Air Quality Parameters and Associated Health Effects

A.1 Carbon Monoxide

A.2 Particulate Matter

A.3 Sulphur Dioxide

A.4 Hydrocarbons (Volatile Organic Compounds)

A.5 Oxides of Nitrogen

A.6 Ozone (Photochemical Smog)

A.1 Carbon Monoxide

Carbon monoxide (CO) is an odourless, colourless gas that is formed naturally due to emissions from the sea, combustion processes (bush fires) and oxidation of methane in the atmosphere (as a result of organic decomposition).

As an anthropogenic (man-made) source, CO is a product of a combustion process where there is a limited oxygen supply, typically occurring in internal combustion engines. CO is easily oxidised to Carbon Dioxide in the presence of the concentrations of oxygen found in the atmosphere, and as such it generally does not present a problem unless the space or oxygen concentration is confined.

In the body, CO combines with haemoglobin to form carboxyhaemoglobin. Haemoglobin has a greater affinity for carbon monoxide than oxygen (by a factor of 200). As such, when it is inhaled, it reduces the uptake of oxygen by the lungs. This process is reversible, and providing exposure to carbon monoxide is reduced, the detrimental effects of exposure will be remedied within a matter of hours.

Short term effects of acute exposure to CO include headaches, nausea and lethargy. However, these are generally not reported until concentrations of carboxyhaemoglobin (formed when CO is taken up by the blood) are in excess of 10% of saturation. This is approximately the equilibrium value achieved with an ambient atmospheric concentration of 70 mg/m^3 for a person engaged in light activity. However, there is evidence that there is a risk for individuals with cardiovascular disease when the carboxyhaemoglobin concentration reaches 4% and the World Health Organisation (WHO) recommends that ambient concentrations be kept from exceeding the 4% saturation level.

A.2 Particulate Matter

Total Suspended Particulate (TSP) consists of course and fine particles. In the atmosphere, particles range in size from 0.1 µm to 50 µm. Even without human activity, the atmosphere contains particles from sources such as wind-blown dust, volcanos, fires, sea salt, pollens and bacteria. With regard to human activity, industry is usually the largest producer of particulates.

Atmospheric particulates include primary and secondary pollutants. The main source of primary fine particulates from internal combustion engines is diesel emissions. Secondary particles include sulphates and nitrates which derive from sulphur dioxide and nitrogen dioxide emissions respectively and organic aerosols which derive from volatile organic compounds (VOCs - refer **Section A.4**).

The size of the particles determines how far into the respiratory system the particles penetrate. Particles with an aerodynamic diameter greater than 10 microns (µm) are screened out in the upper respiratory tract while particles smaller than 10 µm, known as PM_{10}, may penetrate into the lower respiratory tract. Recent health research has shown that fine particles with an aerodynamic diameter less than 2.5 µm, $PM_{2.5}$, are able to penetrate deep into the lungs.

Potential adverse health impacts associated with exposure to fine particles include increased mortality from cardiovascular and respiratory diseases, chronic obstructive pulmonary disease and heart disease, reduced lung capacity in asthmatic children, etc.

The health effects of particulate matter are further compounded by the chemical nature of the particles and by the possibility of synergistic effects with other air pollutants such as sulphur dioxide. A (negative) synergistic effect is where the combination of two pollutants becomes more detrimental to health upon mixture. In the above case, sulphur dioxide is able to adhere to fine particles and is therefore carried deep within the lungs where it may cause greater damage.

A.3 Sulphur Dioxide

Sulphur dioxide is an acid gas that can have harmful effects on the respiratory system as well as on vegetation and building materials when it combines with moisture in the atmosphere to become “acid rain”.

Exposure to sulphur dioxide is more common due to incidents of “plume grounding” (when a pollutant plume is not dispersed and hits the surrounding land) from power stations burning high-sulphur coal. These typically occur in short episodes, and this is reflected in the short averaging times (10 minute and 1 hour) given for the sulphur dioxide air quality goal (as specified by the National Health and Medical Research Council).

A.4 Hydrocarbons (Volatile Organic Compounds)

Natural emissions, such as those generated by eucalypts, account for over 50% of Volatile Organic Compound (VOC) emissions in many environments. However in an urban environment, emissions are usually dominated by vehicle emissions, as the biogenic sources are generally located away from urban centres. Sources of volatile organic compounds (VOCs) include fugitive vapour emissions of lubricants and fuel, as well as the products of incomplete combustion of fuel. The amount of evaporative emissions is related to the diurnal temperature.

VOCs are an important precursor to photochemical pollution, or smog (refer **Section A.6**). The environmental effects of VOCs include acid rain as they undergo chemical reactions in the atmosphere.

Hydrocarbons alone do not generally pose a problem at the concentrations commonly experienced at roadside environments. Hydrocarbons such as benzene are known to have an adverse effect on human health, but these effects are thought to occur at concentrations higher than the levels of exposure found at roadsides from traffic emissions.

Volatile organics such as benzene and 1,3 butadiene have been highlighted as key pollutants as they are known carcinogens. The WHO specifies a risk factor for developing leukaemia of between 4.4×10^{-6} to 7.5×10^{-6} for a lifetime exposure to 1 $\mu g/m^3$ of benzene, and it is the current view of many in the medical/scientific community that there is no safe limit for benzene exposure.

A.5 Oxides of Nitrogen

Oxides of nitrogen (NO_X) include nitric oxide (NO) and nitrogen dioxide (NO_2). All combustion processes in the presence of air produce nitric oxide, and concentrations are increased under high pressure.

NO is produced naturally by microbial activity, and also by lightning storms in significant amounts. Anthropogenically, NO is formed in the atmosphere by combustion processes, particularly high temperature (>1000°C) processes such as those occurring in power stations and within the internal combustion engines of motor vehicles. Typically, NO will constitute between 5% and 10% of total NO_X emissions from combustion sources.

NO_X may be formed during combustion either as thermal NO_X or fuel NO_X. Thermal NO_X is formed through the oxidation of atmospheric nitrogen in the combustion air. Fuel NO_X is produced through the oxidation of nitrogen intrinsic to the fuel source. Fuel NO_X is therefore only significant when combusting nitrogen-rich compounds such as heavy fuel oils.

The majority of NO_2 finds its way into the atmosphere through the oxidation of nitric oxide (NO), with only a small proportion emitted directly into the atmosphere. The oxidation of NO, and its inter-relationship with ozone formation and destruction is discussed in **Section A.6**.

NO_X in the atmosphere contribute to regional air pollution as a principal reactant in the production of photochemical smog (refer **Section A.6**) and also may contribute to the formation of acid rain. NO_2 is a brown gas and NO_X produce nitrate particles, both of which reduce visibility.

NO_2 is a toxic gas. Exposure to NO_2 can result in decreased lung function and increases in respiratory illness. Exposure to high atmospheric levels can lead to significant increases in hospital admissions and emergency room visits for respiratory and cardiovascular disease.

A.6 Ozone (Photochemical Smog)

Photochemical pollution occurs when chemical reactions occur with oxides of nitrogen (NO_X), hydrocarbons and atmospheric oxygen in the presence of ultraviolet radiation. Ozone (O_3) is classed as a secondary pollutant as it is a product of these chemical reactions.

The principal chemical reactions driving the formation of photochemical smog pollution is summarised in equations 1-4 below:

The oxidation of NO occurs in two forms atmospherically, the first being through its reaction with ozone.

$$NO + O_3 \rightarrow NO_2 + O_2 \qquad (1)$$

The above reaction is relatively slow, with the destruction of O_3 occurring 24-hours a day, regardless of the presence of sunlight.

The second route for the formation of NO_2 is through the reaction of NO with peroxy radicals. Peroxy radicals are atmospheric radicals formed due to the presence of hydrocarbons in the atmosphere, and therefore this route becomes more significant in an urban or roadside situation, where there are high concentrations of hydrocarbons produced by exhaust emissions.

$$NO + RO_2 \rightarrow NO_2 + RO \qquad (2)$$

The two reactions above are opposed by the following rapid reactions of NO_2 with sunlight. This disassociates the NO_2, and therefore reforms the nitric oxide and ozone.

$$NO_2 + hv \rightarrow NO + O \qquad (\lambda < 400nm) \qquad (3)$$

$$O + O_2 \rightarrow O_3 \qquad (4)$$

When there are equal rates of formation and destruction of NO_2, equations 1-4 describe a photostationary state.

However, this equilibrium is disturbed since the reaction in equation (2) means that nitric oxide may be oxidised to nitrogen dioxide without the loss of ozone. Reaction (2) effectively “recycles” the NO_2, meaning that a small quantity of NO_X can produce a large amount of O_3, when significant quantities of VOCs are present. This imbalance is responsible for the high concentrations of tropospheric ozone found in urban environments during daylight. Equations (3) and (4) represent the only anthropogenic route for ozone production.

Depending upon the concentrations of the above reactants in the ambient air, either reaction (1), (2) or (3) may dominate in determining the ability of the atmosphere to produce photochemical smog. Whether reaction (1), (2) or (3) drives the reaction chemistry establishes whether smog formation conditions are “NO_X-limited”, “VOC-limited” or “light-limited”. When competing reactions consume the nitrogen oxides and produce stable products such as nitric acid and nitrogenous aerosol particles, further smog production is halted, and the air chemistry is said to be “NO_X-limited” (Azzi et al, 1998). Where the regeneration of NO_2 is halted due to consumption of peroxy radicals within the air parcel, this is known as a “VOC-limited” regime. When sufficient ambient concentrations of NO_2 are available, smog formation will be dependant upon sunlight intensity, and is said to be “light-limited”.

Typically, smog formation is VOC or light limited in core urban areas, and NO_X limited at varying distances downwind (Duc et al, 2003). The photolytic rate at which new smog will be produced is determined by sunlight intensity and the value of R_{smog}, a photolytic rate coefficient. Values of R_{smog} for ambient air are related to the emissions of VOC.

Photochemical smog is likely to build up on days of stable conditions when the air is still, when there are clear skies and when there are high NO_X emission rates. The reduced visibility during photochemical smog episodes is due to fine aerosols formed by ozone as well as nitrogen dioxide (a brown gas), nitrate particles and organic aerosols.

The health effects of ozone include irritation of the eyes and the respiratory tract. More serious effects include respiratory and cardiovascular disease resulting in increased hospital admissions and emergency room visits.

Ozone has significant environmental effects. Due to its highly reactive nature, a large number of plant species are affected by ground level (tropospheric) ozone. Ozone can cause damage to buildings and structural materials and cause rubber products and textiles to deteriorate.

Climate Averages, Seasonal Wind Roses and Stability Classes for the Project Site

B1 Climate Averages Recorded at the Nowra RAN Air Station

B2 Annual / Seasonal Wind Roses for the Project Site - 2006

B3 Annual / Seasonal Wind Roses for the Nowra RAN - 2006

B4 TAPM Predicted Seasonal Stability Classes for the Project Site

Climate Averages, Seasonal Wind Roses and Stability Classes for the Project Site

Table B1 Climate Averages for Nowra RAN Air Station

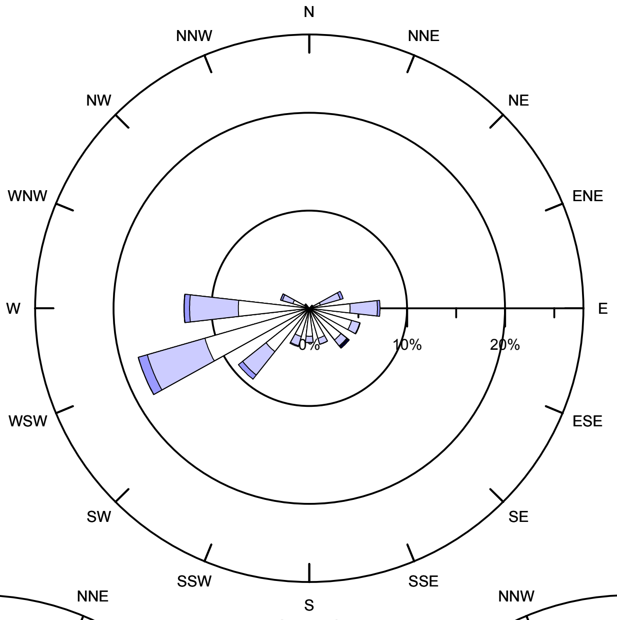
Element	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Mean daily maximum temperature - ºC	25.8	25.8	24.5	22.1	19	16.4	15.8	17.1	19.4	21.5	23.1	25.1	21.3
Mean no. of days where Max Temp >= 40.0ºC	0.3	0.2	0	0	0	0	0	0	0	0	0.1	0.2	0.9
Mean no. of days where Max Temp >= 35.0ºC	1.5	1.1	0.4	0	0	0	0	0	0	0.2	0.7	1	5
Mean no. of days where Max Temp >= 30.0ºC	5.4	4.1	3	0.5	0	0	0	0	0.3	1.7	2.8	4.3	22
Highest daily Max Temp - ºC	43.1	44.2	41	36.4	29	25.4	25.4	29.4	35.1	38.7	42.8	42.7	44.2
Mean daily minimum temperature - ºC	15.9	16.3	14.8	12.1	9.7	7.6	6.2	6.7	8.3	10.6	12.6	14.6	11.3
Mean no. of days where Min Temp <= 2.0ºC	0	0	0	0	0	0.2	1	0.8	0.1	0	0	0	2
Mean no. of days where Min Temp <= 0.0ºC	0	0	0	0	0	0	0.1	0	0	0	0	0	0.1
Lowest daily Min Temp - ºC	9.2	8.6	4.6	4.5	2.2	1.4	-0.8	-0.4	0.6	3.2	3.9	6.4	-0.8
Mean 9am air temp - ºC	20.8	20.6	19.6	17.1	13.8	11.1	10	11.6	14.4	17	18.3	20	16.2
Mean 9am wet bulb temp - ºC	17.5	17.8	16.7	14.1	11.4	9	7.8	8.8	10.9	13.1	14.5	16.3	13.1
Mean 9am dew point - ºC	15.2	15.9	14.6	11.5	8.9	6.5	4.9	5.4	6.9	9.4	11.2	13.3	10.3
Mean 9am relative humidity - %	72	76	74	71	74	75	72	68	63	64	66	68	70
Mean 9am wind speed - km/h	8.2	7.8	8.5	10.8	12.9	14.9	15.5	15.4	14.6	12.1	10.5	9.2	11.7
Mean 3pm air temp - ºC	24.1	24.2	23	20.8	18	15.4	14.8	15.9	17.8	19.5	21.2	23.3	19.8
Mean 3pm wet bulb temp - ºC	19	19.3	18.2	15.9	13.5	11.4	10.3	11	12.5	14.4	16	17.8	14.9
Mean 3pm dew point - ºC	15.6	16.1	14.8	11.7	9.2	7	5.1	5.3	6.9	9.7	11.5	13.6	10.5
Mean 3pm relative humidity - %	62	63	63	59	59	59	54	52	52	57	58	59	58
Mean 3pm wind speed - km/h	17.7	17.3	15.8	14.9	14.2	15	16.9	19	20.5	19.7	19.7	19.3	17.5
Mean monthly rainfall - mm	95.8	125.7	130.4	100.6	92.5	110.9	55.7	67.7	68	113.3	100.4	73.7	1134.7
Median (5th decile) monthly rainfall - mm	73.3	70.9	76.6	51.6	72.2	62.1	40.5	35.2	47.7	68.8	64.4	63.1	1092.8
9th decile of monthly rainfall - mm	191.5	340.6	318.9	288.8	198.5	249	137.1	214.7	148.6	213.7	208.2	166.8	1574.6
1st decile of monthly rainfall - mm	15.6	7.3	7.2	10.6	8.1	18.9	5	7.2	9.5	13.6	11.5	8.9	578.4
Mean no. of raindays	12.8	12.1	12.3	9.6	10.1	10.1	7.6	8.7	9.9	12.5	13	11.2	129.8
Highest monthly rainfall - mm	333.2	500.9	428.9	503.4	510	609.2	195.3	365.4	235.2	815.3	585.4	225.8	
Lowest monthly rainfall - mm	10	1.6	2.3	1	0.5	8.1	0	1.4	2.5	4	4.8	2.2	

Climate Averages, Seasonal Wind Roses and Stability Classes for the Project Site

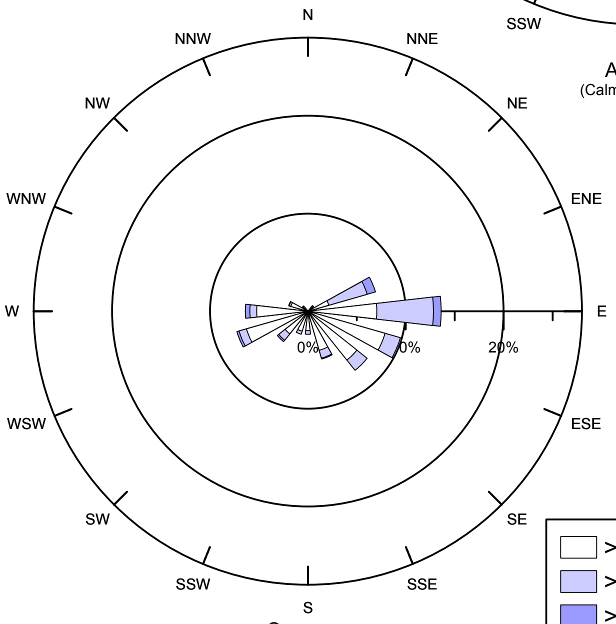
Table B1 Cont. Climate Averages for Nowra RAN Air Station

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Highest recorded daily rainfall - mm	117	208.2	180.8	245.9	190.2	174.8	128	165.1	134.4	157.4	188.7	127.8	245.9
Mean no. of clear days	6.9	5.7	7.2	9.2	8.9	8.9	11.8	12.8	9.5	7.2	6.2	5.3	99.6
Mean no. of cloudy days	14	12.9	12.3	9.7	10.6	9.7	7.6	7.2	8.4	11.7	12	11.7	128
Mean daily hours of sunshine	6.7	6.6	6.4	6.7	5.9	5.7	6.7	7.5	7.4	7.2	7.3	7.3	6.8
Highest recorded wind gust - km/h	101.9	100.1	107.6	114.8	116.6	118.4	129.6	131.4	146.5	118.4	126	103.7	146.5
Mean daily evaporation - mm	6.3	5.7	4.7	4	3.1	2.9	3.1	4.1	5	5.7	6.1	6.9	4.8

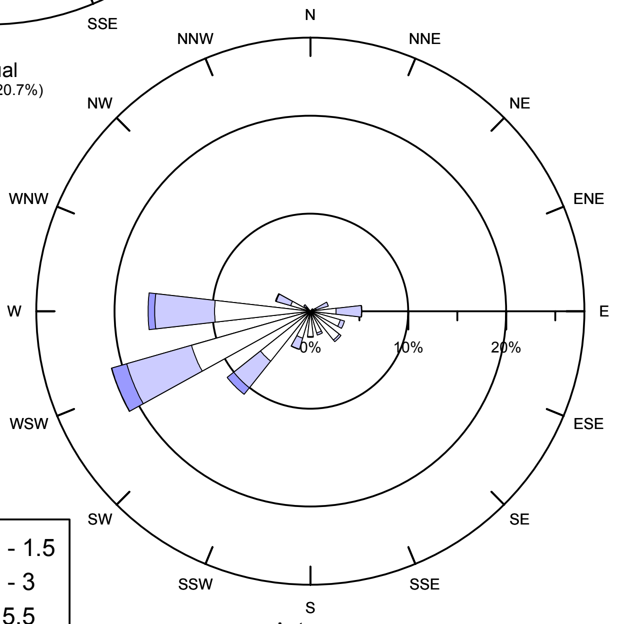
Source: Bureau of Meteorology, 2007



Annual
(Calms = 20.7%)

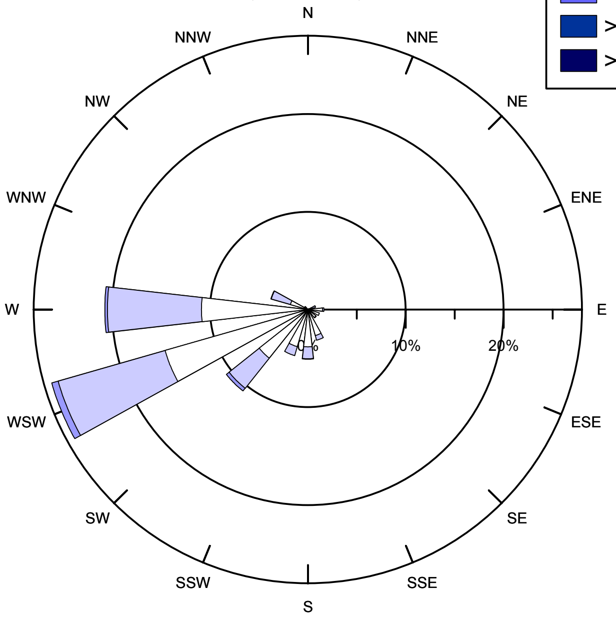


Summer
(Calms = 28.0%)

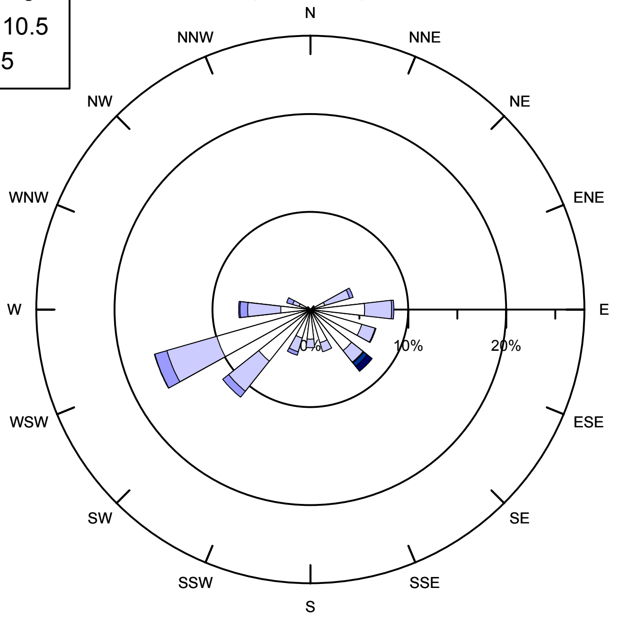


Autumn
(Calms = 21.2%)

☐ >0.5 - 1.5
▨ >1.5 - 3
▨ >3 - 5.5
▨ >5.5 - 8
■ >8 - 10.5
■ >10.5



Winter
(Calms = 16.8%)



Spring
(Calms = 16.9%)

Heggies Pty Ltd
Consulting Engineers and Scientists
2 Lincoln Street
Lane Cove NSW 2066 Australia
PO Box 176 Lane Cove NSW 1595
Telephone +612 9427 8100 Facsimile +612 9427 8200
Email Sydney@heggies.com

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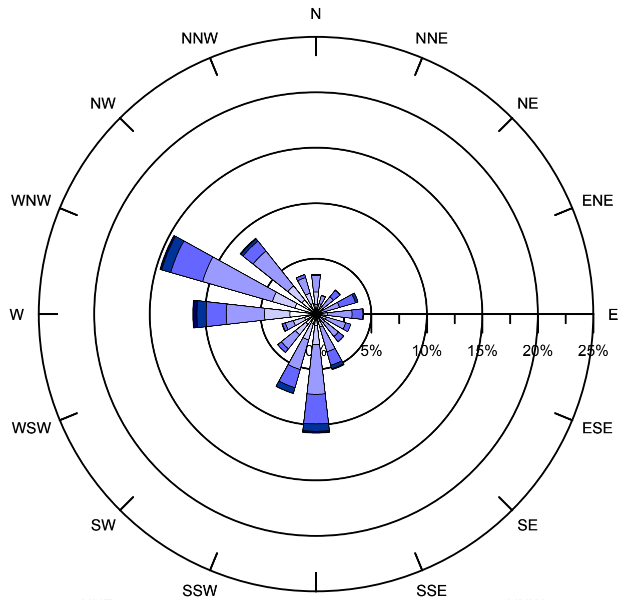
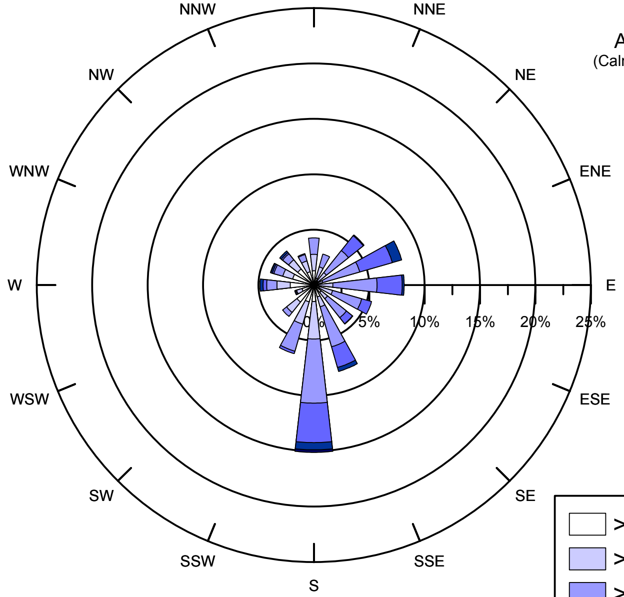
SF	MD			20/12/2007

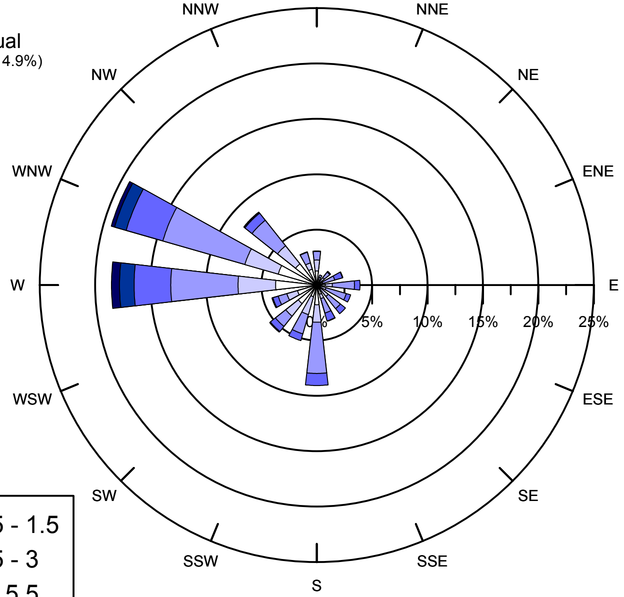
Appendix B2: Annual / Seasonal Wind Roses for the Project Site - 2006



Annual
(Calms = 4.9%)

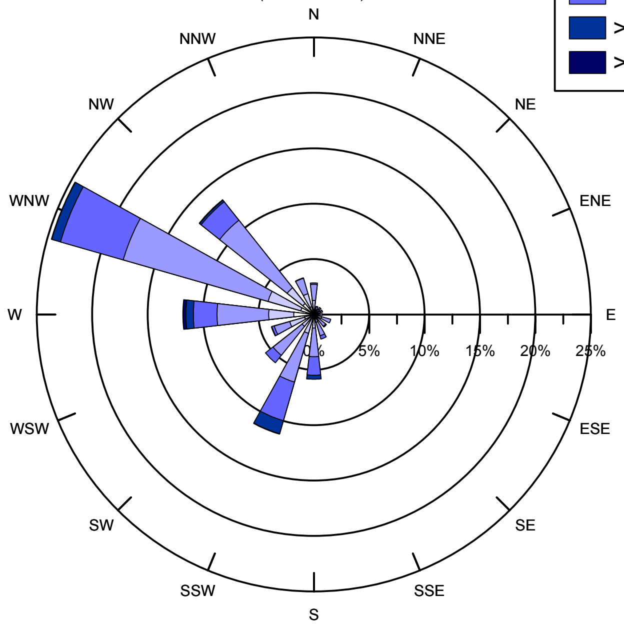


Summer
(Calms = 5.9%)

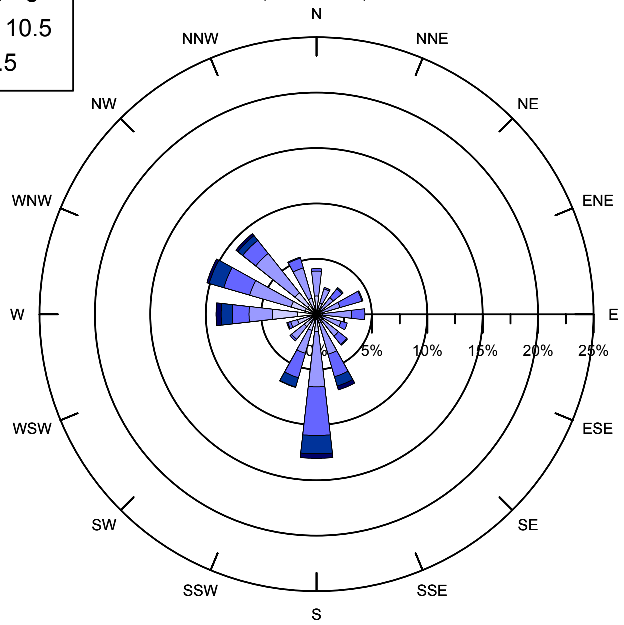


Autumn
(Calms = 1.6%)

□ >0.5 - 1.5
▨ >1.5 - 3
▨ >3 - 5.5
▨ >5.5 - 8
■ >8 - 10.5
■ >10.5



Winter
(Calms = 4.7%)



Spring
(Calms = 7.6%)

Heggies Pty Ltd
Consulting Engineers and Scientists
2 Lincoln Street
Lane Cove NSW 2066 Australia
PO Box 176 Lane Cove NSW 1595
Telephone +612 9427 8100 Facsimile +612 9427 8200
Email Sydney@heggies.com

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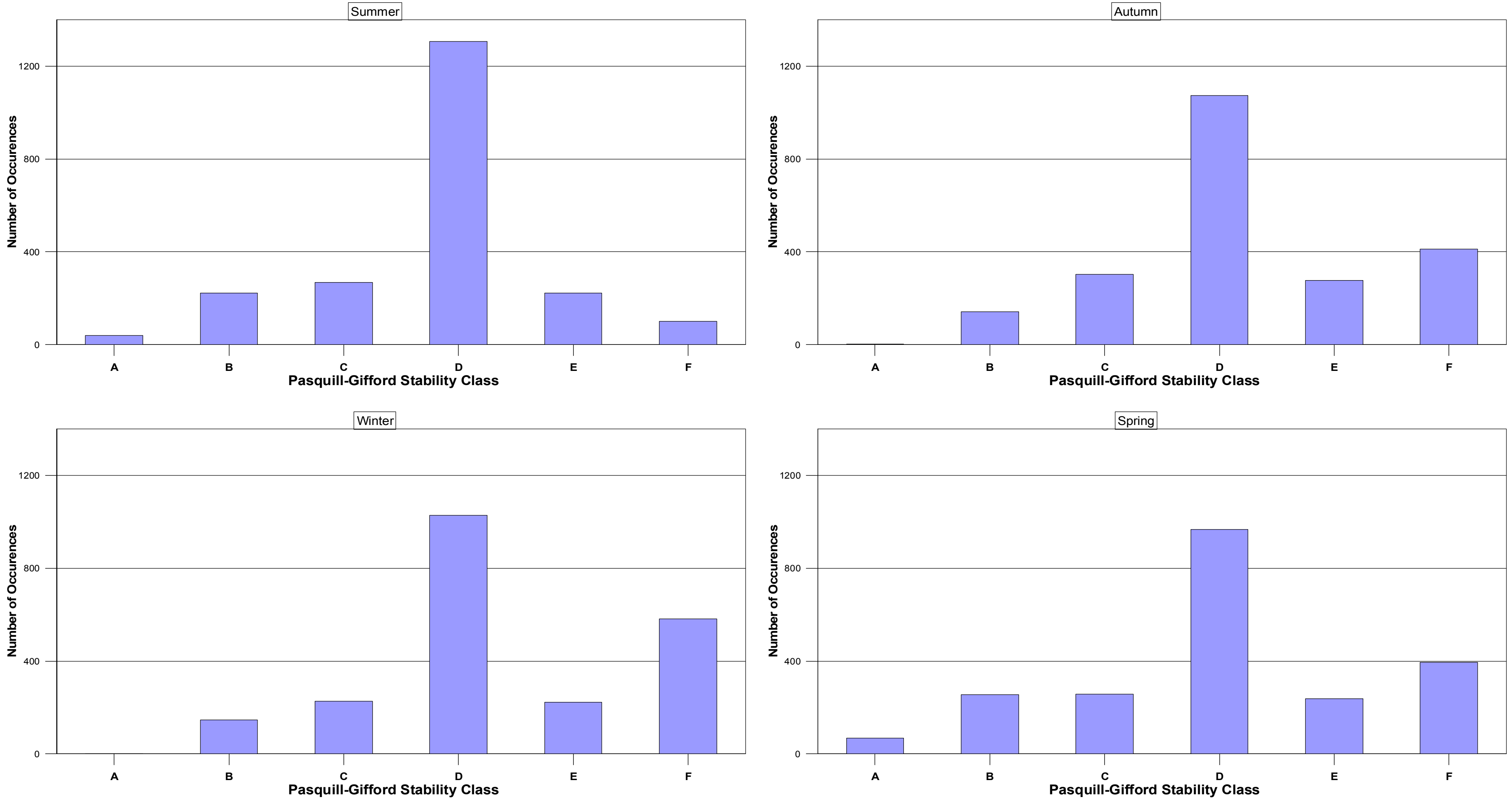
Appendix B3: Annual / Seasonal Wind Roses for the Nowra RAN Air Station - 2006



Heggies Pty Ltd

Consulting Engineers and Scientists
Level 2, 2 Lincoln Street
Lane Cove NSW 2066 Australia
PO Box 176 Lane Cove NSW 1595
Telephone +612 9427 8100 Facsimile +612 9427 8200
Email sydney@heggies.com.au

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APPENDIX B4

TAPM Predicted Seasonal Stability Class Frequency Distribution for the Project Site - 2006

Quality System
Quality
Endorsed
Company
ISO 9001 Lic 3236
Standards Australia