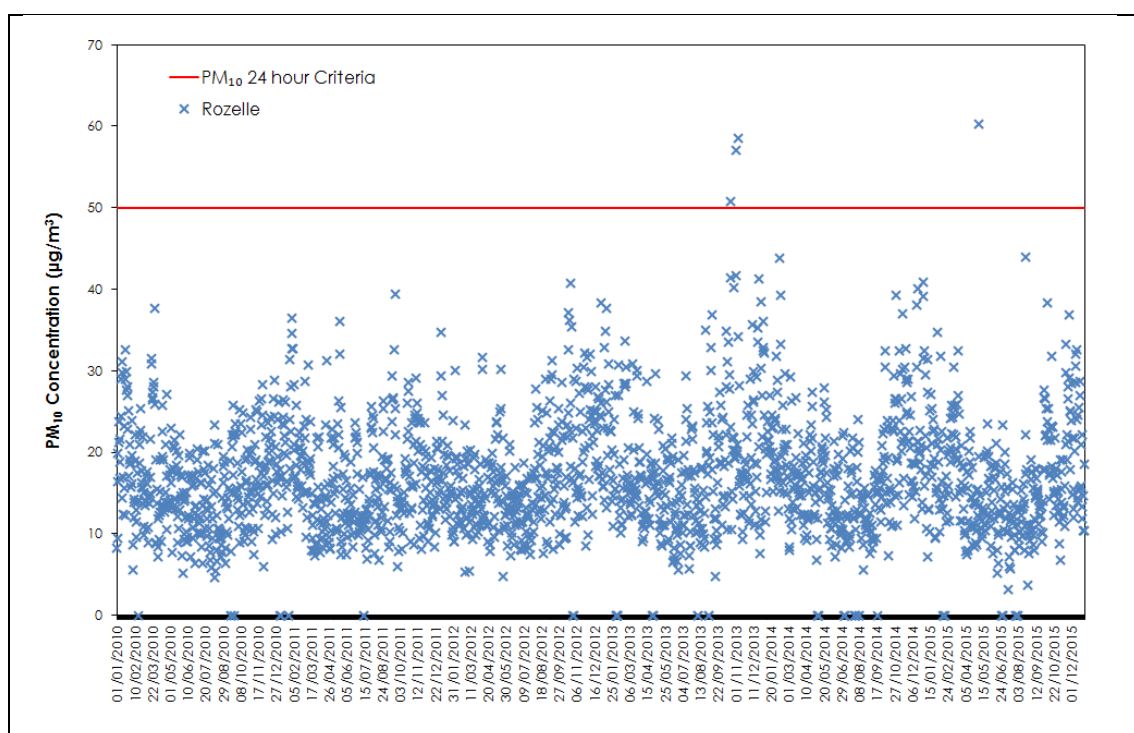


Figure 3-4: 24-hour PM<sub>10</sub> concentrations measured at Rozelle from 2010 to 2015 inclusive

A summary of the background concentrations used in the assessment is provided in **Table 3-4**.

Table 3-4: Summary of background concentrations referenced within this assessment

Pollutant	Background Concentration (µg/m <sup>3</sup> )		
	Annual Mean	24-hour Mean	1-hour Mean
NO <sub>2</sub>	24.6 <sup>i</sup>	N/A	143.5 <sup>i</sup>
PM <sub>10</sub>	18.3 <sup>i</sup>	37.6 <sup>ii</sup>	N/A

<sup>i</sup> 100th percentile (maximum) of monitoring data

<sup>ii</sup> 99<sup>th</sup> percentile of monitoring data

## 4. Modelling Approach

The approach to the assessment generally follows the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW DEC, 2005)* using the Level 2 assessment methodology. The Approved Methods specify how assessments based on the use of air dispersion models should be completed. They include guidelines for the preparation of meteorological data to be used in dispersion models and the relevant air quality criteria for assessing the significance of predicted concentration and deposition rates from projects.

### 4.1 Stack Modelling System

AERMOD was chosen as the most suitable model for the evaluation of the impact of nearby ventilation stacks due to the source types, location of nearest receivers and nature of local topography. AERMOD is the US-EPA's recommended steady-state plume dispersion model for regulatory purposes and it is an accepted model of the NSW EPA.

The AERMOD system includes AERMET, used for the preparation of meteorological input files and AERMAP, used for the preparation of terrain data.

Terrain data was sourced from NASA's Shuttle Radar Topography Mission (SRTM) Data (3 arc second (~30m) resolution) and processed within AERMAP to create the necessary input files.

AERMET requires surface and upper air meteorological data as input. The surface data was sourced from CALMET (**Section 3.2**), modelled over the site. Appropriate values for three surface characteristics are required for AERMET as follows:

- Surface roughness, which is the height at which the mean horizontal wind speed approaches zero, based on a logarithmic profile.
- Bowen ratio, which is an indicator of surface moisture.
- Albedo, which is an indicator of reflectivity of the surface.

Values of surface roughness, Bowen ratio and albedo were determined based on a review of aerial photography for a radius of 3 km centred on the site. A conservative default value of urban were selected in AERMOD to represent the area around the site.

Building wake effects were included in the modelling simulations to represent the commercial/urban setting that the proposed site would be located. The CCT ventilation outlet was represented as a point source 60 m above ground level.

A summary of the modelling inputs is presented in **Appendix A**.

### 4.2 Roadway Modelling System

The CAL3QHCR dispersion model was used to estimate the worst-case concentrations of vehicle emissions from the current traffic along the Western Distributor. This model is a steady state Gaussian model which can determine concentrations at receptor locations downwind of "at grade", "fill", "bridges" and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, roadway orientation and receptor location.

## 5. Emissions Estimation

### 5.1 Stack Emissions

#### 5.1.1 Cross City Tunnel Ventilation Outlet

Predictions were made for three CCT operating scenarios, as follows:

- Low Emissions (night time, low traffic, reduced fan speed).
- Medium Emissions (off peak traffic, medium fan speed).
- High Emissions (peak hour, maximum fan speed).

Stack parameters are based on the Approved Design of the CCT ventilation stack. NO<sub>2</sub> emission rates have been (conservatively) based on predicted rather than actual traffic volumes through the CCT. This provides a worse-case scenario but is appropriate as traffic volumes could ultimately reach levels predicted within the CCT Environmental Assessment and subsequent studies. Emission rates for PM<sub>10</sub> are based upon the maximum allowable 1.6 mg/m<sup>3</sup> in-stack concentration outlined in the consent conditions for the CCT.

The modelled emission parameters are given in **Table 5-1**. The stack temperature has been set at the ambient level to reflect neutral buoyancy of the plume (i.e. equivalent to the meteorological input file).

Table 5-1: Stack parameters adopted for Cross City Tunnel stack

	Value		
MGA Coordinates	333655, 6250358		
Stack Height (m)	60		
Stack Diameter (m)	5.97		
Stack Temperature (K)	293		
	NO <sub>2</sub> Emission Rate (g/s)	PM <sub>10</sub> Emission Rate (g/s)	Exit Velocity (m/s)
Low Emissions (night time)	0.4	0.2	5
Medium Emissions (off peak)	1.0	0.5	11
High Emissions (peak hour)	1.8	0.9	21

A 3-dimensional extract from the AERMOD dispersion model showing the CCT stack, surrounding buildings included in the model and proposed development is presented in **Figure 5-1**.

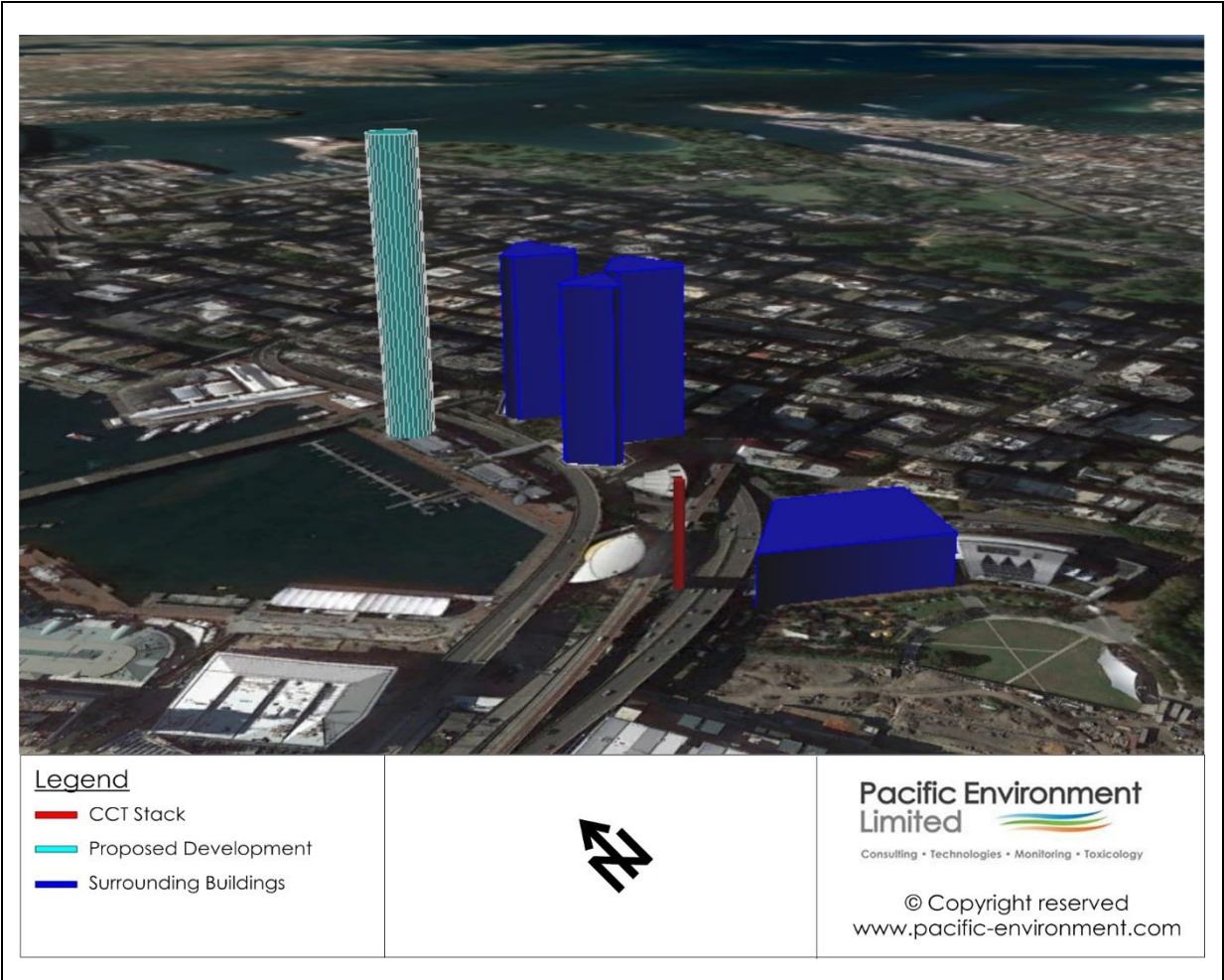


Figure 5-1: Three-dimensional representation of assessment area



### 5.1.2 Darling Park Tunnel Ventilation Points

The Darling Park Tunnel ventilation points release emissions from the underpass adjacent to the proposed development (see **Figure 1-1**). **Figure 5-2** below identifies the two emission points.

These vents were not considered in the assessment as they are not anticipated to be a major source of air pollution in comparison to the CCT stack (**Section 5.1.1**) and the roadside Western Distributor emissions (**Section 5.2**) which have been accounted for.

These two existing ventilation points are located in close proximity to existing high rise buildings and recreational areas, and do not appear from site inspection to be equipped with any mechanical ventilation.

Their comparatively low release heights, lack of mechanical ventilation, and length of underpass being serviced by the vents (less than 150 m) supports that their specific characterisation within the modelling is not warranted for the current assessment.

Rather, all vehicle emissions that potentially report to these ventilation points are accounted for within the roadway modelling (i.e. emissions from these areas are simulated to occur at the two portals of the Darling Park Tunnel, approximately 150m apart).



Figure 5-2: Darling Park Ventilation Points evaluated during site inspection (30/08/2016)



## 5.2 Roadside Emissions

### 5.2.1 Western Distributor Flyover (Vehicle Emissions)

Roadside vehicle emissions along the Western Distributor have been considered in the assessment. The vehicle movements along these roads were sourced from the RTA online traffic database (**RMS, 2016**).

Vehicle emission data from PIARC<sup>2</sup> (**PIARC, 2004**) were adjusted to reflect the NSW vehicle fleet. The modified tables include emissions of NO<sub>x</sub> and PM<sub>10</sub> by age and type of vehicle. The ages of vehicles are categorised into seven periods which correspond to the introduction of emission standards. The types of vehicle are categorised into light and heavy vehicle groups.

The modelling assumptions for the Western Distributor are as follows:

- The peak traffic flow is 6,498 vehicles per hour in the southbound direction.
- The peak traffic flow is 8,262 vehicles per hour in the northbound direction.
- The traffic speed is 80 km/h (modelled as 60km/hr during peak periods and 70 km/hr in the intermittent periods).

Emission estimates are summarised in **Table 5-2**.

Table 5-2: Emissions from Western Distributor (g/km/hr)

Hour of Day	Western Distributor (Southbound)		Western Distributor (Northbound)	
	Nitrogen Oxides (NO <sub>x</sub> )	Particulate Matter (PM <sub>10</sub> )	Nitrogen Oxides (NO <sub>x</sub> )	Particulate Matter (PM <sub>10</sub> )
1	200	0.04	375	0.04
2	153	0.04	265	0.04
3	134	0.04	231	0.04
4	203	0.04	357	0.04
5	664	0.04	972	0.04
6	1,937	0.04	2,260	0.04
7	2,659	0.05	2,643	0.05
8	2,926	0.05	2,413	0.05
9	2,706	0.05	2,448	0.05
10	2,355	0.05	2,410	0.05
11	2,321	0.05	2,482	0.05
12	2,480	0.04	2,707	0.04
13	2,274	0.04	2,693	0.04
14	2,283	0.04	2,920	0.04
15	2,568	0.04	3,265	0.04
16	2,669	0.05	3,283	0.05
17	2,784	0.05	3,087	0.05
18	2,579	0.05	2,739	0.05
19	1,796	0.05	2,009	0.05
20	1,129	0.05	1,587	0.05
21	1,146	0.04	1,734	0.04
22	1,108	0.04	1,782	0.04
23	626	0.04	1,249	0.04
24	358	0.04	665	0.04

<sup>2</sup> The acronym PIARC refers to the Permanent International Association of Road Congress. While this body is now known as the World Road Association, the PIARC acronym has been retained.

## 5.3 Building Wake Effects

Wind flow is often disrupted in the immediate vicinity of buildings. Plumes emitted nearby are assumed to be unaffected by building wakes if they reach building height plus 1.5 times the lesser of building height or projected building width. If this is not the case, pollutants can be brought to ground within a highly turbulent, generally recirculating cavity region in the immediate lee of the building and/or be subject to plume downwash and enhanced dispersion in a turbulent region which extends further downwind behind the building (EPAV, 1999).

The simulation of building wake effects, modelled using the BPIP-PRIME model is based on a relatively simple building geometry, as it is not possible to incorporate complex building shapes adequately within the AERMOD model. A simplified building geometry shown in **Figure 5-1** was incorporated for assessment purposes.

BPIP-PRIME uses heights and corner locations of buildings in the vicinity of the plume to simulate the effective height and width of the structures. The downwash algorithm calculates effective building dimensions relative to the plume, resolved down to ten degree intervals. AERMOD then calculates the impact of these buildings on plume dispersion and consequently on ground level concentrations. Although a simplified building geometry is used, it should provide a reasonable indication of how the building may disrupt wind flow in the immediate vicinity.

### 5.3.1 Impact of Proposed Development on the CCT Plume

To determine the impact of the building downwash (the effect of the proposed development upon the CCT plume) on ground level concentrations, a model run was completed without the building located within the modelling domain.

There was found to be no difference in the ground level concentration predictions for the model runs with and without the proposed building incorporated within the model. This is since the building is a considerable distance from the CCT stack, and hence not anticipated to cause building wake effects, or adversely impact upon CCT stack plume dispersion.

## 5.4 Nitrogen Dioxide Characterisation

Much of the oxides of nitrogen ( $\text{NO}_x$ ) emissions from the roadway source (Western Distributor) are released as nitric oxide (NO), with some nitrogen dioxide ( $\text{NO}_2$ ) emitted at the point of release. The rate at which the NO undergoes oxidation to form  $\text{NO}_2$  depends on prevailing atmospheric conditions including temperature, humidity and the presence of other substances in the atmosphere, such as ozone.

Based upon previous air quality assessments completed by Pacific Environment, a conversion rate of NO to  $\text{NO}_2$ , was assumed to be 20%. This is considered to be a conservative assumption for such a near-field assessment.

## 6. Dispersion Modelling

### 6.1 CCT Stack

The AERMOD model was run to determine any potential air quality impacts from the CCT ventilation outlet in the vicinity of the proposed development site. To account for the worst case impacts, receptors were placed at the southern edge of the site closest to the ventilation outlet emission source.

Further, in addition to predictions at ground level of the proposed overpass / land bridge (modelled at 9 m above the ground), concentrations were also determined at heights corresponding to the building storeys (or levels), up to a maximum of 217 m above ground (see **Table 6-2**).

The resultant maximum 1-hour ground level contours for NO<sub>2</sub> associated with the operation of the CCT stack under the high emission scenario is presented in **Figure 6-1**. Contour plots for the other emission scenarios are not presented as the high emission scenario predicts the greatest potential impact upon the proposed development location.

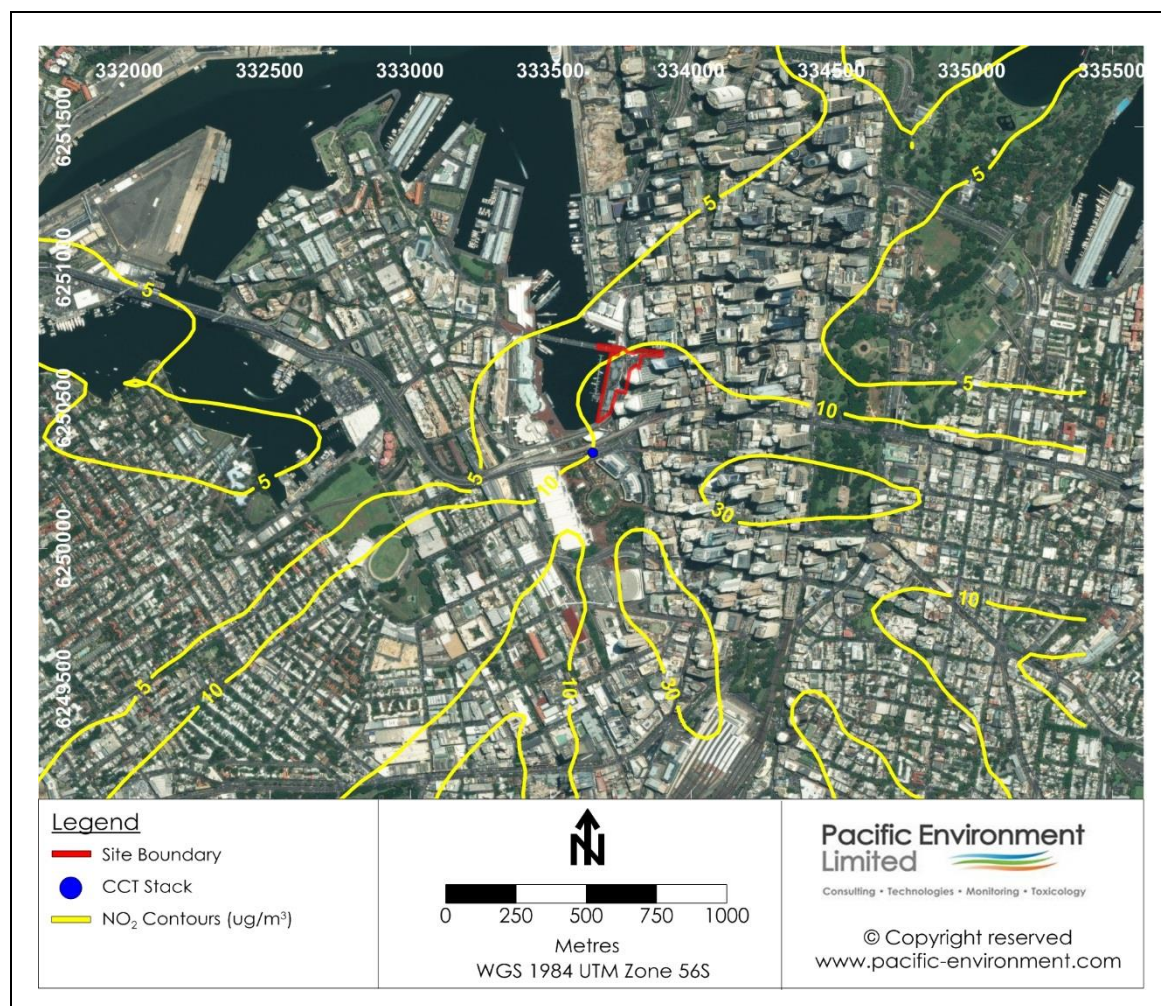


Figure 6-1: Predicted maximum 1-hour NO<sub>2</sub> concentrations at ground level associated with the operation of the CCT stack



## 6.2 Vehicle Emissions

The CAL3QHCR dispersion model was used to estimate the worst-case concentration of oxides of nitrogen and particulate matter, from the current traffic along the Western Distributor.

The Western Distributor was modelled with different traffic volumes across the northbound and southbound lanes (**Section 5.2**).

Although that the pollutant concentrations were modelled at the same receptor locations in both assessments, only the ground level receptors were assessed in the roadside dispersion model as they are anticipated to be the most impacted (i.e. closest to the road surface).

The maximum 1-hour ground level contours for  $\text{NO}_2$  associated with Western Distributor vehicle emissions is presented in **Figure 6-2**. The  $\text{NO}_x$  to  $\text{NO}_2$  ratio of 20% has been accounted for in this figure.

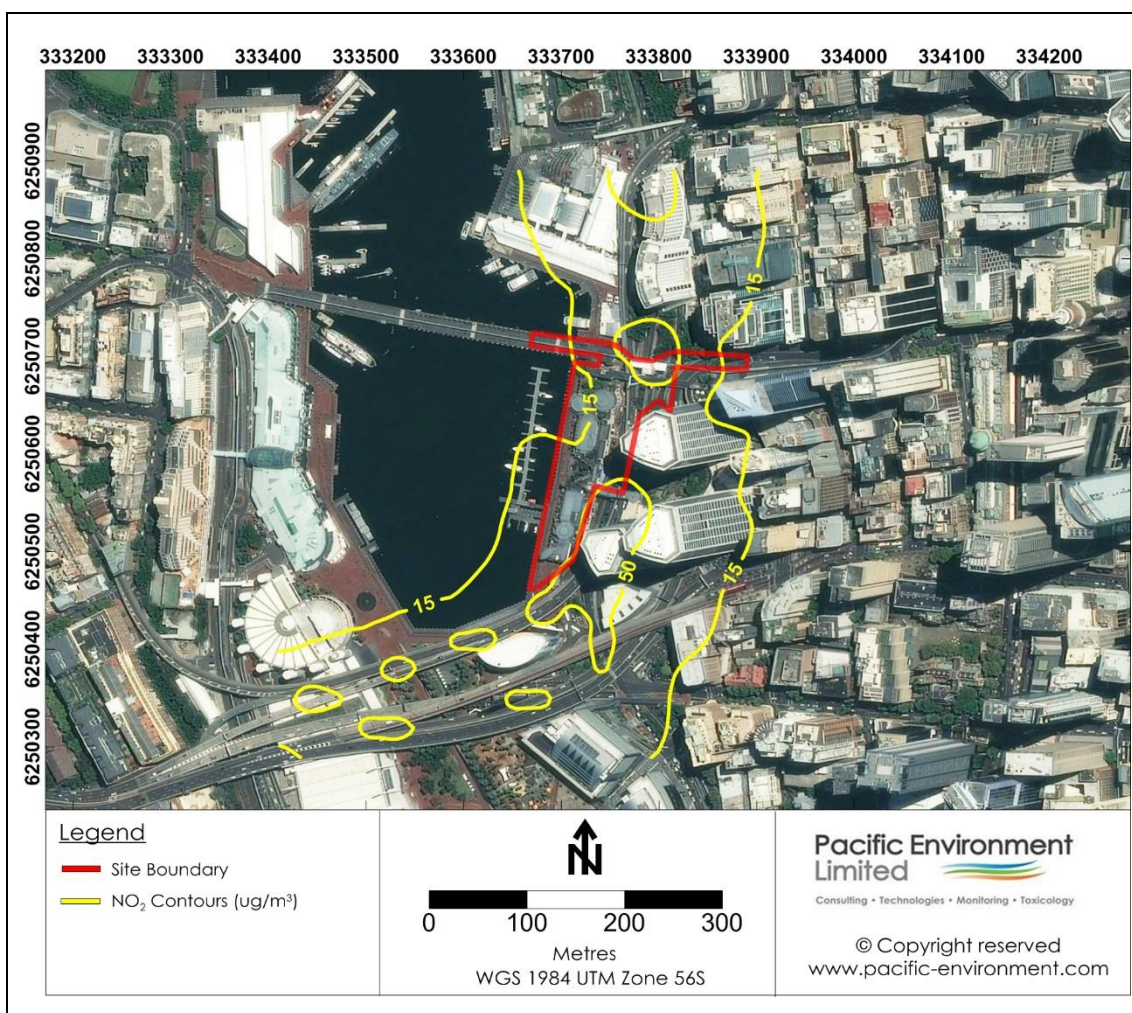


Figure 6-2: Predicted maximum 1-hour  $\text{NO}_2$  concentrations at ground level associated with vehicle movements on the Western Distributor

## 6.3 Air Quality Assessment

Presented in **Table 6-1** are the maximum predicted ground level concentrations of NO<sub>2</sub> and PM<sub>10</sub> from the CCT stack and Western Distributor at the proposed development area in Cockle Bay Wharf.

Note that the results presented show the maximum predicted ground level concentrations at the proposed development for the CCT stack and roadside emissions separately. These maximum events, when added to the background concentration (i.e. a conservative estimation of cumulative impacts), are still well below the respective NSW EPA air quality impact assessment criteria.

This approach is considered highly conservative, as in reality it would not be expected that peak concentrations from the CCT would occur concurrently with peak concentrations from the Western Distributor.

The highest predicted concentrations from the CCT stack on the building occur at approximately 110m above ground level (see **Table 6-2**), with up to an approximate 70 µg/m<sup>3</sup> difference between the maximum predicted 1-hour NO<sub>2</sub> values between ground level and the proposed maximum concentration measured at the building. This contrasts with the Western Distributor emissions where it would be expected that greater impacts would occur at the base of the proposed development.

Table 6-1: Predicted maximum NO<sub>2</sub> and PM<sub>10</sub> concentrations at ground level of the proposed development

Pollutant	Units	Period	Assessment Criterion	Maximum Predicted Concentration at ground level of development area			Cumulative Ground Level Concentration
				CCT Stack	Western Distributor	Background Concentration	
NO <sub>2</sub>	µg/m <sup>3</sup>	1-hour	246	15.7	33.4 <sup>1</sup>	143.5	192.6
		Annual	62	0.1	2.1 <sup>1</sup>	24.6	26.8
PM <sub>10</sub>	µg/m <sup>3</sup>	24-hour	50	0.68	1.7	37.6	40.0
		Annual	30	0.06	0.5	18.3	18.9

Note: <sup>1</sup> 20% conversion of NO<sub>x</sub> assumed.

Table 6-2: Concentrations of NO<sub>2</sub> and PM<sub>10</sub> at varying heights of the proposed development

Modelled height above ground (m)	NO <sub>2</sub> (µg/m <sup>3</sup> )		PM <sub>10</sub> (µg/m <sup>3</sup> )	
	1-hour	Annual	24-hr	Annual
9 (ground level)	11.8	0.1	0.3	0.0
30	21.2	0.1	0.6	0.0
60	35.9	0.2	1.1	0.1
90	41.7	0.3	2.4	0.2
100	74.5	0.4	3.8	0.2
110 <sup>1</sup>	82.2	0.4	4.5	0.2
120	68.0	0.3	4.3	0.2
150	52.0	0.2	1.4	0.1
180	31.3	0.2	1.0	0.1
210	11.8	0.1	0.7	0.1
217 (maximum height)	21.2	0.1	0.3	0.0

Note: <sup>1</sup> Building height of 110 m anticipated to have the highest air quality impacts from the CCT stack.  
 Bottom level of the development predicted to be 9 m above ground level.  
 Maximum concentration at each height across all emission scenarios presented.



## 7. Conclusions

The Minister for Planning's Approval Condition 274 for the Cross City Tunnel (CCT) states that any development in the vicinity of the CCT stack requires an air quality assessment of potential impacts from the stack plume. The proposed development at Cockle Bay Wharf, Sydney is within 300 metres of the CCT stack and therefore triggered the requirement to undertake an air quality assessment.

Pacific Environment completed an air quality assessment of the CCT ventilation stack and Western Distributor in order to determine the air quality impact of these sources on the proposed development.

The assessment concludes that the emissions from the CCT stack and Western Distributor are not anticipated to result in any exceedances of the NSW EPA criteria for the air quality metrics assessed in the vicinity of the proposed development.

The modelling completed to date indicates that higher concentrations of the air quality metrics evaluated are predicted to occur at approximately half the maximum height of the proposed development (110m) compared with those at ground level.

It is noted however, that given the complexity of the modelled scenario, optimisation of any air intakes locations for the proposed development should necessarily occur during the detailed design stage for the development. It is recommended that this be completed using a micro-scale modelling technique such as computational fluid dynamics (CFD) or the GRAL roadway assessment modelling scheme.

## 8. References

EPAV (1999). Ausplume Gaussian Plume Dispersion Model Technical User Manual. Melbourne, Environmental Protection Authority of Victoria. Publication No. 671.

Golder, D. (1972). "Relations among Stability Parameters in the Surface Layer", Boundary-Layer Meteorology, 3: 47-58.

NSW DEC (2005). "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales". NSW Department of Environment & Conservation. Sydney.

PIARC (2004). Road Tunnels: Vehicle Emissions and Air Demand for Ventilation, PIARC Technical Committee on Road Tunnels Operation (C5).

Roads & Maritime Service (2016). Traffic Volume Viewer.  
<http://www.rms.nsw.gov.au/about/corporate-publications/statistics/traffic-volumes/index.html>,  
visited 16/09/16

Seinfeld, J. and S. Pandis (2006). "Atmospheric Chemistry and Physics: From Air Pollution to Climate Change." Hoboken, New Jersey, John Wiley & Sons, Inc.

# Appendix A

## Model Inputs

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Table 8-1: Model Inputs for CCT Dispersion Modelling

<b>AERMOD</b>	
<b>Meteorology</b>	
Meteorological data for Surface Files –(Samson file)	CALMET generate meteorology (integrating surrounding BOM weather stations) <ul style="list-style-type: none"> <li>• Air temperature</li> <li>• Relative Humidity</li> <li>• Wind speed</li> <li>• Wind direction</li> </ul> TAPM centred over Darling Harbour <ul style="list-style-type: none"> <li>• Cloud cover</li> <li>• Cloud height</li> </ul>
Land Use	Urban (Albedo – 0.2075, Bowen ratio- 1.625 and Surface roughness – 1)
AERMET PFL	Upper Air estimator
Year of analysis	January 2013 - December 2013
<b>Model Set up</b>	
Centre of domain (lat, long)	-33°52'25" S, 151°12'20" E
Centre of domain (easting, northing)	333600, 6250400
MGA coordinate zone	56 S
Grid domain size	5km x 5km
Grid spacing	100m
South west corner of gridded receptor domain (m)	331600, 6248400
Number of grid points	40 x 40
Terrain data	SRTM3 at 30m resolution
Rural Mode	Selected
<b>Output Options</b>	
Highest values	