ACOUSTICS AND AIR

SYDNEY ZOO

AIR QUALITY IMPACT ASSESSMENT

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PREPARED FOR

SYDNEY ZOO
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WILKINSON MURRAY

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TABLE OF CONTENTS

GLOSSARY OF AIR QUALITY TERMS

Air Pollution – The presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects.

Air Quality Standards – The level of pollutants prescribed by regulations that are not to be exceeded during a given time in a defined area.

Air Toxics – Any air pollutant for which a national ambient air quality standard (NAAQS) does not exist (i.e. excluding ozone, carbon monoxide, PM-10, sulphur dioxide, nitrogen oxide) that may reasonably be anticipated to cause cancer; respiratory, cardiovascular, or developmental effects; reproductive dysfunctions, neurological disorders, heritable gene mutations, or other serious or irreversible chronic or acute health effects in humans.

Airborne Particulates – Total suspended particulate matter found in the atmosphere as solid particles or liquid droplets. Chemical composition of particulates varies widely, depending on location and time of year. Sources of airborne particulates include dust, emissions from industrial processes, combustion products from the burning of wood and coal, combustion products associated with motor vehicle or non-road engine exhausts, and reactions to gases in the atmosphere.

Area Source – Any source of air pollution that is released over a relatively small area, but which cannot be classified as a point source. Such sources may include vehicles and other small engines, small businesses and household activities, or biogenic sources, such as a forest that releases hydrocarbons, may be referred to as nonpoint source.

Concentration – The relative amount of a substance mixed with another substance. Examples are 5 ppm of carbon monoxide in air and 1 mg/l of iron in water.

Emission – Release of pollutants into the air from a source. We say sources emit pollutants.

Emission Factor – The relationship between the amount of pollution produced and the amount of raw material processed. For example, an emission factor for a blast furnace making iron would be the number of pounds of particulates per ton of raw materials.

Emission Inventory – A listing, by source, of the amount of air pollutants discharged into the atmosphere of a community; used to establish emission standards.

Flow Rate – The rate, expressed in gallons -or litres-per-hour, at which a fluid escapes from a hole or fissure in a tank. Such measurements are also made of liquid waste, effluent, and surface water movement.

Fugitive Emissions – Emissions not caught by a capture system.

Hydrocarbons (HC) – Chemical compounds that consist entirely of carbon and hydrogen.

Hydrogen Sulphide (H_2S) – Gas emitted during organic decomposition. Also, a by-product of oil refining and burning. Smells like rotten eggs and, in heavy concentration, can kill or cause illness.

Inhalable Particles – All dust capable of entering the human respiratory tract.

Nitric Oxide (NO) – A gas formed by combustion under high temperature and high pressure in an internal combustion engine. NO is converted by sunlight and photochemical processes in ambient air to nitrogen oxide. NO is a precursor of ground-level ozone pollution, or smog.

Nitrogen Dioxide (NO_2) – The result of nitric oxide combining with oxygen in the atmosphere; major component of photochemical smog.

Nitrogen Oxides (NO_x) – A criteria air pollutant. Nitrogen oxides are produced from burning fuels, including gasoline and coal. Nitrogen oxides are smog formers, which react with volatile organic compounds to form smog. Nitrogen oxides are also major components of acid rain.

Mobile Sources – Moving objects that release pollution; mobile sources include cars, trucks, buses, planes, trains, motorcycles and gasoline-powered lawn mowers.

Particulates; Particulate Matter (PM-10) – A criteria air pollutant. Particulate matter includes dust, soot and other tiny bits of solid materials that are released into and move around in the air. Particulates are produced by many sources, including burning of diesel fuels by trucks and buses, incineration of garbage, mixing and application of fertilizers and pesticides, road construction, industrial processes such as steel making, mining operations, agricultural burning (field and slash burning), and operation of fireplaces and woodstoves. Particulate pollution can cause eye, nose and throat irritation and other health problems.

Parts Per Billion (ppb)/Parts Per Million (ppm) – Units commonly used to express contamination ratios, as in establishing the maximum permissible amount of a contaminant in water, land, or air.

PM10/PM2.5 – PM10 is measure of particles in the atmosphere with a diameter of less than 10 or equal to a nominal 10 micrometers. PM2.5 is a measure of smaller particles in the air.

Point Source – A stationary location or fixed facility from which pollutants are discharged; any single identifiable source of pollution; e.g. a pipe, ditch, ship, ore pit, factory smokestack.

Scrubber – An air pollution device that uses a spray of water or reactant or a dry process to trap pollutants in emissions.

Source – Any place or object from which pollutants are released.

Stack – A chimney, smokestack, or vertical pipe that discharges used air.

Stationary Source – A place or object from which pollutants are released and which does not move around. Stationary sources include power plants, gas stations, incinerators, houses etc.

Temperature Inversion – One of the weather conditions that are often associated with serious smog episodes in some portions of the country. In a temperature inversion, air does not rise because it is trapped near the ground by a layer of warmer air above it. Pollutants, especially smog and smog-forming chemicals, including volatile organic compounds, are trapped close to the ground. As people continue driving and sources other than motor vehicles continue to release smog-forming pollutants into the air, the smog level keeps getting worse.

1 INTRODUCTION

1.1 Project Background

Sydney Zoo is seeking approval under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the construction of a zoo (Sydney Zoo) within the Bungarribee Precinct in the Western Sydney Parklands.

The project was declared to be State Significant Development (SSD). Assessment and approval is being pursued in accordance with the EP&A Act. The Secretary's Environmental Assessment Requirements (SEARs) for the project have been issued and set out the environmental assessment requirements for the project.

This Air Quality Impact Assessment (AQIA) has been prepared to address the relevant SEARs in relation to the preparation of the Environmental Impact Statement (EIS) for the project, and was conducted in general accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005).

1.2 The Project

The proposed development of Sydney Zoo will include:

- Animal exhibits across several enclosures of varying design for a range of native and exotic animals.
- Back-of-house buildings for exhibits.
- Main entrance building comprising entry/exit, and gift shop.
- Restaurant and café.
- Kiosks and amenities.
- Show arena.
- Picnic areas and gardens.
- Wetlands and waterways.
- Service building containing:
    - Administration areas;
    - Curatorial and food preparation areas; and,
    - Veterinarian space.
- Service yard with maintenance shelter.
- Main car park for approximately 475 vehicles, with an overflow car park for approximately 800 vehicles, accessed via an internal road connecting to the Great Western Highway.
- Bus parking.

Construction of the project is expected to take approximately 8 – 12 months to complete.

2 SITE DESCRIPTION

2.1 Site Location

The site is located approximately 33 kilometres west of the Sydney Central Business District, and approximately 15 kilometres east of Penrith. It falls within the Western Sydney Parklands, and is in close proximity to the Great Western Highway, M4 Western Motorway, and Westlink M7, providing excellent access to both the state and regional road network and surrounding parkland areas.

The project site is 16.5 hectares in size, and irregular in shape. Access will be from the Great Western Highway, approximately 75 metres from the southern border of the project site.

The site location is shown in Figure 2-1.

Figure 2-1 Site Location

2.2 Surrounding Land Use and Sensitive Receptors

To the north of the site is the residential suburb of Bungarribee, approximately 700 metres away, with separation via Bungarribee Creek which meanders through the parklands. Numerous sensitive receptors are located in this area.

The Arndell Park industrial estate is to the east of the site. This estate contains a large number of industrial businesses, none of which are identified as sensitive receptors in this assessment.

To the south, across the Great Western Highway, sit additional industrial development in Huntingwood, again with a mixture of industrial and warehouse type businesses. A number of isolated residential dwellings are located to the south of the site, the nearest of which is Lot 1 Great Western Highway (R1), approximately 250 metres away.

Westlink M7 Motorway is to the west of the site, providing a strong border to the parklands. A portion of the suburb of Eastern Creek is located to the west of the site and contains sensitive residential receptors within approximately 800 metres of the site.

The nearest sensitive receptors identified for this assessment are presented in Table 2-1 and shown in Figure 2-2.

Table 2-1 Sensitive Receptors

Receptor / Catchment	Distance (m)
Bungarribee	> 700
Lot 1 Great Western Highway, Eastern Creek (R1)	250
Eastern Creek	> 800

Figure 2-2 Sensitive Receptors

3 AIR QUALITY CRITERIA

3.1 Introduction

The NSW EPA's *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005) sets out applicable impact assessment criteria for a number of air pollutants.

Air quality criteria are benchmarks set to protect the general health and amenity of the community in relation to air quality. The sections below identify the pollutants of interest in this study and the application air quality criteria for each pollutant.

3.2 Pollutants of Interest

Potential pollutants identified for this development with the potential to result in air quality impacts include odour and dust.

A number of potential odour sources associated with the operation of the project have been identified. Therefore the assessment of potential odour impacts from the project is the primary focus of this investigation.

In addition to operational odour impacts, the potential for dust impacts during the construction of the project is also investigated.

3.3 Impact Assessment Criteria

3.3.1 Odour

NSW legislation prohibits emissions that cause offensive odour to occur at any off-site receptor. Offensive odour is evaluated in the field by authorised officers, who are obliged to consider the odour in the context of its receiving environment, frequency, duration, character and so on and to determine whether the odour would unreasonably interfere with the comfort and repose of the normal person. In this context, the concept of offensive odour is applied to operational facilities and relates to actual emissions in the air.

However, in the approval and planning process for proposed new operations or modifications to existing projects, no actual odour exists and it is necessary to consider hypothetical odour. In this context, odour concentrations are used and are defined in odour units. The number of odour units represents the number of times that the odour would need to be diluted to reach a level that is just detectable to the human nose. Thus by definition, odour less than one odour unit (1 OU), would not be detectable to most people.

The range of a person's ability to detect odour varies greatly in the population, as does their sensitivity to the type of odour. Therefore there can be a wide range of variability in the way odour response is interpreted. As a result the assessment of odour impacts and the application of specific air quality goals related to odour is a challenging aspect of air science.

It should be noted that odour refers to complex mixtures of odours, and not 'pure" odour arising from a single chemical. Odour from a single, known chemical very rarely occurs (when it does, it is best to consider that specific chemical in terms of its concentration in the air). In most situations, odour will be comprised of a cocktail of many substances that is referred to as a complex mixture of odorous pollutants, or more simply odour.

For developments with potential for odour it may be necessary to predict the likely odour impact that may arise. This is done by using air dispersion modelling which can calculate the level of dilution of odours emitted from the source at the point that it reaches surrounding receptors. This approach allows the air dispersion model to produce results in terms of odour units.

The NSW criteria for acceptable levels of odour range from 2 to 7 OU, with the more stringent 2 OU criteria applicable to densely populated urban areas and the 7 OU criteria applicable to sparsely populated rural areas, as outlined below.

Table 3-1 presents the relevant impact assessment criteria for complex mixtures of odorous pollutants.

Table 3-1 Impact assessment criteria – complex mixtures of odorous pollutants

Population of affected community	Impact assessment criteria (OU)*
Urban (≥~2000) and/or schools and hospitals	2.0
~500	3.0
~125	4.0
~30	5.0
~10	6.0
Single rural residence (≤~2)	7.0

Note: * 99^{th} percentile nose-response time.

Considering the population in close proximity to the site, an impact assessment criterion of 2.0 OU/m^3 has been adopted for this development.

3.3.2 Dust and Particulate Matter

The EPA Approved Methods specifies air quality assessment criteria for assessing impacts from dust generating activities. These criteria are consistent with the National Environment Protection Measures for Ambient Air Quality (NEPC, 1998).

Table 3-2 summarises the air quality goals for dust and particulate matter that are relevant to this study. The air quality goals relate to the total concentrations of dust and particulate matter in the air and not just that from the project. Therefore, some consideration of background levels needs to be made when using these goals to assess impacts.

Table 3-2 Impact assessment criteria – dust and particulate matter

Pollutant	Averaging period	Impact	Criteria
Total suspended particulates (TSP)	Annual	Total	90 $\mu g/m^3$
Particulate matter ≤10 µm (PM_{10})	Annual	Total	30 $\mu g/m^3$
	24-hour	Total	50 $\mu g/m^3$
Deposited dust (DD)	Annual	Total	4 g/m^2/month
	Annual	Incremental	2 g/m^2/month

There are currently no air quality goals for particulate matter ≤ 2.5 µm ($PM_{2.5}$) for projects within NSW. However, the National Environmental Protection Council (NEPC) has developed an advisory National Environmental Protection Measure (NEPM) for $PM_{2.5}$, as follows:

- A maximum 24 hour average concentration of 25 µg/m^3; and,
- An annual average concentration of 8 µg/m^3.

The above goals for $PM_{2.5}$ concentrations are considered advisory only.

4 EXISTING ENVIRONMENT

4.1 Local Climate

Long term meteorological data for the area surrounding the project site is available from the Bureau of Meteorology (BOM) operated Automatic Weather Station (AWS) at the Horsley Park Equestrian Centre. The Horsley Park Equestrian Centre AWS is located approximately 7 kilometres south of the project site and records observations of a number of meteorological data including temperature, humidity, rainfall, wind speed and wind direction.

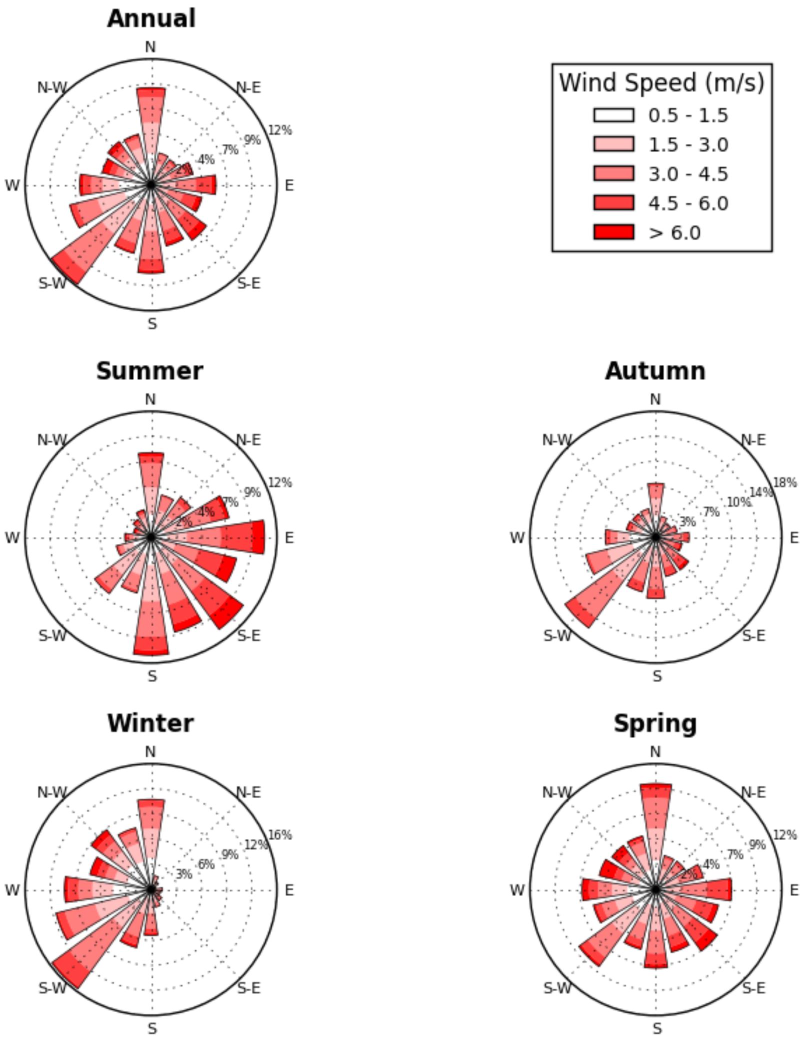
Long-term climate statistics are presented in Table 4-1. Temperature data recorded at the Horsley Park Equestrian Centre AWS indicates that January is the hottest month of the year, with a mean daily maximum temperature of 29.8°C. July is the coolest month with a mean daily minimum temperature of 5.8°C. February is the wettest month with an average rainfall of 112 mm falling over almost 8 days. There are on average 77 rain days per year, delivering 770 mm of rain.

Table 4-1 Long-term climate averages – Horsley Park Equestrian Centre AWS

Observation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
9am Mean Observations													
Temperature (°C)	22.0	21.5	19.4	17.5	13.8	11.1	10.3	12.0	15.6	18.1	19.2	20.9	16.8
Humidity (%)	73	77	81	76	77	80	78	70	65	61	70	71	73
3pm Mean Observations													
Temperature (°C)	28.2	27.1	25.3	22.2	19.2	16.6	16.1	17.8	20.8	22.5	24.2	26.5	22.2
Humidity (%)	49	53	54	53	52	55	50	42	42	45	50	48	49
Daily Minimum and Maximum Temperatures													
Minimum (°C)	17.7	17.8	15.9	12.8	9.0	7.1	5.8	6.5	9.4	11.6	14.4	16.1	12.0
Maximum (°C)	29.8	28.6	26.7	23.5	20.3	17.6	17.2	19.1	22.5	24.6	26.3	28.0	23.7
Rainfall													
Rainfall (mm)	71.1	111.7	74.3	81.8	48.7	65.4	38.3	38.6	34.9	57.5	82.9	65.1	770.2
Rain days	7.7	7.4	7.5	7.7	5.6	6.3	5.5	4.4	4.9	5.7	7.3	7.1	77.1

Windrose plots showing the distribution of wind direction and wind speed at the Horsley Park Equestrian Centre AWS between 2009 and 2014 are presented in Figure 4-1.

Figure 4-1 Windroses – Horsley Park Equestrian Centre AWS, 2009 – 2014



4.2 Local Ambient Air Quality

4.2.1 Odour

Potential existing sources of odour in the area surrounding the project site are the Arnott's biscuit factory in Huntingwood, and the Eastern Creek Landfill.

The Arnott's biscuit factory is located approximately 1,000 metres to the south east of the project site, and according to some local residents, produces a noticeable odour from time to time. The Eastern Creek Landfill is located approximately 2,500 metres south of the project site and according to some local residents, produces a noticeable odour from time to time.

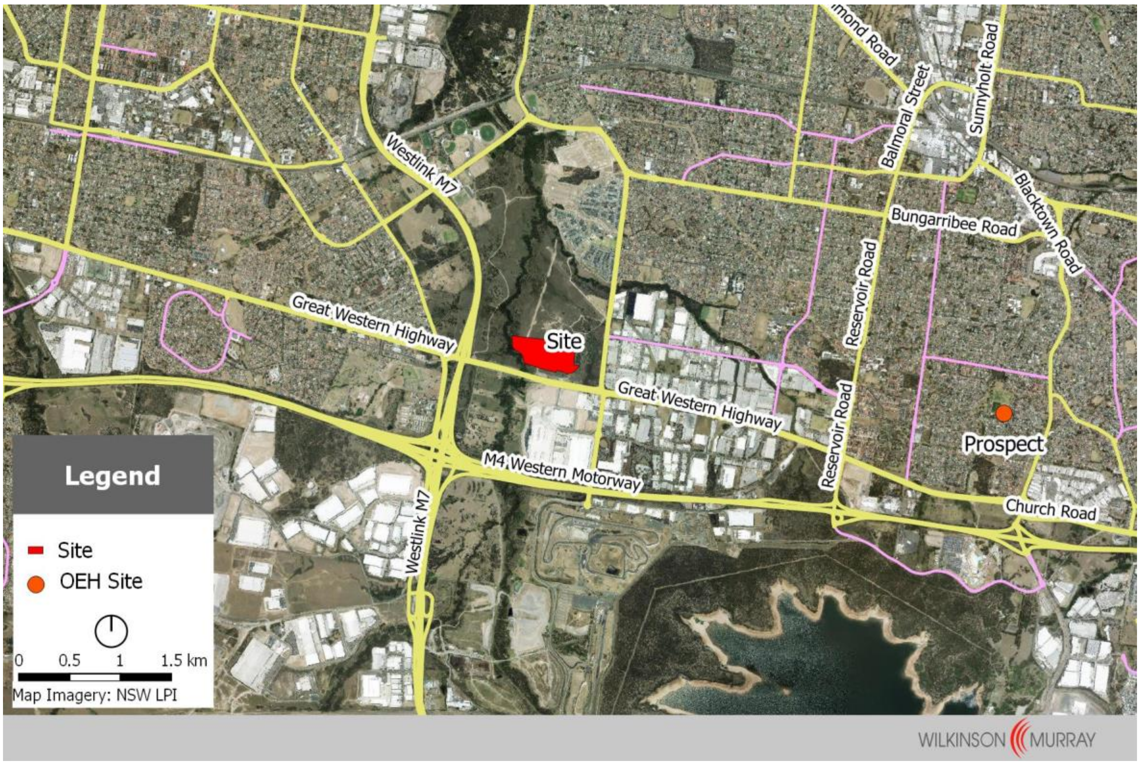
No publicly available information could be found which quantifies the extent of odour emissions from either the biscuit factory or landfill site.

Figure 4-2 Existing Potential Odour Sources

4.2.2 Dust and Particulate Matter

Air Quality monitoring data from the Office of Environment and Heritage (OEH) air quality monitoring site at Prospect has been used to characterise the ambient air quality in the area surrounding the project site. The OEH's Prospect site is located approximately 4.5 kilometres east of the project site, as shown in Figure 4-3.

Figure 4-3 OEH Air Quality Monitoring Site - Prospect



A summary of the PM_{10} monitoring results from 2012 to 2014 collected at the Prospect monitoring site is presented in Table 4-2

Table 4-2 PM_{10} Monitoring Results – Prospect

Year	Annual Average (µg/m3)	24 Hour Average (µg/m^3)	
		Maximum	90th Percentile
2012	17.2	38.7	26.4
2013	19.2	81.8	29.9
2014	17.6	44.3	25.6

Table 4-2 indicates that ambient PM_{10} concentrations in the area surrounding the project site are generally below recommended limit of 50 µg/m^3. Serious bushfires in the Blue Mountains during October 2013 resulted in a number of days where ambient PM_{10} concentrations were significantly elevated.

There are no readily available site specific TSP and deposited dust monitoring data. The Prospect monitoring site does not measure these components; however estimates of the background levels for the site are required to assess the impacts per the criteria presented in Section 3.3.2.

Estimates of the annual average background TSP concentrations can be determined from a relationship between measured PM_{10} concentrations. This relationship assumes that 40% of the TSP is PM_{10} and was established as part of a review of ambient monitoring data collected by co-located TSP and PM_{10} monitors operated for reasonably long periods of time in the Hunter Valley (NSW Minerals Council, 2000).

Applying this relationship with the 2012 annual average PM_{10} concentration of 17.2 µg/m3 at the Prospect monitoring station estimates an annual average TSP concentration of the order of 31 µg/m3.

To estimate annual average dust deposition levels, a similar process to the method used to estimate TSP concentrations is applied. This approach assumes that a TSP concentration of 90µg/m3 will have an equivalent dust deposition value of 4 g/m^2/month; and indicates a background annual average dust deposition of 1.4 g/m^2/month for the area surrounding the project.

The OEH monitoring site in Prospect began to record ambient concentrations of $PM_{2.5}$ in December 2014. Table 4-3 presents a summary of this data between December 2014 and 15 October 2015.

Table 4-3 $PM_{2.5}$ Monitoring Results – Prospect

Year	Annual Average (µg/m3)	24 Hour Average (µg/m^3)	
		Maximum	90th Percentile
2014/15	8.4	29.6	13.8

It should be noted that the annual average and maximum 24 hour average $PM_{2.5}$ concentrations measured at the Prospect OEH monitoring site exceed the NEPM advisory goals.

5 MODELLING METHODOLOGY

5.1 Meteorological Modelling

5.1.1 TAPM

No meteorological observation data is available for the site. The Horsley Park Equestrian Centre AWS is located approximately 7 kilometres south of the project site. Therefore, site-specific meteorological data was generated through the use of a prognostic model. The prognostic model used was The Air Pollution Model (TAPM), developed and distributed by the Commonwealth Scientific and industrial Research Organisation (CSIRO).

TAPM is an incompressible, non-hydrostatic, primitive equations prognostic model with a terrain-following vertical coordinate for three-dimensional simulations. It predicts the flows important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of large scale meteorology provided by synoptic analyses. TAPM benefits from having access to databases of terrain, vegetation and soil type, leaf area index, sea-surface temperature, and synoptic scale meteorological analyses for various regions around the world.

The prognostic modelling domain was centred at 33.8° S, 150.9° E and involved three nesting grids of 10 km, 3 km and 1km with 41 grids in the lateral dimensions and 25 vertical levels.

The TAPM model included assimilation of data collected at the Horsley Park Equestrian Centre AWS during the year 2012. This modelling year was chosen based on a long term meteorological analysis (see Appendix A).

5.1.2 AERMET

The TAPM results, including predictions of wind speed, wind direction, temperature, humidity, cloud cover, solar radiation and rainfall, were used as inputs to AERMET – AERMOD's meteorological pre-processor. AERMET uses the TAPM data, along with land use data, to calculate mixing heights and velocity scaling parameters.

5.2 Dispersion Modelling

5.2.1 AERMOD

The dispersion model chosen for this assessment was AERMOD – the US EPA regulatory Gaussian plume air dispersion model.

AERMOD is a steady state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts. It includes treatment of both surface and elevated sources, and both simple and complex terrain.

AERMOD was selected by the Victorian EPA to replace AUSPLUME from 1 January 2014.

5.2.2 Peak to Mean Ratios

To account for the time-averaging limitations of the dispersion model, peak-to-mean ratios have been incorporated into all odour flux rates in accordance with the Approved Methods. Peak-to-mean ratios for various source types, as prescribed by the Approved Methods, are presented in Table 5-1.

Table 5-1 Peak-to-mean ratios

Source type	Pasquill-Gifford stability class	P/M60	
		Near-field	Far-field
Area	A,B,C,D	2.5	2.3
	D,E	2.3	1.9
Line	A-F	6	6
Surface wake-free point	A,B,C	12	4
	D,E,F	25	7
Tall wake-free point	A,B,C	17	3
	D,E,F	35	6
Wake-affected point	A-F	2.3	2.3
Volume	A-F	2.3	2.3

Note: * Ratio of peak 1-second average concentrations to mean 1-hour average concentrations.

5.2.3 Building Wake Effects

All emissions associated with this development were modelled using volume sources, which are not affected by building wakes.

6 EMISSIONS TO AIR

6.1 Odour Emissions

Significant sources of operational odour have been identified from information from the client, and from recent observations in the area surrounding Taronga Park Zoo. An inventory of odour emissions has been developed based on information supplied by the client, and a literature review of odour assessments elsewhere in NSW.

Subjective observations were made in the area surrounding the Taronga Park Zoo during the evening of Thursday 1 October and the afternoon Friday 2 October 2015 to detect odours from the zoo. No odours were detectable at any off-site receptors, however faint odours were detectable near the south eastern boundary of the zoo, at a location approximately 50 metres away from animal enclosures. The odour exhibited characteristics associated with animal manure and hay.

The most significant source of odour from the project site is a small area near the north eastern corner of the project site where animal manure, green waste and food organics are stockpiled and composted. Animal enclosures would not be a significant source of odour as manure would be collected from the enclosures regularly and taken to the composting area.

The locations of the odour sources are presented in Figure 6-1.

Figure 6-1 Odour Source Locations

Water conditions in the various moats, lagoons and other waterways on the site would be maintained by pumping and filtration systems to avoid the onset of anaerobic conditions, which can lead to the generation of significant odours.

According to the Waste Management Plan for the project, approximately 345 tonnes of organic waste would be available for composting per year, with animal manure, compostable food waste and green waste contributing approximately 80%, 15% and 5%, respectively.

The client has advised that the organic waste would be composted in small windrows in the composting area. The total area of the windrows is not expected to exceed 300 m^2.

Site specific odour emission data for the composting activities is not available. A literature review of a number of various waste processing facilities and composting facilities in NSW was undertaken to determine suitable odour emission data for this process. The best available data was found in the Air Quality Assessment for the Woodlawn Bioreactor Facility (Heggies, 2010). The specific odour emission rate (SOER) for composted organic and green waste adopted in Heggies, 2010 was 5.65 OUV/m^2/s. This SOER has been adopted for the assessment of odour emissions from the composting area.

A summary of the estimate odour emissions from the composting area are presented in Table 6-1.

Table 6-1 Odour Emission Estimate

Source	SOER	Area (m^2)	Odour flux rate	Peak to mean ratio	Peak odour flux rate
Composting Area	5.65	300	1,695	2.3	3,899

6.2 Dust Emissions

Dust emissions during construction of the project have been estimated based on information provided by the client, using emission factors sourced from both locally developed and US EPA developed documentation. The bulk earthworks phase will generate the highest dust emissions of all construction phases and will last for a period of 3 – 4 months. Since the bulk earthworks phase represents the worst case for construction dust emissions, it will be the focus of the assessment.

Total dust emissions from all significant dust generating activities during the bulk earthworks are presented in Table 6-2. Detailed emission inventory and emission estimation calculations are presented in Appendix B.

Table 6-2 Estimated Dust and Particulate Emissions

Activity	Emissions (kg)		
	TSP	PM_{10}	$PM_{2.5}$
Loading/Dumping topsoil and fill material	72.3	34	5.3
Dozer shaping fill	1023	216	107
Grader on roads and fill	968	338	30
Wind erosion	672	336	50
Total	**2735**	**924**	**192**

Table 6-2 presents the total dust emissions over the entire bulk earthworks phase. For assessment purposes, it is assumed that these emissions will occur over a 3 month period.

7 ASSESSMENT OF IMPACTS

The following section presents quantitative assessments of the potential odour and dust impacts on nearby receptors from the operation and construction of the project, respectively.

7.1 Assessment of Operational Odour Impacts

Based on dispersion modelling results, the predicted operational odour impacts on nearby receptors is presented numerically in Table 7-1 and graphically via contours in Figure 7-1.

Table 7-1 Predicted 99th percentile peak odour concentrations

Receptor	Predicted peak odour concentration (OU/m^3)	Impact assessment criterion (OU/m^3)	Complies? (Yes/ No)
Bungarribee	<1	2.0	Yes
Eastern Creek	<1	2.0	Yes
R1	<1	2.0	Yes

Figure 7-1 Predicted 99th percentile peak odour concentrations

Review of Table 7-1 indicates that the predicted 99th percentile odour concentrations comply with the established criterion of 2.0 OU/m³. The 1.0 OU/m³ contour does not include any sensitive receptors, indicating that peak odour emissions from the project site would not be detectable.

The contours in Figure 7-1 indicate that odours associated with the composting activities may occasionally be noticeable at some locations within the project site. Steps should be taken to have this serve as an early warning indicator of potential odour issues. Any odour complaints from patrons should be entered into a complaints register and acted on accordingly. For instance, if multiple complaints are received from different patrons on a given day, steps should be taken to identify the source of the odour and rectify the issue. If the source of the odour relates to the composting area, the design and operation of the composting should be reviewed to

If odour complaints are received from off-site receptors, they should be entered into the register, and a suitably qualified air quality consultant should be engaged to identify the source of the odour and recommend suitable management and mitigation measures.

7.1.1 Cumulative Odour Impacts

As discussed in Section 4.2.1, odour concentrations at sensitive receptors due to the operation of the Arnott's biscuit factory and the Eastern Creek Landfill are unknown. However, since the predicted odour concentrations at sensitive off-site receptors due to the operation of the project are well below 1.0 OU/m³, the project is unlikely to contribute to cumulative odour levels at sensitive receptors in the surrounding area.

7.2 Assessment of Construction Dust Impacts

The following section presents the predicted dust and particulate matter impacts associated with the bulk earthworks phase of the project construction. The bulk earthworks phase is anticipated to last for 3 – 4 months, however to predict the impact on annual average pollutant concentrations, the bulk earthworks activities have been modelled as running for an entire year, at the intensity corresponding to the earthworks being complete in only 3 months.

7.2.1 TSP

The predicted incremental and total 100th percentile annual average concentrations of TSP at sensitive receptors, due to the construction of the project, are presented in Table 7-2.

Table 7-2 Predicted Construction TSP Impacts

Receptor	Annual Average (criterion = 90 µg/m³)		
	Incremental	Total*	Complies?
Bungarribee	0.6	31.6	Yes
Eastern Creek	0.4	31.4	Yes
R1	1.7	32.7	Yes

* Total impacts include background concentrations.

Review of Table 7-2 indicates that the predicted total concentrations of TSP at sensitive receptors comply with the impact assessment criterion of 90 µg/m³.

7.2.2 PM_{10}

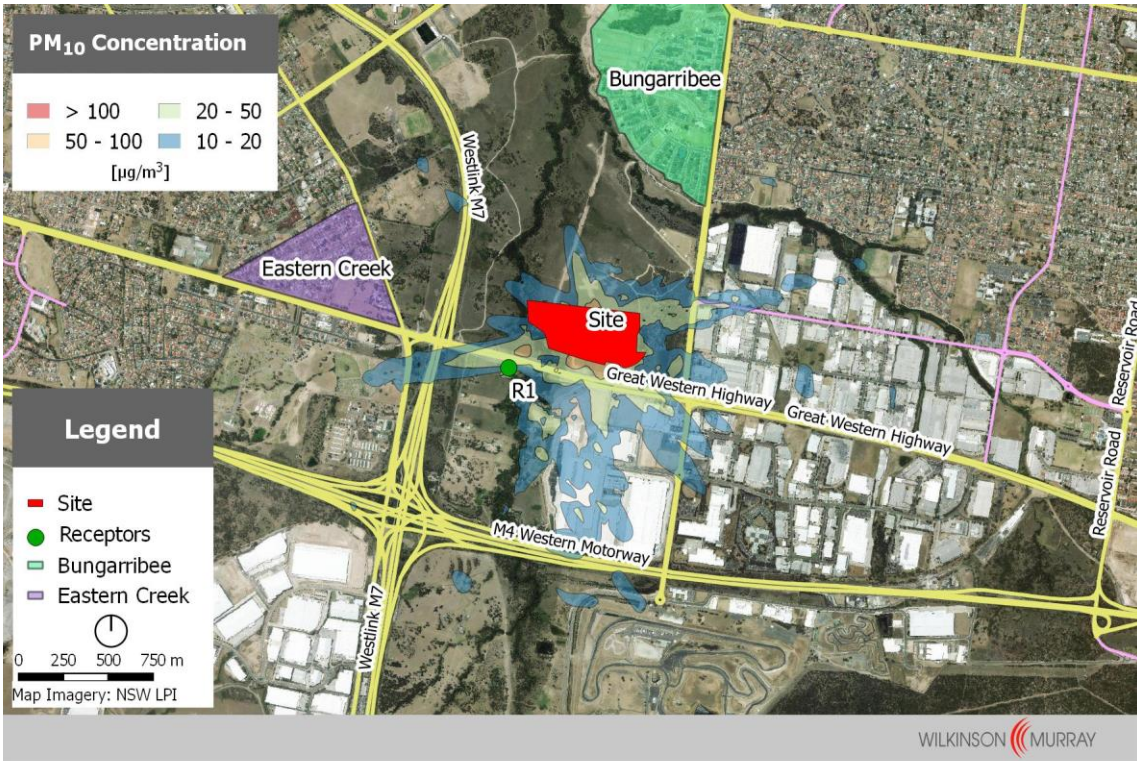
The predicted incremental and total 100th percentile ground level concentrations of PM_{10} at nearby receptors are presented in Table 7-3. The predicted total impact on 24 hour average PM_{10} concentrations includes the 100th percentile 24 hour average background concentration of PM_{10}, as recorded at the OEH monitoring site in Prospect during 2012. Contours of the predicted incremental 24 hour average PM_{10} concentrations are presented in Figure 7-2.

Table 7-3 Predicted Construction PM_{10} Impacts

Receptor	24 Hour Average (criterion = 50 µg/m³)			Annual Average (criterion = 30 µg/m³)		
	Incremental	Total*	Complies?	Incremental	Total*	Complies?
Bungarribee	12.5	**51.2**	No	0.5	17.7	Yes
Eastern Creek	5.5	44.2	Yes	0.3	17.5	Yes
R1	23	**61.7**	No	1.3	18.5	Yes

* Total impacts include background concentrations.

Figure 7-2 Predicted maximum 24-hour average PM_{10} concentrations due to emissions from the Project (µg/m³)



Review of Table 7-3 indicates that the total impact on 24 hour average PM_{10} concentrations, calculated conservatively in accordance with the Approved Methods, has the potential to exceed the impact assessment criterion of 50 µg/m³ in Bungarribee and at R1. In accordance with the Approved Methods, a contemporaneous assessment of 24 hour average PM_{10} concentrations at these receptors is warranted.

The contemporaneous assessment of 24 hour average PM_{10} concentrations involves adding the background PM_{10} concentrations observed at the OEH monitoring site in Prospect to the predicted incremental concentrations on a day by day basis. This has been completed for the modelling year of 2012.

Table 7-5 and Table 7-5 present contemporaneous assessments of 24 hour average PM_{10} concentrations in Bungarribbee and at R1, respectively. Table 7-5 and Table 7-5 identify the seven days with the highest 24 hour average total PM_{10} concentrations, and present the background and incremental concentrations on those days.

Table 7-4 Contemporaneous 24 Hour Average PM_{10} Levels – Bungarribee

Date	PM_{10} 24 Hour Average (µg/m^3)		
	Background	Predicted Increment	Total
26/11/12	38.7	0.1	38.8
8/12/12	35.5	0.1	35.6
19/5/12	34.2	0.7	34.9
11/9/12	34.4	0.5	34.9
20/10/12	34.6	0.2	34.8
6/11/12	33.9	0.1	34.0
30/8/12	33.4	0.3	33.7

Table 7-5 Contemporaneous 24 Hour Average PM_{10} Levels – R1

Date	PM_{10} 24 Hour Average (µg/m^3)		
	Background	Predicted Increment	Total
26/11/12	38.7	0.8	39.5
4/4/12	16.6	21.1	37.7
19/5/12	34.2	3.5	37.7
8/12/12	35.5	1.3	36.8
25/11/12	30.1	6.5	36.6
20/10/12	34.6	0.9	35.5
11/9/12	34.4	0.7	35.1

Review of Table 7-4 and Table 7-5 indicates that the total 24 hour average PM_{10} concentrations, based on a contemporaneous assessment, comply with the impact assessment criterion of 50 µg/m^3.

7.2.3 Deposited Dust

The predicted incremental and total 100th percentile annual average levels of deposited dust at sensitive receptors, due to the construction of the project, are presented in Table 7-6.

Table 7-6 Predicted Construction Deposited Dust Impacts

Receptor	Annual Average		
	Incremental (criterion = 2 g/m^2/month)	Total* (criterion = 4 g/m^2/month)	Complies?
Bungarribee	0.02	1.42	Yes
Eastern Creek	0.01	1.41	Yes
R1	0.07	1.47	Yes

* Total impacts include background concentrations.

Review of Table 7-6 indicates that the predicted incremental and total levels of deposited dust at sensitive receptors comply with the impact assessment criteria of 2 g/m^2/month and 4 g/m^2/month, respectively.

7.2.4 $PM_{2.5}$

The predicted incremental and total ground level concentrations of $PM_{2.5}$ at nearby receptors are presented in Table 7-7. The predicted total impact on 24 hour average $PM_{2.5}$ concentrations includes the 90th percentile 24 hour average background concentration of $PM_{2.5}$, as recorded at the OEH monitoring site in Prospect since the beginning of $PM_{2.5}$ monitoring at that site.

Table 7-7 Predicted Construction $PM_{2.5}$ Impacts

Receptor	24 Hour Average (advisory goal = 25 $\mu g/m^3$)		Annual Average (advisory goal = 8 $\mu g/m^3$)	
	Incremental	Total	Incremental	Total
Bungarribee	2.6	16.4	0.1	8.5
Eastern Creek	1.2	15	<0.1	8.4
R1	4.8	18.6	0.3	8.7

Review of Table 7-7 indicates that the predicted incremental 24 hour and annual average concentrations of $PM_{2.5}$ due to the construction of the project are very small compared to the existing $PM_{2.5}$ concentrations. As presented in Section 4.2.2, the existing concentrations of $PM_{2.5}$ recorded at the OEH monitoring site in Prospect have exhibited exceedances of the NEPM goals.

8 MITIGATION AND MANAGEMENT

The preceding air quality impact assessment has demonstrated that the construction and operation of the project is expected to comply with relevant air quality criteria. Notwithstanding this, responsible developments should implement reasonable and feasible measures to reduce their burden on local and regional air quality. To this end, the following section presents a number of measures to mitigate odour and dust emissions from the site.

8.1 Odour Mitigation

Potential odour mitigation measures which should be considered during the operation of the project are as follows:

- Procedures for staff to report the presence of odours, particularly in unexpected places;
- If composting windrows require turning, this should be done during periods of good atmospheric dispersion; and,
- Maintaining an odour complaints register which captures all complaints from patrons and off-site receptors.

8.2 Dust Mitigation

Potential construction dust mitigation measures which should be considered during the construction of the project are as follows:

- Engines of construction plant to be switched off when not in use;
- Maintain and service plant in accordance with manufacturer's specifications;
- Use of water carts and sprays to suppress any instances of visible dust leaving the site;
- Limit vehicle speeds to 40 km/h;
- Cover vehicle loads if transporting material off-site;
- Reduce drop heights during loading and unloading of fill material;
- Minimise area of exposed surfaces;
- Minimise amount of stockpiled materials;
- Where possible, apply barriers, covering or temporary rehabilitation;
- Rehabilitate completed sections as soon as practicable; and,
- Restrict construction activities during unfavourable weather conditions.

9 CONCLUSION

Wilkinson Murray has conducted an air quality impact assessment for the proposed Sydney Zoo.

The assessment has been conducted in general accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005).

A quantitative assessment of potential odour impacts from the operation of the project has been conducted, based on TAPM meteorological simulations and AERMOD plume dispersion modelling. The results of the dispersion modelling indicate that the predicted ground level odour concentrations due to the operation of the project comply with the established criteria.

A quantitative assessment of potential dust impacts from the bulk earthworks phase of the project's construction has also been conducted. Construction dust impacts are considered unlikely, and mitigation measures have been recommended to control excessive levels of construction dust.

10 REFERENCES

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"Woodlawn Bioreactor – Odour and Dust Impact Assessment, Woodlawn Expansion Project", Heggies Pty Ltd, August 2010.

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"Emission Estimation Technique Manual for Combustion Engines, Version 3.0", National Pollutant Inventory, June 2008

NPI (2012)

"Emission Estimation Technique Manual for Mining, Version 3.1", National Pollutant Inventory, January 2012

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"Approved Methods for the Modelling and Assessment of Air Pollutants in NSW", August 2005.

NSW Minerals Council (2000)

"Technical Paper – Particulate Matter and Mining Interim Report"

SPCC (1983)

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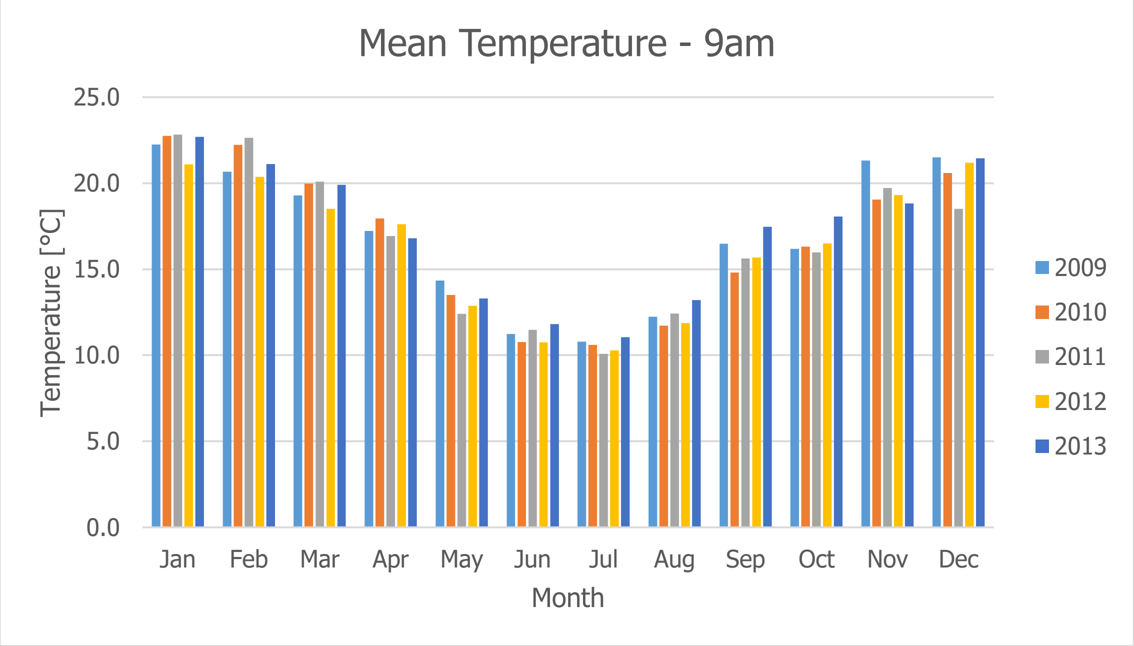
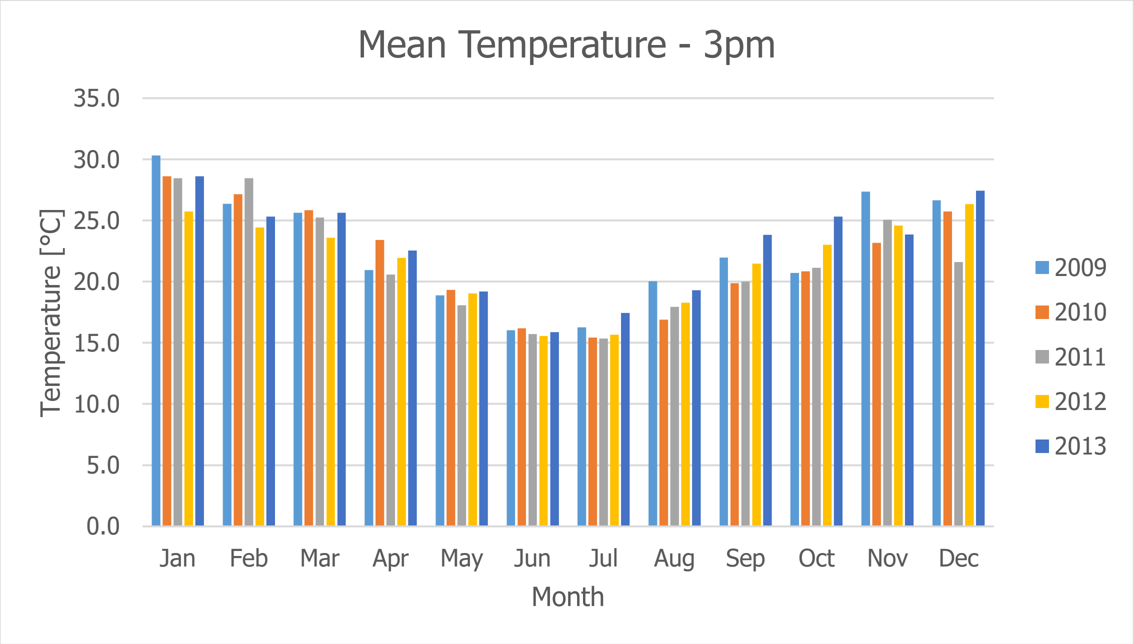
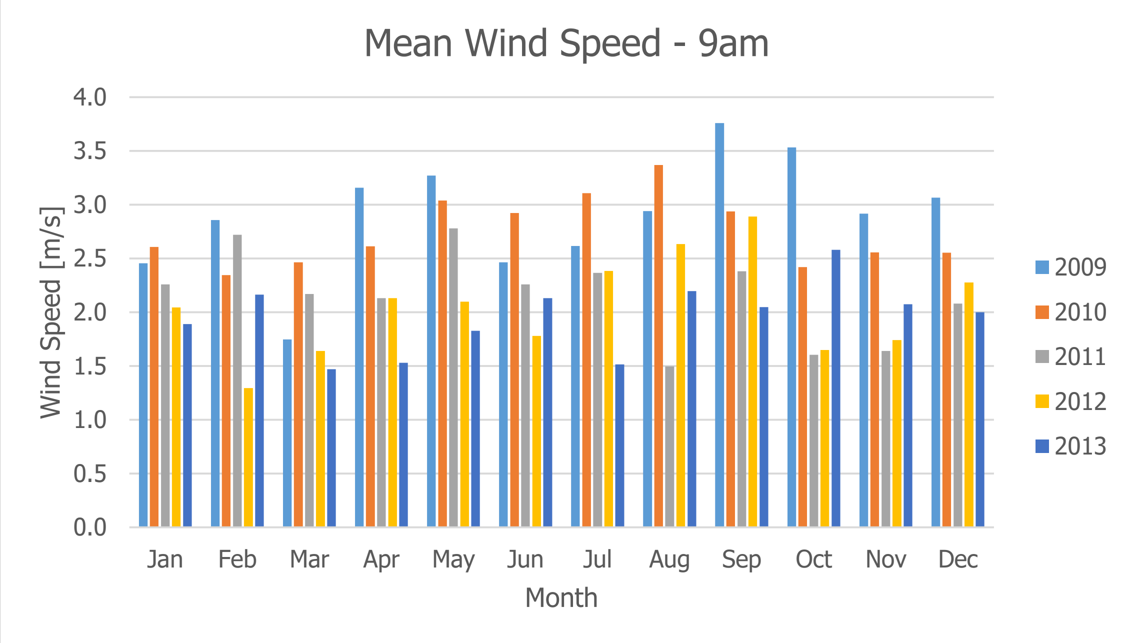
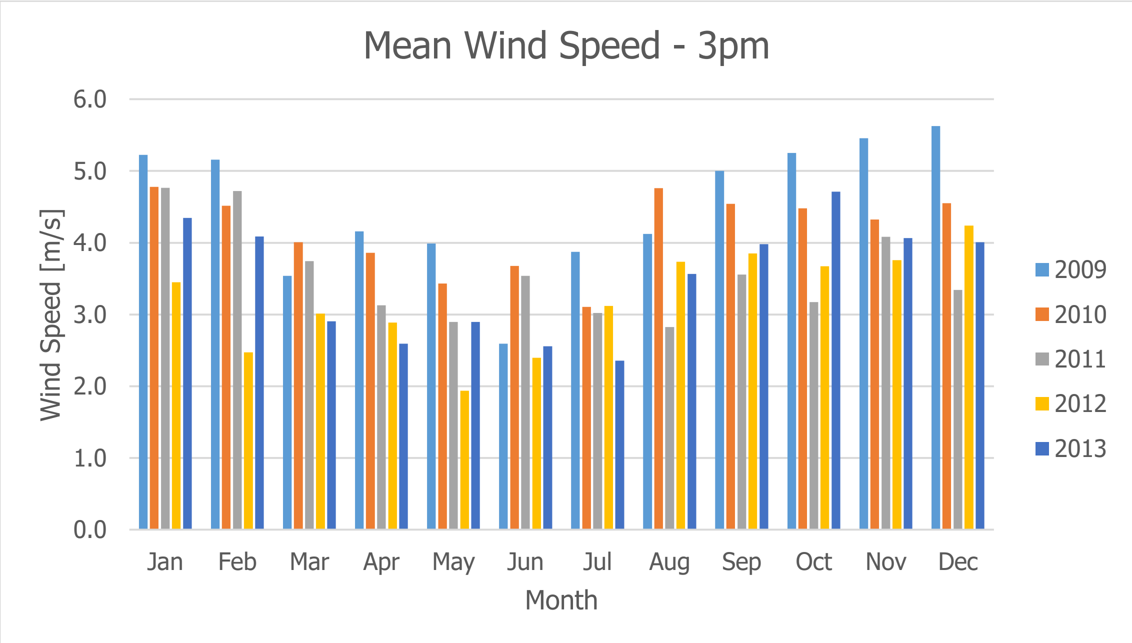
APPENDIX A

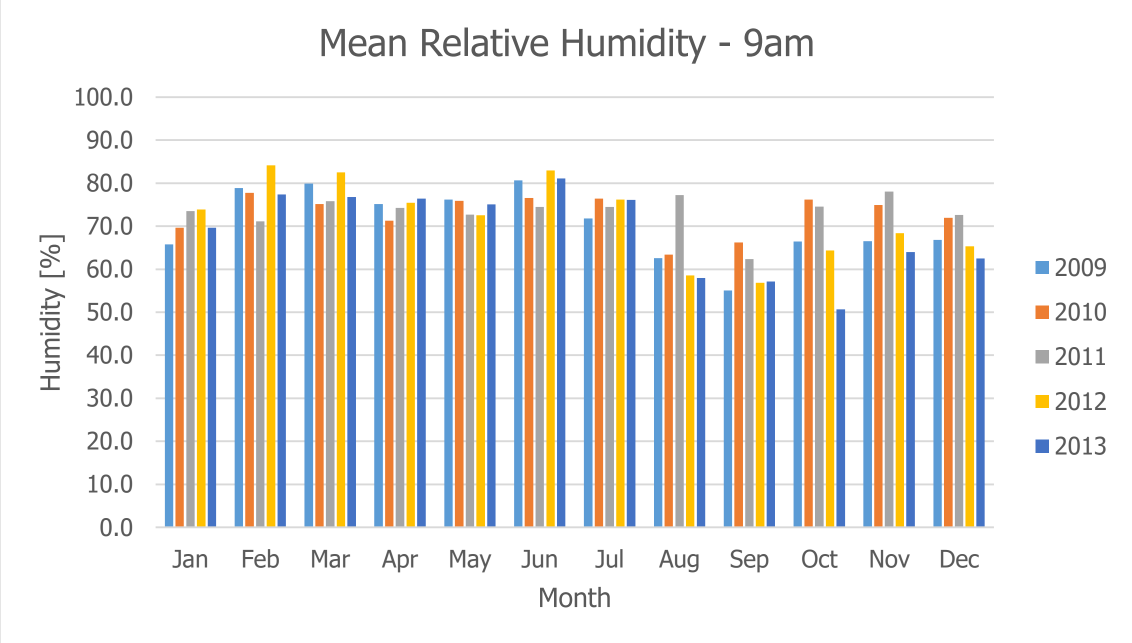
METEOROLOGICAL COMPARISON, HORSLEY PARK EQUESTRIAN CENTRE AWS: 2009 – 2014

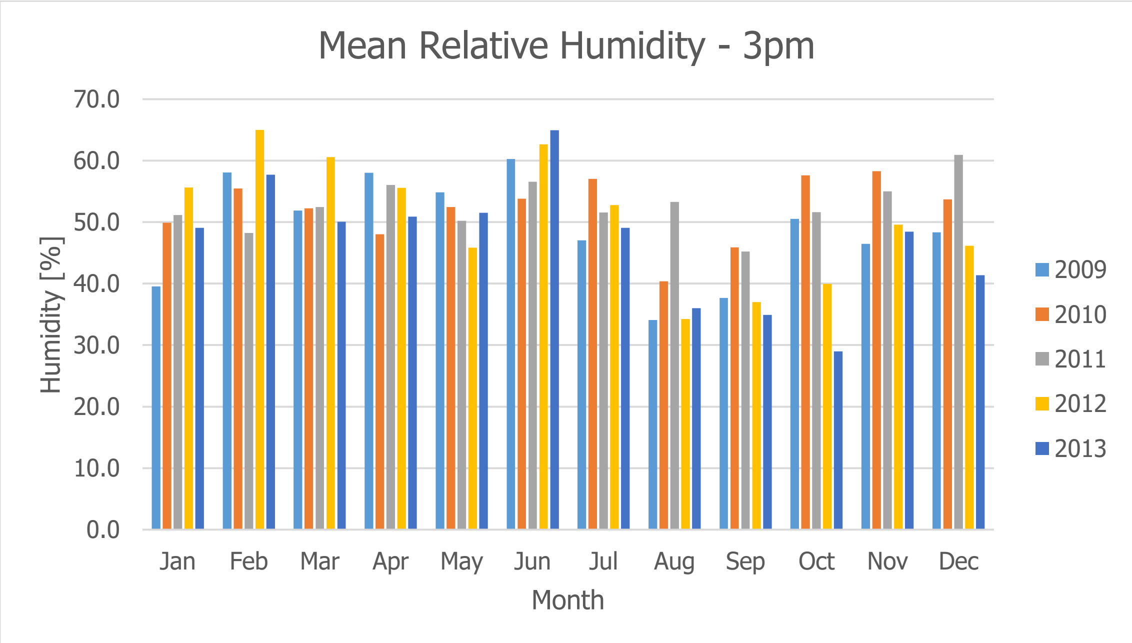

Mean Temperature - 9am
Temperature [°C]
25.0
20.0
15.0
10.0
5.0
0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
2009
2010
2011
2012
2013


Mean Temperature - 3pm
Temperature [°C]
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
2009
2010
2011
2012
2013


Mean Wind Speed - 9am
Wind Speed [m/s]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2009
2010
2011
2012
2013


Mean Wind Speed - 3pm
Wind Speed [m/s]
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2009
2010
2011
2012
2013


Mean Relative Humidity - 9am
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Humidity [%]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2009
2010
2011
2012
2013


Mean Relative Humidity - 3pm
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Humidity [%]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2009
2010
2011
2012
2013

APPENDIX B

DUST EMISSIONS INVENTORY

B.1 Particulate Emission Factor Equations

Loading / unloading / transferring material

Each tonne of material handles will generate quantities of particulate matter that will depend on the wind speed and the moisture content of the material according to the US EPA emission factor (US EPA, 1985 and updates) shown below:

$$E[kg/t] = k \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2.0}\right)^{1.4}} \right)$$

Where:

k = 0.74 for TSP, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$

U = wind speed [ms^{-1}]

M = moisture content [%]

The wind speed is taken as the average wind speed from the TAPM dataset.

Dozers shaping fill material

Particulate emissions for dozers have been estimated using US EPA emission factor equations (US EPA, 1985 and updates) for dozers on overburden as follows:

$$E[kg/h] = a \times \left(\frac{s^b}{M^c} \right)$$

Where:

a = 2.6 for TSP, 0.8775 for PM_{10} and 0.273 for $PM_{2.5}$

b = 1.2 for TSP, 1.5 for PM_{10} and 1.2 for $PM_{2.5}$

c = 1.3 for TSP, 1.4 for PM_{10} and 1.3 for $PM_{2.5}$

s = silt content [%]

M = moisture content [%]

Graders levelling fill

Particulate emissions from graders levelling filled areas have been estimated using US EPA emission factor equations (US EPA, 1985 and updates) for graders on unsealed roads as follows:

$$E[kg/VKT] = a \times S^b$$

Where:

a = 0.0034 for TSP, 0.00336 for PM_{10} and 0.0001054 for $PM_{2.5}$

b = 2.5 for TSP, 2.0 for PM_{10} and 2.5 for $PM_{2.5}$

S = vehicle speed [km/h]

Wind erosion

Particulate emission factors for wind erosion, taken from US EPA emission factor equations (US EPA, 1985 and updates), are 0.1 kg/ha/h for TSP, 0.05 kg/ha/h for PM_{10}, and 0.0075 kg/ha/h for $PM_{2.5}$.

B.2 Emission Estimates

Table B-1 Summary of TSP Emissions

Activity	Emission [g/s]	Total Emission [kg]	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Control [%]
loading stripped topsoil into trucks	3.82E-03	8.3	21000	t	3.96E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping topsoil on stockpile	3.82E-03	8.3	21000	t	3.96E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
Excavating waterways	4.19E-03	9.1	23000	t	3.96E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping elsewhere	4.19E-03	9.1	23000	t	3.96E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping imported fill	5.73E-03	12.5	31500	t	3.96E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dozer on fill	9.39E-01	2044.9	393	hr	5.20E+00	kg/hr	8	silt content [%]	4	moisture content [%]	0
grader on fill/roads	4.45E-01	968.1	3146	km	6.15E-01	kg/km	8	grader speed [km/h]			0
Wind Erosion	1.41E-01	672.0	1680	hr	4.00E-01	kg/hr	4	ha	0.100	kg/ha/hr	0

Table B-2 Summary of PM_{10} Emissions

Activity	Emission [g/s]	Total Emission [kg]	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Control [%]
loading stripped topsoil into trucks	1.81E-03	3.9	21000	t	1.87E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping topsoil on stockpile	1.81E-03	3.9	21000	t	1.87E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
Excavating waterways	1.98E-03	4.3	23000	t	1.87E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping elsewhere	1.98E-03	4.3	23000	t	1.87E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping imported fill	2.71E-03	5.9	31500	t	1.87E-04	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dozer on fill	9.90E-02	215.6	393	hr	1.10E+00	kg/hr	8	silt content [%]	4	moisture content [%]	0
grader on fill/roads	1.55E-01	338.3	3146	km	2.15E-01	kg/km	8	grader speed [km/h]			0
Wind Erosion	7.07E-02	336.0	1680	hr	2.00E-01	kg/hr	4	ha	0.100	kg/ha/hr	0

Table B-3 Summary of $PM_{2.5}$ Emissions

Activity	Emission [g/s]	Total Emission [kg]	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Control [%]
loading stripped topsoil into trucks	2.74E-04	0.6	21000	t	2.84E-05	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping topsoil on stockpile	2.74E-04	0.6	21000	t	2.84E-05	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
Excavating waterways	3.00E-04	0.7	23000	t	2.84E-05	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping elsewhere	3.00E-04	0.7	23000	t	2.84E-05	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dumping imported fill	4.11E-04	0.9	31500	t	2.84E-05	kg/t	2	wind speed [m/s]	4	moisture content [%]	0
dozer on fill	4.93E-02	107.4	393	hr	5.46E-01	kg/hr	8	silt content [%]	4	moisture content [%]	0
grader on fill/roads	1.38E-02	30.0	3146	km	1.91E-02	kg/km	8	grader speed [km/h]			0
Wind Erosion	1.06E-02	50.4	1680	hr	3.00E-02	kg/hr	4	ha	0.100	kg/ha/hr	0