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**AIR QUALITY & ODOUR ASSESSMENT:  
PROPOSED MALTING FACILITY & PACKING PLANT, MINTO NSW**

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*Prepared for  
Cardno Pty Ltd*

*by*

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## 1. INTRODUCTION

This report has been prepared by Holmes Air Sciences for Cardno Pty Ltd who in turn are acting on behalf of Joe White Maltings Pty Ltd (JWM). The report provides a semi-quantitative air quality assessment of the proposed malt processing plant and export grain container packing facility to be located at Stonny Batter Road, Minto (see **Figure 1**). The report comprises the following components.

- Background to the study
- A discussion of relevant air quality goals
- Review of the existing environment with respect to air quality and meteorology
- Air quality issues, including dust, odour and oxides of nitrogen
- A semi-quantitative air quality assessment

## 2. BACKGROUND TO THE STUDY

Joe White Maltings Pty Ltd (JWM) propose to establish a malt processing plant and export grain packing facility to be located at Stonny Batter Road, Minto. The site location is shown in **Figure 1**. The surrounding land use is industrial with the nearest residential receptors approximately 400 m to the east.

The plant would convert barley into malt through a kilning process. In addition the grain packing facility would receive and pack wheat, oats, barley and a variety of other grain/pulse commodities for overseas dispatch. The annual capacity of the malt plant would be 110,000 tonnes. The layout of the site is shown in **Figure 2**.

The malting process involves steeping the barley in water for approximately 24 hours to initiate germination. The germination process takes about four days.

The kilning process is the final stage of the malting process, whereby germinated barley at around 43% moisture by weight is kilned or dried, with moisture being reduced to around 4%. The kilning process takes place in a purpose built kiln, with gas-fired air heaters providing the required heat.

Potential air quality impacts arise from dust generated during the packing process, odour from the kiln and emissions of oxides of nitrogen from the gas-fired burners which heat the kiln. Oxides of nitrogen can have a regional as well as a local air quality impact.

## 3. RELEVANT AIR QUALITY GOALS

Air quality in New South Wales is regulated by the Department of Environment and Climate Change (DECC formerly Department of Environment and Conservation).

### 3.1 Dust

Air quality goals for particulate matter are determined largely from health studies which assess the health effects of people with exposure to known pollutant levels.

**Table 1** and **Table 2** summarise the air quality assessment criteria for particulate matter concentrations and deposited (fallout) dust respectively. The air quality criteria or goals relate to the total dust burden in the air and not just the dust from one operation. In other words, some consideration of background levels needs to be made when using these goals to assess impacts.

**Table 1 – NSW DECC criteria for particulate matter concentrations**

POLLUTANT	STANDARD / GOAL	AVERAGING PERIOD	AGENCY
Total suspended particulate matter (TSP)	90 µg/m <sup>3</sup>	Annual mean	NHMRC
Particulate matter less than 10 µm in equivalent aerodynamic diameter (PM <sub>10</sub> )	50 µg/m <sup>3</sup>	24-hour maximum	DECC
	30 µg/m <sup>3</sup>	Annual mean	DECC

**Table 2 – NSW DECC criteria for dust fallout**

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m <sup>2</sup> /month	4 g/m <sup>2</sup> /month

### **3.2 Odour**

The proposed facility will be a potential source of odour emissions. This section discusses the measurement and air quality criteria that relate to odour.

#### **3.2.1 Measurement of Odour**

Odour is measured using panels of people who are presented with samples of odorous gas diluted with decreasing quantities of clean odour-free air. The panellists then note when the smell becomes detectable. Odour in the air is then quantified in terms of odour units which is the number of dilutions required to bring the odour to a level at which 50% of the panellists can just detect the odour. This process is known as olfactometry.

Olfactometry can involve a “forced-choice” end point or a “free choice” endpoint. The “forced-choice” method is where panellists identify from multiple sniffing ports, the one port where odour is detected, regardless of whether they are sure they can detect odour. The “free choice” endpoint is a “yes/no” decision where panellists are required to say whether or not they can detect odour from one sniffing port. Forced-choice olfactometry generally detects lower odour levels than free choice olfactometry.

In both the “forced-choice” and “free choice” cases, odorous air is presented to the panellists in increasing concentrations. For the forced-choice method, where there are multiple ports for each panellist, the concentration is increased until all panellists consistently distinguish the port with the sample from the blanks. For a yes/no olfactometer (which has only one sniffing port) one method used is to increase the concentration of odour in the sample until all panellists respond. The sample is then shut off and once all panellists cease to respond, the sample is introduced again at random dilutions and the panellists are asked whether they can detect the odour.

An Australian Standard (AS/NZS 4323.3.2001) for olfactometry has been developed which is consistent with the European Standard, CEN. These standards have adopted the certainty threshold as the odour standard and referencing this to a concentration of butanol (40 ppb). The odour levels referred to in this report are the certainty odour levels.

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As with all sensory methods of identification there is variability between individuals. Consequently the results of odour measurements depend on the way in which the panel is selected and the way in which the panel responses are interpreted. The process by which these imprecise measurements are translated into regulatory criteria is outlined in the recently published DECC Technical Framework for assessment and management of odour (**DEC 2006a and 2006b**).

### **3.2.2 Odour Criteria**

The DECC has in recent times refined odour criteria and the way in which they should be applied with dispersion models to assess the likelihood of nuisance impact arising from the emission of odour.

Odour impacts are determined by several factors. The most important factors (the so-called **FIDOL** factors) are:

- the **F**requency of the exposure
- the **I**ntensity of the odour
- the **D**uration of the odour episodes
- the **O**ffensiveness of the odour, and
- the **L**ocation of the source

In determining the offensiveness of an odour it needs to be recognised that for most odours the context in which an odour is perceived is also relevant. Some odours, for example the smell of sewage, hydrogen sulfide, butyric acid, landfill gas etc., are likely to be judged offensive regardless of the context in which they occur. Other odours such as the smell of jet fuel may be acceptable at an airport, but not in a house, and diesel exhaust may be acceptable near a busy road, but not in a restaurant.

In summary, whether or not an individual considers an odour to be a nuisance will depend on the FIDOL factors outlined above and although it is possible to derive formulae for assessing odour annoyance in a community, the response of any individual to an odour is still unpredictable.

The DECC framework documents include some recommendations for odour criteria. The criteria have been refined by DECC to take account of population density in the area. **Table 3** lists the odour certainty thresholds, to be exceeded not more than 1% of the time, for different population densities.

The difference between odour criteria is based on considerations of risk of odour impact rather than differences in odour acceptability between urban and rural areas. For a given odour level there will be a wide range of responses in the population exposed to the odour. In a densely populated area there will therefore be a greater risk that some individuals within the community will find the odour unacceptable than in a sparsely populated area.

The criteria assume that 7 odour units at the 99<sup>th</sup> percentile would be acceptable to the average person, but as the number of exposed people increases there is a chance that sensitive individuals would be exposed. The criterion of 2 odour units at the 99<sup>th</sup> percentile is considered to be acceptable for the whole population.

**Table 3 – Odour performance criteria for the assessment of odour**

Population of affected community	Odour assessment criteria (ou)
≤ ~2	7
~10	6
~30	5
~125	4
~500	3
Urban (~2000) and/or schools and hospitals	2

Source: DEC, 2005

It is common practice to use dispersion models to determine compliance with odour criteria. This introduces a complication because Gaussian dispersion models are only able to directly predict concentrations over an averaging period of 3-minutes or greater. The human nose, however, responds to odours over periods of the order of a second or so. During a 3-minute period, odour levels can fluctuate significantly above and below the mean depending on the nature of the source.

To determine more rigorously the ratio between the one-second peak concentrations and three-minute and longer period average concentrations (referred to as the peak-to-mean ratio) that might be predicted by a Gaussian dispersion model, the NSW DECC commissioned a study by Katestone Scientific Pty Ltd (see **Katestone 1995** and **1998**). This study recommended peak-to-mean ratios for a range of source types. The ratio is also dependent on atmospheric stability and the distance from the source.

The DECC Technical Framework for odour assessment (**DEC 2006a** and **2006b**) and *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (**DEC, 2005**) take account of this peaking factor and the criteria shown in Table 3 are based on nose-response time.

### 3.3 Oxides of nitrogen

**Table 4** lists the air quality goals for nitrogen dioxide noted by the DECC (**DEC, 2005**) and National Environment Protection Measures (NEPM) that are relevant to this study. The primary air quality objective for most projects is to ensure that the air quality goals are not exceeded at any location where there is a possibility of human exposure.

**Table 4 – Air quality goals for nitrogen dioxide**

POLLUTANT	GOAL	AVERAGING PERIOD	AGENCY
<b>Nitrogen dioxide (NO<sub>2</sub>)</b>	0.12 ppm or 246 µg/m <sup>3</sup>	1-hour maximum <sup>1</sup>	NSW DECC, NEPM
	0.03 ppm or 62 µg/m <sup>3</sup>	Annual mean	NSW DECC, NEPM

Source: DEC, 2005

## 4. EXISTING ENVIRONMENT

This section discusses the existing local environment with respect to air quality and meteorology.

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#### 4.1 Existing air quality

The DECC monitoring station closest to the study area was located in Campbelltown on Blaxland Road off Farrow Street. It was located in Sydney's suburban south-west region, but has been completely decommissioned as of October 2004. The monitoring station measured meteorological data as well as concentrations of ozone (O<sub>3</sub>), NO<sub>2</sub>, and PM<sub>10</sub>.

**Table 5** shows maximum 1-hour values for NO<sub>2</sub>, 1-hour maximum values for O<sub>3</sub> and the annual average values for PM<sub>10</sub> measured at the Campbelltown monitoring site between 1996 and 2001.

Maximum NO<sub>2</sub> values ranged from 125.1 µg/m<sup>3</sup> to 207.1 µg/m<sup>3</sup>, which are well within the DECC's goal of 246 µg/m<sup>3</sup>. The maximum 1-hour O<sub>3</sub> ranged from 76.9 µg/m<sup>3</sup> to 146.4 µg/m<sup>3</sup>, which are also well within the DECC's goal of 210 µg/m<sup>3</sup>. The annual average PM<sub>10</sub> values ranged from 9.9 to 17.4 µg/m<sup>3</sup>, which are within the DECC goal of 30 µg/m<sup>3</sup>.

**Table 5 - DECC monitoring data from Campbelltown 1996 - 2001**

	NO <sub>2</sub> (µg/m <sup>3</sup> )		O <sub>3</sub> (µg/m <sup>3</sup> )		TEOM-PM <sub>10</sub> (µg/m <sup>3</sup> )
	Annual Value	Maximum	1-hour Value	Maximum	Annual average
1996	203.0		76.9		9.9
1997	207.1		125.9		14.3
1998	125.1		146.2		13.8
1999	141.5		146.4		15.9
2000	153.8		138.8		15.3
2001	145.6		128.8		17.4
<b>DECC goal</b>	<b>246</b>		<b>210</b>		<b>30</b>

#### 4.2 Existing meteorology

The closest meteorological station to the site is at Campbelltown. **Figure 3** presents the annual and seasonal windroses prepared from data collected in 1989. On an annual basis the winds are predominantly from the southwest. This persists throughout the year with winds from the northeast and east sectors also present in spring and summer. The lower strength winds (0.5 to 1.5 m/s) were most commonly from the north-northwest and north with an even higher percentage in the winter and autumn months.

**Table 6** shows the frequency of occurrence of the stability categories expected in the area. The most common stability occurrences were D class stabilities (27%). Under these conditions odours disperse reasonably rapidly.

Joint wind speed, wind direction and stability class<sup>1</sup> frequency tables generated from the Campbelltown data are presented in **Appendix A**.

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<sup>1</sup> In dispersion modelling stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford-Turner stability class assignment scheme there are six stability classes A through to F. Class A relates to unstable conditions such as might be found on a sunny day with light winds. In such conditions plumes will spread rapidly. Class F relates to stable conditions, such as occur when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

**Table 6 – Frequency of occurrence of stability classes at Campbelltown**

Stability Class %	1989
A	23.8
B	11.4
C	5.1
D	27.0
E	18.8
F	14.0
<b>Total</b>	<b>100</b>

#### 4.3 Climate data

**Table 7** presents the temperature, humidity and rainfall data from the Campbelltown Automatic Weather Station (**Bureau of Meteorology, 2008**). Temperature and humidity data consist of monthly averages of 9 am and 3 pm readings. Also presented are monthly averages of maximum and minimum temperatures. Rainfall data consists of mean and median monthly rainfall and the average number of raindays per month.

**Table 7 – Temperature, humidity and rainfall data for Campbelltown**

(Station number 068081; Commenced: 1959, Last record: 1984; Latitude (deg S): - 34.08; Longitude (deg E): 150.82)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
<b>9 am Mean Dry-bulb and Wet-bulb Temperatures ( ° C)</b>													
Dry-bulb	22.2	22.3	21.1	17.6	13.6	10.7	9.4	11.5	14.9	18.0	19.7	21.6	16.9
Wet-bulb	18.6	19.1	17.9	14.7	11.4	8.8	7.3	8.9	11.4	13.8	15.5	17.2	13.7
<b>3 pm Mean Dry-bulb and Wet-bulb Temperatures ( ° C)</b>													
Dry-bulb	26.6	26.6	25.2	22.5	19.1	16.3	16.0	17.3	19.8	21.7	24.0	26.0	21.8
Wet-bulb*	19.8	20.5	19.2	16.5	13.7	11.7	10.6	11.6	13.2	15.2	16.9	18.6	15.6
<b>Daily Maximum Temperature ( ° C)</b>													
Mean	28.2	28.4	26.8	24.1	20.4	17.6	17.1	18.7	21.4	23.5	25.8	27.9	23.3
<b>Daily Minimum Temperature ( ° C)</b>													
Mean	16.7	16.9	15.0	11.2	7.6	5.2	3.2	4.5	7.0	10.4	12.6	15.1	10.4
<b>Rainfall (mm)</b>													
Mean	90.6	78.6	100.7	64.1	60.2	81.6	33.7	50.4	40.7	74.3	84.3	70.5	831.0
Median	73.4	73.1	83.4	48.1	29.3	61.6	21.6	23.1	36.8	57.6	65.8	55.8	842.4
<b>Raindays (Number)</b>													
Mean	10.8	10.4	10.5	7.7	8.1	8.8	6.0	7.9	8.0	10.8	9.5	9.1	8.9

Source: Bureau of Meteorology (2008)

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The annual average maximum and minimum temperatures experienced at Campbelltown are 23.3°C and 10.4°C respectively. On average February is the hottest month with an average maximum temperature of 28.4°C. July is the coldest month, with average minimum temperature of 3.2°C.

Rainfall data collected at Campbelltown shows that March is the wettest month, with an average rainfall of 100.7 mm. The average annual rainfall is 831 mm with an average of 8.9 raindays per month.

#### **4.3 Regional air quality**

The DECC are concerned about emissions of NO<sub>x</sub> in the Sydney and Illawarra air sheds because of the role that NO<sub>x</sub> emissions play in the formation of photochemical smog (ozone). The concern is not so much with the primary impacts of NO<sub>2</sub> associated with the emissions of NO<sub>x</sub>, but with secondary effects involving the formation of photochemical smog, in particular ozone.

Twelve years of ozone monitoring data from Sydney, the Illawarra and the Lower Hunter has demonstrated that exceedances of the ozone goals occur regularly in the Sydney region, less frequently in the Illawarra and have only been recorded once in the Lower Hunter since 1999. Based on these data Sydney and the Illawarra are being targeted for emission reduction and from photochemical modelling studies DECC have undertaken, they believe that they must reduce NO<sub>x</sub> and reactive hydrocarbon emissions in the Sydney air shed by 25% in order to achieve compliance with the NEPM ozone goal.

Any new proposal which has significant NO<sub>x</sub> emissions will be required to demonstrate Best Available Technology or to consider NO<sub>x</sub> offsets.

### **5. ESTIMATE OF AIR EMISSIONS**

Dust and odour impacts have been dealt with qualitatively.

The kilning process takes place in a purpose built kiln, with gas-fired air heaters providing the required heat. The kiln has been designed by Flucorrex AG, Switzerland incorporating three low NO<sub>x</sub> Weishaupt gas heaters. The design is similar to those used at other JMW plants in Australia and is suitable for this scale of operation.

Weishaupt have advised that the NO<sub>x</sub> emission levels will be between 90-120 mg/Nm<sup>3</sup>. While this is higher than the limit of 50 mg/Nm<sup>3</sup> referred to by the DECC, it is substantially lower than the DECC limit for new plant of 350 mg/Nm<sup>3</sup>. JWM have also advised that under maximum load with a heating capacity of 6060 kW, the flue gas flow from each burner will be 32,000 kg/h. Assuming a density of flue gas of 1.28 kg/Nm<sup>3</sup>, this equates to a NO<sub>x</sub> emission rate from each of the three burners of 0.83 g/s (32,000 [kg/h] x 3.6 [h.g/kg.s] / 1.28 [kg/m<sup>3</sup>] x 120 [mg/Nm<sup>3</sup>] / 1000 [mg/g]).

### **6. APPROACH TO ASSESSMENT**

As discussed, dust and odour have been assessed qualitatively.

Potential impacts of emissions of oxides of nitrogen have been assessed using AUSPLUME Version 6 for Windows. Account has been taken of local dispersion conditions and estimated emissions from the facility. AUSPLUME is an advanced Gaussian dispersion model developed on behalf of the Victorian EPA (VEPA, 1986) and is based on the United States Environmental Protection Agency's Industrial Source Complex (ISC) model. It has recently been upgraded with a graphical user interface

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and other features. It is widely used throughout Australia and is regarded as a "state-of-the-art" model. AUSPLUME has been used extensively for assessing odour impacts and is the recommended model in the NSW DECC guidelines for air quality impact assessments (DEC, 2005).

The way in which the model has been used in this study has been to predict the 1-hour average levels of oxides of nitrogen at a set of receptors at 50 m spacing arranged in a square (2 km by 2 km) around the site.

Meteorological data from Campbelltown as described in **Section 4.2** was used in conjunction with the assumed emission conditions outlined in **Table 8**. Data were supplied by JWM.

**Table 8 – Assumed source parameters and emission rates used for NO<sub>x</sub> modelling**

Modelling parameters	Three stacks
Source location (MGA) (easting, northing, m)	300591,6231793 300591,6231784 300591,6231804
Stack height (m)	23.5
Stack tip diameter (m)	0.6
Temperature (°C)	26.9
Exit velocity (m/s)	127
Emission rate NO <sub>x</sub> (g/s)	0.83

## 7. AIR QUALITY IMPACTS AND CONCLUSIONS

This section discusses the potential air quality impacts of the proposal and the proposed mitigation measures.

### 7.1 Dust

The majority of the grain being processed in the malting facility is in wet form; therefore dust generation is likely to be relatively minor. Dry handling will be confined to conveying barley from the storage silos to steep vessels via the cleaning plant and returning from the kiln through the malt cleaning plant back to the storage silos. The movement of dry product will be in fully sealed conveyors to contain dust emissions with negative air pressure to prevent dust emission.

By-product and collected dust will be transported off-site in sealed trucks and transported to dairy farms to be used as stock feed. A regular site cleaning process will be carried out to collect dust, which has escaped the dust collection system. This also minimises the potential for spontaneous combustion by regulating the availability of oxygen and maintaining a hygienic environment.

With respect to the packing operations, grain movements into receipt, storage and out-loading will be in covered conveyors, with appropriate dust collection and control.

During the demolition and construction phase of the proposed facility dust emissions may occur. Dust generated during the initial earthworks stage is expected to be minor. The demolition and building contractors will implement appropriate erosion and sediment controls to minimise potential impacts of dust generation on surrounding land uses.

A Construction Management Plan will be prepared prior to construction commencing which will provide further details.

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## 7.2 Odour

While the DECC odour criteria are based on odour frequency and concentration alone, in practice the hedonic tone of the odour plays a significant role in whether the odour is considered offensive by the surrounding community.

JWM has advised that their operations in other parts of Australia have had no complaints of offensive odour from the malting process. The only distinctive odour detectable from the other plants has been described as similar to a 'fresh cut lawn', a 'grassy smell', sometimes faintly smelling of 'cucumbers'.

Odour will be generated during the germination phase, when the air off the grain bed is emitted to atmosphere. During kilning, again, the heated air is passed through the grain bed and into the atmosphere and will produce the 'cut-lawn' odour.

The nearest residential properties are approximately 400 metres to the east. The dominant wind direction is from the southwest particularly during autumn and winter when dispersion conditions are poor. Therefore the worst-case impacts are likely to be to the northeast of the site where nearest residential areas are about 600 m away. JWM have operated a plant in Perth for ten years without odour complaints with residential areas within one kilometre. It is therefore likely that the proposed plant will have a similar low level of impact with respect to odour.

## 7.3 Oxides of nitrogen

**Figure 4** and **Figure 5** present the predicted maximum 1-hour average and annual average concentrations of total NO<sub>x</sub> due to emissions from the three gas heaters under maximum load.

The maximum 1-hour off-site concentrations of total NO<sub>x</sub> are predicted to be 300 µg/m<sup>3</sup>. At the point of emission, the percentage of NO<sub>2</sub> in total NO<sub>x</sub> is typically 5-10%. The remaining 90-95% nitric oxide (NO) is converted to NO<sub>2</sub> in the presence of oxidants such as ozone. If it is assumed conservatively that 20% of the NO<sub>x</sub> is converted to NO<sub>2</sub> giving a maximum value of 60 µg/m<sup>3</sup> and this concentration is added to typical maximum 1-hour NO<sub>2</sub> concentrations in Campbelltown of 154 µg/m<sup>3</sup>, the goal of 246 µg/m<sup>3</sup> is not exceeded.

The maximum off-site annual average concentration of total NO<sub>x</sub> is 30 µg/m<sup>3</sup>. However, this modelling is based on a worst case scenario that assumes peak emission rates continue throughout the year. Average gas consumption for normal operation of the malting facility would be less than 60 % of the peak load. This results in a maximum predicted annual off-site average NO<sub>2</sub> concentration of 18 µg/m<sup>3</sup> (30 µg/m<sup>3</sup> x 60%) assuming conservatively that all NO<sub>x</sub> was converted to NO<sub>2</sub>. Typical annual average background concentrations of NO<sub>2</sub> in Sydney are of the order of 30 µg/m<sup>3</sup>. Adding the malting facilities maximum predicted annual average off-site NO<sub>2</sub> level of 18 µg/m<sup>3</sup> to the assumed background level gives a total of 48 µg/m<sup>3</sup>. This is below the DECC annual average goal of 62 µg/m<sup>3</sup> (refer to Table 4).

Therefore it is very unlikely that the gas burners would result in any exceedances of the NO<sub>2</sub> air quality goals at any sensitive receptors.

## 7.4 Conclusions

Air emissions from the proposed malting facilities have been identified and assessed semi-quantitatively. Dust emissions are likely to be minor and would be controlled by maintaining negative pressure on dust generating processes and by good housekeeping. There will be odour emissions generated during the germination and kilning process but these will have a positive hedonic tone and therefore will be unlikely to cause offense. Emissions of oxides of nitrogen from

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the kilning process are unlikely to result in exceedances of air quality goals off-site. The gas-fired heaters will be fitted with low NO<sub>x</sub> burners to minimise regional air quality effects.

## **8. REFERENCES**

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**APPENDIX A**

**JOINT WIND SPEED, WIND DIRECTION AND STABILITY CLASS FREQUENCY TABLES**

STATISTICS FOR FILE: C:\Users\Public\jobs\MINTO MALTINGS\metdata\CAMP89r.AUS  
 MONTHS: All  
 HOURS : All  
 OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

WIND SECTOR	Wind Speed Class (m/s)								TOTAL
	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	
NNE	0.001256	0.014041	0.010160	0.002397	0.000228	0.000000	0.000000	0.000000	0.028082
NE	0.002055	0.008562	0.007877	0.002511	0.000685	0.000000	0.000000	0.000000	0.021689
ENE	0.001598	0.002055	0.001712	0.001598	0.000342	0.000114	0.000000	0.000000	0.007420
E	0.001598	0.002968	0.002169	0.001484	0.000114	0.000114	0.000000	0.000000	0.008447
ESE	0.001027	0.003311	0.003995	0.001826	0.000457	0.000000	0.000000	0.000000	0.010616
SE	0.001712	0.002169	0.003311	0.001941	0.000685	0.000228	0.000000	0.000000	0.010046
SSE	0.001826	0.001941	0.003082	0.002397	0.000799	0.000228	0.000342	0.000000	0.010616
S	0.002854	0.003425	0.003082	0.002397	0.000342	0.000457	0.000114	0.000000	0.012671
SSW	0.007306	0.008447	0.005479	0.003311	0.001484	0.000000	0.000000	0.000000	0.026027
SW	0.012215	0.014840	0.006279	0.003311	0.001027	0.000342	0.000000	0.000000	0.038014
WSW	0.007648	0.009247	0.002626	0.001370	0.001256	0.000799	0.000228	0.000114	0.023288
W	0.004795	0.004338	0.001370	0.000685	0.000457	0.000228	0.000114	0.000114	0.012100
WNW	0.002169	0.004338	0.001027	0.000457	0.000457	0.000571	0.000228	0.000114	0.009361
NW	0.000799	0.003311	0.000799	0.000571	0.000114	0.000114	0.000000	0.000000	0.005708
NNW	0.000228	0.001941	0.000342	0.000228	0.000114	0.000114	0.000000	0.000000	0.002968
N	0.000000	0.002055	0.000342	0.000000	0.000000	0.000228	0.000000	0.000000	0.002626
CALM									0.007991
TOTAL	0.049087	0.086986	0.053653	0.026484	0.008562	0.003539	0.001027	0.000342	0.237671
MEAN WIND SPEED (m/s) = 2.92									
NUMBER OF OBSERVATIONS = 2082									

PASQUILL STABILITY CLASS 'B'

WIND SECTOR	Wind Speed Class (m/s)								TOTAL
	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	
NNE	0.000228	0.003539	0.003425	0.000571	0.000000	0.000000	0.000000	0.000000	0.007763
NE	0.000571	0.002055	0.004338	0.003767	0.001256	0.000000	0.000000	0.000000	0.011986
ENE	0.000228	0.000913	0.001826	0.003539	0.001826	0.000228	0.000000	0.000000	0.008562
E	0.000685	0.001484	0.001941	0.001826	0.000228	0.000000	0.000000	0.000000	0.006164
ESE	0.000342	0.001826	0.003995	0.002626	0.000114	0.000000	0.000000	0.000000	0.008904
SE	0.000228	0.000913	0.003425	0.001256	0.000571	0.000000	0.000000	0.000000	0.006393
SSE	0.000685	0.000457	0.001484	0.000799	0.000342	0.000114	0.000000	0.000000	0.003881
S	0.000685	0.001142	0.001256	0.000913	0.000000	0.000114	0.000000	0.000000	0.004110
SSW	0.001484	0.002854	0.000799	0.000457	0.000000	0.000000	0.000000	0.000000	0.005594
SW	0.005479	0.009018	0.002169	0.001142	0.000913	0.000114	0.000114	0.000000	0.018950
WSW	0.002055	0.002511	0.001598	0.001598	0.001484	0.001826	0.000913	0.000571	0.012557
W	0.001027	0.001027	0.000913	0.000685	0.001598	0.001142	0.000799	0.000342	0.007534
WNW	0.000799	0.001142	0.001256	0.000913	0.000457	0.000685	0.000228	0.000114	0.005594
NW	0.000457	0.000799	0.000114	0.000000	0.000114	0.000114	0.000000	0.000000	0.001598
NNW	0.000000	0.000799	0.000114	0.000114	0.000000	0.000000	0.000000	0.000000	0.001027
N	0.000000	0.000342	0.000457	0.000342	0.000000	0.000000	0.000000	0.000000	0.001142
CALM									0.001826
TOTAL	0.014954	0.030822	0.029110	0.020548	0.008904	0.004338	0.002055	0.001027	0.113584
MEAN WIND SPEED (m/s) = 3.79									
NUMBER OF OBSERVATIONS = 995									

PASQUILL STABILITY CLASS 'C'

		Wind Speed Class (m/s)								
WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL	
NNE	0.000000	0.001826	0.001598	0.000457	0.000114	0.000000	0.000000	0.000000	0.003995	
NE	0.000228	0.001256	0.001027	0.001712	0.000457	0.000114	0.000000	0.000000	0.004795	
ENE	0.000457	0.000342	0.000685	0.001256	0.001142	0.000000	0.000000	0.000000	0.003881	
E	0.000228	0.000342	0.000457	0.000228	0.000000	0.000000	0.000000	0.000000	0.001256	
ESE	0.000000	0.000342	0.000114	0.000114	0.000000	0.000000	0.000000	0.000000	0.000571	
SE	0.000228	0.000228	0.000342	0.000342	0.000000	0.000000	0.000000	0.000000	0.001142	
SSE	0.000000	0.000228	0.000342	0.000114	0.000000	0.000000	0.000000	0.000000	0.000685	
S	0.000571	0.000342	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.001142	
SSW	0.002740	0.002055	0.000342	0.000000	0.000000	0.000000	0.000000	0.000000	0.005137	
SW	0.007306	0.004909	0.000799	0.000342	0.000228	0.000114	0.000000	0.000000	0.013699	
WSW	0.002626	0.002055	0.000457	0.000457	0.000913	0.000342	0.000000	0.000000	0.006849	
W	0.000913	0.000342	0.000000	0.000457	0.000685	0.000571	0.000228	0.000000	0.003196	
WNW	0.000342	0.000457	0.000228	0.000342	0.000342	0.000000	0.000000	0.000000	0.001712	
NW	0.000228	0.000342	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000799	
NNW	0.000114	0.000457	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000571	
N	0.000000	0.000000	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114	
CALM									0.001484	
TOTAL	0.015982	0.015525	0.006963	0.005822	0.003881	0.001142	0.000228	0.000000	0.051027	

MEAN WIND SPEED (m/s) = 2.87  
NUMBER OF OBSERVATIONS = 447

PASQUILL STABILITY CLASS 'D'

		Wind Speed Class (m/s)								
WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL	
NNE	0.000685	0.003767	0.002055	0.000799	0.000114	0.000000	0.000000	0.000000	0.007420	
NE	0.001598	0.005822	0.005365	0.004338	0.001370	0.000114	0.000000	0.000000	0.018607	
ENE	0.001142	0.006393	0.010502	0.005708	0.001712	0.000000	0.000000	0.000000	0.025457	
E	0.000685	0.002968	0.005594	0.001484	0.000000	0.000000	0.000000	0.000000	0.010731	
ESE	0.000799	0.002169	0.005365	0.000799	0.000000	0.000000	0.000000	0.000000	0.009132	
SE	0.000913	0.000685	0.005137	0.001826	0.000342	0.000114	0.000114	0.000000	0.009132	
SSE	0.001142	0.000685	0.002626	0.001712	0.000685	0.000342	0.000114	0.000000	0.007306	
S	0.001712	0.001027	0.003539	0.001598	0.000571	0.000342	0.000000	0.000000	0.008790	
SSW	0.006621	0.006279	0.004795	0.002968	0.000799	0.000114	0.000000	0.000000	0.021575	
SW	0.038470	0.031735	0.005708	0.001256	0.000342	0.000000	0.000228	0.000114	0.077854	
WSW	0.014612	0.005251	0.007648	0.006621	0.003425	0.001256	0.000342	0.000000	0.039155	
W	0.005023	0.001370	0.003425	0.002055	0.001484	0.001484	0.000457	0.000000	0.015297	
WNW	0.003653	0.000799	0.001712	0.000685	0.000457	0.000228	0.000000	0.000000	0.007534	
NW	0.001712	0.000799	0.000457	0.000228	0.000000	0.000114	0.000000	0.000000	0.003311	
NNW	0.000114	0.000913	0.000685	0.000228	0.000000	0.000000	0.000114	0.000000	0.002055	
N	0.000000	0.000114	0.000457	0.000114	0.000114	0.000000	0.000000	0.000000	0.000799	
CALM									0.005365	
TOTAL	0.078881	0.070776	0.065068	0.032420	0.011416	0.004110	0.001370	0.000114	0.269521	

MEAN WIND SPEED (m/s) = 2.90  
NUMBER OF OBSERVATIONS = 2361

PASQUILL STABILITY CLASS 'E'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001027	0.002511	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.004224
NE	0.001941	0.003082	0.000114	0.000114	0.000000	0.000000	0.000000	0.000000	0.005251
ENE	0.001598	0.003311	0.000457	0.000000	0.000000	0.000000	0.000000	0.000000	0.005365
E	0.001598	0.002854	0.000571	0.000114	0.000000	0.000000	0.000000	0.000000	0.005137
ESE	0.002055	0.003539	0.001142	0.000000	0.000000	0.000000	0.000000	0.000000	0.006735
SE	0.002169	0.002968	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.005822
SSE	0.000799	0.001712	0.001027	0.000000	0.000000	0.000000	0.000000	0.000000	0.003539
S	0.001941	0.003196	0.000799	0.000000	0.000000	0.000000	0.000000	0.000000	0.005936
SSW	0.009247	0.012671	0.001142	0.000000	0.000000	0.000000	0.000000	0.000000	0.023059
SW	0.040068	0.035502	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.075799
WSW	0.018037	0.005936	0.000342	0.000000	0.000000	0.000000	0.000114	0.000000	0.024429
W	0.006050	0.001256	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.007534
WNW	0.003995	0.000685	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.004909
NW	0.002626	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002854
NNW	0.000457	0.000342	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000913
N	0.000000	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114
CALM									0.006507
TOTAL	0.093607	0.079909	0.007763	0.000228	0.000000	0.000000	0.000114	0.000000	0.188128

MEAN WIND SPEED (m/s) = 1.60  
NUMBER OF OBSERVATIONS = 1648

PASQUILL STABILITY CLASS 'F'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000685	0.001826	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002511
NE	0.001484	0.002055	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003539
ENE	0.001826	0.002511	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.004452
E	0.001941	0.003767	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005708
ESE	0.001826	0.005479	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007306
SE	0.001826	0.002854	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004680
SSE	0.001256	0.002511	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003767
S	0.003539	0.002968	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006507
SSW	0.008105	0.010160	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.018265
SW	0.023858	0.018836	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.042808
WSW	0.012100	0.004110	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.016210
W	0.004110	0.001370	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005479
WNW	0.002626	0.000799	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003425
NW	0.000799	0.000913	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001712
NNW	0.000571	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001256
N	0.000000	0.000342	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000342
CALM									0.012100
TOTAL	0.066553	0.061187	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.140068

MEAN WIND SPEED (m/s) = 1.44  
NUMBER OF OBSERVATIONS = 1227

ALL PASQUILL STABILITY CLASSES

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.003881	0.027511	0.017922	0.004224	0.000457	0.000000	0.000000	0.000000	0.053995
NE	0.007877	0.022831	0.018721	0.012443	0.003767	0.000228	0.000000	0.000000	0.065868
ENE	0.006849	0.015525	0.015297	0.012100	0.005023	0.000342	0.000000	0.000000	0.055137
E	0.006735	0.014384	0.010731	0.005137	0.000342	0.000114	0.000000	0.000000	0.037443
ESE	0.006050	0.016667	0.014612	0.005365	0.000571	0.000000	0.000000	0.000000	0.043265
SE	0.007078	0.009817	0.012900	0.005365	0.001598	0.000342	0.000114	0.000000	0.037215
SSE	0.005708	0.007534	0.008562	0.005023	0.001826	0.000685	0.000457	0.000000	0.029795
S	0.011301	0.012100	0.008904	0.004909	0.000913	0.000913	0.000114	0.000000	0.039155
SSW	0.035502	0.042466	0.012557	0.006735	0.002283	0.000114	0.000000	0.000000	0.099658
SW	0.127397	0.114840	0.015297	0.006050	0.002511	0.000571	0.000342	0.000114	0.267123
WSW	0.057078	0.029110	0.012671	0.010046	0.007078	0.004224	0.001598	0.000685	0.122489
W	0.021918	0.009703	0.005936	0.003881	0.004224	0.003425	0.001598	0.000457	0.051142
WNW	0.013584	0.008219	0.004452	0.002397	0.001712	0.001484	0.000457	0.000228	0.032534
NW	0.006621	0.006393	0.001598	0.000799	0.000228	0.000342	0.000000	0.000000	0.015982
NNW	0.001484	0.005137	0.001256	0.000571	0.000114	0.000114	0.000114	0.000000	0.008790
N	0.000000	0.002968	0.001370	0.000457	0.000114	0.000228	0.000000	0.000000	0.005137
CALM									0.035274
TOTAL	0.319064	0.345205	0.162785	0.085502	0.032763	0.013128	0.004795	0.001484	1.000000

MEAN WIND SPEED (m/s) = 2.55  
 NUMBER OF OBSERVATIONS = 8760

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

- A : 23.8%
- B : 11.4%
- C : 5.1%
- D : 27.0%
- E : 18.8%
- F : 14.0%

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## FIGURES



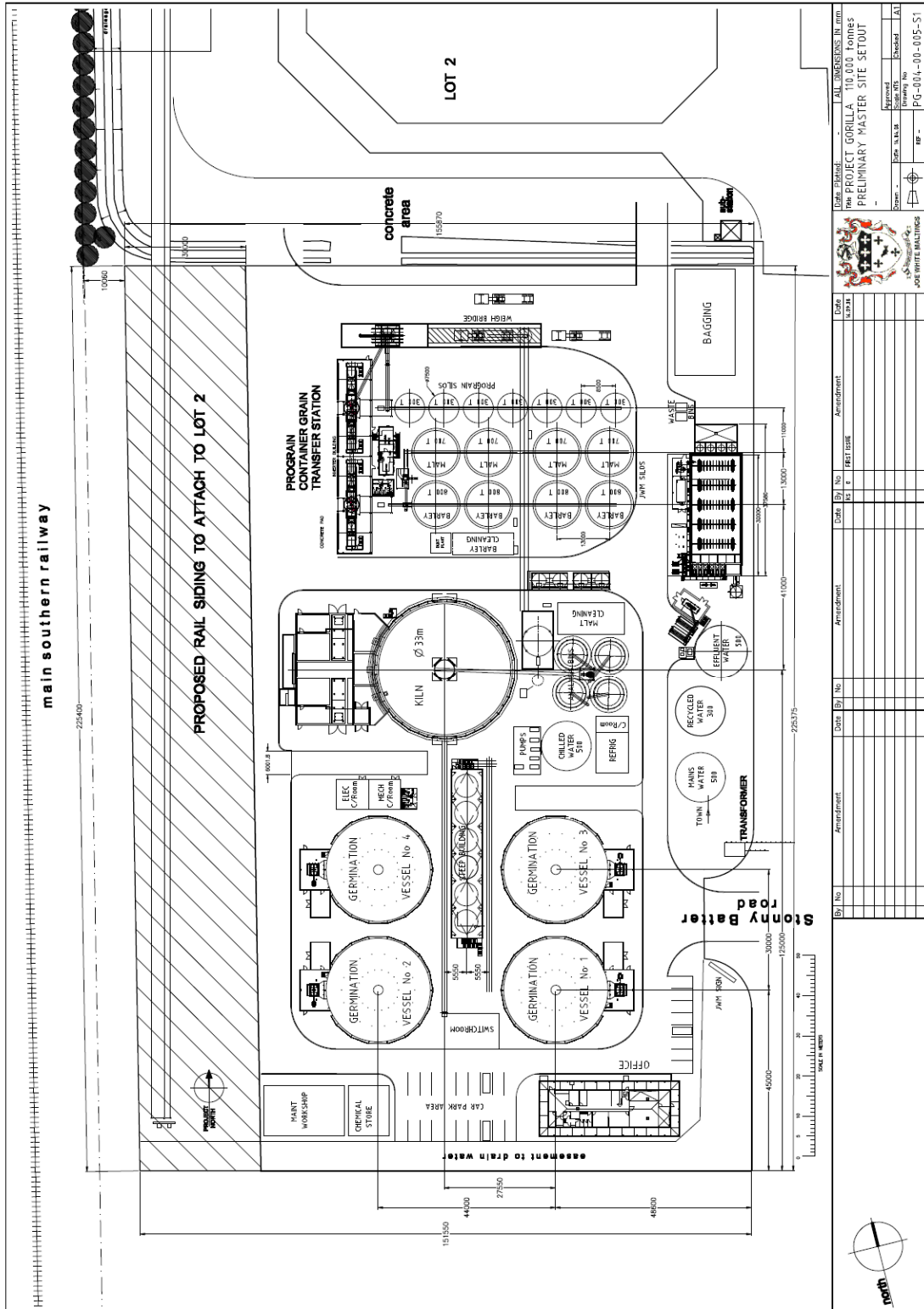
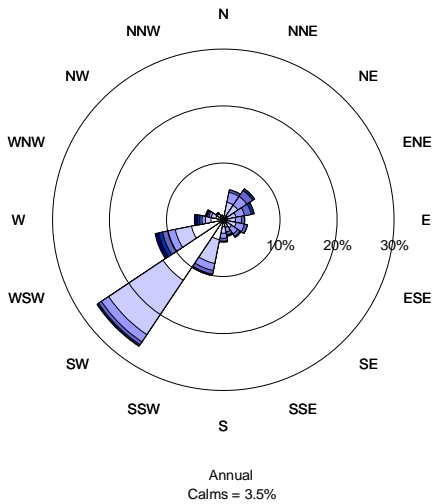


Figure 2 Site Layout



### Annual and seasonal windroses for Campbelltown 1989

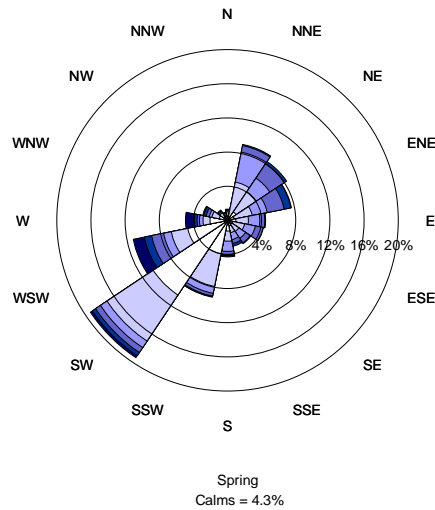
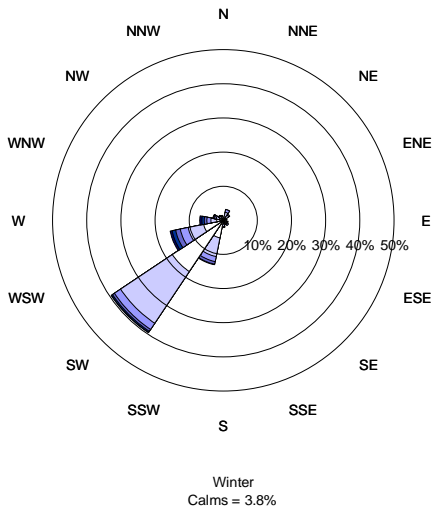
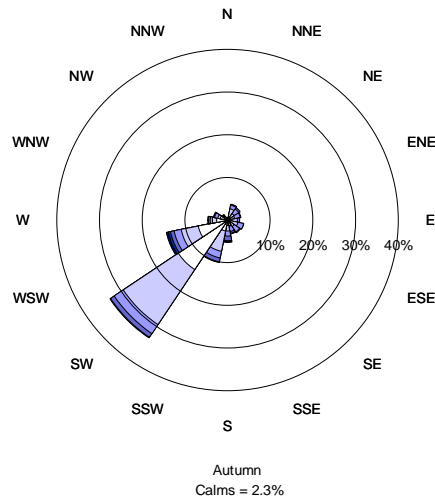
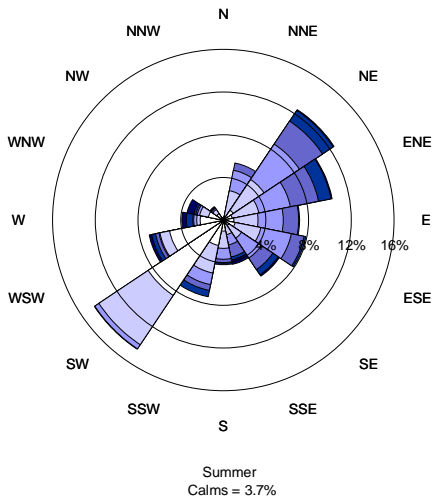
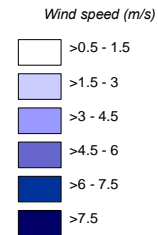
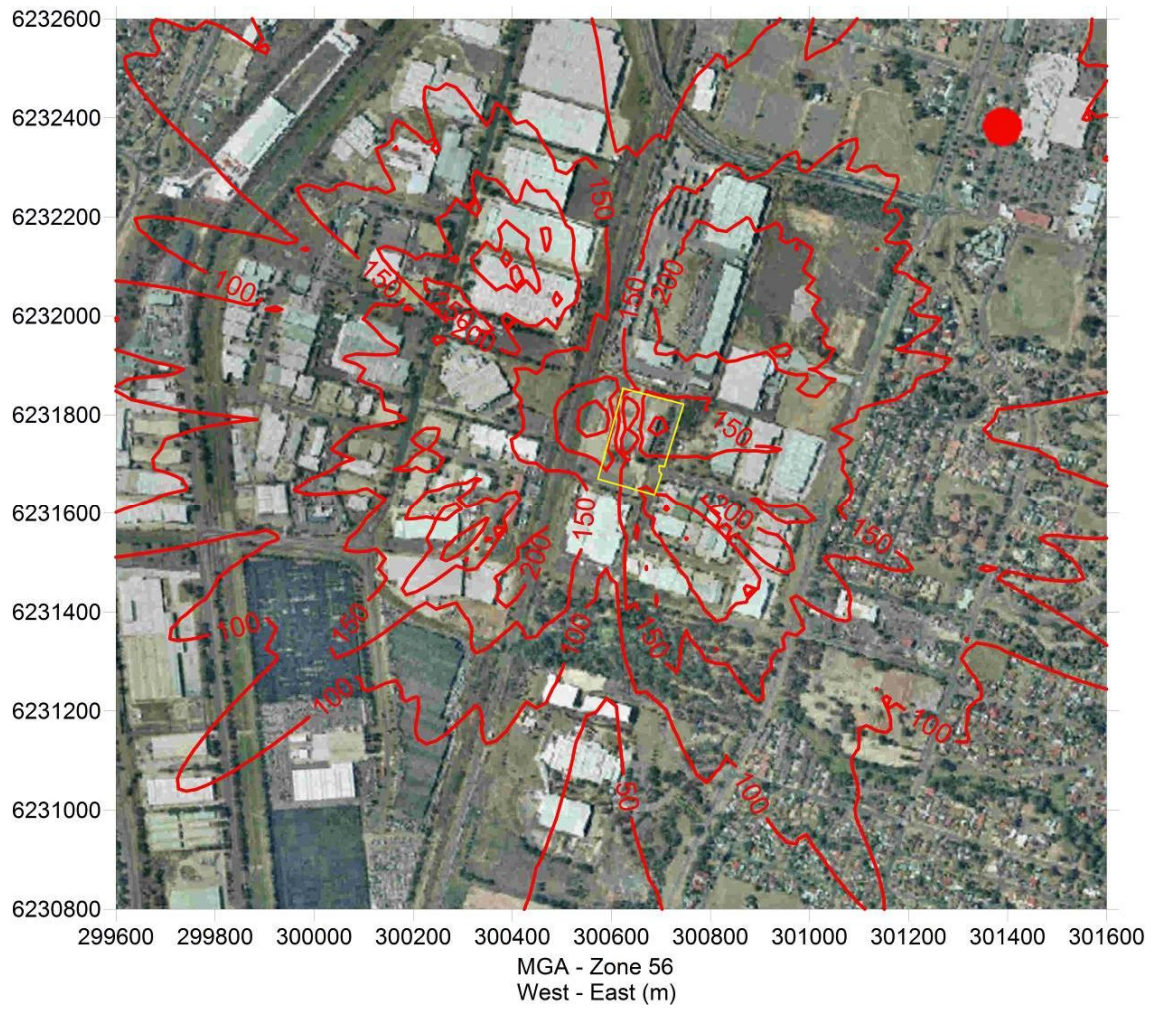
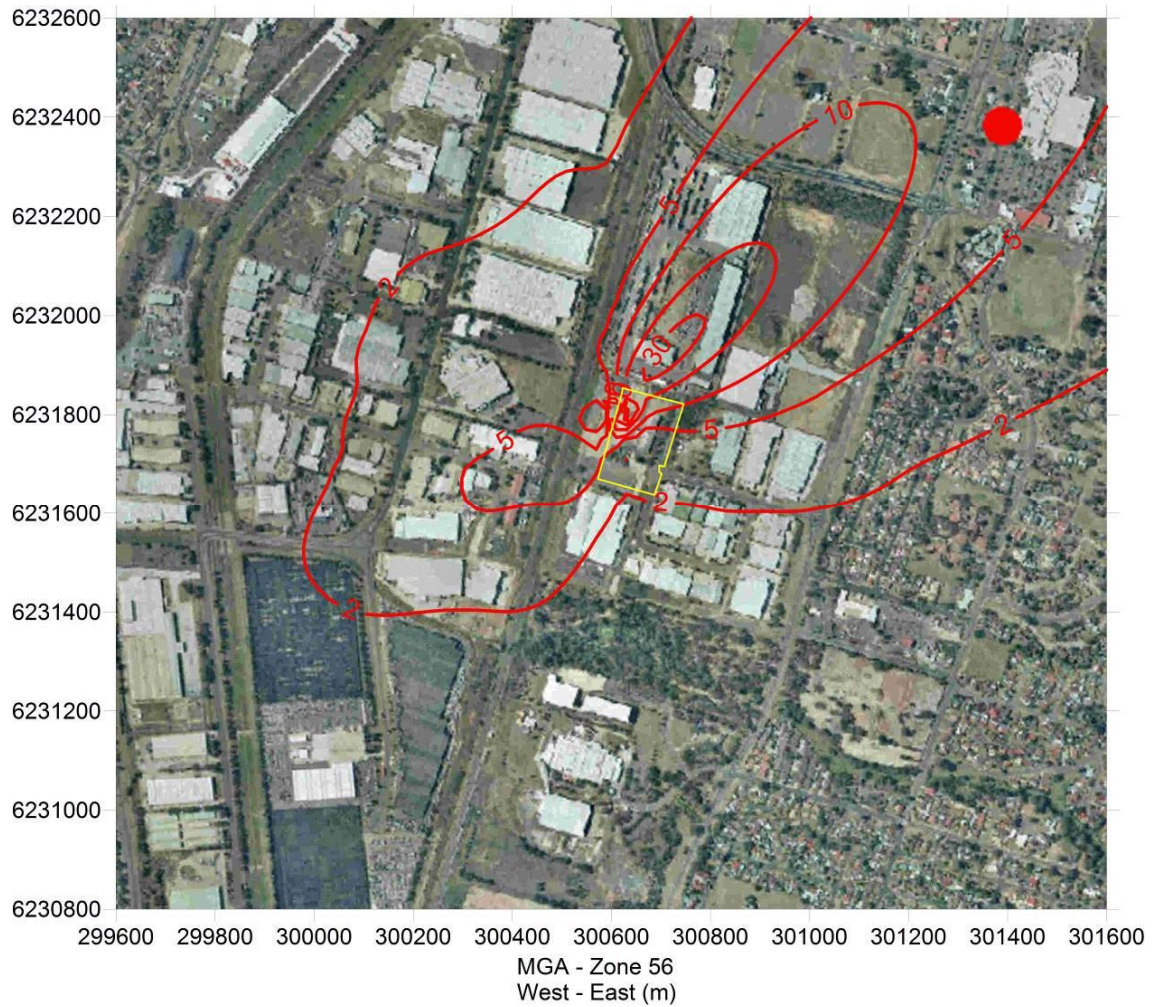


Figure 3 Annual and seasonal windroses



**Figure 4 Predicted maximum 1-hour average NO<sub>x</sub> concentrations due to emissions from Joe White Maltings –  $\mu\text{g}/\text{m}^3$**



**Figure 5** Predicted annual average NO<sub>x</sub> concentrations due to emissions from Joe White Maltings -  $\mu\text{g}/\text{m}^3$