AIR QUALITY IMPACT ASSESSMENT: MODIFICATIONS TO ILLAWARRA COGENERATION PLANT PROJECT

July 2008

Prepared for
CH2M HILL

On behalf of
BlueScope Steel

by
Holmes Air Sciences

Suite 2B, 14 Glen St
Eastwood NSW 2122
Phone : (02) 9874 8644
Fax : (02) 9874 8904
Email : has@holmair.com.au

BlueScope SCP_Air_Final_11 July 08.doc

CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES (All figures are at the end of the report)

1. INTRODUCTION

This report has been prepared by Holmes Air Sciences for CH2M HILL Australia Pty Ltd (CH2M HILL) who are acting on behalf of BlueScope Steel Limited (BlueScope). The purpose of the report is to assess the air quality impacts of proposed modifications to the original development consent for the BlueScope Illawarra Cogeneration Plant (ICP) Project (the Project) at the Port Kembla Steelworks. An approval for modifications to the existing development consent will be sought under Section 75W of Part 3A of the *Environmental Planning and Assessment Act, 1979*. CH2M Hill are preparing the Environmental Assessment (EA).

The air quality impact assessment follows the procedures outlined by the NSW Department of Environment and Climate Change (DECC) in their guidance document titled "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (**DEC, 2005**). A computer-based dispersion model has been used to predict ground-level pollutant concentrations due to various emission sources and scenarios for the steelworks site. Model predictions have been compared to relevant air quality criteria to assess the effect that the Project would have on the existing air quality environment. Predictions have also been compared with the approved ICP, where relevant.

In summary, this report provides information on the following:

- Proposed modifications to the ICP Project;
- Air quality criteria relevant for this Project;
- Existing meteorological and ambient air quality conditions;
- Estimated pollutant emissions;
- Methods used to assess air quality impacts of the Project; and
- Predicted dispersion patterns and concentrations and assessment of these predictions with regulatory air quality criteria.

2. LOCAL SETTING AND PROJECT DESCRIPTION

Figure 1 shows the extent of area defined for the purposes of this assessment as the "Project area" (that is, a region of 20 kilometres (km) by 20 km). ICP site is located within the Port Kembla Steelworks which is bounded by residential areas to the north and south. There are various landuses in the area ranging from heavy industrial to residential, mixed commercial, parkland and water bodies.

Terrain is shown in **Figure 2**. There are gentle undulating hills close to the steelworks however the escarpment to the west of the site rises sharply to over 500 metres (m) AHD. The terrain information has been included in the dispersion modelling.

The ICP will use by-product fuels of the iron and steel making processes, for power generation. The by-product fuels are coke ovens gas (COG), blast furnace gas (BFG) and Linz-Donawitz gas (LDG, formerly basic oxygen steelmaking or BOS off-gas). Natural gas will also be used in the proposed boilers. The ICP will allow the decommissioning of a number of energy facilities currently operating at the steelworks.

The air quality impacts of the currently approved Project have been assessed by **Holmes Air Sciences (2001)**. The approach to the original assessment was to compare estimated ICP emissions with existing emissions that will effectively be replaced with the ICP Project. Therefore, the original assessment considered the net change in emissions and impacts of the Project. The current assessment takes the same approach and also compares predictions with the approved ICP, where relevant.

On 9 August 2002, the ICP was granted development consent. The main components of the original development were:

- The cogeneration plant itself including four 275 tonnes/hour boilers, a nominal 225 megawatts (MW) steam turbine generator and auxiliary equipment required by the plant;
- A closed circuit turbine condenser cooling system using tertiary treated effluent from the Wollongong Sewage Treatment Plant as make-up to the cooling towers;
- An LDG off-gas collection system; and
- Piping and infrastructure connections from the plant to BlueScope and Integral Energy facilities.

The current proposal now includes the installation of three new boilers, with the retention of the existing No. 25 Boiler for the remainder of its economic life. The main components of the modified Project are summarised below:

- Three new boilers and the existing No.25 Boiler to generate approximately 1,100 tonnes per hour of steam;
- Relocation and re-sizing of the Basic Oxygen Steelmaking off-gas (LDG) gas holder and associated ductwork;
- Use of a once-through salt water cooling system instead of a closed circuit fresh water cooling system with a cooling tower;
- Relocation of the high voltage substation and electrical connections;
- Consolidation of the ICP footprint; and

- Relocation of construction laydown areas.

The ICP Project is an important development for BlueScope and is designed to ensure the on-going viability of the Port Kembla Steelworks. The ICP will operate with sufficient steam and energy to meet BlueScope's requirements while proactively creating environmental benefits, due to the capture and re-use of most of the by-product gases currently flared. Due to the considerable variability of the by-product fuel availability, the new boilers have been sized to reduce the flaring of by-product gases to a practical minimum.

BlueScope have calculated the fuel usage and pollutant emissions for many potential ICP operating scenarios. As a result there were many combinations of emission scenarios and it was necessary to isolate the scenarios that were indicative of the potential range of air quality impacts.

The selection process for key dispersion model scenarios considered the frequency of occurrence as well as the magnitude of mass emission rates, among other factors. The selection process is outlined in more detail in **Section 5**.

Figure 3 shows the location of the ICP site, within the Port Kembla Steelworks, and the location of the 25 Boiler and new ICP boiler stacks. This figure also shows outlines of the various sections of the steelworks for reference in other figures.

3. AIR QUALITY CRITERIA

In assessing any project with significant air emissions, it is necessary to compare the impacts of the project with relevant air quality criteria. Air quality criteria are used to assess the potential for ambient air quality to give rise to adverse health or nuisance effects.

The most significant emissions produced from the ICP will be oxides of nitrogen (NO_x), particulate matter with equivalent aerodynamic diameter of less than 10 microns (PM_{10}) and sulfur dioxide (SO_2). **Table 1** summarises the current air quality assessment criteria noted by the Department of Environment and Climate Change (DECC) (**DEC, 2005**). Generally, the air quality criteria relate to the total burden of pollutants in the air and not just the pollutants from the sources being modelled. In other words, some consideration of background levels needs to be made when using these criteria to assess impacts. The estimation of appropriate background levels will be discussed further in **Section 4.3**.

The primary air quality objective for most projects is to ensure that the air quality criteria listed in **Table 1** are not exceeded at any location where there is a possibility of human exposure for the time period relevant to the criterion. A discussion of the health effects of these pollutants is provided in **Appendix A**.

Table 1 : DECC air quality criteria relevant to this Project

Pollutant	Criterion	Averaging period
Nitrogen dioxide (NO_2)	246 µg/m^3 62 µg/m^3	1-hour maximum Annual mean
Ozone (O_3)	214 µg/m^3 171 µg/m^3	1-hour maximum 4-hour maximum
Particulate matter less than 10 µm (PM_{10})	50 µg/m^3 30 µg/m^3	24-hour maximum Annual mean
Sulfur dioxide (SO_2)	570 µg/m^3 228 µg/m^3 60 µg/m^3	1-hour maximum 24-hour maximum Annual mean

Source: ***DEC, 2005***

4. EXISTING ENVIRONMENT

This section describes the dispersion meteorology and existing air quality of the study area in order to characterise the existing environment.

For air quality assessment purposes, the existing environment of the Project area (refer **Figure 1**) can be characterised by the prevailing meteorology and the existing air quality. This section provides a review of meteorological and ambient air quality monitoring data that have been collected in the Project area. This information has been used to characterise air quality in the local airshed and to establish differences in air quality for different locations. Meteorology will also vary across the region, particularly wind patterns. The meteorology has been incorporated into the study by considering data from several monitoring stations to determine local wind conditions and extrapolating to other areas using a wind-field model.

4.1 Dispersion Meteorology

Wind patterns are important for the transportation and dispersion of air pollutants. The meteorology in the Project area would be influenced by several factors including the local terrain and landuse. On a relatively small scale, winds would be largely affected by the local topography (see **Figure 2** for a representation of the local terrain). At larger scales, winds are affected by synoptic scale winds, which are modified by sea breezes in the daytime in summer (also to a certain extent in the winter) and also by a complex pattern of regional drainage flows that develop overnight.

Given the relatively diverse terrain and land use in the study corridor, differences in wind patterns at different locations in the Project area would be expected. These varying wind patterns would arise as a result of the interaction of the air flow with the surrounding topography and the differential heating of the land and water.

In the air quality assessment undertaken for this report it is not necessary to document the complex mechanisms that affect air movements in the area, it is simply necessary to ensure that these air movements are incorporated into the dispersion modelling studies that are done. A limitation of common Gaussian plume dispersion models (such as AUSPLUME) is that they assume that the meteorological conditions are the same spatially over the entire modelling domain for any given hour. This may be adequate for sources in relatively uncomplicated terrain however when the terrain or landuse is more complex the meteorological conditions can be more accurately represented using wind field and puff models.

This assessment has made use of the CALPUFF dispersion model. The CALPUFF model, through the CALMET meteorological processor, simulates complex meteorological patterns that exist in a particular region and the effects of local topography and changes in land surface characteristics can be incorporated into the model.

One of the objectives for reviewing local meteorological data is to assess the suitability of available data for the CALPUFF modelling. Typically, one year of hourly records will be sufficient to cover most variations in meteorology that will be experienced at a site, however it is important that the year of data available is generally representative of the prevailing meteorology.

Figure 1 shows the location of surface meteorological monitoring sites which were used to compare localised wind patterns throughout the region. Wind data from three DECC monitoring sites (Kembla Grange, Warrawong and Wollongong) have been reviewed.

There are meteorological data from other monitoring sites in the Illawarra region (such as Albion Park) which could also have been reviewed for this study however, the Kembla Grange, Warrawong and Wollongong sites are the most suitably located sites for characterising meteorological conditions where the highest impacts of the Project would occur (refer **Section 7.2**).

In addition to the meteorological records from ground-level surface stations, the CALMET model requires upper air data in order to generate a year-long three-dimensional wind-field. The CSIRO's prognostic model (The Air Pollution Model, TAPM) was used to generate upper air and information on higher altitude winds and temperature profiles as required by the CALMET model. TAPM is a prognostic model which has the ability to generate meteorological data for any location in Australia (from 1997 onwards) based on synoptic information determined from the six hourly Limited Area Prediction System (LAPS) (**Puri *et al.,* 1997**). The model is discussed further in the accompanying user manual (see **Hurley, 2002**).

To examine wind patterns from year to year, annual wind roses for each of the DECC monitoring sites for 1997 and 2005 have been constructed and are shown in **Figure 4**. The 1997 year was used for dispersion modelling of the approved Project and 2005 was the most recent year where data from all three monitoring locations were available. It can be seen from **Figure 4** that there are some variations in the wind patterns from site to site but the wind patterns do not vary substantially from year to year. On this basis, 2005 has been considered to be a representative year.

The following sections describe each of the surface meteorological data sets in detail.

Kembla Grange
Figure 5 shows annual and seasonal wind roses for the DECC's Kembla Grange site for 2005. On an annual basis the winds are predominantly from the west. Very few are from north or south sectors however there are some winds from the north-east, representing the direction of the sea-breeze. Winds from the west prevail in the cooler seasons (autumn and winter) while the north-east sea-breeze becomes more common in the warmer seasons (summer and spring).

The annual average wind speed at the Kembla Grange site in 2005 was 2.9 m/s and the site recorded calm conditions, where winds are less than or equal to 0.5 m/s, for 9% of the time.

Warrawong
DECC's Warrawong site was located approximately 2 km to the south of the steelworks site but was decommissioned in 2006. **Figure 6** shows the annual and seasonal wind roses for this site in 2005. As for Kembla Grange, the predominant winds are from the west or north-east although the presence of winds from the south-south-east is more evident from the Warrawong wind roses. Again, the general pattern shows that north-easterly winds occur more often in the warmer months and the westerly winds in the cooler months.

Wind speeds in the Warrawong area are similar to the Kembla Grange site with an annual average wind speed for 2005 of 2.9 m/s. The percentage of calms in 2005 was 4%.

Wollongong
The Wollongong monitoring site is approximately 5 km to the north of the steelworks. Meteorological data are collected at the Wollongong site and **Figure 7** shows the 2005 annual and seasonal wind roses. Annually, winds at this site are predominantly from the south-west or north-east. This is generally consistent with the other two DECC monitoring locations although the predominant westerly winds at Kembla Grange and Warrawong are

shifted to the south-west at Wollongong. Again, the off-shore (south-westerly) winds prevail in the cooler months and the on-shore (north-easterly) winds prevail in the warmer months.

Wollongong experiences slightly calmer conditions than Kembla Grange and Warrawong. The annual average wind speed from Wollongong in 2005 was 2.1 m/s and the percentage of calms was 14%.

For the purposes of the air quality assessment, data collected in 2005 from the three DECC meteorological monitoring sites discussed above have been considered to be the suitable datasets for the CALMET meteorological model. The proximity of these sites to the area of interest ensures that they would contain data that are representative of the dispersion conditions in the Project area.

A wind field has been generated by CALMET for the 2005 calendar year. The wind field was generated using meteorological information by the three local DECC monitoring sites. The CALMET model has essentially used surface and upper-air meteorological data to determine wind patterns over the entire modelling domain, given information on the local landuse and terrain features. **Figure 8** shows the model extents, meteorological site, grid points and landuse information used as input to the CALMET model.

Figure 9 shows a snapshot of winds simulated by the CALMET model for stable night-time conditions. The diagram shows the effect of the terrain and landuse differences on the flow of winds for a particular set of atmospheric conditions. The difference in wind speed and direction at various locations of the Project area is evident.

A summary of the data and parameters used as part of the meteorological component of this study are shown in **Table 2**.

Table 2 : Summary of meteorological parameters used for this study

TAPM (v 3.0)	
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Number of grids point	25 x 25 x 25
Year of analysis	Jan 2005 to Dec 2005
Centre of analysis	Wollongong (34°28' S, 150°53.5' E)
Meteorological data assimilation	Wind velocity data from Kembla Grange, Warrawong and Wollongong
CALMET (v 6.212)	
Meteorological grid domain	20 km x 20 km
Meteorological grid resolution	0.5 km
Surface meteorological stations	Temperature and wind velocity from local DECC stations. Cloud cover from Sydney Airport (BoM). Ceiling height and pressure by TAPM.
Upper air meteorological station	Generated for Wollongong by TAPM.
Simulation length	8760 hours (Jan 2005 to Dec 2005)

4.2 Atmospheric Stability

Dispersion models typically require information on atmospheric stability class[1] and mixing height[2]. Plume dispersion models usually assume that the atmospheric stability is uniform over the entire study domain and these estimates are commonly calculated from measurements of sigma-theta, cloud cover information or solar radiation and temperature. Hourly estimates of mixing height can be determined by a combination of empirical methods and/or soundings.

The CALPUFF dispersion model, however, obtains estimates of atmospheric stability and mixing height from the CALMET meteorological model. CALMET determines these parameters using the cloud cover data and temperature profiles it is provided in order to run. The output of the CALMET model can subsequently be processed to extract meteorological information for any site of interest in the modelling domain, including atmospheric stability. **Table 3** provides the frequency of occurrence of the six stability classes as determined by CALMET for the three DECC monitoring locations.

Table 3 : Frequency of occurrence of atmospheric stability class

Pasquill-Gifford-Turner stability class	Frequency (%)		
	Kembla Grange	Warrawong	Wollongong
A	0.3	0.2	0.4
B	6.6	7.6	10.0
C	16.6	17.5	19.7
D	35.1	34.1	25.2
E	9.5	11.4	8.8
F	32.0	29.3	35.8
TOTAL	100	100	100

It can be seen from **Table 3** that the most common stability classes are determined to be D and F-class. Pollutant dispersion is slow for F-class stabilities since these conditions are generally associated with night-time conditions with light winds and a temperature inversion. D-class stabilities are associated with strong winds at any time of day and these conditions result in rapid dispersion. Differences in the calculated distribution of stability class is largely due to the different wind speeds at each site, but also from differences in local landuse.

Joint wind speed, wind direction and stability class frequency tables generated for each site by CALMET are presented in **Appendix B**.

[1] 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.

[2] The term mixed-layer height refers the height of the turbulent layer of air near the earth's surface, into which ground-level emissions will be rapidly mixed. A plume emitted above the mixed-layer will remain isolated from the ground until such time as the mixed-layer reaches the height of the plume. The height of the mixed-layer is controlled mainly by convection (resulting from solar heating of the ground) and by mechanically generated turbulence as the wind blows over the rough ground.

4.3 Existing Air Quality

This section presents a review of air quality monitoring data that have been collected in and around the Project area. The data are used as indicators of the existing air quality at various locations and can be compared with relevant air quality criteria. One objective of this review is to estimate background pollution levels.

At any location within the airshed the "background" concentration of the pollutant is determined by the contributions from all sources that have at some stage or another been upwind of the source. In the case of PM_{10} for example, the background concentration may contain emissions from the combustion of wood from domestic heating, from bushfires, from industry, roads, wind blown dust from nearby and remote areas, fragments of pollens, moulds, sea-salts and so on.

In airsheds such as Sydney and the Illawarra the background level of pollutants could also include recirculated pollutants which have moved through complicated pathways in sea breeze/land breeze cycles. In general, the further away a particular source is from the area of interest, the smaller will be its contribution to air pollution at the area of interest. However the larger the area considered the greater would be the number of sources contributing to the background.

DECC air quality monitoring in the Illawarra occurs or has occurred in the past at Kembla Grange, Warrawong and Wollongong. A summary of the air quality monitoring for 2000 to 2006 is given in **Table 4**. These levels may have contained some contribution from emissions generated by the Steelworks operations at the time. This needs to be considered when determining background levels to ensure that there is minimal "double-counting" when model predictions are added.

Table 4 : Air quality monitoring data for the Illawarra

Year	Kembla grange		Warrawong		Wollongong	
Measured NO_2 concentrations ($\mu g/m^3$). Annual average criterion = 62 $\mu g/m^3$; 1-hour average criterion = 246 $\mu g/m^3$						
Year	Annual Average	Maximum 1-hour average	Annual Average	Maximum 1-hour average	Annual Average	Maximum 1-hour average
2000	15	96	15	135	21	133
2001	14	103	15	92	21	115
2002	16	146	17	111	22	115
2003	13	103	15	100	21	100
2004	10	107	11	94	17	90
2005	12	94	15	113	18	119
2006	11	68	11	88	18	103
Measured ozone concentrations ($\mu g/m^3$). 1-hour average criterion = 214 $\mu g/m^3$; 4-hour average criterion = 171 $\mu g/m^3$						
Year	Maximum 1-hour average	Maximum 4-hour average	Maximum 1-hour average	Maximum 4-hour average	Maximum 1-hour average	Maximum 4-hour average
2000	**250**	-	212	-	**231**	-
2001	**255**	-	178	-	**248**	-
2002	212	**178**	**225**	**197**	**259**	**212**
2003	**242**	**229**	190	**173**	208	171
2004	**257**	**214**	**246**	**186**	**220**	**193**
2005	195	**180**	**208**	**199**	**218**	**212**
2006	199	**173**	167	158	205	**184**
Measured PM_{10} concentrations by TEOM ($\mu g/m^3$). Annual average criterion = 30 $\mu g/m^3$; 24-hour average criterion = 50 $\mu g/m^3$						
Year	Annual Average	Maximum 24-hour average	Annual Average	Maximum 24-hour average	Annual Average	Maximum 24-hour average
2000	-	-	17	-	18	-
2001	-	-	20	-	19	-
2002	-	-	24	**73**	21	**77**
2003	-	-	15	48	13	**60**
2004	-	-	21	**83**	18	48
2005	-	-	22	**55**	19	**55**
2006	-	-	23	48	20	50

Year	Kembla grange			Warrawong			Wollongong		
Measured SO_2 concentrations ($\mu g/m^3$). Annual average criterion = 60 $\mu g/m^3$; 1-hour average criterion = 570 $\mu g/m^3$; 24-hour average criterion = 228 $\mu g/m^3$									
Year	Annual Average	Maximum 1-hour average	Maximum 24-hour average	Annual Average	Maximum 1-hour average	Maximum 24-hour average	Annual Average	Maximum 1-hour average	Maximum 24-hour average
2000	-	-	-	3	315	-	4	89	-
2001	-	-	-	4	463	-	4	86	-
2002	-	-	-	4	132	26	5	112	23
2003	-	-	-	3	180	34	4	89	17
2004	-	-	-	3	252	34	3	152	43
2005	-	-	-	3	200	26	3	109	17
2006	-	-	-	2	63	20	3	100	20

Nitrogen Dioxide (NO_2)
Historically, that is between 2000 and 2006, there have been no exceedances of the DECC's 246 $\mu g/m^3$ criterion for maximum 1-hour average NO_2 concentrations at any of the three monitoring locations in the Illawarra. The highest 1-hour average was 146 $\mu g/m^3$ at Kembla Grange in 2002.

Annual average NO_2 concentrations were below the 62 $\mu g/m^3$ criterion at all sites between 2000 and 2006.

Hourly NO_2 concentrations have been obtained from the DECC for 2005, to match the year for which meteorological data are available. The hourly data are shown graphically in **Figure 10**. The NO_2 levels exhibit a weak seasonal cycle of higher concentrations in the winter and lower concentrations in the summer. This would be largely due to the poorer dispersion conditions which prevail in the cooler months.

From **Figure 10** there appears to be very little variation in measured NO_2 concentrations from site to site. The historical data records (**Table 4**) suggest that Wollongong, on average, experiences slightly higher NO_2 concentrations than Kembla Grange and Warrawong although the differences are small and are not obvious from the graphical display in **Figure 10**. These historical data also suggest that NO_2 concentrations have lowered slightly over recent years.

An important issue to consider in relation to NO_x is the conversion rate from nitric oxide (NO) to NO_2. This conversion rate will vary depending on a number of factors, such as the presence of oxidising agents and the distance from the source (that is, the time allowed for conversion to take place). The main sources of NO_x in the Project area are likely to be emissions from industry and motor vehicles.

Nitrogen oxides are produced in most combustion processes and are formed during the oxidation of nitrogen in the fuel and nitrogen in the air. During high-temperature processes a variety of nitrogen oxides are formed including nitric oxide (NO) and nitrogen dioxide (NO_2). Generally, at the point of emission NO will comprise the greatest proportion of the emission with 95% by volume of the NO_x. The remaining 5% will be mostly NO_2. The effects of NO on human health are such that it is not regarded as an air pollutant at the concentrations at which it is normally found in the environment. However, NO_x emissions can be of concern in urban environments where the control of photochemical smog is important.

Ultimately, however, all oxides of nitrogen emitted into the atmosphere are oxidised to NO_2 and then further to other higher oxides of nitrogen. The rate at which this oxidisation takes place depends on prevailing atmospheric conditions including temperature, humidity and the presence of other substances in the atmosphere such as ozone. It can vary from a few minutes to many hours. The rate of conversion is quite important because from the point of emission to the point of maximum ground-level concentration there will be an interval of time during which some oxidation will take place. If the dispersion is sufficient to have diluted the plume to the point where the concentration is very low it is unimportant that the oxidation has taken place. However, if the oxidation is rapid and the dispersion slow then high concentrations of NO_2 can occur.

Monitoring of NO_x concentrations in the ambient air show that the ratio of NO_2 is inversely proportional to the total NO_x concentration. **Figure 11** shows the relationship for the Kembla Grange, Warrawong and Wollongong monitoring sites, for data collected in 2005. It can be seen from this figure that the NO_2 fraction decreases to less than 20% with the higher NO_x

concentrations. This is an important relationship as estimates of short-term (say, 1-hour average) NO_2 concentrations are commonly derived from NO_x predictions (refer **Section 7.2.1**).

Ozone (O_3)
Ozone is a secondary pollutant formed in the atmosphere through a complicated set of reactions involving reactive hydrocarbons, oxides of nitrogen and sunlight. The net result of these reactions is to produce ozone and nitrogen dioxide and other oxidation products, which are collectively referred to as photochemical smog.

Historical monitoring results for ozone in the Illawarra are presented in **Table 4** while a graph of the 2005 hourly data records is shown in **Figure 12**. In recent years, all three monitoring sites have experienced exceedances of both the 1-hour and 4-hour average criteria. There is no trend to indicate improvement in ozone levels and this pollutant remains one of two (the other being fine particles) that are of particular concern for the NSW Government, as outlined in *Action for Air* (**DEC, 2006**). *Action for Air* documents the NSW Government's 25-year management plan for the Greater Metropolitan Region of NSW.

As for NO_2 concentrations, the graph in **Figure 12** shows a seasonal variation in ozone concentrations. Levels tend to peak during the warmer months and decline in the cooler months. This is consistent with the dependence of ozone formation on the presence of sunlight.

Particulate Matter (PM_{10})
The presence of particulate matter in the atmosphere can have an adverse effect on health and amenity. There are many sources of particulate matter in an urban environment including motor vehicles, construction activities and sea salt. However, the most common causes of exceedances of the short-term PM_{10} air quality criterion (50 $\mu g/m^3$) in NSW are widespread events such as dust storms or bushfires.

The historical monitoring of PM_{10} in the Illawarra by the DECC (refer **Table 4**) show measured 24-hour average PM_{10} concentrations have exceeded 50 $\mu g/m^3$ at Warrawong and Wollongong in the past. Concentrations of PM_{10} using a TEOM at the Kembla Grange site were not reported in the monthly monitoring reports published by the DECC.

A time series of 24-hour average PM_{10} concentrations is shown in **Figure 13**. From inspection of these graphs, the elevated PM_{10} concentrations appear to occur at each site on the same days, suggesting that the highest levels are influenced by widespread events.

Particulate matter is one of the two main pollutants being targeted by *Action for Air*.

Sulfur Dioxide (SO_2)
Sulfur dioxide has historically been measured at Warrawong and Wollongong. The monitoring results (**Table 4**) have shown that annual average levels have been well below the 60 $\mu g/m^3$ criterion. Maximum 1-hour and 24-hour average concentrations have also been below their respective criteria. The Warrawong site generally experienced higher short-term SO_2 concentrations than the Wollongong site which may have been due to its proximity to industrial developments. The Warrawong site was decommissioned in 2006.

4.4 Summary of Existing Environment

Meteorological and ambient air quality monitoring data from the Illawarra region have been reviewed to characterise the existing environment of the Project area. The monitoring sites covered various settings, including residential areas and parklands to locations near heavy industry. The spatial separation of each monitoring site allowed a range of meteorological and air quality conditions to be identified.

Meteorological data collected in the Illawarra area show the following:

- West to south-west winds generally prevail in the cooler months, while the sea-breeze from the north-east is the dominant wind in the warmer months;
- Wind patterns for each monitoring location are similar from year to year; and
- Minor variation in wind patterns exist from site to site and are likely to be influenced by the land-use and topography of the surrounding environment.

Ambient air quality data collected in the Illawarra region show the following:

- NO_2 concentrations have been, and are likely to continue to be, below the DECC's ambient air quality criteria;
- Ozone and PM_{10} concentrations have exceeded the DECC's short-term (24-hour averages or less) criteria on a number of occasions at each monitoring location. These pollutants are of key concern for metropolitan areas. Exceedances of the 24-hour average PM_{10} criteria are likely to be due to widespread events (such as bushfires and dust-storms) which can influence large areas;
- Annual average PM_{10} concentrations are below the DECC's air quality criteria at all monitoring locations;
- SO_2 concentrations have been, and are likely to continue to be, below the DECC's ambient air quality criteria.

The most recent year of monitoring data available (2006) suggests that the most conservative estimates of background pollutant levels, based on location with highest measured levels, are as follows:

- 103 $\mu g/m^3$ for maximum 1-hour average NO_2 concentrations;
- 18 $\mu g/m^3$ for annual average NO_2 concentrations;
- 50 $\mu g/m^3$ for maximum 24-hour average PM_{10} concentrations, but highly variable depending on natural events;
- 23 $\mu g/m^3$ for annual average PM_{10} concentrations
- 100 $\mu g/m^3$ for maximum 1-hour average SO_2 concentrations
- 20 $\mu g/m^3$ for maximum 24-hour average SO_2 concentrations
- 3 $\mu g/m^3$ for annual average SO_2 concentrations

5. ESTIMATION OF EMISSIONS

The most significant emissions produced from the ICP, and other sources affected by the introduction of the ICP, will be NO_x, PM_{10} and SO_2. These are listed by the DECC (**DEC, 2005**) as criteria pollutants which are general indicators of ambient air quality and are the focus of the dispersion modelling.

Estimated emissions of NO_x, PM_{10} and SO_2 are required as input to computer-based dispersion models in order to predict pollutant concentrations in the area of interest (that is, the 20 km by 20 km region shown by **Figure 1**) and to compare these concentrations with associated air quality criteria.

The by-product fuel available to the ICP is equivalent to the fuel currently consumed in the existing boilers plus the fuel which is currently flared. Data from the 2006/07 financial year has been used to determine the range of possible fuel availability. BlueScope have identified up to 40 scenarios covering the range of possible ICP operation, containing 24 different fuel scenarios. The available fuel for each scenario, and the predicted NO_x performance of the proposed new boilers, was then used to calculate NO_x, PM_{10} and SO_2 emissions from the ICP boiler stacks, the No.25 Boiler stack and the flares.

The 24 fuel scenarios, descriptions and mass emission rates (in grams per second) of NO_x, PM_{10} and SO_2 from each source are provided below in **Table 5**. Of these scenarios, seven (7) have been selected for the dispersion modelling, shown in bold font. The selection process considered the frequency of occurrence as well as the magnitude of NO_x, PM_{10} and SO_2 mass emission rates. The dispersion model scenarios and the logic for the use of these scenarios are provided below:

- "1": Based on highest NO_X mass emission rate from the ICP boilers.
- "2": Based on the description "Normal operations" and relatively high operating occurrence (8.57%).
- "14": Based on highest combined SO_x emissions from the No.25 Boiler and the ICP boilers.
- "17": Based on high frequency of occurrence (15%), and relatively high total NO_x emissions.
- "28": Based on relatively high frequency of occurrence (approximately 9%) and selected to cover scenarios 29, 30, 30A and 30B, which are similar.
- "34": Near highest PM_{10} emissions from flares. This scenario would occur more often than the scenario with highest PM_{10} emissions from flares.
- "35": Based on the scenario description, that is, “Normal operations with natural gas”. Scenario would also have a high frequency of occurrence (assuming 15% peaking with natural gas).

The dispersion model scenarios shown above were generally selected on the basis of the NO_x mass emission rates. It should be noted that most of the scenarios that would have been selected on the basis of SO_2 or PM_{10} emissions would be the same as the above scenarios.

It should also be noted that under Scenario 1 (maximum fuel availability) the steam turbine generator would be operating at maximum capacity, with a small quantity of BFG being flared. Any additional boiler capacity could not be utilised, as the steam generated could not be consumed.

In addition to the ICP model scenarios described above, a base case scenario has been developed. The base case represents the consumption of maximum available by-product fuel (from the FY06/07 data set) in the existing facilities, and should only be directly compared to ICP Scenario 1, which represents the same fuel consumption. Under the base case there would be minimal off-gas being flared as most fuel will be consumed for power generation.

Table 6 shows the source characteristics, as modelled, for the existing operations (base case) and ICP Scenario 1. Both of these model scenarios represent emissions for maximum fuel availability and consequently near maximum NO_X, PM_{10} and SO_2 emissions from the power generation sources. It is important to note also that most of the fuel scenarios listed above could be common for operations with or without the ICP.

The remaining ICP scenarios (provided in **Appendix C**) have identical source location, diameter, height, elevation and temperature characteristics as ICP Scenario 1 shown in **Table 6**. Stack exit velocities however, vary slightly between the ICP scenarios.

The *Protection of the Environment Operations (Clean Air) Regulation 2002* ("the Regulation") sets the maximum pollutant concentrations that industry is allowed to emit in discharges to air. The calculated in-stack boiler concentrations from the mass emission rates and flow characteristics in **Table 5** and **Table 6** meet the Regulation limits

Table 5 : Emissions characteristics for each fuel scenario

Scenario	Description	Percentage of time (%)	NO_x mass emission rates (g/s)					PM_{10} mass emission rates (g/s)					SO_2 mass emission rates (g/s)				
			No. 25	ICP	BFG Flares	COG Flares	LDG Flares	No. 25	ICP	BFG Flares	COG Flares	LDG Flares	No. 25	ICP	BFG Flares	COG Flares	LDG Flares
1	**Maximum Fuel Case - 3 new boilers plus 25 Boiler; Normal steam consumption**	**4.70**	**0.24**	**45.21**	**3.75**	**0.00**	**0.00**	**0.91**	**7.22**	**1.30**	**0.00**	**0.00**	**3.03**	**90.17**	**4.33**	**0.00**	**0.00**
2, 3, 4, 5, 11, 12, 13, 19	**Normal operations: 3 new boilers plus 25 Boiler**	**8.57**	**0.24**	**28.55**	**0.00**	**0.00**	**0.00**	**0.91**	**5.90**	**0.00**	**0.00**	**0.00**	**3.03**	**55.91**	**0.00**	**0.00**	**0.00**
6, 10	#25 boiler OOS (planned R&M or trip etc.)	4.65	0.00	30.45	0.00	0.00	0.00	0.00	6.81	0.00	0.00	0.00	0.00	58.94	0.00	0.00	0.00
7	#25 boiler OOS, blast furnace stop, BOS reduced rate	0.21	0.00	30.57	0.00	0.00	0.00	0.00	3.19	0.00	0.00	0.00	0.00	55.62	0.00	0.00	0.00
8	#25 boiler OOS, blast furnace stop, BOS zero production	0.07	0.00	26.44	0.00	0.00	0.00	0.00	2.25	0.00	0.00	0.00	0.00	55.54	0.00	0.00	0.00
9	#25 boiler OOS, zero blast furnace operations	0.03	0.00	9.94	0.00	6.89	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	24.60	0.00
14, 16	**1 x Blast furnace OOS, Reduced BOS production**	**3.47**	**11.76**	**15.36**	**0.00**	**0.00**	**0.00**	**0.16**	**3.02**	**0.00**	**0.00**	**0.00**	**21.09**	**34.53**	**0.00**	**0.00**	**0.00**
15	1 x Blast furnace OOS, Zero BOS Production	0.63	11.76	23.01	0.00	0.00	0.00	0.16	2.09	0.00	0.00	0.00	21.09	34.45	0.00	0.00	0.00
17, 20, 21, 22, 28A, 29A	**1 x ICP boiler OOS (planned maintenance or trip etc.)**	**14.79**	**0.38**	**27.87**	**0.86**	**0.00**	**0.00**	**1.42**	**5.09**	**0.30**	**0.00**	**0.00**	**4.72**	**53.23**	**1.00**	**0.00**	**0.00**
18	TA trip	0.14	0.24	10.91	7.02	4.21	4.85	0.91	1.57	2.44	0.12	0.86	3.03	32.62	8.11	15.04	0.14
23	1 x ICP boiler OOS, 1 x blast furnace stop	0.31	11.76	15.75	0.00	0.00	0.00	0.16	3.02	0.00	0.00	0.00	21.09	34.53	0.00	0.00	0.00
24	1 x ICP boiler OOS, zero blast furnace operations	0.03	13.72	4.94	0.00	6.93	0.00	0.19	0.00	0.00	0.19	0.00	24.60	0.00	0.00	24.75	0.00
25	1 x ICP boiler OOS, another ICP boiler trips. (N-2 scenario)	0.18	0.38	7.49	6.76	6.30	4.85	1.42	1.10	2.35	0.18	0.86	4.72	23.78	7.80	22.50	0.14
26	LDG Holder outage eg liner change	0.66	0.24	23.38	0.00	0.00	0.00	0.91	4.13	0.00	0.00	0.00	3.03	55.77	0.00	0.00	0.00
27	Maximum Fuel Case - 2 new boilers plus 25 Boiler	0.68	0.38	25.10	4.97	10.77	0.00	1.42	5.35	1.73	0.30	0.00	4.72	46.50	5.74	38.45	0.00
28	**Max BFG Case: BFG Avg + 2SD, COG Avg LDG Avg**	**8.57**	**0.38**	**29.67**	**2.29**	**0.00**	**0.00**	**1.42**	**6.67**	**0.64**	**0.00**	**0.00**	**4.72**	**58.46**	**2.12**	**0.00**	**0.00**
29	Max COG Case: BFG Avg, COG Avg + 2SD, LDG Avg	8.57	0.24	34.63	0.00	0.00	0.00	0.91	6.15	0.00	0.00	0.00	3.03	88.11	0.00	0.00	0.00
30	Min BFG Case: BFG Avg - 2SD, COG Avg, LDG Avg	8.57	0.24	23.26	0.00	0.00	0.00	0.91	4.63	0.00	0.00	0.00	3.03	51.68	0.00	0.00	0.00
30A	Max LDG Case: BFG Avg, COG Avg, LDG Max	8.57	0.24	29.61	0.00	0.00	0.00	0.91	6.36	0.00	0.00	0.00	3.03	55.95	0.00	0.00	0.00
30B	Min LDG Case: BFG Avg, COG Avg, LDG Min	8.57	0.24	25.85	0.00	0.00	0.00	0.91	5.25	0.00	0.00	0.00	3.03	55.86	0.00	0.00	0.00
32	Critical Steam Generation on Natural Gas Only	0.01	14.56	7.91	13.54	12.09	4.85	0.00	0.00	4.71	0.34	0.86	0.00	0.00	15.64	43.16	0.14
33	TA major overhaul: Average Fuel Availability	2.90	0.24	10.75	7.09	4.21	4.85	0.91	1.55	2.46	0.12	0.86	3.03	32.54	8.18	15.04	0.14
34	**TA major overhaul: Max Fuel Availability**	**0.15**	**0.24**	**10.75**	**10.75**	**13.23**	**4.85**	**0.91**	**1.55**	**3.74**	**0.37**	**0.86**	**3.03**	**32.54**	**12.42**	**47.24**	**0.14**
35	**Normal operations: Average Indigenous Fuel Plus NG Peaking to TA capacity of 240MW**	**15.00**	**0.24**	**33.51**	**0.00**	**0.00**	**0.00**	**0.91**	**5.90**	**0.00**	**0.00**	**0.00**	**3.03**	**55.91**	**0.00**	**0.00**	**0.00**

Table 6 : Source characteristics for primary modelling scenarios

Source	Emission point ID	ID	Easting (MGA, m)	Northing (MGA, m)	Height (m)	Internal stack tip diameter (m)	Base elevation (m)	Temperature of emissions (K)	Emissions exit velocity (m/s)	Mass emission rate (g/s)		
										NO_X	PM_{10}	SO_2
Base case representing existing operations with maximum fuel availability												
No. 2 Powerhouse	DP 21 / 22	DP21	306123	6184521	61	4.3	12.5	423	6.9	0.63	1.63	5.38
	DP 23	DP23	306103	6184539	61	3.6	12.2	440	7.1	6.65	0.91	14.36
	DP 24	DP24	306085	6184555	61	3.6	11.8	423	7.2	3.61	1.08	9.24
	DP 25	DP25	306046	6184566	63	2.59	12	423	14.8	11.02	0.92	21.49
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	2.72	0.76	0.08
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	2.72	0.76	0.08
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	2.72	0.76	0.08
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	5.44	0.93	19.40
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	5.44	0.15	19.40
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	3.46	0.10	0.34
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	3.46	0.10	0.34
ICP Scenario 1: Maximum fuel case - 3 new boilers plus 25 Boiler, normal steam consumption												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	16.3	15.07	2.41	30.06
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	16.3	15.07	2.41	30.06
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	16.3	15.07	2.41	30.06
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	0.24	0.91	3.03
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	0.00	0.00	0.00
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	0.00	0.00	0.00
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	0.00	0.00	0.00
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	0.00	0.00	0.00
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	0.00	0.00	0.00
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	1.87	0.65	2.16
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	1.87	0.65	2.16

The design of the new ICP boilers includes low NO_x technology burner systems, incorporating staged combustion and flue gas recirculation. "Over-fire air", where a portion of the combustion air is introduced to the boiler's combustion chamber above the burners, may also be included. The by-product fuels are also being mixed prior to delivery to the burners. All of these measures are aimed at minimising the maximum flame temperature, and thereby reducing thermal NO_x generation.

The NO_x mass emission rates used for the new ICP boilers are from the boiler designer, and include a 25% performance guarantee margin above the NO_x concentration calculated for the fuel blend fired in each scenario. It is expected that the concentration, and hence mass emissions used in the modelling, are conservatively high. ICP Scenario 35 represents a "peaking" case, where supplementary natural gas is fired in the new boilers, along with the average by-product fuel, to achieve maximum steam generation.

The NO_x mass emission rates used for other sources have been calculated using emission factors in the form of milligrams (mg) of NO_x per mega joule (MJ) fuel, derived from the BlueScope Load Based Licensing (LBL) protocol. The emission factors used are listed in Table 5 below.

Table 7 : NO_x emission factors for non-ICP sources

Source	Emission Factor (mg NO_x/MJ)
COG Flares	175.0
COG in Boilers	134.4
BFG Flares	33.0
BFG in Boilers	2.9
Natural Gas in Boilers	112.0
LDG Flares	33.0

BlueScope has committed to achieving NO_x neutrality, that is, the annual NO_x emissions will be maintained below the approved Project limit of 1,080 tonnes per year to satisfy the DECC policy for gas fired power stations in Sydney and the Illawarra.

Due to the position of NO_x neutrality, no regional assessment of ozone formation is required.

It should also be noted that mass emissions of SO_x would not change due to the ICP, as the quantity of by-product fuels combusted on the steelworks site would not change.

6. APPROACH TO ASSESSMENT

In August 2005 the DECC published guidelines for the assessment of air pollution sources using dispersion models (**DEC, 2005**). The guidelines specify how assessments based on the use of air dispersion models should be undertaken. They include guidelines for the preparation of meteorological data, emissions data and relevant air quality criteria. The approach taken in this assessment follows the approaches suggested by the guidelines.

As discussed in **Section 4.1**, pollutant levels due to estimated emissions have been predicted using CALPUFF (Version 6.113). CALPUFF is an advanced computer-based dispersion model that simulates the dispersion of emissions by representing emissions as a series of puffs emitted sequentially. Provided the rate at which the puffs are emitted is sufficiently rapid, the puffs will overlap and the serial release will represent a continuous release. The advantage of the puff modelling approach over the steady state Gaussian models such as ISCST3 and AUSPLUME, which have also been widely used in source dispersion assessments in the past, is that the progress and dispersion of each individual puff can be treated separately and can be made to account for local wind conditions and the way in which wind conditions at a particular place vary with time.

The modelling has been performed using the meteorological information provided by the CALMET model (**Section 4.1**) and the emission information from **Section 5**. The way in which the model has been used in this study has been to predict the pollutant concentrations at a set of receptors covering a region of 20 km by 20 km. Gridded receptors with spacing of 1 km were used for the entire model domain while a finer spaced set of discrete receptors was manually selected close to the Steelworks site. Spacing between the discrete receptors was set finer in areas closer to the emission sources and coarser in areas further from sources. The receptor spacing and locations have been chosen to provide high resolution model output where needed. Predictions were made at ground-level and local building effects were modelled where relevant.

Elevated ground-level concentrations may occur in the Project location as a result of the dispersion process known as coastal fumigation. Coastal fumigation can occur when a plume, released from a tall stack within the stable onshore breeze, is entrained into the thermal internal boundary layer (TIBL) that forms over land. Under these circumstances the plume can become mixed by convective turbulence within the TIBL and brought to ground. The TIBL module was activated in the CALPUFF model via a data file containing information on the location of the coastline.

A total of eight scenarios were modelled including a maximum fuel base case, representing existing operations, as well as seven ICP fuel scenarios. Each model scenario assumed that emissions would occur continuously. This assumption is unlikely to represent reality, particularly for annual average predictions since each scenario would only occur for a certain fraction of the year, however it provides a comparison of the relative potential impacts of each scenario.

Contour plots have been prepared showing the distribution of predicted concentrations and the results have been compared with the relevant air quality criteria.

7. ASSESSMENT OF AIR QUALITY IMPACTS

This section provides an assessment of the air quality impacts associated with the ICP. The focus is on comparing impacts of the modified Project with the existing operations and also with the approved Project.

7.1 Predicted Impacts of Approved Project

Air quality impacts of the approved Project were assessed by **Holmes Air Sciences (2001)**. This assessment used dispersion modelling to predict ground-level pollutant concentrations due to stack emissions. The assessment considered a baseline case (existing operations based on fuel usage in 1998), a base case (the existing operations based on expected fuel usage in 2003) and an ICP case (proposed ICP operating based on expected fuel usage in 2003).

The original assessment considered the net change in emissions and impacts of the Project and the outcomes of the assessment can be summarised as follows:

- The dispersion models provided a reasonable and conservative estimate of existing air quality impacts;
- Criteria pollutant levels in the area were likely to be lower with the ICP operating;
- Impacts of air toxics and metal emissions were likely to be lower with the ICP operating and concentrations would comply with all relevant air quality criteria; and
- Carcinogenic risk factors for the ICP were well below an acceptable level of risk.

7.2 Predicted Impacts of Modified Project

The current assessment takes the same approach to the original assessment in that the net change to emissions and impacts has been reviewed. In addition, there have been improvements to the dispersion models and modelling techniques since 2001.

Contour plots showing the model results for the current assessment are presented in **Figures 14** to **20**. These figures show the predicted concentrations due to modelled emissions only and do not include existing pollutant concentrations. The contour plots include all eight scenarios in each figure and are provided in this form to allow the general dispersion pattern of each scenario to be compared easily. Predictions extend over all ground-level locations in an area of approximately 20 km by 20 km, which includes a range of population densities and sensitive receptor locations as well as existing and proposed development zones.

It should be noted that the predictions for maximum levels (that is, maximum 1-hour and 24-hour averages) do not show the dispersion pattern at any one point in time but show the maximum levels that occurred at each location in the model domain over the entire meteorological dataset.

For a more precise assessment of model predictions (than can be derived from inspection of the contour plots) the results are summarised in **Table 8**. These results show the highest predictions in the model domain as well as predictions at the DECC monitoring locations. One objective for providing model predictions at these monitoring locations is to gain an understanding of how the local air quality could change with the Project and to determine whether this change would be detectable. Results for more distant locations (from the Steelworks site) will be lower than the results presented in **Table 8**.

Table 8 : CALPUFF air dispersion model predictions

Pollutant and averaging time	"App"+	Base case	ICP fuel scenario							Criteria
			1	2	14	17	28	34	35	
Highest predicted ground-level concentrations in the model domain (µg/m^3)										
Maximum 1-hour average NO_X	230	292	278	168	165	166	185	367	194	-
Maximum 1-hour average NO_2*	N/A	58	56	34	33	33	37	73	39	246
Annual average NO_X	3	14	3	2	2	1	2	17	2	62
Maximum 24-hour average PM_{10}	N/A	13	6	5	4	5	6	5	5	50
Annual average PM_{10}	N/A	2.1	0.5	0.4	0.3	0.3	0.5	0.7	0.3	30
Maximum 1-hour average SO_2	505	997	554	343	339	336	376	1263	339	570
Maximum 24-hour average SO_2	91	275	69	43	50	42	47	344	42	228
Annual average SO_2	7	48	5	4	4	3	4	60	3	60
Predicted ground-level concentrations at Kembla Grange (µg/m^3)										
Maximum 1-hour average NO_X	N/A	35	36	23	25	20	25	57	25	-
Maximum 1-hour average NO_2*	N/A	7	7	5	5	4	5	11	5	246
Annual average NO_X	N/A	0.4	0.3	0.2	0.2	0.2	0.2	0.3	0.2	62
Maximum 24-hour average PM_{10}	N/A	0.7	1.1	0.8	0.6	0.7	1.0	1.1	0.7	50
Annual average PM_{10}	N/A	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0	30
Maximum 1-hour average SO_2	N/A	85	69	46	55	40	49	161	42	570
Maximum 24-hour average SO_2	N/A	13	11	7	8	6	8	19	7	228
Annual average SO_2	N/A	0.7	0.6	0.3	0.4	0.3	0.4	0.8	0.3	60
Predicted ground-level concentrations at Warrawong (µg/m^3)										
Maximum 1-hour average NO_X	N/A	41	38	25	25	22	27	55	26	-
Maximum 1-hour average NO_2*	N/A	8	8	5	5	4	5	11	5	246
Annual average NO_X	N/A	0.7	0.3	0.2	0.2	0.2	0.2	0.8	0.2	62
Maximum 24-hour average PM_{10}	N/A	0.9	0.9	0.7	0.4	0.7	0.9	0.8	0.7	50
Annual average PM_{10}	N/A	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	30
Maximum 1-hour average SO_2	N/A	147	75	50	57	45	53	179	46	570
Maximum 24-hour average SO_2	N/A	16	10	6	7	6	7	20	6	228
Annual average SO_2	N/A	2.0	0.5	0.3	0.4	0.3	0.4	2.6	0.3	60
Predicted ground-level concentrations at Wollongong (µg/m^3)										
Maximum 1-hour average NO_X	N/A	85	84	50	50	49	56	72	57	-
Maximum 1-hour average NO_2*	N/A	17	17	10	10	10	11	14	11	246
Annual average NO_X	N/A	0.7	0.5	0.3	0.3	0.3	0.3	0.6	0.4	62
Maximum 24-hour average PM_{10}	N/A	1.2	1.3	0.9	0.5	0.9	1.2	1.2	0.9	50
Annual average PM_{10}	N/A	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	30
Maximum 1-hour average SO_2	N/A	162	166	102	102	100	113	173	101	570
Maximum 24-hour average SO_2	N/A	16	13	8	8	8	9	19	8	228
Annual average SO_2	N/A	1.5	1.0	0.6	0.7	0.6	0.7	1.7	0.6	60

*+ Dispersion model results for Project as originally approved for maximum emission rates (**Duke Energy International, 2002**)*
** Assumes 20% of the NO_x is NO_2 from the point of emission to the point of prediction.*
*N/A = not available. Only NO_x and SO_2 emissions were estimated in the Technical Submission to EPA (**Duke Energy International, 2002**). The highest predictions in the model domain only were available.*

As discussed in **Section 6**, the annual average predictions have assumed that each fuel scenario will operate for 100% of the year. For short-term averaging periods, the results represent emissions coinciding with the worst-case weather conditions in a year and it is important to consider the forecast operational time for each scenario to assess the probability of these model predictions. For example, the probability of Scenario 34 emissions coinciding with worst-case weather conditions (that is, those conditions which would produce maximum impacts from stack emissions) to result in the 1-hour average NO_x concentration of 367 $\mu g/m^3$ (**Table 8**) is very low since the steelworks operating conditions represented by the scenario has been statistically estimated to occur for less than 0.2% of the time. In reality, plant outages leading to reduced by-product fuel consumption (for example, Hot Strip Mill maintenance periods) would be managed so that they did not coincide with maintenance outages of the ICP turbo alternator. Nevertheless, an analysis of the model output suggested that weather conditions producing the predicted concentration were very light winds (less than 0.4 m/s) during the day-time. These weather conditions occur in the area for less than 10% of the time. Therefore, the coincidence of both the plant and weather conditions required to produce the modelled impact is very unlikely.

In addition to considering the frequency of each scenario in the assessment, direct comparison of results for the ICP scenarios with the base case may not tell the complete story. For example, Scenario 34 shows a slight increase in impacts over the base case however the impacts of Scenario 34 may in fact already occur under existing operations. This is because Scenario 34 results are largely due to emissions from flares, which are not included in the base case scenario considered in this report (as base case is maximum fuel availability and minimal flaring). Also, the slight increase in impacts south of the steelworks for Scenario 34 are primarily due to higher COG flaring from the existing flare stacks, which are significantly shorter than the proposed boiler stacks and located at the southern end of the Steelworks.

The above factors need to be considered in any explanation of the model results. Results for the base case are most appropriately compared with results for ICP Scenario 1 since these scenarios represent maximum fuel availability for the power generation facilities.

Also presented in **Table 8** are the dispersion model results for the Project as originally approved (“App”). The “App” results are most appropriately compared with the results for ICP Scenario 1 and from this comparison the modified ICP represents a similar level of impact to the approved Project. Increases over the “App” results are predicted for 1-hour averages and decreases for longer term averages. Some differences between the “App” and current set of model results can be attributed to modifications to emission factors.

Discussion of the dispersion model results for each of the pollutants is provided below.

7.2.1 Nitrogen Dioxide (NO_2)

Figure 14 shows predicted maximum 1-hour average ground-level NO_x concentrations for the eight modelled scenarios. **Figure 15** shows annual average predictions. For both 1-hour averages and annual averages, the highest ground-level concentrations are predicted to occur close to or at least within a few kilometres of the emission sources for all scenarios.

The highest predicted 1-hour average NO_x concentrations in **Table 8** can be taken to be relatively close to the emission sources. Under these conditions, the time from the point of emission to the point of maximum impact would be short and insufficient for all the NO to be oxidized to NO_2. Based on the monitoring data (**Section 4.3**) the percentage of NO_2 in the NO_x when NO_x concentrations are at a maximum is less than 20%. It has therefore been assumed that 20% of the NO_x is NO_2 for the highest predicted 1-hour average NO_x concentrations in order to estimate highest 1-hour average NO_2 concentrations. For 1-hour average predictions at the monitoring locations there will be a slightly longer period of time for oxidation to take place and it may be more appropriate, and conservative, to assume the percentage of NO_2 is greater than 20%.

For the most affected locations in the model domain, 1-hour average NO_x concentrations are predicted to be lower than the base case for all ICP scenarios except Scenario 34.

Between the base case and ICP Scenario 1 the difference is small (that is, 292 $\mu g/m^3$ compared with 278 $\mu g/m^3$). The maximum 1-hour average NO_2 concentrations for the base case and ICP Scenario 1 are essentially the same.

For assessment purposes the DECC's criterion for 1-hour average NO_2 concentrations is 246 $\mu g/m^3$. It can be demonstrated via the model results that both the base case and all ICP scenarios result in compliance with 246 $\mu g/m^3$ at all ground-level locations. The highest 1-hour average NO_2 concentration is predicted to be 73 $\mu g/m^3$ (Scenario 34) which, when added to the assumed maximum background level of 103 $\mu g/m^3$ is below 246 $\mu g/m^3$. On this basis, it can be said that the Project can maintain compliance with the DECC criteria.

At the three DECC monitoring locations, maximum 1-hour average NO_x concentrations are up to 85 $\mu g/m^3$ at the Wollongong site under the base case. Predictions are below this level for either the Kembla Grange or Warrawong sites and for all ICP scenarios. If it is conservatively assumed that 100% of the NO_x concentration is NO_2 and that a maximum background level of 103 $\mu g/m^3$ applies, then the modelling demonstrates compliance with the 246 $\mu g/m^3$ NO_2 criterion [85+103=188 $\mu g/m^3$].

Assuming results for the base case are most appropriately compared with the results for ICP Scenario 1, the differences in predicted NO_2 concentrations at the monitoring sites are unlikely to be detectable.

Predicted annual average NO_x concentrations can be assumed to be 100% NO_2 and adding the highest prediction (17 $\mu g/m^3$ for ICP Scenario 34) to highest average background levels (18 $\mu g/m^3$) demonstrates compliance with the 62 $\mu g/m^3$ criterion.

Following decommissioning of No. 25 Boiler, the fuel currently modelled as being combusted in No. 25 Boiler would be consumed in the three new boilers. As described in **Section 5**, these new boilers would be equipped with sophisticated NO_x control technology whereas No. 25 Boiler has no NO_x control technology. Total NO_x emissions would therefore be lower after the decommissioning of No. 25 Boiler and ground-level NO_x concentrations would be expected to be lower than predicted in this assessment.

7.2.2 Particulate Matter (PM_{10})

Assessment of particulate matter (PM_{10}) is often complicated by cases where background levels already have exceeded the short-term air quality criteria in the past. This is the case for 24-hour average PM_{10} concentrations in the Illawarra and it makes the approach of adding maximum background levels to maximum Project contributions less meaningful. The availability of results for existing operations (base case) for this assessment however, is useful for identifying whether the Project will cause any additional exceedances of the air quality criteria.

Predicted maximum 24-hour average PM_{10} concentrations are shown in **Figure 16** and annual averages in **Figure 17**. As for the NO_x contour plots, the highest PM_{10} predictions are close to the emission sources and decrease with distance from the Steelworks site. For the highest predictions in the model domain, all ICP scenarios show lower impacts than the base case. Predictions are relatively low with 6 $\mu g/m^3$ being the maximum 24-hour average for any of the ICP scenarios. On the basis of maximum ground-level concentrations, the model results show that the ICP scenarios would not cause any additional exceedances of 50 $\mu g/m^3$.

Maximum 24-hour average PM_{10} concentrations at the monitoring locations can be rounded to just 1 µg/m^3 for all modelled scenarios. This is well below 50 µg/m^3 and the predicted differences in results between each of the scenarios would not be detectable by current measurement technologies.

Similarly, predicted annual average PM_{10} concentrations are very low for all locations – less than 1 µg/m^3 for all ICP scenarios. Assuming background levels of 23 µg/m^3, the Project would not cause exceedances of the DECC's 30 µg/m^3 criterion and no measurable differences to off-site PM_{10} levels would be expected.

Consumption of the available by-product fuels in the three new boilers (without No. 25 Boiler) would not lead to any change in mass emissions of particulate matter, and would likely result in slightly lower ground-level concentration predictions due to the slightly higher stack elevations and exit velocities for the new boilers compared to No. 25 Boiler.

7.2.3 Sulfur Dioxide (SO_2)

Contour plots for 1-hour, 24-hour and annual average SO_2 concentrations are provided in **Figures 18, 19** and **20** respectively. The highest ground level concentrations are predicted to be close to the emission sources.

From the summary in **Table 8**, and with the exception of Scenario 34, all ICP scenarios show lower maximum predictions than the base case. As discussed earlier, the frequency of Scenario 34 is less than 0.2% and the probability of this impact occurring would be near zero.

Figure 18 shows that the highest 1-hour average SO_2 concentrations for Scenario 34 are predicted to be within the Steelworks boundary (the 570 µg/m^3 contour is wholly contained within the boundary). The highest ground-level concentrations are most influenced by the emissions from the flares in particular, the COG sources which are shorter (around 30 m high) than the other modelled emission sources which are taller than 60 m. It is important to note that Scenario 34 is not exclusively associated with the Project, since current operations are likely to include events with high flare emissions also. Thus, modelling of this scenario has highlighted the potential for elevated concentrations close to the Steelworks under either existing or ICP operations. The very low frequency of this scenario means the modelled impacts are unlikely to eventuate.

In terms of compliance with ambient air quality criteria, maximum 1-hour average SO_2 concentrations are predicted to be 997 µg/m^3 for the base case, reducing to 554 µg/m^3 for ICP Scenario 1 (the highest of the ICP scenarios, with the exception of 34). Hence, the highest impacts of the base case are predicted to exceed 570 µg/m^3 while impacts of ICP Scenario 1 are below 570 µg/m^3. Assumed maximum 1-hour average background SO_2 levels are 100 µg/m^3 which suggests that the base case emissions scenario is more likely to result in exceedances of 570 µg/m^3 than ICP Scenario 1. As discussed above, the predicted highest levels are close to the emission sources.

Maximum 1-hour average SO_2 concentrations at the DECC monitoring locations are predicted to be well below 570 µg/m^3 for all modelled scenarios, even with consideration of maximum background levels at around 100 µg/m^3.

The SO_2 model results for the base case, representative of maximum available by-product fuel in the existing facilities for 2007, can also be compared with the recent (2006) monitoring results in **Table 4**. This comparison suggests that the model results are conservative for 1-hour average predictions, based on the Warrawong and Wollongong measurements of 63 and 100 µg/m^3 respectively which are below the model results of 147 and 162 µg/m^3.

Predicted 24-hour average SO_2 concentrations show similar outcomes to the 1-hour averages. Impacts of ICP Scenario 1 are considerably lower than the base case scenario. Again, Scenario 34 shows a potential for elevated concentrations, close to the steelworks, which could exist under current operations as well. The addition of an assumed background 24-hour average SO_2 concentration of 20 µg/m^3 to ICP demonstrates compliance with the 228 µg/m^3 criterion.

Annual average SO_2 concentrations are predicted to be highest for the base case (48 µg/m^3) and Scenario 34 (60 µg/m^3). From **Figure 20**, the highest predictions are on the Steelworks site. The model results suggest that impacts of ICP Scenario 1 would be significantly lower than impacts of the base case. The predicted improvements in maximum impacts from base case and ICP Scenario 1 are significant enough to be detectable by current monitoring technologies. Differences between impacts of the base case and ICP Scenario 1 at the DECC monitoring locations are less significant.

SO_2 is generated from the oxidation of fuel gas sulfur components in the boilers, and emissions are therefore based on the composition of the fuel gases. Consumption of the available by-product fuels in the three new boilers (without No. 25 Boiler) would not lead to any change in mass emissions, and would likely result in slightly lower ground level concentrations due to the slightly higher stack elevation and exit velocities for the new boilers compared to No. 25 Boiler.

7.2.4 Air Toxics and Metals

The currently proposed modifications to the approved ICP project would not increase emissions of substances collectively referred to as air toxics and metals. No emission calculations or dispersion modelling for air toxics and metals have therefore been carried out for the proposed modifications to the ICP. It is useful however to refer to the projected outcomes of the modelling and assessment of air toxics and metals for the approved Project.

For estimating emissions for the approved Project it assumed that there was no incineration of volatile organic compound (VOC) air toxics and metals, that is, the content in the fuel was carried through to the emissions from stacks. This is similar to the approach adopted for sulfur dioxide however in the case of air toxics it will be conservative as there is likely to be some destruction in the boilers.

The outcomes from assessment of the approved Project can be summarised as follows:

- Concentrations will improve (that is, decrease) with the ICP in place;
- Model predictions were well below air quality criteria; and
- Carcinogenic risk factors for the ICP case were well below $1x10^{-6}$, which is considered to be an acceptable level of risk;

As there will be no increase in air toxics or metals emissions, these conclusions also apply to the proposed modifications to the ICP Project.

It should be noted that effective thermal oxidation of lean gases containing hydrocarbons is achieved following exposure of those compounds to temperatures above 800°C for more than 2 seconds. The current ICP boiler supplier has advised that the boiler combustion chamber exit temperature would be above 1050°C and the residence time would be greater than 2 seconds. Therefore, the original assumptions used for estimating air toxics (that is, no incineration of VOC air toxics) is also conservative for the modifications to the ICP.

8. CONCLUSIONS

This report has assessed the air quality impacts from proposed modifications to the original development consent for the BlueScope ICP. The ICP will use by-product fuels of the iron and steel making processes, for power generation. Annual NO_x mass emissions for the modified Project will be maintained below the approved Project limit.

Dispersion modelling has been used to quantify air quality impacts arising from resultant pollutant emissions. Seven ICP fuel scenarios were modelled to capture a range of operating conditions, emissions and potential air quality impacts.

The conclusions of the study can be summarised as follows:

- Existing maximum and average NO_2 and SO_2 concentrations are within air quality criteria noted by the DECC.
- Existing maximum O_3 and PM_{10} concentrations exceed the DECC's criteria on several occasions each year in the Illawarra region.
- Particulate matter concentrations arising from natural sources, such as bushfires or dust storms, may continue to result in elevated PM_{10} levels on occasions.
- Air quality impacts of NO_x, PM_{10} and SO_2 emissions from the ICP are predicted to be close to or slightly lower than current operations, for comparable scenarios.
- The most significant improvements are predicted to be for SO_2 although these improvements are most likely to be observed close to the Steelworks, rather than in residential areas which are further from the site.
- Differences between impacts of the base case and ICP for all pollutants are unlikely to be detectable at the DECC monitoring locations or beyond.
- The most common operational ICP scenarios are unlikely to cause exceedances of the DECC's ambient air quality criteria.
- One operational scenario (Scenario 34 where a significant proportion of off-gases are flared), which is present for both the current and ICP operations, has been identified as having the potential for ground-level concentrations above ambient air quality criteria close to the emission sources. The frequency of this scenario, in the ICP case, is low at less than 1% so the probability of adverse air quality impacts is also low. This highlights a benefit of using the off-gases for power generation rather than flaring these gases.
- Predicted maximum impacts of the modified ICP Project represent a similar level of impact to the approved Project, for the comparable emission scenarios.
- Air quality impacts of NO_x, PM_{10} and SO_2 emissions from the ICP would not increase after the decommissioning of No. 25 Boiler.

These outcomes are consistent with the outcomes of the assessment of the approved Project in that the ICP is likely to provide some benefits, albeit small in some scenarios, to local air quality. It was observed also, that predicted air quality impacts of NO_x and SO_2 emissions from the modified ICP Project are similar to impacts of the approved ICP Project, for the comparable scenario.

9. REFERENCES

DEC (2005)
“Approved Methods for the Modelling and Assessment of Air Pollutants in NSW”, August 2005.

DEC (2005)
“Action for Air: 2006 Update”. Prepared by the Department of Environment and Conservation. ISBN 1 74137 999 7, DEC 2006/465, August 2006.

Dockery D W, Pope C A, Xiping Xu, Spengler J D, Ware J H, Fay M E, Ferris B G and Speizer F E (1993)
“An association between air pollution and mortality in six US cities” The New England Journal of Medicine, Volume 329, Number 24,1753-1759.

Health Effects Institute (2003)
“Revised analyses of time-series studies of air pollution and health”. Special Report May 2003.

Holmes Air Sciences (2001)
“Air Quality Assessment: Duke Energy”. Prepared for CH2M Hill Pty Ltd by Holmes Air Sciences, 21 May 2001.

Hurley, P J (2002)
"The Air Pollution Model (TAPM) Version 2 : User Manual", CSIRO Atmospheric Research Internal Paper No. 25, April 2002

Puri, K., Dietachmayer, G. S., Mills, G. A., Davidson, N. E., Bowen, R. A., and Logan, L. W (1997)
“The BMRC Limited Area Prediction System, LAPS”. Aust. Met. Mag., **47**, 203-223

APPENDIX A
HEALTH EFFECTS OF COMMON AIR POLLUTANTS

APPENDIX A
HEALTH EFFECTS OF COMMON AIR POLLUTANTS

Oxides of nitrogen

Nitrogen oxides (NO_x) emitted from combustion sources are comprised mainly of nitric oxide (NO, approximately 95% at the point of emission) and nitrogen dioxide (NO_2, approximately 5% at the point of emission). Nitric oxide is much less harmful to humans than nitrogen dioxide and is not generally considered a pollutant with health impacts at the concentrations normally found in urban environments. Concern with nitric oxide relates to its transformation to nitrogen dioxide and its role in the formation of photochemical smog. Nitrogen dioxide has been reported to have an effect on respiratory function although the evidence concerning effects has been mixed and conflicting. The DECC has not set any air quality criteria for nitric oxide, however it has set 1-hour and annual average goals for nitrogen dioxide.

Particulate matter

The presence of particulate matter in the atmosphere can have an adverse effect on health and amenity. The health effects of particles are largely related to the extent to which they can penetrate the respiratory tract. Larger particles, that is those greater than 10 µm, generally adhere to the mucous in the nose, mouth, pharynx and larger bronchi and from there are removed by either swallowing or expectorating. Finer particles can enter bronchial and pulmonary regions of the respiratory tract, with increased deposition during mouth breathing which increases during exercise. The very fine particles can be deposited in the pulmonary region and it is these which are of particular concern.

The health effects of particulate matter are further complicated by the chemical nature of the particles and by the possibility of synergistic effects with other air pollutants such as sulfur dioxide.

Much of the recent concern over the health effects of fine particulate matter is based on investigations carried out in the US, with the view to quantifying the health risks associated with both long-term and short-term exposure to airborne particulate matter. The study is colloquially referred to as "The Six Cities Study" from the original work by **Dockery et al. (1993)**, which determined a relationship between fine particulate matter (defined as particles smaller than 2.5 µm in diameter) in the air and mortality in six US cities.

The basic findings of the Six Cities Study is that there is an increase in mortality with increasing concentrations of fine particulate matter. The conclusions appear to be robust and have been supported by subsequent studies and as far as can be determined are not confounded by other known variables. It is important to note that the observed association between fine particles and mortality is statistical. The particles are not the primary cause of death, but are one of many environmental and other risk factors. More recently the statistical associations have been revised downwards based on a review of the statistical methods used, but the association remains (**HEI, 2003**). However the current Australian air quality goals for particulate matter are still based on the more conservative associations.

Sulfur dioxide

Sulfur dioxide (SO_2) is an acid gas which can have harmful effects on the respiratory system as well as on vegetation and building materials. It is a colourless and non-flammable gas. The DECC notes 10-minute maximum, 1-hour maximum, 24-hour maximum and annual average air quality criteria for SO_2.

APPENDIX B
JOINT WIND SPEED, WIND DIRECTION AND STABILITY CLASS FREQUENCY TABLES

APPENDIX B
JOINT WIND SPEED, WIND DIRECTION AND STABILITY CLASS FREQUENCY TABLES

Kembla Grange:

STATISTICS FOR FILE: C:\Jobs\BS_ICP\calmet\2005\prtmet\stab\kg.aus
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

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	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
NE	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
ENE	0.000115	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000344
E	0.000115	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000344
ESE	0.000230	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000344
SE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SSE	0.000000	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
S	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SSW	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
SW	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
WSW	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
W	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
WNW	0.000115	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000459
NW	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
NNW	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CALM									0.000230
TOTAL	0.001148	0.001722	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003099

MEAN WIND SPEED (m/s) = 1.61
NUMBER OF OBSERVATIONS = 27

PASQUILL STABILITY CLASS 'B'

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	0.000918	0.001722	0.000574	0.000115	0.000000	0.000000	0.000000	0.000000	0.003329
NE	0.001607	0.001377	0.001148	0.000000	0.000000	0.000000	0.000000	0.000000	0.004132
ENE	0.000689	0.001377	0.004017	0.001033	0.000000	0.000000	0.000000	0.000000	0.007117
E	0.001148	0.001377	0.001148	0.000000	0.000000	0.000000	0.000000	0.000000	0.003673
ESE	0.002066	0.001607	0.001722	0.000115	0.000000	0.000000	0.000000	0.000000	0.005510
SE	0.001837	0.002640	0.003903	0.000574	0.000000	0.000000	0.000000	0.000000	0.008953
SSE	0.000803	0.001033	0.000230	0.000115	0.000000	0.000000	0.000000	0.000000	0.002181
S	0.000459	0.000803	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.001492
SSW	0.001377	0.000574	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.002066
SW	0.001033	0.000230	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.001377
WSW	0.001263	0.000918	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.002755
W	0.002870	0.000344	0.000918	0.000230	0.000000	0.000000	0.000000	0.000000	0.004362
WNW	0.001607	0.000344	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.002296
NW	0.000344	0.000803	0.001033	0.000000	0.000000	0.000000	0.000000	0.000000	0.002181
NNW	0.000230	0.001033	0.001033	0.000000	0.000000	0.000000	0.000000	0.000000	0.002296
N	0.000574	0.001263	0.001722	0.000000	0.000000	0.000000	0.000000	0.000000	0.003558
CALM									0.008264
TOTAL	0.018825	0.017447	0.018825	0.002181	0.000000	0.000000	0.000000	0.000000	0.065542

MEAN WIND SPEED (m/s) = 2.15
NUMBER OF OBSERVATIONS = 571

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	0.002296	0.001607	0.001377	0.000230	0.000000	0.000000	0.000000	0.000000	0.005510
NE	0.001837	0.002410	0.004017	0.002296	0.001263	0.001607	0.000803	0.000115	0.014348
ENE	0.001377	0.002181	0.007461	0.006428	0.001148	0.000459	0.000115	0.000000	0.019169
E	0.001377	0.000918	0.002066	0.000574	0.000000	0.000000	0.000000	0.000000	0.004936
ESE	0.001492	0.001722	0.003214	0.001377	0.000115	0.000000	0.000000	0.000000	0.007920
SE	0.002755	0.004247	0.009527	0.006428	0.001148	0.000000	0.000000	0.000000	0.024105
SSE	0.002181	0.001377	0.001722	0.001607	0.000459	0.000000	0.000000	0.000000	0.007346
S	0.000344	0.000230	0.000918	0.001377	0.000344	0.000000	0.000000	0.000000	0.003214
SSW	0.001722	0.000459	0.001492	0.000803	0.000000	0.000000	0.000000	0.000000	0.004477
SW	0.001607	0.000230	0.002181	0.000918	0.000000	0.000000	0.000000	0.000000	0.004936
WSW	0.002410	0.001722	0.002181	0.000918	0.000459	0.000689	0.000000	0.000000	0.008379
W	0.008035	0.003788	0.002984	0.001837	0.000918	0.000459	0.000000	0.000000	0.018021
WNW	0.005624	0.002181	0.001722	0.001492	0.000344	0.000115	0.000000	0.000000	0.011478
NW	0.002525	0.001607	0.001148	0.000344	0.000000	0.000000	0.000000	0.000000	0.005624
NNW	0.000918	0.001492	0.001263	0.000459	0.000000	0.000000	0.000000	0.000000	0.004132
N	0.000918	0.000803	0.000689	0.000574	0.000000	0.000000	0.000000	0.000000	0.002984
CALM									0.019054
TOTAL	0.037420	0.026974	0.043962	0.027663	0.006198	0.003329	0.000918	0.000115	0.165634

MEAN WIND SPEED (m/s) = 3.02
NUMBER OF OBSERVATIONS = 1443

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	0.000574	0.004706	0.004247	0.001492	0.000230	0.000000	0.000000	0.000000	0.011249
NE	0.000574	0.006772	0.011938	0.013085	0.014004	0.007691	0.001148	0.000115	0.055326
ENE	0.000459	0.004821	0.005969	0.006657	0.003673	0.000574	0.000115	0.000000	0.022268
E	0.000803	0.003214	0.002984	0.001033	0.000459	0.000000	0.000000	0.000000	0.008494
ESE	0.000574	0.003788	0.004132	0.001837	0.000000	0.000000	0.000000	0.000000	0.010331
SE	0.000803	0.007691	0.009183	0.007461	0.001837	0.000115	0.000000	0.000000	0.027089
SSE	0.000918	0.005510	0.007461	0.006657	0.001492	0.000115	0.000000	0.000000	0.022153
S	0.000115	0.003214	0.006428	0.004591	0.001492	0.000000	0.000000	0.000000	0.015840
SSW	0.000803	0.004362	0.005510	0.004591	0.002870	0.001033	0.000115	0.000000	0.019284
SW	0.000918	0.004477	0.004477	0.002984	0.001263	0.000344	0.000574	0.000000	0.015037
WSW	0.001377	0.004821	0.005969	0.003444	0.003099	0.000918	0.000230	0.000000	0.019858
W	0.003788	0.009871	0.006657	0.013659	0.016414	0.008609	0.002181	0.000803	0.061983
WNW	0.002640	0.011019	0.005624	0.004477	0.003673	0.002181	0.001377	0.001377	0.032369
NW	0.001722	0.002410	0.001377	0.000689	0.001263	0.000115	0.000000	0.000000	0.007576
NNW	0.000803	0.001263	0.001263	0.001377	0.001377	0.000574	0.000344	0.000000	0.007002
N	0.001033	0.002525	0.002755	0.001492	0.000803	0.000918	0.000000	0.000000	0.009527
CALM									0.005624
TOTAL	0.017906	0.080464	0.085973	0.075528	0.053949	0.023186	0.006084	0.002296	0.351010

MEAN WIND SPEED (m/s) = 4.48
NUMBER OF OBSERVATIONS = 3058

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	0.000000	0.005165	0.002870	0.001033	0.000000	0.000000	0.000000	0.000000	0.009068
NE	0.000000	0.003673	0.001607	0.000574	0.000000	0.000000	0.000000	0.000000	0.005854
ENE	0.000000	0.000574	0.000115	0.000230	0.000000	0.000000	0.000000	0.000000	0.000918
E	0.000000	0.000344	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000459
ESE	0.000000	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000689
SE	0.000000	0.001722	0.000459	0.000115	0.000000	0.000000	0.000000	0.000000	0.002296
SSE	0.000000	0.001492	0.000918	0.000230	0.000000	0.000000	0.000000	0.000000	0.002640
S	0.000000	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000344
SSW	0.000000	0.001492	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.001951
SW	0.000000	0.000918	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.001263
WSW	0.000000	0.002755	0.000918	0.000459	0.000000	0.000000	0.000000	0.000000	0.004132
W	0.000000	0.013774	0.008953	0.004362	0.000000	0.000000	0.000000	0.000000	0.027089
WNW	0.000000	0.021120	0.008953	0.002066	0.000000	0.000000	0.000000	0.000000	0.032140
NW	0.000000	0.001263	0.000803	0.000230	0.000000	0.000000	0.000000	0.000000	0.002296
NNW	0.000000	0.000344	0.000574	0.000344	0.000000	0.000000	0.000000	0.000000	0.001263
N	0.000000	0.001033	0.000918	0.000230	0.000000	0.000000	0.000000	0.000000	0.002181
CALM									0.000000
TOTAL	0.000000	0.056703	0.028007	0.009871	0.000000	0.000000	0.000000	0.000000	0.094582

MEAN WIND SPEED (m/s) = 3.02
NUMBER OF OBSERVATIONS = 824

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	0.008838	0.004706	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.014118
NE	0.005969	0.004017	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.010445
ENE	0.004132	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004591
E	0.003673	0.000918	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004591
ESE	0.002066	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002640
SE	0.003099	0.001263	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004362
SSE	0.002296	0.000803	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.003214
S	0.000344	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000459
SSW	0.001837	0.001033	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002870
SW	0.001722	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002410
WSW	0.003329	0.002066	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.005624
W	0.034206	0.012511	0.002296	0.000000	0.000000	0.000000	0.000000	0.000000	0.049013
WNW	0.084940	0.029270	0.002296	0.000000	0.000000	0.000000	0.000000	0.000000	0.116506
NW	0.022039	0.003788	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.026171
NNW	0.006887	0.000918	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007805
N	0.004821	0.002066	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.007231
CALM									0.058081
TOTAL	0.190197	0.065197	0.006657	0.000000	0.000000	0.000000	0.000000	0.000000	0.320133

MEAN WIND SPEED (m/s) = 1.16
NUMBER OF OBSERVATIONS = 2789

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	0.012741	0.018021	0.009642	0.002870	0.000230	0.000000	0.000000	0.000000	0.043503
NE	0.010101	0.018251	0.019169	0.015955	0.015266	0.009298	0.001951	0.000230	0.090220
ENE	0.006772	0.009642	0.017562	0.014348	0.004821	0.001033	0.000230	0.000000	0.054408
E	0.007117	0.007002	0.006313	0.001607	0.000459	0.000000	0.000000	0.000000	0.022498
ESE	0.006428	0.008494	0.009068	0.003329	0.000115	0.000000	0.000000	0.000000	0.027433
SE	0.008494	0.017562	0.023072	0.014578	0.002984	0.000115	0.000000	0.000000	0.066804
SSE	0.006198	0.010445	0.010445	0.008609	0.001951	0.000115	0.000000	0.000000	0.037764
S	0.001263	0.004706	0.007576	0.005969	0.001837	0.000000	0.000000	0.000000	0.021350
SSW	0.005739	0.008035	0.007576	0.005395	0.002870	0.001033	0.000115	0.000000	0.030762
SW	0.005395	0.006657	0.007117	0.003903	0.001263	0.000344	0.000574	0.000000	0.025253
WSW	0.008494	0.012397	0.009871	0.004821	0.003558	0.001607	0.000230	0.000000	0.040978
W	0.048898	0.040404	0.021809	0.020087	0.017332	0.009068	0.002181	0.000803	0.160583
WNW	0.094927	0.064279	0.018939	0.008035	0.004017	0.002296	0.001377	0.001377	0.195248
NW	0.026745	0.009871	0.004706	0.001263	0.001263	0.000115	0.000000	0.000000	0.043962
NNW	0.008838	0.005051	0.004132	0.002181	0.001377	0.000574	0.000344	0.000000	0.022498
N	0.007346	0.007691	0.006428	0.002296	0.000803	0.000918	0.000000	0.000000	0.025482
CALM									0.091253
TOTAL	0.265496	0.248508	0.183425	0.115243	0.060147	0.026515	0.007002	0.002410	1.000000

MEAN WIND SPEED (m/s) = 2.88
NUMBER OF OBSERVATIONS = 8712

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

- A : 0.3%
- B : 6.6%
- C : 16.6%
- D : 35.1%
- E : 9.5%
- F : 32.0%

Wollongong:

STATISTICS FOR FILE: C:\Jobs\BS_ICP\calmet\2005\prtmet\stab\wol.aus
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

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	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NE	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
ENE	0.000230	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000918
E	0.000230	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000803
ESE	0.000000	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000574
SE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SSE	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
S	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
SSW	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SW	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
WSW	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
W	0.000344	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000459
WNW	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
NW	0.000115	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000344
NNW	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
CALM									0.000344
TOTAL	0.001148	0.002984	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004477

MEAN WIND SPEED (m/s) = 1.89
NUMBER OF OBSERVATIONS = 39

PASQUILL STABILITY CLASS 'B'

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	0.001148	0.002066	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.003903
NE	0.001837	0.003099	0.006657	0.001377	0.000000	0.000000	0.000000	0.000000	0.012971
ENE	0.001263	0.005280	0.011364	0.000000	0.000000	0.000000	0.000000	0.000000	0.017906
E	0.000918	0.003788	0.002410	0.000000	0.000000	0.000000	0.000000	0.000000	0.007117
ESE	0.000574	0.004362	0.001722	0.000115	0.000000	0.000000	0.000000	0.000000	0.006772
SE	0.000918	0.003788	0.004132	0.000574	0.000000	0.000000	0.000000	0.000000	0.009412
SSE	0.000803	0.000803	0.001148	0.000115	0.000000	0.000000	0.000000	0.000000	0.002870
S	0.001263	0.000918	0.001033	0.000000	0.000000	0.000000	0.000000	0.000000	0.003214
SSW	0.001722	0.002410	0.001033	0.000115	0.000000	0.000000	0.000000	0.000000	0.005280
SW	0.002296	0.002984	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.005969
WSW	0.001722	0.001148	0.000918	0.000115	0.000000	0.000000	0.000000	0.000000	0.003903
W	0.000918	0.002066	0.001951	0.000115	0.000000	0.000000	0.000000	0.000000	0.005051
WNW	0.000689	0.000459	0.000803	0.000000	0.000000	0.000000	0.000000	0.000000	0.001951
NW	0.000689	0.000689	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.001607
NNW	0.000574	0.001263	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.002525
N	0.001263	0.002984	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.004936
CALM									0.004591
TOTAL	0.018595	0.038108	0.036157	0.002525	0.000000	0.000000	0.000000	0.000000	0.099977

MEAN WIND SPEED (m/s) = 2.53
NUMBER OF OBSERVATIONS = 871

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	0.003444	0.003214	0.003903	0.002296	0.000000	0.000000	0.000000	0.000000	0.012856
NE	0.003444	0.005969	0.014922	0.009642	0.000115	0.000000	0.000000	0.000000	0.034091
ENE	0.001492	0.009757	0.007576	0.001033	0.000000	0.000000	0.000000	0.000000	0.019858
E	0.001492	0.004936	0.001148	0.000000	0.000000	0.000000	0.000000	0.000000	0.007576
ESE	0.001033	0.004936	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005969
SE	0.002640	0.003558	0.002870	0.000230	0.000000	0.000000	0.000000	0.000000	0.009298
SSE	0.001148	0.002525	0.004477	0.001837	0.000000	0.000000	0.000000	0.000000	0.009986
S	0.001951	0.002525	0.001837	0.000230	0.000000	0.000000	0.000000	0.000000	0.006543
SSW	0.002181	0.002984	0.001492	0.000000	0.000000	0.000000	0.000000	0.000000	0.006657
SW	0.009183	0.007920	0.001377	0.000344	0.000000	0.000000	0.000000	0.000000	0.018825
WSW	0.004936	0.005165	0.004247	0.000918	0.000000	0.000000	0.000000	0.000000	0.015266
W	0.002066	0.004132	0.005739	0.001951	0.000115	0.000000	0.000000	0.000000	0.014004
WNW	0.000574	0.001837	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.002870
NW	0.001033	0.001263	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002296
NNW	0.001377	0.002410	0.001492	0.000230	0.000000	0.000000	0.000000	0.000000	0.005510
N	0.003214	0.002640	0.000803	0.000000	0.000000	0.000000	0.000000	0.000000	0.006657
CALM									0.019054
TOTAL	0.041208	0.065771	0.052342	0.018710	0.000230	0.000000	0.000000	0.000000	0.197314

MEAN WIND SPEED (m/s) = 2.52
NUMBER OF OBSERVATIONS = 1719

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	0.000918	0.010101	0.007002	0.000918	0.000000	0.000000	0.000000	0.000000	0.018939
NE	0.001492	0.010101	0.009527	0.004132	0.000574	0.000000	0.000000	0.000000	0.025826
ENE	0.001033	0.008609	0.004706	0.000115	0.000115	0.000000	0.000000	0.000000	0.014578
E	0.000115	0.005510	0.001148	0.000230	0.000000	0.000000	0.000000	0.000000	0.007002
ESE	0.000574	0.004591	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.005624
SE	0.000689	0.007805	0.002984	0.000000	0.000000	0.000000	0.000000	0.000000	0.011478
SSE	0.000803	0.009986	0.009068	0.000344	0.000000	0.000000	0.000000	0.000000	0.020202
S	0.000574	0.008724	0.007117	0.002984	0.000344	0.000000	0.000000	0.000000	0.019743
SSW	0.002066	0.011823	0.012282	0.003099	0.000230	0.000000	0.000000	0.000000	0.029500
SW	0.004477	0.019513	0.005510	0.000344	0.000344	0.000000	0.000000	0.000000	0.030188
WSW	0.003099	0.007805	0.005624	0.001492	0.000000	0.000000	0.000000	0.000000	0.018021
W	0.000574	0.003444	0.003099	0.004362	0.002525	0.000918	0.000115	0.000000	0.015037
WNW	0.000115	0.000918	0.000918	0.000574	0.000344	0.000230	0.000115	0.000115	0.003329
NW	0.000689	0.001837	0.003099	0.000689	0.000000	0.000000	0.000000	0.000000	0.006313
NNW	0.000918	0.003673	0.002755	0.000574	0.000115	0.000000	0.000000	0.000000	0.008035
N	0.002755	0.008379	0.001837	0.000000	0.000115	0.000000	0.000000	0.000000	0.013085
CALM									0.005395
TOTAL	0.020891	0.122819	0.077135	0.019858	0.004706	0.001148	0.000230	0.000115	0.252296

MEAN WIND SPEED (m/s) = 2.94
NUMBER OF OBSERVATIONS = 2198

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	0.000000	0.004017	0.000918	0.000000	0.000000	0.000000	0.000000	0.000000	0.004936
NE	0.000000	0.001148	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001148
ENE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
E	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
ESE	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
SE	0.000000	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
SSE	0.000000	0.002066	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002066
S	0.000000	0.003214	0.001377	0.000230	0.000000	0.000000	0.000000	0.000000	0.004821
SSW	0.000000	0.004247	0.001377	0.000000	0.000000	0.000000	0.000000	0.000000	0.005624
SW	0.000000	0.029385	0.002066	0.000115	0.000000	0.000000	0.000000	0.000000	0.031566
WSW	0.000000	0.011938	0.006887	0.001033	0.000000	0.000000	0.000000	0.000000	0.019858
W	0.000000	0.001837	0.001263	0.001148	0.000000	0.000000	0.000000	0.000000	0.004247
WNW	0.000000	0.000230	0.000459	0.000344	0.000000	0.000000	0.000000	0.000000	0.001033
NW	0.000000	0.000689	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.001377
NNW	0.000000	0.003788	0.001148	0.000000	0.000000	0.000000	0.000000	0.000000	0.004936
N	0.000000	0.004936	0.000918	0.000000	0.000000	0.000000	0.000000	0.000000	0.005854
CALM									0.000000
TOTAL	0.000000	0.067837	0.017103	0.002870	0.000000	0.000000	0.000000	0.000000	0.087810

MEAN WIND SPEED (m/s) = 2.64
NUMBER OF OBSERVATIONS = 765

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	0.010445	0.004017	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.014463
NE	0.004706	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005165
ENE	0.000803	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001263
E	0.000459	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000574
ESE	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000574
SE	0.001837	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002181
SSE	0.003903	0.001722	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005624
S	0.004362	0.003099	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.007576
SSW	0.006543	0.002525	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.009183
SW	0.035354	0.032369	0.001377	0.000000	0.000000	0.000000	0.000000	0.000000	0.069100
WSW	0.036157	0.024105	0.004821	0.000000	0.000000	0.000000	0.000000	0.000000	0.065083
W	0.010101	0.003444	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.014233
WNW	0.003099	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003673
NW	0.005051	0.001951	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.007346
NNW	0.012856	0.006313	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.019628
N	0.018365	0.011938	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.030418
CALM									0.102043
TOTAL	0.154614	0.093434	0.008035	0.000000	0.000000	0.000000	0.000000	0.000000	0.358127

MEAN WIND SPEED (m/s) = 1.15
NUMBER OF OBSERVATIONS = 3120

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	0.015955	0.023416	0.012511	0.003214	0.000000	0.000000	0.000000	0.000000	0.055096
NE	0.011478	0.020891	0.031107	0.015152	0.000689	0.000000	0.000000	0.000000	0.079316
ENE	0.004821	0.024793	0.023646	0.001148	0.000115	0.000000	0.000000	0.000000	0.054522
E	0.003214	0.014922	0.004706	0.000230	0.000000	0.000000	0.000000	0.000000	0.023072
ESE	0.002755	0.014578	0.002181	0.000115	0.000000	0.000000	0.000000	0.000000	0.019628
SE	0.006084	0.015725	0.009986	0.000803	0.000000	0.000000	0.000000	0.000000	0.032599
SSE	0.006772	0.017218	0.014692	0.002296	0.000000	0.000000	0.000000	0.000000	0.040978
S	0.008150	0.018595	0.011478	0.003444	0.000344	0.000000	0.000000	0.000000	0.042011
SSW	0.012511	0.023990	0.016299	0.003214	0.000230	0.000000	0.000000	0.000000	0.056244
SW	0.051309	0.092287	0.011019	0.000803	0.000344	0.000000	0.000000	0.000000	0.155762
WSW	0.046028	0.050275	0.022498	0.003558	0.000000	0.000000	0.000000	0.000000	0.122360
W	0.014004	0.015037	0.012741	0.007576	0.002640	0.000918	0.000115	0.000000	0.053030
WNW	0.004477	0.004132	0.002640	0.000918	0.000344	0.000230	0.000115	0.000115	0.012971
NW	0.007576	0.006657	0.004362	0.000689	0.000000	0.000000	0.000000	0.000000	0.019284
NNW	0.015725	0.017447	0.006543	0.000803	0.000115	0.000000	0.000000	0.000000	0.040634
N	0.025597	0.030992	0.004362	0.000000	0.000115	0.000000	0.000000	0.000000	0.061065
CALM									0.131428
TOTAL	0.236455	0.390955	0.190771	0.043962	0.004936	0.001148	0.000230	0.000115	1.000000

MEAN WIND SPEED (m/s) = 2.14
NUMBER OF OBSERVATIONS = 8712

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

A : 0.4%
B : 10.0%
C : 19.7%
D : 25.2%
E : 8.8%
F : 35.8%

Warrawong:

STATISTICS FOR FILE: C:\Jobs\BS_ICP\calmet\2005\prtmet\stab\war.aus
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

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	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
NE	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
ENE	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
E	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
ESE	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
SE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SSE	0.000000	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
S	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
SSW	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
SW	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
WSW	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
W	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000230
WNW	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
NW	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115
NNW	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CALM									0.000230
TOTAL	0.000574	0.001033	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001837

MEAN WIND SPEED (m/s) = 1.66
NUMBER OF OBSERVATIONS = 16

PASQUILL STABILITY CLASS 'B'

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	0.000803	0.000689	0.001607	0.000230	0.000000	0.000000	0.000000	0.000000	0.003329
NE	0.000689	0.002755	0.007461	0.001607	0.000000	0.000000	0.000000	0.000000	0.012511
ENE	0.001033	0.002525	0.005854	0.000230	0.000000	0.000000	0.000000	0.000000	0.009642
E	0.000344	0.000689	0.004477	0.000000	0.000000	0.000000	0.000000	0.000000	0.005510
ESE	0.000230	0.001377	0.003673	0.000574	0.000000	0.000000	0.000000	0.000000	0.005854
SE	0.000230	0.001607	0.004591	0.000230	0.000000	0.000000	0.000000	0.000000	0.006657
SSE	0.000115	0.002410	0.002296	0.000230	0.000000	0.000000	0.000000	0.000000	0.005051
S	0.000918	0.000803	0.000344	0.000115	0.000000	0.000000	0.000000	0.000000	0.002181
SSW	0.000459	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000918
SW	0.001377	0.000574	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.002296
WSW	0.005051	0.001951	0.000918	0.000000	0.000000	0.000000	0.000000	0.000000	0.007920
W	0.002181	0.001492	0.000459	0.000000	0.000000	0.000000	0.000000	0.000000	0.004132
WNW	0.000689	0.000574	0.001033	0.000000	0.000000	0.000000	0.000000	0.000000	0.002296
NW	0.000459	0.000459	0.000230	0.000115	0.000000	0.000000	0.000000	0.000000	0.001263
NNW	0.000574	0.000459	0.000344	0.000115	0.000000	0.000000	0.000000	0.000000	0.001492
N	0.000344	0.000918	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.001607
CALM									0.003099
TOTAL	0.015496	0.019743	0.033976	0.003444	0.000000	0.000000	0.000000	0.000000	0.075758

MEAN WIND SPEED (m/s) = 2.67
NUMBER OF OBSERVATIONS = 660

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	0.001148	0.002755	0.003214	0.001377	0.000115	0.000000	0.000000	0.000000	0.008609
NE	0.001033	0.006313	0.015037	0.011364	0.000230	0.000000	0.000000	0.000000	0.033976
ENE	0.001951	0.003673	0.005395	0.001837	0.000000	0.000000	0.000000	0.000000	0.012856
E	0.001148	0.002984	0.002870	0.000115	0.000000	0.000000	0.000000	0.000000	0.007117
ESE	0.000803	0.003214	0.002410	0.000459	0.000000	0.000000	0.000000	0.000000	0.006887
SE	0.001033	0.003329	0.004362	0.000344	0.000000	0.000000	0.000000	0.000000	0.009068
SSE	0.000574	0.002410	0.004706	0.003673	0.000459	0.000000	0.000000	0.000000	0.011823
S	0.000803	0.001607	0.003214	0.002640	0.000803	0.000230	0.000115	0.000000	0.009412
SSW	0.001148	0.001377	0.002296	0.001033	0.000000	0.000000	0.000000	0.000000	0.005854
SW	0.002525	0.001148	0.002296	0.000115	0.000000	0.000000	0.000000	0.000000	0.006084
WSW	0.004821	0.004477	0.001377	0.000344	0.000115	0.000000	0.000000	0.000000	0.011134
W	0.005624	0.003673	0.002181	0.001607	0.000344	0.000000	0.000000	0.000000	0.013430
WNW	0.004477	0.002410	0.002870	0.002984	0.000459	0.000344	0.000000	0.000000	0.013545
NW	0.002296	0.001837	0.002870	0.000803	0.000230	0.000115	0.000000	0.000000	0.008150
NNW	0.001263	0.001492	0.002296	0.000803	0.000000	0.000000	0.000000	0.000000	0.005854
N	0.001263	0.001033	0.001033	0.000230	0.000000	0.000000	0.000000	0.000000	0.003558
CALM									0.007461
TOTAL	0.031910	0.043733	0.058425	0.029729	0.002755	0.000689	0.000115	0.000000	0.174816

MEAN WIND SPEED (m/s) = 3.10
NUMBER OF OBSERVATIONS = 1523

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	0.000689	0.006772	0.010216	0.001722	0.000115	0.000000	0.000000	0.000000	0.019513
NE	0.001033	0.013200	0.015725	0.006543	0.001377	0.000115	0.000000	0.000000	0.037994
ENE	0.000574	0.006772	0.003903	0.000803	0.000000	0.000000	0.000000	0.000000	0.012052
E	0.000574	0.004247	0.003788	0.001377	0.000000	0.000000	0.000000	0.000000	0.009986
ESE	0.000115	0.003444	0.004821	0.001033	0.000000	0.000000	0.000000	0.000000	0.009412
SE	0.000115	0.005969	0.005739	0.001951	0.000115	0.000000	0.000000	0.000000	0.013889
SSE	0.001033	0.007117	0.011478	0.008379	0.003558	0.000459	0.000000	0.000000	0.032025
S	0.000459	0.007002	0.015152	0.013430	0.006428	0.001951	0.000115	0.000000	0.044536
SSW	0.000803	0.006313	0.010560	0.005739	0.003099	0.000459	0.000230	0.000000	0.027204
SW	0.001377	0.006657	0.011364	0.003788	0.000230	0.000344	0.000115	0.000000	0.023875
WSW	0.001148	0.005395	0.002755	0.001033	0.000115	0.000115	0.000000	0.000000	0.010560
W	0.001377	0.002755	0.002640	0.003329	0.001263	0.000000	0.000000	0.000000	0.011364
WNW	0.001837	0.004821	0.007117	0.013315	0.010445	0.004936	0.000344	0.000000	0.042815
NW	0.001033	0.002755	0.004132	0.004821	0.003444	0.002755	0.000918	0.000574	0.020432
NNW	0.000689	0.002984	0.003788	0.001951	0.000918	0.000230	0.000000	0.000000	0.010560
N	0.000689	0.004132	0.005280	0.001837	0.000115	0.000000	0.000000	0.000000	0.012052
CALM									0.002296
TOTAL	0.013545	0.090335	0.118457	0.071051	0.031221	0.011364	0.001722	0.000574	0.340565

MEAN WIND SPEED (m/s) = 4.04
NUMBER OF OBSERVATIONS = 2967

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	0.000000	0.007346	0.004821	0.000000	0.000000	0.000000	0.000000	0.000000	0.012167
NE	0.000000	0.005739	0.002525	0.000115	0.000000	0.000000	0.000000	0.000000	0.008379
ENE	0.000000	0.001837	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001837
E	0.000000	0.000689	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000918
ESE	0.000000	0.001148	0.000115	0.000115	0.000000	0.000000	0.000000	0.000000	0.001377
SE	0.000000	0.001837	0.000803	0.000000	0.000000	0.000000	0.000000	0.000000	0.002640
SSE	0.000000	0.002296	0.000803	0.000574	0.000000	0.000000	0.000000	0.000000	0.003673
S	0.000000	0.002525	0.001377	0.000344	0.000000	0.000000	0.000000	0.000000	0.004247
SSW	0.000000	0.005739	0.001492	0.001263	0.000000	0.000000	0.000000	0.000000	0.008494
SW	0.000000	0.013085	0.003329	0.000115	0.000000	0.000000	0.000000	0.000000	0.016529
WSW	0.000000	0.005395	0.002410	0.000000	0.000000	0.000000	0.000000	0.000000	0.007805
W	0.000000	0.004017	0.003444	0.000689	0.000000	0.000000	0.000000	0.000000	0.008150
WNW	0.000000	0.002640	0.009757	0.006198	0.000000	0.000000	0.000000	0.000000	0.018595
NW	0.000000	0.002296	0.004706	0.001263	0.000000	0.000000	0.000000	0.000000	0.008264
NNW	0.000000	0.001951	0.001951	0.000344	0.000000	0.000000	0.000000	0.000000	0.004247
N	0.000000	0.002525	0.003329	0.000459	0.000000	0.000000	0.000000	0.000000	0.006313
CALM									0.000000
TOTAL	0.000000	0.061065	0.041093	0.011478	0.000000	0.000000	0.000000	0.000000	0.113636

MEAN WIND SPEED (m/s) = 3.13
NUMBER OF OBSERVATIONS = 990

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	0.007461	0.010675	0.002410	0.000000	0.000000	0.000000	0.000000	0.000000	0.020546
NE	0.003903	0.005510	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.009757
ENE	0.003214	0.001148	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004362
E	0.001837	0.001607	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.003558
ESE	0.002296	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002984
SE	0.001377	0.000689	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002066
SSE	0.003788	0.000689	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.004706
S	0.002296	0.002181	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.004706
SSW	0.004132	0.002755	0.000230	0.000000	0.000000	0.000000	0.000000	0.000000	0.007117
SW	0.004706	0.005165	0.000574	0.000000	0.000000	0.000000	0.000000	0.000000	0.010445
WSW	0.012626	0.004821	0.000344	0.000000	0.000000	0.000000	0.000000	0.000000	0.017792
W	0.027204	0.009757	0.001377	0.000000	0.000000	0.000000	0.000000	0.000000	0.038338
WNW	0.048898	0.009986	0.001951	0.000000	0.000000	0.000000	0.000000	0.000000	0.060836
NW	0.017562	0.005969	0.001492	0.000000	0.000000	0.000000	0.000000	0.000000	0.025023
NNW	0.012741	0.008953	0.000918	0.000000	0.000000	0.000000	0.000000	0.000000	0.022612
N	0.012052	0.009986	0.001377	0.000000	0.000000	0.000000	0.000000	0.000000	0.023416
CALM									0.035124
TOTAL	0.166093	0.080579	0.011593	0.000000	0.000000	0.000000	0.000000	0.000000	0.293388

MEAN WIND SPEED (m/s) = 1.35
NUMBER OF OBSERVATIONS = 2556

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	0.010216	0.028352	0.022268	0.003329	0.000230	0.000000	0.000000	0.000000	0.064394
NE	0.006657	0.033632	0.041093	0.019628	0.001607	0.000115	0.000000	0.000000	0.102732
ENE	0.006772	0.016070	0.015152	0.002870	0.000000	0.000000	0.000000	0.000000	0.040863
E	0.003903	0.010216	0.011478	0.001492	0.000000	0.000000	0.000000	0.000000	0.027089
ESE	0.003558	0.009986	0.011019	0.002181	0.000000	0.000000	0.000000	0.000000	0.026745
SE	0.002755	0.013430	0.015496	0.002525	0.000115	0.000000	0.000000	0.000000	0.034320
SSE	0.005510	0.015152	0.019513	0.012856	0.004017	0.000459	0.000000	0.000000	0.057507
S	0.004477	0.014233	0.020317	0.016529	0.007231	0.002181	0.000230	0.000000	0.065197
SSW	0.006657	0.016644	0.014578	0.008035	0.003099	0.000459	0.000230	0.000000	0.049702
SW	0.009986	0.026630	0.017906	0.004017	0.000230	0.000344	0.000115	0.000000	0.059229
WSW	0.023646	0.022039	0.007805	0.001377	0.000230	0.000115	0.000000	0.000000	0.055211
W	0.036501	0.021809	0.010101	0.005624	0.001607	0.000000	0.000000	0.000000	0.075643
WNW	0.056015	0.020432	0.022727	0.022498	0.010904	0.005280	0.000344	0.000000	0.138200
NW	0.021350	0.013430	0.013430	0.007002	0.003673	0.002870	0.000918	0.000574	0.063246
NNW	0.015266	0.015840	0.009298	0.003214	0.000918	0.000230	0.000000	0.000000	0.044766
N	0.014348	0.018595	0.011364	0.002525	0.000115	0.000000	0.000000	0.000000	0.046947
CALM									0.048209
TOTAL	0.227617	0.296488	0.263545	0.115702	0.033976	0.012052	0.001837	0.000574	1.000000

MEAN WIND SPEED (m/s) = 2.88
NUMBER OF OBSERVATIONS = 8712

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

A : 0.2%
B : 7.6%
C : 17.5%
D : 34.1%
E : 11.4%
F : 29.3%

APPENDIX C
EMISSION INVENTORIES FOR MODELLED ICP SCENARIOS

Table C1 : Emission inventories for modelled ICP scenarios

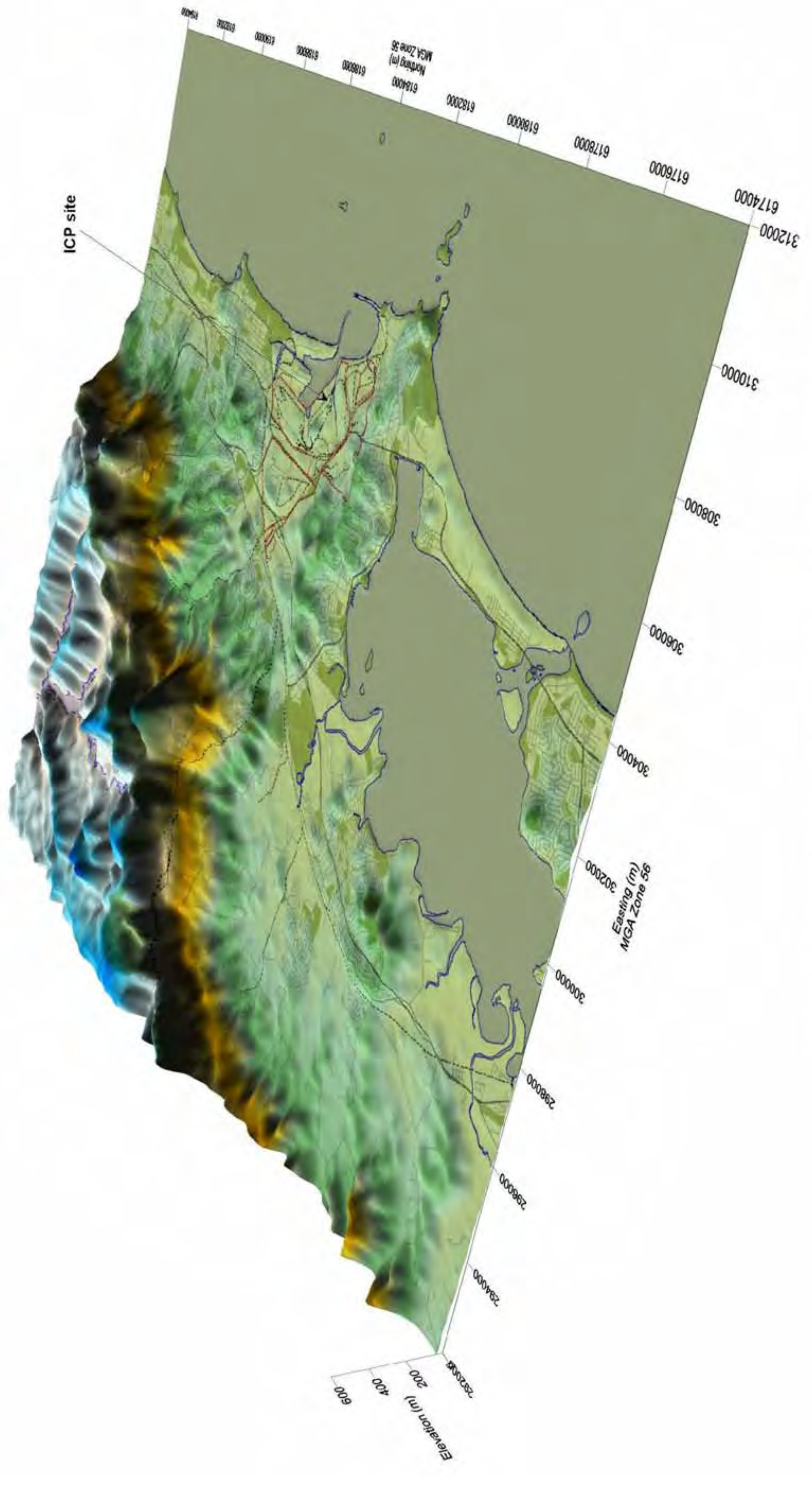
Source	Emission point ID	ID	Easting (MGA, m)	Northing (MGA, m)	Height (m)	Internal stack tip diameter (m)	Base elevation (m)	Temperature of emissions (K)	Emissions exit velocity (m/s)	Mass emission rate (g/s)		
										NO_X	PM_{10}	SO_2
ICP scenario 1: Maximum fuel case - 3 new boilers plus 25 Boiler, normal steam consumption												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	16.3	15.07	2.41	30.06
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	16.3	15.07	2.41	30.06
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	16.3	15.07	2.41	30.06
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	0.24	0.91	3.03
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	0.00	0.00	0.00
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	0.00	0.00	0.00
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	0.00	0.00	0.00
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	0.00	0.00	0.00
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	0.00	0.00	0.00
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	1.87	0.65	2.16
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	1.87	0.65	2.16
ICP scenario 2												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	12.68	9.52	1.97	18.64
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	12.68	9.52	1.97	18.64
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	12.68	9.52	1.97	18.64
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	0.24	0.91	3.03
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	0.00	0.00	0.00
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	0.00	0.00	0.00
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	0.00	0.00	0.00
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	0.00	0.00	0.00
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	0.00	0.00	0.00
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	0.00	0.00	0.00
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	0.00	0.00	0.00
ICP scenario 14												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	6.13	5.12	1.01	11.51
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	6.13	5.12	1.01	11.51
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	6.13	5.12	1.01	11.51
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	11.76	0.16	21.09
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	0.00	0.00	0.00
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	0.00	0.00	0.00

Source	Emission point ID	ID	Easting (MGA, m)	Northing (MGA, m)	Height (m)	Internal stack tip diameter (m)	Base elevation (m)	Temperature of emissions (K)	Emissions exit velocity (m/s)	Mass emission rate (g/s)		
										NO_X	PM_{10}	SO_2
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	0.00	0.00	0.00
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	0.00	0.00	0.00
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	0.00	0.00	0.00
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	0.00	0.00	0.00
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	0.00	0.00	0.00
ICP scenario 17												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	16.41	9.29	1.70	17.74
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	16.41	9.29	1.70	17.74
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	16.41	9.29	1.70	17.74
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	0.38	1.42	4.72
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	0.00	0.00	0.00
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	0.00	0.00	0.00
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	0.00	0.00	0.00
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	0.00	0.00	0.00
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	0.00	0.00	0.00
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	0.43	0.15	0.50
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	0.43	0.15	0.50
ICP scenario 28												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	14.18	9.89	2.22	19.49
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	14.18	9.89	2.22	19.49
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	14.18	9.89	2.22	19.49
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	0.38	1.42	4.72
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	0.00	0.00	0.00
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	0.00	0.00	0.00
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	0.00	0.00	0.00
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	0.00	0.00	0.00
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	0.00	0.00	0.00
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	1.14	0.32	1.06
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	1.14	0.32	1.06
ICP scenario 34												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	6	3.58	0.52	10.85
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	6	3.58	0.52	10.85
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	6	3.58	0.52	10.85
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	0.24	0.91	3.03

Source	Emission point ID	ID	Easting (MGA, m)	Northing (MGA, m)	Height (m)	Internal stack tip diameter (m)	Base elevation (m)	Temperature of emissions (K)	Emissions exit velocity (m/s)	Mass emission rate (g/s)		
										NO_X	PM_{10}	SO_2
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	1.62	0.29	0.05
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	1.62	0.29	0.05
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	1.62	0.29	0.05
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	6.62	0.18	23.62
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	6.62	0.18	23.62
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	5.38	1.87	6.21
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	5.38	1.87	6.21
ICP scenario 35												
ICP	Boiler 31 stack	ICP31	306298	6184371	64	2.7	15.2	397	15.51	11.17	1.97	18.64
	Boiler 32 stack	ICP32	306271	6184395	64	2.7	14.8	397	15.51	11.17	1.97	18.64
	Boiler 33 stack	ICP33	306257	6184408	64	2.7	14	397	15.51	11.17	1.97	18.64
Boiler 25	Boiler 25 stack	DP25	306046	6184566	63	2.59	12	423	14.8	0.24	0.91	3.03
LDG	No. 1 Vessel	no1v	305621	6184747	86	1.75	21.4	873	13.4	0.00	0.00	0.00
	No. 2 Vessel	no2v	305593	6184760	86	1.75	21	873	13.4	0.00	0.00	0.00
	No. 3 Vessel	no3v	305565	6184772	86	1.75	21	873	13.4	0.00	0.00	0.00
Flares	COG 1	cog1	305681	6183570	28.8	0.65	12.9	873	3.0	0.00	0.00	0.00
	COG 2	cog2	306192	6184159	36.6	1.07	10.5	873	3.0	0.00	0.00	0.00
	No. 6 BFG Bleeder	no6bf	306200	6184462	88.6	1.82	11.2	873	5.0	0.00	0.00	0.00
	No. 5 BFG Bleeder	no5bf	305934	6184602	83.9	0.91	15.7	873	5.0	0.00	0.00	0.00

FIGURES

Location of project area



Pseudo three-dimensional representation of the local terrain

Location of ICP site within Port Kembla Steelworks

FIGURE 3

Annual windroses for DECC monitoring sites for 1997 and 2005

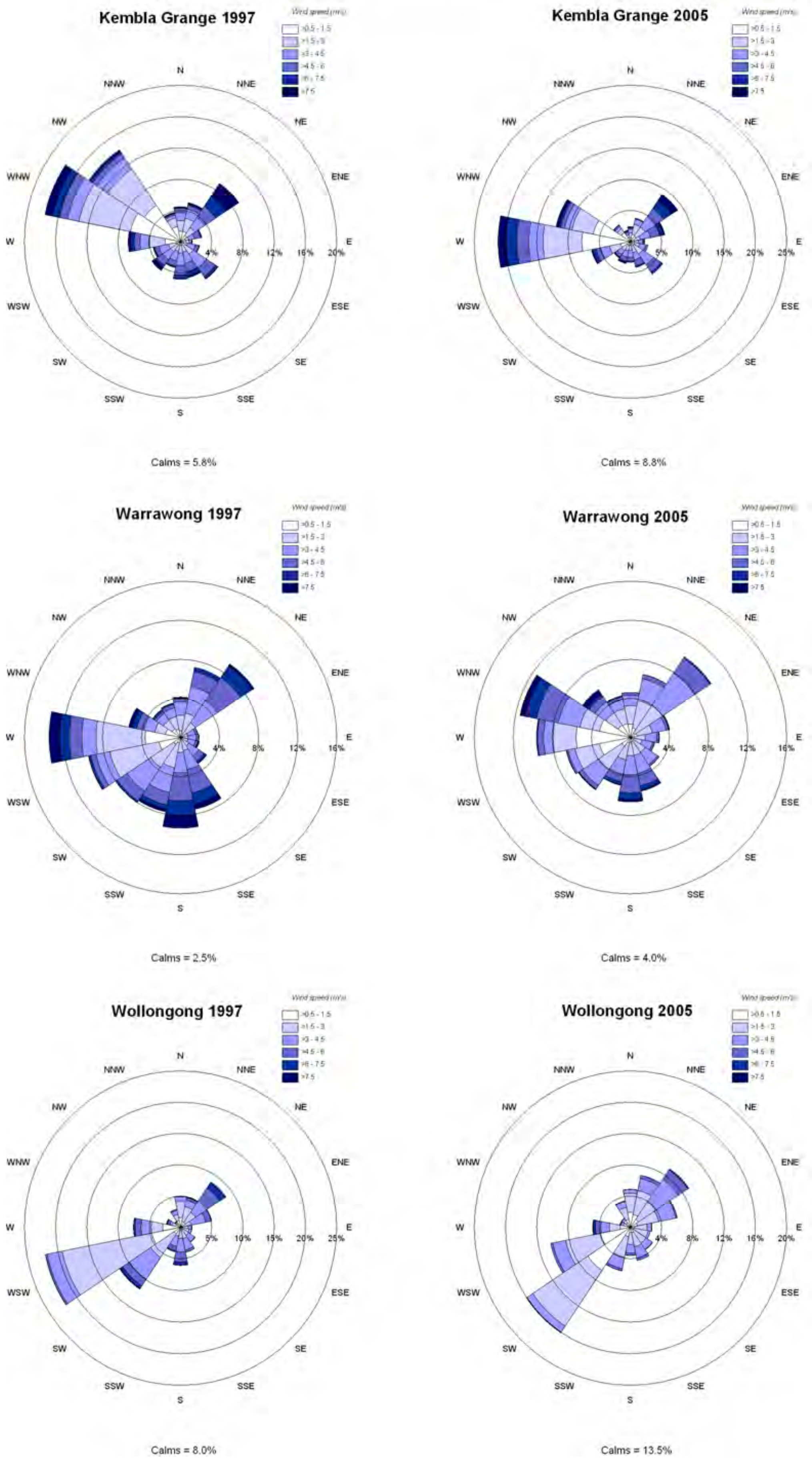
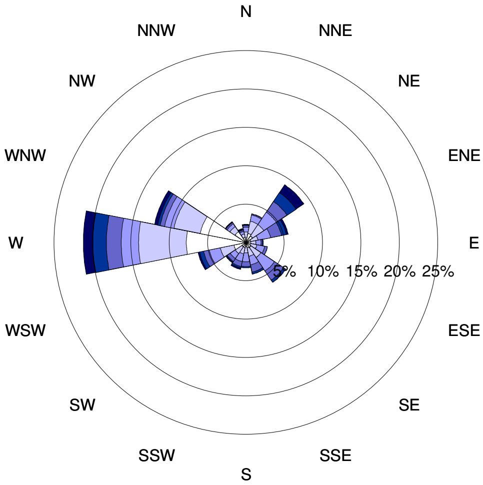
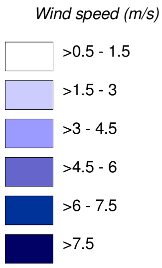


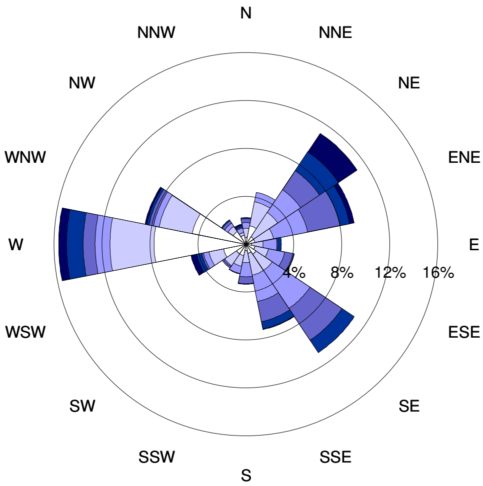
FIGURE 4

Annual and seasonal windroses for Kembla Grange (2005)

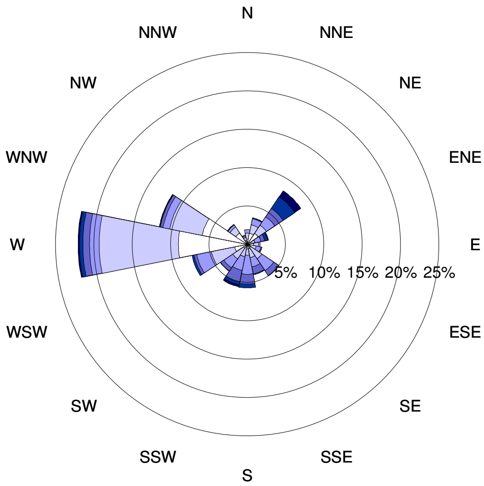


Annual
Calms = 8.8%

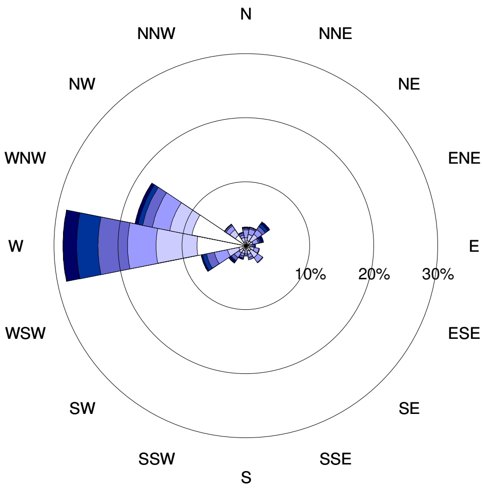




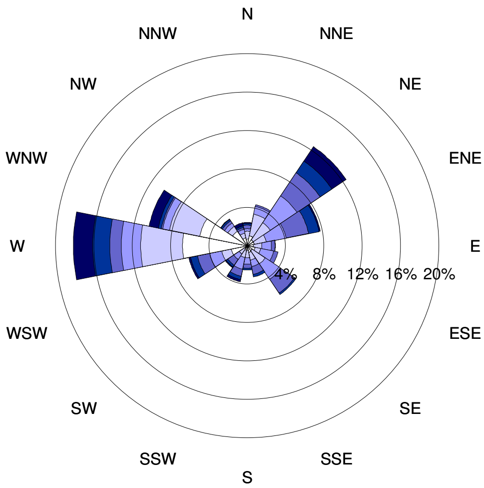
Summer
Calms = 6.6%



Autumn
Calms = 9.7%



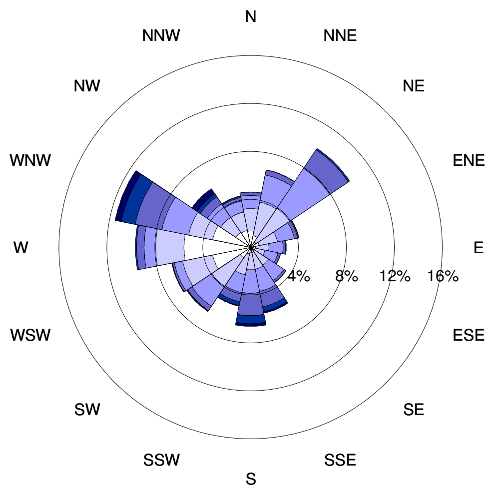
Winter
Calms = 10.9%



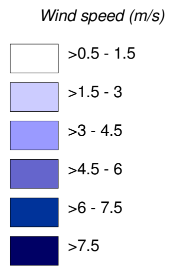
Spring
Calms = 7.8%

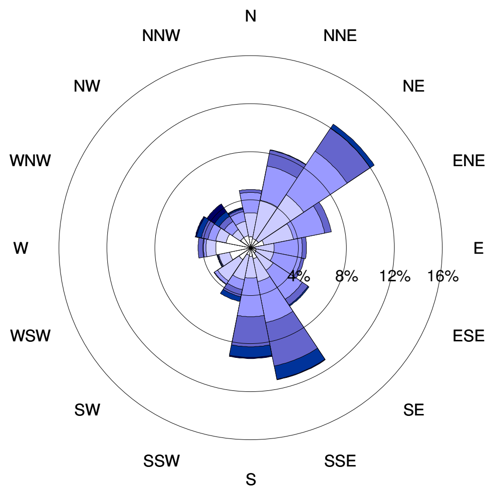
FIGURE 5

Annual and seasonal windroses for Warrawong (2005)

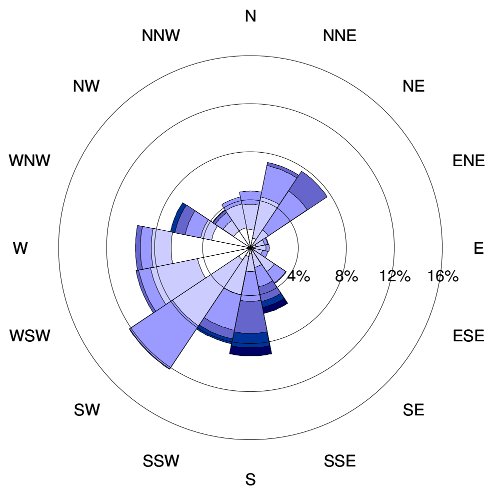


Annual
Calms = 4.0%

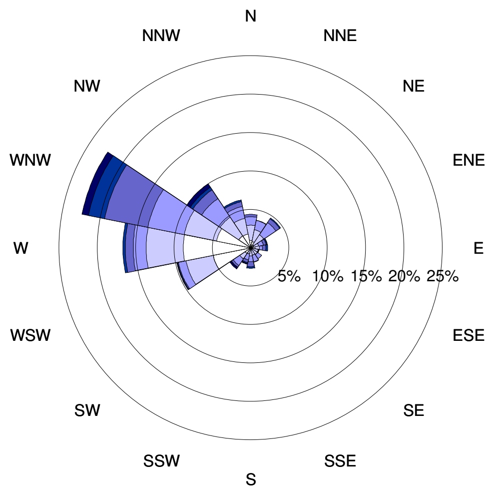




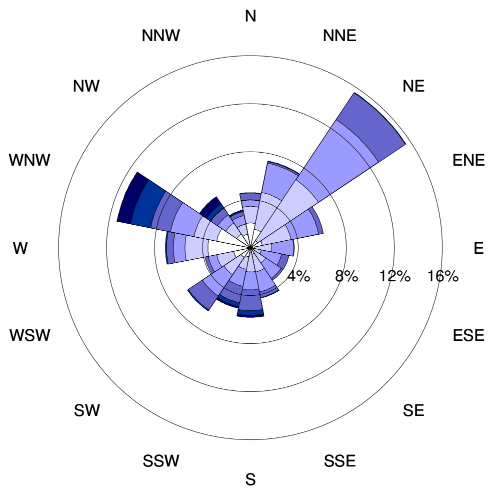
Summer
Calms = 4.0%



Autumn
Calms = 3.1%



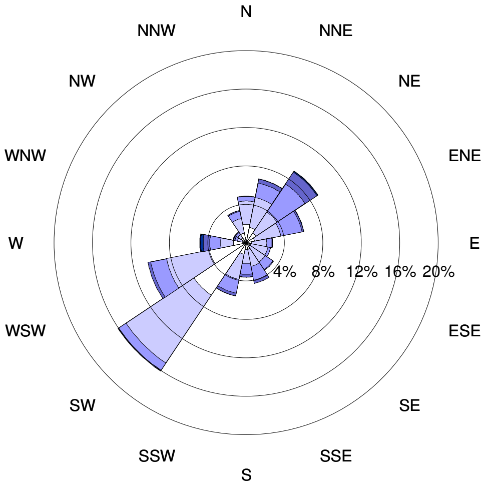
Winter
Calms = 4.7%



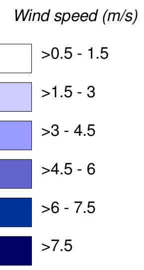
Spring
Calms = 3.9%

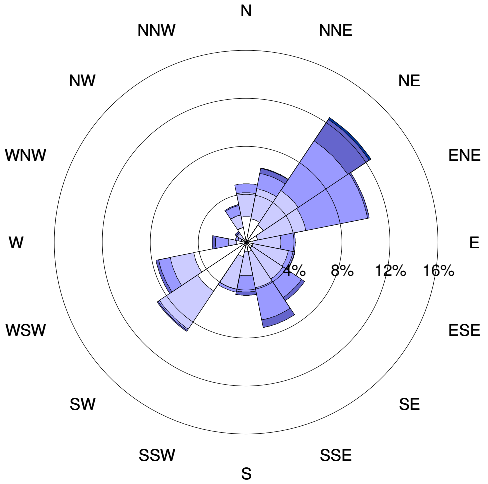
FIGURE 6

Annual and seasonal windroses for Wollongong (2005)

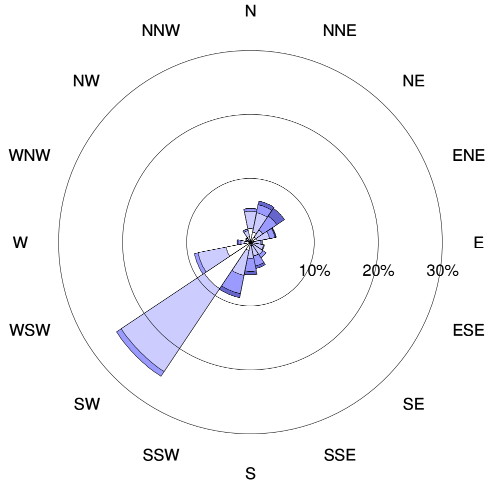


Annual
Calms = 13.5%

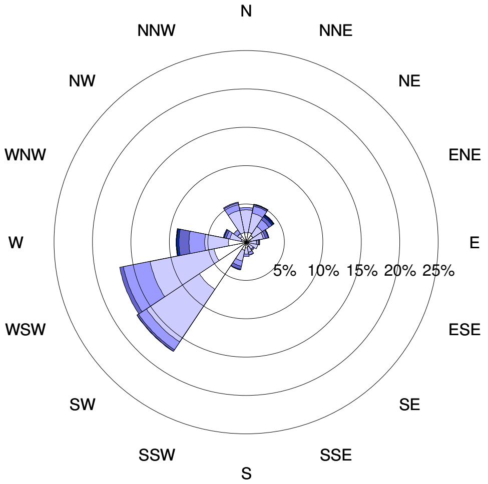




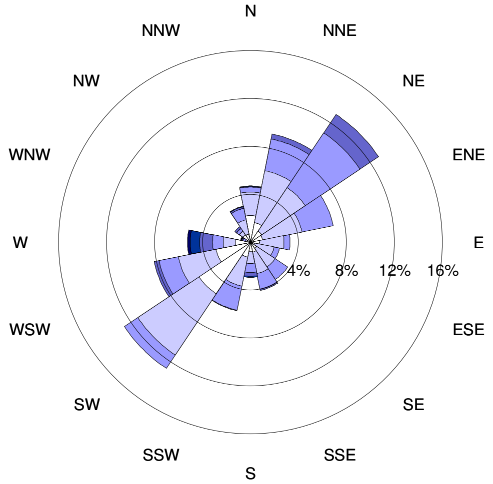
Summer
Calms = 11.2%



Autumn
Calms = 12.5%

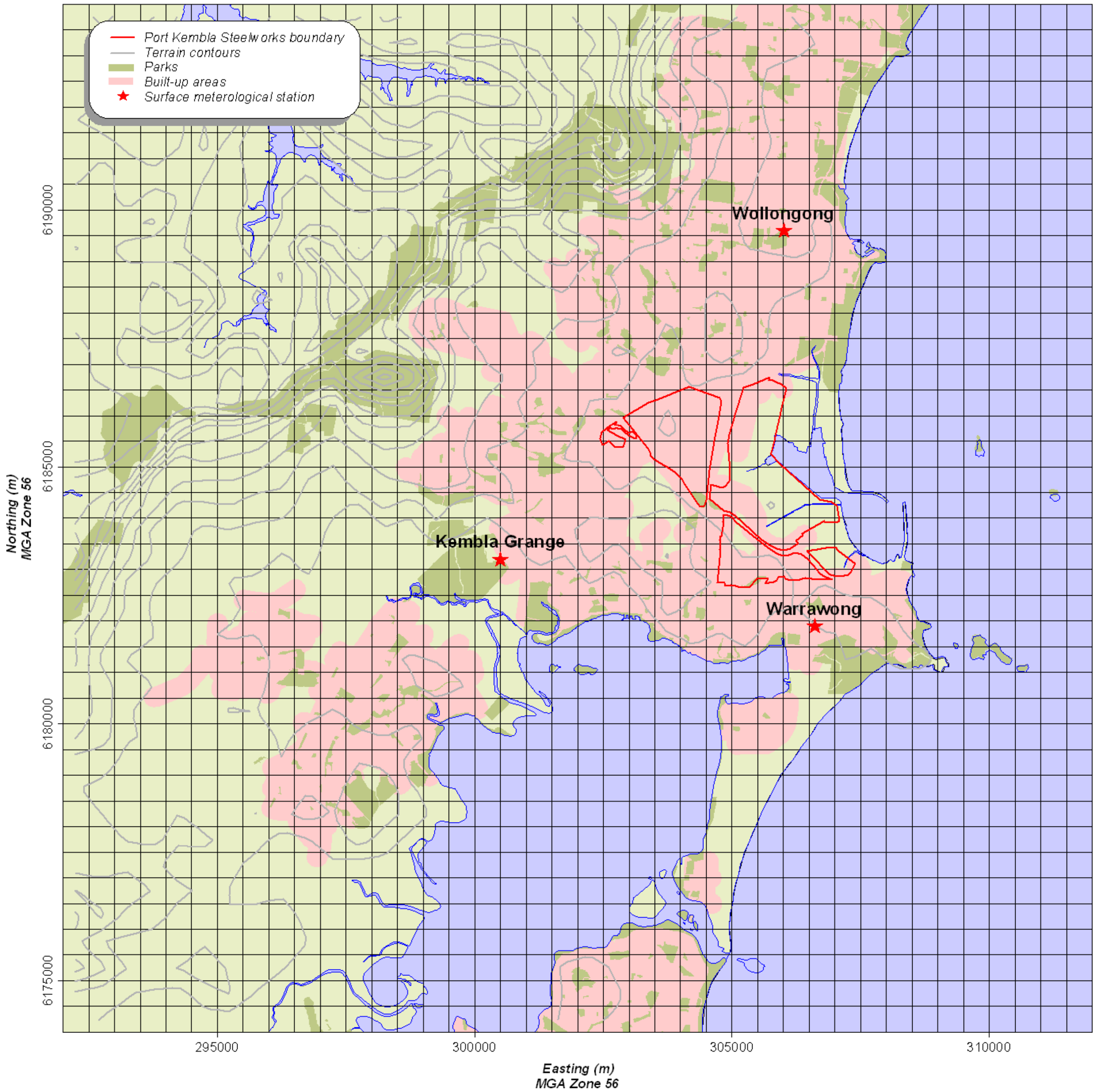


Winter
Calms = 17.8%

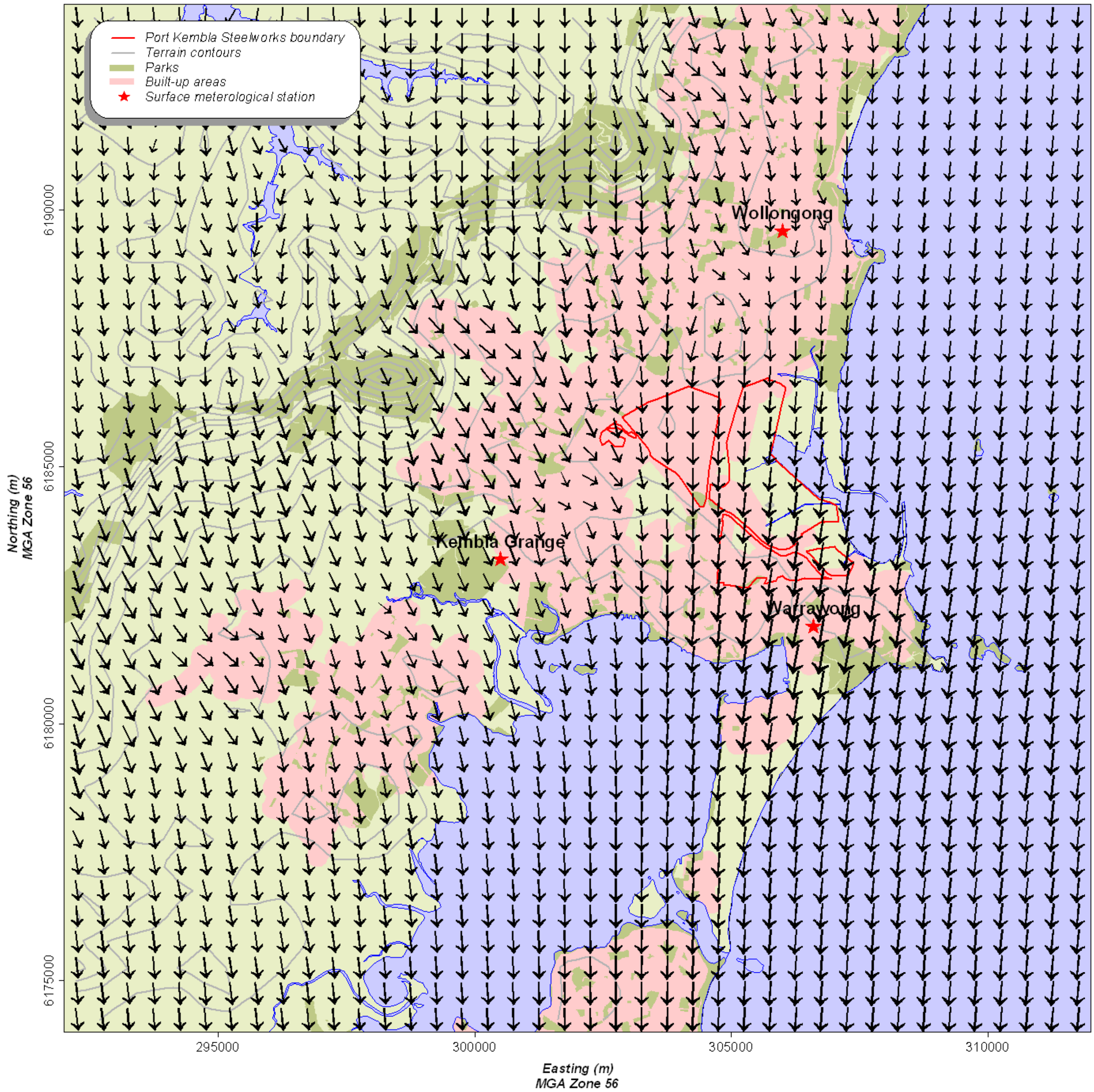


Spring
Calms = 12.3%

FIGURE 7



CALMET model grid, landuse, meteorological stations and terrain



Example of ground-level wind patterns as simulated by CALMET (2 July 2007 hour 1)

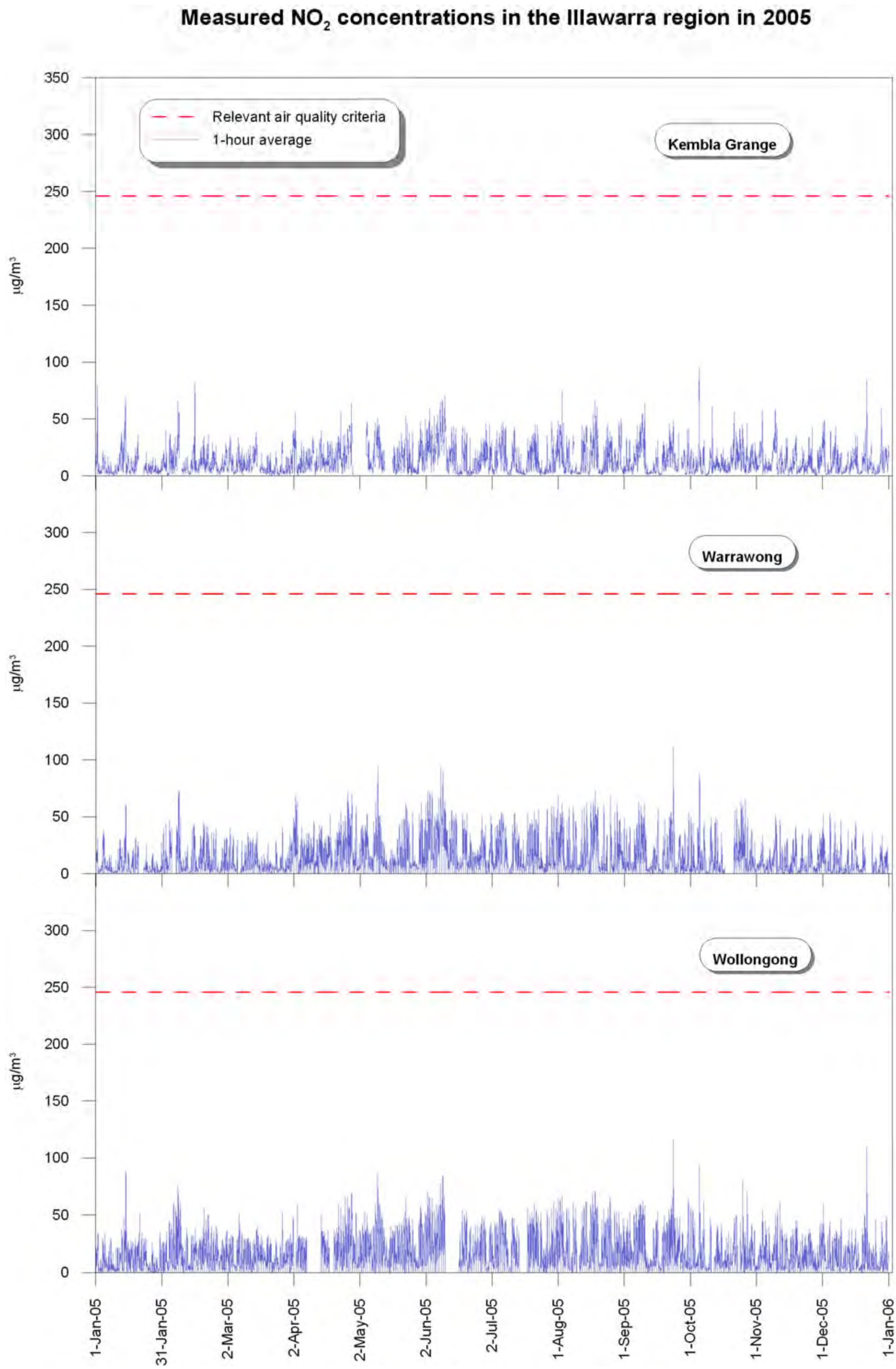
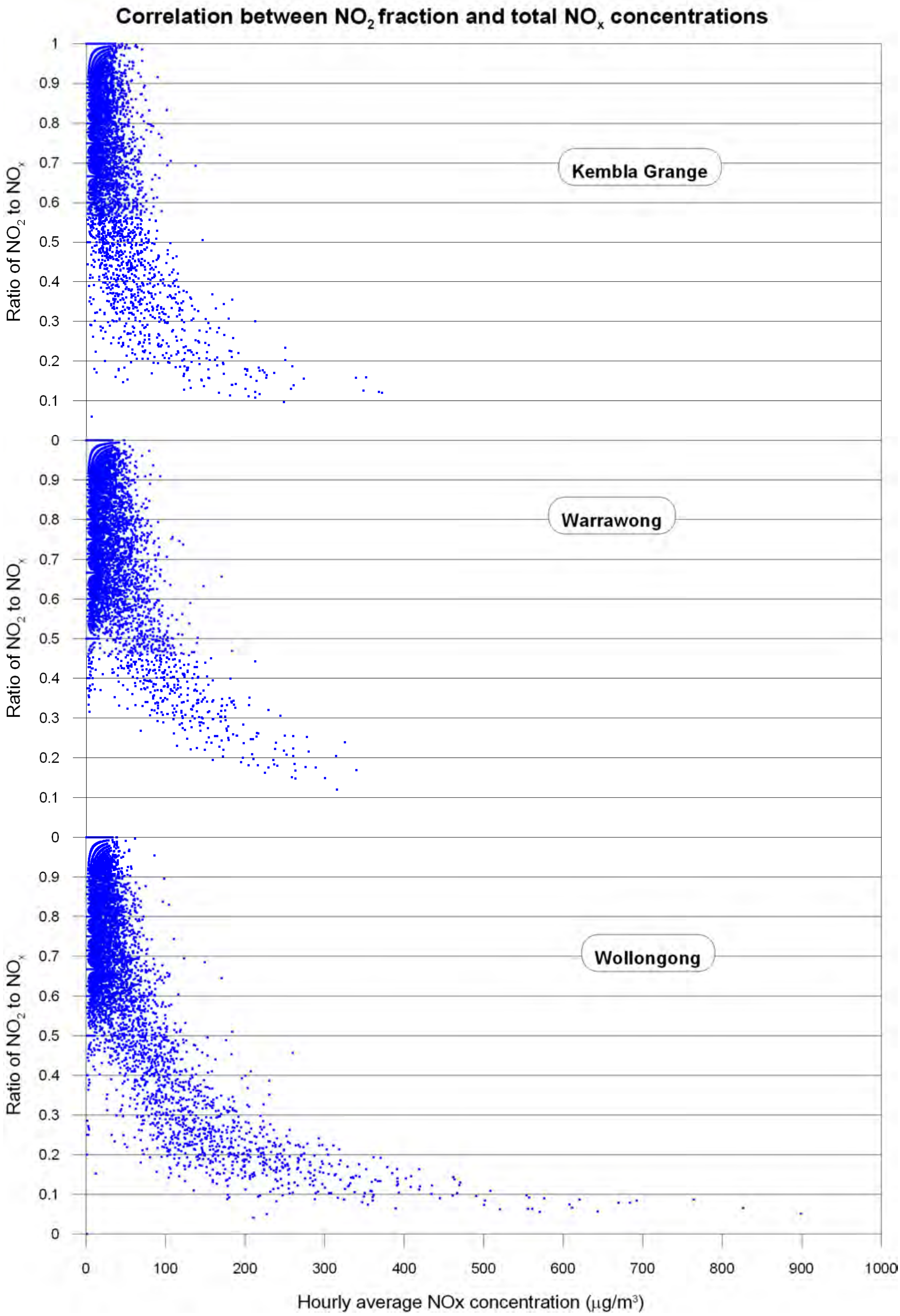

Measured NO_2 concentrations in the Illawarra region in 2005
Relevant air quality criteria
1-hour average
Kembla Grange
Warrawong
Wollongong
µg/m³
350
300
250
200
150
100
50
0
1-Jan-05
31-Jan-05
2-Mar-05
2-Apr-05
2-May-05
2-Jun-05
2-Jul-05
1-Aug-05
1-Sep-05
1-Oct-05
1-Nov-05
1-Dec-05
1-Jan-06

FIGURE 10



Correlation between NO2 fraction and total NOx concentrations
Kembla Grange
Warrawong
Wollongong
Ratio of NO2 to NOx
Hourly average NOx concentration (µg/m³)
0
100
200
300
400
500
600
700
800
900
1000
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

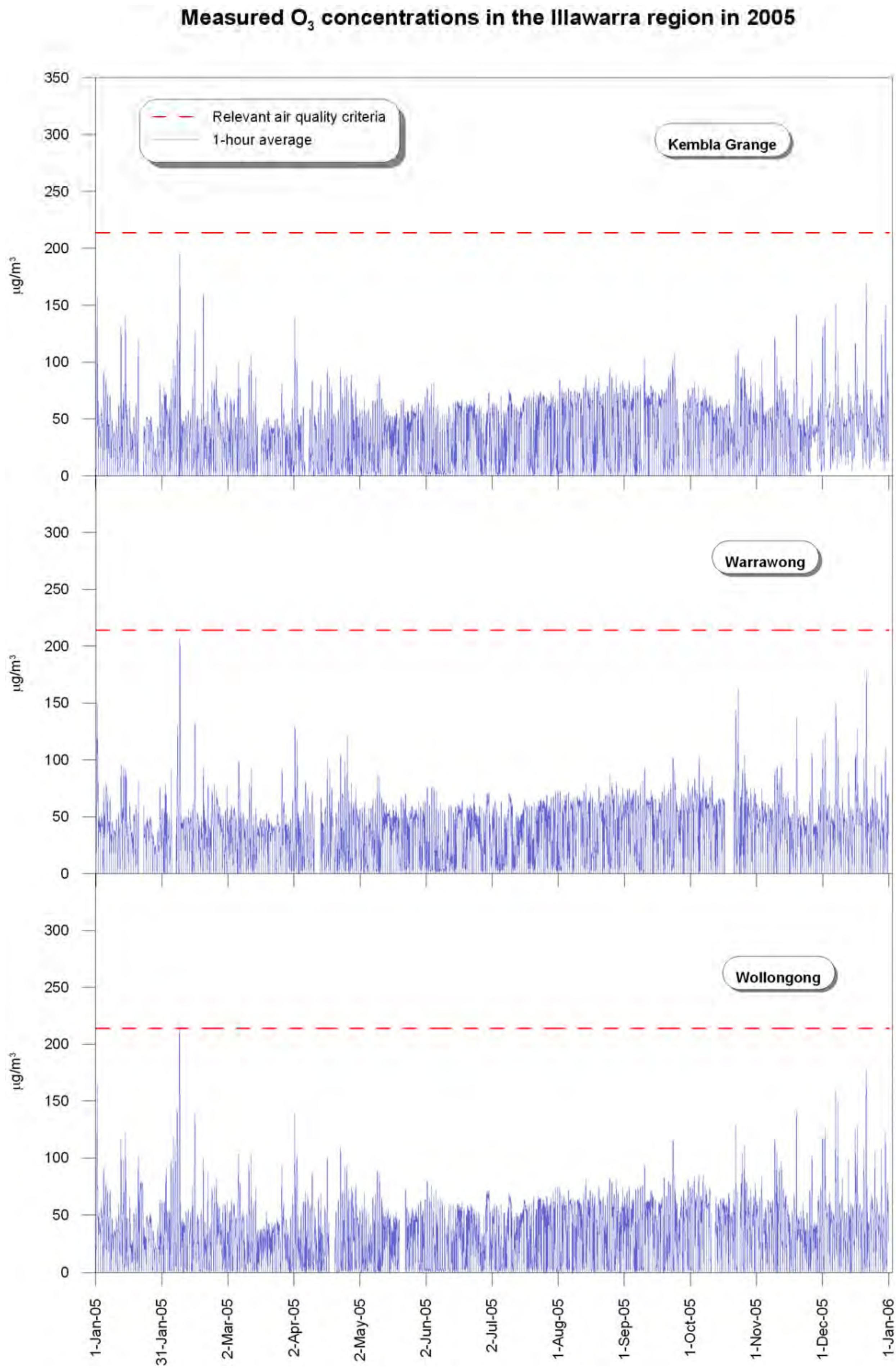

Measured O_3 concentrations in the Illawarra region in 2005
Relevant air quality criteria
1-hour average
Kembla Grange
Warrawong
Wollongong
µg/m³
350
300
250
200
150
100
50
0
1-Jan-05
31-Jan-05
2-Mar-05
2-Apr-05
2-May-05
2-Jun-05
2-Jul-05
1-Aug-05
1-Sep-05
1-Oct-05
1-Nov-05
1-Dec-05
1-Jan-06

FIGURE 12

Measured PM_{10} concentrations in the Illawarra region in 2005

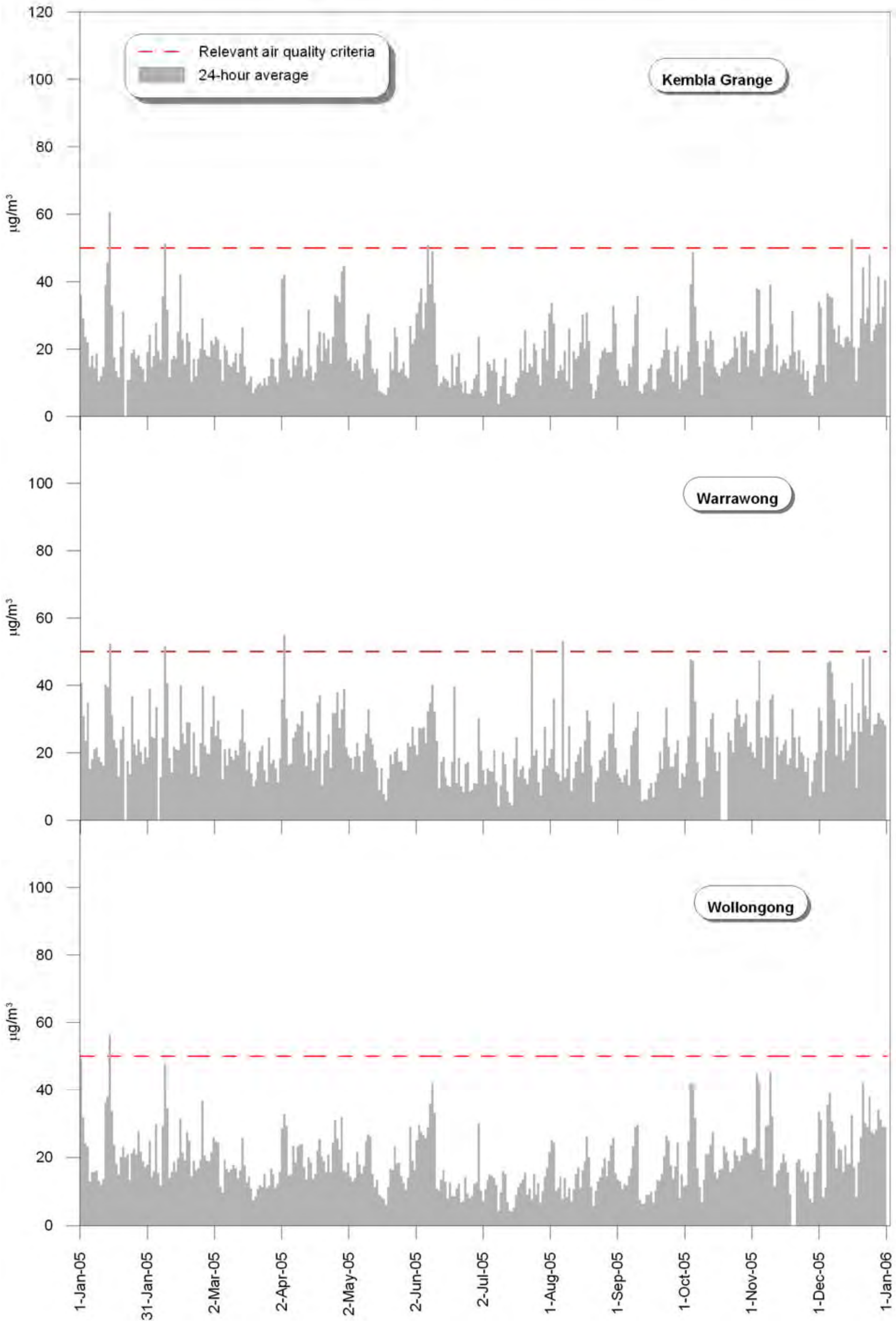
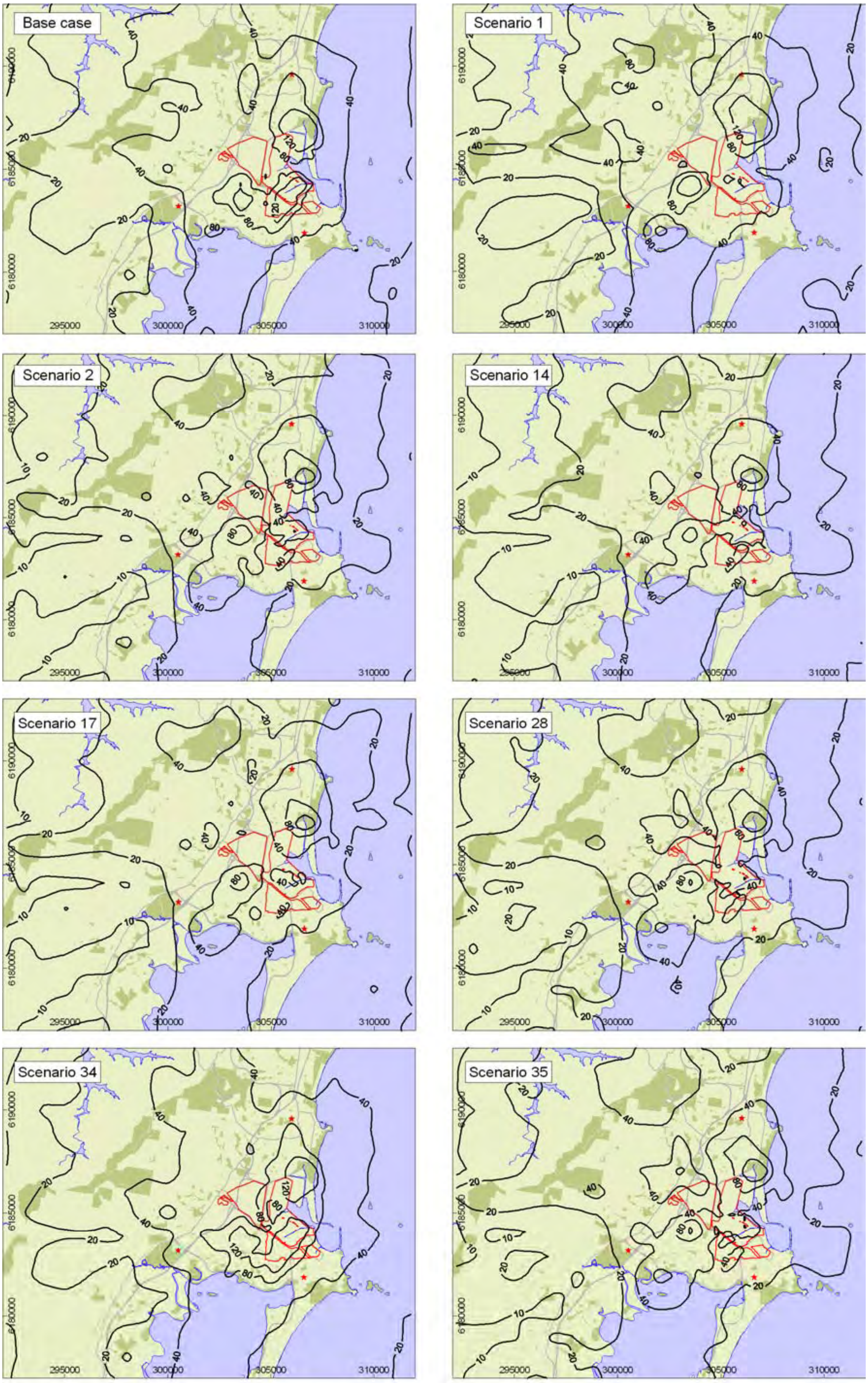
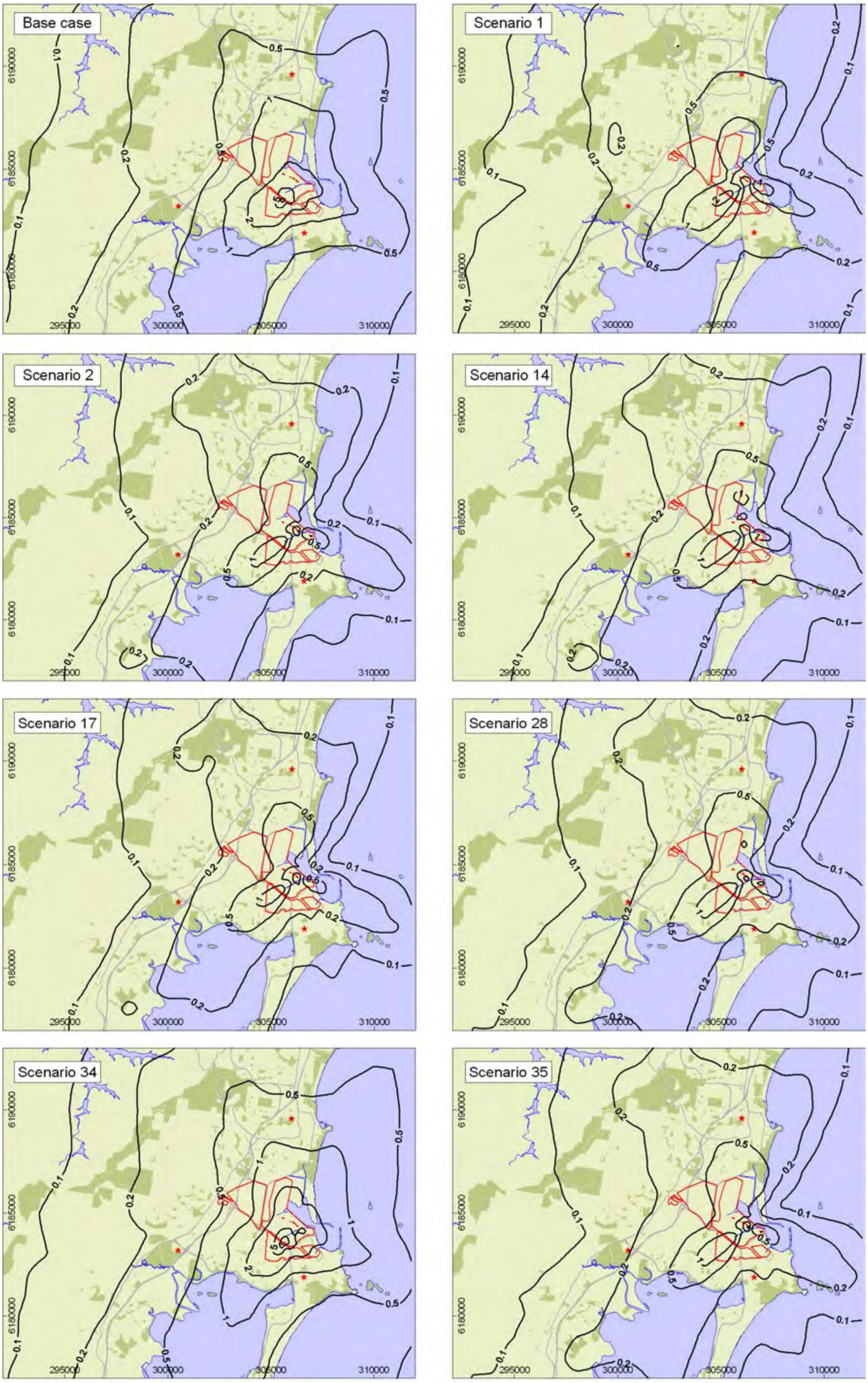


FIGURE 13



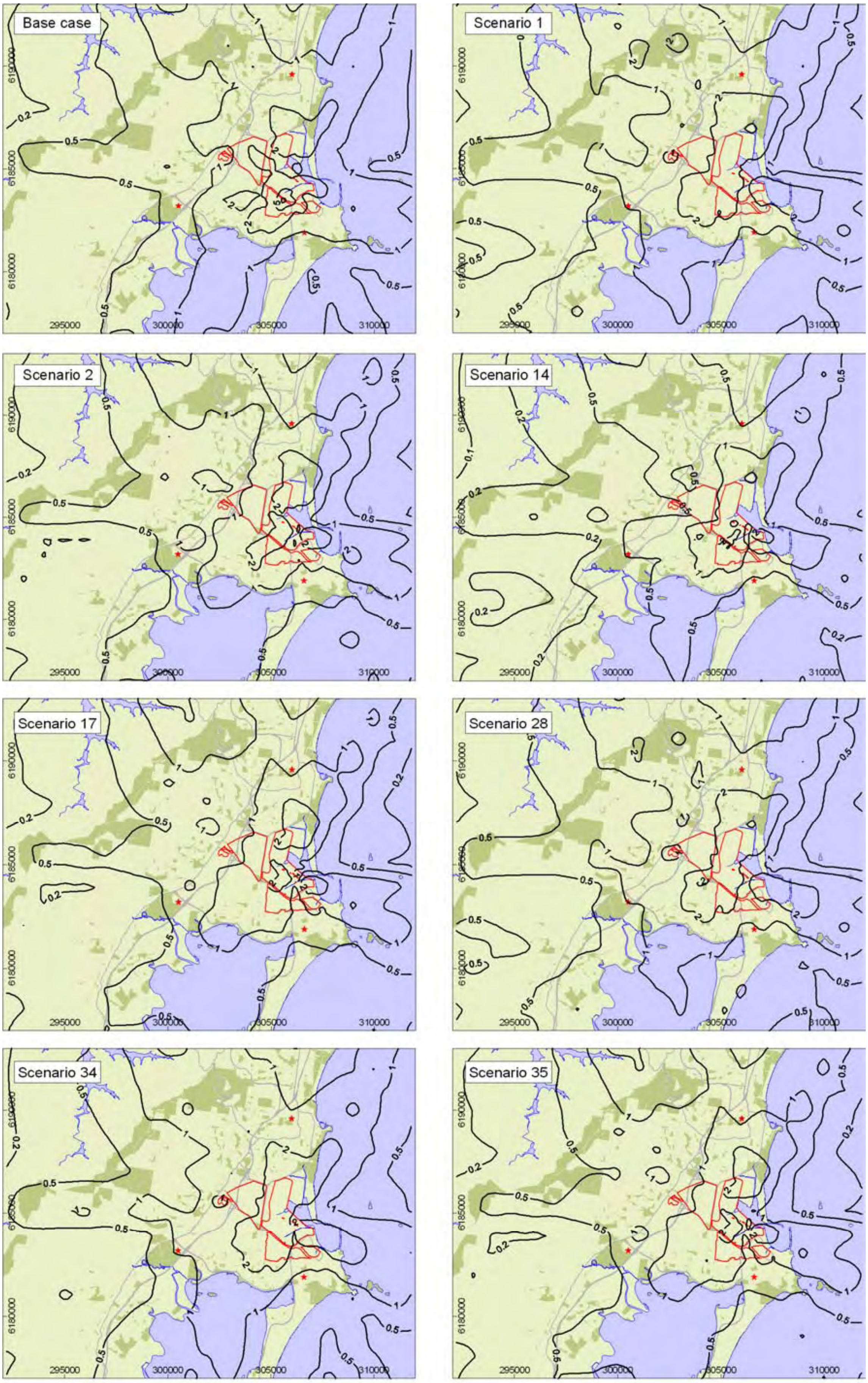
Predicted maximum 1-hour average NO_x concentrations at ground-level (μg/m^3)

FIGURE 14



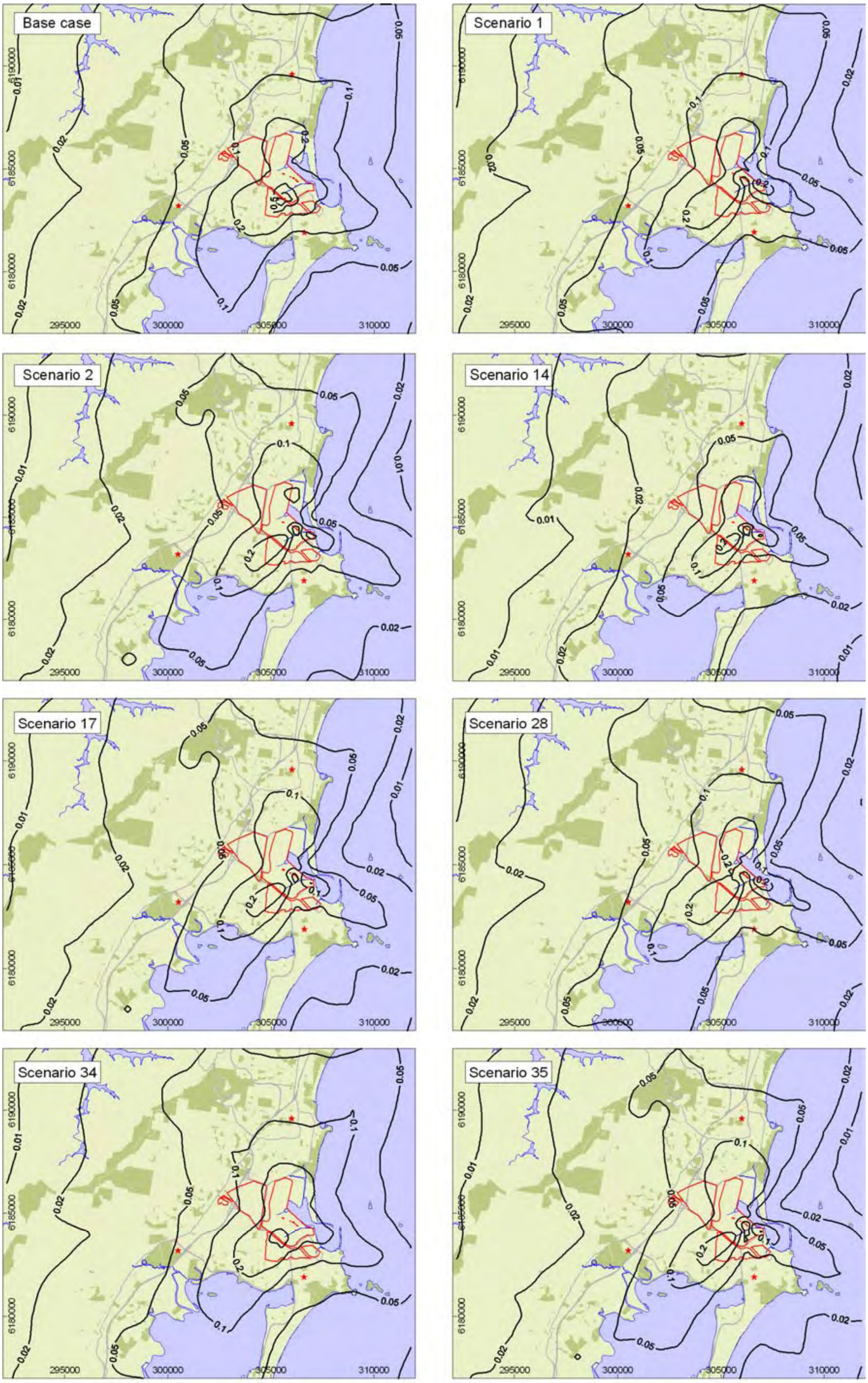
Predicted annual average NO_x concentrations at ground-level ($\mu g/m^3$)

FIGURE 15



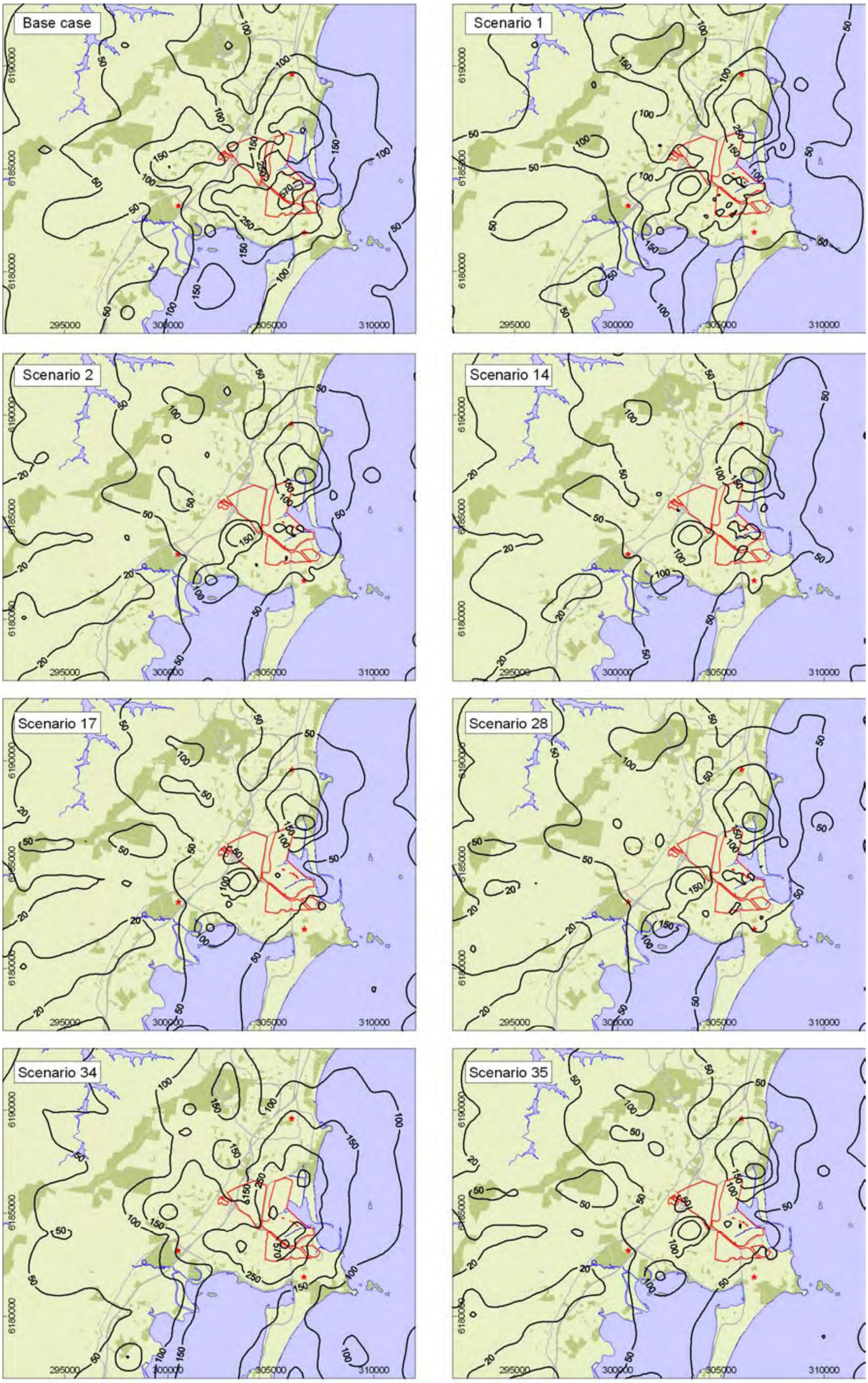
Predicted maximum 24-hour average PM_{10} concentrations at ground-level (µg/m^3)

FIGURE 16

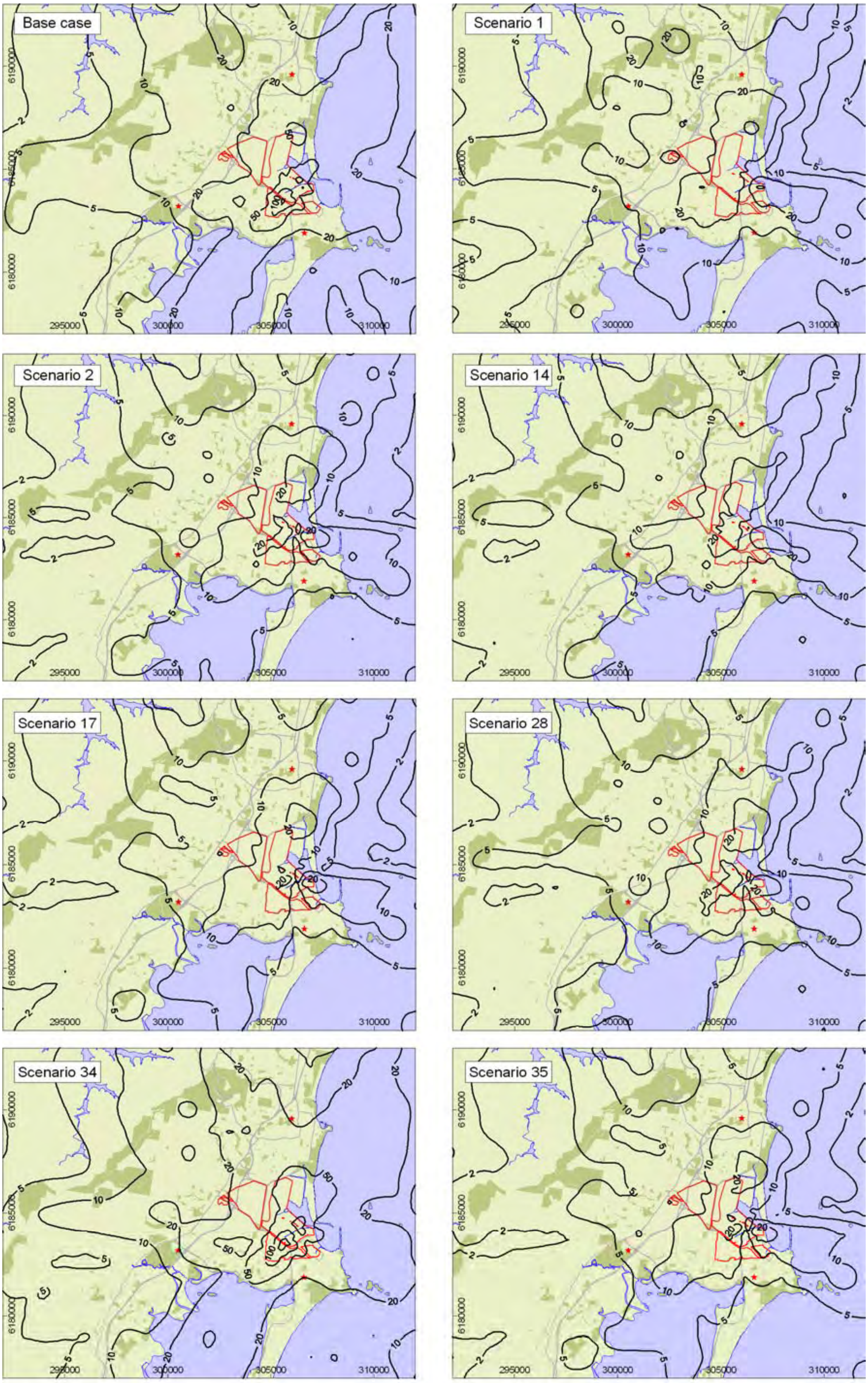


Predicted annual average PM_{10} concentrations at ground-level ($\mu g/m^3$)

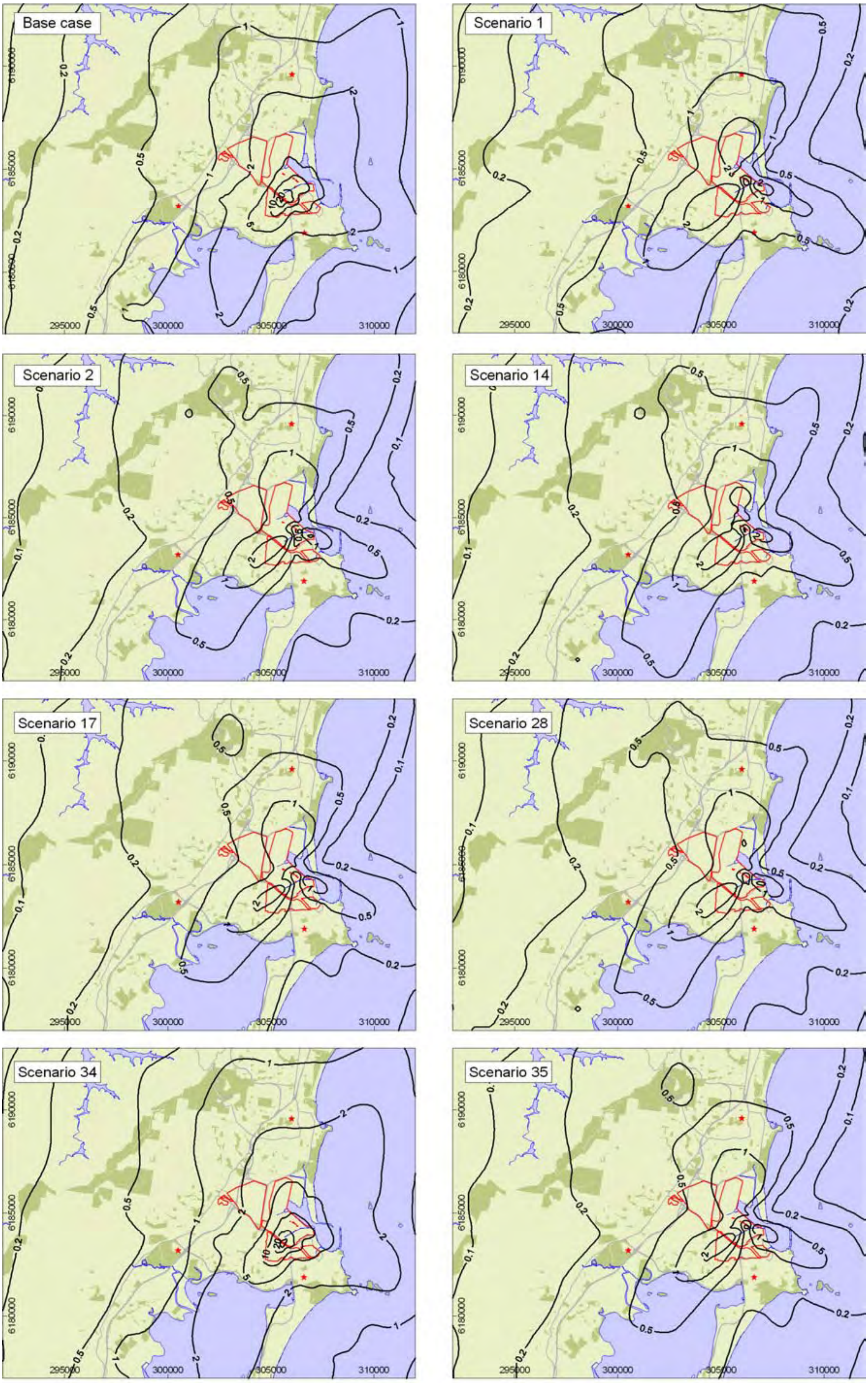
FIGURE 17



Predicted maximum 1-hour average SO_2 concentrations at ground-level (μg/m^3)



Predicted maximum 24-hour average SO_2 concentrations at ground-level ($\mu g/m^3$)



Predicted annual average SO_2 concentrations at ground-level (μg/m^3)

FIGURE 20