Figure 4 Sensitive receiver locations to the east

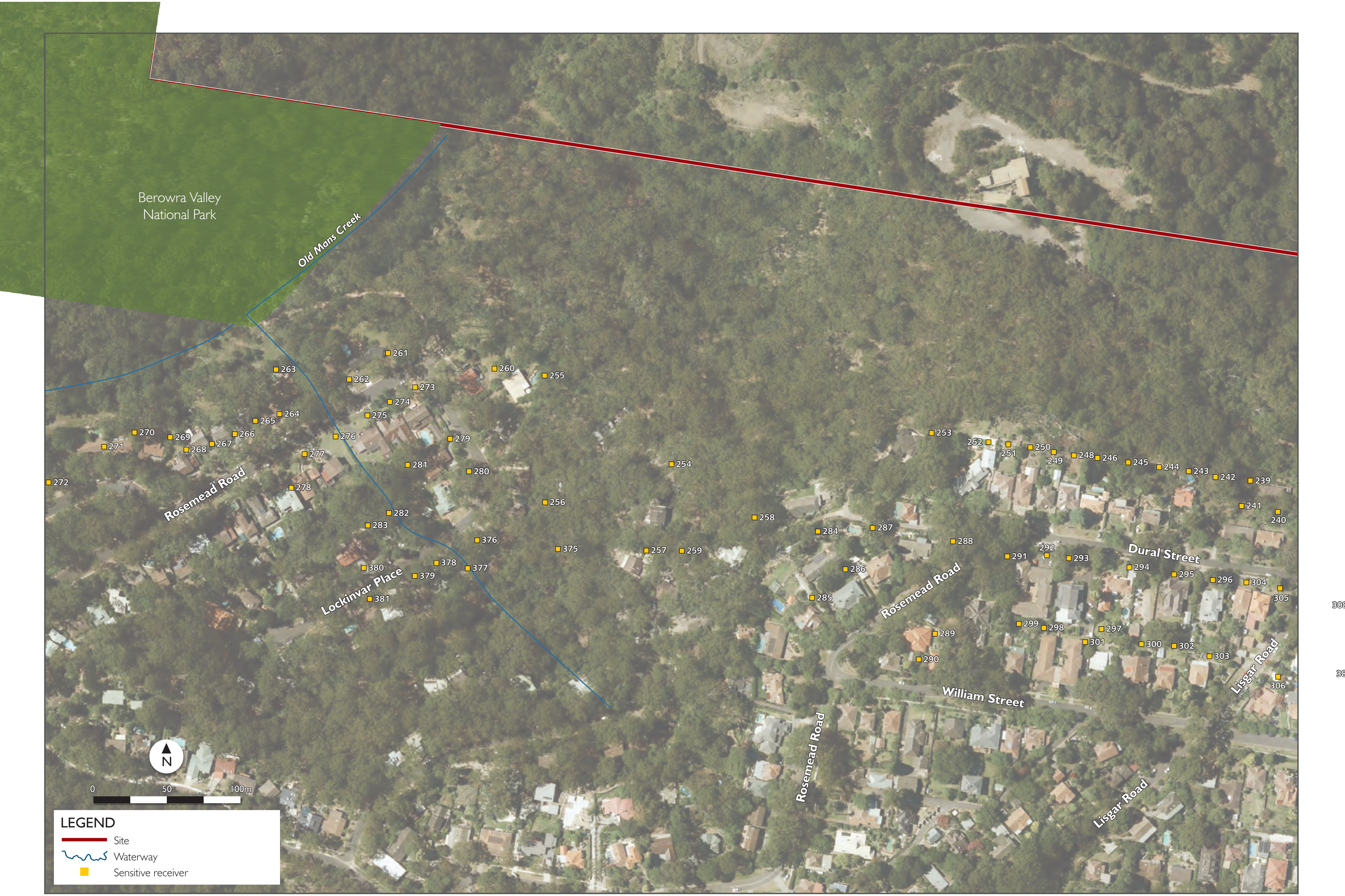

Figure 5 Sensitive receiver locations to the south

4.0 Assessment Methodology

4.1 Assessment scenarios

Two operational scenarios have been modelled as part of this assessment and are described below in **Table 8**.As the timing of stockpiling and void filling is likely to be staggered (refer to **Table 2**) Scenario 1 accounts for only stockpiling activities while Scenario 2 takes into account both stockpiling and void filling occurring concurrently.

For each scenario it is assumed that the generator powering the onsite conveyor and all mobile equipment used for the shaping and redistribution of spoil from the temporary stockpiles to the void would operate for 80 per cent of the time within the confines of the operational hours stated in **Section 2.2.2**. This 80 percent utilisation rate has been applied to account for normal day to day periods of down time including during refuelling, staff breaks, equipment maintenance and scheduling of onsite operations.

Table 8 Modelling Scenarios

Scenario	Scenario Description
Scenario 1	- Movement of up to 4,620 bcm/day of spoil from NorthConnex project construction sites to the Hornsby Quarry sites. - Storage of 170,000 m^3 of spoil in temporary stockpiles located on the flats within the eastern part of the Hornsby Quarry site.
Scenario 2	- Movement of up to 4,620 bcm/day of spoil from NorthConnex project construction sites to the Hornsby Quarry site. - Storage of 170,000 m^3 of spoil in temporary stockpiles located on the flats within the eastern part of the Hornsby Quarry site. - Transport of up to 7920 t/day of spoil from the temporary stockpiles via conveyor to the quarry floor. A minimum volume of 1,000,000 m^3 of spoil would be used to fill the void.

4.2 Dispersion models

The CALPUFF suite of models has been used to model pollutant dispersion from the stockpiling and filling activities at the Hornsby Quarry site and to estimate the effects of the project on ambient air quality. The CAL3QHCR model has been used to model pollutant concentrations associated with emissions from vehicles on surface roads around the project. The outputs from CALPUFF and CAL3QHCR have been combined with the adopted ambient (background) pollutant concentrations (where applicable) to provide a cumulative estimate of pollutant concentrations in the vicinity of the project during the spoil management activities.

The models are briefly described in the following sections, with further details provided in **Appendix C**. The modelling has been undertaken in accordance with relevant guidance documents (DEC, 2005; Barclay & Scire, 2011).

4.2.1 CALPUFF

The CALPUFF suite of programs, including meteorological (CALMET), dispersion (CALPUFF) and post processing modules (CALPOST), is an advanced non-steady state modelling system designed for meteorological and air quality modelling. CALPUFF is approved for use in NSW by the EPA, particularly in applications involving complex terrain, non-steady-state conditions, in areas where coastal effects may occur, and/ or when there are high frequencies of stable or calm meteorological conditions. CALPUFF was selected for use in this assessment as the topography of the area surrounding the project is complex and is considered close enough to the coast to be potentially affected by coastal breeze circulation.

4.2.2 CAL3QHCR

The CAL3QHCR model is a specialised model for the assessment of road emissions. The line source model predicts pollutant concentrations of carbon monoxide, nitrogen dioxide, particulate matter, and other inert gases from idle or moving motor vehicles based on the Gaussian diffusion equation. The model was accessed through the CALRoads View user interface.

4.3 Meteorological data

Meteorological data for meteorological modelling has been sourced from selected NorthConnex monitoring stations and for consistency from BoM and the OEH monitoring stations used in the NorthConnex EIS assessment (AECOM, 2014).The most recent calendar year of full data, 2014 has been used in the assessment and analysis of available meteorological data is presented in Appendix B.

The meteorological data used in the dispersion model are of fundamental importance, as these data drive the predictions of the transport and dispersion of the air pollutants in the atmosphere. The most critical parameters are:

- Wind direction, which determines the initial direction of transport of pollutants from their sources.
- Wind speed, which dilutes the plume in the direction of transport and determines the travel time from source to receiver.
- Atmospheric turbulence, which indicates the dispersive ability of the atmosphere.

Both measured and prognostic meteorological data were used in this assessment. Meteorological data were sourced from six local surface meteorological stations located in the Sydney basin. NorthConnex monitoring stations James Park and Brickpit were incorporated into the meteorological model due to the site's proximity to the Hornsby Quarry, while collectively data from BoM and EPA sites (Terrey Hills, Richmond RAAF Base, Prospect and Sydney Airport) were chosen to provide good coverage over the wider modelling domain. Additionally Sydney Airport and Richmond RAAF monitoring stations are also able to provide air pressure data, which is required for at least one observational site for input into CALMET. Additional information regarding the selection of these six sites is provided in Appendix B.

These measured data were used in conjunction with CSIRO's The Air Pollution Model (TAPM) prognostic three-dimensional meteorological data to simulate the three-dimensional complex meteorological patterns that exist within the modelling domain, accounting for the effects of local topography and changes in land surface characteristics. Gridded three-dimensional TAPM data were input into the CALMET model to generate the initial guess wind field[1] in CALMET, after which observational data from meteorological stations were included by the program to generate the final three-dimensional wind fields for use in CALPUFF. The dispersion modelling was undertaken using one year of meteorological data (January 2014 – December 2014).

4.4 Terrain and land use data

The underlying terrain and dominant land use are important functions of plume transport modelling. Gridded terrain elevations for the modelling domain were derived from the Shuttle Radar Topography Mission (SRTM) three arc-second or around 90 metre resolution data[2] for the meteorological modelling, while higher one metre resolution NSW Land and Property Information (LPI) Light Detection and Ranging (LiDAR) data[3] was used for point source terrain heights and all gridded receptors for the air dispersion modelling. Land use within the study area primarily consists of urban areas, which are interspersed with rangeland and forest land. Land use data within the study area has been derived from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and supplied to AECOM by the OEH. The data are representative of the actual area associated with the project, are recent and of a very fine resolution to increase the accuracy of the modelling.

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[1] CALMET uses a two step procedure in developing final wind fields. The "initial guess" wind field is developed based on a domain-average wind profile, and this domain-average profile of winds is adjusted for terrain effects and divergence minimisation to produce a 'Step 1' wind field. The second step is the processing of the wind field is the introduction of observational data into the terrain adjusted Step 1 field.

[2] Based on the findings described in the *North Connex Environmental Impact Statement; Submissions and Proffered Infrastructure Report Chapters 1-5 2014* SRTM is accurate with relatively low error magnitudes on average, Where errors do occur, they are more likely to overestimate the height of topography. Here the risk of over estimation of sensitive receptor heights around elevated point sources may lead to over estimation of potential impacts at these locations. Given emissions from the spoil management facility are from largely ground based sources the risk of overestimation of impacts resultant form overestimation of receptor heights is minimal in this case.

[3] The LPI LiDAR 2011 data set has a horizontal spatial accuracy of 0.8 and a vertical spatial accuracy of 0.3.

The land use data used in this application are different to the default land use data used in TAPM and for most CALMET model applications outside of the United States, which are the USGS one kilometre land use data. Until recently, the USGS one kilometre global land use data set was the most readily available data set for air quality applications. Limitations of the USGS data set, however, include its age (more than 20 years old), coarse resolution (between 900 metres and 1.2 kilometres), and the fact that it is categorised according to the North American land use category system, which does not correspond to all relevant Australian land use types.

As stated above, plume transport is an important function of the underlying dominant land use. The inclusion of the Australian land use data set is, therefore, an important relevant addition to this modelling application as the data are recent, relevant and of a very fine resolution. For this project, specific surface characteristics, albedo, roughness length and leaf area index for the Sydney basin were determined from Gero and Voidman (2006) for bushland, agricultural land, dense urban, new urban and established urban areas. Bushland is described as natural vegetation (primarily around 20 metre trees with 40 per cent cover). Agricultural land incorporates all agricultural activity in western Sydney, which is mostly pasture for grazing or market gardens. Urban categories are split into dense urban (which is confined to the Sydney and Parramatta central business districts), new urban (newly established residential suburbs lacking mature trees), and established urban (residential suburbs with mature trees).

4.5 Sensitive receivers

A total of 420 sensitive receivers were specifically considered in this assessment. That is, pollutant concentrations were calculated at these specific locations. Pollutant concentrations were also calculated at each of the grid points within the modelling domain (refer to **Section 4.6**). Locations of the sensitive receiver are shown in **Figure 3**, **Figure 4** and **Figure 5** and details of the sensitive receivers are provided in **Appendix D**.

Existing background concentrations for 2014 at sensitive receiver locations were assumed to be equal to air quality concentrations recorded at the closest ambient air quality monitoring station James Park for 2014 (see **Section 3.2**)

4.6 Model input parameters

A summary of the data and parameters used as input parameters for CALMET and CALPUFF is shown in **Table 9**.

Table 9 Summary of meteorological and CALPUFF input parameters – operational assessment

Parameter	Input
CALMET (v6.42)	
Meteorological grid domain	60 kilometres x 62.5 kilometres
Meteorological grid resolution	250 metre resolution (240 x 250 grid cells)
Reference grid coordinate of southwest corner	295.000 E, 6232.000 S
Cell face heights in vertical grid	0, 20, 40, 80, 160, 320, 700, 1300, 1700, 2300 and 3000 m
Simulation length	1 year (2014)
Surface meteorological stations	CALMET Hybrid Mode: Run using a combination of TAPM gridded numerological data supplemented by data from six surface meteorological stations operated by NorthConnex, BOM and OEH (described below). **James Park NorthConnex Monitoring Station** *Hourly data:* Temperature, precipitation, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 325.161 E 6269.429 S **Brickpit Park NorthConnex Monitoring Station** *Hourly data:* Temperature, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 323.028 E 6266.847 S

Parameter	Input
	Terry Hills BOM Monitoring Station (Station No. 066059) *Hourly data:* Temperature, precipitation, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 335.509 E, 6270.714 S **Richmond RAAF BOM Monitoring Station (Station No. 067105)** *Hourly data:* Temperature, precipitation, humidity, pressure, wind speed and wind direction. *MGA Coordinates (km)*: 293.651 E, 6279.933 S
	Prospect OEH Monitoring Station *Hourly data:* Temperature, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 306.745 E, 6258.646 S **Sydney Airport BOM Monitoring Station (Station No. 066307)** *Hourly data:* Temperature, precipitation, humidity, pressure, wind speed and wind direction. *MGA Coordinates (km)*: 331.173 E, 6242.272 S
Upper air meteorological station	No upper air stations. The 3-dimensional gridded prognostic data from TAPM were used as the initial guess wind-field for CALMET.
Wind field input parameters	RMAX = 2, RMAX1 = 8 and RMAX3 = 10, TERRAD = 6, R1 = 0.8, R2 = 3, IEXTRP = -4 and all layer dependant biases = 0
Terrain data	Terrain elevations were extracted from the NASA Shuttle Radar Topography Mission data set (SRTM 90 metre, 3-arc sec).
Land use data	Land use information for CALMET was derived from the OEH land use data set between June 2000 and June 2007 for NSW. The data set has a resolution of 150 square metres over the modelling domain. Higher resolution LPI LiDAR data was used for point source terrain heights and all gridded receptors for the air dispersion modelling.
TAPM	
TAPM Version	v4.04
Number of grids (spacing)	5 (30 km, 10 km, 3 km, 1km, 0.3km)
Number of grid points	40 x 40 x 30
Simulation period	2014
Terrain information	AUSLIG 9 second (horizontal resolution 9”)
Centre of analysis	33°46 S, 151°7.5 E
Local data assimilation	None
Mode	Meteorology mode only
CALPUFF (v6.42)	
Modelling domain	**Computation grid:** 22.5km x 20km **Sampling grid:** No gridded receivers. Discrete receipts only. *MGA SW Coordinates (km)*: 322.150 E, 6268.450 S *MGA NE Coordinates (km)*: 334.600 E, 6270.950 S
Modelling grid resolution	Grid resolution of approximately 50m. A higher density of receivers have been placed within close proximity to the facility and strategic placement of receivers along the haul routes was required to account for assimilation of results with CAL3QHCR data.

Parameter	Input
Number of sensitive receivers	All grid resolutions provided above were modelled as discrete receiver locations (i.e. no gridded receivers) to account for varying grid resolution over the modelling domain. A total of 2,999 discrete receiver locations resulted from the modelling grids, including 420 sensitive receivers around the spoil management facility and an additional 58 receivers along the haul route.
Dispersion algorithm	Turbulence-based coefficients
Hours modelled	8,760 hours
Meteorological modelling period	1 January 2014 – 31 December 2014

4.6.1 Emissions calculation

Vehicle emission rates have been based on internationally recognised emission factors coupled with projected traffic volumes, including the proportion of heavy vehicles and tunnel and outlet emission characteristics. Emissions associated with the spoil management activities have been based on Australian Government Department of Environment's National Pollution Inventory (NPI) Emission Estimation Technique Manuals and the United States Environmental Protection Agency (US EPA)*AP-42, Compilation of Air Pollutant Emission Factors*.

4.6.1.1 Vehicle emission factors

Pollutant emissions from the trucks on the public roads has been estimated using internationally recognised vehicle emission factors prepared by the World Road Association (PIARC, 2012), which provide Australian-specific emissions based on respective fleet compositions. The PIARC emissions dataset has been used for the calculation of ventilation design parameters for the NorthConnex project, and is considered to be an appropriate, if conservative, approach[4].

PIARC (2012) provides emissions data for the year 2010 for fine particulate matter (PM_{10}) (referenced as opacity), carbon monoxide and oxides of nitrogen for passenger car, light duty vehicle (LDV; < 3.5 tonnes) and heavy duty vehicle (HDV; > 3.5 tonnes) classifications. Factors are provided to account for varying vehicle speeds and road gradients. Non-exhaust related particulate emissions ($PM_{2.5}$), based on brake wear and the re-suspension of particulates from road surfaces, are also provided.

PIARC (2012) provides adjustment factors that can be used to forecast future emissions that are based on agreed assumptions on the expected continuous improvement in engine technologies, the phase-out of older, less efficient cars and the gradual tightening of emissions legislation. The adjustment factors are provided for each year up to 2020 and as such the 2016 adjustment factors were applied in the assessment for the project year of 2016.

The surface road modelling has reviewed the emissions from diesel heavy vehicles (material delivery trucks) only. Additional relevant road vehicle emissions not contained within PIARC (2012) (that is, exhaust-related $PM_{2.5}$ and total volatile organic compounds) were sourced from the National Pollutant Inventory (DEWHA, 2008). Total suspended particulates have not been included in the modelling because the particulate emissions from vehicle exhausts primarily comprise the smaller fractions (i.e. PM_{10} and $PM_{2.5}$). As a result, PIARC and the National Pollutant Inventory do not include emission factors for total particulates.

[4] The recently developed database and calculation tool, COPERT Australia, was reviewed as part of the assessment process. While the software was designed specifically for road transport emission inventories across Australia, discussions with the developer determined that, due to a lack of a valid fleet mix model to allow the calculation of fleet emissions, it was not considered suitable for use in project-related road source dispersion modelling.

4.6.1.2 Emissions from haul roads

The haul road assessment has modelled the emissions from the spoil haulage trucks to and from the site only, to avoid double counting of emissions from the existing suburban traffic conditions. Background air quality monitoring data from James Park monitoring station for the year 2014 has been used in the assessment to represent the background air quality environment and hence separate baseline modelling of existing road use has not been undertaken. The surface roads for the haul route used in the project have been converted to 50 road links with associated gradients, which have then been entered into the CAL3QHCR model. Hourly pollutant emission rates were estimated for each road link applying emissions for heavy diesel vehicles at the respective grades and speeds from PIARC (2012). Pollutants have been modelled for the operational year 2016 using meteorological data from 2014 to capture the likely meteorological conditions. Further information regarding calculation of emissions from haul roads is presented in **Appendix E**.

4.6.1.3 Emissions from spoil management activities

Combustion emissions from mobile and stationary plant and equipment for spoil management activities have been calculated using the NPI *Emission Estimation Technique Manual for Combustion Engines, Version 3.0* (DEWHA 2008). Dust emissions associated with spoil management and materials handling activities have been calculated using the *Emission Emissions Estimation Technique Manual for Mining, Version 3.1* (DSEWPC 2012), and the US EPA *AP-42, Compilation of Air Pollutant Emission Factors*, Fifth edition (1995) (and updates).

A summary of the assumptions used in the calculation of emissions from spoil management activities is provided in **Table 10**. A description of the emission calculations and assumptions is presented in **Appendix E**.

Table 10 Emission calculation assumptions

Parameter	Assigned Value
Correction Parameters	
Moisture Content (%)	10
Silt Content (%)	12
Sealed Road Silt Loading (g/m^2)	0.6
Unsealed Road Silt Content (%)	7.1
Mean Wind Speed (m/s)	1.96
Mean Vehicle Speed (km/h)	5
Precipitation >0.25mm (d/y)	229
All hours where wind speed > 5.4m/s (h)	20
Activity Rates	
Volume of spoil per truck (BCM)	12
Maximum haul trucks per hour	35
Rate of Stockpiling and throughput to conveyor[1] (t/h)	900
Equipment utilisation[2] (%)	80
Surface Areas	
Exposed area on flats (ha)	4.3
Exposed area in void (ha)	7.5
Equipment Numbers	
Haul Trucks present onsite at any one time	6
Bulldozer on flats	2
Bulldozer in void	2
Excavator / Front-end loader on flats	2

Parameter	Assigned Value
Correction Parameters	
Excavator / Front-end loader in void	2
Roller in void	2
Articulated dump trucks	2
Water cart	1
Onsite generator (50KVA) (Site & Amenities)	1
Onsite generator (500KVA) (Conveyor)	1
Onsite generator (50KVA) (Pit Amenities)	1

[1] A utilisation rate of 80 percent has been applied to the maximum capacity of the conveyor for emissions rate calculations; equating to 720t/h (refer to **Appendix E**).
[2] Refers to the generator powering the onsite conveyor and all mobile equipment used for the shaping and redistribution of spoil from the temporary stockpiles to the void

4.6.2 Emission rates

Emission rates for Scenario 1 and Scenario 2 are summarised in **Table 11** and **Table 12** respectively. Emission calculations are provided in Appendix E.

Table 11 Scenario 1 emission rates

Operation/Activity Description	Emission Type	Source Type	Location	Emission Rate per Modelled Source (g/s)							Operating Hours#	Number of Modelled Sources*
				CO	NO_x	TSP	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		
Bulldozer working on temporary stockpiles	Combustion	Point	Flats	6.27×10^{-2}	2.28×10^{-1}	2.02×10^{-2}	2.02×10^{-2}	1.86×10^{-2}	8.48×10^{-6}	2.20×10^{-2}	Normal	2
	Dust	Volume	Flats	N/A	N/A	2.86×10^{-1}	6.21×10^{-2}	3.00×10^{-2}	N/A	N/A	Normal	2
Trucks dumping spoil	Dust	Volume	Flats	N/A	N/A	5.15×10^{-3}	2.44×10^{-3}	3.65×10^{-4}	N/A	N/A	Normal	2
Haul trucks (full)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	7.67×10^{-2}	1.47×10^{-2}	3.56×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	2.11×10^{-1}	5.83×10^{-2}	5.83×10^{-3}	N/A	N/A	Normal	1
Haul trucks (empty)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	2.34×10^{-2}	4.50×10^{-3}	1.09×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	1.25×10^{-1}	3.45×10^{-2}	3.45×10^{-3}	N/A	N/A	Normal	1
Water cart	Combustion	Point	Flats	4.15×10^{-2}	9.97×10^{-2}	8.15×10^{-3}	8.15×10^{-3}	7.48×10^{-3}	3.70×10^{-6}	9.09×10^{-3}	Normal	1
Wind erosion from exposed areas	Dust	Area	Flats	N/A	N/A	3.65×10^{-5}	1.83×10^{-5}	2.74×10^{-6}	N/A	N/A	When wind speed >5.4m/s	1
Onsite generator (50KVA) (Amenities)	Combustion	Point	Flats	5.56×10^{-2}	5.22×10^{-2}	4.44×10^{-3}	4.44×10^{-3}	4.44×10^{-3}	6.67×10^{-10}	1.44×10^{-2}	Normal	1

*Number of modelled sources refers to the number of sources modelled per actual emission source. For the number of actual sources refer to Appendix E.
#Normal operating conditions refer to Weekdays 7am to 6pm and Saturdays 8am to 1pm.

Table 12 Scenario 2 emission rates

Operation/Activity Description	Emission Type	Source Type	Location	Emission Rate per Modelled Source (g/s)							Operating Hours#	No. of Modelled Sources*
				CO	NO_x	TSP	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		
Front-end loader transferring spoil from stockpiles to conveyor	Combustion	Point	Flats	8.63×10^{-2}	2.81×10^{-1}	2.57×10^{-2}	2.57×10^{-2}	2.36×10^{-2}	1.47×10^{-5}	3.78×10^{-2}	Normal	2
	Dust	Volume	Flats	N/A	N/A	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	N/A	N/A	Normal	2
Bulldozer working on temporary stockpiles	Combustion	Point	Flats	6.27×10^{-2}	2.28×10^{-1}	2.02×10^{-2}	2.02×10^{-2}	1.86×10^{-2}	8.48×10^{-6}	2.20×10^{-2}	Normal	2
	Dust	Volume	Flats	N/A	N/A	2.86×10^{-1}	6.21×10^{-2}	3.00×10^{-2}	N/A	N/A	Normal	2
Trucks dumping spoil	Dust	Volume	Flats	N/A	N/A	5.15×10^{-3}	2.44×10^{-3}	3.65×10^{-4}	N/A	N/A	Normal	2
Haul trucks (full)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	7.67×10^{-2}	1.47×10^{-2}	3.56×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	2.11×10^{-1}	5.83×10^{-2}	5.83×10^{-3}	N/A	N/A	Normal	1
Haul trucks (empty)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	2.34×10^{-2}	4.50×10^{-3}	1.09×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	1.25×10^{-1}	3.45×10^{-2}	3.45×10^{-3}	N/A	N/A	Normal	1
Conveyor transfer points	Dust	Volume	Flats	N/A	N/A	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	N/A	N/A	Normal	3
Water cart	Combustion	Point	Flats	4.15×10^{-2}	9.97×10^{-2}	8.15×10^{-3}	8.15×10^{-3}	7.48×10^{-3}	3.70×10^{-6}	9.09×10^{-3}	Normal	1
Wind erosion from exposed areas	Dust	Area	Flats	N/A	N/A	3.65×10^{-5}	1.83×10^{-5}	2.74×10^{-6}	N/A	N/A	When wind speed >5.4m/s	1
Onsite generator (50KVA) (site compound and amenities)	Combustion	Point	Flats	5.56×10^{-2}	5.22×10^{-2}	4.44×10^{-3}	4.44×10^{-3}	4.44×10^{-3}	6.67×10^{-10}	1.44×10^{-2}	Normal	1
Onsite generator (500KVA)	Combustion	Point	Flats	3.11×10^{-1}	3.56×10^{-1}	1.78×10^{-2}	1.78×10^{-2}	1.78×10^{-2}	5.33×10^{-9}	1.16×10^{-1}	Normal	1

Operation/Activity Description	Emission Type	Source Type	Location	Emission Rate per Modelled Source (g/s)							Operating Hours#	No. of Modelled Sources*
				CO	NO_x	TSP	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		
(conveyor)												
Arterial dump trucks	Combustion	Point	Void	1.25×10^{-1}	2.89×10^{-1}	1.79×10^{-2}	1.79×10^{-2}	1.64×10^{-2}	5.05×10^{-6}	1.33×10^{-2}	Normal	2
	Dust (full)	Volume	Void	N/A	N/A	1.64×10^{-1}	4.51×10^{-2}	4.51×10^{-3}	N/A	N/A	Normal	2
	Dust (empty)	Volume	Void	N/A	N/A	1.19×10^{-1}	3.28×10^{-2}	3.28×10^{-3}	N/A	N/A	Normal	2
Excavators transferring spoil from conveyor	Combustion	Point	Void	7.20×10^{-2}	2.97×10^{-1}	2.09×10^{-2}	2.09×10^{-2}	1.92×10^{-2}	1.38×10^{-5}	3.54×10^{-2}	Normal	2
	Dust	Volume	Void	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	7.49×10^{-3}	Normal	2
Bulldozers working in void	Combustion	Point	Void	8.34×10^{-2}	3.04×10^{-1}	2.69×10^{-2}	2.69×10^{-2}	2.47×10^{-2}	1.13×10^{-5}	2.93×10^{-2}	Normal	2
	Dust	Volume	Void	N/A	N/A	2.86×10^{-1}	6.21×10^{-2}	3.00×10^{-2}	N/A	N/A	Normal	2
Rollers working in void	Combustion	Point	Void	8.71×10^{-2}	1.89×10^{-1}	1.12×10^{-2}	1.12×10^{-2}	1.03×10^{-2}	5.50×10^{-6}	1.40×10^{-2}	Normal	2
	Dust	Volume	Void	N/A	N/A	5.28×10^{-2}	2.36×10^{-2}	3.78×10^{-3}	N/A	N/A	Normal	2
Conveyor transfer points	Dust	Volume	Void	N/A	N/A	2.14×10^{-2}	1.01×10^{-2}	1.53×10^{-3}	N/A	N/A	Normal	1
Wind erosion from exposed areas	Dust	Area	Void	N/A	N/A	5.22×10^{-5}	2.61×10^{-5}	3.92×10^{-6}	N/A	N/A	When WS >5.4m/s	1
Onsite generator (50KVA) (Site and water pump)	Combustion	Point	Flats	5.56×10^{-2}	5.22×10^{-2}	4.44×10^{-3}	4.44×10^{-3}	4.44×10^{-3}	6.67×10^{-10}	1.44×10^{-2}	Normal	1

*Number of modelled sources refers to the number of sources modelled per actual emission source. For the number of actual sources refer to Appendix E.
#Normal operating conditions refer to Weekdays 7am to 6pm and Saturdays 8am to 1pm.

The information relevant to the surface road modelling emissions is provided in **Table 13** and is applicable for both scenarios. The data is provided for each of the 50 links for both peak and non-peak hours, where peak hours are assigned to 7am-9am and 3pm-5pm and non-peak hours are 9am-3pm. The emission rates have been calculated using PIARC emission factors, as described in **Sections 4.6.1.1** and **4.6.1.2**. Further information on emission calculations are provided in **Appendix E**.

Table 13 Surface road emissions rates

Link	Vehicles Per Hour (VPH)	Peak hours (7am-9am and 3pm 5pm)						Vehicles per Hour (VPH)*	Non Peak hours (9am-3pm)					
		Emission rates (g/v mile)							Emission rates (g/v mile)					
		CO	NOx	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		CO	NOx	PM_{10}	$PM_{2.5}$	PAHs	TVOCs
1	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
2	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
3	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
4	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
5	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
6	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
7	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
8	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
9	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
10	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
11	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
12	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
13	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
14	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
15	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
16	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
17	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311

18	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
19	35	1.03	2.89	0.334	0.318	8.40×10^{-5}	0.213	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
20	35	1.03	2.89	0.334	0.318	8.40×10^{-5}	0.213	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
21	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
22	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
23	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
24	35	0.334	0.470	0.225	0.214	2.72×10^{-5}	6.89×10^{-2}	70	2.11	13.7	0.567	0.539	1.72×10^{-4}	0.436
25	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
26	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
27	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
28	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
29	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
30	35	1.03	2.89	0.334	0.318	8.40E-05	0.213	0	-	-	-	-	-	-
31	35	1.03	2.89	0.334	0.318	8.40E-05	0.213	0	-	-	-	-	-	-
32	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
33	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
34	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
35	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
36	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
37	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
38	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
39	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
40	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
41	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-

42	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
43	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
44	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
45	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
46	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
47	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
48	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	0	-	-	-	-	-	-
49	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	0	-	-	-	-	-	-
50	35	1.03	2.89	0.334	0.318	8.40×10^{-5}	0.213	0	-	-	-	-	-	-
*Number of vehicle movements refers to the sum of haul trucks entering (35 trucks per hour) and leaving (35 trucks per hour) the Hornsby Quarry site.														

4.7 Mitigation measures applied into the modelling

Best industry practice mitigation measures would be applied on a day to day basis and are largely source based, where dust generation is minimised through the application of specific measures designed to reduce dust emissions at the source of generation. The measures that were assumed to be undertaken were:

- All site haul roads will be sealed.
- Water sprays will be used on the spoil stockpiles and conveyor transfer points.
- Water carts will wet down the material being transported by arterial dump trucks and worked by the roller and bulldozers.
- Wind barriers, such as shade cloth on boundary fencing, will be erected around the stockpile site perimeter.
- Management of speed limits on internal site haul roads.

Mitigation measures are described in further detail in **Section 7.1**.

4.8 Assessment of pollutants

For most of the assessed pollutants, the model's output data were in a form that could be directly used for the assessment. For NO_2 and VOCs, additional analysis of the model output data was required. For PM_{10}, $PM_{2.5}$, NO_2 and CO, consideration of existing pollutant concentrations in the ambient air also required consideration. Further information is provided in the following sections.

4.8.1.1 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 nitrogen dioxide (NO_2). NO will generally comprise 95 per cent of the volume of NO_X at the point of emission. The remaining NO_X will consist of NO_2. The conversion of NO to NO_2 requires ozone to be present in the air, as ozone is the catalyst for the conversion. Ultimately, however, all NO emitted into the atmosphere is oxidised to NO_2 and then further to other higher oxides of nitrogen.

The USEPA's Ozone Limiting Method (OLM) is the most common method adopted in NSW for the estimation of the conversion of ground level concentrations of NO to NO_2. The OLM is based on the generic assumption that 10 per cent of the initial NO_X emissions are emitted as NO_2. If the ozone (O_3) concentration is greater than 90 per cent 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 OLM equation outlined in the NSW EPA Approved Methods (NSW EPA, 2005). 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.

The assumptions inherent to the OLM equation result in the methodology being considered to be a conservative approach to NO_2 estimation (as explained in **Appendix F**). The assumption most relevant to this investigation that should be considered is the initial NO_2 proportion assumed by the OLM equation. As advised by the NSW EPA as part of the NorthConnex air quality investigation, NO_2 emissions from vehicle exhausts are closer to 16 per cent rather than the 10 percent accounted for in the OLM. On this basis, it was recommended that for the NorthConnex investigation that the 0.1 value be increased to 0.16 to account for the vehicle specific emissions.

For the emissions associated with this project, there is a mix of sources which are dominated by on-site diesel generators rather than vehicle emissions. On this basis the use of vehicle dominated OLM equation may not be appropriate for the calculation of emissions. However as the use of the 16% initial NO_2 concentration would result in predictions accounting for the higher initial NO_2 value for the vehicles that are on site and as a result, the 0.16 initial NO_2 ratio has been adopted for the OLM equation which is as follows:

$$NO_2 = 0.16 \times NO_X + \min\{(46/48 \times O_3),(0.84 \times NO_X)$$

Background ozone data from the James Park monitoring station (refer to **Section 5.1**) were used to convert the modelled NO_2 concentrations in accordance with the EPA-approved OLM (Method 2, Level 2 Assessment; DEC, 2005)

4.8.1.2 VOCs – vehicle emissions

The total VOC concentrations for heavy vehicle have been speciated using the profile (i.e. the types of pollutants) provided in OEH (2012). The vehicle fleet has been solely based on diesel emissions from heavy vehicles, accounting for both mobile vehicle on site and haul trucks. These data are summarised in **Table 14**.

The VOCs considered for the vehicle emissions were benzene, toluene, xylenes, 1,3-butadiene, acetaldehyde and formaldehyde. The mass fraction percentages reported in **Table 14** were multiplied by the 99.9th percentile total VOC concentrations predicted by the dispersion modelling to estimate the concentrations of the individual VOC species at sensitive receiver locations around the project.

Table 14 VOC speciation profile for vehicle emissions

VOC	Mass fraction for vehicle fleet in project (% VOC) (heavy vehicles diesel emissions)
1,3-butadiene	0.4
acetaldehyde	3.81
benzene	1.07
formaldehyde	9.86
xylenes	0.38
toluene	0.47
VOC speciation from OEH (2012)	

4.8.2 Cumulative assessment

The assessment investigated pollutant concentrations associated with emissions from the spoil disposal activities (via CALPUFF) and from trucks transporting the spoil to the site (CAL3QHCR). The predicted pollutant concentrations for each sensitive receiver location from each model have been summed to provide a total project contribution (i.e. site plus haul route contributions).

For the criteria pollutants (TSP, PM_{10}, carbon monoxide and nitrogen dioxide) and $PM_{2.5}$, the predicted concentrations were added to the relevant ambient (background) pollutant concentrations and compared to the relevant assessment criteria. For PM_{10}, $PM_{2.5}$ and NO_2, ambient pollutant concentrations were added contemporaneously – that is, the ambient pollutant concentrations for each hour of the modelling period were added to the modelling predictions from the same hour at each receiver location.

For PAHs and VOCs, cumulative assessment using background data is not required by the EPA (DEC, 2005). Furthermore, background data are not available to conduct a cumulative assessment of these pollutants. As such, the cumulative assessment for these pollutants was limited to summing the contributions from the spoil disposal and transport activities at sensitive receiver locations.

4.8.3 Contemporaneous assessment methodology

Where predicted pollutant concentrations added to maximum measured values exceeded (or approached) their criteria a contemporaneous assessment in accordance with the EPA Approved Methods (DEC 2005) has been completed. The Approved Method provides that emissions can be modelled during the same hourly time period as the measured background concentration i.e. add the first hourly average dispersion model prediction to the first hourly average background concentration and so on. This allows a cumulative assessment of the predicted impacts and the background in relation to the time of year the release occurs. Background emissions are generally higher during winter months where temperatures and wind speeds are lower resulting in less dispersion. Assessing the total predicted ground level concentrations using a contemporaneous approach provides a more realistic estimation of the likely actual impacts. Where suitable background data are available, the contemporaneous method discussed has been applied in the assessment.

The contemporaneous assessment methodology has been applied to short term particulate averaging period concentrations due to the background concentrations exceeding the EPA ambient criteria and to NO_2 as the Approved Methods NO conversion calculation Level 1 (Method 2 – maximum predicted NO_2 concentration with maximum NO_2 background not paired in time) resulted in exceedences.

4.8.4 Limitations

The atmosphere is a complex, physical system, and the movement of air in a given location is dependent on a number of different variables, including temperature, topography and land use, as well as larger-scale synoptic processes. Dispersion modelling is a method of simulating the movement of air pollutants in the atmosphere using mathematical equations. The model equations necessarily involve some level of simplification of these very complex processes based on our understanding of the processes involved and their interactions, available input data, and processing time and data storage limitations.

These simplifications come at the expense of accuracy, which particularly affects model predictions during certain meteorological conditions and source emission types. For example, the prediction of pollutant dispersion under low wind speed conditions (typically defined as those wind speeds less than 1 m/s) or for low-level, non-buoyant sources, is problematic for most dispersion models. To accommodate these known deficiencies, the model outputs tend to provide conservative estimates of pollutant concentrations at particular locations.

While the models contain a large number of variables that can be modified to increase the accuracy of the predictions under any given circumstances, the constraints of model use in a commercial setting, as well as the lack of data against which to compare the results in most instances, typically precludes extensive testing of the impacts of modification of these variables. With this in mind, model developers typically specify a range of default values for model variables that are applicable under most modelling circumstances. These default values are recommended for use unless there is sufficient evidence to support their modification.

As a result, the results of dispersion modelling provide an indication of the likely level of pollutants within the modelling domain. While the models, when used appropriately and with high quality input data, can provide very good indications of the scale of pollutant concentrations and the likely locations of the maximum concentrations occurring, their outputs should not be considered to be representative of exact pollutant concentrations at any given location or point in time. As stated above, however, the model predictions are typically conservative, and tend to over predict maximum pollutant concentrations at receiver locations.

This assessment was undertaken with the data available at the time of the assessment. Should changes to the project be made, further assessment may be required to determine if the findings of this assessment are still applicable.

5.0 Impact assessment criteria

5.1 NSW assessment criteria

In addition to specifying the statutory methods that are to be used to model and assess emissions of air pollutants from sources in NSW, the *Approved Methods for the Modelling and Assessment of Air Pollutants* (DEC, 2005) (to be referred to as the *Approved Methods*) provides assessment criteria against which the emissions from a site or activity are to be assessed. These criteria are intended to minimise the adverse effects of airborne pollutants on sensitive receivers and are summarised in **Table 15**.

There are currently no criteria for the assessment and regulation of $PM_{2.5}$ in NSW. For the purpose of this assessment, the advisory reporting standards and goals for airsheds were adopted from the *National Environment Protection Measure for Ambient Air Quality* (Air NEPM) (NEPC, 2003). It should be noted that these standards are not criteria for specific facility emissions, but have nonetheless been applied in a similar manner as other air quality criteria for the purpose of consistency and completeness. The advisory reporting standards for $PM_{2.5}$ are summarised in **Table 16**.

The assessment criteria for the criteria pollutants (PM_{10}, NO_2 and CO) apply to the maximum predicted total pollutant concentrations (that is, the 100th percentile incremental contribution from the site or activity added to the background pollutant concentration). The assessment criteria for the principal and individual air toxic pollutants (benzene,1,3-butadiene and formaldehyde) and individual odorous air pollutants (toluene, xylenes and acetaldehyde) apply to the 99.9th percentile incremental concentrations (that is, concentrations from the assessed source(s) alone) from the activity for a refined dispersion modelling assessment, such as the current study.

In addition to impact assessment criteria for pollutant concentrations the *Approved Methods* provides dust deposition criteria for both the maximum increase in contribution of deposited dust levels and the maximum total deposited dust level. These are presented in **Table 17**.

Table 15 NSW air quality criteria adopted by the EPA

Pollutant	Averaging Period	Percentile	Criteria (μg/m^3)	Source
PM_{10}	24 hour	100	50	DEC (2005)
	Annual	100	30	DEC (2005)
Total suspended particulates (TSP)	Annual	100	90	DEC (2005)
Nitrogen dioxide (NO_2)	1 hour	100	246	DEC (2005)
	Annual	100	62	DEC (2005)
Carbon monoxide (CO)	1 hour	100	30,000	DEC (2005)
	8 hours	100	10,000	DEC (2005)
Benzene (VOC)	1 hour	99.9*	29	DEC (2005)
Toluene (VOC)	1 hour	99.9*	360	DEC (2005)
Xylenes (VOC)	1 hour	99.9*	190	DEC (2005)
1,3-butadiene	1 hour	99.9*	40	DEC (2005)
acetaldehyde	1 hour	99.9*	42	DEC (2005)
formaldehyde	1 hour	99.9*	20	DEC (2005)
PAHs (as benzo[a]pyrene)	1 hour	99.9*	0.4	DEC (2005)
* The 99.9th percentile concentrations are used for Level 2 assessments, which are those that are conducted using at least one year of site-specific meteorological data. These concentrations are appropriate for this assessment.				

Table 16 Advisory reporting standards for $PM_{2.5}$ in the Air NEPM

Pollutant	Averaging Period	Percentile	Criteria (μg/m^3)	Source
$PM_{2.5}$	24 hours	100	25	NEPM (2003)
	Annual	100	8	NEPM (2003)

Table 17 NSW dust deposition criteria

Pollutant	Averaging Period	Percentile	Criteria (g/m^2/month)		Source
			Maximum Increase	Maximum Total	
Deposited Dust*	Annual	100	2	4	DEC (2005)
*Dust is assessed as insoluble solids as defined by AS 3580.10.1-1991 (AM-19)					

6.0 Impact assessment

As discussed in **Section 4.2**, dispersion modelling was used to predict resultant pollutant concentrations from the spoil management facility (using CALPUFF) and return trips from haul trucks carrying spoil from the NorthConnex project site (using CAL3QHCR). The predicted emission concentrations from each model at each receiver location (where relevant) were combined to provide a total project contribution for each pollutant for each assessment scenario.

For PM_{10}, $PM_{2.5}$, NO_2 and CO, the predicted concentrations were added to the relevant ambient (background) pollutant concentrations to estimate cumulative pollutant concentrations, which were compared to the relevant assessment criteria. For PM_{10}, $PM_{2.5}$ and NO_2, the ambient pollutant concentrations were added contemporaneously – that is, the measured ambient pollutant concentrations were added to the associated model predictions for each receiver for that same time period. The maximum of the CAL3QHCR predictions and the James Park monitoring data at each receiver location were used to represent ambient pollutant concentrations.

The predicted pollutant concentrations reported below refer to concentrations at the identified 420 sensitive receptors. Outside this, impacts from combustion emissions from haul trucks travelling from the NorthConnex Project to the spoil disposal facility on receptors adjacent to haul routes were found to be negligible. These values are presented in **Appendix E**.

6.1 Total suspended particulates

Table 18 shows the predicted annual average TSP concentrations for each scenario; including the project contribution and the maximum cumulative concentration. In the absence of local TSP monitoring data the annual average TSP concentration has been based on the annual average PM_{10} concentration at James Park representing 40 percent (NSW Minerals Council 2000) of the total TSP concentration. That is an annual average TSP concentration equating to 45 µg/m^3.

The predicted project contribution for annual average TSP concentration was 3.5 µg/m^3 and 18.4 µg/m^3 for Scenario 1 and Scenario 2 which equates to 4 and 20 percent of the OEH criterion for the airshed. Combined with the annual average background of 45 µg/m^3 the maximum cumulative concentration for TSP reported in **Table 18** is well below the assessment criterion of 90 µg/m^3 for both Scenario 1 and Scenario 2.

Table 18 Predicted maximum TSP pollutant concentrations

Averaging period	Source	Predicted maximum TSP concentrations (µg/m^3)		Impact Assessment Criteria (µg/m^3)
		Scenario 1	Scenario 2	
Annual	Peak project contribution	3.5	18.4	-
	Peak cumulative concentration (project plus background)	48.5	63.4	90

6.2 Particulate matter (PM_{10})

Predicted PM_{10} ground level concentrations at the nearby worst affected receiver (receptor 327 situated at the Hornsby TAFE building immediately to the east of the stockpiles on the flats) found to have the highest maximum cumulative 24-hour PM_{10} concentration for each scenario are presented in **Table 19**. **Table 19** ranks the ten highest predicted 24-hour PM_{10} concentration for 2014 at this receptor in order of background, increment (project contribution) and cumulative concentration.

For Scenario 1 there are no exceedences of the maximum 24-hour PM_{10} concentration OEH criterion of 50 µg/m^3 at the highest cumulative concentration ranking discrete receptor with a maximum predicted cumulative 24-hour concentration of 49.5 µg/m^3. Nine out of ten of the highest predicted cumulative concentration values are also the highest ranked values based on background concentration at this sensitive receptor (refer to **Table 19**). Top ten background concentrations make up 71 to 88 percent of the OEH criterion in isolation. The maximum project contribution was found to be 14.0 µg/m^3 which represents 28 percent of the OEH criterion.

In **Table 19** higher 24-hour PM_{10} project contributions for Scenario 2, are attributed to materials handling activities both on the flats and within the void. For Scenario 2 there is one exceedence of the maximum 24-hour OEH criterion at the highest cumulative concentration ranking discrete receptor with a predicted value of 53.6 µg/m^3. When the data is analysed in terms of the data ranked for highest cumulative concentration at Receptor 327, the background concentration is 35.5 µg/m^3 contributing 71 percent of the allowable criterion and the predicted project contribution is 18.1 µg/m^3, contributing 36 per cent of the allowable criterion for the airshed.

As discussed above the existing background 24-hour PM_{10} concentration takes up a large proportion allowable for the air shed. When the data is analysed in terms of the data ranked for highest project contribution concentration, the highest ranked project contribution for sensitive receptor 327 is 22.1 µg/m^3 which equates to 44 percent of the OEH criterion and falls to 10.9 µg/m^3 for the tenth highest day representing 22 percent of the criterion. There were no exceedences of the 24-hour criterion at other sensitive receptors.

Table 19 Predicted maximum background, incremental and cumulative PM_{10} concentrations (µg/m^3)

Rank	Ranked by Highest Background Concentration (µg/m^3)			Ranked by Highest Increment Concentration (µg/m^3)			Ranked by Highest Cumulative Concentration (µg/m^3)		
	Background	Increment	Cumulative	Background	Increment	Cumulative	Background	Increment	Cumulative
Scenario 1									
1	43.8	1.3	45.0	20.3	15.7	36.0	35.5	14.0	49.5
2	43.6	0.0	43.6	35.5	14.0	49.5	43.8	1.3	45.0
3	41.1	0.5	41.6	16.2	11.4	27.6	43.6	0.0	43.6
4	40.8	1.4	42.2	14.9	10.8	25.8	40.8	1.4	42.2
5	40.5	0.9	41.4	13.3	10.3	23.7	41.1	0.5	41.6
6	38.8	0.1	38.9	16.4	10.2	26.6	40.5	0.9	41.4
7	37.1	0.1	37.2	11.1	9.7	20.8	35.3	5.1	40.4
8	36.3	0.1	36.3	22.6	9.3	31.9	38.8	0.1	38.9
9	35.7	3.0	38.7	12.5	9.3	21.8	35.7	3.0	38.7
10	35.5	14.0	49.5	25.9	8.5	34.4	37.1	0.1	37.2
Scenario 2									
1	43.8	1.4	45.2	20.3	22.1	42.4	35.5	18.1	53.6
2	43.6	0.0	43.6	35.5	18.1	53.6	43.8	1.4	45.2
3	41.1	0.4	41.6	16.2	15.7	31.9	43.6	0.0	43.6
4	40.8	1.6	42.4	13.3	13.3	26.6	20.3	22.1	42.4
5	40.5	1.0	41.5	14.9	13.0	27.9	40.8	1.6	42.4
6	38.8	0.1	38.9	7.9	12.6	20.5	35.3	6.5	41.8
7	37.1	0.0	37.1	22.6	12.2	34.8	41.1	0.4	41.6
8	36.3	0.0	36.3	16.4	11.3	27.7	40.5	1.0	41.5
9	35.7	3.4	39.1	20.5	10.9	31.4	35.7	3.4	39.1
10	35.5	18.1	53.6	11.1	10.9	22.0	38.8	0.1	38.9

Table 20 shows the results of the ten highest ranking discrete receptors for predicted cumulative annual average PM_{10} concentrations for Scenario 1 and Scenario 2. **Table 20** shows for the 10 predicted highest values for each scenario there are no exceedences of the PM_{10} annual average concentration OEH criteria (30 µg/m^3) with a maximum cumulative impact of 20.1 µg/m^3 for Scenario 1 and 20.5 µg/m^3 for Scenario 2. Here the maximum incremental impact was found to be 2.0 µg/m^3 for Scenario 1 and 2.4 µg/m^3 for Scenario 2 which equates to 7 percent and 8 percent of the criterion respectively.

Contour plots showing the project contribution for 24-hour and annual average PM_{10} for both scenarios are shown in **Figure 6** to **Figure 9**.

Table 20 Predicted annual average cumulative PM_{10} concentrations (µg/m^3)

Receptor	Scenario 1			Receptor	Scenario 2		
	Concentration (µg/m^3)				Concentration (µg/m^3)		
	Background	Increment	Cumulative		Background	Increment	Cumulative
327	18.1	2.0	20.1	**327**	18.1	2.4	20.5
219	18.1	1.1	19.2	**219**	18.1	1.5	19.6
223	18.1	1.0	19.1	**223**	18.1	1.3	19.4
328	18.1	0.9	19.0	**328**	18.1	1.2	19.3
221	18.1	0.8	18.9	**209**	18.1	1.1	19.2
218	18.1	0.8	18.9	**218**	18.1	1.1	19.2
222	18.1	0.8	18.9	**210**	18.1	1.1	19.2
220	18.1	0.8	18.9	**220**	18.1	1.1	19.2
217	18.1	0.7	18.8	**221**	18.1	1.1	19.2
210	18.1	0.7	18.8	**222**	18.1	1.1	19.2

Additional analysis of the frequency of predicted cumulative concentrations was undertaken to understand more clearly the expected PM_{10} concentrations and the potential for future exceedences. **Figure 10** shows the frequency of occurrence of cumulative 24 hour PM10 concentrations for Receptor 327 (Hornsby TAFE). This is the predicted worst affected receptor location and it shows that there are a low number of exceedences (one exceedance out of the year of modelled data) and a small number of predicted concentrations close to the criteria i.e. less than 3% of the time the receptor is expected to have a PM_{10} concentration greater than 40µg/m^3.

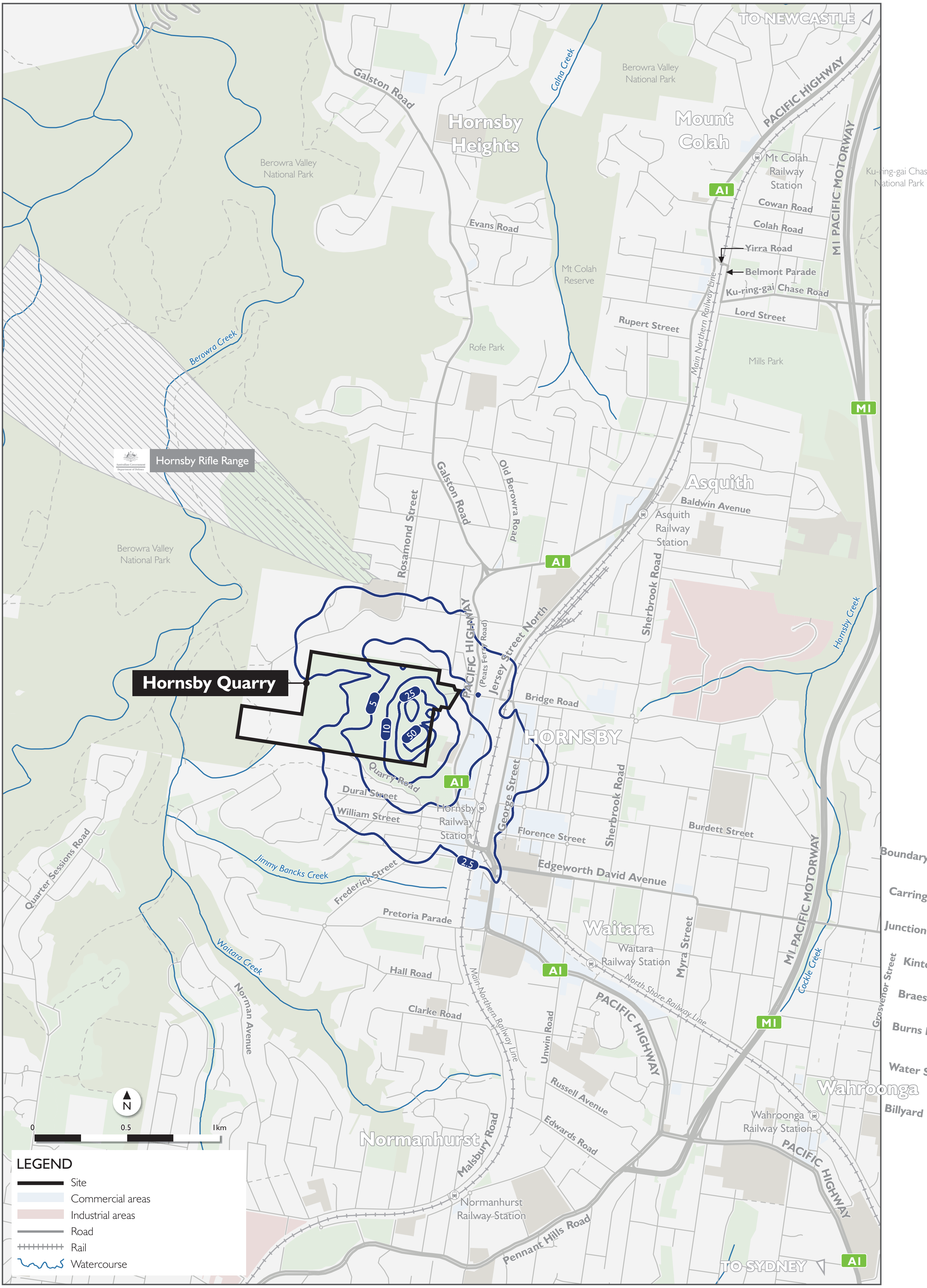

Figure 6 Scenario 1: Maximum 24-hour PM_{10} project contribution concentration ($\mu g/m^3$)

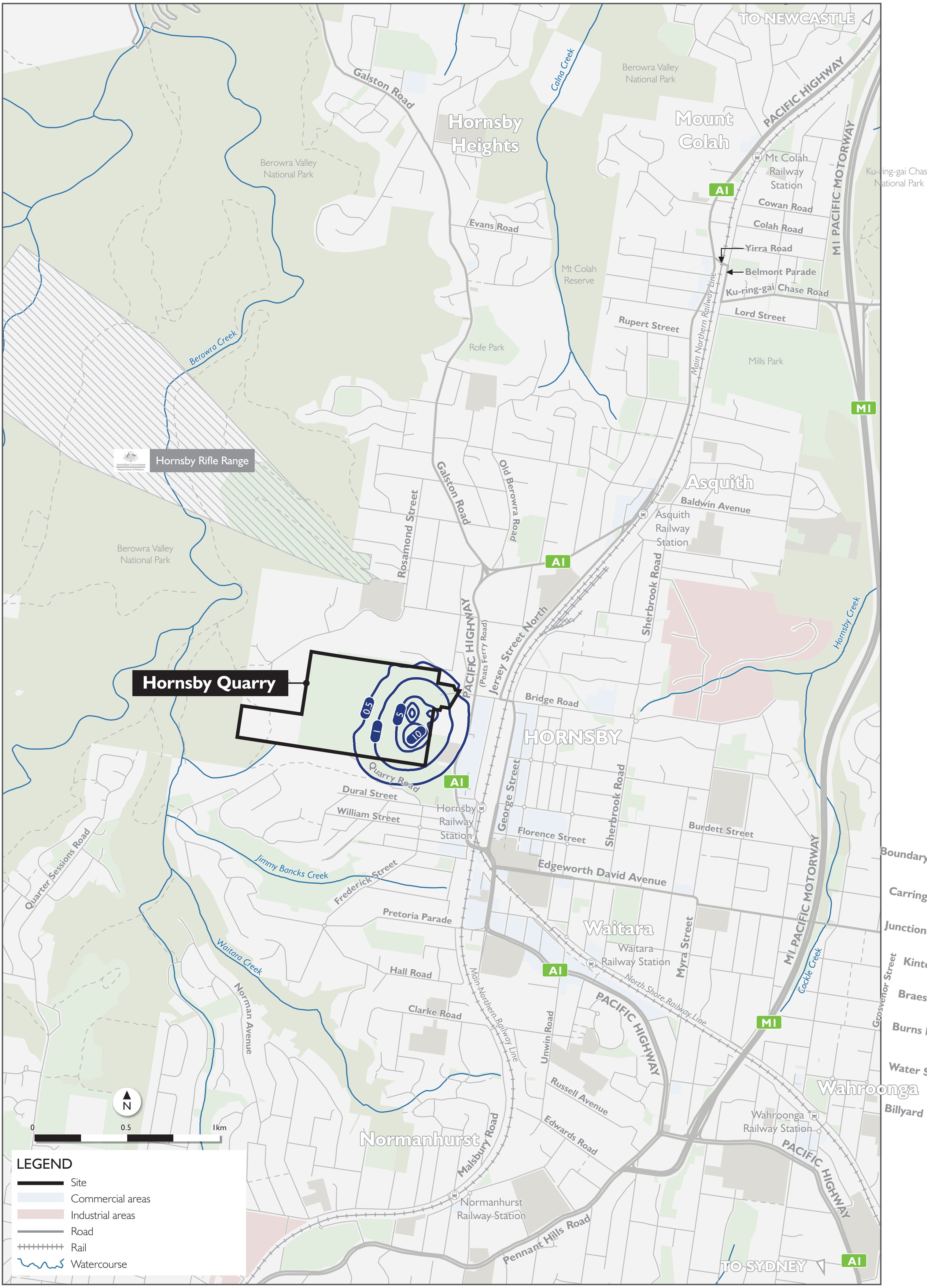

Figure 7 Scenario 1: Annual average PM_{10} project contribution concentration (µg/m^3)

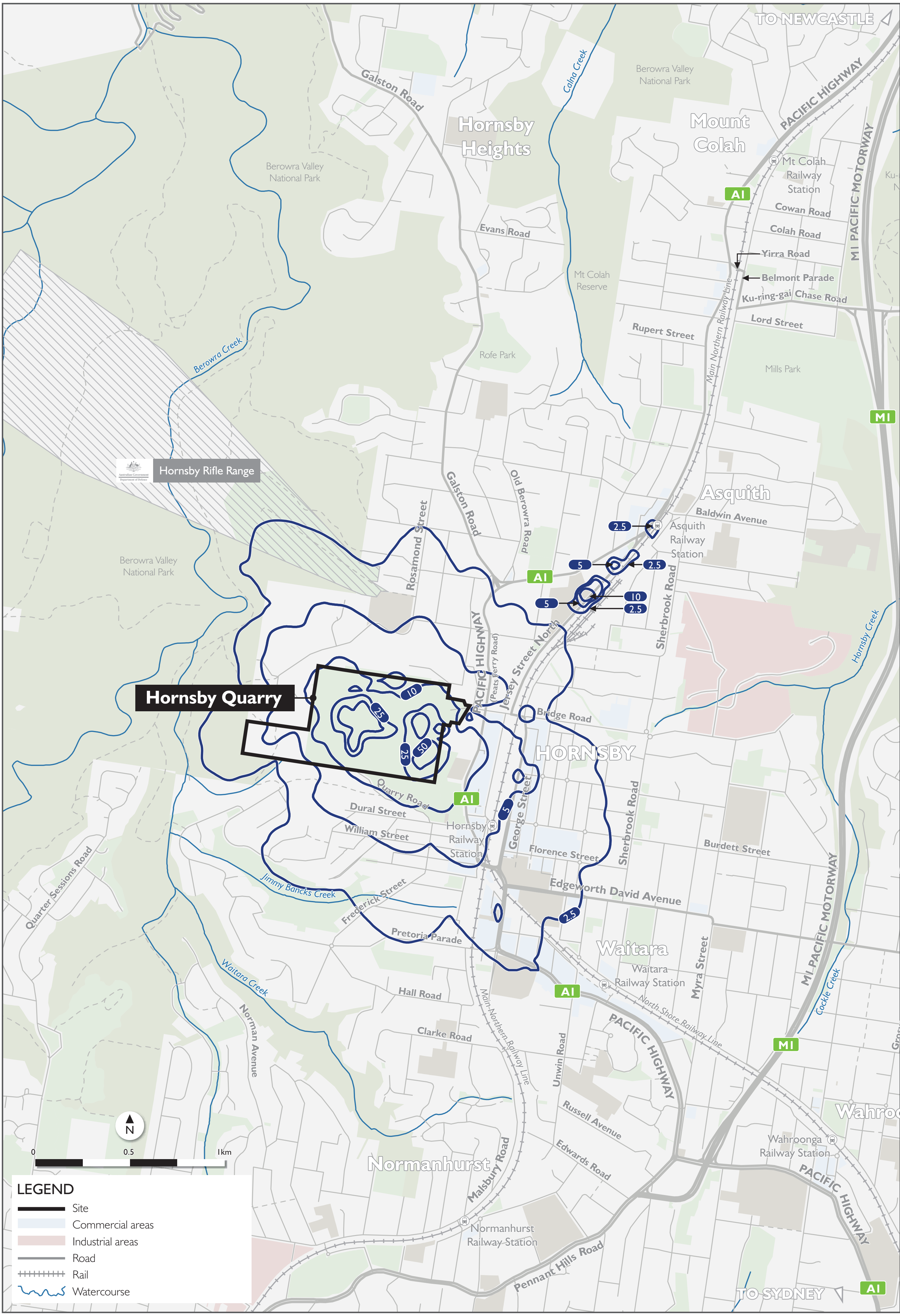

Figure 8 Scenario 2: Maximum 24-hour PM_{10} project contribution concentration ($\mu g/m^3$)

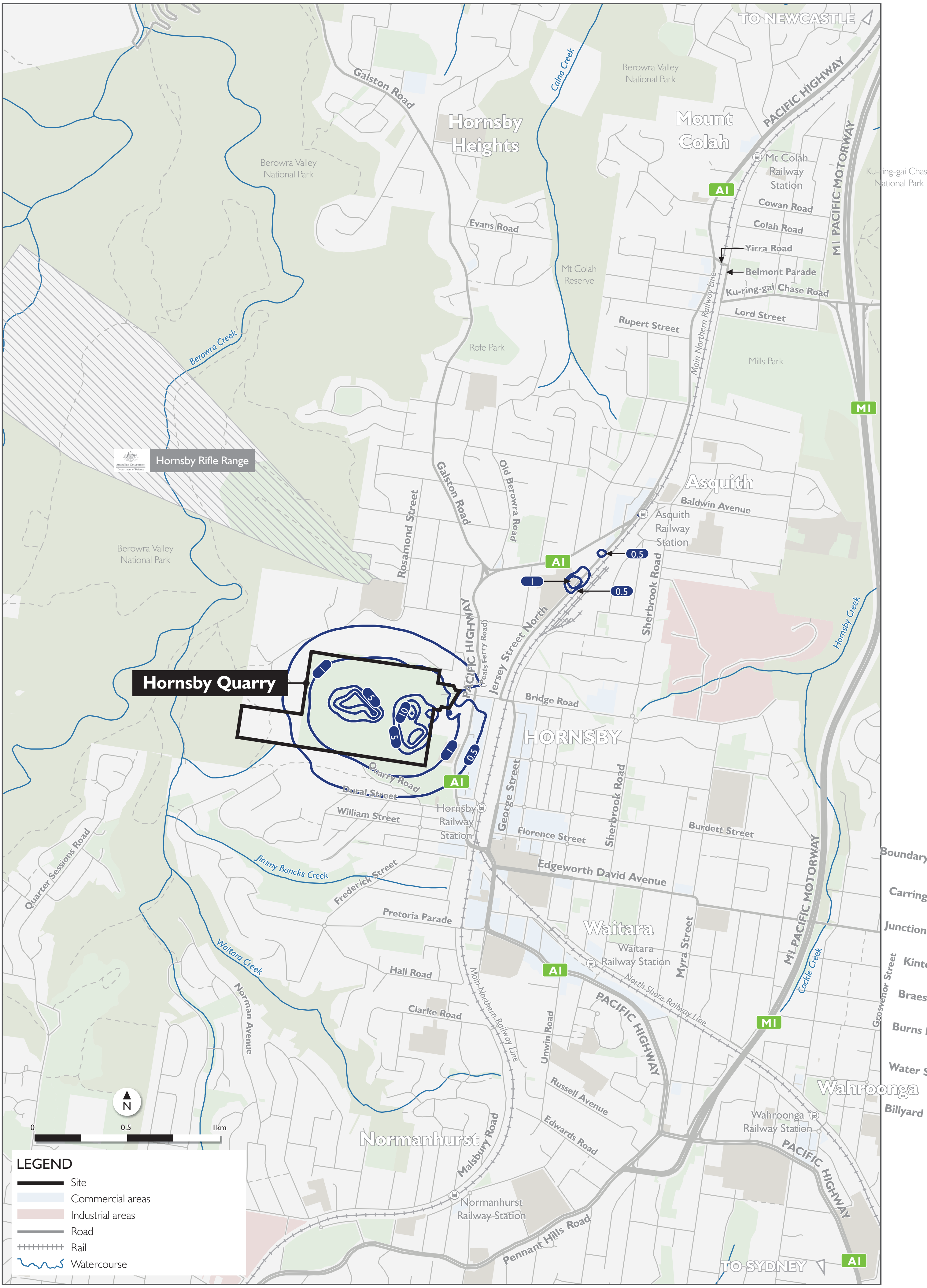

Figure 9 Scenario 2: Annual average PM_{10} project contribution concentration ($\mu g/m^3$)

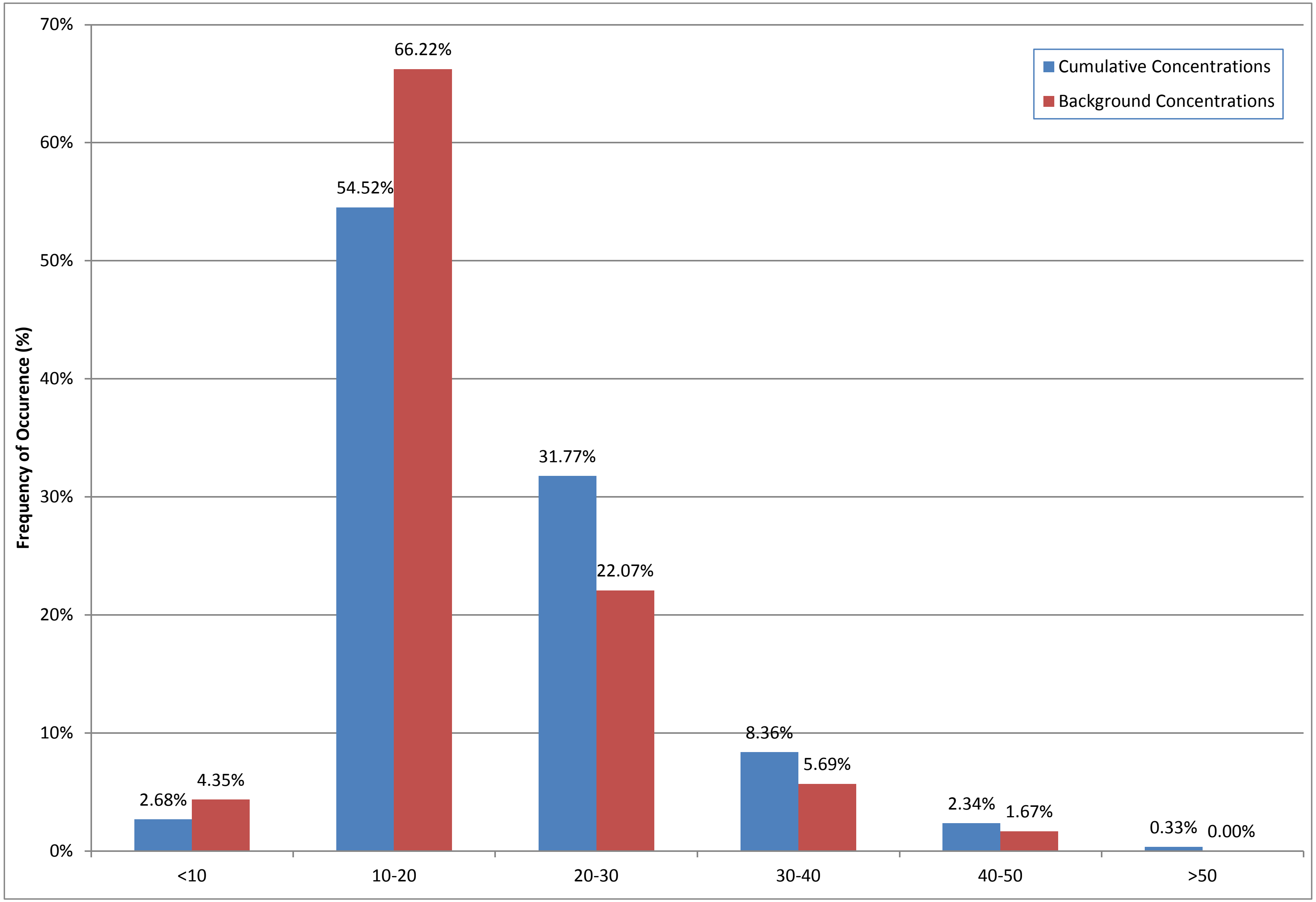

Figure 10 **Cumulative 24-hour PM10 Occurrence at Receptor 327 (Hornsby TAFE)**

6.3 Particulate matter ($PM_{2.5}$)

Predicted $PM_{2.5}$ ground level concentrations at the worst effected sensitive receiver found to have the highest maximum cumulative 24-hour $PM_{2.5}$ concentration for each scenario are presented in **Table 21** (worst affected receptor was receptor 327 situated at the Hornsby TAFE building immediately to the east of the stockpiles on the flats). **Table 21** ranks the ten highest predicted 24-hour $PM_{2.5}$ concentration for 2014 at this receptor in order of background, increment (project contribution) and cumulative concentration.

For Scenario 1 there are two exceedences of the maximum 24-hour NEPM advisory standard of 25 µg/m^3 at the highest cumulative concentration ranking discrete receptor with predicted 24-hour concentrations of 30.9 µg/m^3 and 27.8 µg/m^3. The two highest predicted cumulative concentration values are also the two highest concentrations based on background concentration (refer to **Table 21**). Here the maximum project contribution is relatively small on both accounts (5.8 µg/m^3 and 2.0 µg/m^3) when compared to the background contribution (25.1 µg/m^3 occurring on 30 August 2014 and 25.8 µg/m^3 occurring on 15 April 2014), which exceeds the 24-hour $PM_{2.5}$ NEPM advisory standard in isolation. The high background concentration recorded on 30 August 2014 of 25.1 µg/m^3 may be attributed to hazard reduction burning undertaken by the NSW Rural Fire Service along Lisgar Road, Hornsby (RFS 2014).

For Scenario 2, 24-hour $PM_{2.5}$ project contributions are notably higher which can largely be attributed to materials handling activities both on the flats and within the void. For Scenario 2 there are also two exceedences of the maximum 24-hour advisory standard at the highest cumulative concentration ranking discrete receptor. Similar to Scenario 1 this occurs on the two same days in 2014 where the 24-hour recorded background concentration exceeds the NEPM advisory standard in isolation. The highest project contribution for 14-hour PM_{10} was predicted to be 8.0 µg/m^3, approximately 32 percent of the advisory standard.

Results of the ten highest ranking discrete receptors for predicted cumulative annual average $PM_{2.5}$ concentrations for both scenarios are presented in **Table 22**. **Table 22** shows the 10 predicted highest values for each scenario are on or above the NEPM advisory standard of 8 µg/m^3. Additionally there were a total of 11 receptors where annual average concentration for Scenario 1 and 70 receptors for Scenario 2 was predicted to be equal to or above the advisory standard. The exceedences however can largely be attributed to the background contribution of 7.6 µg/m^3 (which equates to 95 percent of the advisory standard) due to high $PM_{2.5}$ levels recorded between March and August of 2014. The highest project contributions are small in comparison equating to 14 percent (1.1 µg/m^3) for Scenario 1 and 18 percent (1.4 µg/m^3) for Scenario 2 of the advisor standard.

Contour plots showing the project contribution for 24-hour and annual average $PM_{2.5}$ for both scenarios are shown in **Figure 11** to **Figure 14**.

Table 21 Predicted maximum background, incremental and cumulative $PM_{2.5}$ concentrations (µg/m^3)

Rank	Ranked by Highest Background Concentration (µg/m^3)			Ranked by Highest Increment Concentration (µg/m^3)			Ranked by Highest Cumulative Concentration (µg/m^3)		
	Background	Increment	Cumulative	Background	Increment	Cumulative	Background	Increment	Cumulative
Scenario 1									
1	25.8	2.0	27.8	13.1	6.5	19.6	25.1	5.8	30.9
2	25.1	5.8	30.9	25.1	5.8	30.9	25.8	2.0	27.8
3	22.3	0.3	22.6	9.2	5.5	14.7	22.3	0.3	22.6
4	19.1	0.1	19.2	10.4	5.5	15.9	17.1	4.2	21.3
5	18.1	1.9	20.0	4.4	5.5	9.9	18.1	1.9	20.0
6	17.4	2.1	19.6	7.4	5.3	12.7	13.1	6.5	19.6
7	17.1	0.0	17.1	11.7	5.0	16.7	17.4	2.1	19.6
8	17.1	4.2	21.3	0.9	4.5	5.4	19.1	0.1	19.2
9	16.7	2.1	18.7	13.2	4.4	17.6	16.7	2.1	18.7
10	15.5	0.0	15.5	7.4	4.4	11.7	14.4	4.2	18.6
Scenario 2									

Rank	Ranked by Highest Background Concentration (µg/m³)			Ranked by Highest Increment Concentration (µg/m³)			Ranked by Highest Cumulative Concentration (µg/m³)		
	Background	Increment	Cumulative	Background	Increment	Cumulative	Background	Increment	Cumulative
1	25.8	2.8	28.6	13.1	9.9	23.1	25.1	8.0	33.1
2	25.1	8.0	33.1	25.1	8.0	33.1	25.8	2.8	28.6
3	22.3	0.3	22.6	9.2	7.5	16.7	13.1	9.9	23.1
4	19.1	0.1	19.2	9.2	6.8	16.0	22.3	0.3	22.6
5	18.1	2.9	21.0	10.4	6.8	17.2	17.1	5.3	22.4
6	17.4	3.0	20.5	4.4	6.3	10.7	18.1	2.9	21.0
7	17.1	0.0	17.1	10.8	6.3	17.1	17.4	3.0	20.5
8	17.1	5.3	22.4	13.2	6.1	19.3	14.4	5.2	19.6
9	16.7	2.1	18.7	7.4	5.8	13.1	13.2	6.1	19.3
10	15.5	0.0	15.5	0.9	5.6	6.5	19.1	0.1	19.2

Table 22 **Predicted annual average cumulative $PM_{2.5}$ concentrations (µg/m³)**

Scenario 1				Scenario 2			
Receptor	Concentration (µg/m³)			Receptor	Concentration (µg/m³)		
	Background	Increment	Cumulative		Background	Increment	Cumulative
327	7.6	1.1	8.7	327	7.6	1.4	9.0
219	7.6	0.7	8.3	219	7.6	0.9	8.5
223	7.6	0.6	8.2	223	7.6	0.8	8.4
218	7.6	0.5	8.1	218	7.6	0.7	8.3
328	7.6	0.5	8.1	328	7.6	0.7	8.3
217	7.6	0.5	8.1	217	7.6	0.7	8.3
221	7.6	0.5	8.1	210	7.6	0.7	8.3
222	7.6	0.5	8.1	220	7.6	0.7	8.3
220	7.6	0.5	8.1	221	7.6	0.7	8.3
210	7.6	0.4	8.0	222	7.6	0.7	8.3

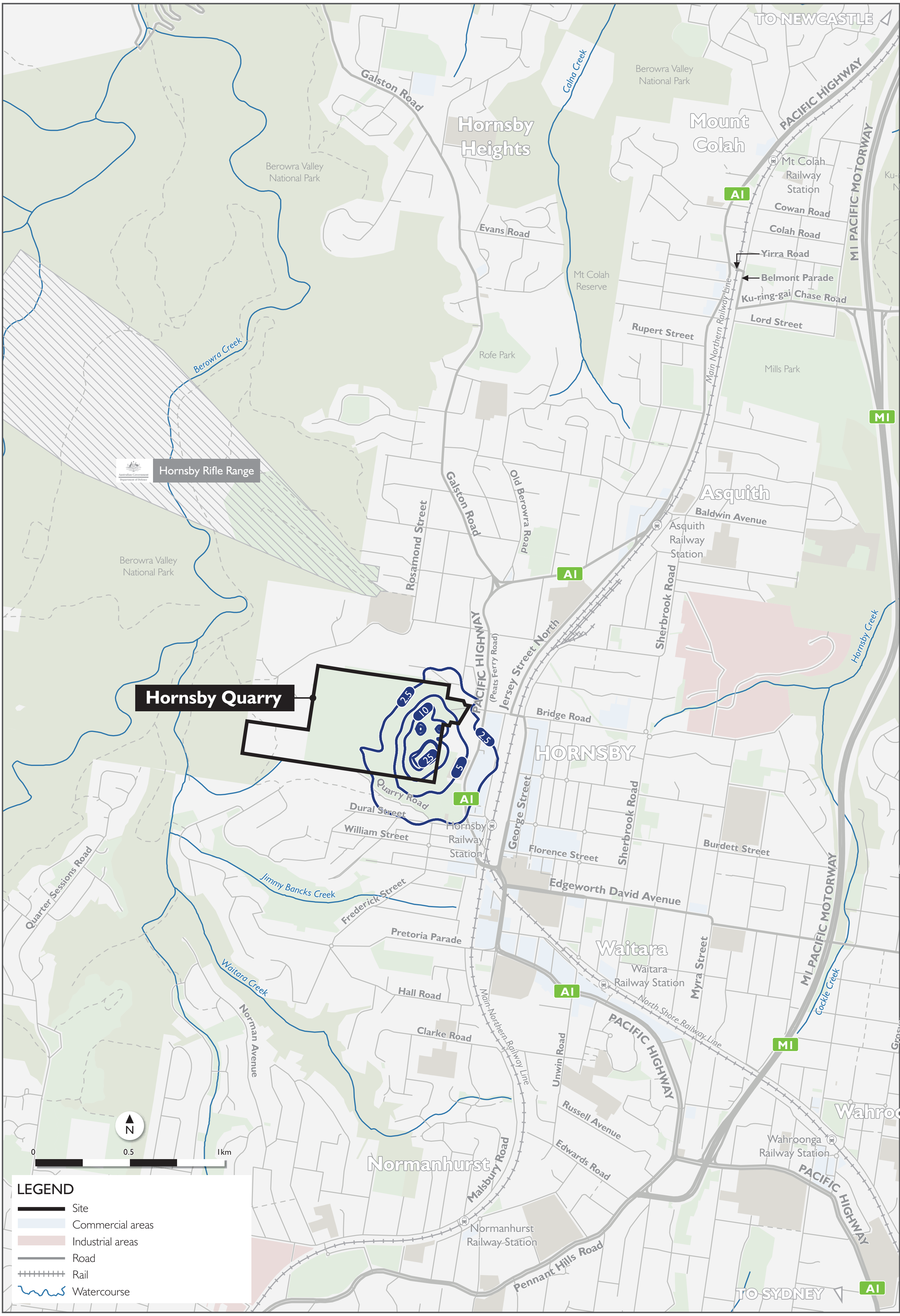

Figure 11 Scenario 1: Maximum 24-hour $PM_{2.5}$ project contribution concentration ($\mu g/m^3$)

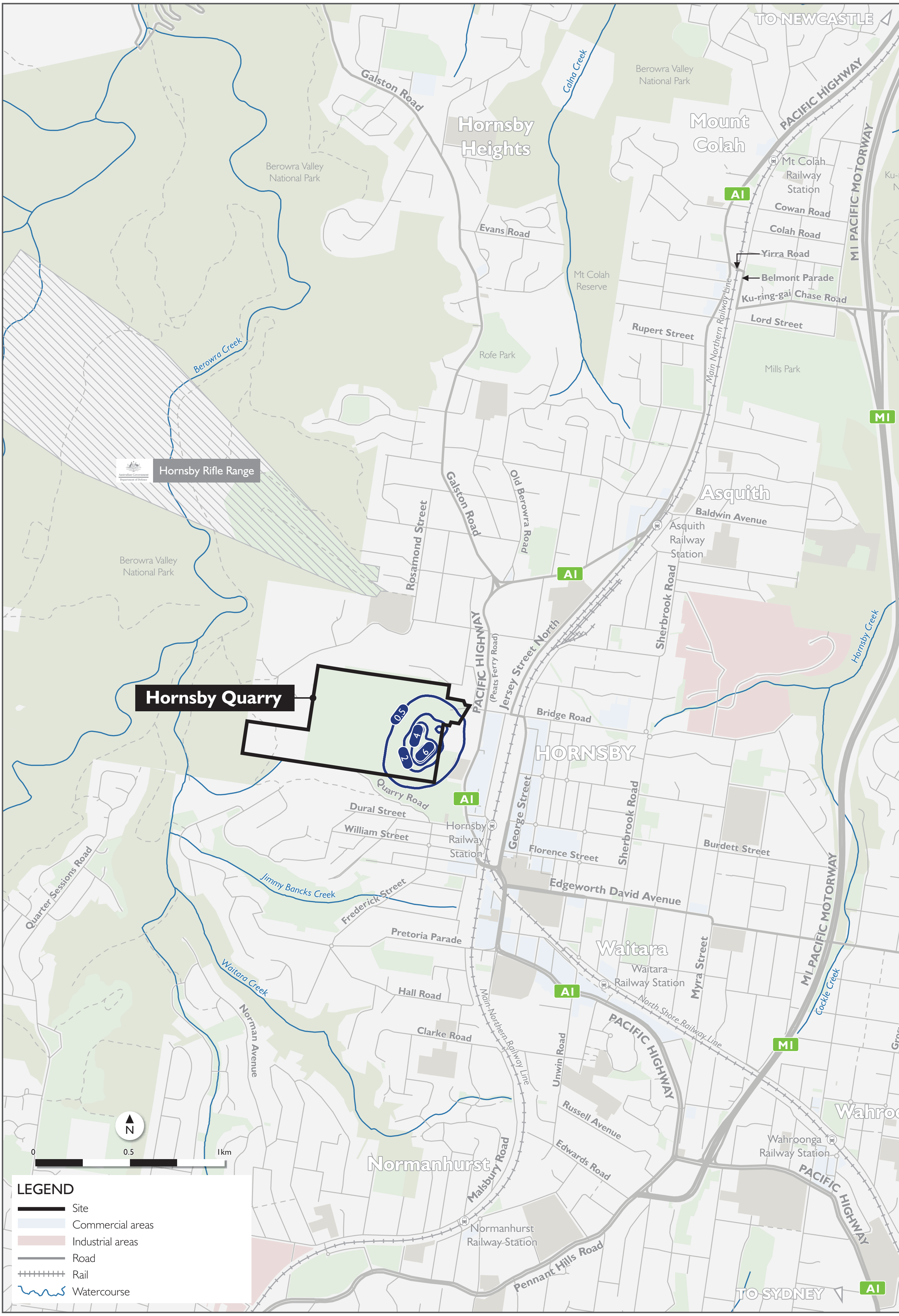

Figure 12 Scenario 1: Annual average $PM_{2.5}$ project contribution concentration ($\mu g/m^3$)

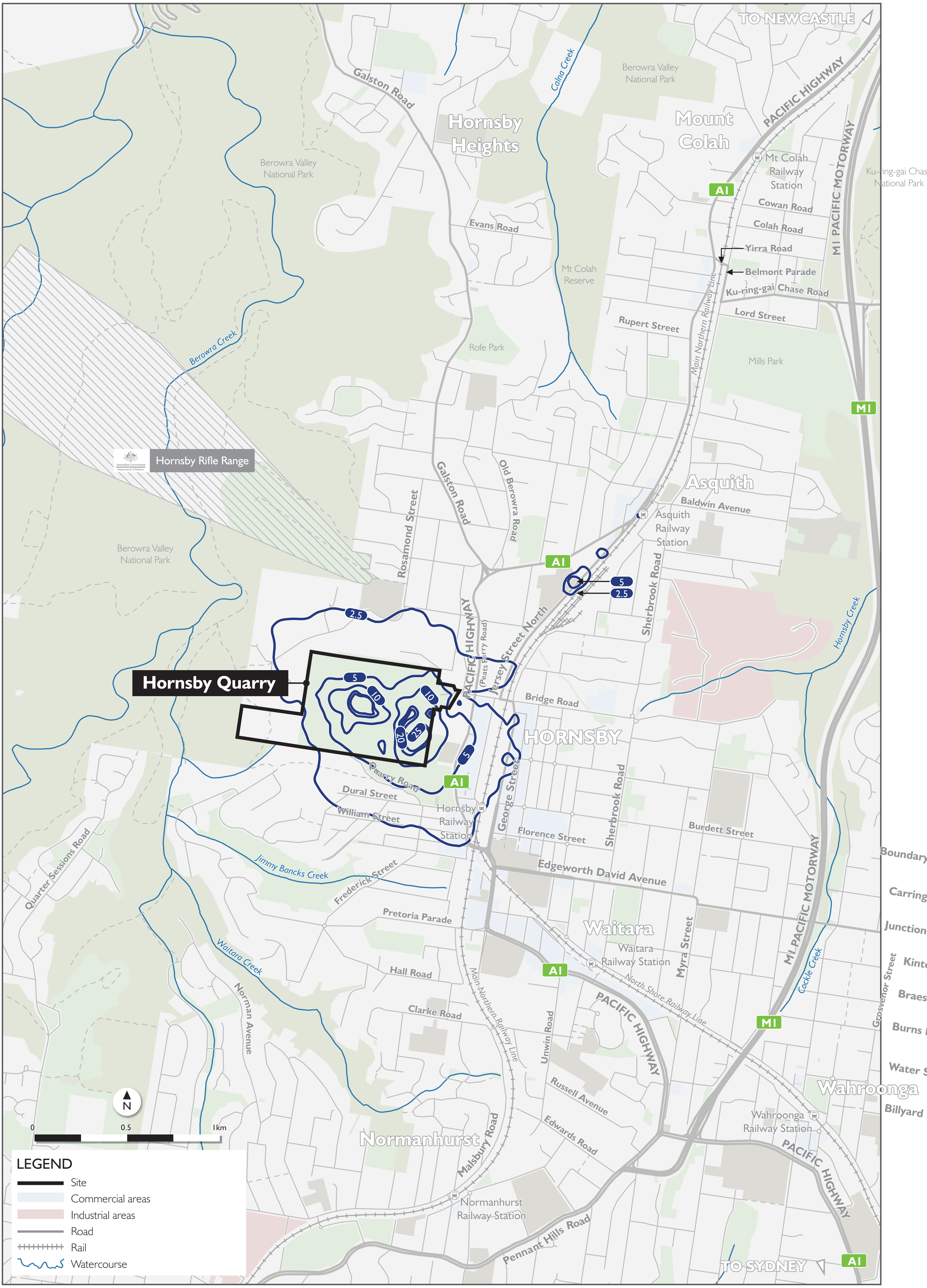

Figure 13 Scenario 2: Maximum 24-hr $PM_{2.5}$ project contribution concentration (μg/m^3)

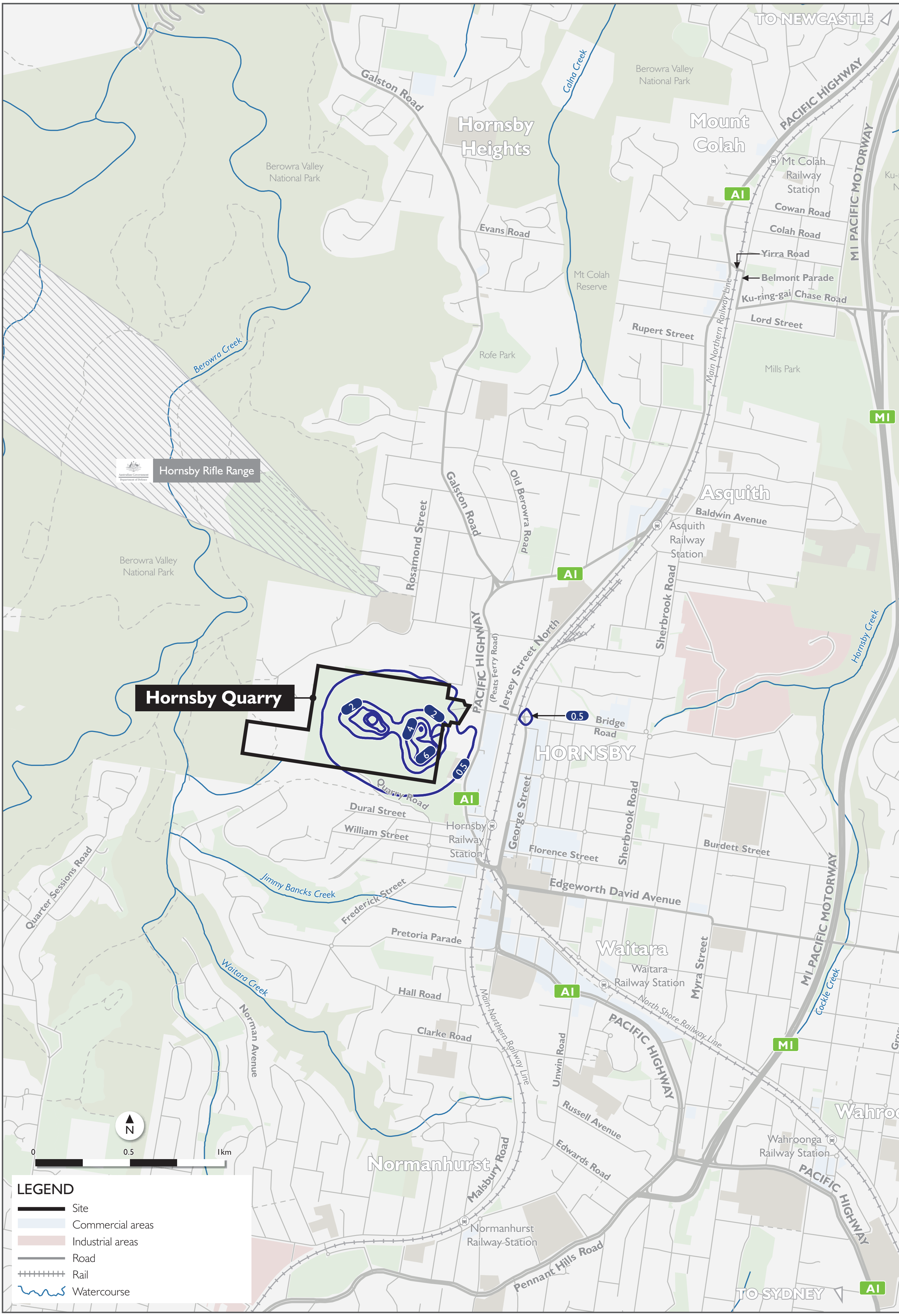

Figure 14 Scenario 2: Annual average $PM_{2.5}$ project contribution concentration ($\mu g/m^3$)

6.4 Deposited dust

The predicted maximum deposited dust contribution for each scenario is shown in **Table 23**. It can be seen that both Scenario 1 (0.8g/m^2/month) and Scenario 2 (0.8g/m^2/month) are below the project contribution criterion of 2g/m^2/month. The predicted dust deposition rates equate to 20 per centand 25 percent of the cumulative OEH criterion of 4.0 g/m^2/month for Scenario 1 and 2 respectively, however this does not account for local background dust deposition rates for which available data is absent.

It should be noted that dust deposition attributed from the activities at the spoil management facility are temporary in nature with stockpiling and void filling activities expected to occur concurrently over 28 months, and predicted dust deposition rates have been based on the highest intensity of site operational activities during 2017.

Table 23 Predicted maximum dust deposition levels

Averaging period	Source	Predicted maximum dust deposition (g/m^2/month)		Impact Assessment Criteria (g/m^2/month)
		Scenario 1	Scenario 2	
Annual	Peak project contribution	0.8	1.0	2

6.5 Nitrogen dioxide

Predicted 1-hour nitrogen dioxide ground level concentrations were calculated using the adapted OLM method as described in **Section 4.8.1.1**. **Table 24** shows the predicted cumulative concentrations for both maximum 1-hour and annual average NO_2 were below the criteria of 246 μg/m^3 and 62 μg/m^3 respectively for both scenarios. Project contributions for the peak 1-hour NO_2 concentrations were predicted to be 38 (93.1 μg/m^3) and 49 (121.4 μg/m^3) percent of the OEH criterion for Scenario 1 and Scenario 2 respectively. While this represents a large proportion of the allowable NO_2 concentration for the air shed; the maximum recorded background concentration at James Park for 2014 is 93.8 μg/m^3, approximately 38 percent of the OEH criterion. Thus when the maximum background concentration is added to the predicted maximum 1-hour NO_2 project contribution for Scenario 1 (186.9 μg/m^3) and Scenario 2 (215.2μg/m^3) the sum still does not exceed the criterion.

The largest contributor of NO_2 emissions from the site would be from onsite generators providing power to the onsite amenities, compound and conveyer.

Table 24 Predicted maximum NO_2 pollutant concentrations

Averaging period	Source	Predicted maximum NO_2 concentrations (μg/m^3)		Impact Assessment Criteria (μg/m^3)
		Scenario 1	Scenario 2	
1 Hour	Peak project contribution	93.1	121.4	-
	Peak cumulative concentration (project plus background)	106.8	139.8	246
Annual	Peak project contribution	3.2	5.3	-
	Peak cumulative concentration (project plus background)	20.6	22.7	62

6.6 Carbon monoxide

Table 25 shows both the project contribution and cumulative predicted maximum 1-hour and 8-hour concentrations for carbon monoxide for each modelling scenario. The results for both scenarios show the maximum predicted project contributions for both scenarios and averaging periods equate to 1 percent of the OEH criterion for the airshed and when combined with maximum background concentrations the predicted maximum cumulative concentrations for both averaging periods are well below the criterion

The predicted maximum 1-hour and 8-hour concentrations for carbon monoxide reported in **Table 25** are based on non-reactive mitigation dispersion modelling results.

Table 25 Predicted maximum CO pollutant concentrations

Averaging period	Source	Predicted maximum CO concentrations (µg/m³)		Impact Assessment Criteria (µg/m³)
		Scenario 1	Scenario 2	
1 Hour	Peak project contribution	245	391	-
	Peak cumulative concentration (project plus background)	1938	1983	30,000
8 Hour	Peak project contribution	92	119	-
	Peak cumulative concentration (project plus background)	1059	1086	10,000

6.7 Volatile Organic Compounds

The total VOC concentrations from **Table 14** were speciated using the profile for diesel emissions from heavy vehicles provided in OEH (2012). As shown in **Table 26**, the predicted concentrations of individual VOC species for both modelled scenarios were all orders of magnitude below the applicable impact assessment criteria for the individual compounds.

Predicted 99.9th percentile concentrations for VOCs reported in **Table 26** are based on non-reactive mitigation dispersion modelling results.

Table 26 Predicted 99.9th percentile concentration of speciated VOCs (µg/m³) (project contribution).

Pollutant	Averaging period	Predicted 99.9th percentile VOC concentrations (µg/m³)		Impact Assessment Criteria (µg/m³)
		Scenario 1	Scenario 2	
Total VOCs	1 hour 99.9%	15.02	40.61	-
1,3-butadiene	1 hour 99.9%	0.06	0.16	40
Acetaldehyde	1 hour 99.9%	0.57	1.55	42
Benzene	1 hour 99.9%	0.16	0.43	29
Formaldehyde	1 hour 99.9%	1.48	4.00	20
Xylenes	1 hour 99.9%	0.06	0.15	190
Toluene	1 hour 99.9%	0.07	0.19	360

6.8 Polycyclic Aromatic Hydrocarbons

Table 27 shows the predicted 99.9th concentration of total PAHs (reported benzo(a)pyrene) for each modelling scenario. The results for both scenarios are orders of magnitude below the impact assessment criterion of 0.4 µg/m3.

The predicted 99.9th percentile concentrations for total PAHs reported in **Table 27** are based on non-reactive mitigation dispersion modelling results.

Table 27 Predicted 99.9th percentile concentration of speciated PAHs (µg/m³) (project contribution).

Pollutant	Averaging period	Predicted maximum PAH concentrations (µg/m³)		Impact Assessment Criteria (µg/m³)
		Scenario 1	Scenario 2	
Total PAHs (as benzo(a)pyrene)	1 hour 99.9%	0.00362	0.00769	0.4

7.0 Mitigation and management measures

7.1 Best industry practice mitigation measures

Dust emissions can generally be well managed through best practice management and mitigation strategies. A hierarchy of emission controls is recommended as best practice, where prevention of emissions is the primary goal of management actions, followed by suppression and containment. The management and mitigation measures described in **Table 28** would be included in the Construction and Operational Environmental Management Plan(s) and associated sub plans for the project.

Table 28 Proposed air quality management and mitigation measures

Proposed management and mitigation measures
General
Site inductions and ongoing toolbox talks would be provided to make construction works aware of sound air quality control practices and responsibilities.
Construction activities would be modified, reduced or controlled during high or unfavourable wind conditions if they may potentially increase off-site dust emissions.
All site haul roads will be sealed.
Control measures would be implemented to control dust emissions, which could include water carts, sprinklers, sprays, internal site road speed limits and dust screens.
Exposed areas will be minimised as much as practical to prevent or minimise windblown dust
Controls would be implemented to minimise the tracking of dirt onto public roads.
Drop height from excavators and front-end loaders would be maintained at 1.5m or less
Ensure that all material handled by bulldozers is kept moist through the use of water carts, sprinklers or sprays.
Hardstand areas and surrounding public roads would be cleaned, as required and good housekeeping practices will be implemented to minimise dust on hardstand areas.
Speed limits would be posted and observed by all vehicles on the site.
Vehicular access will be confined to designated access roads. Haul road lengths will be minimised.
All loaded haulage trucks would be covered at all times on public roads and onsite where there is a risk of release of dust or other materials.
Haul trucks and plant equipment would be switched off when not used for periods of greater than 15 minutes.
Engines of plant located next to residential properties would be switched off when not in operation. Vehicle engines will be turned off while parked on site.
Construction plant, vehicles and machinery would be maintained in good working order and in accordance with manufacturers' specifications.
Where required onsite generators would be switched off when facilities and associated plant equipment are non-operational.
Spills will be immediately cleaned up.
A complaints management system will be implemented and maintained
Monitoring
The weather forecast would be reviewed daily, and appropriate measures implemented where unfavourable weather conditions (dry weather, strong winds) are anticipated.

Proposed management and mitigation measures
A formal dust observation program would be implemented during the works, involving daily observations of meteorological conditions and dust generation. This would inform activities that could be undertaken and mitigation measures implemented during unfavourable weather conditions (see **Section 7.2**)

7.2 Air quality monitoring program

No ambient air quality monitoring has been undertaken at the Hornsby Quarry site to date. The closest monitoring stations are the former NorthConnex stations at James Park and Brickpit Park, which have now been decommissioned. Due to the close proximity of sensitive receptors to the spoil handling facility a comprehensive dust management plan would be prepared incorporating an air quality monitoring program. The dust management plan would include:

- A reactive management strategy with site procedures for targeting the visual observation of dust leaving the site. Dust observations would be undertaken on a regular basis by trained site staff with all staff encouraged to make proactive dust observations whenever on-site. Should visible dust be observed to be crossing the site boundary, contingency measures would be implemented to reduce the potential for off-site impacts.
- Details of contingency measures that would be further considered as part of the reactive management strategy where dust is observed to be crossing the site boundary. Contingency measures would be confirmed as part of detailed design and would target activities that are expected to result in the highest dust generation. Contingency measures are expected to include measures such as:
    - Increases to active mitigation measures such as additional watering, covering stockpiles (where practical) etc.
    - Temporary modifications to dust generating activities e.g. focusing on activities to the pit when dust problems occur on the flats (where practicable).
    - Temporary reductions in materials handling intensity (where practicable).
- Key performance indicators (KPIs) for dust management at the site. The emissions inventory assumptions used in project modelling, which are considered to be key controlling factors for dust generation for the project (such as, the number of trucks per hour delivering spoil to the site) would form the basis of KPIs for dust management in the plan. The plan would detail the KPIs and monitoring measures for each to measure their performance during the project.

8.0 Conclusion

Roads and Maritime is seeking approval for the use of the Hornsby Quarry site for the handling, management and beneficial reuse of spoil generated by the NorthConnex project. The Environmental Impact Statement exhibited for the NorthConnex project identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The Hornsby Quarry site has been identified as one of the preferred options for the management of spoil generated during construction of the NorthConnex project from late 2015. This technical working paper assesses the potential effects on air quality associated with the handling, management and beneficial reuse of spoil at the Hornsby Quarry site.

A quantitative assessment of the project was undertaken using the CALPUFF suite of models, and was coupled with estimations of emissions along the haul roads from the CAL3QHCR model. Two operational scenarios were modelled as part of this assessment to account for potential staggering of stockpiling and void filling activities. Scenario 1 accounts for only stockpiling activities while Scenario 2 takes into account both stockpiling and void filling consecutively. Both operational scenarios have been modelled at the greatest intensity of activities on site for the year 2017.

The results of the dispersion modelling determined that project dust deposition rates and cumulative concentrations of total suspended particulates, carbon monoxide, volatile organic compounds and polycyclic aromatic hydrocarbons for both modelled scenarios would all be well below the applicable impact assessment criteria.

Predicted maximum 1-hour and annual cumulative concentrations for NO_2 ground level concentrations also complied with the criteria, however project contributions for the peak 1-hour NO_2 concentrations represent a large proportion of the allowable NO_2 concentration for the air shed. The largest contributor of NO_2 emissions from the site would be from onsite generators which would provide power to the onsite amenities, compound and conveyer.

Results for predicted 24-hour PM_{10} concentrations should comply with OEH criterion for Scenario 1 with a single exceedence predicted for Scenario 2, likely attributable to materials handling activities both on the flats and within the void. Background concentrations were also found to be a contributing factor to high cumulative concentrations at nearby sensitive receptors with the top ten 24-hour PM_{10} concentrations from James Park monitoring station making up 71 to 88 percent of the OEH criterion in isolation. Results for the PM_{10} modelling indicated no exceedences for annual average concentrations for both scenarios.

For $PM_{2.5}$ there were two exceedences of the 24-hour advisory criterion at all sensitive receptors. This was attributed to the high background concentration which exceeded the NEPM advisory standard in isolation. Similarly to predicted 24-hour PM_{10} concentrations the project contribution for Scenario 2 was higher due to materials handling activities both on the flats and within the void. There were also a number of exceedences for the annual average NEPM advisory standard for both scenarios. Here the project contributions were found to be relatively small in comparison to the local background concentration which already takes up 95 percent of the advisory standard for the airshed.

Based on the proximity of nearby sensitive receptors and existing elevated background concentrations for particulates it is recommended that the comprehensive dust management plan for the project incorporate a monitoring program, to confirm the findings of this assessment and to aid in the efficient implementation of mitigation and management measures as required and based on information and data obtained during site activities.

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Appendix A

Relevant Pollutants

Appendix A Pollutants of Potential Concern

Particulate matter - PM_{10}, $PM_{2.5}$ and TSP

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 cause aesthetic impacts associated with coarse particles settling on surfaces, which also causes soiling and discolouration. These large particles can, however, cause some irritation of mucosal membranes; they pose a greater risk to health when ingested if they are contaminated. Particles with diameters less than or equal to 10 μm (known as PM_{10}) are primarily created through crushing and grinding of rocks and soil, and typically comprise soot, dirt, mould and pollen. These particles tend to remain suspended in the air for longer periods than larger particles (minutes or hours), and can penetrate into human lungs. Fine particulates (those with diameters less than or equal to 2.5 μm, known as $PM_{2.5}$) are typically generated from vehicle exhaust, bushfires and some industrial activities, and can remain suspended in the air for days or weeks. As these fine particulates can travel further into human lungs than the larger particulates and are often made up of heavy metals and carcinogens, fine particulates are considered to pose a greater risk to health.

Exposure to particulate matter has been linked to a variety of adverse health effects, such as respiratory problems (for example coughing, aggravated asthma, chronic bronchitis), lung damage and non-fatal heart attacks. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from inhalation of the dust.

Particulate Matter - PM_1

There are a large number of studies establishing links between concentration of ambient aerosols level of air pollution and adverse health and environmental effects. While PM_{10} and $PM_{2.5}$ measures provide very important steps toward air quality assessment, it is also apparent that more accurate descriptors of the actual atmosphere are still needed. There is a growing consensus that PM_1 would be a more suitable size than $PM_{2.5}$ to assess health impacts; there is, however, a limited amount of data for the sub-micrometre ambient particle fraction available. Very little data currently exist relating to ambient PM_1 concentrations, and existing PM_1 data sets are restricted to measurements of limited time periods from field campaigns, and little information exists regarding the chemical compositions of these particles.

Small particles around 1 μm in size are affected by relative humidity, wind speed and traffic. Knowledge regarding this fraction of particulate matter includes the following points:

- Particles in 1 μm range are equally spread throughout air layer, and evenly spread regionally, meaning that fine particles in this size range are transported globally.
- Increasing humidity causes these particles to grow in size to the $PM_{2.5}$ due to hygroscopic growth; similarly, evaporation can cause particles to reduce in size again.
- As wind speed increases, dispersion of PM_1 is increased.
- As traffic increases, fine particles increase.

A study conducted in Austria (Gomiscek et al., 2004) determined that PM_1 counted for about 50 – 60 percent and $PM_{2.5}$ accounted for about 70 percent of all PM_{10}.

As no monitoring of PM_1 is currently conducted in Sydney, and no criteria for this fraction exist, PM_1 was not modelled in this assessment.

Carbon monoxide

Carbon monoxide (CO) is a colourless, odourless gas produced by the incomplete combustion of fuels containing carbon (e.g. oil, gas, coal and wood). CO is absorbed through the lungs, where it reacts to reduce the blood's oxygen-carrying capacity. In urban areas, motor vehicles account for up to 90 per cent of all CO emissions.

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 oxides of nitrogen (NO_x). As NO_x is a product of combustion processes, motor vehicles and industrial combustion processes are the major sources of ambient NO_x in urban areas. 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 presence of other pollutants such as ozone and sulfur dioxide. NO_x are primary ingredients in the reactions that lead to photochemical smog formation.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a group of over 100 chemicals, which are formed through the incomplete combustion of organic materials, such as petrol. Exposure to these chemicals can cause a range of adverse reactions, including irritation of the eyes, nose and throat and skin. Exposure to very high levels can result in symptoms such as headaches, nausea, damage to the liver and kidneys, and damage to red blood cells. A number of PAHs were declared to be probably or possibly carcinogenic to humans by the IARC.

PAHs can attach to dust particles and be transported through the air. The compounds break down over days or weeks through chemical reactions in the atmosphere.

PAHs are moderately or highly acutely toxic to birds and aquatic organisms and moderately/highly chronic toxicity to aquatic life. Some can cause damage and death to crops. PAHs can bioaccumulate, and are moderately persistent in the environment.

Volatile organic compounds

Organic compounds with a vapour pressure at 20 °C exceeding 0.13 kPa are referred to as volatile organic compounds (VOCs). VOCs were implicated as a major precursor in the production of photochemical smog, which causes atmospheric haze, eye irritation and respiratory problems. VOCs are emitted from vehicle exhausts.

Three primary VOCs (benzene, toluene and xylenes) are components of petroleum and diesel fuel and are typically the focus for assessments of engine combustion emissions.

Benzene

Benzene is an airborne substance that is a precursor to photochemical smog. 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 result from car exhaust.

Benzene is considered to be a toxic health hazard and a carcinogen. It has high acute toxic effects on aquatic life and long-term effects on marine life and agricultural crops. Human exposure to very high levels for even brief periods of time can potentially result in death, while lower level exposure can cause skin and eye irritation, drowsiness, dizziness, headaches and vomiting, 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. Due to relatively fast degradation, toluene emissions are usually confined to the local area in which it is emitted. 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. The substance can cause membrane damage in plant leaves, and is moderately toxic to aquatic life with long-term exposure.

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. High-level exposure can cause death. The substances have high acute and chronic toxicity to aquatic life and can adversely affect crops.

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Appendix B

Meteorological Monitoring Data Review

Appendix B Meteorological Monitoring Data Review

Prior to incorporation into the meteorological model, review of available 2014 meteorological monitoring data measured by the NorthConnex project, Office of Environment and Heritage (OEH) and Bureau of Meteorology (BoM) was conducted to determine the suitability of each data set.

Commissioned in December 2013, the NorthConnex project currently has five operating monitoring stations, which measure both meteorological conditions and ambient pollutant levels within the study area. Of these, three stations - Headen Sports Park, James Park and Brickpit Park - are within 3 kilometres of the Hornsby Quarry site. Data recorded at James Park and Brickpit Park were incorporated into the meteorological model due to the proximity of the sites to the Hornsby Quarry. The data from Headen Sports Park were, however, not used due the absence of wind flow data from north and northeast directions. Observatory Park and Rainbow Farm monitoring stations, situated 5 kilometres and 8 kilometres from the project site respectively were not used as the local meteorological conditions at these sites were considered to have little influence over conditions at the project area.

For the NorthConnex Technical Working Paper: Air Quality (AECOM 2014), meteorological modelling was undertaken using data from 2009 to 2011 from five meteorological stations run by the BoM and the OEH. For consistency, 2014 data from those monitoring stations (Lindfield, Prospect, Terrey Hills, Richmond RAAF and Sydney Airport) were reviewed for this study. While the BoM and EPA sites are generally sited further from the project site than the NorthConnex monitoring stations, their data are collectively thought to provide good coverage over the wider modelling domain. Sydney Airport and Richmond RAAF monitoring stations also record air pressure data, which are needed by the model. For these reasons, data from these stations were included in the meteorological model with the exception of the Lindfield station. The use of Lindfield data was criticised in the NorthConnex assessment as data from the station were considered to be unrepresentative of conditions outside its immediate area due to the siting of the station. As such, data from Lindfield were excluded from this assessment.

The table below shows the 2014 data available for each station; the following subsections provide more detailed information regarding the data at each station, including frequency distribution tables and wind rose plots.

Station Operator	Location	Available 2014 Data					
		Wind Speed (m/s)	Wind Direction	Temperature (°C)	Relative Humidity (%)	Pressure (mb)	Precipitation (mm)
NorthConnex	Headen Sports Park	x	x	x	x		
	James Park	x	x	x	x		x
	Brickpit Park	x	x	x	x		
	Observatory Park	x	x	x	x		
	Rainbow Farm	x	x	x	x		x
Office of Environment and Heritage (OEH)	Lindfield	x	x	x	x		
	Prospect	x	x	x	x		
Bureau of Meteorology (BoM)	Terrey Hills	x	x	x	x		
	Richmond RAAF	x	x	x	x	x	x
	Sydney Airport	x	x	x	x	x	x

Headen Sports Park

Headen Sports Park monitoring station is located approximately three kilometres southwest of Hornsby Quarry, sited at the northwestern end of the park oval. The station is situated at the base of a slope, with screening vegetation backing onto residential premises approximately 30 metres to the north. The station is located at approximately 175 metres above MSL, with the slope rising approximately 6 metres to the northwest within 6 metres of the site.

Due to the siting of this monitoring station on a slope and tall trees located within 30 metres of the station, calm winds are recorded more than 22 per cent of the time, and wind flow data are not recorded for the north to northeast directions (i.e. almost a quadrant of wind directions are missing in the recorded data). Data recorded at Headen Park are summarised below.

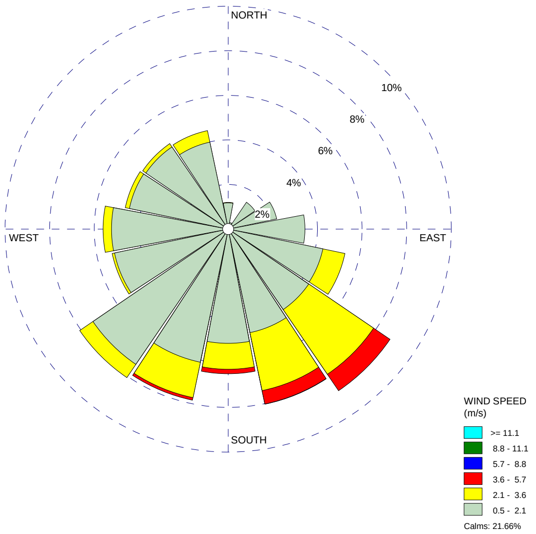
Aerial view of Headon Park. The location of the monitoring station is marked by a red cross (Image taken from Google Earth 2015)

View of monitoring station from Sinclair Avenue facing east (Image taken from Google Earth street view 2015)

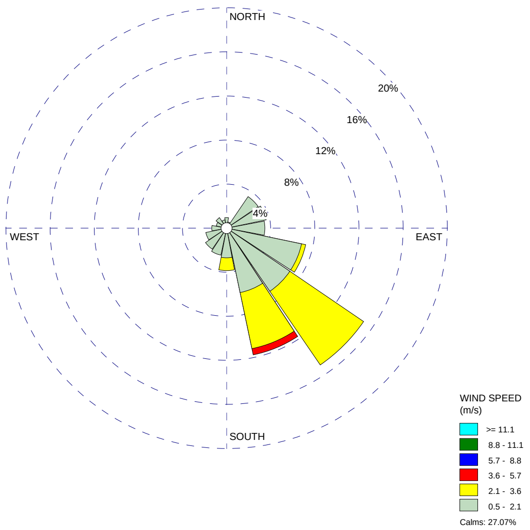
Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	1.142%	0.023%	0.000%	0.000%	0.000%	0.000%	1.164%
NNE	0.297%	0.000%	0.000%	0.000%	0.000%	0.000%	0.297%
NE	1.416%	0.000%	0.000%	0.000%	0.000%	0.000%	1.416%
ENE	2.158%	0.000%	0.000%	0.000%	0.000%	0.000%	2.158%
E	3.345%	0.000%	0.000%	0.000%	0.000%	0.000%	3.345%
ESE	4.212%	0.982%	0.000%	0.000%	0.000%	0.000%	5.194%
SE	4.247%	3.413%	0.868%	0.000%	0.000%	0.000%	8.527%
SSE	4.612%	2.580%	0.594%	0.011%	0.000%	0.000%	7.797%
S	4.977%	1.130%	0.194%	0.000%	0.000%	0.000%	6.301%
SSW	5.925%	1.575%	0.114%	0.000%	0.000%	0.000%	7.614%
SW	7.135%	0.696%	0.000%	0.000%	0.000%	0.000%	7.831%
WSW	5.057%	0.103%	0.000%	0.000%	0.000%	0.000%	5.160%
W	5.080%	0.365%	0.000%	0.000%	0.000%	0.000%	5.445%
WNW	4.395%	0.183%	0.000%	0.000%	0.000%	0.000%	4.578%
NW	4.338%	0.171%	0.000%	0.000%	0.000%	0.000%	4.509%
NNW	3.870%	0.514%	0.000%	0.000%	0.000%	0.000%	4.384%
SUM	62.203%	11.735%	1.769%	0.011%	0.000%	0.000%	75.719%
Annual (Jan to Dec, 2014). Total periods = 8,760; Valid periods = 8,530; Calm wind periods = 1,897; Calm winds: 21.655%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	41.2		100.1	356.9	5.9
Minimum	0.0		0.0	0.0	0.0
Average	17.1		73.9	193.2	1.1

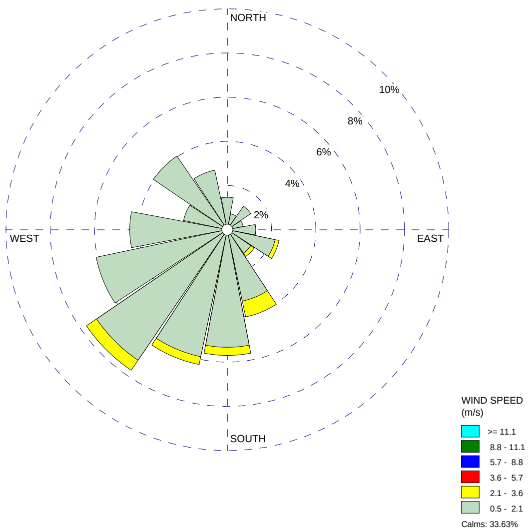
Annual 2014



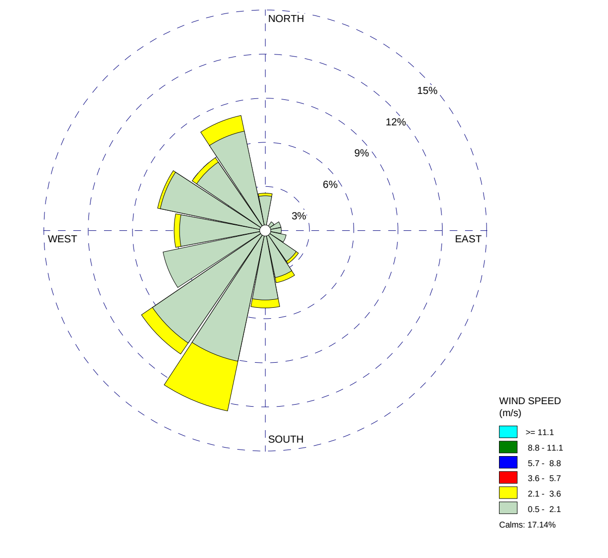
Summer 2014



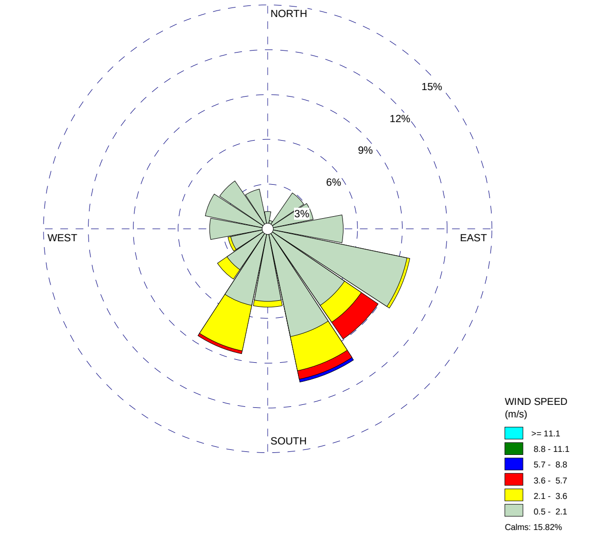
Autumn 2014



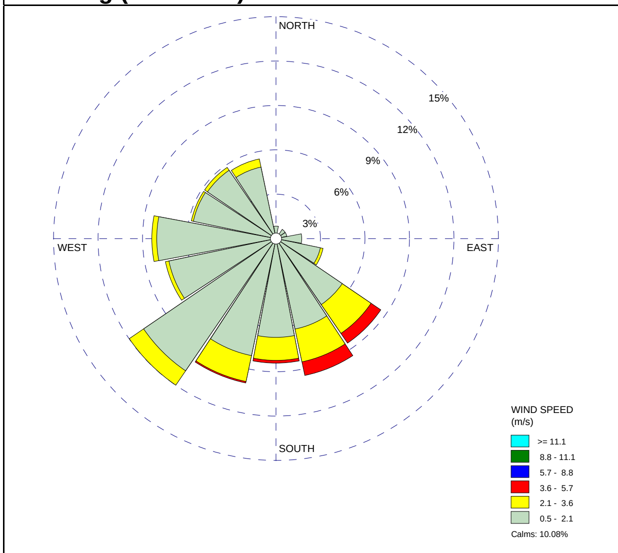
Winter 2014



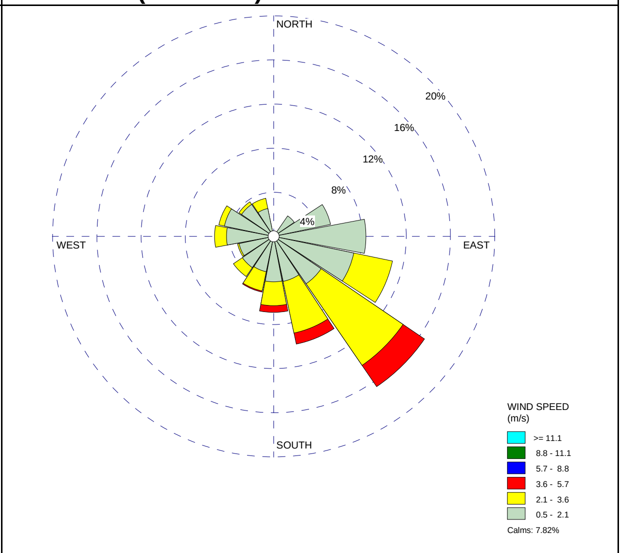
Spring 2014



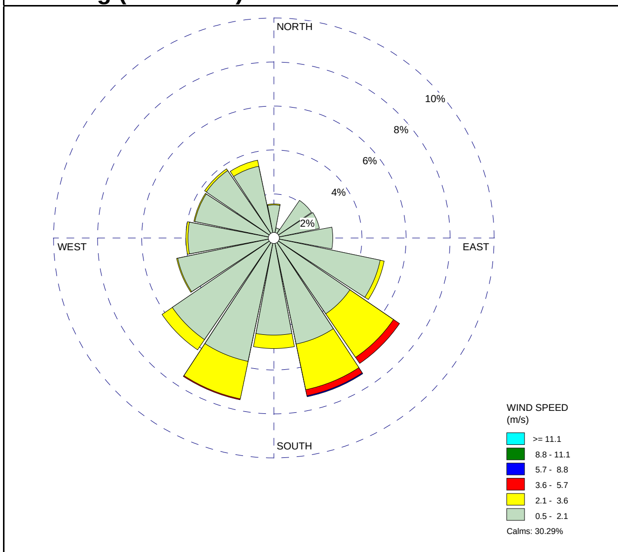
Morning (07h – 12h)



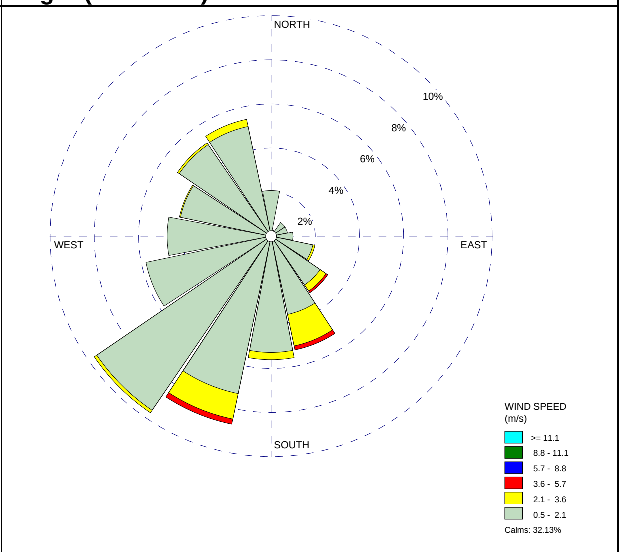
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



James Park

The NorthConnex monitoring station at James Park is the closest monitoring station to the project site, located approximately two kilometres east of Hornsby Quarry. Potential issues with the James Park data include missing winds from the north and a high percentage of light winds and calms. Data from this station are summarised below.

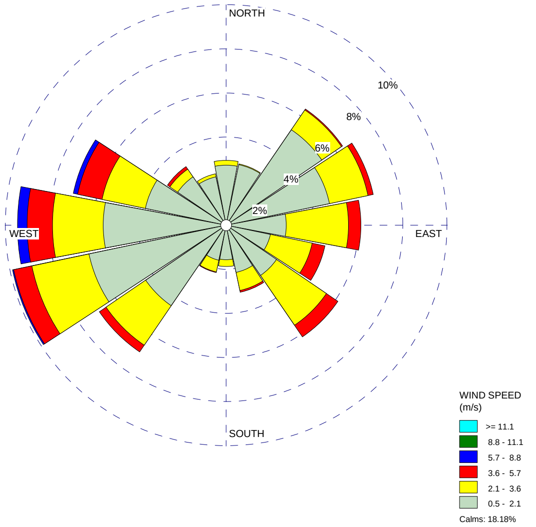
Aerial View of James Park. The location of the monitoring station is marked by a red cross (image from Google Earth 2015).

View of monitoring station location (marked by red cross) from Lowe Road facing north (image from Google Earth street view 2015).

Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	2.705%	0.217%	0.000%	0.000%	0.000%	0.000%	2.922%
NNE	2.785%	0.034%	0.000%	0.000%	0.000%	0.000%	2.820%
NE	5.205%	1.073%	0.057%	0.000%	0.000%	0.000%	6.336%
ENE	4.749%	1.769%	0.240%	0.000%	0.000%	0.000%	6.758%
E	2.705%	2.797%	0.559%	0.000%	0.000%	0.000%	6.062%
ESE	2.032%	1.918%	0.594%	0.000%	0.000%	0.000%	4.543%
SE	2.740%	2.717%	0.628%	0.000%	0.000%	0.000%	6.084%
SSE	2.169%	0.833%	0.080%	0.000%	0.000%	0.000%	3.082%
S	1.553%	0.308%	0.000%	0.000%	0.000%	0.000%	1.861%
SSW	1.610%	0.537%	0.034%	0.000%	0.000%	0.000%	2.180%
SW	4.384%	2.158%	0.365%	0.000%	0.000%	0.000%	6.906%
WSW	6.301%	2.626%	0.833%	0.057%	0.000%	0.000%	9.817%
W	5.525%	2.283%	1.142%	0.434%	0.000%	0.000%	9.384%
WNW	3.710%	1.986%	1.130%	0.194%	0.000%	0.000%	7.021%
NW	2.637%	0.422%	0.137%	0.000%	0.000%	0.000%	3.196%
NNW	2.226%	0.137%	0.000%	0.000%	0.000%	0.000%	2.363%
SUM	53.037%	21.815%	5.799%	0.685%	0.000%	0.000%	81.336%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,718; Calm wind periods = 1,593; Calm winds: 18.185 %;							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	39.6	6.8	100.3	359.7	8.5
Minimum	0.0	0.0	0.0	0.0	0.0
Average	17.3	0.0	73.2	164.7	1.6

Annual 2014



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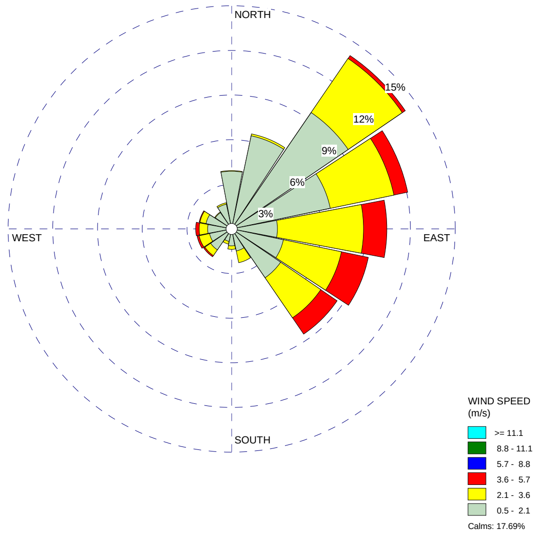
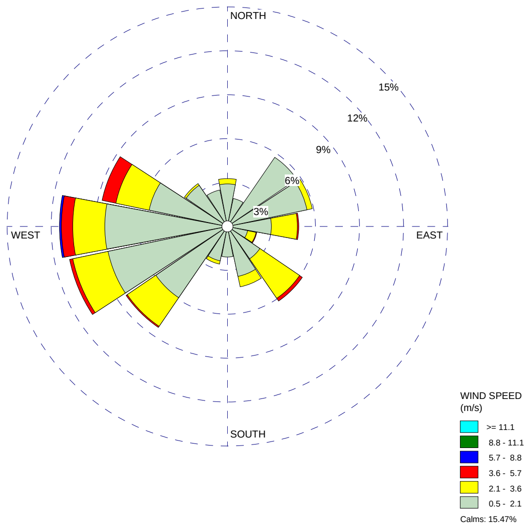
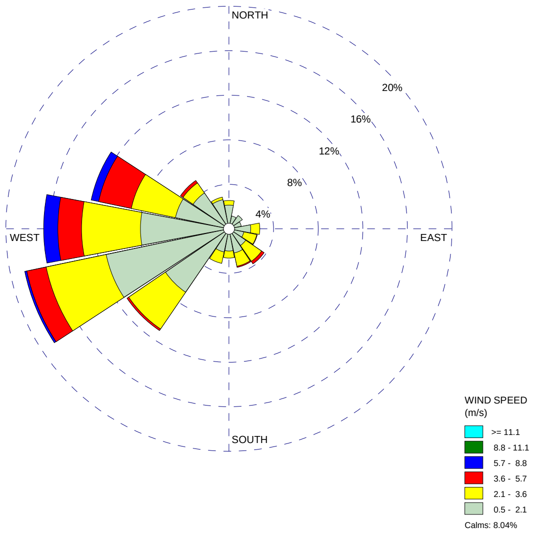


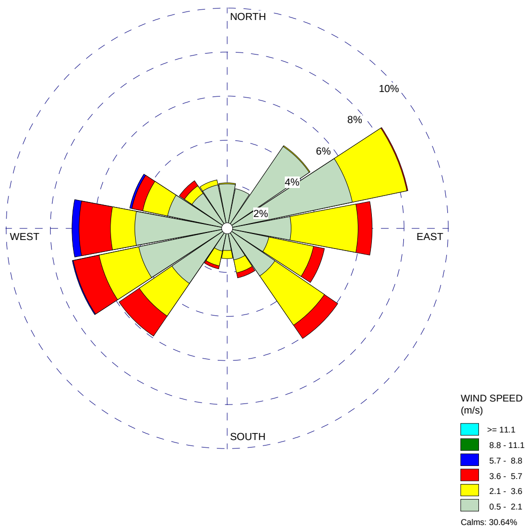
Autumn 2014



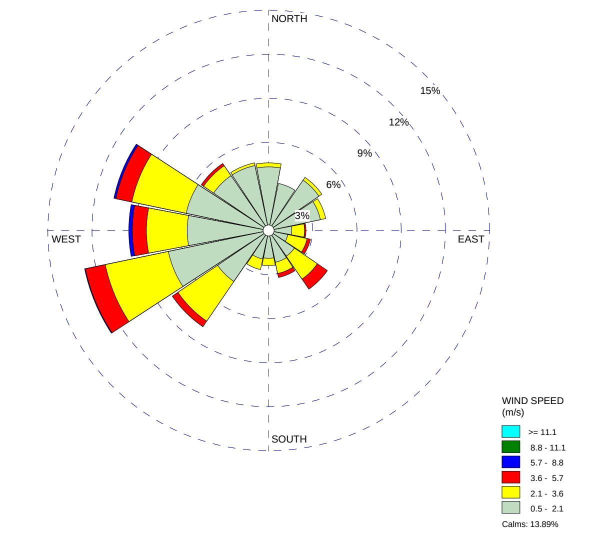
Winter 2014



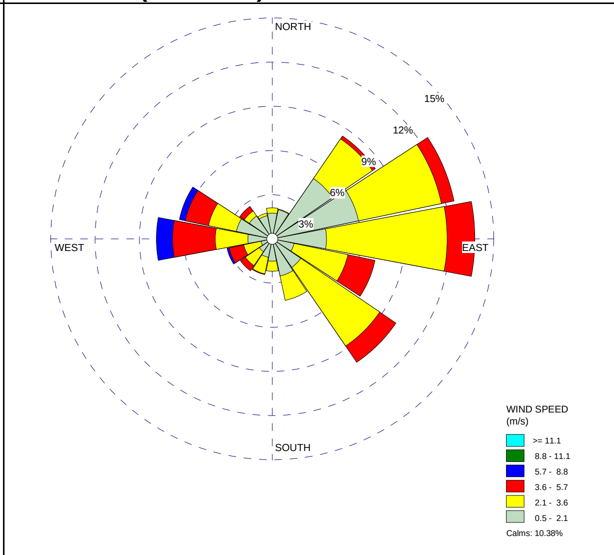
Spring 2014



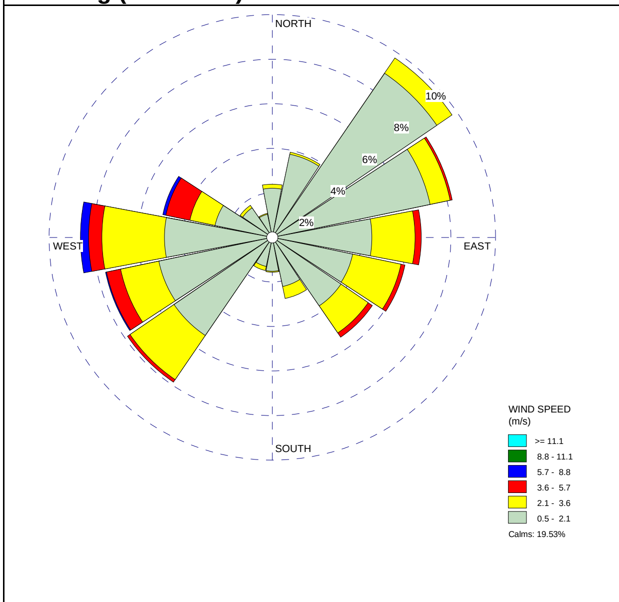
Morning (07h – 12h)



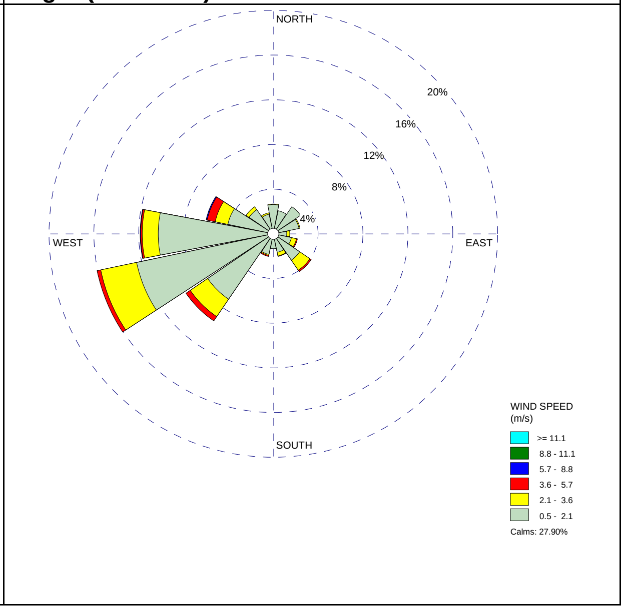
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Brickpit Park

Brickpit Park monitoring station is located approximately 3 kilometres south of Hornsby Quarry. The monitoring station is sited between tall vegetation approximately 10 metres to the east and west. Data from this station are summarised below.


Aerial view of Brickpit Park. Location of the monitoring station is marked with a red cross (image from Google Earth 2015).


View of monitoring station from Pennant Hills Road facing north (image from Google Earth street view 2015).

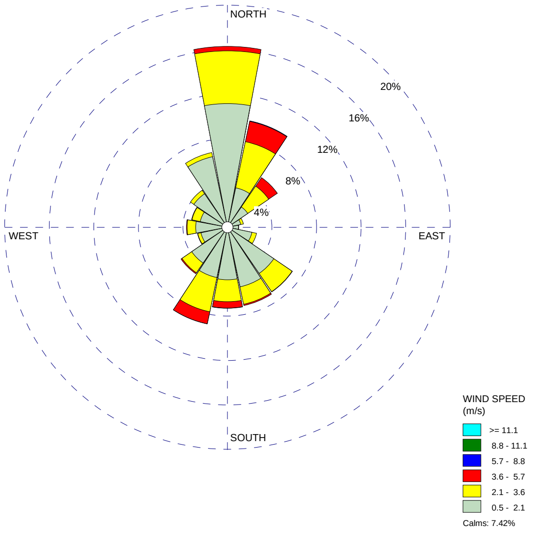

View of monitoring station from Pennant Hills Road facing northeast (image from Google Earth street view 2015).


View of monitoring station from Pennant Hills Road facing northwest (image from Google Earth street view 2015).

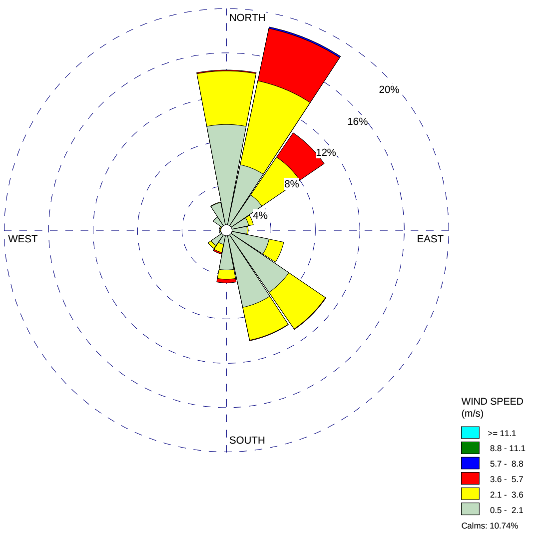
Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	11.107%	4.737%	0.400%	0.000%	0.000%	0.000%	16.244%
NNE	3.619%	4.235%	1.861%	0.046%	0.000%	0.000%	9.760%
NE	2.203%	2.272%	0.925%	0.000%	0.000%	0.000%	5.400%
ENE	1.221%	0.240%	0.000%	0.000%	0.000%	0.000%	1.461%
E	0.993%	0.023%	0.000%	0.000%	0.000%	0.000%	1.016%
ESE	2.237%	0.422%	0.000%	0.000%	0.000%	0.000%	2.660%
SE	5.023%	1.986%	0.023%	0.000%	0.000%	0.000%	7.032%
SSE	5.468%	1.598%	0.114%	0.000%	0.000%	0.000%	7.180%
S	4.715%	1.975%	0.571%	0.023%	0.000%	0.000%	7.283%
SSW	4.623%	3.139%	1.096%	0.011%	0.000%	0.000%	8.870%
SW	3.881%	1.062%	0.103%	0.000%	0.000%	0.000%	5.046%
WSW	2.420%	0.297%	0.023%	0.000%	0.000%	0.000%	2.740%
W	2.842%	0.776%	0.057%	0.000%	0.000%	0.000%	3.676%
WNW	2.489%	0.753%	0.034%	0.000%	0.000%	0.000%	3.276%
NW	3.642%	0.377%	0.000%	0.000%	0.000%	0.000%	4.018%
NNW	6.473%	0.388%	0.000%	0.000%	0.000%	0.000%	6.861%
SUM	62.957%	24.281%	5.205%	0.080%	0.000%	0.000%	92.523%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,755; Calm wind periods = 650; Calm winds: 7.420 %							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	39.8		99.3	360.0	6.4
Minimum	0.0		0.0	0.0	0.0
Average	17.5		71.2	183.3	1.6

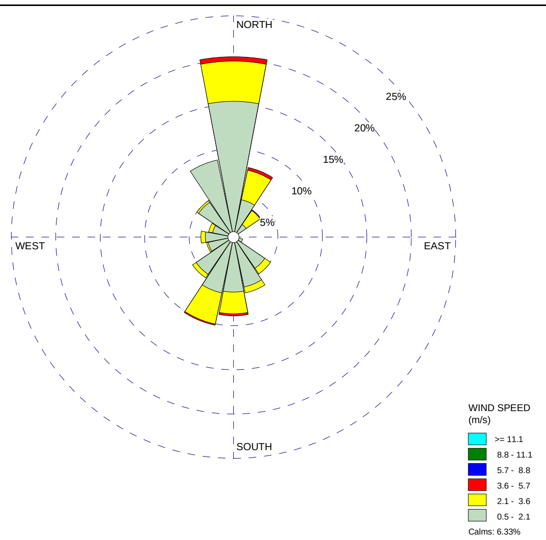
Annual 2014



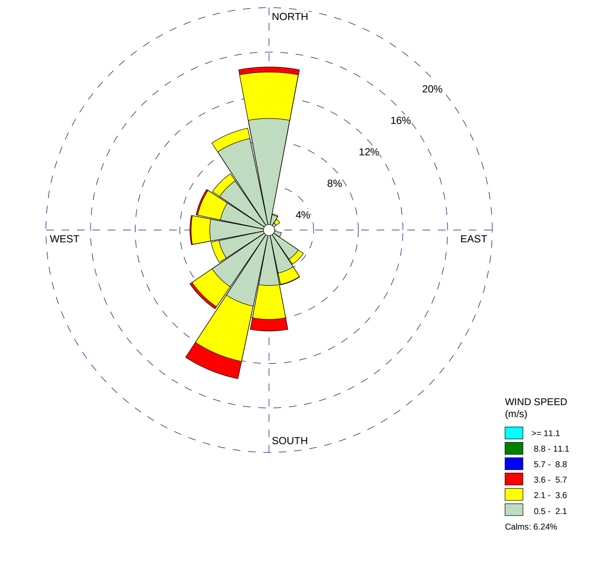
Summer 2014



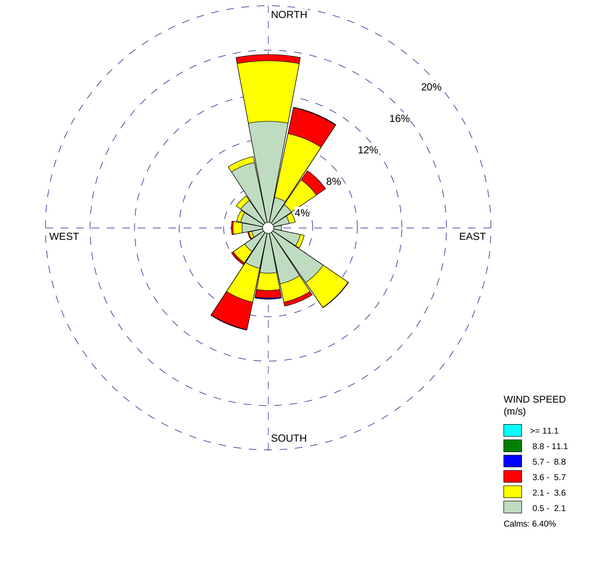
Autumn 2014



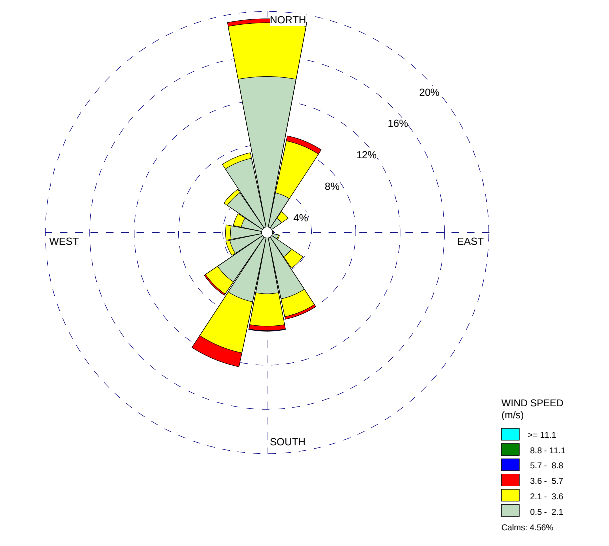
Winter 2014



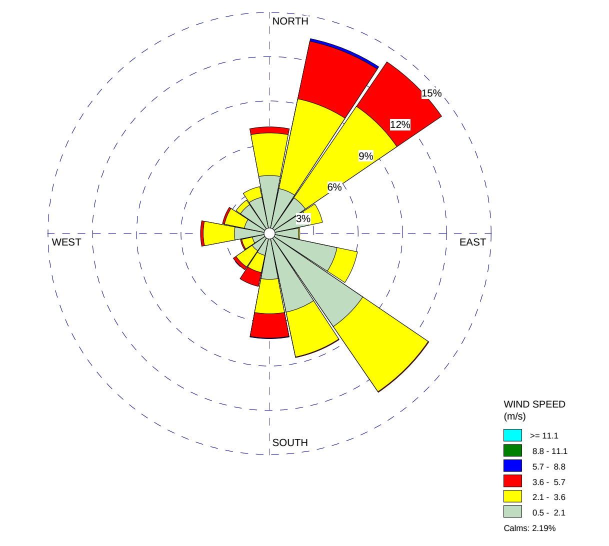
Spring 2014



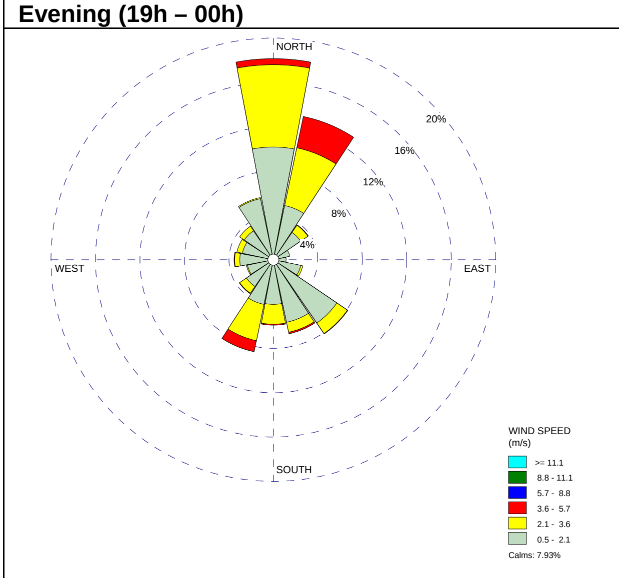
Morning (07h – 12h)



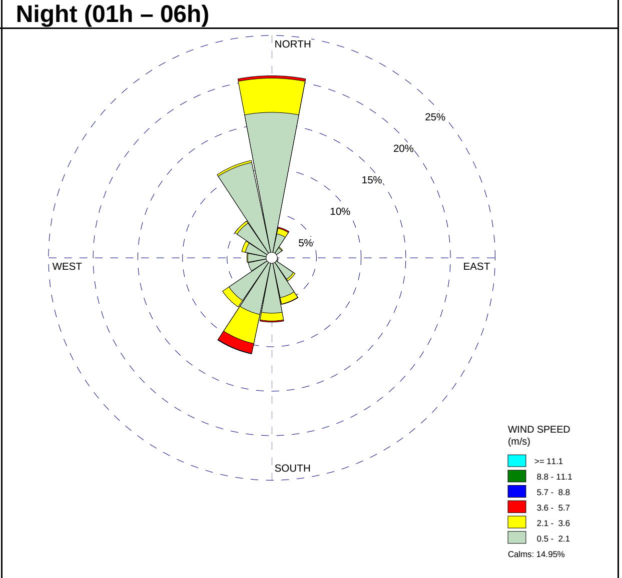
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Observatory Park

Observatory Park Monitoring Station is approximately 5 kilometres southwest of Hornsby Quarry. The monitoring station is located on the corner of Pennant Hills Road and Beecroft Road fronting onto tall vegetation in the southwest. The land slopes south from 192 metres above MSL at the site, dropping 37 metres in elevation to 155 metres above MSL 350 metres to the south. The nearby road follows a distinct ridgeline.

All winds from the dominant direction (southwest) are missing due to the positioning of the monitoring station. Data measured at the station are summarised below.

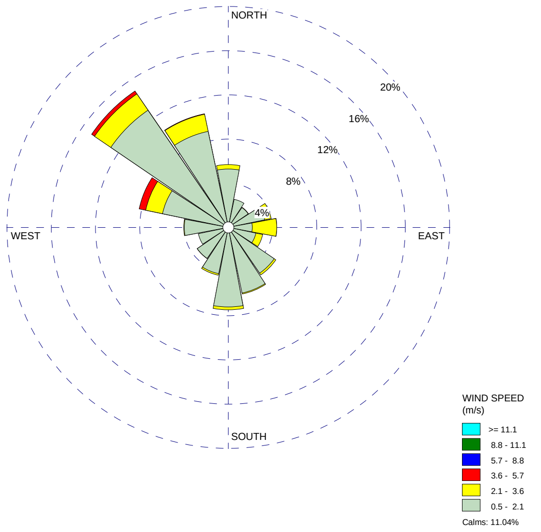
Aerial view of Observatory Park. The location of the monitoring station is marked with a red cross (image from Google Earth 2015).

View of the monitoring station from Beecroft Road facing south west (image from Google Earth street view 2015).

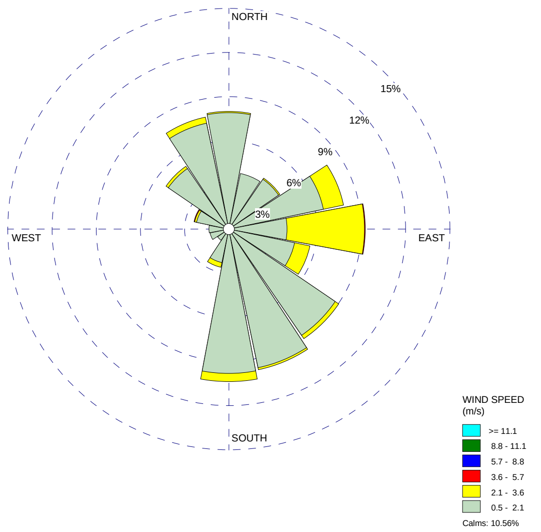
Wind Direction	Wind Speed Category (m/s) 0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	5.274%	0.400%	0.000%	0.000%	0.000%	0.000%	5.674%
NNE	2.591%	0.000%	0.000%	0.000%	0.000%	0.000%	2.591%
NE	2.169%	0.034%	0.000%	0.000%	0.000%	0.000%	2.203%
ENE	3.356%	0.594%	0.000%	0.000%	0.000%	0.000%	3.950%
E	2.158%	2.203%	0.011%	0.000%	0.000%	0.000%	4.372%
ESE	2.534%	0.628%	0.000%	0.000%	0.000%	0.000%	3.162%
SE	5.000%	0.194%	0.000%	0.000%	0.000%	0.000%	5.194%
SSE	6.050%	0.091%	0.000%	0.000%	0.000%	0.000%	6.142%
S	7.180%	0.251%	0.000%	0.000%	0.000%	0.000%	7.432%
SSW	4.269%	0.137%	0.000%	0.000%	0.000%	0.000%	4.406%
SW	3.390%	0.011%	0.000%	0.000%	0.000%	0.000%	3.402%
WSW	2.763%	0.000%	0.000%	0.000%	0.000%	0.000%	2.763%
W	3.961%	0.057%	0.000%	0.000%	0.000%	0.000%	4.018%
WNW	6.050%	1.553%	0.605%	0.000%	0.000%	0.000%	8.208%
NW	12.820%	1.769%	0.320%	0.000%	0.000%	0.000%	14.909%
NNW	8.858%	1.575%	0.046%	0.000%	0.000%	0.000%	10.479%
SUM	78.425%	9.498%	0.982%	0.000%	0.000%	0.000%	88.904%
Annual(Jan to Dec) Calm Winds: 11.039% Total Periods = 8760; Valid Periods = 8755; Calm Wind Periods = 967							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

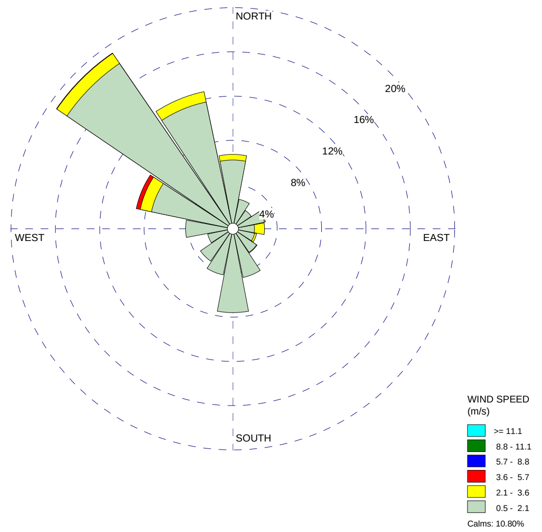
Annual 2014



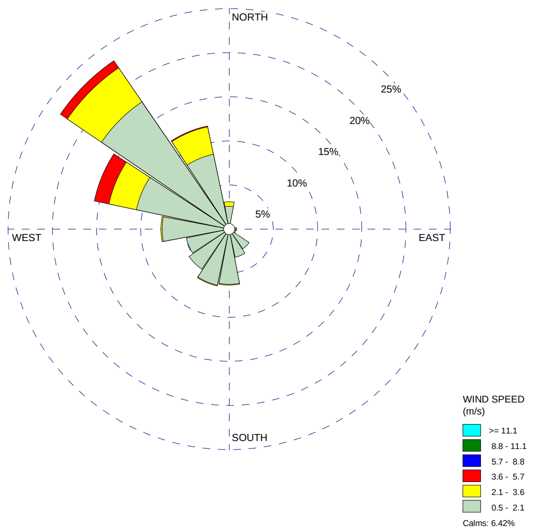
Summer 2014



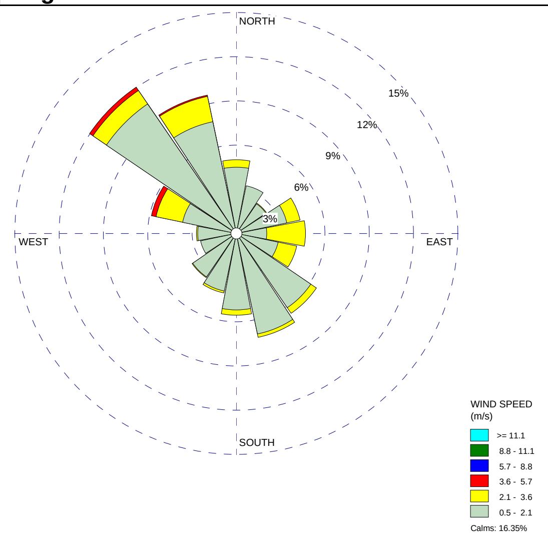
Autumn 2014



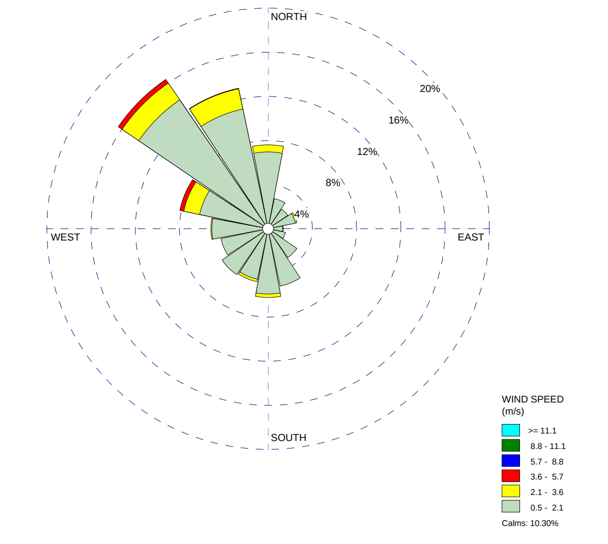
Winter 2014



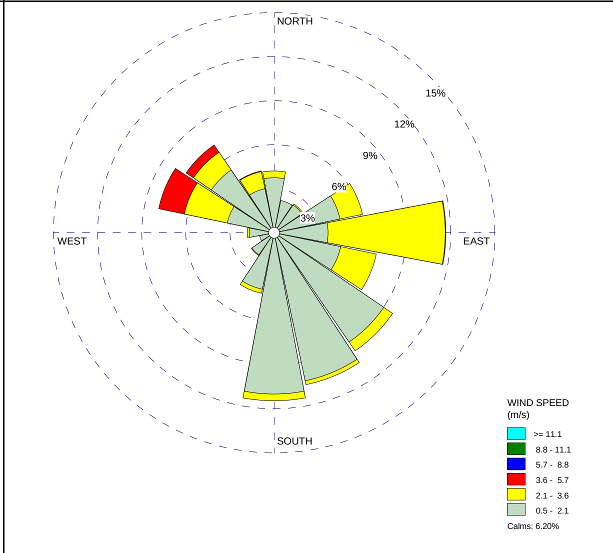
Spring 2014



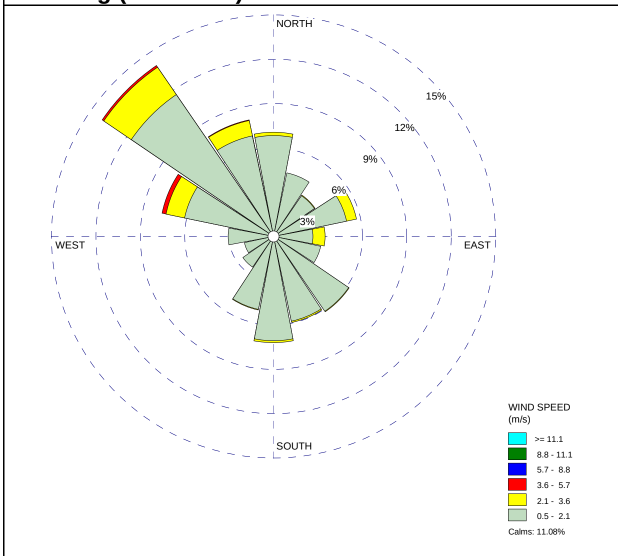
Morning (07h – 12h)



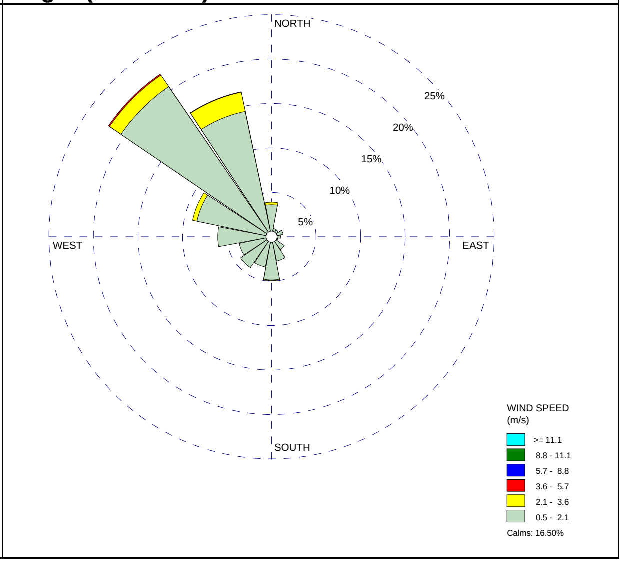
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Rainbow Farm

The monitoring station at Rainbow Farm is located approximately 8 kilometres south west of Hornsby Quarry. The meteorological station fronts both vegetation and residential properties to the southwest. Data collected by this station are summarised below.

Aerial view of Rainbow Farm. Location of the monitoring station is marked with a red cross (image from Google Earth 2015).

View of monitoring station from Coral Tree Drive facing south. (image from Google Earth street view 2015).

Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	3.539%	1.233%	0.148%	0.000%	0.000%	0.000%	4.920%
NNE	2.374%	0.639%	0.000%	0.000%	0.000%	0.000%	3.014%
NE	2.432%	0.331%	0.000%	0.000%	0.000%	0.000%	2.763%
ENE	1.701%	0.000%	0.000%	0.000%	0.000%	0.000%	1.701%
E	3.836%	0.582%	0.000%	0.000%	0.000%	0.000%	4.418%
ESE	3.699%	1.781%	0.114%	0.000%	0.000%	0.000%	5.594%
SE	2.911%	3.037%	1.735%	0.046%	0.000%	0.000%	7.728%
SSE	2.740%	2.911%	0.970%	0.011%	0.000%	0.000%	6.632%
S	1.861%	0.468%	0.023%	0.000%	0.000%	0.000%	2.352%
SSW	1.598%	0.240%	0.000%	0.000%	0.000%	0.000%	1.838%
SW	2.226%	0.605%	0.023%	0.000%	0.000%	0.000%	2.854%
WSW	3.265%	1.199%	0.502%	0.000%	0.000%	0.000%	4.966%
W	3.619%	0.845%	0.422%	0.011%	0.000%	0.000%	4.897%
WNW	4.783%	0.947%	0.594%	0.023%	0.000%	0.000%	6.347%
NW	7.180%	1.336%	0.434%	0.000%	0.000%	0.000%	8.950%
NNW	4.053%	1.233%	0.354%	0.000%	0.000%	0.000%	5.639%
SUM	51.815%	17.386%	5.320%	0.091%	0.000%	0.000%	74.612%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,333; Calm wind periods = 1,797; Calm winds: 20.514%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

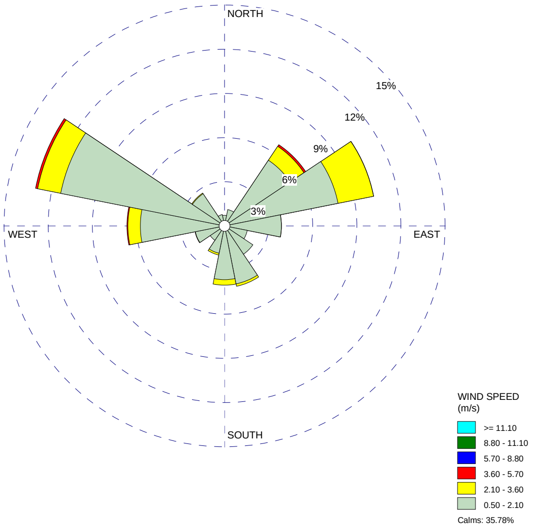
Lindfield

High frequency of calms unusual when compared to 2009-2011 data from Lindfield due to the large amount of calms recorded in the data and criticism received from using this meteorological station in the NorthConnex meteorological modelling. Data collected by this station are summarised below.

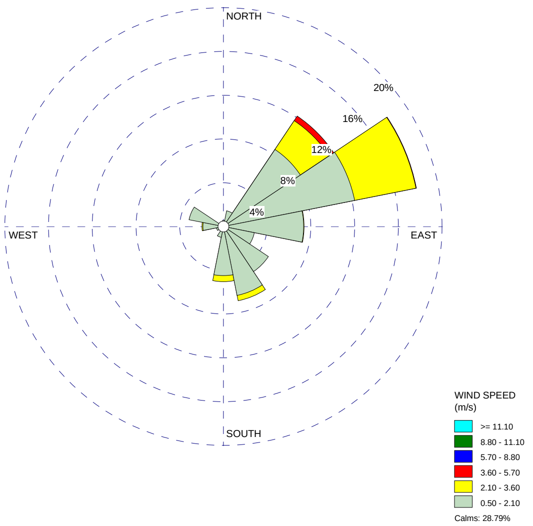
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	0.727%	0.000%	0.000%	0.000%	0.000%	0.000%	0.727%
NNE	1.143%	0.000%	0.000%	0.000%	0.000%	0.000%	1.143%
NE	5.413%	1.143%	0.139%	0.000%	0.000%	0.000%	6.694%
ENE	7.941%	2.482%	0.012%	0.000%	0.000%	0.000%	10.434%
E	3.901%	0.012%	0.000%	0.000%	0.000%	0.000%	3.913%
ESE	1.593%	0.000%	0.000%	0.000%	0.000%	0.000%	1.593%
SE	2.332%	0.000%	0.000%	0.000%	0.000%	0.000%	2.332%
SSE	4.051%	0.162%	0.000%	0.000%	0.000%	0.000%	4.213%
S	3.682%	0.381%	0.000%	0.000%	0.000%	0.000%	4.063%
SSW	1.904%	0.127%	0.000%	0.000%	0.000%	0.000%	2.031%
SW	1.189%	0.000%	0.000%	0.000%	0.000%	0.000%	1.189%
WSW	2.043%	0.012%	0.012%	0.000%	0.000%	0.000%	2.066%
W	5.783%	0.854%	0.058%	0.000%	0.000%	0.000%	6.694%
WNW	11.461%	1.616%	0.150%	0.000%	0.000%	0.000%	13.227%
NW	2.655%	0.058%	0.000%	0.000%	0.000%	0.000%	2.712%
NNW	0.796%	0.000%	0.000%	0.000%	0.000%	0.000%	0.796%
SUM	6.844%	0.369%	0.000%	0.000%	0.000%	63.128%	6.844%
Annual(Jan to Dec) Calm Winds: 36.17% Total Periods = 8760; Valid Periods = 8664; Calm Wind Periods = 3134							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

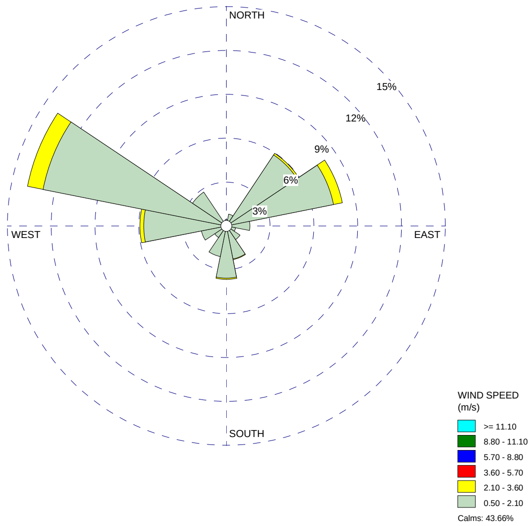
Annual 2014



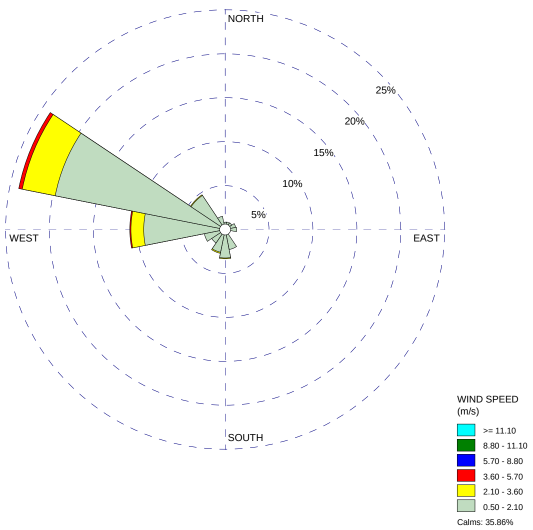
Summer 2014



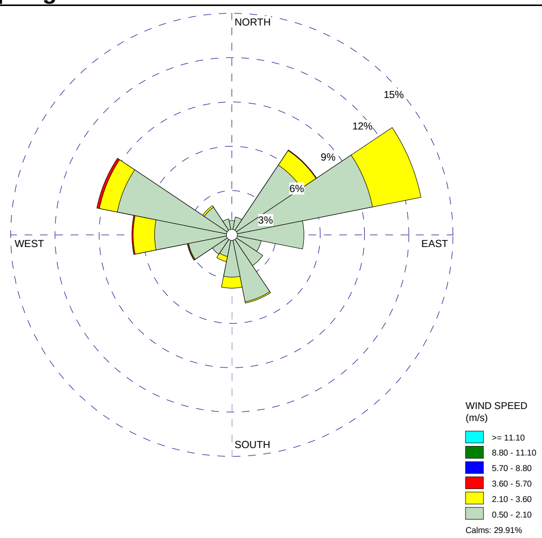
Autumn 2014



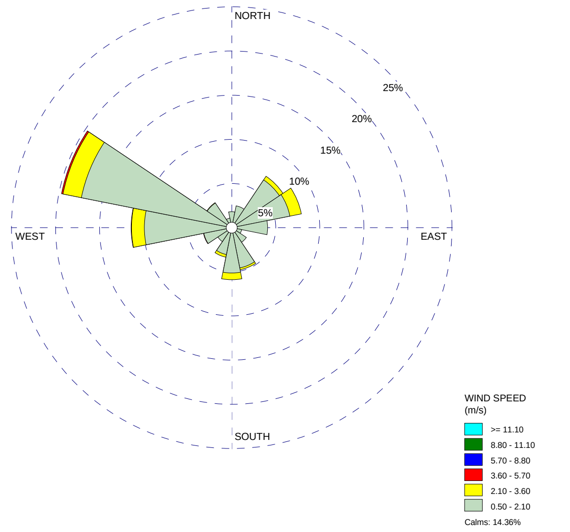
Winter 2014



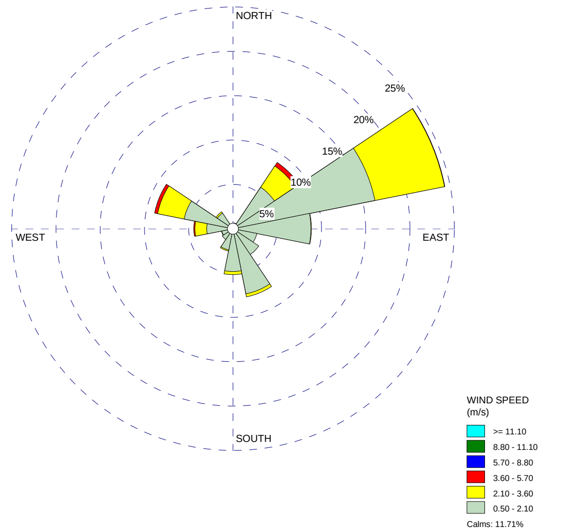
Spring 2014



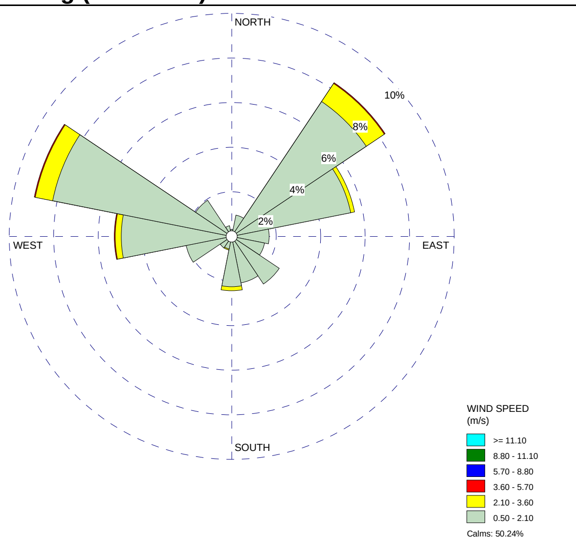
Morning (07h – 12h)



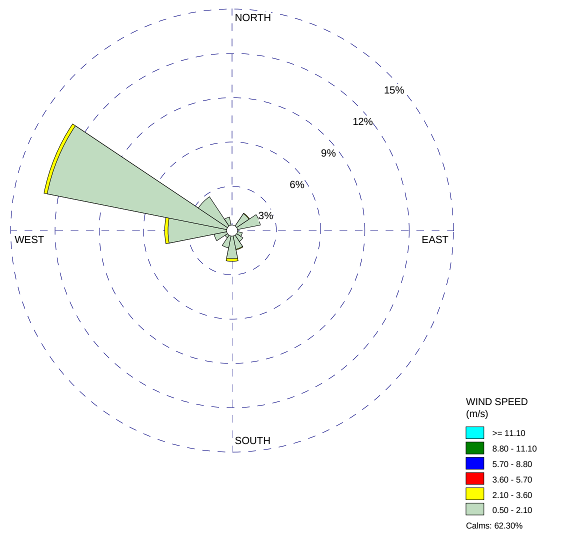
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



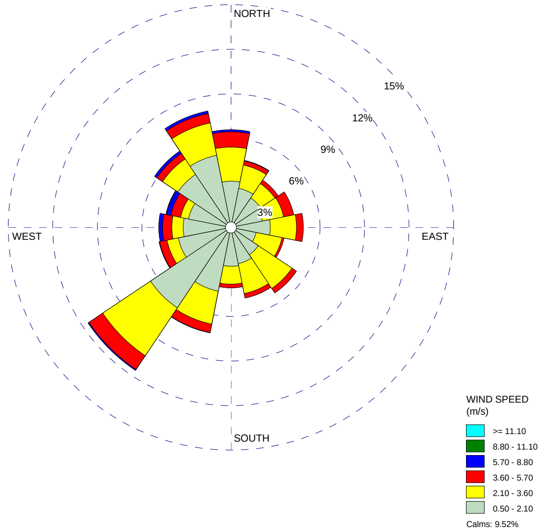
Prospect

Data collected by this station are summarised below.

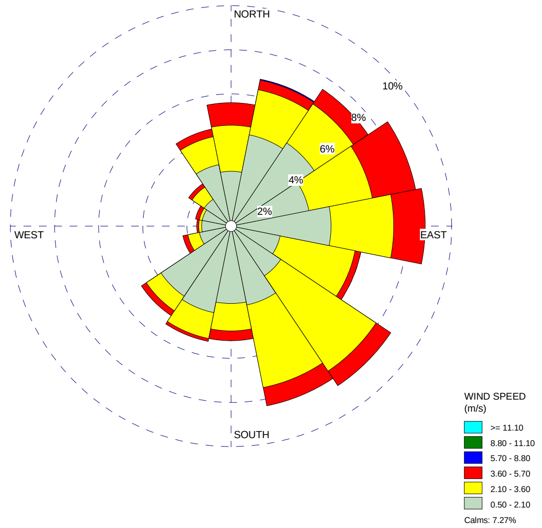
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	3.146%	2.325%	1.041%	0.139%	0.000%	0.000%	6.651%
NNE	2.718%	1.608%	0.289%	0.035%	0.000%	0.000%	4.650%
NE	2.418%	1.180%	0.278%	0.000%	0.000%	0.000%	3.875%
ENE	2.186%	1.469%	0.706%	0.000%	0.000%	0.000%	4.361%
E	2.684%	1.781%	0.463%	0.000%	0.000%	0.000%	4.928%
ESE	1.747%	1.793%	0.150%	0.000%	0.000%	0.000%	3.690%
SE	2.233%	2.765%	0.370%	0.000%	0.000%	0.000%	5.367%
SSE	2.510%	2.082%	0.312%	0.000%	0.000%	0.000%	4.905%
S	2.649%	1.215%	0.255%	0.000%	0.000%	0.000%	4.118%
SSW	4.430%	2.279%	0.590%	0.023%	0.000%	0.000%	7.322%
SW	6.582%	3.921%	1.134%	0.069%	0.000%	0.000%	11.706%
WSW	3.655%	0.787%	0.521%	0.035%	0.000%	0.000%	4.997%
W	3.250%	0.775%	0.636%	0.255%	0.000%	0.000%	4.916%
WNW	2.950%	0.544%	0.683%	0.312%	0.035%	0.000%	4.523%
NW	4.338%	1.272%	0.463%	0.185%	0.000%	0.000%	6.258%
NNW	5.009%	2.244%	0.659%	0.174%	0.000%	0.000%	8.086%
SUM	52.504%	28.039%	8.548%	1.226%	0.035%	0.000%	89.167%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,645; Calm wind periods = 834; Calm winds: 9.521%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

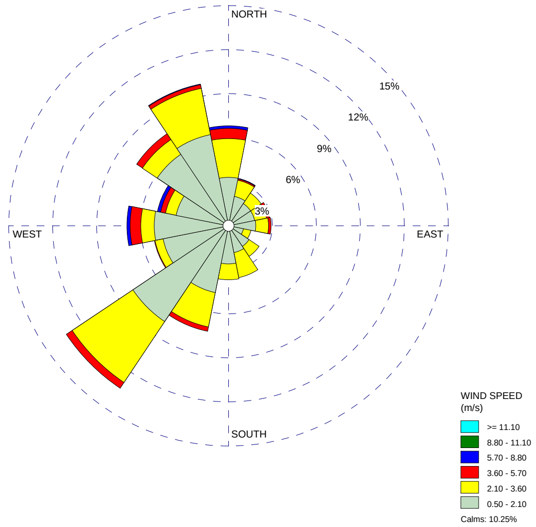
Annual 2014



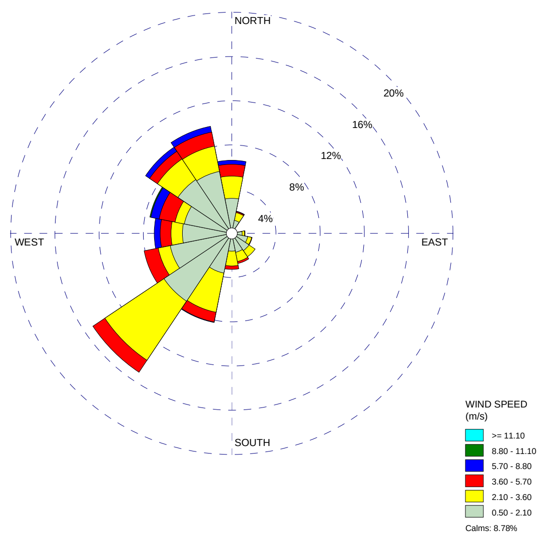
Summer 2014



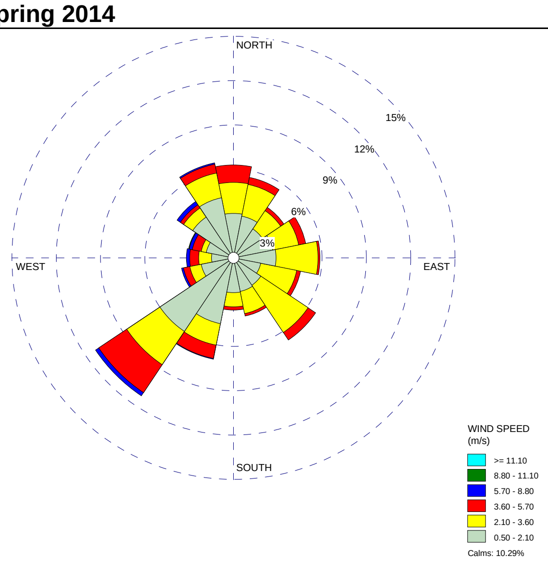
Autumn 2014



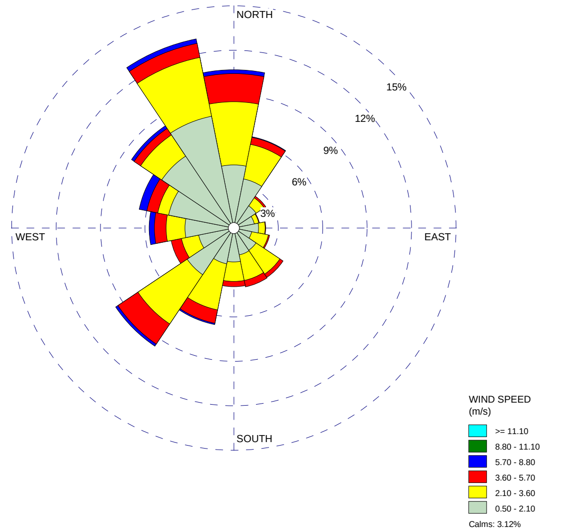
Winter 2014



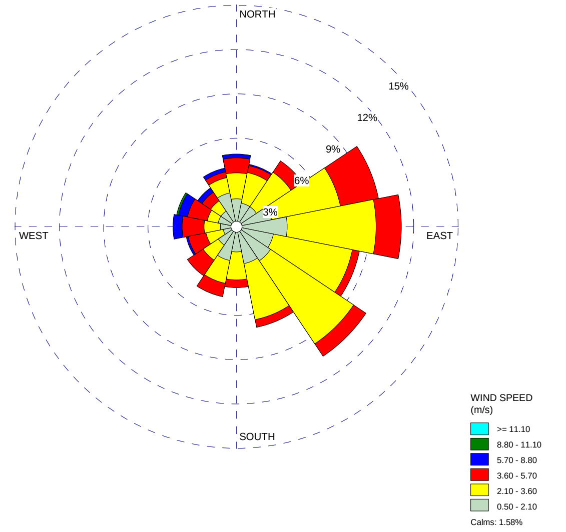
Spring 2014



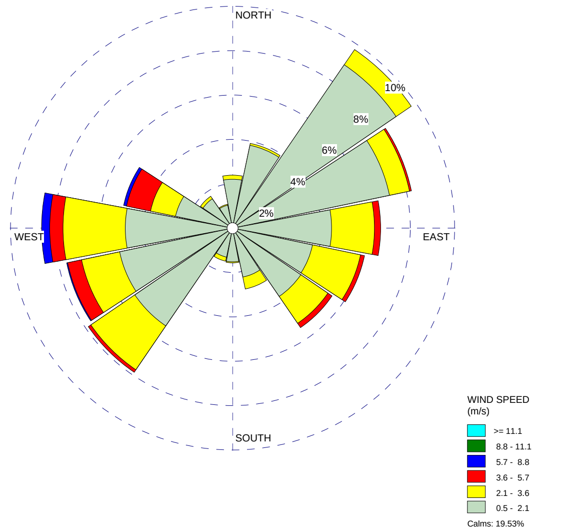
Morning (07h – 12h)



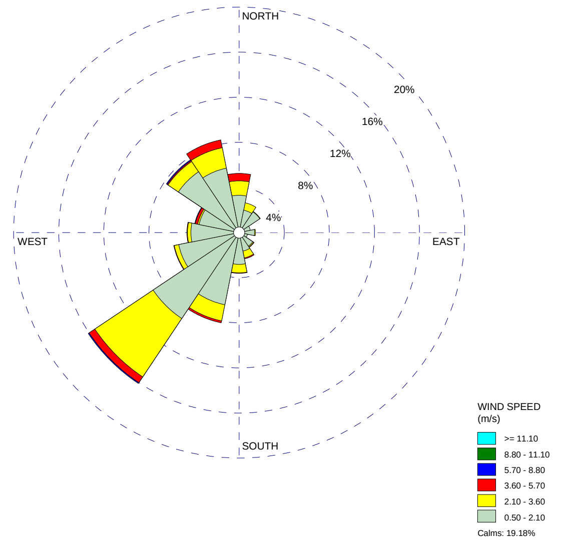
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



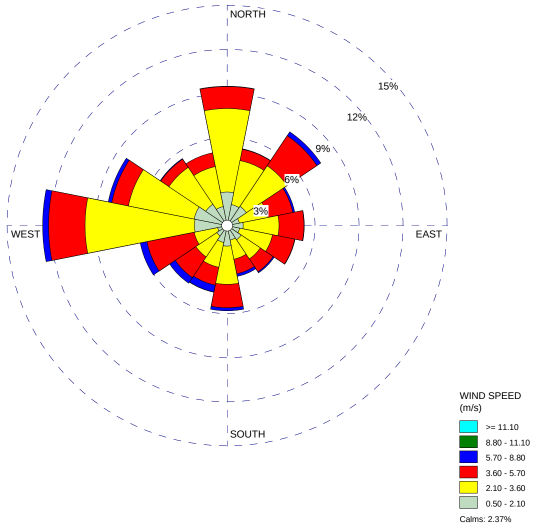
Terrey Hills

Data collected by this station are summarised below.

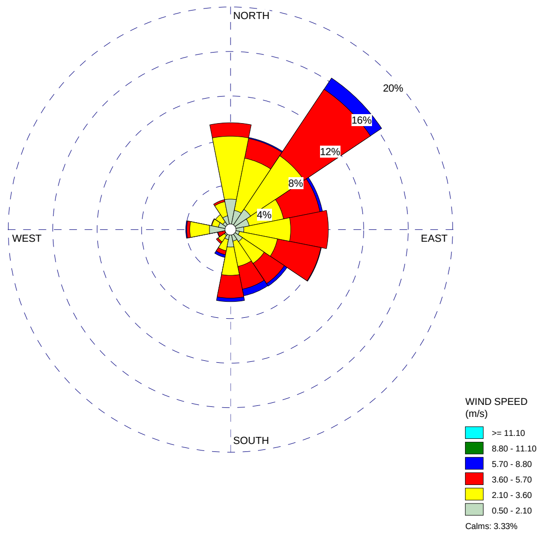
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	2.299%	5.713%	1.506%	0.023%	0.000%	0.000%	9.541%
NNE	1.471%	3.069%	0.793%	0.023%	0.000%	0.000%	5.357%
NE	1.586%	3.345%	2.472%	0.310%	0.000%	0.000%	7.714%
ENE	0.862%	1.989%	1.736%	0.138%	0.000%	0.000%	4.725%
E	1.104%	2.449%	1.713%	0.023%	0.000%	0.000%	5.288%
ESE	0.874%	2.299%	1.552%	0.023%	0.000%	0.000%	4.748%
SE	1.161%	1.575%	1.058%	0.092%	0.000%	0.000%	3.886%
SSE	1.012%	1.334%	1.012%	0.184%	0.000%	0.000%	3.541%
S	1.403%	2.621%	1.598%	0.207%	0.000%	0.000%	5.828%
SSW	1.173%	1.736%	1.242%	0.483%	0.012%	0.000%	4.644%
SW	0.851%	1.724%	1.701%	0.460%	0.000%	0.000%	4.736%
WSW	0.667%	1.632%	3.299%	0.471%	0.000%	0.000%	6.070%
W	2.230%	7.507%	2.495%	0.402%	0.000%	0.000%	12.634%
WNW	2.299%	4.598%	1.161%	0.241%	0.000%	0.000%	8.300%
NW	1.759%	3.035%	0.678%	0.046%	0.000%	0.000%	5.518%
NNW	1.334%	2.782%	0.966%	0.000%	0.000%	0.000%	5.081%
SUM	22.083%	47.408%	24.980%	3.127%	0.012%	0.000%	96.929%
Annual (Jan to Dec, 2014). Total periods = 8,760; Valid periods = 8,699; Calm wind periods = 61; Calm winds: 2.39%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

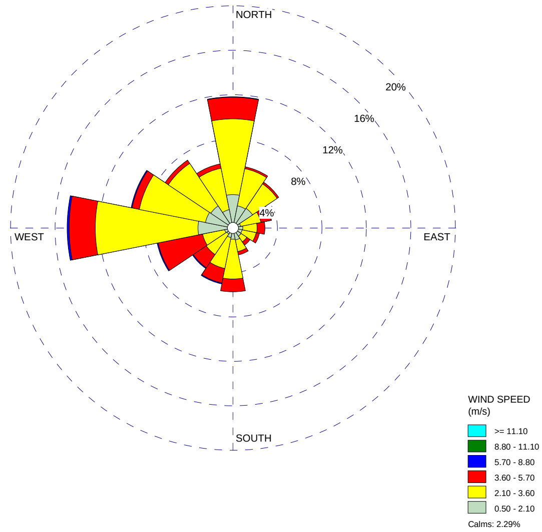
Annual 2014



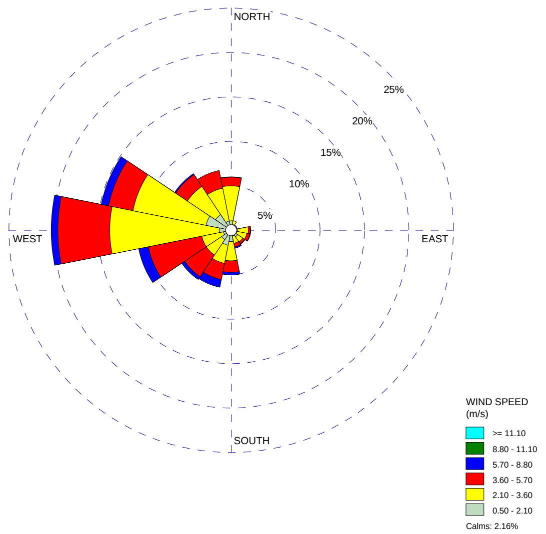
Summer 2014



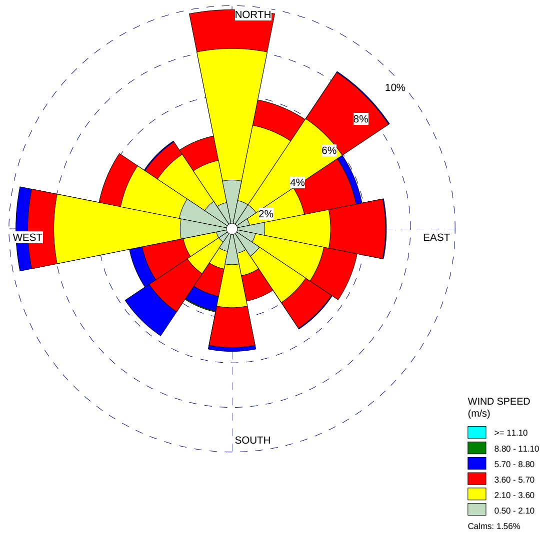
Autumn 2014



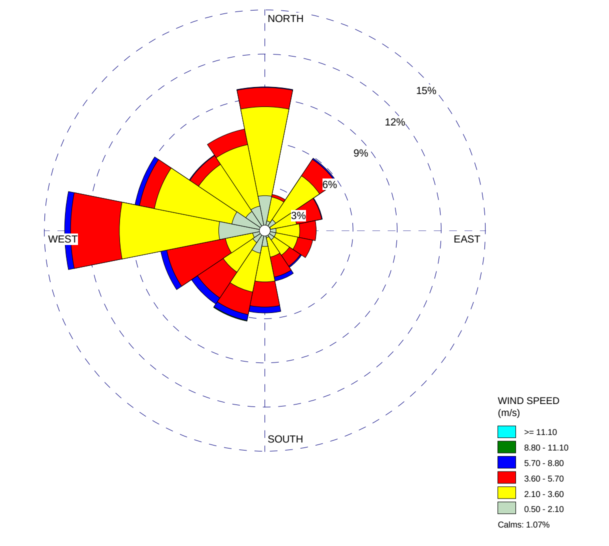
Winter 2014



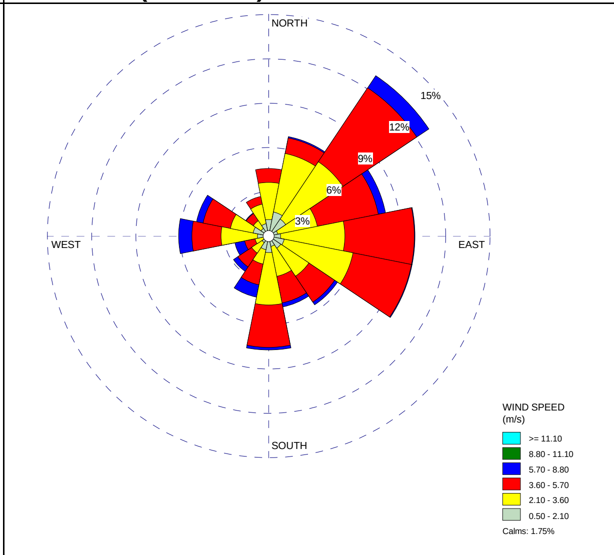
Spring 2014



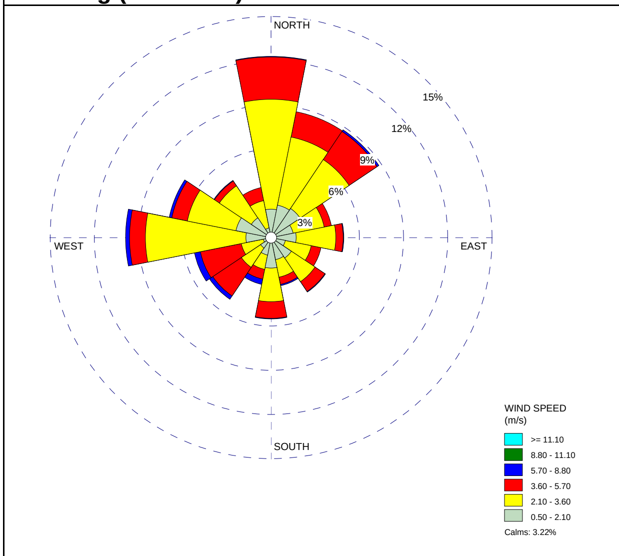
Morning (07h – 12h)



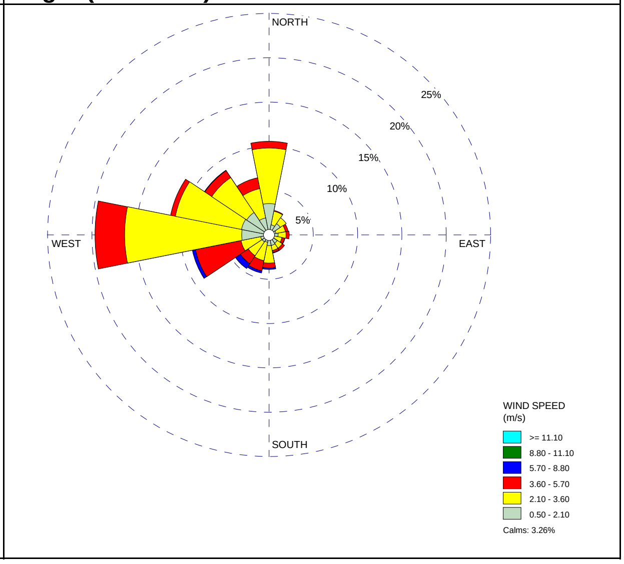
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



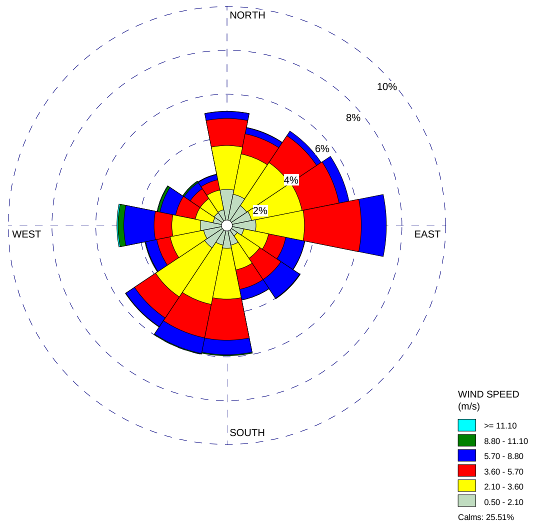
Richmond RAAF

Data collected by this station are summarised below.

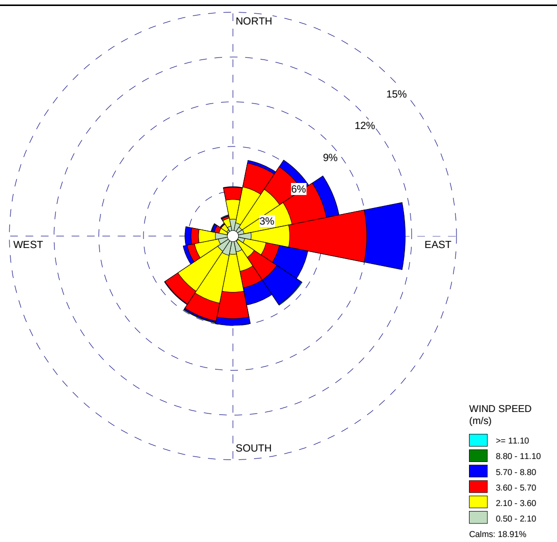
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	1.662%	2.020%	1.247%	0.323%	0.012%	0.000%	5.205%
NNE	1.466%	1.893%	0.946%	0.289%	0.012%	0.000%	4.555%
NE	1.096%	2.389%	1.489%	0.254%	0.000%	0.000%	5.171%
ENE	1.154%	2.378%	1.743%	0.462%	0.000%	0.000%	5.674%
E	1.339%	2.239%	2.620%	1.154%	0.000%	0.000%	7.272%
ESE	0.796%	1.166%	0.808%	0.889%	0.012%	0.000%	3.630%
SE	0.577%	1.247%	1.177%	1.039%	0.012%	0.012%	4.018%
SSE	0.923%	1.166%	0.912%	0.496%	0.012%	0.000%	3.470%
S	1.050%	2.343%	1.893%	0.669%	0.046%	0.000%	5.936%
SSW	0.923%	2.782%	1.570%	0.739%	0.035%	0.000%	5.982%
SW	1.235%	2.724%	1.166%	0.485%	0.023%	0.000%	5.571%
WSW	1.096%	1.570%	0.635%	0.519%	0.012%	0.023%	3.813%
W	1.223%	1.316%	0.819%	1.397%	0.265%	0.058%	5.023%
WNW	0.658%	0.831%	0.923%	0.739%	0.115%	0.023%	3.253%
NW	0.704%	0.785%	0.554%	0.335%	0.058%	0.023%	2.432%
NNW	0.739%	0.923%	0.485%	0.242%	0.012%	0.012%	2.386%
SUM	16.461%	27.466%	18.779%	9.920%	0.616%	0.148%	73.390%
Annual (Jan to Dec, 2014). Total periods = 8,760; Valid periods = 8,664; Calm wind periods = 2,235; Calm winds: 25.514%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	**43.5**	**38.0**	**101**	**360**	**18.0**
Minimum	**-3.0**	**0.0**	**9**	**0**	**0.0**
Average	**17.4**	**1.1**	**72**	**125**	**2.4**

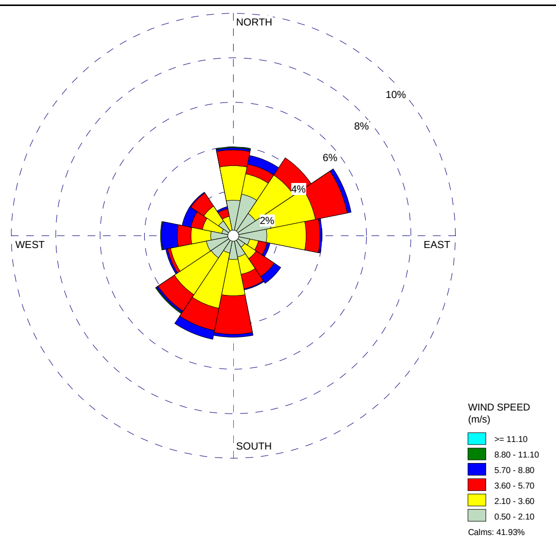
Annual 2014



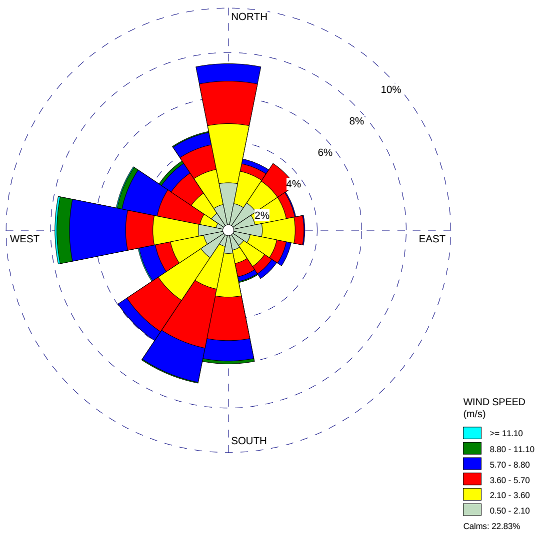
Summer 2014



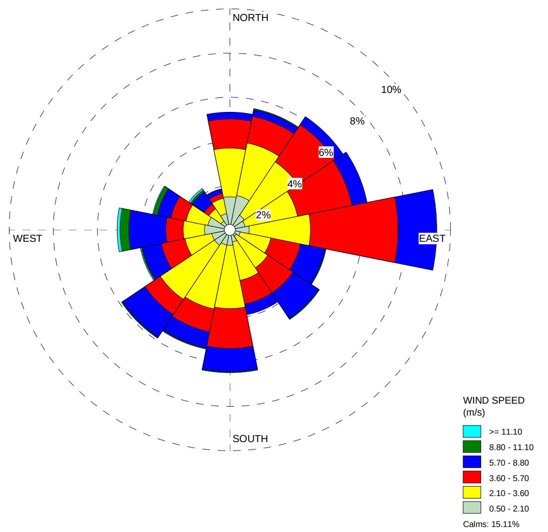
Autumn 2014



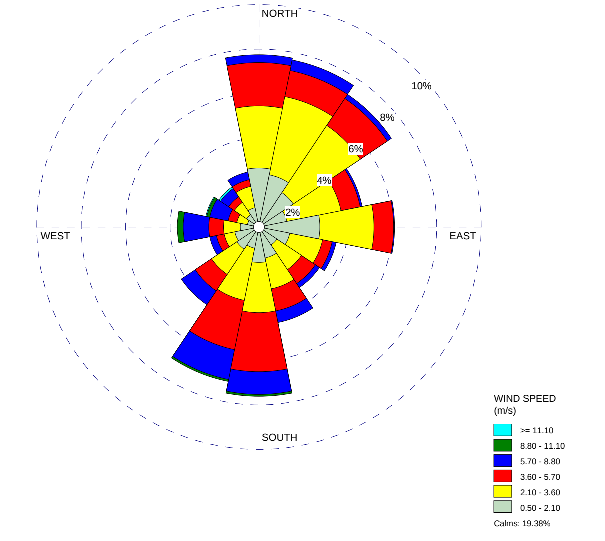
Winter 2014



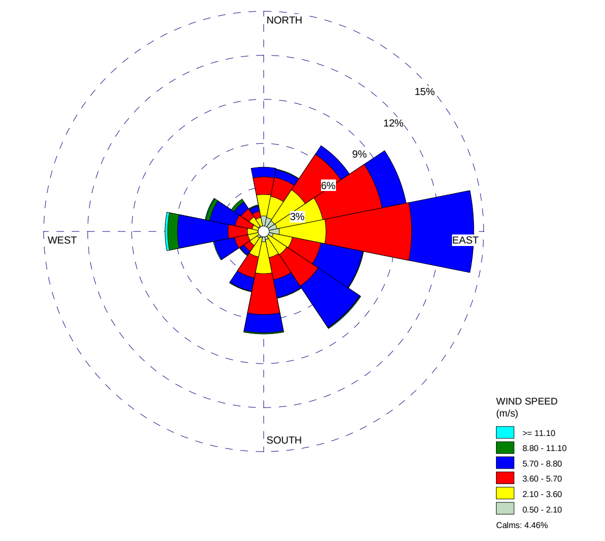
Spring 2014



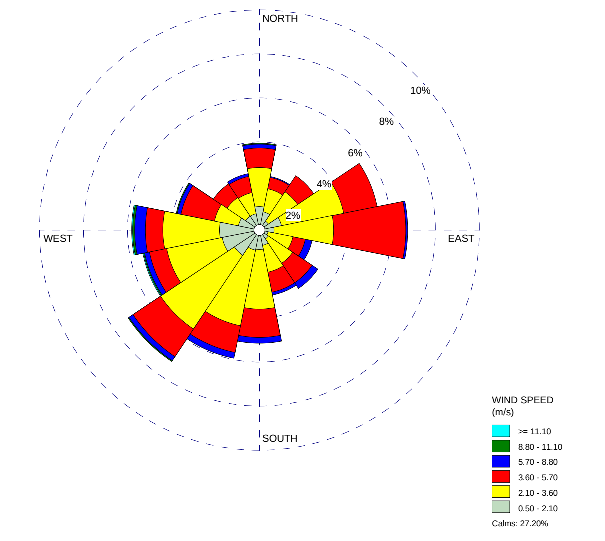
Morning (07h – 12h)



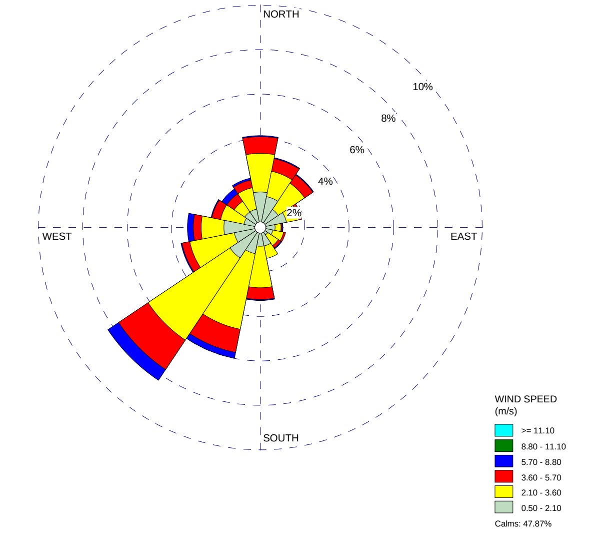
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



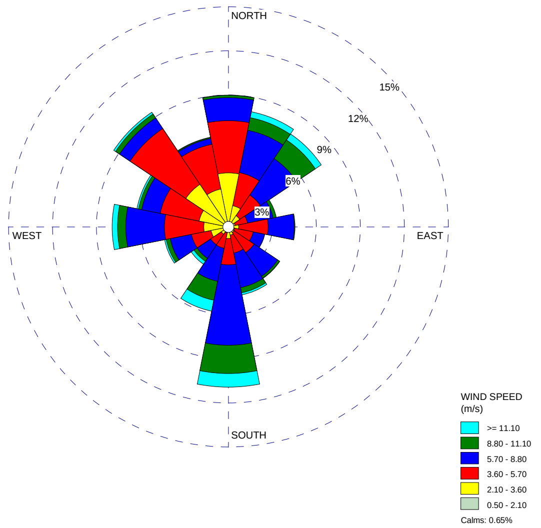
Sydney Airport

Data collected by this station are summarised below.

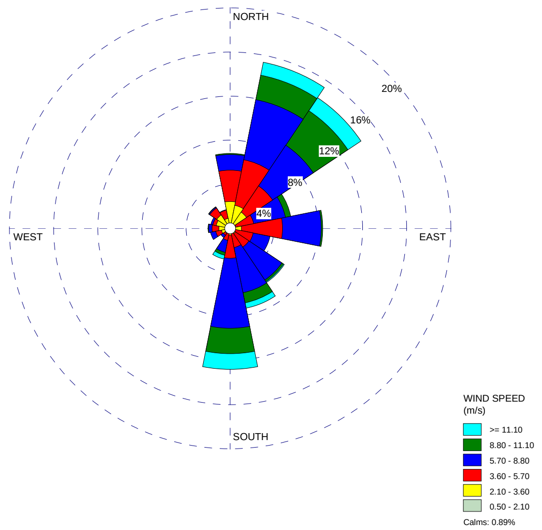
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	0.394%	3.336%	3.602%	1.587%	0.162%	0.012%	8.961%
NNE	0.104%	1.390%	2.328%	2.977%	0.892%	0.405%	7.979%
NE	0.116%	0.822%	1.714%	3.012%	1.552%	0.498%	7.603%
ENE	0.035%	0.429%	0.880%	1.807%	0.220%	0.000%	3.322%
E	0.081%	0.626%	2.039%	1.807%	0.046%	0.000%	4.532%
ESE	0.070%	0.359%	1.309%	0.811%	0.012%	0.000%	2.523%
SE	0.046%	0.417%	1.668%	1.969%	0.151%	0.023%	4.212%
SSE	0.081%	0.498%	1.263%	2.433%	0.359%	0.139%	4.703%
S	0.093%	0.707%	1.819%	5.548%	1.946%	0.938%	10.890%
SSW	0.035%	0.382%	1.089%	2.317%	1.332%	0.765%	5.833%
SW	0.035%	0.568%	0.880%	1.124%	0.255%	0.232%	3.048%
WSW	0.070%	1.158%	1.367%	1.506%	0.278%	0.116%	4.429%
W	0.162%	1.541%	2.711%	2.676%	0.568%	0.371%	7.911%
WNW	0.127%	1.934%	2.734%	1.309%	0.220%	0.116%	6.347%
NW	0.151%	3.382%	4.633%	0.880%	0.324%	0.151%	9.384%
NNW	0.139%	2.525%	3.151%	0.405%	0.070%	0.023%	6.221%
SUM	1.712%	19.783%	32.705%	31.701%	8.265%	3.733%	97.900%
Annual (Jan to Dec 2014) .Total periods = 8,760; Valid periods = 8,633; Calm wind periods = 57; Calm winds: 0.651%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	**37.4**	**101.0**	**100**	**360**	**19.0**
Minimum	**5.0**	**0.0**	**9**	**0**	**0.0**
Average	**18.8**	**1.3**	**63**	**193**	**5.5**

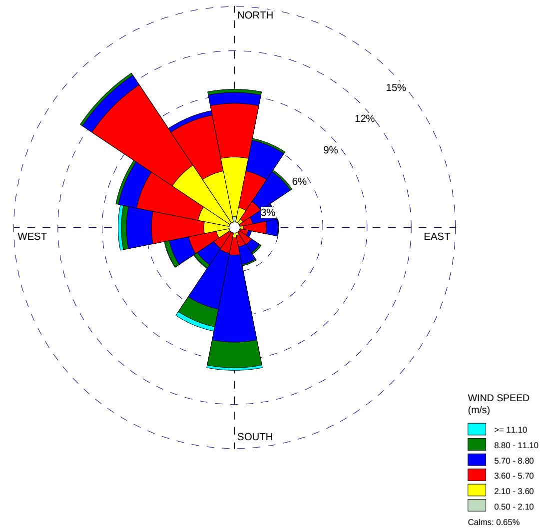
Annual 2014



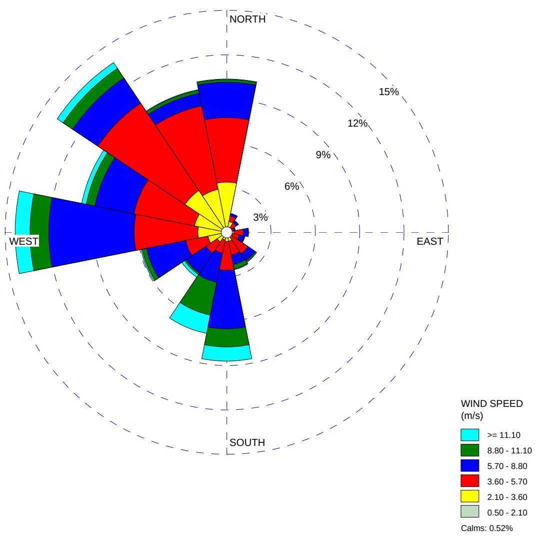
Summer 2014



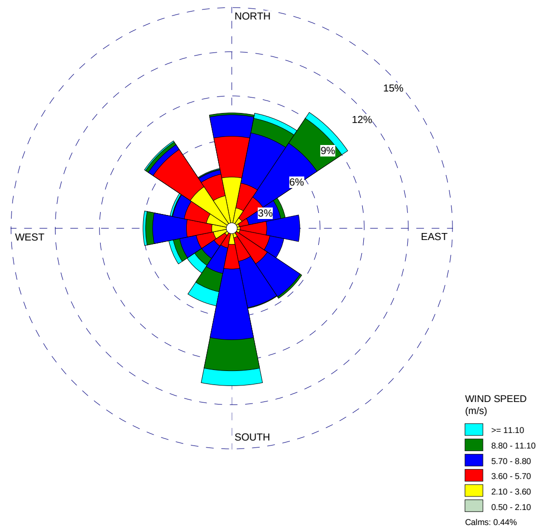
Autumn 2014



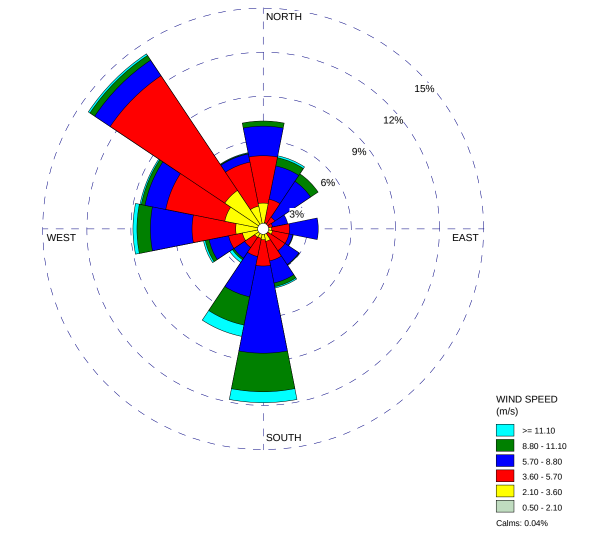
Winter 2014



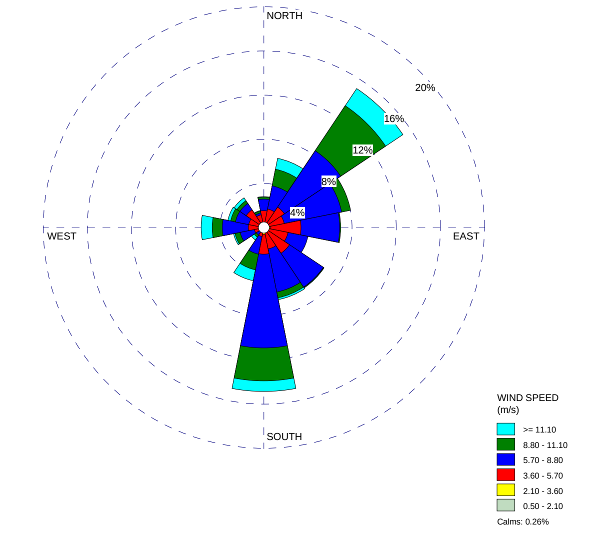
Spring 2014



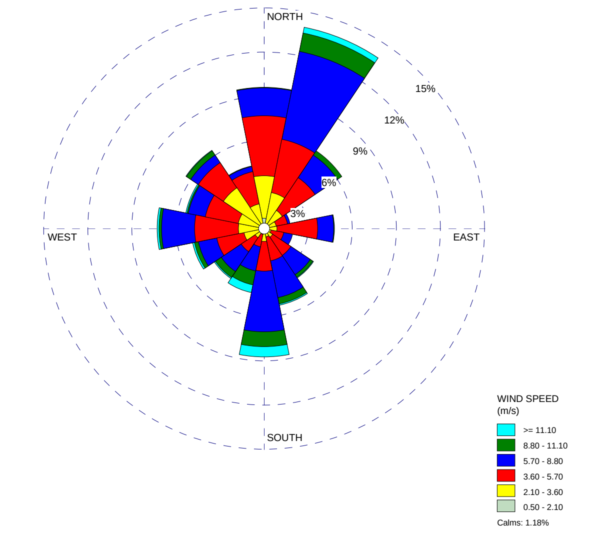
Morning (07h – 12h)



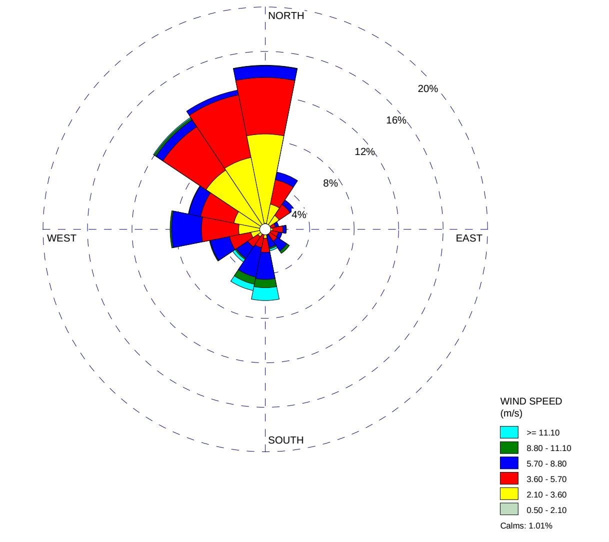
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Appendix C

Dispersion Model Details

Appendix C Dispersion Model Details

Dispersion modelling uses mathematical equations to characterise atmospheric processes, which disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, dispersion models can be used to predict concentrations at selected downwind receiver locations. Air quality models are used to determine compliance with air quality standards. Two well-known and internationally used US EPA guideline models were used in this assessment - CALPUFF and CALROADS. Details of both these models can be found on the US EPA SCRAM (Support Centre for Regulatory Atmospheric Modeling) Bulletin board. The models are addressed in Appendix A of the US EPA's Guideline on Air Quality Models (also published as Appendix W.pdf) of 40 CFR Part 51.

Dispersion models

Two dispersion models are recommended for regulatory assessments in Australia and New Zealand, which are CALPUFF and AERMOD. AERMOD has recently replaced AUSPLUME as the guideline model for all near-field, steady state modelling applications in Victoria. CALPUFF is recommended for use for all modelling applications where the steady state assumption does not apply; this includes complex terrain and coastal environments. A major difference between AERMOD and CALPUFF is in the models' treatment of meteorology. AERMOD is a 2-dimensional model where the effects of one single surface station and one single upper air station are assumed to be spatially uniform across the entire modelling region in its meteorological processor. In contrast, CALMET (CALPUFF's meteorological module) is a 3-dimensional model and is able to use the output of numerical prognostic meteorological models as well as multiple observation sites to assist in the development of three-dimensional wind fields.

Overview of the CALPUFF suite of models

The CALPUFF modelling system provides a non-steady state modelling approach, which evaluates the effects of spatial changes in the meteorological and surface characteristics. It offers the ability to treat stagnation, multiple-hour pollutant build-up, recirculation and causality effects, which are beyond the capabilities of steady-state models. The CALPUFF modelling system was adopted by the U.S. EPA as a guideline model for long range transport applications and, on a case-by-case basis, for near-field applications involving complex flows (Federal Register, April 15, 2003, pp 18,440-18,482). CALPUFF is also recommended by both the Federal Land Managers Air Quality Workgroup (FLAG, 2000, 2008) and the Interagency Workgroup on Air Quality Modelling (IWAQM, 1998). It was adopted for world-wide use by the United Nations International Atomic Energy Agency (IAEA). CALPUFF is widely used in many countries (over 100 countries) throughout the world, and has been incorporated as a regulatory model in several countries.

The CALPUFF modelling system includes three main components - CALMET, CALPUFF and CALPOST - and a large set of pre-processing programs designed to interface the model to standard, routinely-available meteorological and geophysical datasets. In simple terms, CALMET is a meteorological model, which develops hourly wind and temperature fields on a three-dimensional gridded modelling domain. CALPUFF is a transport and dispersion model, which advects 'puffs' of material emitted from modelled source, simulating dispersion and transformation processes along the way. In doing so, it uses the fields generated by CALMET. The primary output files from CALPUFF contain either hourly concentrations or hourly deposition fluxes evaluated at selected receiver locations. CALPOST is used to process these files, producing summaries of the results of the simulation.

CALMET overview

CALMET is a diagnostic meteorological model, which produces three-dimensional wind fields based on parameterised treatments of terrain effects such as slope flows and terrain blocking effects. Meteorological observations are used to determine the wind field in areas of the domain within which the observations are representative. Fine scale terrain effects are determined by the diagnostic wind module in CALMET.

The CALMET meteorological model consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers (Scire et al., 2000a). When using large domains, the user has the option to adjust input winds to a Lambert Conformal Projection coordinate system to account for the Earth's curvature. The diagnostic wind field module uses a two-step approach to the computation of the wind fields (Douglas and Kessler, 1988). In the first step, an initial-guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects to produce a Step 1 wind field. The second step consists of an objective analysis procedure to introduce observational data into the Step 1 wind field in order to produce a final wind field.

An option is provided to allow gridded prognostic wind fields to be used by CALMET, which may better represent regional flows and certain aspects of sea breeze circulations and slope/valley circulations. The prognostic data (as a 3D.DAT file) can be introduced into CALMET in three different ways;

- As a replacement for the initial guess wind field
- As a replacement for the Step 1 field
- As observations in the objective analysis procedure

The techniques used in the CALMET model are briefly described below.

Step 1 wind field

Kinematic effects on terrain: CALMET uses the approach of Liu and Yocke (1980) to evaluate kinematic terrain effects. The domain-scale winds are used to compute a terrain-forced vertical velocity, subject to an exponential stability-dependent decay function. The kinematic effects of terrain on the horizontal wind components are evaluated by applying a divergence-minimisation scheme to the initial guess wind field. The divergence minimisation scheme is applied iteratively until the three dimensional divergence is less than a threshold value.

Slope flows. Slope flows are computed based on the shooting flow parameterisation of Mahrt (1982). Shooting flows are buoyancy-driven flows, balanced by advection of weaker momentum, surface drag and entrainment at the top of the slope flow layer. The slope flow is parameterised in terms of the terrain slope, distance to the crest and local sensible heat flux. The thickness of the slope flow layer varies with the elevation drop from the crest.

Blocking effects. The thermodynamic blocking effects of terrain on the wind flow are parameterised in terms of the local Froude number (Allwine and Whiteman 1985). If the Froude number at a particular grid point is less than a critical value and the wind has an uphill component, the wind direction is adjusted to be tangential to the terrain.

Step 2 wind field

The wind field resulting from the adjustments of the initial guess wind described above is the Step 1 wind field. The second step of the procedure involves the introduction of observational data into the Step 1 wind field through an objective analysis procedure. An inverse-distance squared interpolation scheme is used, which weighs observational data heavily in the vicinity of the observational station, while the Step 1 wind field dominates the interpolated wind field in regions with no observational data. The resulting wind field is subject to smoothing, an optional adjustment of vertical velocities based on the O'Brien (1970) method, and divergence minimisation to produce final Step 2 wind fields.

Overview of CALPUFF

CALPUFF is a non-steady-state puff dispersion model. It accounts for spatial changes in the meteorological fields, variability in surface conditions such as (elevation, surface roughness, vegetation type, etc.), chemical transformation, wet removal due to rain and snow, dry deposition and terrain influences on plume interaction with the surface. CALPUFF can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF contains algorithms for near-source effects, such as building downwash, transitional plume rise, partial plume penetration, sub-grid scale terrain interactions, as well as longer range effects, such as pollutant removal (wet scavenging and dry deposition), chemical transformation, vertical wind shear, overwater transport and coastal interaction effects. It can accommodate arbitrarily-varying point source and gridded area source emissions. The major features of CALPUFF model are detailed below (after Scire et al., 2002).

Major features of the CALPUFF model

- Source types
  - Point sources (constant or variable emissions)
  - Line sources (constant or variable emissions)
  - Area sources (constant or variable emissions)
  - Volume sources (constant or variable emissions)
- Non-steady-state emissions and meteorological conditions
  - Gridded 3D fields of meteorological variables

  - Spatially variable 3D fields of mixing height, friction velocity, convective velocity scale, Monin-Obukhov length, precipitation rate
  - Vertically and horizontally-varying turbulence and dispersion rates
  - Time-dependent source and emissions data
- Efficient sampling functions
  - Integrated puff formulation
  - Elongated puff (slug) formulation
- Dispersion coefficient options
  - Direct measures of sigma v and sigma w
  - Estimated values of sigma v and sigma w based on similarity theory
  - PG dispersion coefficients (rural areas)
  - McElroy Pooler dispersion coefficients (urban areas)
  - CTDM dispersion coefficients (neutral/stable)
- Vertical wind shear
  - Puff Splitting
  - Differential advection and dispersion
- Plume Rise
  - Partial penetration
  - Buoyant and momentum rise
  - Stack tip downwash effects
  - Vertical wind shear
  - Building downwash effects
- Building downwash
  - Huber-Snyder method
  - PRIME downwash
  - Schulman Scire method
- Dry deposition
  - Gases and particulate matter
  - Three options
    - Full treatment of space and time variations of deposition with a resistance model
    - User-specified diurnal cycles for each pollutant
    - No dry deposition
- Overwater and coastal interaction effects
  - Overwater boundary layer parameters
  - Abrupt change in meteorological conditions, plume dispersion at coastal boundary
  - Plume fumigation
  - Option to introduce sub grid scale TIBLs into coastal grid cells
- Chemical transformation options
  - Pseudo-first-order chemical mechanism for SO2, SO4, NOx HNO3 and NO3 (MESOPUFF II method)

- User specified diurnal cycles of transformation rates
- No chemical conversion
- Wet Removal
- Scavenging coefficient approach
- Removal rate a function of precipitation intensity and precipitation type

Overview of CAL3QHCR

CAL3QHCR is a CALINE3-based model with queuing and hot spot calculations and with a traffic model to calculate delays and queues that occur at signalised intersections. The CALINE3 model on which it is based is a steady-state Gaussian dispersion model designed to determine air pollution concentrations at receiver locations downwind of highways located in relatively uncomplicated terrain.

The CAL3QHC model can predict carbon monoxide and other inert pollutant concentrations from motor vehicles at roadway intersections. The model includes the CALINE-3 line source dispersion model and a traffic algorithm for estimating vehicular queue lengths at signalised intersections. CALINE-3 was designed to predict air pollutant concentrations near highways and arterial streets due to emissions from motor vehicles operating under free flow conditions. CALINE-3, however, does not permit the direct estimation of the contribution of emissions from idling vehicles. CAL3QHC was developed to enhance CALINE-3 by incorporating methods for estimating queue lengths and the contributions of emissions from idling vehicles. The model permits the estimation of total air pollution concentrations from both moving and idling vehicles. CAL3QHC requires details on roadway geometries, receiver locations, meteorological conditions and vehicular emission rates. In addition, the model requires other parameters such as signal timing data and information describing the configuration of the intersection being modelled.

The CAL3QHCR model is an enhanced version of CAL3QHC, which can process up to a year of hourly meteorological data. Vehicular emissions, traffic volume, and signalisation data can be specified for each hour of a week. Further, the latest version also accommodates up to 5,000 receivers and 5,000 sources (previously 60 receivers and 120 sources). In order to accommodate the large number of receivers associated with this assessment, the CAL3QHCR model was considered to be the most appropriate choice for modelling the traffic movements on roadways external to the tunnels. The line source model predicts pollutant concentrations based on the Gaussian diffusion equation. CAL3QHCR was used to predict concentrations of carbon monoxide, nitrogen dioxide and particulate matter in this assessment.

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Appendix D

Sensitive Receivers

Appendix D Sensitive Receivers

The receiver locations included in the modelling are provided below.

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
1	313936.0	6273136.2	100.4	**141**	323349.5	6270489.2	189.5	**281**	322651.0	6269311.7	83.0
2	322768.4	6269869.6	158.1	**142**	323340.6	6270473.5	190.0	**282**	322638.3	6269278.9	80.3
3	322749.0	6269856.1	159.5	**143**	323324.4	6270481.2	188.0	**283**	322623.9	6269270.4	86.0
4	322732.8	6269844.9	159.5	**144**	323294.0	6270496.8	185.4	**284**	322931.0	6269266.3	186.2
5	322716.3	6269836.4	160.3	**145**	323252.5	6270503.8	183.4	**285**	322927.0	6269221.0	192.7
6	322697.3	6269822.1	159.1	**146**	323233.1	6270506.6	184.1	**286**	322949.6	6269240.5	192.7
7	322664.7	6269804.6	153.8	**147**	323211.8	6270512.4	184.2	**287**	322968.3	6269268.6	188.6
8	322616.3	6269828.4	150.9	**148**	323275.7	6270499.5	184.3	**288**	323023.0	6269259.5	196.7
9	322684.2	6269838.4	163.8	**149**	323329.8	6270522.5	186.6	**289**	323010.7	6269196.4	199.4
10	322657.6	6269841.5	162.8	**150**	323302.0	6270526.5	184.4	**290**	322999.6	6269178.9	199.3
11	322624.2	6269866.1	160.5	**151**	323280.9	6270530.0	182.8	**291**	323059.9	6269249.2	199.4
12	322619.5	6269889.6	162.4	**152**	323261.0	6270533.1	181.8	**292**	323086.9	6269250.0	199.1
13	322802.8	6269949.6	154.4	**153**	323240.2	6270535.8	181.5	**293**	323102.0	6269248.0	198.9
14	322774.3	6269995.7	171.2	**154**	323224.8	6270538.4	181.5	**294**	323143.3	6269241.7	196.4
15	322794.1	6270011.3	166.3	**155**	323214.3	6270539.7	181.7	**295**	323173.8	6269236.9	194.1
16	322823.7	6269964.4	141.4	**156**	323198.5	6270570.8	179.9	**296**	323200.2	6269233.1	192.6
17	322821.6	6270012.3	157.6	**157**	323196.9	6270542.6	182.0	**297**	323124.2	6269199.6	196.9
18	322841.2	6270033.5	160.7	**158**	323176.3	6270545.1	182.6	**298**	323084.9	6269200.4	199.2
19	322865.0	6270038.8	155.1	**159**	323185.0	6270562.6	181.0	**299**	323067.9	6269203.2	199.5
20	322884.9	6270047.0	154.1	**160**	323170.7	6270564.7	180.9	**300**	323151.6	6269189.3	194.1
21	322628.6	6269911.3	170.6	**161**	323149.3	6270549.6	182.7	**301**	323113.0	6269190.7	197.7
22	322639.3	6269934.7	176.5	**162**	323138.4	6270550.9	182.4	**302**	323173.8	6269188.2	192.7
23	322698.9	6269933.1	178.5	**163**	323142.3	6270580.6	180.4	**303**	323197.9	6269181.0	190.6
24	322723.1	6269907.7	173.3	**164**	323121.4	6270553.7	182.5	**304**	323223.1	6269231.4	191.4
25	322700.0	6269891.4	171.6	**165**	323122.7	6270580.3	180.8	**305**	323246.2	6269227.3	188.5
26	322687.5	6269904.6	175.9	**166**	323104.1	6270584.7	180.8	**306**	323244.7	6269167.0	187.2
27	322748.9	6269910.1	170.7	**167**	323090.6	6270558.1	182.8	**307**	323261.2	6269163.8	187.5
28	322744.5	6269947.8	176.4	**168**	323171.7	6270466.5	188.2	**308**	323278.3	6269215.9	186.1
29	322692.1	6269951.7	179.7	**169**	323191.2	6270492.7	185.6	**309**	323291.2	6269221.4	185.1
30	322725.4	6269943.8	177.6	**170**	323198.8	6270473.4	187.0	**310**	323304.4	6269218.9	184.5
31	322731.4	6269972.0	178.4	**171**	323216.4	6270460.6	187.7	**311**	323318.8	6269217.6	185.0
32	322757.2	6269968.0	172.3	**172**	323204.5	6270435.6	189.3	**312**	323335.1	6269215.3	185.5
33	322774.7	6269910.1	163.0	**173**	323233.6	6270432.7	189.4	**313**	323350.3	6269212.7	185.2
34	322609.2	6269974.0	167.0	**174**	323249.3	6270418.2	190.5	**314**	323366.4	6269210.6	185.2

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
35	322660.0	6269989.8	180.2	**175**	323280.9	6270410.8	191.4	**315**	323381.6	6269208.7	183.9
36	322650.8	6270010.5	180.2	**176**	323313.6	6270406.5	192.8	**316**	323396.9	6269205.5	182.4
37	322639.3	6270026.8	179.1	**177**	323238.1	6270457.7	187.1	**317**	323411.9	6269204.3	181.1
38	322626.6	6270042.6	176.8	**178**	323261.6	6270454.0	187.2	**318**	323434.1	6269200.2	180.3
39	322615.1	6270057.7	175.4	**179**	323286.2	6270450.8	188.2	**319**	323477.9	6269193.7	180.1
40	322605.2	6270075.2	168.8	**180**	323313.7	6270446.8	189.7	**320**	323513.5	6269188.8	179.7
41	322575.0	6270096.2	162.2	**181**	323336.8	6270443.4	191.1	**321**	323544.8	6269184.8	180.7
42	322603.2	6270114.9	163.2	**182**	323334.3	6270428.0	191.8	**322**	323697.6	6269321.7	183.6
43	322631.8	6270080.3	175.3	**183**	323269.0	6270239.1	197.2	**323**	323693.7	6269291.6	183.6
44	322651.6	6270037.1	179.7	**184**	323086.4	6270282.2	183.9	**324**	323697.9	6269276.2	183.6
45	322682.6	6270004.9	181.3	**185**	323213.8	6270087.3	168.2	**325**	323704.0	6269279.8	183.5
46	322737.7	6270042.6	177.8	**186**	323220.1	6270132.5	180.6	**326**	323717.4	6269290.2	182.8
47	322760.8	6270058.9	175.8	**187**	323243.0	6270128.4	183.1	**327**	323560.7	6269670.4	149.6
48	322781.8	6270073.6	173.9	**188**	323266.2	6270126.2	185.3	**328**	323637.8	6269676.9	175.5
49	322727.8	6270092.6	171.1	**189**	323302.3	6270104.0	172.4	**329**	323733.6	6269698.3	186.0
50	322718.3	6270108.9	167.2	**190**	323325.3	6270132.1	178.6	**330**	323732.7	6269681.0	186.0
51	322715.9	6270082.7	175.2	**191**	323300.3	6270046.8	153.0	**331**	323727.0	6269663.6	186.1
52	322682.6	6270113.3	170.5	**192**	323337.1	6270046.6	148.2	**332**	323724.1	6269646.9	186.1
53	322706.8	6270124.0	164.1	**193**	323401.6	6269982.5	116.0	**333**	323733.1	6269611.5	185.6
54	322690.1	6270056.5	179.5	**194**	323460.4	6269964.6	135.2	**334**	323731.2	6269596.1	185.6
55	322811.1	6270091.4	172.2	**195**	323372.9	6270218.0	189.9	**335**	323739.2	6269718.0	186.9
56	322823.6	6270096.8	172.4	**196**	323434.8	6270199.4	171.9	**336**	323753.5	6269639.3	184.0
57	322809.0	6270129.5	162.4	**197**	323457.4	6270189.0	158.7	**337**	323747.3	6269693.5	185.4
58	322844.7	6270105.1	172.5	**198**	323589.7	6270188.6	179.8	**338**	323832.3	6269695.2	181.6
59	322697.3	6270012.9	181.2	**199**	323590.5	6270171.2	179.5	**339**	323814.8	6269611.7	181.1
60	322713.5	6270024.4	180.4	**200**	323606.1	6270137.3	185.9	**340**	323805.7	6269567.9	181.8
61	322856.4	6270168.0	163.1	**201**	323601.1	6270102.1	183.0	**341**	323793.9	6269536.3	182.3
62	322869.9	6270114.8	172.9	**202**	323592.1	6270025.9	177.4	**342**	323715.1	6269548.8	186.7
63	322889.8	6270121.5	173.1	**203**	323615.1	6270179.7	187.9	**343**	323724.5	6269526.9	186.2
64	322915.2	6270127.9	173.5	**204**	323599.5	6270049.0	182.8	**344**	323721.3	6269510.1	184.8
65	322938.9	6270134.0	174.3	**205**	323579.1	6269984.4	172.0	**345**	323756.7	6269526.4	184.4
66	322935.9	6270176.6	165.0	**206**	323571.1	6270003.7	171.7	**346**	323666.4	6269497.8	188.6
67	322960.9	6270058.9	152.8	**207**	323571.5	6269949.0	166.3	**347**	323794.4	6269490.2	181.3
68	322878.9	6270161.1	165.6	**208**	323432.2	6270028.4	128.0	**348**	323789.6	6269446.5	181.3
69	322917.3	6270063.0	161.3	**209**	323326.3	6269985.2	131.0	**349**	323778.1	6269406.4	181.5
70	323023.7	6270084.1	161.7	**210**	323613.6	6269852.2	170.8	**350**	323753.9	6269346.9	181.8
71	322987.0	6270151.0	175.3	**211**	323629.5	6269862.5	172.9	**351**	323755.4	6269327.4	182.2

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
72	323019.4	6270157.7	177.0	**212**	323642.6	6269875.6	183.0	**352**	323754.7	6269292.5	181.8
73	323049.5	6270179.1	178.8	**213**	323693.8	6269886.3	190.8	**353**	323756.7	6269271.9	182.3
74	323071.0	6270194.9	181.9	**214**	323689.4	6269863.3	188.7	**354**	323655.1	6269903.2	188.1
75	323086.1	6270144.6	178.8	**215**	323686.2	6269842.3	187.3	**355**	323697.4	6269931.8	192.7
76	323103.5	6270152.0	179.1	**216**	323681.9	6269818.9	184.8	**356**	323660.9	6269937.3	190.0
77	323138.2	6270130.5	166.6	**217**	323667.2	6269787.9	182.4	**357**	323631.5	6269959.3	179.2
78	323157.8	6270152.8	174.2	**218**	323653.9	6269766.6	180.8	**358**	323633.9	6269973.5	180.9
79	323137.9	6270186.5	181.4	**219**	323617.2	6269714.1	169.1	**359**	323639.8	6270011.3	188.5
80	323099.8	6270220.6	184.9	**220**	323650.1	6269687.5	180.9	**360**	323637.0	6269994.9	185.7
81	323182.6	6270173.8	183.6	**221**	323643.0	6269613.7	181.3	**361**	323756.3	6269807.3	187.4
82	323205.7	6270172.3	184.8	**222**	323637.8	6269587.1	182.5	**362**	323760.7	6269854.4	188.4
83	323196.8	6270117.7	171.1	**223**	323566.4	6269501.0	183.2	**363**	323695.3	6269945.3	193.2
84	323017.9	6270260.6	162.9	**224**	323648.8	6269435.6	188.5	**364**	323693.9	6269956.1	193.4
85	323026.4	6270279.2	164.2	**225**	323646.2	6269419.3	187.7	**365**	323688.8	6269974.0	194.0
86	323026.2	6270299.1	165.8	**226**	323644.9	6269382.7	186.6	**366**	323686.3	6269988.6	193.9
87	323030.6	6270317.3	171.3	**227**	323646.9	6269347.4	186.3	**367**	323706.4	6269985.5	194.4
88	323037.6	6270335.9	174.0	**228**	323647.7	6269312.8	185.1	**368**	323740.8	6269740.8	186.8
89	323035.7	6270357.1	173.9	**229**	323553.3	6269251.7	177.2	**369**	323734.5	6269760.7	186.6
90	323035.0	6270374.9	174.3	**230**	323537.8	6269253.7	174.4	**370**	323767.1	6269750.6	186.9
91	323003.5	6270378.0	168.4	**231**	323467.9	6269264.8	166.6	**371**	323840.0	6269747.9	184.5
92	323064.0	6270302.5	178.4	**232**	323437.0	6269269.6	165.4	**372**	323806.4	6269799.0	186.1
93	323124.6	6270352.6	191.1	**233**	323399.3	6269251.3	174.6	**373**	323842.1	6269837.7	186.8
94	323121.8	6270313.5	189.7	**234**	323375.5	6269254.1	173.8	**374**	323841.1	6269796.0	186.0
95	323104.6	6270266.6	186.3	**235**	323334.6	6269276.8	171.0	**375**	322753.6	6269254.2	117.0
96	323165.4	6270259.1	191.6	**236**	323314.4	6269285.9	170.3	**376**	322698.4	6269260.2	89.4
97	323402.6	6270709.9	189.9	**237**	323292.3	6269289.6	172.6	**377**	322692.0	6269241.1	91.3
98	323359.2	6270698.2	185.0	**238**	323273.1	6269292.2	175.0	**378**	322670.6	6269244.8	87.9
99	323342.8	6270709.2	184.4	**239**	323225.8	6269300.9	176.7	**379**	322655.9	6269235.8	91.3
100	323328.3	6270711.6	183.2	**240**	323244.5	6269279.5	181.5	**380**	322621.1	6269241.4	92.5
101	323383.4	6270694.8	187.5	**241**	323219.9	6269283.5	180.4	**381**	322625.2	6269220.2	94.8
102	323375.7	6270679.3	187.5	**242**	323202.0	6269303.3	176.8	**382**	323281.3	6269169.1	188.3
103	323373.7	6270664.9	188.7	**243**	323183.8	6269307.3	176.5	**383**	323295.4	6269167.9	188.6
104	323348.0	6270668.3	187.0	**244**	323163.5	6269310.1	178.0	**384**	323308.3	6269166.3	189.3
105	323333.9	6270676.9	184.9	**245**	323142.5	6269313.2	180.1	**385**	323316.5	6269165.0	189.3
106	323306.8	6270681.1	182.6	**246**	323121.5	6269316.4	184.3	**386**	323323.5	6269163.6	189.4
107	323293.4	6270674.1	181.3	**247**	323288.2	6269266.8	177.1	**387**	323331.4	6269162.7	189.4
108	323345.3	6270653.6	187.2	**248**	323105.6	6269318.0	189.7	**388**	323342.7	6269160.7	189.2

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
109	323381.5	6270648.1	190.1	**249**	323091.7	6269320.4	191.1	**389**	323373.1	6269156.0	188.2
110	323372.7	6270634.6	190.4	**250**	323075.8	6269323.6	193.2	**390**	323396.9	6269153.1	186.9
111	323354.9	6270616.1	190.9	**251**	323060.7	6269325.5	193.2	**391**	323424.0	6269149.7	185.2
112	323382.5	6270711.3	188.0	**252**	323047.3	6269327.1	193.2	**392**	323361.7	6269160.3	188.3
113	323321.8	6270678.8	183.8	**253**	323008.4	6269333.5	184.4	**393**	323465.1	6269142.2	182.3
114	323326.5	6270591.2	186.9	**254**	322831.0	6269312.2	156.1	**394**	323475.8	6269140.3	182.3
115	323312.9	6270603.4	185.3	**255**	322744.4	6269372.5	98.2	**395**	323493.8	6269139.7	182.1
116	323301.1	6270606.4	183.3	**256**	322744.8	6269286.0	109.4	**396**	323514.2	6269136.1	182.1
117	323293.4	6270608.0	182.9	**257**	322813.9	6269253.2	155.8	**397**	323543.2	6269132.7	182.0
118	323281.1	6270609.6	181.6	**258**	322887.7	6269275.6	174.5	**398**	323563.7	6269129.5	182.2
119	323265.9	6270611.7	180.3	**259**	322838.1	6269253.0	163.8	**399**	323622.5	6269120.8	185.6
120	323358.4	6270599.3	191.4	**260**	322710.3	6269377.2	90.2	**400**	323633.3	6269119.4	186.2
121	323369.9	6270571.9	191.5	**261**	322637.7	6269388.0	82.1	**401**	323617.2	6269178.9	184.1
122	323279.3	6270685.2	180.1	**262**	322611.1	6269369.9	80.1	**402**	323614.7	6269153.6	185.2
123	323252.5	6270613.8	179.2	**263**	322561.3	6269376.6	73.4	**403**	323640.7	6269133.0	187.1
124	323236.5	6270616.3	178.4	**264**	322563.6	6269346.4	78.6	**404**	323633.5	6269153.3	186.5
125	323222.6	6270618.3	177.8	**265**	322547.1	6269341.7	79.4	**405**	323580.8	6269223.6	180.5
126	323208.2	6270620.6	177.3	**266**	322533.1	6269332.6	80.9	**406**	323641.9	6269236.9	184.6
127	323169.9	6270626.4	176.9	**267**	322517.5	6269325.8	80.0	**407**	323704.1	6269227.5	184.2
128	323146.8	6270629.6	176.9	**268**	322500.1	6269322.0	81.4	**408**	323642.6	6269275.5	184.7
129	323153.1	6270663.5	174.5	**269**	322489.1	6269330.5	78.4	**409**	323693.1	6269310.0	183.6
130	323129.6	6270632.3	177.0	**270**	322464.8	6269333.7	76.8	**410**	323775.3	6269933.5	190.3
131	323112.0	6270634.8	177.0	**271**	322444.0	6269324.1	76.8	**411**	323778.5	6269954.1	190.9
132	323119.3	6270669.9	174.5	**272**	322406.1	6269299.6	79.7	**412**	323768.2	6270001.2	191.8
133	323169.4	6270659.2	175.3	**273**	322656.1	6269364.6	83.8	**413**	323644.9	6270031.6	190.6
134	323160.9	6270702.3	172.8	**274**	322639.0	6269354.6	82.6	**414**	323646.2	6270047.2	190.8
135	323142.1	6270705.5	171.6	**275**	322623.5	6269345.3	81.4	**415**	323688.8	6270024.5	194.9
136	323206.2	6270695.7	175.7	**276**	322601.9	6269330.9	80.2	**416**	323692.3	6270039.6	195.2
137	323284.5	6270720.2	179.6	**277**	322580.8	6269319.1	82.2	**417**	323376.1	6270132.6	170.4
138	323382.9	6270542.3	192.1	**278**	322571.7	6269296.0	85.4	**418**	323558.9	6270180.7	173.7
139	323349.0	6270519.7	188.4	**279**	322680.0	6269329.4	89.8	**419**	322695.2	6270135.4	163.6
140	323371.5	6270500.9	191.3	**280**	322692.9	6269307.2	92.9	**420**	322840.0	6270164.6	161.2

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Appendix E

Emission Calculations

Appendix E Emission Calculations

The following subsections provide a detailed description of all emission calculations and assumptions used in the dispersion modelling. These values have been based on the operation of Hornsby Quarry filling at its peak operational capacity to ensure that prediction of maximum impacts. Site operations have been assumed to under maximum capacity for all hours to ensure that worst case operating conditions coincided with worst case meteorological conditions. As such predicted annual average concentrations for all pollutants are likely to be overestimated.

All emission sources were assigned a base level height using LPI LiDAR 2011 data with a grid resolution of 1m, with the exception to sources within the void. The modelling has been undertaken for the year 2017 were the pit is presumed to be largely filled as such a pit height of 100m above MSL was assigned, equating to approximately 25-30m below the surrounding flats.

Onsite Haul Truck Combustion Emissions

Onsite haul truck combustion emissions were calculated using PIARC emission rates for heavy vehicles. It was assumed that a total of 6 haul trucks would be present onsite at any one time.

Combustion Emissions from Mobile Sources

Combustion emissions for mobile plant equipment were calculated using the following equation, specified in the NPI Emissions Estimation Technique (EET) Manual for Combustion Engines (DEWHA, 2009):

$$E_i = P \times OpHrs \times LF \times EF_i$$

Where:

E_i	=	Emission rate (kg/y)
P	=	Power output (kW)
OpHrs	=	Operational hours (h/y)
LF	=	Load factor
EF_i	=	Emissions factor (kg/kWh)

Emission factors for mobile plant equipment were classified in accordance with Table 5 under Section 5.4 of the NPI EET Manual for Mining (DSEWPC, 2012). All mobile plant equipment was assumed to be operating at 80 percent utilisation rate between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays with the exception to haul trucks which would be operational for 100 percent of the time during the confined work hours..

Combustion Emissions for Stationary Combustion Engines

Combustion emissions for onsite generators were calculated using the equation for stationary combustion engines specified in the NPI Emissions EET Manual for Combustion Engines (DEWHA, 2009):

$$E_i = P \times OpHrs \times EF_i$$

Where:

E_i	=	Emission rate (kg/y)
P	=	Power output (kW)
OpHrs	=	Operational hours (h/y)
EF_i	=	Emissions factor (kg/kWh)

Emission factors from US EPA Tier 3 non-road diesel engine emission standards (37-75 kW and 225-450 kW) (Environ 2014) were used for carbon monoxide, oxides of nitrogen, particulates and volatile organic compounds. Emission factors from Table 49 (stationary diesel engines < 450kW) of the EET manual (DEWHA, 2009) were used for polycyclic aromatic hydrocarbons. Two onsite generators of 40 kW (50 kVA) were assumed to be used for site compounds, amenities. The generator used for the conveyor was assumed to have a power output of 400 kW (500 kVA). An additional 40 kW generator to be used for pumping water out of the void was excluded for the assessment as sight preparation works would be outside the timeframe of maximum haulage volumes conducted in 2017.

Generators for site compounds, amenities and the conveyor would be operational between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays. Generators for onsite amenities and site compound would 100 percent operational, while the generator for the conveyor would be operational for 80 percent of the time.

Dust Emissions from Excavators and Front-End Loaders.

Dust emissions rates for excavators and front-end loaders moving spoil were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y)
A	=	Activity rate (t/h)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

The emission factors for excavators and front-end loaders transfer points were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
k_i	=	Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U	=	Mean wind speed (m/s)
M	=	Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[5], provided by Lend Lease, was used.

The excavators and front-end loaders were assumed to be operating at 80 percent utilisation between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays. An activity rate of 720t/h (at 80 percent utilisation) was applied to all excavators and front-end loaders with the exception to those loading to arterial dump trucks in the pit which had an activity rate of equates to 216t/h at 80 percent utilisation.

A control efficiency of 30 percent was applied to all sources by reducing the drop height from 3m to 1.5m (Katestone Environmental 2011)

Dust Emissions from Bulldozers

Dust emissions from bulldozers shaping spoil stockpiles were calculated using the following equation:

$$E_i = OP \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y/vehicle)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

Bulldozers would be operating at 80 percent utilisation between 7 am and 6 pm on weekdays and 8 am to 1 pm on Saturdays.

[5] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

Emission factors were based on the following US EPA AP-42 equation (Chapter 11.9)

$$EF_{TSP} = 2.6 \times {s^{1.2}}/{M^{1.3}}$$

$$EF_{PM10} = 0.45 \times {s^{1.5}}/{M^{1.4}} \times 0.75$$

$$EF_{TSP} = 2.6 \times {s^{1.2}}/{M^{1.3}} \times 0.105$$

Where:

EF_{TSP}/EF_{PM10}	=	Emission rate (kg/h/vehicle)
s	=	Silt content by weight (%)
M	=	Moisture content by weight (%)

Moisture and silt contents of 10 % and 12 % respectively (provided by Lend Lease) were used to calculate the emission factors for particulates.

A control efficiency of 50% has been applied to bulldozer emissions; ensuring that all material handled by bulldozers is kept moist with the use of water sprays (Katestone Environmental 2011).

Dust Emissions from Trucks Dumping Spoil

Dust emissions from haul trucks dumping spoil to temporary stockpiles were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y)
A	=	Activity rate (t/h)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

An activity rate of 1155 t/h was calculated based on a total of 35 trucks per hour delivering 12 bcm/truck (information provided by Lend Lease) and a spoil density of 2.65 t/bcm (information provided by Transurban). Haul truck deliveries would occur between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays.

The emission factors for excavators and front-end loaders transfer points were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
k_i	=	Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U	=	Mean wind speed (m/s)
M	=	Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[6], provided by Lend Lease, was used.

An emission reduction efficiency of 70 % was applied for unloading trucks using water sprays based on *Table 4: Estimated control factors for various mining operations for coal mines* of the EET manual for Mining (DSEWPAC, 2012).

[6] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

Dust Emissions from Articulated Dump Trucks in Pit

Dust emissions from articulated dump trucks dumping spoil within the pit were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y)
A	=	Activity rate (t/h)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

Articulated dump trucks would be active in the pit between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays and operate 80 percent of the time. An activity rate of 30 percent of all spoil entering the pit would be moved by arterial dump trucks. This equates to 216t/h at 80 percent utilisation.

The emission factors for arterial dump trucks were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
k_i	=	Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U	=	Mean wind speed (m/s)
M	=	Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[7], provided by Lend Lease, was used.

An emission reduction efficiency of 70 % was applied for unloading trucks using water sprays based on *Table 4: Estimated control factors for various mining operations for coal mines* of the EET manual for Mining (DSEWPAC, 2012).

Dust Emissions from Roller in Void

Dust emissions from the roller were calculated using the following NPI EET manual for mining (DSEWPAC, 2012) equation:

$$E_i = VKT \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y)
VKT	=	Vehicle kilometres travelled per year
EF_i	=	Uncontrolled emissions factor (kg/VKT)
CE_i	=	Overall control efficiency (kg/t)

Roller activities be conducted between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays and would operate at 80 percent utilisation during this time. The roller was assumed to operate at a speed of 5 km/h. Emission factors for TSP and PM_{10} were calculated using the equations below, while a particle size ratio for $PM_{2.5}/PM_{10}$ of 0.1 was applied to calculate the $PM_{2.5}$ emission rate based on Cowherd et.al (2006).

$$EF_{TSP} = 0.0034 \times S^{2.5}$$

[7] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

$$EF_{PM10} = 0.0034 \times S^{2.0}$$

Where:

EF_{TSP}/EF_{PM10}	=	Uncontrolled emissions factor (kg/VKT)
S	=	Mean vehicle speed (km/h)

An emission reduction efficiency of 75 % was applied for rollers using Level 2 watering of exposed surfaces (> 2 litres/m^2/h) based on Table 4 of the EET Manual for Mining (DSEWPAC, 2012).

Dust Emissions from Conveying Spoil

Dust emissions from conveyor transfer points were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y/transfer point)
A	=	Activity rate (t/h)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
CE_i	=	Overall control efficiency (kg/t)

The temporary stockpiles on the flats were assumed to have two loading points with a capacity of up to 450t/h each. The southernmost conveyor would drop the spoil onto the other conveyor, which would transfer it to the pit at a maximum capacity of 900 t/h. The activity rate of the conveyors is assumed to be operating at an 80 percent utilisation rate, which equates to 720 t/h. It was, therefore, assumed that each transfer point on the flats would have an activity rate of 360 t/h (i.e. each taking half the load), while the activity rate for the conveyor leading into the pit would be 720 t/h (the total combined throughput). The conveyor would be operational between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays.

The emission factor conveying material were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
k_i	=	Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U	=	Mean wind speed (m/s)
M	=	Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[8], provided by Lend Lease, was used.

An emission reduction efficiency of 50 % was applied for using water sprays based on *Table 4: Estimated control factors for various mining operations for coal mines* of the EET manual for Mining (DSEWPAC, 2012). Conveyor emissions from the base of the pit were assumed to be uncontrolled.

Wind Erosion from Stockpiles and Exposed Areas

Dust emissions from exposed areas were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = A \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

[8] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

Where:

E_i	=	Emission rate (kg/y)
A	=	Area (ha)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

The exposed surface areas of the flats and pit were estimated to be approximately 4.3 ha and 7.5 ha respectively. The AP-42 (US EPA, 1988) equation referenced in the NPI EET Manual for Mining (DSEWPAC, 2012) was used to calculate the emission factor equation for TSP, and factors of 50 % (US EPA, 1988) and 15 % (Cowherd *et al*., 2006) were used to calculate the emission rates for PM_{10} and $PM_{2.5}$ respectively.

$$\mathrm{EF}_{\boldsymbol{TSP}} = \left(\frac{s}{1.5}\right) \times 365 \times \left(\frac{365-p}{235}\right) \times \left(\frac{f}{15}\right)$$

Where:

EF_{TSP}	=	Emission rate (kg/y)
s	=	Silt content by weight (%)
p	=	Number of days per year when rainfall is greater than 0.25 mm
f	=	Time that wind speed is greater than 5.4 m/s

A silt content of 12 % was used to calculate the emission factor for TSP (provided by Lend Lease). The 2014 CALMET data from the site were used to calculate the meteorological input parameters. There were 229 days in the year 2014 where the precipitation exceeded 0.25 mm, and winds higher than 5.4 m/s only occurred 0.23 % of the time.

An emission reduction efficiency of 50 % was applied for exposed areas within the pit using water sprays based on Table 4 of DSEWPAC (2012). For the temporary stockpiles on the flats, it was assumed that both water sprays and wind breaks would be used, resulting in an emission reduction efficiency of 85 %.

Wheel Generated Dust on Paved Roads

Dust emissions from haul trucks on paved roads were calculated using the following equation:

$$E_i = VKT \times EF_i$$

Where:

E_i	=	Emission rate (kg/y)
VKT	=	Vehicle kilometres travelled per year
EF_i	=	Uncontrolled emissions factor (kg/VKT)

The emission factor conveying material were calculated using the US EPA AP-42 Predictive Emission Factor Equation for paved roads (Chapter 13.2.2.2). The equation can be seen here:

$$EF_i = k_i \times (sL)^{0.91} \times (W)^{1.02} \times 1000$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/VKT)
k_i	=	Constant; where k = 3.23 for TSP, k= 0.62 for PM_{10} and k = 0.015 for $PM_{2.5}$
sL	=	Road surface silt loading (g/m^2)
W	=	Average weight of vehicles travelling the road (t)

A silt loading content of 0.6 was assumed based on Table 13.2 1-2 of the US EPA AP-42 document. Haul trucks were assumed to have an empty vehicle mass of 15 tonnes, and a full load mass of 48 tonnes. Based on a roundhouse trip of 0.45km, and 35t/h between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays a total of 49140 VKT was used.

Wheel Generated Dust on Unpaved Roads

Dust emissions from both haul trucks and articulated dump trucks on unpaved roads were calculated using the following equation:

$$E_i = VKT \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y)
VKT	=	Vehicle kilometres travelled per year
EF_i	=	Uncontrolled emissions factor (kg/VKT)
CE_i	=	Overall control efficiency (kg/t)

The emission factor conveying material were calculated using the US EPA AP-42 Predictive Emission Factor Equation for unpaved roads (Chapter 13.2.1.3). The equation can be seen here:

$$EF_i = \frac{0.4536}{1.6093} \times k_i \times \left(\frac{s}{12}\right)^a \times \left(\frac{W}{3}\right)^b$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/VKT)
k_i	=	Constant (lb/VMT); where k = 4.9 for TSP, k= 1.5 for PM_{10} and k = 0.15 for $PM_{2.5}$
s	=	Silt content by weight (%)
a	=	Constant where a = 0.7 for TSP and a = 0.9 for PM_{10} and $PM_{2.5}$.
W	=	Average weight of vehicles travelling the road (t)
b	=	Constant where b = 0.45 for all particulates fractions.

A silt content of 7.1 was assumed based on Table 13.2 2-1 of the US EPA AP-42 document for both haul trucks and articulated dump trucks.

Haul trucks were assumed to have an empty vehicle mass of 15 tonnes, and a full load mass of 48 tonnes. Based on a round trip of 0.05km around temporary stockpile areas, and 35t/h between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays a total of 5460 VKT was used.

Articulated dump trucks were assumed to have an empty vehicle mass of 22.95 tonnes, and a full load mass of 23.6 tonnes based on a based on CAT 725C tree axle articulated truck. Thirty percent of material transferred into the void would be transported by articulated dump truck, accounting for a round trip of 0.3km and articulated dump trucks operating 80 percent of the time between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays this equates to 8566 VKT/y.

External Haul Route Emissions

Onsite haul truck combustion emissions were calculated using PIARC emission rates for heavy vehicles. A total of 70 vehicles per hour were modelled (35 inbound trucks and 35 outbound trucks). Expected haulage routes used in the CALROADS model are identified below:

- **In:** Pacific Highway from the intersection with Pennant Hills Road, then along George Street and onto Bridge Road.
- **Out (non-peak hours):** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road.
- **Out (peak hours):** out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

All vehicle emissions have been modelled at grade as heavy vehicles with a speed of 60km per hour with exception to vehicles entering and exiting the site (links 25 to 29) which are assumed to have a speed of 10km per hour. The mixing width was assumed to be 20m for all road links. The location of all links, vehicles per hour and road grades are shown in the table below.

Link	Endpoint 1 Coordinate		Endpoint 2 Coordinate		Peak hours (7am-9am and 3am-5pm)			Non-Peak hours (9am-3pm)		
	X1	Y1	X2	Y2	Direction	VPH	Grade	Direction	VPH	Grade*
1	324873	6267434	324717	6267471	Inbound	35	2	Bi-Directional	70	2 / -2
2	324717	6267471	324721	6267522	Inbound	35	2	Bi-Directional	70	2 / -2
3	324721	6267522	324753	6267722	Inbound	35	0	Bi-Directional	70	0 / 0
4	324753	6267722	324741	6267808	Inbound	35	-4	Bi-Directional	70	-4 / 4
5	324741	6267808	324657	6268036	Inbound	35	-4	Bi-Directional	70	-4 / 4
6	324657	6268036	324624	6268096	Inbound	35	-4	Bi-Directional	70	-4 / 4
7	324624	6268096	324568	6268157	Inbound	35	-4	Bi-Directional	70	-4 / 4
8	324568	6268157	324516	6268193	Inbound	35	-4	Bi-Directional	70	-4 / 4
9	324516	6268193	324312	6268299	Inbound	35	-4	Bi-Directional	70	-4 / 4
10	324312	6268299	324180	6268335	Inbound	35	0	Bi-Directional	70	0 / 0
11	324180	6268335	324117	6268370	Inbound	35	0	Bi-Directional	70	0 / 0
12	324117	6268370	324063	6268425	Inbound	35	0	Bi-Directional	70	0 / 0
13	324063	6268425	324001	6268459	Inbound	35	0	Bi-Directional	70	0 / 0
14	324001	6268459	323832	6268534	Inbound	35	0	Bi-Directional	70	0 / 0
15	323832	6268534	323796	6268558	Inbound	35	0	Bi-Directional	70	0 / 0
16	323796	6268558	323830	6268790	Inbound	35	0	Bi-Directional	70	0 / 0
17	323830	6268790	323838	6268890	Inbound	35	0	Bi-Directional	70	0 / 0
18	323838	6268890	323802	6268970	Inbound	35	0	Bi-Directional	70	0 / 0
19	323802	6268970	323857	6269235	Inbound	35	-2	Bi-Directional	70	-2 / 2
20	323857	6269235	323950	6269673	Inbound	35	-2	Bi-Directional	70	-2 / 2
21	323950	6269673	323948	6269709	Inbound	35	2	Bi-Directional	70	2 / -2
22	323948	6269709	323940	6269761	Inbound	35	2	Bi-Directional	70	2 / -2
23	323940	6269761	323652	6269807	Inbound	35	0	Bi-Directional	70	0 / 0
24	323652	6269807	323607	6269736	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
25	323607	6269736	323586	6269741	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
26	323586	6269741	323578	6269800	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
27	323578	6269800	323563	6269836	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
28	323563	6269836	323528	6269837	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
29	323528	6269837	323496	6269692	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
30	325619	6271882	325324	6271921	Outbound	35	2			
31	325324	6271921	325042	6271881	Outbound	35	2			
32	325042	6271881	325080	6272091	Outbound	35	2			
33	325080	6272091	325006	6272101	Outbound	35	2			
34	325006	6272101	324997	6272021	Outbound	35	2			
35	324997	6272021	324975	6271952	Outbound	35	2			
36	324975	6271952	324897	6271801	Outbound	35	2			
37	324897	6271801	324883	6271740	Outbound	35	2			
38	324883	6271740	324877	6271369	Outbound	35	2			
39	324877	6271369	324859	6271286	Outbound	35	4			
40	324859	6271286	324799	6271111	Outbound	35	4			
41	324799	6271111	324768	6271040	Outbound	35	0			
42	324768	6271040	324696	6270901	Outbound	35	0			
43	324696	6270901	324581	6270730	Outbound	35	0			
44	324581	6270730	324540	6270675	Outbound	35	0			

45	324540	6270675	324070	6270156	Outbound	35	0			
46	324070	6270156	324031	6270114	Outbound	35	0			
47	324031	6270114	323984	6270042	Outbound	35	0			
48	323984	6270042	323948	6269984	Outbound	35	0			
49	323948	6269984	323910	6269897	Outbound	35	0			
50	323910	6269897	323871	6269780	Outbound	35	0			

* Inbound grade / outbound grade

Appendix F

NO_X to NO_2 Conversion

Appendix F NO$_X$ to NO$_2$ Conversion

One of the challenges of modelling NOx emissions is determining the amount of NO_2 at a receiver, due to uncertainties in the conversion rates. Early studies (Hegg et al., 1977) showed that the rate of oxidation is controlled by the rate of plume mixing rather than by gas reaction kinetics. Ozone is usually the chemical that is responsible for most of the oxidation, but other reactive atmospheric gases can also oxidise NO.

Several methods were proposed for evaluating the amount of NO_2 that is formed from NO. These include:

1) Total conversion;
2) The Ambient Ratio Method (ARM), (0.75 is the US default value) when no measured nearby NOx/NO_2 ratios are available;
3) Ozone Limiting Method (OLM);
4) Jansenn's equations (which assume approximately 10 per cent of all NOx is NO_2) – used in Australia and New Zealand; and
5) Plume Volume Molar Ratio method.

All of these methods are referenced in the Federal Guideline on Air Quality Models (GAQM) and DEC (2005).

NOx to NO2 conversion in NSW

In NSW, the oxidation of NO to NO_2 is assessed by three methods (Method 1, the most simple, to Method 3, the most complex). Method 1, which assumes 100 per cent conversion of NO to NO2, can be used in one of two ways. A Level 1 assessment uses maximum predicted NO_X concentrations (assuming NOx = NO_2) and maximum ambient NO_2 concentrations to determine a cumulative NO_2 concentration. If the facility fails to meet the NO_2 impact assessment criteria, a Level 2 assessment is conducted, which again assumes 100 per cent conversion but with contemporaneous assessment of model predictions and ambient concentrations.

Method 2 is the OLM, where NO to NO_2 conversion is limited by the amount of ozone available. The OLM uses a simple approach to the reaction chemistry; it assumes that O_3 and NO react to form NO_2 in proportion to their ground level concentrations. That is, for each hour,

- if $O_3 < NO_{plume}$,
  - $NO_{2\ plume} = NO_{2\ initial} + O_3$, and if
- $O_3 \geq NO_{plume}$, $NO_{2\ plume} = NO_{x\ plume}$

Method 3 uses an empirical relationship to convert NO to NO_2 based on the equation developed by Janssen et al. (1988). The conversion is based on the distance of the receiver downwind from the source, and can be used with various levels of refinement (i.e. using maxima or contemporaneous data).

NOx to NO$_2$ assessment in the United States

In the United States, the first level recommended technique in the Guideline on Air Quality Models (GAQM) is to assume the total conversion of NO to NO_2. This is the same first tier level as DEC (2005). It is a conservative, first-level technique, which may lead to unnecessary control in areas where the predicted impacts are close to ambient air quality criteria.

The Ambient Ratio Method (ARM) is the second-level technique recommended in the GAQM. The ARM is defined as the ratio of the average NO_2 and NOx ambient concentrations measured at a representative site. It uses local monitoring or a default 75per cent ratio to find the ambient equilibrium NO_2/NOx ratio (annual average). Theoretically, equilibrium occurs when the rate of NO_2 formation equals the rate of dissociation of NO_2 by sunlight. Chu and Meyer (1991), who developed this technique, recommended that this monitoring be performed far away so that true equilibrium would occur. Unfortunately, ambient monitoring is usually insufficient for determining this ratio because ambient concentrations are frequently below the minimum monitoring threshold for NOx (20 ppb). Further, if the monitoring is performed too close to an existing source, the ARM's assumption of equilibrium is violated and the monitoring results are not applicable to receivers further downwind.

The third-level tier is the OLM (stated above) and a Plume Volume Molar Ratio method (PVMRM). The PVMRM method better simulates the NO to NO_2 conversion chemistry during plume expansion and is particularly well suited for the receivers located close to sources where maximum modelled NO concentrations are usually predicted. The PVMRM method follows the chemistry of the main forward reaction of NO with O_3 as it occurs during expansion of a plume segment travelling downwind:

NO + O3 → NO2 + O2

This is accomplished by computing the number of moles of NOx and O_3 that are contained within a plume segment as it reaches a receiver. Although the PVMRM follows the same chemical reactions as those used in the OLM, it uses both plume size and O_3 concentration to derive the amount of O_3 available for the reaction. NOx moles are determined by emission rate and travel time through the plume segment. The number of O_3 moles is determined by the size of the plume segment and the measured background O_3 concentration. This plume segment always contains the same amount of primary NOx emissions as it travels downwind. The amount of O_3 available for reaction, however, increases as the plume segment enlarges downwind. The last approach, which is not yet included in any US Guideline criteria, is based on an empirical approach of some 3,000 co-located NOx and NO_2 monitors in Europe. The approach uses a scaled approach to NOx bins of concentration levels. This method was developed by the Atmospheric Studies Group and is included in the US EPA guideline model CALPOST. It has been used on a case-by-case basis when all other methods fail.

Concerns with and likely conservatism of the OLM

The OLM employed by the EPA (DEC, 2005) was taken from the US EPA OLM, originally developed by Cole and Summerhays (1979) and Tikvart (1996). The method assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the O_3 or all the NO is used up. The approach is known to be conservative. Some of the reasons for its lack of robustness and conservatism are listed below:

- The OLM approach assumes that the atmospheric reaction is instant, whereas in reality the reaction takes place over a number of hours.
- The actual reactions of NO to NO_2 occur in proportion to the moles of each reactant rather than in proportion to the concentration assumed by the OLM. At constant volume, 1 ppm of a gas is proportional to 1 mole of a gas. This assumption is not valid in the open atmosphere, as there is virtually unlimited amount of O_3 available for reaction. As plumes expand downwind, more O_3 is available for reaction, and even lower concentrations of O_3 can react with NO in the plume.
- The OLM is further complicated as some of the NOx is already converted to NO_2 upstream in the plume before it reaches the receiver.
- Studies have shown that the NOx emission rates are extremely important with respect to the rate of conversion to NO_2. The size of the plume is not affected by the NOx emission rate, which means that there is the same amount of O_3 available for chemical conversion regardless of the NOx emission rate. Larger NOx emission rates lead to lower predicted ratios of NO_2/NOx. Maximum impacts that occur at receivers located further away have high predicted NO_2/NOx ratios. Further emissions emitted into stable (narrow) plumes will have less conversion to NO_2 compared to those emissions emitted into less stable (wider) plumes. The OLM does not take the NOx emission rate or plume size into consideration.
- The OLM can only be used on one plume at a time. The US EPA states that the OLM should be used with a ‘plume-by-plume’ approach. This is a big limitation to a facility with lots of different plumes. The OLM will therefore be very conservative for close in NO_2 impacts for large multi plume sources. The OLM may not be conservative for single plumes downwind, where low concentrations of O_3 can still react with the plume.

The OLM is expected to be conservative during daylight hours when the photochemical equilibrium reverses the oxidation of NO by O_3. It is also expected to be conservative during stable and night conditions when both NO_2 and O_3 are removed by reaction with vegetation and other surfaces.

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Appendix G

Pollutant Concentrations Along Haul Routes

Appendix G Pollutant Concentrations Along Haul Routes

ID	Predicted ground level concentration (µg/m³)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_001	1.6	0.0	0.00050	0.00002	0.0838	0.0215	0.0797	0.0205	0.00018	0.00000011	Ku-Ring-Gai Chase Rd
R_002	1.5	0.0	0.00049	0.00002	0.0711	0.0222	0.0677	0.0211	0.00017	0.00000011	Ku-Ring-Gai Chase Rd
R_003	2.1	1.2	0.00063	0.00003	0.1174	0.0335	0.1117	0.0319	0.00024	0.00000015	Ku-Ring-Gai Chase Rd
R_004	1.7	1.2	0.00057	0.00003	0.0914	0.0336	0.0869	0.032	0.00020	0.00000012	Ku-Ring-Gai Chase Rd
R_005	1.7	1.2	0.00057	0.00003	0.1079	0.0335	0.1026	0.0319	0.00020	0.00000012	Ku-Ring-Gai Chase Rd
R_006	2.2	1.2	0.00072	0.00003	0.1106	0.0398	0.1052	0.0378	0.00026	0.00000016	Ku-Ring-Gai Chase Rd
R_007	1.7	1.2	0.00097	0.00007	0.0899	0.0402	0.0855	0.0382	0.00020	0.00000012	Ku-Ring-Gai Chase Rd
R_008	2.8	1.2	0.00103	0.00005	0.1568	0.0508	0.1492	0.0483	0.00031	0.00000020	Ku-Ring-Gai Chase Rd
R_009	3.5	1.2	0.00147	0.00009	0.1695	0.0674	0.1612	0.0641	0.00040	0.00000025	Pacific Hwy
R_010	5.5	1.2	0.00300	0.00006	0.2332	0.0314	0.2218	0.0299	0.00063	0.00000039	Pacific Hwy
R_011	6.0	2.3	0.00329	0.00020	0.3887	0.0988	0.3697	0.094	0.00068	0.00000042	Pacific Hwy
R_012	3.9	2.3	0.00214	0.00012	0.1541	0.0659	0.1466	0.0626	0.00044	0.00000027	Pacific Hwy
R_013	2.9	1.2	0.00160	0.00011	0.1225	0.0544	0.1165	0.0518	0.00033	0.00000020	Pacific Hwy
R_014	6.5	2.3	0.00359	0.00017	0.326	0.0822	0.31	0.0782	0.00075	0.00000046	Pacific Hwy
R_015	3.0	1.2	0.00158	0.00010	0.1311	0.0501	0.1247	0.0476	0.00034	0.00000021	Pacific Hwy
R_016	5.0	2.3	0.00272	0.00012	0.3151	0.0614	0.2997	0.0584	0.00057	0.00000035	Pacific Hwy
R_017	4.4	1.2	0.00243	0.00012	0.2433	0.0588	0.2314	0.0559	0.00051	0.00000031	Pacific Hwy
R_018	4.2	1.2	0.00222	0.00012	0.182	0.0602	0.1731	0.0573	0.00048	0.00000030	Pacific Hwy
R_019	3.5	1.2	0.00182	0.00010	0.1497	0.0513	0.1424	0.0488	0.00040	0.00000025	Pacific Hwy
R_020	4.2	1.2	0.00232	0.00012	0.235	0.0585	0.2235	0.0557	0.00048	0.00000030	Pacific Hwy
R_021	3.4	1.2	0.00184	0.00008	0.1902	0.0435	0.1809	0.0414	0.00038	0.00000024	Pacific Hwy
R_022	2.3	1.2	0.00105	0.00005	0.1565	0.0404	0.1488	0.0385	0.00026	0.00000016	Pacific Hwy
R_023	2.0	1.2	0.00086	0.00005	0.1552	0.038	0.1476	0.0361	0.00023	0.00000014	Pacific Hwy
R_024	2.1	1.2	0.00079	0.00005	0.1515	0.0399	0.1441	0.038	0.00024	0.00000015	Pacific Hwy
R_025	1.2	0.0	0.00052	0.00002	0.0554	0.0165	0.0527	0.0157	0.00013	0.00000008	Pacific Hwy
R_026	3.0	1.2	0.00111	0.00006	0.195	0.0528	0.1855	0.0502	0.00034	0.00000021	Pacific Hwy
R_027	2.6	1.2	0.00096	0.00006	0.1578	0.0462	0.1501	0.044	0.00029	0.00000018	Pacific Hwy
R_028	0.9	0.0	0.00040	0.00002	0.0398	0.0125	0.0379	0.0119	0.00011	0.00000007	Pacific Hwy
R_029	1.3	0.0	0.00055	0.00002	0.0485	0.0176	0.0462	0.0168	0.00015	0.00000009	Pacific Hwy

ID	Predicted ground level concentration (µg/m³)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_030	2.4	1.2	0.00088	0.00005	0.1377	0.0411	0.131	0.0391	0.00027	0.00000017	Pacific Hwy
R_031	2.0	1.2	0.00075	0.00004	0.1187	0.0341	0.1129	0.0324	0.00022	0.00000014	Pacific Hwy
R_032	1.4	1.2	0.00052	0.00003	0.096	0.0237	0.0913	0.0225	0.00016	0.00000010	Pacific Hwy
R_033	1.7	1.2	0.00064	0.00004	0.1118	0.0296	0.1063	0.0281	0.00019	0.00000012	Pacific Hwy
R_034	1.7	1.2	0.00066	0.00004	0.1157	0.0306	0.11	0.0291	0.00020	0.00000012	Pacific Hwy
R_035	1.1	1.2	0.00041	0.00002	0.0867	0.0176	0.0825	0.0167	0.00012	0.00000008	Jersey St North
R_036	2.4	1.2	0.00096	0.00005	0.1639	0.0411	0.1558	0.0391	0.00028	0.00000017	Jersey St North
R_037	2.4	1.2	0.00107	0.00005	0.1586	0.0382	0.1509	0.0363	0.00027	0.00000017	Jersey St North
R_038	2.6	1.2	0.00121	0.00007	0.1514	0.0486	0.144	0.0462	0.00030	0.00000019	Jersey St North
R_039	2.5	2.3	0.00095	0.00007	0.2572	0.0676	0.2446	0.0643	0.00029	0.00000018	Jersey St North
R_040	4.7	3.5	0.00194	0.00007	0.3587	0.0533	0.3411	0.0507	0.00054	0.00000033	George St
R_041	6.2	4.6	0.00258	0.00015	0.5384	0.1017	0.512	0.0967	0.00071	0.00000044	George St
R_042	5.6	4.6	0.00230	0.00012	0.4547	0.1038	0.4324	0.0987	0.00063	0.00000039	George St
R_043	5.8	4.6	0.00239	0.00012	0.4746	0.1072	0.4513	0.1019	0.00066	0.00000041	George St
R_044	4.7	3.5	0.00189	0.00010	0.3557	0.0873	0.3382	0.083	0.00054	0.00000034	George St
R_045	3.1	1.2	0.00119	0.00005	0.1585	0.0433	0.1507	0.0412	0.00035	0.00000022	George St
R_046	6.3	4.6	0.00259	0.00014	0.5246	0.1202	0.4988	0.1143	0.00072	0.00000044	George St
R_047	4.8	3.5	0.00200	0.00012	0.4011	0.1025	0.3815	0.0975	0.00055	0.00000034	George St
R_048	5.6	4.6	0.00231	0.00013	0.4692	0.1172	0.4462	0.1115	0.00064	0.00000040	Pacific Hwy
R_049	5.5	3.5	0.00225	0.00013	0.4287	0.1143	0.4076	0.1087	0.00062	0.00000039	Pacific Hwy
R_050	3.1	2.3	0.00123	0.00007	0.1995	0.0579	0.1897	0.0551	0.00035	0.00000022	Pacific Hwy
R_051	5.8	3.5	0.00217	0.00015	0.4081	0.1229	0.3881	0.1169	0.00066	0.00000041	Pacific Hwy
R_052	3.6	2.3	0.00134	0.00008	0.327	0.0653	0.3109	0.0621	0.00041	0.00000025	Pacific Hwy
R_053	5.9	4.6	0.00220	0.00014	0.5319	0.1175	0.5058	0.1117	0.00067	0.00000042	Pacific Hwy
R_055	4.1	3.5	0.00152	0.00011	0.364	0.0919	0.3461	0.0874	0.00046	0.00000029	Pacific Hwy
R_056	4.4	3.5	0.00164	0.00013	0.3601	0.1126	0.3425	0.1071	0.00050	0.00000031	Pacific Hwy
R_057	3.9	2.3	0.00149	0.00011	0.2998	0.0897	0.2851	0.0853	0.00045	0.00000028	Pacific Hwy
R_058	4.6	3.5	0.00175	0.00014	0.3814	0.1143	0.3627	0.1087	0.00052	0.00000033	Pacific Hwy
R_059	4.2	2.3	0.00158	0.00013	0.2774	0.1063	0.2638	0.1011	0.00048	0.00000030	Pacific Hwy
R_060	2.9	2.3	0.00111	0.00006	0.245	0.0472	0.233	0.0449	0.00033	0.00000021	Pacific Hwy
R_061	4.8	2.3	0.00183	0.00009	0.3048	0.0776	0.2899	0.0738	0.00055	0.00000034	Pacific Hwy
R_062	4.6	3.5	0.00174	0.00011	0.3567	0.0951	0.3393	0.0904	0.00053	0.00000033	Pacific Hwy

ID	Predicted ground level concentration (µg/m³)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_063	4.0	2.3	0.00152	0.00010	0.3147	0.0866	0.2993	0.0824	0.00046	0.00000029	Pacific Hwy
R_064	4.2	3.5	0.00158	0.00012	0.3473	0.0967	0.3303	0.092	0.00048	0.00000030	Pacific Hwy
R_065	4.0	3.5	0.00148	0.00011	0.3324	0.0947	0.3161	0.0901	0.00045	0.00000028	Pacific Hwy
R_066	5.9	3.5	0.00226	0.00013	0.4914	0.1093	0.4673	0.104	0.00067	0.00000042	Pacific Hwy
R_067	2.9	2.3	0.00111	0.00007	0.2528	0.0607	0.2404	0.0577	0.00034	0.00000021	Pacific Hwy
R_068	6.3	3.5	0.00249	0.00016	0.5179	0.1321	0.4925	0.1256	0.00071	0.00000044	Pacific Hwy
R_069	5.3	4.6	0.00199	0.00012	0.4598	0.1001	0.4373	0.0952	0.00061	0.00000038	Pacific Hwy
R_070	4.2	2.3	0.00157	0.00011	0.2964	0.0878	0.2819	0.0835	0.00048	0.00000030	Pacific Hwy
R_071	5.7	3.5	0.00268	0.00011	0.4205	0.0896	0.3999	0.0853	0.00065	0.00000041	Pacific Hwy
R_072	4.4	3.5	0.00217	0.00012	0.3609	0.0908	0.3432	0.0864	0.00051	0.00000031	Pacific Hwy
R_073	6.5	3.5	0.00327	0.00012	0.3646	0.0942	0.3467	0.0896	0.00074	0.00000046	Pacific Hwy
R_074	4.3	3.5	0.00209	0.00011	0.3147	0.0836	0.2993	0.0796	0.00049	0.00000030	Pacific Hwy
R_075	5.1	3.5	0.00248	0.00014	0.3802	0.1072	0.3615	0.1019	0.00058	0.00000036	Pacific Hwy
R_076	4.5	2.3	0.00219	0.00008	0.2815	0.0615	0.2677	0.0585	0.00051	0.00000032	Pacific Hwy
R_077	3.2	2.3	0.00161	0.00010	0.2389	0.0775	0.2272	0.0737	0.00037	0.00000023	Pacific Hwy
R_078	3.6	2.3	0.00177	0.00007	0.2545	0.0584	0.2421	0.0556	0.00041	0.00000026	Pacific Hwy
R_079	3.8	2.3	0.00189	0.00011	0.2403	0.082	0.2285	0.078	0.00043	0.00000027	Pacific Hwy
R_080	4.1	2.3	0.00194	0.00008	0.2847	0.0627	0.2707	0.0596	0.00047	0.00000029	Pacific Hwy
R_081	4.4	3.5	0.00214	0.00014	0.3163	0.1116	0.3008	0.1061	0.00050	0.00000031	Pacific Hwy
R_082	7.3	4.6	0.00363	0.00012	0.4843	0.0941	0.4606	0.0895	0.00084	0.00000052	Pacific Hwy
R_083	3.5	2.3	0.00132	0.00011	0.2369	0.0864	0.2253	0.0821	0.00039	0.00000024	Pacific Hwy
R_084	3.5	2.3	0.00153	0.00005	0.1983	0.0436	0.1886	0.0415	0.00040	0.00000025	Pacific Hwy
R_085	4.0	2.3	0.00155	0.00012	0.3253	0.1	0.3093	0.0951	0.00046	0.00000028	Pacific Hwy
R_086	2.8	1.2	0.00108	0.00007	0.1837	0.0547	0.1747	0.052	0.00032	0.00000020	Pacific Hwy
R_087	5.5	3.5	0.00228	0.00016	0.5032	0.1122	0.4785	0.1067	0.00063	0.00000039	Pacific Hwy
R_088	3.0	2.3	0.00125	0.00015	0.3107	0.0976	0.2954	0.0928	0.00035	0.00000021	Pacific Hwy
R_089	4.8	2.3	0.00201	0.00010	0.2734	0.067	0.26	0.0637	0.00055	0.00000034	Pacific Hwy
R_090	4.0	2.3	0.00162	0.00009	0.2624	0.0596	0.2495	0.0567	0.00045	0.00000028	Pacific Hwy
R_091	2.4	2.3	0.00100	0.00010	0.271	0.0661	0.2577	0.0629	0.00028	0.00000017	Pacific Hwy
R_092	4.8	3.5	0.00179	0.00013	0.3947	0.1089	0.3754	0.1035	0.00055	0.00000034	Bridge Rd
R_093	4.6	1.2	0.00168	0.00009	0.216	0.0724	0.2054	0.0688	0.00053	0.00000033	Bridge Rd
R_094	4.0	1.2	0.00142	0.00008	0.2155	0.0643	0.205	0.0611	0.00045	0.00000028	Bridge Rd
R_095	3.3	2.3	0.00117	0.00009	0.2965	0.0774	0.282	0.0736	0.00038	0.00000023	Bridge Rd
R_096	4.6	3.5	0.00175	0.00013	0.39	0.1088	0.3709	0.1035	0.00052	0.00000032	Bridge Rd
R_097	4.0	3.5	0.00156	0.00012	0.3703	0.1031	0.3521	0.0981	0.00046	0.00000029	Bridge Rd

ID	Predicted ground level concentration (µg/m³)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_098	7.2	3.5	0.00298	0.00014	0.4682	0.1192	0.4453	0.1134	0.00082	0.00000051	Bridge Rd
R_099	7.9	3.5	0.00316	0.00018	0.3851	0.1441	0.3662	0.1371	0.00091	0.00000056	Bridge Rd
R_100	8.1	4.6	0.00254	0.00010	0.3857	0.0843	0.3668	0.0801	0.00092	0.00000057	Bridge Rd
R_101	8.8	4.6	0.00343	0.00014	0.3879	0.1129	0.3689	0.1074	0.00101	0.00000062	Bridge Rd
R_102	17.8	8.1	0.00589	0.00012	0.6573	0.0967	0.6251	0.092	0.00203	0.00000126	TAFE Entry Rd
R_103	5.5	3.5	0.00184	0.00007	0.3035	0.0606	0.2887	0.0576	0.00063	0.00000039	TAFE Entry Rd
R_104	6.9	5.8	0.00287	0.00014	0.5718	0.1244	0.5438	0.1183	0.00079	0.00000049	George St
R_105	5.0	3.5	0.00207	0.00011	0.41	0.096	0.3899	0.0913	0.00057	0.00000035	George St
R_106	8.6	6.9	0.00354	0.00019	0.7107	0.1542	0.6758	0.1466	0.00098	0.00000061	George St
R_107	9.8	8.1	0.00404	0.00029	0.8454	0.1965	0.8039	0.1868	0.00111	0.00000069	George St
R_108	3.7	1.2	0.00176	0.00008	0.2309	0.0596	0.2196	0.0567	0.00043	0.00000027	George St
R_109	2.3	1.2	0.00106	0.00005	0.1246	0.0326	0.1185	0.031	0.00027	0.00000017	Jersey St North
R_110	2.3	1.2	0.00093	0.00004	0.158	0.0359	0.1502	0.0342	0.00027	0.00000016	Jersey St North
R_111	2.1	1.2	0.00082	0.00004	0.1473	0.0363	0.14	0.0345	0.00024	0.00000015	Jersey St North
R_112	2.4	1.2	0.00093	0.00005	0.1551	0.0422	0.1475	0.0401	0.00028	0.00000017	Jersey St North
R_113	1.7	1.2	0.00065	0.00004	0.1188	0.0299	0.113	0.0285	0.00020	0.00000012	Jersey St North
R_114	1.9	1.2	0.00071	0.00004	0.1157	0.0336	0.11	0.032	0.00022	0.00000013	Pacific Hwy
R_115	3.3	1.2	0.00124	0.00007	0.1827	0.0544	0.1738	0.0517	0.00037	0.00000023	Pacific Hwy
R_116	2.3	1.2	0.00085	0.00005	0.134	0.04	0.1274	0.038	0.00026	0.00000016	Pacific Hwy
R_117	2.8	1.2	0.00106	0.00006	0.1616	0.0486	0.1537	0.0462	0.00032	0.00000020	Pacific Hwy
R_118	1.2	0.0	0.00048	0.00002	0.044	0.0155	0.0419	0.0147	0.00013	0.00000008	Pacific Hwy
R_119	1.0	0.0	0.00042	0.00002	0.0415	0.0141	0.0394	0.0134	0.00012	0.00000007	Pacific Hwy
R_120	1.2	0.0	0.00051	0.00002	0.055	0.0179	0.0523	0.017	0.00014	0.00000009	Pacific Hwy

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Appendix F

Technical working paper: Health

Technical Working Paper: Human Health Risk Assessment – Hornsby Quarry

Prepared for: AECOM

28 July 2015

EnRiskS

Document History and Status

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Limitations

Environmental Risk Sciences has prepared this technical working paper for the use of AECOM and Roads and Maritime Services in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this technical working paper.

It is prepared in accordance with the scope of work and for the purpose outlined in the Section 1 of this technical working paper.

The methodology adopted and sources of information used are outlined in this technical working paper. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found that information contained in the reports for use in this assessment was false.

This report was prepared between May and July 2015 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

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Appendices

Appendix A Methodology for Particulate Risk Assessment

Glossary of Terms

Acute exposure	Contact with a substance that occurs once or for only a short time (up to 14 days).
absorption	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.
Adverse health effect	A change in body function or cell structure that might lead to disease or health problems.
ANZECC	Australia and New Zealand Environment and Conservation Council
AQIA	Technical Working Paper: Air Quality (AECOM, 2014) for the NorthConnex project.
Background level	An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.
Biodegradation	Decomposition or breakdown of a substance through the action of micro-organisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).
Body burden	The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.
BTX	Benzene, toluene and total xylenes
Carcinogen	A substance that causes cancer.
Chronic exposure	Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure].
COPD	Chronic Obstructive Pulmonary Disease
DECCW	Department of Environment, Climate Change and Water
Detection limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.
DGRs	Director General Requirements
Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
EC	European Commission
EP&A Act	Environmental Planning and Assessment Act 1979
EPA	Environment Protection Authority
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].
Exposure assessment	The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure pathway	The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed) to it. An exposure pathway has five parts: a source of contamination (such as chemical leakage into the subsurface); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receiver population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.
Guideline value	Guideline value is a concentration in soil, sediment, water, biota or air (established by relevant regulatory authorities such as the NSW Department of Environment and Conservation (DEC) or institutions such as the National Health and Medical Research Council (NHMRC), Australia and New Zealand Environment and Conservation Council (ANZECC) and World Health Organisation (WHO)), that is used to identify conditions below which no adverse effects, nuisance or indirect health effects are expected. The derivation of a guideline value utilises relevant studies on animals or humans and relevant factors to account for inter- and intra-species variations and uncertainty factors. Separate guidelines may be identified for protection of human health and the environment. Dependent on the source, guidelines will have different names, such as investigation level, trigger value, ambient guideline etc.
HIA	Health Impact Assessment
HHRA	Human Health Risk Assessment
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see route of exposure].
Intermediate exposure Duration	Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].
LGA	Local Government Area
LOAEL	Lowest-observed-adverse-effect-level - The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
LOR	Limit of Reporting
Metabolism	The conversion or breakdown of a substance from one form to another by a living organism.
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NOAEL	No-observed-adverse-effect-level - The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
NSW	New South Wales
OEH	Office of Environment and Heritage
OEHHA	Office of Environmental Health Hazard Assessment, California Environment Protection Agency (Cal EPA)
PAH	Polycyclic aromatic hydrocarbon
PM	Particulate matter
$PM_{2.5}$	Particulate matter of aerodynamic diameter 2.5 µm and less
PM_{10}	Particulate matter of aerodynamic diameter 10 µm and less
Point of exposure	The place where someone can come into contact with a substance present in the environment [see exposure pathway].
Population	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Receiver population	People who could come into contact with hazardous substances [see exposure pathway].
Risk	The probability that something will cause injury or harm.
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact]
Toxicity	The degree of danger posed by a substance to human, animal or plant life.
Toxicity data	Characterisation or quantitative value estimated (by recognised authorities) for each individual chemical for relevant exposure pathway (inhalation, oral or dermal), with special emphasis on dose-response characteristics. The data are based on based on available toxicity studies relevant to humans and/or animals and relevant safety factors.
Toxicological profile	An assessment that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.
Toxicology	The study of the harmful effects of substances on humans or animals.
TSP	Total suspended particulate
Uncertainty factor	Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organisation

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Executive Summary

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by road construction (the project).

On 13 January 2015 Roads and Maritime received approval under Part 5.1 of the EP&A Act to construct and operate the NorthConnex project, a multi-lane tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at the Pennant Hills Road interchange at Carlingford in northern Sydney. The Environmental Impact Statement (EIS) exhibited for the NorthConnex project identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The NorthConnex EIS also identified a number of potential spoil management location options, with the final option(s) to be determined at the construction stage.

Following design development, the Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnel excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portals could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of approximately one million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Council separately rehabilitating and developing the site for public recreation in the future.

This technical working paper was prepared to assess potential risks to human health associated with key aspects of the project, namely local air quality impacts, noise and vibration.

A human health risk assessment is a way of deciding now, what the consequences (to health) of some future action (such as this project) may be. In this case the technical working paper includes a detailed review of what impacts to air quality, noise and vibration may occur, who may be exposed to these impacts and whether there is potential for these impacts to result in adverse health effects within the local community. It has been conducted in accordance with national guidance available from enHealth (enHealth 2001, 2012a) and it has involved the following:

- review of predicted impacts to air quality, noise and vibration associated with the project;
- identification and characterisation of the community (including the presence of sensitive receivers such as childcare centres, aged care centres, schools and hospitals) who may be affected by these impacts;

- assessment of air quality impacts on health including:
  - o review of the key pollutants to air that are predicted from the carrying out of the project;
  - o identifying guidelines that are based on protection of the health of all members of the population for exposure to these pollutants all day, every day;
  - o comparing the predicted impacts with the health based guidelines; and
  - o a more detailed assessment of exposure to particulate matter utilising robust (published) associations between exposure to increased concentrations of particulates (as $PM_{2.5}$ or PM_{10}) and specific health effects (or health endpoints). The assessment conducted has evaluated the impact of the project on these health endpoints within the local community.
- assessment of noise and vibration impacts on health including:
  - o review of the impacts that are predicted from the carrying out of the project;
  - o identifying guidelines that are based on the protection of health and wellbeing of all members of the population;
  - o comparing the predicted impacts with the health based guidelines. Where the health based guidelines cannot be met, consideration of the implementation of practical and feasible mitigation/management measures and the duration of the works to determine the potential for impacts on health.

Based on the assessment undertaken and presented in this technical working paper the following has been concluded:

Air Quality:

All predicted concentrations of carbon monoxide, nitrogen dioxide, key individual volatile organic compounds and polycyclic aromatic hydrocarbons in the local community are below health based guidelines.

For the assessment of potential impacts of $PM_{2.5}$ and PM_{10} the following has been determined:

- Potential concentrations of silica that may be present in $PM_{2.5}$ and PM_{10} dust emissions are not considered to be of concern for community health.
- Calculated risks associated with exposures to PM_{10} and $PM_{2.5}$ (including diesel particulate matter, DPM) from emissions from trucks on the haulage route roads are not considered to be of concern for community health.
- In relation to the proposed activities at the quarry site, where standard mitigation measures are considered, risks are considered to be tolerable.
- Where risks are determined to be tolerable, it is expected that mitigation measures be implemented to minimise exposures associated with the project. For this project, air impacts and hence health risks are proposed to be further minimised through the implementation of best industry practice dust management and mitigation measures, to be outlined in a comprehensive dust management plan for the project. Such measures would result in lower levels of exposure and risk at all receptors in the surrounding community. Where these measures are implemented no significant health impacts are expected in the local community.

Noise and Vibration:

In relation to noise and vibration, potential impacts associated with the project have been considered. The worst case assessment predicts that noise criteria would be exceeded at a number of properties without additional noise mitigation measures. Feasible and reasonable mitigation measures would be detailed within the Construction Noise and Vibration Management Plan (CNVMP) to manage and mitigate predicted noise levels at sensitive receivers. In addition the affected community would be notified of the complaint reporting mechanisms should they have any concerns. Where the proposed noise management and mitigation measures are adopted, no adverse health impacts are expected in the local community.

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Section 1. Introduction

1.1 Project background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by road construction (the project).

On 13 January 2015 Roads and Maritime received approval under Part 5.1 of the EP&A Act to construct and operate the NorthConnex project, a multi-lane tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at the Pennant Hills Road interchange at Carlingford in northern Sydney. The Environmental Impact Statement (EIS) exhibited for the NorthConnex project identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The NorthConnex EIS also identified a number of potential spoil management location options, with the final option(s) to be determined at the construction stage.

Following design development, the Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnelling and excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portal could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of up to 1.5 million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Council separately rehabilitating and developing the site for public recreation in the future.

The Hornsby Quarry site is not currently the subject of a development approval that would permit handling, management and beneficial reuse of spoil at that site. Therefore, assessment and approval is being pursued in accordance with the EP&A Act. The Secretary's environmental assessment requirements (SEARs) for the project were issued on 2 July 2015 and included a requirement to undertake an assessment of potential impacts on human health associated with emissions to air as well as noise and vibration from the project. This human health risk assessment has been prepared to inform the EIS being prepared for the Hornsby Quarry Road Construction Spoil Management Project.

1.2 Project location

The Hornsby Quarry site is located off Bridge Road on the western side of Hornsby town centre. The site covers about 35 hectares and is owned by Hornsby Shire Council (Council) (refer to **Figures 1-1 and 1-2**).

The site comprises the quarry void, internal access roads and a cleared area to the east which is likely to have been used as processing areas when the quarry was operational. Disused facilities associated with the previous quarrying operations remain on the site, including concrete office block buildings, a crushing and screening plant, a pipeline, security fencing and gates.

Whilst the site is zoned for public recreation (RE1) under the *Hornsby Local Environmental Plan 2013*, the quarry void itself is unsafe for public access given the steep sides and flooded nature of the void. Council currently maintains exclusion fencing around the void to prevent public access for public safety reasons. The areas outside of the void exclusion fencing are open to public access including mountain bike trails which have been established across the site by Council.

The site and surrounds are densely vegetated with some cleared areas comprising the void itself, internal access roads and areas to the east which were used as processing areas when the quarry was operational. Dense bushland comprising the Berowra Valley National Park lies directly to the west.

The general location and key features of the project are shown in **Figures 1-1, 1-2 and 1-3**.

1.3 Purpose of this report

The SEARs for the project were issued on 2 July 2015. The SEARs have informed the preparation of the EIS for the project. The SEARs include the requirements specific to potential impacts on air quality and noise and vibration and include a human health risk assessment (HHRA). Specifically, the SEARs states that the assessment should include:

An assessment of human health impacts with particular consideration of:

- *how the design of the proposal minimises adverse health impacts*
- *human health risks and costs associated with the proposal, including those associated with air quality, noise and vibration, and social impacts, during the construction and operation of the proposal.*

This technical working paper presents a Human Health Risk Assessment (HHRA) associated with key aspects of the project, namely local air quality impacts, noise and vibration (as proposed in the design as outlined in **Section 2**).

Other aspects of the SEARS relating to air quality, noise and vibration and social impacts have been addressed in separate specific technical working papers.

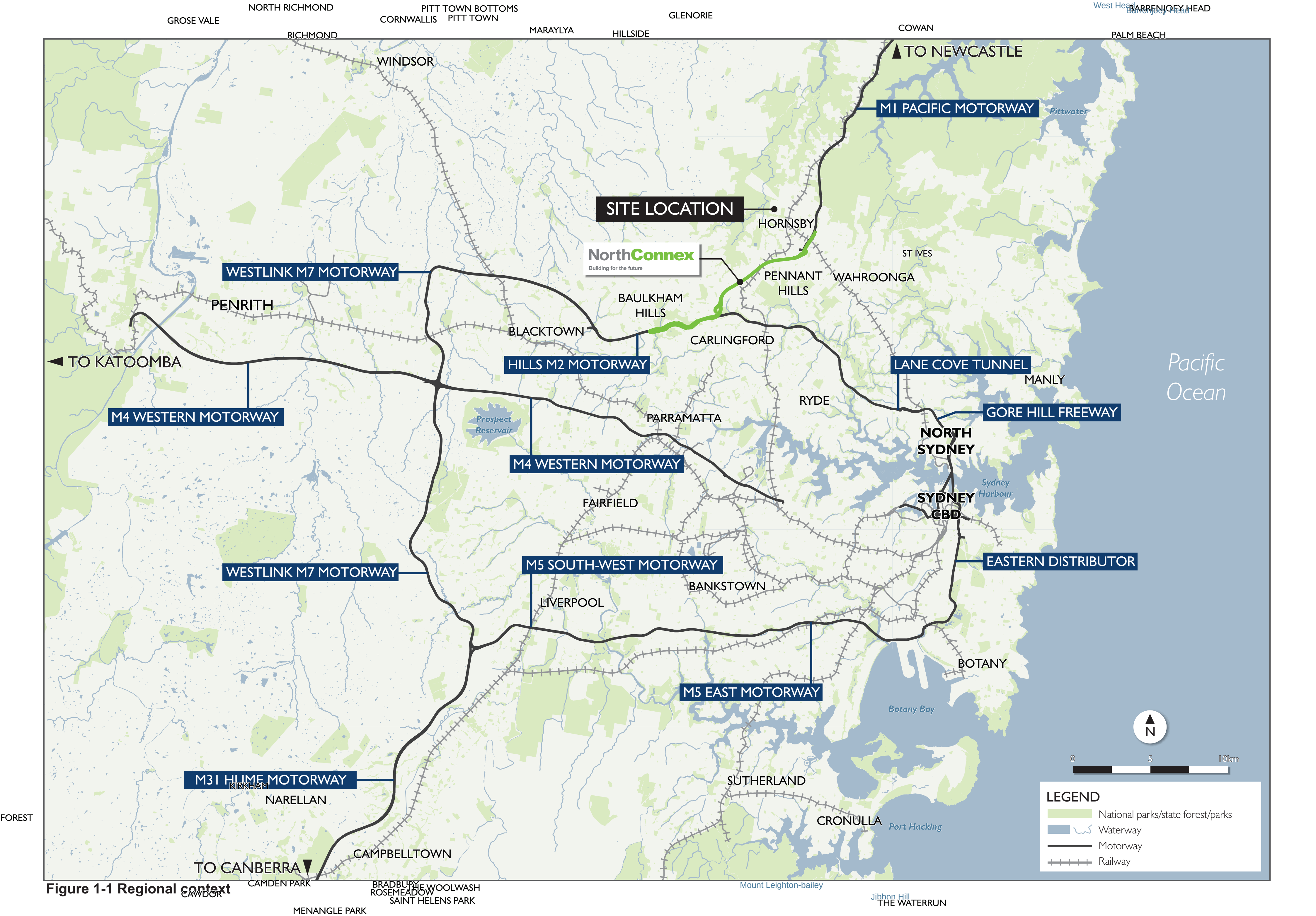

Figure 1-1 Regional context

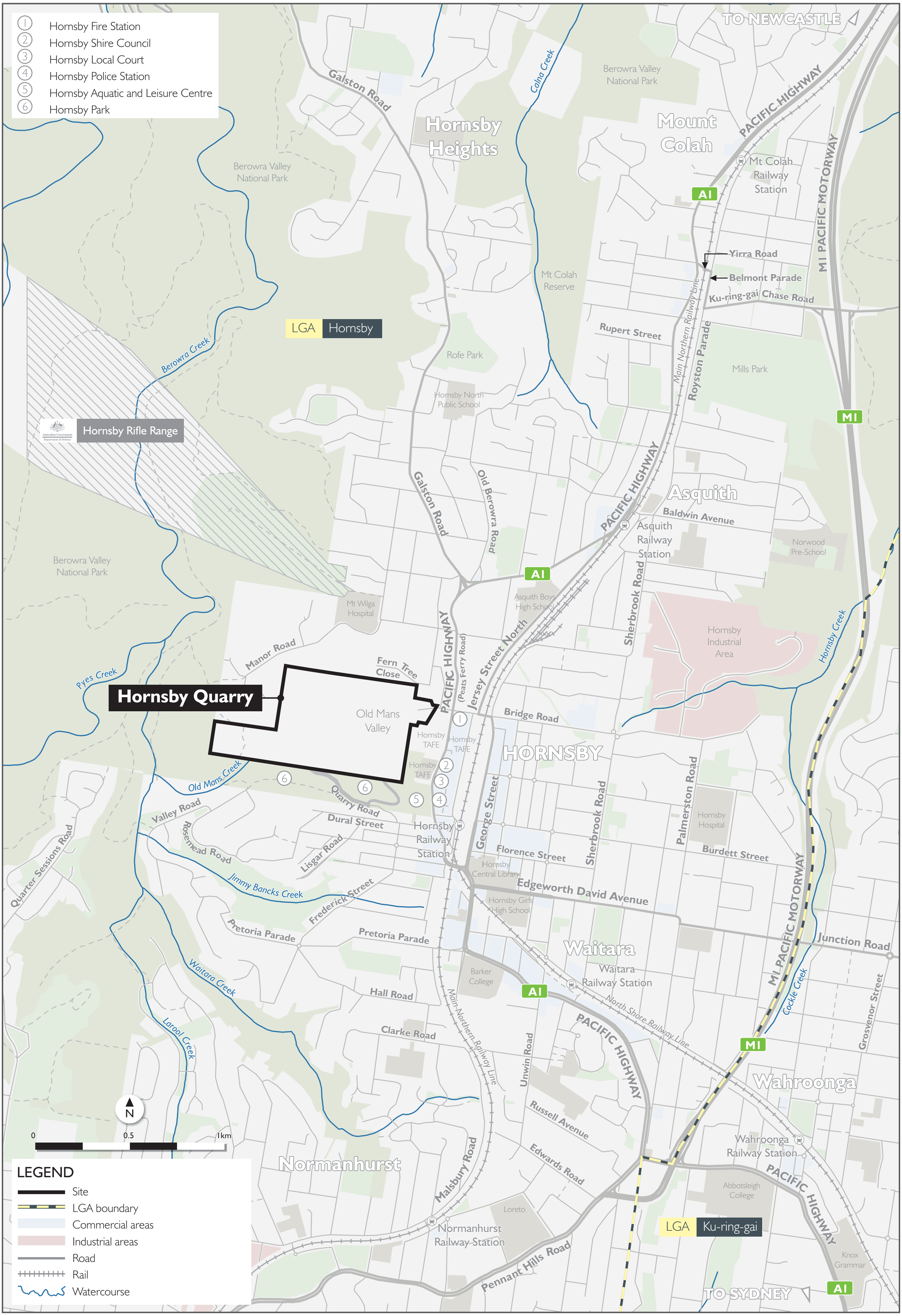

Figure 1-2 Local and site context

Figure 1-3 Indicative Site layout

1.4 Objectives

The overall objective of the HHRA presented in this technical working paper is to assess health risks associated with the following:

- Emissions to air and exposures in the local community (principally dust) as a result of the proposed project.
- Noise and vibration, as a result of the project.

The assessment presented has considered both short-term/acute and long-term/chronic risks to surrounding communities, based on outcomes presented in the air quality, noise and vibration technical working papers that have been completed as part of the environmental impact statement.

1.5 Approach to Human Health Risk Assessment

1.5.1 What is a risk assessment?

Risk

Risk assessment is used extensively in Australia and overseas to assist in decision making on the acceptability of the risks associated with the presence of contaminants in the environment and evaluation of projects with potential risks to the public. Risk is commonly defined as the chance of injury, damage, or loss. Therefore, to put oneself or the environment "at risk" means to participate, either voluntarily or involuntarily, in an activity or activities that could lead to injury, damage, or loss.

Voluntary risks are those associated with activities that we decide to undertake such as driving a vehicle, riding a motorcycle and smoking cigarettes.

Involuntary risks are those associated with activities that may happen to us without our prior consent or forewarning. Acts of nature such as being struck by lightning, fires, floods, tornados, etc, and exposures to environmental contaminants are examples of involuntary risks.

Defining risk

Risks to the public and the environment are determined by direct observation or by applying mathematical models and a series of assumptions to infer risk. No matter how risks are defined or quantified, they are usually expressed as a probability of adverse effects associated with a particular activity. Risk is typically expressed as a likelihood of occurrence and/or consequence (such as negligible, low or significant) or quantified as a fraction of, or relative to, an acceptable risk number.

Risks from a range of facilities (e.g. industrial or infrastructure) are usually assessed through qualitative and/or quantitative risk assessment techniques. In general, risk assessments seek to identify all relevant hazards; assess or quantify their likelihood of occurrence and the consequences associated with these events occurring; and provision of an estimate of the risk levels for people who could be exposed, including those beyond the perimeter boundary of a facility.

1.5.2 Overall approach

The methodology adopted for this HHRA is in accordance with national and international guidance that is endorsed/accepted by Australian health and environmental authorities, and includes:

- EnHealth Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards: 2012 (enHealth 2012a);
- EnHealth Health Impact Assessment Guidelines: September 2001 (enHealth 2001);
- EnHealth Exposure Factors Guide, EnHealth Council, 2012 (enHealth 2012b);
- National Environment Protection Council (NEPC) Schedule B(8) Guideline on Community Consultation and Risk Communication, National Environment Protection (Assessment of Site Contamination) Measure, 1999 (NEPC 1999 amended 2013);
- NEPC National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure, 2003 (NEPC 2003); and
- United States Environment Protection Agency (USEPA) Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment), EPA-540-R-070-002, January 2009 (USEPA 2009a).

More specifically in relation to the assessment of health impacts associated with exposure to particulates, guidelines available from the NEPC ((Burgers & Walsh 2002; NEPC 1998, 2002, 2003, 2009, 2010), World Health Organisation (Ostro 2004; WHO 2003, 2006b; 2006a, {Ostro, 2004 #861; 2013) and the USEPA (USEPA 2005, 2009b) have been used as required.

The methodology used for the conduct of the HHRA presented in this report is consistent with that undertaken for the assessment of the NorthConnex Project (the project from which materials being handled in this project are derived).

In following this guidance, the following tasks have been completed and are presented in this technical working paper.

Data evaluation and issue identification

This task involves a review of all available information that relates to the proposed design and outcomes from relevant specialist studies undertaken in relation to air quality, noise and vibration. Specifically the assessment has considered existing conditions (in relation to air quality and noise) and estimation of short-term (acute) and long-term (chronic) impacts during the project.

This aspect of the assessment also considers the available guidelines for air quality and noise, whether these guidelines are based on the protection of community health, and if a more detailed evaluation of specific impacts is required. The HHRA has considered a more detailed evaluation of exposures to particulate emissions within the surrounding community.

Exposure assessment

This involves the identification of populations located in the vicinity of the project that may be exposed to impacts from the project. The existing air and noise environments as well as the health of the existing population has been considered in relation to the key health endpoints, relevant to the assessment of exposures to particulate matter, that require further detailed consideration in this assessment. The assessment of potential particulate matter exposure has considered both short-term (acute) and chronic inhalation exposures relevant to the project.

Toxicity assessment

The objective of the toxicity assessment is to identify the adverse health effects and quantitative toxicity values or exposure-response relationships that are associated with the key pollutants that have been identified and evaluated as part of this assessment. This has been applied to the assessment of exposures to particulate matter where the following has been undertaken:

1. Identify the adverse health effects associated with exposure to particulate matter. Based on the available information, the most robust health endpoints (effects or outcomes) for the assessment of inhalation exposure to particulate matter (assessed over different size fractions) have been identified. The most robust health endpoints are where a relationship has been established between exposure to particulate matter and a specific health endpoint (effect/outcome).

2. Identify the most relevant and robust exposure-response relationship for the quantitative assessment of exposure to particulate matter. The exposure-response relationships are derived from published peer reviewed sources and relate to the identified health endpoints (effects/outcomes).

For other air pollutants national guidelines based on the protection of health have been adopted.

Risk characterisation

Risks have been characterised using quantitative and qualitative assessment methods. The quantitative assessment of potential exposure to particulate emissions from the project combined with information on exposure (i.e. what additional concentrations of particulate matter would be present in the community as a result of the project) and the exposure-response relationships relevant for the health-endpoints (effect) has been used. This enables an assessment of an increased annual risk and an increased incidence of the effect occurring within the population of concern.

In some cases a qualitative assessment has been undertaken. A qualitative assessment does not specifically require the quantification of risk or exposure. Rather the assessment provides a relative or comparative evaluation of whether the exposure or impact considered is unacceptable in the local population.

The assessment presented has also considered the level of uncertainty associated with all aspects of the technical studies relied on for the conduct of the HHRA and within the HHRA. The final determination of risks to human health will be based on the quantification of risks as well as consideration of these uncertainties.

The overall approach is outlined in **Figure 1-4.**

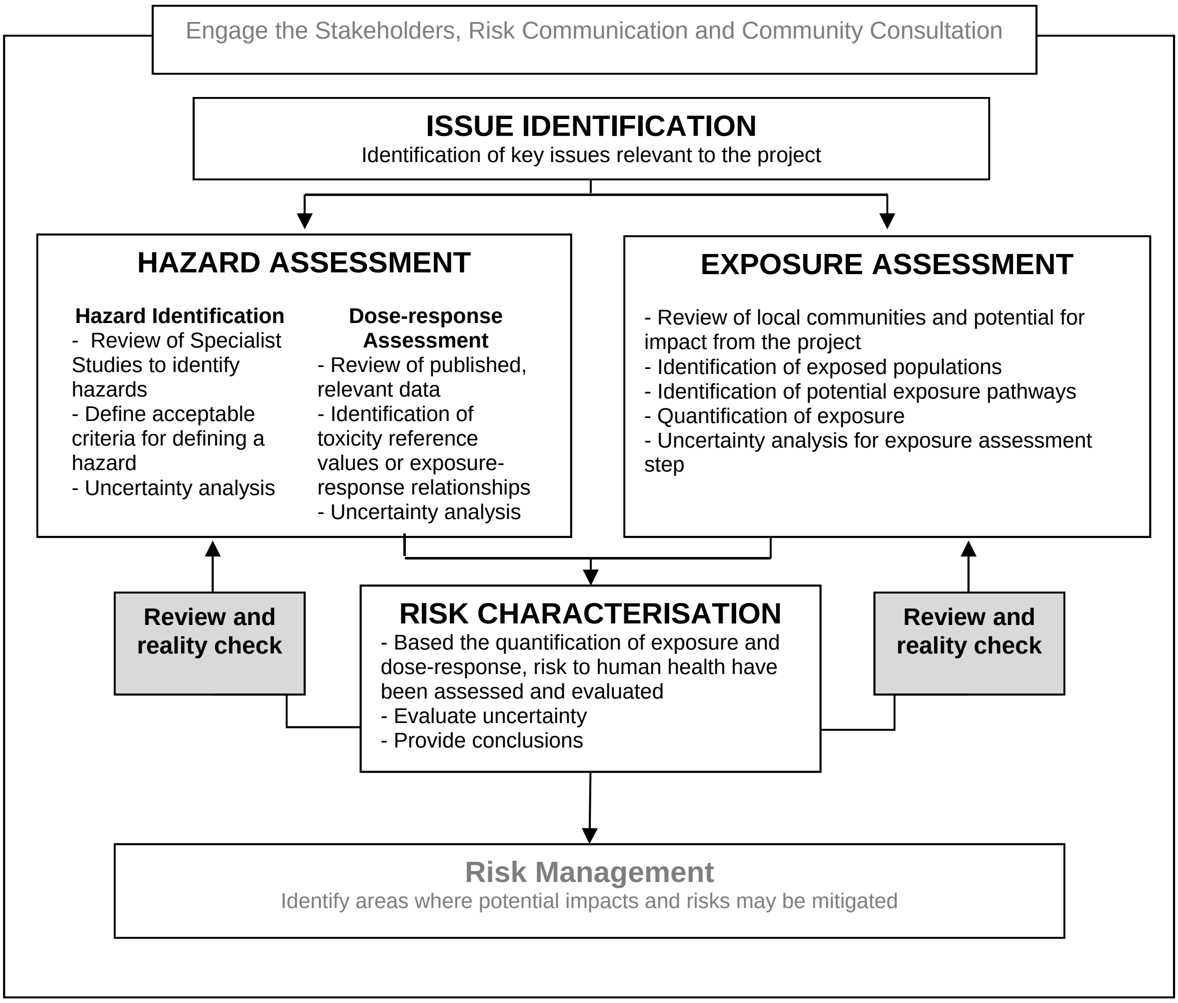

Figure 1-4 Overall human health risk assessment approach (modified from enHealth, 2012)

1.5.3 Features of the risk assessment

The HHRA has been carried out in accordance with international best practice and general principles and methodology accepted in Australia by groups such as NHMRC, NEPC and enHealth. There are certain features of risk assessment methodology that are fundamental to the assessment of the outputs and to drawing conclusions on the significance of the results. These are summarised below:

- A risk assessment is a tool (that is systematic) that addresses potential exposure pathways based on an understanding of the nature and extent of the impact assessed and the uses of the local area by the general public. The risk assessment is based on an estimation of maximum, or worst-case, ground level concentrations modelled in the local community and hence is expected to overestimate the actual risks.
- Conclusions can only be drawn with respect to emissions to air derived from the project as outlined in this technical working paper.
- Available statistics in relation to the existing health status of the existing community are presented in the technical working paper; however the HHRA does not provide an evaluation of the overall health status of the community or any individuals. Rather, it is a logical process of calculating and comparing potential exposure concentrations (acute and chronic) in surrounding areas (associated with the project) with regulatory and published acceptable air concentrations that any person may be exposed to over a lifetime without unacceptable risk to their health. It can also involve calculating an incremental impact that can be evaluated in terms of an acceptable level of risk.
- The risk assessment reflects the current state of knowledge regarding the potential health effects of chemicals identified and evaluated in this assessment. This knowledge base may change as more insight into biological processes is gained, further studies are undertaken and more detailed and critical review of information is conducted.

This assessment does not address all the health impacts, both positive and negative, associated with the project. Rather the assessment presented in this technical working paper has focused on key impacts (negative impacts) to air quality and noise/vibration as requiring detailed consideration within the EIS.

Section 2. Project description

2.1 General

This section presents an overview of the project being considered in this technical working paper. The details presented are only a summary. Full details are presented in the EIS.

The Hornsby Quarry site would receive up to 1.5 million cubic metres of excavated natural material (ENM) and/or virgin excavated natural material (VENM) from the approved NorthConnex construction sites. Only ENM and/or VENM would be received and reused at the Hornsby Quarry site.

Key features of the project would include:

- Widening and sealing of the quarry access road (Bridge Road and track) to facilitate all weather access.
- Clearing and grubbing, and establishment of erosion and sediment controls.
- Establishment of a compound site, security fencing and signage around the works area.
- Dewatering of the void (to be undertaken by Hornsby Council in accordance with its existing groundwater licence) to a suitable level that allows working within the void.
- Construction of a conveyor from the stockpile site to the rim of the quarry void.
- Spoil haulage by truck from the NorthConnex construction sites to the Hornsby Quarry site over a period of approximately 28 months.
- Stockpiling of spoil at stockpile sites within the Hornsby Quarry site using dozers.
- Transport of the spoil via the conveyor from the stockpiles to the rim of the quarry void, where the spoil would fall directly into the void.
- Spreading and grading of the spoil on the quarry floor.
- Site demobilisation and rehabilitation of the compound site, stockpile areas and the conveyer corridor.

The project is anticipated to commence in late 2015 and is expected to take around 33 months to complete.

Detailed descriptions of each activity can be found in Section 4.1 of the EIS for the project.

An indicative project program is provided in **Table 2-1.**

Table 2-1 Indicative program

Activity	Indicative timeframe															
	2015				2016				2017				2018			
Site establishment works				■												
Establishment of conveyer					■											
Spoil haulage and stockpiling					■	■	■	■	■	■	■	■	■	■		
Spoil emplacement (operation of conveyor)						■	■	■	■	■	■	■	■	■	■	
Site clean-up and demobilisation														■	■	

2.2 Project activities

Project activities would generally include:

- Site establishment.
- Maintenance pumping of the quarry void for the duration of the works.
- Conveyor construction works, involving construction of a conveyor from the stockpile site to the rim of the void.
- Spoil haulage from the NorthConnex project by truck and stockpiling at the Hornsby Quarry site.
- Spoil emplacement activities, following the completion of the conveyor construction works.
- Site demobilisation and rehabilitation at the completion of the emplacement activities.

An overview of the activities associated with the project is provided in **Table 2-2**. Detailed descriptions of each project activity can be found in section 4.1 of the EIS for the project.

Table 2-2 Overview of project works

Component	Typical activities
Site establishment (including preparatory works)	The following works would be completed: - Dewatering of the void to a suitable working level - Clearing and grubbing, and establishment of erosion and sediment controls - Establishment of a compound site - Establishment of security fencing and signage around the compound site - Widening and sealing of the currently unsealed quarry access road (Bridge Road) to facilitate all weather access.
Establishment of conveyor	The construction of the conveyor works would include establishment of footings and the conveyor and would occur concurrently with the establishment of the site.
Spoil haulage and stockpiling	Trucks would enter and leave via Bridge Road during standard work hours over a maximum period of 28 months. Spoil would be unloaded from the haulage trucks and stockpiled using dozers. It is expected that this activity would commence whilst the conveyer is still being constructed.
Spoil emplacement	Once the conveyer is constructed, these works would occur concurrently with spoil haulage and stockpiling activities, but would also continue for a period after the completion of spoil haulage onto the site. The activities include: - Placement of spoil from the stockpiles into the conveyor by front end loader - Transport of the spoil via overhead conveyor to the quarry void rim where the spoil would fall directly into the void - Front-end loaders and articulated trucks would move the spoil along the quarry floor and dozers and rollers would spread the material. Periodic maintenance pumping of water from the void would be conducted.

Component	Typical activities
Site demobilisation and rehabilitation	The compound and conveyor would be dismantled and removed from the site. Disturbed areas would be rehabilitated to a standard agreed with the Council. Security fencing would be removed, however would be retained around the quarry void if the void is deemed to remain an ongoing risk to public safety. Public access would then be reinstated to the areas outside the void exclusion zone.

2.3 Project hours

Works would be undertaken in accordance with the Interim Construction Noise Guideline (ICNG) recommended standard work hours, as presented below:

- 7am to 6pm Monday to Friday.
- 8am to 1pm Saturdays.
- No works on Sundays or Public Holidays.

Whilst no works are anticipated to occur outside of standard hours there may be circumstances where out-of-hours activities associated with the project are necessary. Activities which may be undertaken outside of standard daytime hours (in accordance with Section 2.3 of the ICNG) would include the following circumstances:

- The delivery of materials or oversized plant as required by the Police or other authorities for safety reasons.
- Where it is required to avoid the loss of lives, property and / or to prevent environmental harm in an emergency.
- Activities which are determined to comply with the relevant Noise Management Level (NML) at the most affected sensitive receiver.
- Where agreement is reached with affected receivers.

Out of hours work may also be undertaken where explicitly approved through an Environment Protection Licence.

2.4 Haulage routes

The expected haulage routes to and from the Hornsby Quarry site have been identified in consultation with the NorthConnex construction contractor, Hornsby Shire Council and Roads and Maritime with the aim of minimising potential impacts on the community. Expected haulage routes are identified below. These routes would be subject to further investigation as part of detailed design.

- Haulage from spoil locations south of Pennant Hills Road / M1 Motorway intersection:
    - **In:** Pacific Highway from the intersection with Pennant Hills Road, then along George Street and onto Bridge Road.
    - **Out (non-peak hours):** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road.
    - **Out (peak hours):** out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

- Haulage from spoil locations north of Pennant Hills Road / M1 Motorway intersection:
    - **In:** From the Mt Colah M1 Pacific Motorway exit, a U-turn via Ku-ring-gai Chase Road back onto the M1 Pacific Motorway to travel south, then taking the exit onto the A1 (Pacific Highway), turning right and traveling along Pacific Highway as per the southern haulage route (Pacific Highway, George Street and into Bridge Road).
    - **Out (non-peak hours):** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road and back on the M1 Pacific Motorway.
    - **Out (peak hours):** out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

Vehicles during site preparation and establishment would also use the above traffic routes. Only light vehicles (for site personnel) and delivery trucks would access the site (in and out) via Quarry Road. There may be instances, however, when heavy vehicles would be required to access the site from Quarry Road, namely during an emergency and where entry and/or exit via Bridge Road is impeded due to vehicle breakdown.

2.5 Onsite activities

At the peak of site activities (year 2017) a total of 35 trucks per hour hauling 12 bank cubic metres (bcm) of spoil per load would be transported to the temporary stockpile area in the eastern portion of the Hornsby Quarry site. From the stockpiles on the flats, spoil would then be transported via conveyor to the void of the former Hornsby Quarry. A summary of the spoil handling activities onsite is presented in **Figure 2-1**.

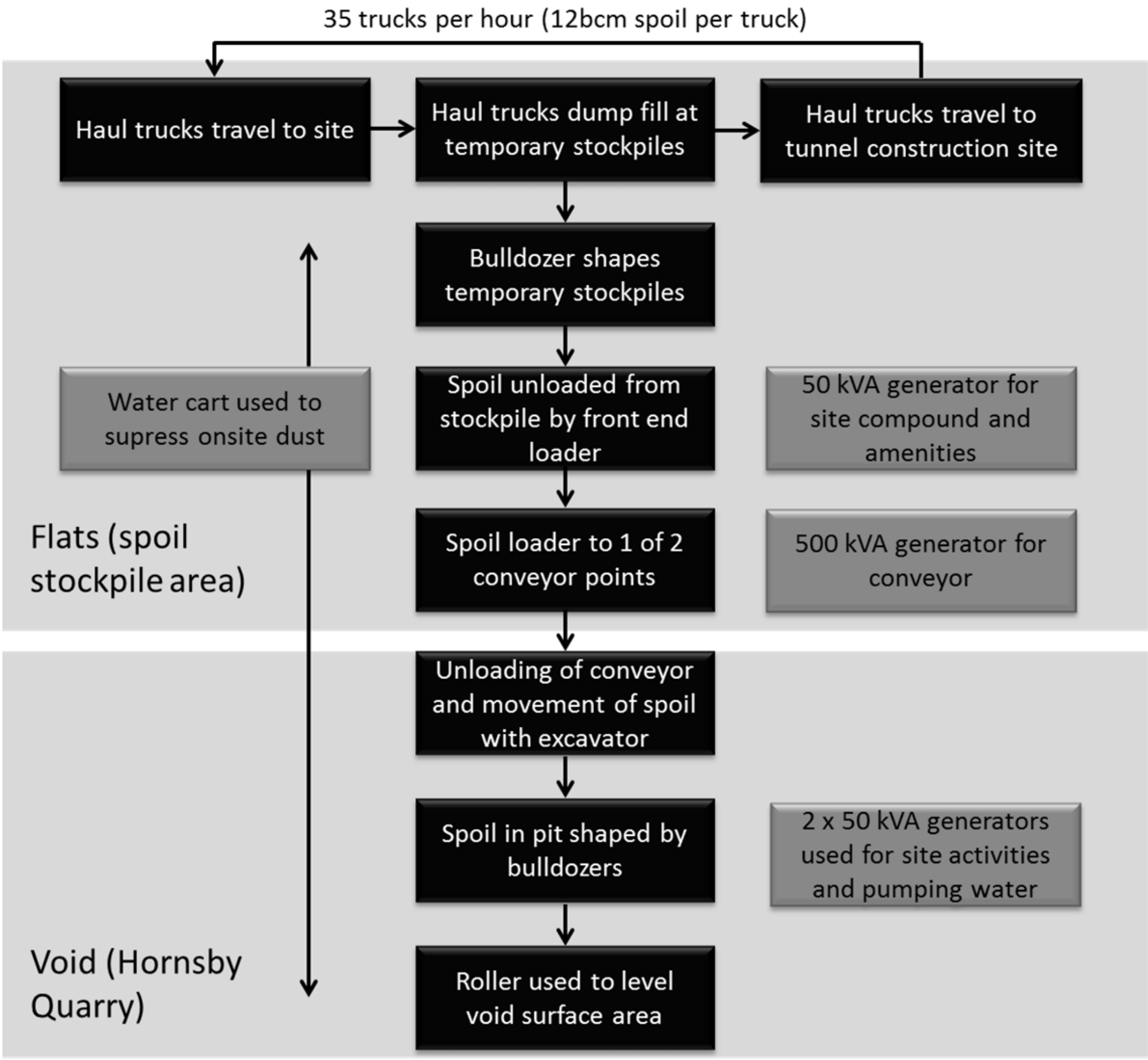

Figure 2-1 Onsite works at the Spoil Management Facility

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