AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED COOLIMBA POWER PROJECT, WESTERN AUSTRALIA

Prepared for

AVIVA CORPORATION LIMITED

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Final Report

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Glossary

Term	***Definition***
CPP	Coolimba Power Project
%	percent
µg/m^3	micrograms per cubic metre
µm	microns
<	less than
>	greater than
^{0}C	degrees Celsius
BoM	Bureau of Meteorology
CO	Carbon monoxide
CO_2	Carbon dioxide
e.g.	for example
EPA	Environmental Protection Agency
EPP	Environmental Protection Policy
MW	Megawatt
GJ	Gigajoules
GJ/s	Gigajoules per second
i.e.	that is,
kL	kilolitres
kL/day	kilolitres per day
km	kilometre
m	metre
M	million
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
mg	milligram
Mt	million tonnes
Mtpa	million tonnes per annum
CO_2-e	Carbon dioxide equivalents
No.	Number
NO_x	Oxides of nitrogen
NO	Nitric oxide
NO_2	Nitrogen dioxide
NPI	National pollution inventory
PM	Particulate matter (fine dust)
$PM_{2.5}$ and PM_{10}	Particulate matter less than 2.5 or 10 microns, respectively
SO_2	sulphur dioxide
VOC	Volatile organic compounds
PAH	Polycyclic aromatic hydrocarbons
t	tonnes
tpa	tonnes per annum
tph	tonnes per hour
GWP	Global warming potential
GHG	Greenhouse gas

1. Introduction

Katestone Environmental has been commissioned by Aviva Corporation Limited (Aviva) to undertake an Air Quality Impact Assessment and a Health Risk Assessment in preparation of a Public Environmental Review (PER) for the proposed Coolimba Power Project (CPP). The CPP, to be constructed and operated in conjunction with the Central West Coal Project (CWCP), is located in the northern half of the SWIS power grid near Eneabba in Western Australia.

The proposed CPP consists of a diversified mix of power generating activities including a base load coal-fired plant and a gas-fired peak load plant. The CPP design includes:

- 450 MW coal-fired plant comprising 3 x 150 MW boiler units
- 330 MW gas-fired plant comprising 2 x 179 MW gas turbine units

The objective of the assessment is to investigate the potential for air emissions associated with the CPP to impact on the air quality in the region. Air emission sources include a single 130 metre stack for the coal-fired plant configured with one flue for each boiler unit and, two 40 metre stacks from each of the gas turbines in the gas-fired plant. The air quality impact assessment has focused on the key criteria air pollutants:

- Oxides of nitrogen (NO_X), as nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Particulate matter with aerodynamic diameter less than 10 microns (PM_{10})

In addition to the criteria pollutants a number of other pollutants, present in trace concentrations, have been investigated for a Health Risk Assessment for the coal-fired plant including:

- Carbon monoxide (CO)
- Volatile Organic Compounds (VOC)
- Fluoride (F)
- Polycyclic Aromatic Hydrocarbons (PAH)
- Persistent Organic Pollutants (Dioxins & Furans)
- Arsenic (As)
- Boron (B)
- Cadmium (Cd)
- Lead (Pb)
- Mercury (Hg)
- Selenium (Se)
- Chromium (Cr)
- Copper (Cu)
- Nickel (Ni)
- Vanadium (V)

An assessment has also been carried to predict the regional impacts of secondary air pollutants such as ozone (O_3), generated as a result of the photochemical oxidation of primary pollutants such as NO_X and VOCs.

Air emission control technology has been proposed for the coal-fired plant consisting of bag filters for control of particulate emissions and a limestone injection system for flue gas desulfurisation to control emissions of SO_2. Aviva propose to design the coal-fired plant to be ready to integrate carbon capture and storage capabilities when the technology becomes available in the future.

The air quality and health impact assessment has been carried out using the CSIRO's TAPM (The Air Pollution Model) dispersion model to predict ground-level concentrations of air contaminants emitted from the CPP stacks. The predicted ground-level concentrations have been compared with the relevant national and international goals and standards including:

- National Environment Protection (Ambient Air Quality) Measure (NEPM(Air))
- National Environment Protection (Air Toxics) Measure (NEPM(Air Toxics))
- National Health and Medical Research Council (NHMRC)
- World Health Organisation (WHO)
- European Union Directive 2004/107/EC
- Australia and New Zealand Environment and Conservation Council 1990 (ANZECC)

The methodology developed to carry out this assessment included a series of preliminary meteorological and dispersion modelling scenarios and validation reports, followed by a process of consultation with the Department of Environment and Conservation (DEC), Western Australia.

The preliminary modelling and validation work was conducted for a 400 MW coal-fired plant comprising two 200 MW boiler units and 330 MW gas-fired CPP scenario. During this preliminary validation assessment process, a review of the proposed design of the CPP coal-fired plant by the proponent led to its modification to three smaller capacity boiler units to increase the plant's overall capacity to 450 MW. Results of the preliminary modelling and power station configuration are presented in Appendix C.

The validation of the meteorological modelling comprised an analysis of several input variables including:

- The assimilation of local meteorological observations (at the surface)
- The use of different grid resolutions for the modelling domain, 1000 m and 300 m
- The adjustment of the TAPM default soil moisture parameter to reflect local monthly rainfall observations

Due to the limited availability of meteorological observations for the power station site, particularly at plume height, the validation assessment is not conclusive. The model used for this assessment, TAPM, has been validated in many situations and has been proven as a suitable model for modelling tall stack sources. However, there is insufficient information at the site to conclude that the local phenomena exclusive to the CPP site are adequately characterised by the model. Due to these uncertainties this assessment presents a range in possible impacts in general areas and has assessed compliance with the maximum exposure regardless of location.

The assessment presented in this report investigated the impact to air quality associated with various scenarios that incorporate:

- Dispersion modelling with and without the assimilation of local meteorological monitoring data
- The range in sulfur content of coal

- The efficiency of the flue-gas desulfurisation controls and its affect on SO_2 impacts

The combustion of carbon-based fuels such as coal and natural gas for electricity generation in the CPP will also produce a range of greenhouse gas emissions such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The greenhouse gas assessment has been conducted to determine the CPP's total contribution to emissions of greenhouse gases in terms of global warming potential. The method provides for the conversion of all greenhouse gases into equivalent units of carbon dioxide or CO_2-e. The report details the calculation of total CO_2 equivalents from emissions to air from the:

- Combustion of coal in the coal-fired boilers
- Combustion of gas in the gas turbines
- Energy associated with plant operations including –
    - Delivery of limestone to the plant for use in the limestone injection system for flue-gas desulfurisation
    - Coal stockpile management
    - Ash disposal and transport

The CPP's total greenhouse gas emissions are reported as a percentage of Australia's total assigned greenhouse gas emissions under the Kyoto Protocol, that is, 108% of Australia's estimated emissions for 1990.

This report provides details of the:

- CPP process and plant design
- Emission rates of air contaminants from the coal- and gas-fired plants
- Discussion of existing air quality and local meteorological conditions
- Methodology for, and validation of, the TAPM meteorological modelling
- Methodology for the TAPM dispersion modelling
- Methodology used in the stochastic modelling to determine the range in SO_2 emissions associated with the variability in coal sulfur content and non-operation of the flue gas desulfurisation system
- A discussion of background sources and method for including other industrial emissions
- Predicted impacts of NO_X, SO_2 and PM_{10} for various averaging periods
- Health risks associated with predicted ambient ground-level concentrations of air toxics emitted from the CPP
- Methodology and results of the photochemical smog modelling using TAPM GRS
- Methodology and assessment of the proposed CPP's contribution to Australia's greenhouse gas emissions

2. Project Infrastructure and Processes

The proposed CPP is to be located approximately 15 km south-southwest of the town of Eneabba in Western Australia. The project is vertically integrated to utilise the proven coal resource associated with the CWCP and the supply of natural gas from either the Parmelia Natural Gas Pipeline or the Dampier-Bunbury Natural Gas Pipeline. The CPP will generate and transmit electricity to the SWIS grid through the proposed Eneabba 330 kV substation along a 20 km long, 330 kV transmission line.

2.1 Coal-fired Power station

For the purpose of the EIS, the following design option was assessed for the operation of the base load coal-fired Power station:

- 450 MW coal-fired plant consisting of three coal-fired steam turbo alternators, each with a nominal output of 150 MW

Table 1 outlines the key characteristics of the Coal-fired Power station.

Table 1 Key characteristics of the Coal-fired Power station design

Element	Value
Net plant electrical output	450 MWe
Number of generating units	3
Nominal net unit output	150 MW
Net plant efficiency (HHV)	32.8%
Load profile	Base load
Main fuel	Coal from Central West Coal Project
Coal consumption	Approximately 2.3 Mtpa
Capacity factor	95%
Start up fuel	Natural gas
Condenser cooling	Water cooled (with possible hybrid optimisations)
Boiler type	Circulating fluidised bed
Emission controls	SO_2 - Flue gas desulfurisation, PM_{10} - Bag filters
Operating life of power station (excluding construction and closure activities)	Approximately 30 years
Note: Information provided by URS	

2.1.1 Coal Product Handling

Coal fuel will be crushed and screened to approximately 40 mm on the adjoining CWCP site, to meet Power station specifications. The product coal can then be stockpiled in the coal product stockpile area at the CWCP site or placed onto the conveyor system for delivery to the coal fuel bins at the Power station. A coal weigher and on-line coal analysis system will be located along this conveyor system for calculation of quantity and quality of coal delivered.

The Power station coal handling plant will comprise belt conveyors, magnetic separators, vibratory feeders, trippers, coal fuel bins and automatic sampling equipment. Sized product coal will be despatched from the coal fuel bins onto the rising transfer conveyor and dispensed into the boiler coal silos via the dual silo feed conveyors. The rising transfer conveyor will be fitted with a weigh-belt scale.

Potential fugitive dust emissions generated by the handling of coal are assessed as part of the CWCP PER.

2.1.2 Boiler, Steam Turbines and Fuel Preparation

The Circulating Fluidised Bed (CFB) boilers have been selected due to their superior sulfur minimisation technology. The desulfurisation process requires the addition of lime-sand to the boiler to convert the gaseous SO_2 to solid calcium sulphate ($CaSO_4$). It is anticipated that approximately 285,000 tonnes per annum (tpa) of lime-sand will be used in the process, with up to 24,000 tonnes stored on site to ensure sufficient supply.

The lime-sand/sorbent preparation will be carried out on-site, with processing equipment consisting of an air swept roller mill with fan, a cyclone collector and a crushed product storage bin. The sorbent feed system will consist of a day bin for storing lime-sand, followed by a rotary airlock feeder which drops the sorbent into a pneumatic conveying line to the boiler process.

The function of the Boiler Fuel Preparation Plant is to deliver appropriately sized fuel to the boiler furnace at a controlled, variable rate, to enable the boiler to deliver steam to satisfy the demand of the steam turbine for high pressure main steam and intermediate pressure reheated steam. The plant will include the coal handling plant, the boiler, coal silos, coal feeders, a rotary airlock valve, and a fuel chute or pipe leading to the lower combustor, where the coal will enter the boiler furnace and be burnt in suspension.

Natural gas or fuel oil will be used as an auxiliary fuel in the boiler process. The supply of natural gas for use in the gas-fired plant makes gas ideal as an auxiliary fuel. This fuel is required for the start up procedure of the boiler to raise the fluidised bed material to a temperature at which stable combustion may be maintained without further auxiliary heat input. At loads above 30% to 40% Boiler Maximum Continuous Rating (BMCR) the boiler furnace will provide stable operating conditions for coal combustion without the need for firing an auxiliary fuel.

The heat generated by the boiler is used to produce high pressure steam which is superheated (raised in temperature above saturation) and passed to a steam turbine. The steam turbine converts the thermal energy from the expansion of the steam into mechanical energy by the rotation of the steam turbine rotor to drive a generator to produce electricity. This power generation process is based on a conventional Rankine cycle steam plant (boiler and steam turbo alternator), which describes a closed loop thermodynamic cycle that uses a recirculating fluid (water/steam) that has energy added in the form of heat, and energy extracted in the form of work (electricity) from the expansion of steam and heat rejection to a waste heat sink. The Rankine cycle boiler and steam turbine system proposed for the CPP will incorporate new generation technology to make the Power station ready to adopt a carbon capture and storage capability when it becomes available in the future.

2.2 Gas-fired Power station

The design of the CPP includes a provision for the generation of electricity to meet peak demand when base load supply reaches capacity on the SWIS grid. This additional power supply will be provided by the proposed Gas-fired Power station that will make use of gas supplied from either the Dampier to Bunbury or Parmelia Natural Gas Pipelines. The Gas-fired Power station will comprise two 179 MW open cycle gas turbines. The system is ideally suited to this application where power generation is required to meet high demand for short duration operating periods. Additionally, plant start up times are also relatively short, typically less than fifteen minutes, in contrast to the start up times to reach full load for the coal-fired boilers of approximately 24 hours.

The open cycle gas turbines will be equipped with evaporative coolers to cool the incoming air, thereby improving performance during hot ambient conditions. It is anticipated that air cooling will be used to dissipate the relatively small gas turbine auxiliary load.

Table 2 outlines the key characteristics of the Gas-fired Power station.

Table 2 Key characteristics of the Gas-fired Power station design

Element	Value
Gas turbines electrical output	358 MW net
Number of gas turbine generating units	2
Nominal unit output	179 MW net
Net plant efficiency (HHV)	32.98 %
Load profile	Peaking load
Main fuel	Natural gas from Dampier to Bunbury or Parmelia Pipeline
Annual gas consumption	11 PJ
Capacity factor	25%

3. Emissions

This section outlines the emissions to air associated with the CPP and has been extracted from the report prepared by PB entitled *Coolimba Power Station Emissions Modelling Data January 2009*, presented in full in Appendix A. The references and assumptions for all the emission rate calculations are also presented in the PB report.

3.1 Coal-fired Power station

3.1.1 Source Characteristics and Emissions

The Coal-fired Power Station design comprises a single stack containing one flue for each of the three boiler units. Table 3 details the source characteristics for the Coal-fired Power Station, while the concentration and emission rate for NO_X, SO_2 and PM_{10} used in the dispersion modelling, are presented in Table 4. Emission rates for all trace elements and air toxics are presented in Table 5 for the maximum expected emission rate. Table 6 presents the speciation of total volatile organic compounds (VOCs) expected to be present in the power station emissions. The estimates are based on the US EPA emission factors (AP42) for coal fired power stations.

Table 3 Source characteristics and emission information for the 450 MW Coal-fired power station

Parameter	Units	Values
Net plant energy output	MWe	450
Net plant heat rate (HHV)	kJ/kWh	10,976
Stack location	m (AMG)	327955 (E), 6685106 (N)
Stack height	m	130
Stack top wind shield diameter	m	10
Number of flues	-	3
Stack top flue diameter (each flue)	m	3.45
Actual cross sectional area (each flue)	m^2	9.35
Effective cross sectional area (all flues combined)	m^2	28.04
Effective stack top flue diameter (all flues combined)	m	5.98
Exhaust gas temperature	^oC	130
Exhaust gas velocity	m/s	24.4
Actual volumetric flow rate	Am^3/s	684
Normalised volumetric flow rate at operating conditions (2.38% oxygen in exhaust gas)	Nm^3/s	465
Normalised volumetric flow rate at standard reference conditions (6% oxygen in exhaust gas, dry basis)	Nm^3/s	518

Table 4 Concentration and emission rate for oxides of nitrogen and sulfur dioxide for the Coal-fired Power station

Pollutant	Concentration (mg/Nm^3)	Emission rate (g/s)
Oxides of nitrogen (as NO_2)	448	208.32
Sulfur dioxide	1,100	511.50[1]
Particles as PM_{10}	45	20.9
[1]A constant SO_2 emission level of 511.5 g/s has been modelled to represent the 75th percentile emission level under normal operations.		

Table 5 Concentration and emission rate for trace elements and air toxics for the Coal-fired Power station

Parameter	Units	Emission concentration[1]
Volatile Organic Compounds [3]	mg/Nm^3	6.3
Fluoride [4]	mg/Nm^3	13.2
Polycyclic aromatic hydrocarbons [3]	µg/Nm^3	2.8
Total Polychlorinated dioxins [3]	µg/Nm^3	8.4 x10^{-5}
Total Polychlorinated furans [3]	µg/Nm^3	1.4 x10^{-4}
Arsenic [4]	µg/Nm^3	19.3
Boron [4]	µg/Nm^3	1127
Cadmium [4]	µg/Nm^3	3.7
Lead [4]	µg/Nm^3	4.9
Mercury [4]	µg/Nm^3	19.2
Selenium [4]	µg/Nm^3	128
Chromium [2,4]	µg/Nm^3	83
Copper [4]	µg/Nm^3	58.6
Nickel [4]	µg/Nm^3	
Vanadium [4]	µg/Nm^3	21.8

Note: [1] Emissions based on operating volume flow basis
[2] 0.5% of total Chromium is expected to be Chromium (VI) PB (2009)
[3] Based on NPI emission factors
[4] Based on coal analysis for Central West Coal Deposit and estimated penetration factors

Table 6 Speciation of Volatile Organic Compounds for the Coal-fired Power station based on AP42 emission factors

VOC speciation	AP42 emission factor (lb/ton)	% of total VOC	Emission concentration (mg/Nm^3)
1,1,1-Trichloroethane	2.00E-05	0.2%	1.37E-02
2,4-Dinitrotoluene	2.80E-07	0.0%	1.92E-04
2-Chloroacetophenone	7.00E-06	0.1%	4.81E-03
Acetaldehyde	5.70E-04	6.2%	3.92E-01
Acetophenone	1.50E-05	0.2%	1.03E-02
Acrolein	2.90E-04	3.2%	1.99E-01
Benzene	1.30E-03	14.2%	8.94E-01
Benzyl chloride	7.00E-04	7.6%	4.81E-01
Bis(2-ethylhexyl)phthalate (DEHP)	7.30E-05	0.8%	5.02E-02
Bromoform	3.90E-05	0.4%	2.68E-02
Carbon disulfide	1.30E-04	1.4%	8.94E-02
Chlorobenzene	2.20E-05	0.2%	1.51E-02
Chloroform	5.90E-05	0.6%	4.06E-02
Cumene	5.30E-06	0.1%	3.64E-03
Cyanide	2.50E-03	27.3%	1.72E+00
Dimethyl sulfate	4.80E-05	0.5%	3.30E-02
Ethyl benzene	9.40E-05	1.0%	6.46E-02
Ethyl chloride	4.20E-05	0.5%	2.89E-02

VOC speciation	AP42 emission factor (lb/ton)	% of total VOC	Emission concentration (mg/Nm^3)
Ethylene dibromide	1.20E-06	0.0%	8.25E-04
Ethylene dichloride	4.00E-05	0.4%	2.75E-02
Formaldehyde	2.40E-04	2.6%	1.65E-01
Hexane	6.70E-05	0.7%	4.61E-02
Isophorone	5.80E-04	6.3%	3.99E-01
Methyl bromide	1.60E-04	1.7%	1.10E-01
Methyl chloride	5.30E-04	5.8%	3.64E-01
Methyl ethyl ketone	3.90E-04	4.3%	2.68E-01
Methyl hydrazine	1.70E-04	1.9%	1.17E-01
Methyl methacrylate	2.00E-05	0.2%	1.37E-02
Methyl tert butyl ether	3.50E-05	0.4%	2.41E-02
Methylene chloride	2.90E-04	3.2%	1.99E-01
Phenol	1.60E-05	0.2%	1.10E-02
Propionaldehyde	3.80E-04	4.1%	2.61E-01
Styrene	2.50E-05	0.3%	1.72E-02
Tetrachloroethylene	4.30E-05	0.5%	2.96E-02
Toluene	2.40E-04	2.6%	1.65E-01
Vinyl acetate	7.60E-06	0.1%	5.22E-03
Xylenes	3.70E-05	0.4%	2.54E-02
Note: Source US EPA AP42 Chapter 1.1 Bituminous and Subbituminous Coal Combustion, 1998			

3.1.1.1 Sulfur Dioxide Emissions Variability

Sulfur dioxide emissions associated with the Coal-fired Power station have been estimated based on the use of CFB boilers to generate steam through coal combustion, and the sulfur content of the coal. When fuels containing sulfur are combusted, most of the sulfur is oxidised to gaseous SO_2, and is released to atmosphere via the stack.

The range of sulfur content in the coal to be received by the Coal-fired Power station has been determined to be in the range of 1.65 - 3.85%. Consequently, SO_2 emissions are expected to vary accordingly. Notwithstanding this variability, blending and mixing of the coal resources between the coal seams due to the mining sequence and coal stockpiling will have an effect of smoothing out the peaks in the sulfur content of the coal received by the Power station.

Table 7 presents the predicted range of variability in SO_2 emission rates due to variability in sulfur content of the coal fuel during normal operations, when the lime injection desulfurisation system is operating. A cumulative frequency distribution of in-stack SO_2 concentrations during normal operations is presented in Figure 1. Table 8 presents the predicted range of variability in SO_2 emission rates during non-normal operations, when the lime injection desulfurisation system is not operating. Non-normal operations are predicted to occur less than 1% of the year.

Table 7 Expected variability in fuel sulfur content, in order of increasing SO_2 emissions for normal operations

Percentage (%)	Cumulative Percentage (%)	SO_2 concentration (mg/Nm³) Normal operations	Emission Rate (g/s)
0.64	0.64	864	402
3.13	3.77	907	422
8.29	12.06	948	441
13.81	25.87	989	460
19.92	45.79	1,028	478
19.84	65.63	1,067	496
13.04	78.67	1,106	514
7.59	86.26	1,143	531
4.74	91.00	1,180	549
3.05	94.05	1,216	565
1.55	95.60	1,251	582
1.12	96.72	1,286	598
0.76	97.48	1,320	614
0.63	98.11	1,353	629
0.44	98.55	1,385	644
0.43	98.98	1,417	659
0.36	99.34	1,449	674
0.27	99.61	1,479	688
0.25	99.86	1,509	702
0.14	100.00	1,549	720

Table 8 Expected variability in fuel sulfur content, in order of increasing SO_2 emissions for non-normal operations for 1% scenario

Percentage (%)	Cumulative Percentage (%)	SO_2 Emissions (mg/Nm³) – Non-normal operations	Emission Rate (g/s)
0.12	0.120	6,465	3,006
0.54	0.660	7,302	3,395
0.28	0.940	8,252	3,837
0.041	0.981	9,669	4,496
0.015	0.996	11,086	5,155
0.004	1.000	12,162	5,655

3.1.2 Emissions Minimisation and Control

3.1.2.1 Oxides of Nitrogen

The selection of CFB boilers for the CPP is highly compatible with the Proponent's objective of minimising impacts to air quality as they generally produce less NO_X emissions than other conventional boiler types. Consequently, the NO_X emissions limit for the CPP has been set at 500 mg/Nm^3 in consideration of the following:

- Directive 2001/80/EC of the European Parliament and the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants has a current limit for large existing boilers (>500 MW thermal) of 500 mg/Nm^3

- A limit of 500 mg/Nm^3 is slightly more conservative than limits approved for other recent Coal-fired Power stations in Western Australia
- This limit is achievable with CFB boilers as they inherently produce lower NO_X levels than pulverised coal boilers due to the lower combustion temperatures involved

3.1.2.2 Sulfur Dioxide

The selection of CFB boilers also provides a means for the capture of SO_2 emissions in the boiler furnace during combustion and eliminates the need for separate flue gas desulfurisation technology in the flue gas exhaust stream.

For the CPP, control of SO_2 emissions will be achieved through the installation of a lime injection system. This system involves the injection of limestone, which consists of calcium carbonate and various impurities, into the CFB boiler furnace. This transforms the limestone in a process known as calcination, as follows:

$CaCO_3 \rightarrow CaO + CO_2$

The primary products formed in this process are solid CaO (lime) and gaseous CO_2. The CO_2 is released in the flue exhaust from the stack and is accounted for as a greenhouse gas emission in Section 10 of this report, while the CaO reacts with the gaseous SO_2 and O_2 to form solid calcium sulphate ($CaSO_4$), according to the following reaction:

$SO_2 + ½\ O_2 + CaO \rightarrow CaSO_4$

The solid calcium sulphate produced through the desulfurisation process is then removed from the flue gas along with the coal combustion ash.

Theoretically, the stoichiometric mole ratio of Calcium to Sulfur (Ca:S) in the desulfurisation process is 1:1. However, this is difficult to achieve in practical systems and is dependent on the:

- Sulfur content of the fuel (the higher the coal sulfur content, the lower the required Ca:S ratio for a given percentage SO_2 removal)
- Purity and reactivity of the limestone
- CFB boiler recycle rates (the greater the internal recycle rates within the CFB boiler, the greater the removal efficiency)

Consequently, the SO_2 removal efficiency for the CFB boilers, to be used for the estimation of SO_2 emission rates for use in the dispersion modelling, has been estimated to be between 85 – 87.7% across the full coal sulfur content range. This assumes that limestone will be injected at a Ca:S ratio of 1.8. More details regarding the desulphurisation process are presented in Appendix A.

3.1.2.3 Particulate Matter as PM_{10}

The preferred technology for the control of particulate matter such as fly ash from the CFB boilers is likely to be bag filters. Bag filters operate by passing dust-laden gases through the semi-porous medium of woven or felted cloth making up the individual filter bags.

An emissions limit for PM_{10} of 50 mg/Nm^3 (6% O_2, dry basis) has been set for the CPP in consideration of the following factors:

- Directive 2001/80/EC of the European Parliament and the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants has a current limit for large existing boilers (>500 MW thermal) of 50 mg/Nm^3
- A limit of 50 mg/Nm^3 is consistent with approved limits for other recent Coal-fired Power stations in Western Australia
- This limit is achievable with standard particulate control equipment

3.2 Gas-fired Power station

3.2.1 Source Characteristics and Emissions

The air emission source characteristics for the Gas-fired Power station used in the dispersion modelling are presented in Table 9. The technical specifications are based on two Alstom 13E2 Gas Turbines operating at Maximum Continuous Rating (MCR), ISO conditions.

Table 9 Source characteristics for the Gas-fired Power station based on a single gas turbine unit

Parameter	Unit	Value
Net plant energy output (per gas turbine)	MWe	179,900
Net plant heat rate (HHV) (per gas turbine)	kJ/kWh	10,829
Number of stacks (per gas turbine)	-	1
Stack height	m	35
Stack diameter	m	6.5
Exhaust gas temperature	^{o}C	510
Exhaust gas velocity	m/s	38
Actual volumetric flow rate (per gas turbine)	Am^3/s	1,264
Normalised volumetric flow rate(per gas turbine)	Nm^3/s	440.78
Note: CPP Gas-fired plant will comprise two gas turbine units		

Table 10 Concentration and emission rate for oxides of nitrogen and carbon monoxide for the Gas-fired Power station

Parameter	Concentration (mg/Nm³)	Emission rate (g/s)
Oxides of nitrogen[1]	25	22.62
Carbon monoxide[1]	10	5.51
[1]Dry gas basis, 0^{o}C, 101.3 kPa, 15% O_2.		

3.3 Start Up, Shut Down and Other Short-term Emission Releases

3.3.1 Diesel Generators

The diesel generator's function is to provide emergency electrical power for station shut down purposes should the normal source of auxiliary power be lost. The generator not be large enough to provide the auxiliary power required for 'Black Start' situations. The diesel generators are expected to be used intermittently and for short durations and consequently their air emissions have not been modelled for this assessment.

Air emissions associated with diesel generators include NO_X, SO_2 (depending on the sulphur content of the fuel), PM_{10} and VOCs. Due to the minimal use of the generators, their total emissions to air are expected to be insignificant in relation to the emissions from the coal-fired plant.

4. Air Quality Criteria

4.1 Human Health

The Department of Environment and Conservation (DEC) in Western Australia has, where applicable, adopted the National Environment Protection Council's (NEPC) standards for air quality. The NEPC provide monitoring requirements and standards for criteria air pollutants and air toxics in the following two documents:

- National Environment Protection (Ambient Air Quality) Measure (NEPM(Air))
- National Environment Protection (Air Toxics) Measure (Air Toxics NEPM)

The DEC's position has been articulated in the following excerpt obtained from their website (DoE, 2004):

> *Ambient Air Quality Guidelines*
> *Ambient air quality guidelines can be used to guide the assessment of impact from new proposals as well as for the management of existing air quality when standards have not been developed. An ambient air quality guideline value is a level (concentration) of air pollutant which it is desirable not to exceed in order to ensure that human health, amenity and the environment are protected. Compliance with a guideline value may or may not be required under legislation, depending on site specific circumstances. Ambient air quality guideline values are intended to be met at all sensitive receptors (both environmental or human). Modelling (in accordance with DEP Modelling Guidelines) may be used to demonstrate that ambient guidelines can be achieved.*
>
> *The Current Situation*
> *The WA DEP and EPA routinely adopt (where necessary) ambient air quality guideline values in the assessment of new proposals, and in the management of both local and regional ambient air quality. As a matter of policy, the EPA and DEP have now adopted the NEPM standards for ambient air quality. For all other air contaminants, the EPA and DEP have routinely adopted and/or adapted guideline values from other jurisdictions where available.*
>
> *An Interim Approach*
> *As of December 2000, the DEP has articulated an interim approach to adopting ambient air quality guideline values. This interim approach is to adopt the NEPM standards for Ambient Air Quality. In the absence of a NEPM standard, the DEP will adopt the WHO Guidelines for Air Quality (2000), with appropriate amendments to suit the WA context; and in the absence of a NEPM standard or a WHO guideline, the DEP will adopt criteria from another jurisdiction (once it has been assessed and determined to be applicable to the WA context).*
>
> *The interim approach has been put in place temporarily for reasons of expediency and to provide industry, community and the government with an appropriate alternative in the short term. It is intended that the interim approach will continue in practice until such time as the final WA ambient air quality guideline values are available which will follow a process of stakeholder consultation.*

The NEPM(Air) provides standards for air pollutants associated with the CPP including nitrogen dioxide, sulfur dioxide, photochemical oxidants (as ozone), carbon monoxide and particles as PM_{10}. Notwithstanding this, several air toxics associated with emissions from the CPP that are not addressed in the NEPM(Air), are addressed in the Air Toxics NEPM including Benzo(a)pyrene as a marker for PAHs and Benzene. Air quality standards for air pollutants not covered in either of these documents have been gathered from other sources including the World Health Organisation guidelines (WHO), National Health and Medical Research Council (NHMRC) and European Union Directive.

Ozone is not emitted by the power station but is formed through a complex series of reactions involving the action of sunlight on nitrogen dioxide released from the power station. Ozone is called a secondary pollutant and has been assessed in this report.

The NEPM standards were developed by the NEPC with agreement from all state governments. Compliance with the NEPM standards is assessed by each state jurisdiction through ambient air quality monitoring undertaken at locations that are representative of large urban populations. The WA DEC and Health Department of WA has yet to finalise a state specific environmental protection policy for ambient air quality and consequently the NEPM(Air) standards have been applied for the assessment of impacts to air quality from the CPP.

A summary of the NEPM(Air) standards is presented in Table 11.

Table 11 National Environment Protection (Ambient Air Quality) Measure, summary of current standards and goals

Pollutant	Averaging period	Standard maximum concentration	Goal within 10 year Maximum allowable exceedences
Sulfur dioxide	1 hour 1 day 1 year	0.20 ppm (570 µg/m³) 0.08 ppm (230 µg/m³) 0.02 ppm (60 µg/m³)	1 day a year 1 day a year none
Nitrogen dioxide	1 hour 1 year	0.12 ppm (246 µg/m³) 0.03 ppm (62 µg/m³)	1 day a year none
Particles as PM_{10}	1 day	50 µg/m³	5 days a year
Photochemical oxidants (as ozone)	1 hour 4 hour	0.10 ppm (214 µg/m³) 0.08 ppm (170 µg/m³)	1 day a year 1 day a year
Carbon monoxide	8 hour	9.0 ppm (11,250 µg/m³)	1 day a year
Lead	1 year	0.5 µg/m³	none

Guidelines and standards for other metals and air toxics not contained within the NEPM(Air) are presented in Table 12 and Texas Commission on Environmental Quality toxicology Section list of Effects Screening Levels (short term and long term) for the speciated VOCs are presented in Table 13.

Table 12 Summary of standards and guidelines for air toxics and metals

Pollutant	Averaging period	Standard or guideline	Comment/source
Arsenic	Annual	0.006 µg/m³	EU Directive
Benzene	1 hour Annual	29 µg/m³ 0.003 ppm	DECC NEPC(2004)
Cadmium	Annual	0.005 µg/m³	WHO (2000)
Copper	1 hour Annual	10 µg/m³ 1 µg/m³	TCEQ
Nickel	Annual	0.02 µg/m³	EU Directive
Mercury	Annual	1 µg/m³	WHO (2000)
PAH (as a marker for BaP)	Annual	0.0003 µg/m³	NEPC(2004)
Selenium	1 hour Annual	2 µg/m³ 0.2 µg/m³	TCEQ
Vanadium	24 hour	1	WHO (2000)

Table 13 Summary of TCEQ Effects Screening Levels for speciated VOCs

VOC speciation	Short-term ESL 1-hour average (µg/m³)	Long-term ESL Annual average (µg/m³)
1,1,1-Trichloroethane	10800	1080
2,4-Dinitrotoluene	1.5	0.15
2-Chloroacetophenone	3.2	0.32
Acetaldehyde	20	2
Acetophenone	490	49
Acrolein	2.3	0.23
Benzene	29	10
Benzyl chloride	50	5
Bis(2-ethylhexyl)phthalate (DEHP)	50	5
Bromoform	50	5
Carbon disulfide	30	3
Chlorobenzene	460	46
Chloroform	10	10
Cumene	500	50
Cyanide	50	5
Dimethyl sulfate	5	0.5
Ethyl benzene	2000	200
Ethyl chloride	500	50
Ethylene dibromide	4	0.4
Ethylene dichloride	160	4
Formaldehyde	15	3.3
Hexane	70	7
Isophorone	230	23
Methyl bromide	120	12
Methyl chloride	1030	130

VOC speciation	Short-term ESL 1-hour average (µg/m³)	Long-term ESL Annual average (µg/m³)
Methyl ethyl ketone	3900	390
Methyl hydrazine	0.2	0.02
Methyl methacrylate	340	34
Methyl tert butyl ether	450	45
Methylene chloride	260	26
Phenol	150	15
Propionaldehyde	20	2
Styrene	110	140
Tetrachloroethylene	2000	26
Toluene	640	4000
Vinyl acetate	150	15
Xylenes	3700	37

In addition to the NEPM standards, the Kwinana Environmental Protection Policy 1999 (EPP) has also been used to assess the impacts of SO_2. Although the Kwinana EPP sets air quality standards that are relevant for the Kwinana area, in consultation with the DEC, they have been deemed a relevant alternative for use in this assessment. The Kwinana EPP consists of the following two documents:

- The Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992
- The Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992

The requirements of the Kwinana EPP were reviewed and released without change in 1999. The Kwinana EPP sets criteria for sulfur dioxide (SO_2) and total suspended particulates (TSP). The Kwinana EPP defines three types of areas covered by the Policy - Area A (Industrial), Area B (Buffer) and Area C (residential) and defines standards and limits for SO_2 and TSP for these areas. The EPP achieves these ambient standards and limits through provision for allocating emission limits on individual industry stack licences issued under the Environmental Protection Act 1986. The Kwinana Industries Council (KIC) manages the allocation of emissions of SO_2 from Kwinana industry, for the purpose of meeting the Kwinana EPP. The KIC consists of representatives of industry in Kwinana.

The Kwinana EPP standard and limits for Area C only have been applied to the assessment of SO_2 for CPP. No exceedences of the limits are allowed, while the standard can be applied to the 99.9th percentile prediction (i.e. nine exceedances allowed).

Table 14 Kwinana EPP standards and limits for SO_2

Region	Standard[1]/limit[2]	Units	Averaging period		
			1-hour	24-hour	Annual
Area A	Standard	µg/m³	700	200	60
	Limit	µg/m³	1400	365	80
Area B	Standard	µg/m³	500	150	50
	Limit	µg/m³	1000	200	60
Area C	Standard	µg/m³	350	125	50
	Limit	µg/m³	700	200	60

[1] Standard - is the concentration of atmospheric waste which it is desirable not to exceed.
[2] Limit - is the concentration of atmospheric waste which shall not be exceeded.
[3] Maximum 1-hour averages are compared to the Kwinana EPP Limits and 9th highest concentrations are compared to the Kwinana EPP Standards.

4.2 Vegetation

Vegetation is also sensitive to several air pollutants associated with the CPP including NO_X, SO_2, and F. Table 15 presents the WHO (2000) guidelines for NO_X an SO_2 for the protection of vegetation, while Table 16 presents the ANZECC (1990) guidelines for F.

Table 15 Oxides of nitrogen and sulfur dioxide guidelines for the protection of vegetation

Pollutant	Type of vegetation	Averaging period	WHO Guideline - Maximum concentration
Oxides of nitrogen (NO and NO_2 expressed as NO_2)	All	Annual	30 µg/m³
Sulfur dioxide	Crops Forest/natural vegetation	Annual Annual	30 µg/m³ 20 µg/m³

Gaseous fluoride can affect sensitive vegetation and may also affect human health, though at levels much higher than for vegetation. Western Australia has set air quality standards for fluoride based on ANZECC (1990) guidelines. These guidelines are designed to protect injury to plants and animals (eating these plants) and are well below concentrations required to protect human health (the human health guidelines are one thousand times less stringent than the vegetation guidelines). The ANZECC guidelines are presented in Table 16.

Table 16: Fluoride guidelines for the protection of vegetation (ANZECC, 1990)

Averaging period	General land use[1] ($\mu g/m^3$)	Specialised land use[2] ($\mu g/m^3$)
12-hours	3.7	1.6
24-hours	2.9	1.5
7 days	1.7	0.8
30 days	0.84	0.4
90 days	0.5	0.25

[1] General land use values are designed to protect most of the sensitive species in the natural environment
[2] Specialised land use values are designed to protect commercially valuable plants, which are shown to be sensitive to fluoride.

5. Existing Environment

The existing environment in the region surrounding the proposed CPP is discussed here in terms of the background air quality, the geophysical and meteorological conditions that are likely to influence the dispersion of air pollutants from the Power station, other existing sources of air pollution in the region and the location of sensitive receptors.

5.1 Terrain and Land Use

The CPP is situated approximately 230 km north-northwest of Perth and 23 km inland from the coast. The terrain surrounding the CPP slopes gradually from the coastline up to a range of low hills that rise up to approximately 260 m above sea level (asl) approximately 10 km to the east of the Power station and as high as 300 m about 25 km to the east. The CPP is situated at an elevation of about 80 m asl. The terrain in the region is a mixture of relatively flat to mildly undulating ground (see Figure 2).

The proposed CPP site and surrounding area is generally rural and sparse low woodland and mallee scrub land. Consequently, the surface roughness length (Z_0) is quite low. This parameter is important for the dispersion of air pollutants, particular short, wake affected point sources and ground-level fugitive emissions, and less important for very tall, wake-free stacks.

The closest population centre is the town of Eneabba, located about 15 km to the north-northeast of the CPP. Ten isolated sensitive receptors have been identified in the region and are discussed in Section 5.2. Sensitive vegetation in the region includes the Tathra National Park to the northeast, the Lesueur National Park to the southwest, the Alexander Morrison National Park to the southeast and various areas of native wildflowers iconic to the region.

5.2 Location of Sensitive Receptors

The locations of the nearest sensitive receptors are presented below in Table 17 and also in Figure 2. The direction to the Power station has been included in this table to help identify the most important wind directions that may result in emissions from the CPP being dispersed toward each of the sensitive receptor locations. For example, winds from the south-southwest would be required to take emissions from the CPP over the township of Eneabba.

Table 17 Location of sensitive receptors

Receptor	Easting GDA94 (m)	Northing GDA94 (m)	Direction to the CPP	Distance to the CPP (km)
R1	327337	6698388	S	13.2
R2	324051	6690326	SSE	6.5
R3	322465	6689554	SE	7
R4	341480	6681401	WNW	14
R5	325159	6681369	NE	4.8
R6	327062	6682264	NE	3.1
R7	327019	6683467	NE	2
R8	326287	6678839	NNE	6.6
R9	327783	6676991	N	8.2
R10	328760	6673579	N	11.7
Eneabba	332559	6700166	SSW	15.6

5.3 Climate

The climate data used in this analysis has been sourced from the Bureau of Meteorology (BoM) meteorological station at Eneabba and from the automatic weather station (AWS) owned and operated by Iluka Resources. The Iluka Resources AWS is located less than three kilometres to the east of the town of Eneabba, and is illustrated in Figure 2.

The BoM meteorological data used for this analysis includes average monthly:

- Maximum and minimum daily temperature
- Highest, mean and lowest rainfall
- 9am and 3pm relative humidity
- Solar radiation exposure

The BoM meteorological station does not record hourly average wind speed and direction information, which is useful for both climate analyses and assimilation with meteorological and dispersion modelling. Consequently, hourly average wind speed and direction data has been obtained from the Iluka Resources AWS for use in this study.

5.3.1 Wind Speed and Direction

The annual distribution of winds recorded at the Iluka Resources AWS near Eneabba is illustrated in a wind rose diagram in Figure 3, with a frequency distribution for the wind speed presented in Figure 4. Seasonal and diurnal distributions for wind speed and direction are presented in wind rose diagrams in Figure 5 and Figure 6 respectively.

The annual distribution of wind direction indicates that winds are fairly evenly distributed between the east-northeast through to the west-southwest, with 79.4% of winds blowing from this broad sector. The seasonal analysis indicates that summer winds tend to blow predominantly from the south-western quadrant, while winter winds tend to be more north-easterly and easterly. The diurnal analysis shows the impact of the sea breeze with strong westerlies and south-westerlies developing during the afternoon (midday – 6pm) and continuing into the evening (6pm – midnight). During the night, winds tend to blow predominantly from the northeast, east and southeast and strengthen in the morning, becoming more easterly and north-easterly.

The distribution of wind speeds at Eneabba shows 36.3% of winds are greater than and 63.7% are less than 5 m/s. Light winds less than 2 m/s account for 20% of the winds.

5.3.2 Temperature and Solar Radiation

The annual mean maximum daily temperature recorded at the BoM meteorological station at Eneabba for the period 1972-2008 is 27.6^{o}C, with a mean minimum daily temperature of 13.6^{o}C. The warmest month is February with an average maximum daily temperature of 36.1^{o}C, while December, January and March also average above 33^{o}C. In contrast, the coolest month is July with an average maximum daily temperature of 19.6^{o}C, while the mean minimum daily temperature is 9.1^{o}C.

The average monthly distribution of maximum and minimum temperatures is illustrated in Figure 7.

Figure 8 presents the hourly averaged distribution of solar radiation recorded at the Iluka Resources meteorological station near Eneabba, while Figure 9 shows the average daily solar exposure by month at the BoM meteorological station at Eneabba. These figures illustrate the typical daily and monthly pattern of solar exposure, with the mean daily maximum solar radiation peaking around midday (12pm) and annual solar exposure 2.5 – 3.0 times greater during the summer than the winter.

5.3.3 Rainfall

Rainfall information has been analysed from data provided by the BoM and indicates that the annual average is 505.1 mm. The wettest period in the Eneabba region is during the winter months from May to August when, on average, 68.4% of the annual rainfall occurs. Only 6.1% of the annual average rainfall occurs during the summer months (December-January).

5.3.4 Relative Humidity

The monthly averaged distribution of relative humidity at 9am and 3pm at the Eneabba BoM meteorological station is presented in Figure 11.

The distribution indicates that the summer months (December-February) tend to be relatively dry with mean daily maximum relative humidity below 50%, while in the winter months the daily maximum relative humidity ranges from 74% to 78%. The data also shows that, on average, the relative humidity is 17% higher at 9am than at 3pm.

5.4 Existing Industries and background Air Quality

Existing industry in the local region is primarily related to sand mining activities and the extraction and transmission of natural gas via pipelines from the gas fields in the north to the population centres in the south. There is no known air quality monitoring conducted in the region for the measurement of background levels of NO_X and SO_2, however, Iluka Resources monitor for PM_{10}. Background levels of criteria air pollutants have not been included in the atmospheric dispersion modelling for the CPP and the prediction of ground-level concentrations. Background levels of PM_{10} have been included in the assessment of dust impacts for the CWCP including a combined assessment of all dust sources from the power station (fugitive and stack).

Table 18 presents a summary of the air pollution sources in the Eneabba region based on the National Pollutant Inventory reporting period for 2006-07. By comparison, annual emissions for the CPP are presented in Table 19.

Table 18 Eneabba region air pollution emission sources based on National Pollutant Inventory Reporting for 2006-07 (kg/yr)

Air Pollutant	APT Parmelia (Compressor Station 1)	ARC Energy LTD (Woodada Gas Field)	DBNGP (WA) Nominees P/L (Compressor 8 and Eneabba)	Iluka Resources LTD (Eneabba West)	Iluka Resources LTD (Eneabba)
Oxides of nitrogen	740	110,000	220,000	5,300	710,000
Sulfur dioxide	30	67	360	5,800	70,000
Particles as PM_{10}	13	300	4,100	180,000	1,500,000

Table 19 Estimated annual emissions for the Coolimba Power Project (kg/yr)

Air Pollutant	Predicted annual emissions
Oxides of nitrogen	6,419,437
Sulfur dioxide	15,324,131
Particulates as PM_{10}	626,896

Sulfur dioxide emissions from the CPP are expected to be more than two orders of magnitude higher than the current total load of sulfur dioxide in the region based on the NPI reporting. The background concentration for sulfur dioxide is therefore insignificant and not required as part of this assessment.

Emissions of oxides of nitrogen from the CPP are expected to be six times higher than the current total load of oxides of nitrogen in the region based on the NPI reporting. The existing sources in the region are distributed within a region of 30 km from the CPP and therefore their combined impact is expected to be very small when compared to the CPP. This report will conclude the predicted maximum impacts associated with the power station are well below the air quality guidelines and unlikely to cause a risk to human health even if background levels were included.

Particulate emissions from the CPP are small compared to the emissions from the Iluka Resources operation at Eneabba or when compared to the emissions that will be associated with the development of the CWCP. Iluka Resources Midwest Annual Environment report 2007 reported that the 24-hour average ground-level concentrations of PM_{10} exceeded the NEPM(Air) standard of 50 $\mu g/m^3$ on three occasions in the town of Eneabba, whilst background levels (recorded at Depot Hill) exceeded 50 $\mu g/m^3$ on four occasions. It was noted that *"these exceedances occurred during periods of high regional winds where elevated dust levels were noted on a regional basis and were not specifically associated with mine activities…"* For 2007, PM_{10} levels at Eneabba were generally lower than 30 $\mu g/m^3$ (24-hour average).

As the impacts associated with particulates from the CWCP are more significant than the impacts from the CPP a cumulative assessment of dust can be found in the CWCP PER, which also includes a background PM_{10} concentration due to other local sources based on available measurements.

6. Atmospheric Dispersion Modelling

6.1 Overview

Air dispersion modelling was conducted using the CSIRO air dispersion model TAPM v3.0.7 (Hurley 2005). TAPM was used to simulate the regional meteorology and to predict ground-level concentrations of air pollutants associated with emissions from the CPP.

The methodology developed to carry out this assessment included a series of preliminary meteorological and dispersion modelling scenarios and validation studies, followed by a process of consultation with the Department of Environment and Conservation (DEC), Western Australia.

The preliminary modelling and validation work was conducted for a 400 MW coal-fired plant comprising two 200 MW boiler units and 330 MW gas-fired CPP scenario. During this preliminary validation assessment process, a review of the proposed design of the CPP coal-fired plant by the proponent led to its modification to three smaller capacity boiler units to increase the plant's overall capacity to 450 MW. Results of the preliminary modelling and power station configuration are presented in Appendix C.

The validation of the meteorological modelling comprised an analysis of several input variables including:

- The assimilation of local meteorological observations (at the surface)
- The use of different grid resolutions for the modelling domain, 1000 m and 300 m
- The adjustment of the TAPM default soil moisture parameter to reflect local monthly rainfall observations

This validation process culminated in the submission of a meteorological validation report to DEC presented here as *Appendix B – Meteorological Assessment for the Eneabba Region*. Appendix B describes the methodology adopted to simulate the wind fields in the Eneabba region and presents a detailed statistical analysis of their comparison with the observed data from the Iluka Resources automatic weather station (AWS) situated to the east of Eneabba. A summary of the adopted methodology and validation analysis is provided in Section 6.2.

Due to the limited availability of meteorological observations for the power station site, particularly at plume height, the validation assessment is not conclusive. The model used for this assessment, TAPM, has been validated in many situations and has been proven as a suitable model for modelling tall stack sources. However, there is insufficient information at the site to conclude that the local phenomena exclusive to the CPP site are adequately characterised by the model. Due to these uncertainties this assessment presents a range in possible impacts in general areas and has assessed compliance with the maximum exposure regardless of location.

The assessment presented in this report investigated the impact to air quality associated with various scenarios that incorporate:

- Dispersion modelling with and without the assimilation of local meteorological monitoring data
- The range in sulfur content of coal
- The efficiency of the flue-gas desulfurisation controls and its affect on SO_2 impacts

6.2 TAPM Modelling Methodology and Validation

6.2.1 Dispersion Meteorology

The TAPM configuration developed to simulate the regional wind fields for the dispersion modelling study underwent a series of adjustments in an attempt to capture the particularities of the local dispersion meteorology. In particular, the regional wind fields are strongly influenced by the site's position between the coast to the west and a range of hills to the east and south. This proximity exposes the CPP site to strong afternoon sea breezes from the southwest that have a tendency to be deflected slightly northward along the range. The sea breeze is strongly developed during the drier spring and summer months when the pressure differential between the Indian Ocean and dry land surface is at its maximum. This is caused by strong solar insolation and dry conditions. During the autumn and winter, the Eneabba winds are increasingly influenced by the range that produce easterly drainage flows. Regional rainfall tends to be concentrated in the cooler months when solar insolation is weaker, and this reduces the influence and intensity of the sea breeze causing winds to flow down drainage lines from the range.

The aim of the validation study was to improve the performance of the TAPM model to predict the wind fields in the Eneabba region without the assimilation of local meteorological observations from the Iluka monitoring station located near Eneabba.

The Iluka monitoring data comprised information for the years 2006 and 2007 only. Consequently, TAPM was initially run with default settings for this period to determine a representative year of meteorological data that could be validated with the observations. This initial TAPM configuration did not adequately simulate the sea breeze, and consequently, the frequency and intensity of the south-westerly and westerly winds. This is significant as the town of Eneabba lies approximately 15 km to the north-northwest of the proposed CPP site, and as discussed above, the range to the east tends to deflect the sea breeze northward along the range passing by Eneabba with a slightly southerly aspect. To address the sea breeze anomaly, the deep soil moisture content in TAPM was adjusted to reflect the annual rainfall pattern based on BoM climate data. This adjustment stimulates the development of the sea breeze by altering the Bowen Ratio (the ratio of sensible to latent heat), affecting the surface heating of the air and consequently increasing the pressure differential between the ocean and the land.

Close inspection of the Iluka monitoring data indicated several gaps in the data collected. To account for this, data for a single year was extracted for the validation analysis between 1 May 2006 and 30 April 2007.

Further investigation was conducted into the development of the wind fields by increasing the resolution of the modelling domain from 1,000 m to 300 m and substituting the TAPM default terrain information with Geoscience Australia 9-second Digital Elevation Model (DEM) terrain data.

The statistical analysis for the validation study is presented in Appendix B. In summary, the following points have been addressed in the analysis:

- The synoptic data used in the simulation is for the period May 2006 to April 2007
- Differences in the windfields as a result of the increase in the terrain resolution from 1,000 m to 300 m and increasing the number of nested grids from four to five (cell resolutions - 30 km, 10 km, 3 km, 1 km and 300 m)

- Modifications to monthly deep soil moisture content to promote the development of the sea breeze

6.2.2 Merged Plume Buoyancy Sensitivity Analysis

The CPP's coal-fired plant's emissions are released to atmosphere via a single 130 m stack comprising three flues, one for each boiler unit. This stack configuration presents a significant variation to a standard single flue stack such as the gas turbine stacks in the manner in which the exhaust streams interact both on release from the stack and further downwind.

There are three possible ways to model the multi-flue stack. These methods include:

- Method 1: Three discrete flues positioned in-situ with actual stack diameter specifications and modelled separately with no buoyancy enhancement
- Method 2: A single flue with a combined, effective stack diameter to account for the total stack cross-sectional area of the three individual flues , effectively pre-merging the plumes prior to release
- Method 3: Method 1 with a buoyancy enhancement factor

Several studies have found that plumes released from closely spaced or multi-flued stacks merge quickly with one another after release (Briggs, 1984; Manins et al, 1992; Anfossiet al, 1978; Overcamp and Ku, 1988). When the plumes merge, there is an enhanced buoyancy effect that results in greater vertical dispersion and, consequently, reduced ground-level impacts. In general, a rising buoyant plume (a plume that is warmer than the ambient air) will mix (entrain) with the surrounding air, eventually cooling to ambient temperature. Conversely, the buoyancy enhancement of the merged plume results from the entrainment of one plume into the other, reducing the rate of mixing of cooler ambient air allowing the plume to remain above the ambient temperature for a greater duration, and therefore increasing plume rise.

By assessing the three flues as three discrete stacks positioned in-situ (Method 1), the simulation does not account for the affect of the plume's interaction, and any buoyancy enhancement effects are ignored. This will result in an under-estimation of the plume's dispersion characteristics and the over-prediction of impacts.

Method 2 uses a single, effective stack configuration, where the multi-flue stack characteristics are combined as a pre-merged plume and assessed as a single source. An effective stack diameter is derived from the sum of the cross sectional areas of the three flues, and by using the actual exhaust gas velocity and temperature the desired volume flow is simulated. This method uses the sum of the volume of air emitted from the multiple flues at stack temperature, so that they are effectively pre-merged upon release. This will result in greater buoyancy as the larger plume volume takes longer to mix and cool to ambient temperature.

Notwithstanding this, Method 3 also employs a buoyancy enhancement factor to incorporate additional plume rise in to the merging plumes. This buoyancy enhancement factor used in TAPM (Mannins, 1992) is provided here:

$$N_E = \left[\frac{n + S}{1 + S}\right]$$

Where: *n* is the number of stacks
S is the dimensionless separation factor, defined as

$$S = 6\left[\frac{(n-1)\,.\,\Delta s}{n^{1/3}\,.\,\Delta z}\right]^{3/2}$$

Where: Δs is the stack separation
Δz is the rise of an individual plume.

By applying the buoyancy enhancement factor presented above, the plume rise is increased resulting in a reduction in predicted ground-level concentrations in comparison to Method 1.

While Method 3 has been developed to account for the effects of merging plumes and enhanced buoyancy, for this air quality assessment Method 2 was adopted as a conservative approach. Consequently, the dispersion modelling has effectively simulated the release of a pre-merged volume of buoyant air, larger in volume than that simulated using Method 1, and therefore incorporated a greater degree of plume rise.

Further investigation into plume buoyancy effects should be conducted once the CPP is developed. A validation study is recommended to correlate measured source emissions with ambient air quality monitoring. This validation would further investigate the effect of plume buoyancy on impacts associated with the CPP.

6.3 Analysis of Dispersion Meteorology for TAPM Configuration Scenarios

Wind field, atmospheric stability and mixing height information has been analysed for both the data assimilated and unassimilated TAPM configuration scenarios at the CPP site.

6.3.1 Wind Speed and Direction

The predicted annual distribution of wind speed and direction at the CPP site for the TAPM assimilated scenario is presented as a wind rose diagram in Figure 12, while the TAPM unassimilated scenario is presented in Figure 13. Frequency distributions of annual wind speeds for each of these scenarios are also presented in Figure 14 and Figure 15.

The wind rose diagrams indicate that the unassimilated TAPM scenario tends to underestimate the frequency of the winds from the southwest quadrant between 180^{o} and 270^{o} that are associated with the sea breeze, although the velocity of the sea breeze is in reasonable agreement. This scenario also tends to overestimate the frequency of the winds from the east and southeast, but underestimate the frequency of the very strong winds from this direction above 10 m/s.

Although the adjustments made to the TAPM configuration improved the model's ability to simulate the sea breeze, it was concluded that assimilation of the local meteorological observations into TAPM at both the CPP site and at Eneabba was required to the improve the simulation. The TAPM simulations suggest that drainage flows from the range to the east and southeast are significant in the region.

The frequency distributions of wind speeds for both TAPM scenarios further illustrate TAPM's underestimation of wind speeds less than 2 m/s and greater than about 7-8 m/s, and its overestimation of the frequency of wind speeds between 2 - 6 m/s.

The under-prediction of the sea breeze is also evident in Figure 16 and Figure 17 which present the seasonal distribution of winds for the TAPM assimilated and unassimilated scenarios, respectively. During the warmer, drier months between October and March when mean monthly rainfall is below approximately 25 mm, the sea breeze should be well developed and would be expected to easily penetrate 23 km inland. Again, the unassimilated TAPM scenario tends to have a greater frequency of winds from the southeast than the southwest at this time. The winds during the autumn and winter months have a more comparative distribution.

Figure 18 and Figure 19 present the diurnal distribution of winds for the CPP site for both the TAPM assimilated and unassimilated scenarios, respectively. This analysis indicates that the unassimilated TAPM scenario underestimates the frequency of night time drainage flows as well as the afternoon and evening sea breeze.

6.3.2 Atmospheric Stability and Mixing Height

Atmospheric stability is classified under the Pasquill-Gifford scheme and ranges from Class A, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to Class F which represents very stable atmospheric conditions that typically occur during light wind conditions at night. Stability refers to the vertical movement of the atmosphere and is therefore an important factor in the dispersion and transport of pollutants within the boundary layer.

Unstable conditions (Class A-C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground, and usually results in material from a plume reaching the ground closer to the source than for neutral conditions or stable conditions. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for neutral conditions (Class D) are dominated by mechanical turbulence generated as the wind passes over irregularities in the local surface, such as terrain features and building structures. During night time, the atmospheric conditions are neutral or stable (Class D, E and F). During stable conditions the plume released from the stack will be subject to minimal atmospheric turbulence. A plume that is hotter than its surroundings and emitted above the night time inversion will remain relatively undiluted but will be trapped above the inversion layer and will not reach the ground unless it encounters elevated terrain.

Atmospheric stability class has been calculated using the USEPA approved Solar Radiation/Delta-T (SRDT) method (EPA, 2000). This method utilises the TAPM modelled wind speeds and solar radiation (W/m^2) to determine daytime stability, while night time stability is determined by wind speeds and the vertical temperature gradient between the surface and the adjacent vertical sigma level at the site location. This approach has been found to provide a more robust and verifiable classification scheme than the one produced internally in TAPM. The percentage frequency distribution of stability classes at the CPP site for both the unassimilated TAPM and assimilated TAPM scenarios are presented in Table 20. The difference in the two distributions is a function of the difference in predicted wind speeds under the two modelling configurations.

Table 20 Percentage frequency distribution for atmospheric stability under the Pasquill-Gifford stability classification scheme

Pasquill-Gifford Stability Class	Frequency (%)	
	Assimilated TAPM scenario	Unassimilated TAPM scenario
A	2.7	3.2
B	11.2	10.4
C	16.9	15.3
D	60.8	54.7
E	4.2	8.5
F	4.3	7.8

There is a high percentage of D class or neutral stability. This is due to high frequency of wind speeds greater than 2 m/s at the site and can largely be attributed to strong sea breezes and drainage flows. The relatively high proportion of B and C class stability is probably due to the daytime heating of the surrounding land, with the small percentage of extremely unstable (Class A) conditions the result of the strong winds. At night, the D class stability is indicative of a stable boundary layer with moderate winds. The stable (Class F) conditions occur during light wind conditions at night.

The mixing height refers to the height above ground within which the plume can mix with ambient air. During stable atmospheric conditions at night, the mixing height (inversion) is often quite low and the tall, buoyant coal–fired plant stack's plume may be emitted above this layer leading to its dispersion in to the upper boundary layer. During these atmospheric conditions, the plume is unlikely to touch the ground unless it encounters elevated terrain. Conversely, the shorter gas-fired plant stack's plume has a greater chance of being trapped below any night inversion due to its height, although its high vertical velocity and temperature is likely to provide it with adequate mechanical and thermal buoyancy to penetrate any low stable layer or temperature inversion.

During the day, solar radiation heats the air at ground level and causes the mixing height to rise. The air above the mixing height during the day is generally colder. The growth of the mixing height is dependent on how well the air can mix with the cooler upper levels of air and therefore depends on meteorological factors such as the intensity of solar radiation and wind speed. During strong wind speed conditions the air will be well mixed, resulting in a high mixing height. During periods when the mixing height is high, the plume emissions will disperse and will be diluted by the large volume of air. When the mixing height is low the plume can become trapped under the mixing layer and have limited air available to mix with, resulting in higher ground-level concentrations.

Mixing height information for the proposed site has been extracted from TAPM for both the assimilated TAPM and unassimilated TAPM scenarios, and is presented in Figure 20 and Figure 21, respectively. The data shows the mixing height tends to develop around 8-9am, peaks around midday (1-2pm) before decreasing again around sunset (6-7pm). The figure also indicates the mixing height's consistent diurnal profile with the 95th percentile extending to approximately 1,400 metres around early afternoon.

6.4 Air Quality Impact Assessment Scenarios

6.4.1 TAPM Configuration Scenarios

As discussed above, due to the limited availability of meteorological observations for the power station site, particularly at plume height, the validation assessment is not conclusive. Consequently, the air quality impact assessment was conducted for two dispersion model configuration scenarios to determine the worst case:

1. Validated TAPM configuration including data assimilation from observations at Eneabba, assimilated at both the CPP site and Eneabba
2. Validated TAPM configuration not including data assimilation

For scenario 1 - data assimilation scenario, the meteorological data was assimilated with a radius of influence of 10 km over three vertical levels at Eneabba and CPP site to create an overlap between the locations and to minimise the influence of the meteorological data in the areas of elevated terrain in the eastern region of the modelling domain.

This methodology will provide a conservative assessment as the uncertainties in the modelling should be outweighed by the relaxation of spatial constraints. That is, the exact predictions at key receptors may not be accurate, but the range in predictions in the general areas should adequately represent the expected range in predicted maximum ground level concentrations due to the operation of the power station. Prior to commissioning of the power station additional studies should be conducted to verify the model predictions.

6.4.2 Background levels

As discussed in Section 5.4, this assessment has not included a background concentration for sulfur dioxide or oxides of nitrogen due to the lack of significant existing sources of these pollutants in the region. Should a background level be added to the modelling results the outcome of the assessment would not change.

The assessment of PM_{10} due to emissions from the power station are presented in this report in isolation. A combined assessment for PM_{10} is presented in the assessment for the CWCP (Katestone, 2008) and includes the following sources:

- Power station stacks
- Coal storage and handling on the power station site
- Coal and overburden extraction, processing, haulage and storage as part of the CWCP
- Background level based on monitoring to account for Iluka operations and general background dust

6.4.3 Emission Scenarios and Averaging Periods

6.4.4 Oxides of Nitrogen

The assessment of the impacts of NO_X associated with emissions from the CPP has been made for the coal- and gas-fired plants operating concurrently at a 100% capacity factor. Due to the lack of local ambient monitoring data and the insignificant contributions of other NO_X sources in the region, background levels have not been included in the assessment. Consequently, the dispersion modelling and presentation of results represent the impacts associated with the CPP in isolation.

The prediction of the impacts of NO_2 has been determined by modelling the total emission rate in grams per second for NO_X, with the subsequent results scaled by an empirical nitric oxide/nitrogen dioxide conversion ratio. Measurements around Power stations in Central Queensland show, under worst possible cases, a conversion of 25-40% of nitric oxide to nitrogen dioxide occurs within the first ten kilometres of plume travel. During days with elevated background levels of hydrocarbons (generally originating from bush-fires, hazard reduction burning or other similar activities), the resulting conversion is usually below 50% in the first thirty kilometres of plume travel (Bofinger et al 1986). For this assessment a conservative ratio of 30% conversion of the NO_X to NO_2 has been applied.

For comparison with the NEPM(Air) standards and Kwinana EPP guidelines, the following averaging periods were calculated:

- Maximum (100th percentile) 1-hour average
- Annual average

6.4.5 Sulfur Dioxide

The air quality and health risk assessments focussed on the impacts associated with the coal- and gas-fired plant operating at a 100% capacity factor under normal and optimum operating conditions for a year. These conditions primarily refer to sulfur dioxide emission rates, as discussed in Section 3.1.1.1, and include a fixed coal fuel sulfur content and the constant operation of the flue gas desulfurisation system. Dispersion modelling was conducted to predict the ground-level impacts associated with the CPP based on the primary operating scenario:

- Normal operations, full capacity –
    - Coal-fired plant at full capacity with three boilers operating and flue gas desulfurisation operating
    - Gas-fired plant operating at full capacity

In reality, several factors inherent in the operation of a mixed fuel Power station will significantly influence the air pollutant emission rates and the subsequent ground-level impacts, including:

- Demand for base load and peak load electricity will affect the plant's capacity factor
- The demand mix will affect the method of generation between coal or gas, which will directly influence the air emissions mix
- The hour by hour sulfur dioxide emission rate is directly attributable to the mass of coal consumed and its sulfur content
- The efficacy of the flue gas desulfurisation system will also directly affect the sulfur dioxide emission rate

For the purpose of the PER, the maximum emissions under normal, full capacity operating conditions were assessed in order to determine the potential upper limit of ground-level air quality impacts. If these impacts were found to meet all relevant air quality assessment criteria, it could be assumed that impacts would be lower when the CPP capacity factor was lower. However, in order to determine the ground-level impacts and potential for exceedences of the air quality standards during non-normal operations such as the combustion of high sulfur content coal (upper 25^{th} percentile) and the non-operation of the flue gas desulfurisation system, a different methodology has been adopted. This method employed the use of stochastic modelling.

For comparison with the NEPM(Air) and Kwinana EPP standards for the normal operating scenario, the following averaging periods were calculated:

- Maximum (100^{th} percentile) 1-hour average
- Ninth highest (99.9^{th} percentile) 1-hour average
- Maximum (100^{th} percentile) 24-hour average
- Annual average

6.4.6 Stochastic Modelling Methodology

Stochastic modelling has been conducted using the methods outlined in Heuff *et al.* (2007).

The assessment of ground-level impacts of SO_2 under normal operating conditions is based on the 75^{th} percentile for the in-stack concentration of SO_2 of 1,100 mg/Nm^3. This concentration has been derived from the percentage distribution of sulfur in the coal, a mass balance for the conversion of solid phase sulfur to gas phase SO_2 through coal combustion and an assumed efficiency rating for the flue gas desulfurisation system.

Notwithstanding this, a reduction in efficiency or complete failure in the flue gas desulfurisation system and an increase in the sulfur content of the coal fuel has the potential to significantly increase the concentration of SO_2 in the emission stream and cause impacts at ground-level. In order to assess the probability, frequency and magnitude of these factors occurring, the predicted impacts for the normal operating scenario were compared with the distribution of SO_2 emissions for each variable using a Monte Carlo process. As discussed in Section 3.1.1.1, Table 7 presents the expected distribution of stack SO_2 concentrations and emission rates based on the frequency distribution for coal sulfur content during the operation of the flue gas desulfurisation system. Table 8 presents the expected distribution of stack SO_2 concentrations and emission rates based on the frequency distribution for coal sulfur content during the non-operation of the flue gas desulfurisation system. The combined distributions were assessed for the stochastic modelling assuming the desulfurisation system was not operational for 1, 2 and 5% of time.

The stochastic simulations comprised the repetition of the Monte Carlo process for 1,000,000 times each hour for each grid point, and the number of times the predicted ground-level concentration exceeded the criteria at each grid point was recorded. To ensure all possible combinations of varying coal sulfur contents and meteorological conditions were compared, the simulations were forced to run for an equivalent of an arbitrary 1,000 years.

The results were then presented as contour plots illustrating the predicted number of exceedences of the NEPM(Air) standard for the 1-hour average of 570 µg/m^3 in a year.

6.4.7 Particles as PM_{10}

The assessment of the impacts of PM_{10} associated with emissions from the CPP has been made for the coal-fired plant operating concurrently at a 100% capacity factor. For the assessment of the CPP, background levels have not been included in the assessment. Major sources of particulates in the region other than the natural environment include the Iluka Resources sand mining operations and the proposed CWCP associated with the CPP development. For this PER, background dust levels have been incorporated into the assessment of impacts to air quality associated with the CWCP due to the expected low emissions and incremental impact from the CPP. Consequently, the dispersion modelling and presentation of results represent the impacts associated with the CPP in isolation.

For comparison with the NEPM(Air) standards the maximum 24-hour average was calculated.

7. Interpretation of Air Quality Impacts

7.1 Human Health

This section presents the results of the air quality impact assessment for the criteria air pollutants NO_2, SO_2 and PM_{10} for the CPP coal- and gas-fired power station. The results are presented as contour plots and tabulated concentrations for groups of sensitive receptors for both TAPM scenarios to represent the potential range in impacts within the region.

Due to the uncertainty in the exact location of predicted impacts, the sensitive receptors have been grouped into areas and the results presented as a range of impacts based on the predictions of the two scenarios. The grouped receptors are presented in Table 21.

Table 21 Summary of grouped sensitive receptors

Location	Receptors	Comment
Eneabba	Eneabba, R1	Receptors more than 10 km to the north of the CPP
Elevated terrain	R4, R8, R9, R10	Receptor to the south and east on terrain greater than 50m above CPP
South West	R5, R6, R7	Near field receptors (<5km from CPP) to the southwest of the CPP
North West	R2, R3	Receptors to the northwest of the CPP (approximately 5-8km from CPP)

7.1.1 Nitrogen Dioxide

For the CPP operating at full capacity under normal operating conditions and assessed in isolation, the range in predicted maximum 1-hour average (100th percentile) and the annual average ground-level concentrations of NO_2 at Eneabba, the nearby sensitive receptors and within the modelling domain for the TAPM with and without data assimilation scenarios are presented in Table 22.

Table 22 Predicted maximum ground-level concentrations of nitrogen dioxide for the Coolimba Power Project during normal operations and assessed in isolation (in µg/m³)

Location	Predicted range of maximum concentrations	
	Maximum 1-hour average[1]	Annual average
Eneabba	10-20	0.1-0.3
Elevated terrain	20-60	0.1-0.2
South West	20-40	0.1-0.2
North West	15-25	0.1-0.3
Maximum on Grid	70	0.6
NEPM(Air) standard	246	62

[1] 100th percentile presented

Figure 22 and Figure 23 present the predicted maximum 1-hour and annual average ground-level concentrations of NO_2 for the CPP in isolation during normal operations for the two TAPM scenarios.

The results show the following:

- There are no exceedances predicted of the NEPM(Air) standard for the 1-hour and annual average ground-level concentration of NO_2 due to the proposed CPP, assessed in isolation and operating at full capacity under normal conditions, at any location within the modelled domain.

- 1-hour average

    - The predicted maximum 1-hour average ground-level concentration of NO_2 at any location within the modelling domain, is 70 µg/m^3, which is less than 30% of the NEPM(Air) standard of 246 µg/m^3

    - The predicted maximum 1-hour average ground-level concentration of NO_2 near Eneabba, is 20 µg/m^3, which is less than 10% of the NEPM(Air) standard of 246 µg/m^3

- Annual average

    - The predicted annual average ground-level concentration of NO_2 at any location within the modelling domain, for is 0.6 µg/m^3, which is approximately 1% of the NEPM(Air) standard of 62 µg/m^3

7.1.2 Sulfur Dioxide

7.1.2.1 Normal Operations – Flue Gas Desulfurisation System Operating

For the CPP operating at full capacity, under normal operating conditions with the flue gas desulfurisation system operating and assessed in isolation, the range in predicted maximum ground-level concentrations for SO_2 for all averaging periods at Eneabba, the nearby sensitive receptors and within the modelling domain are presented in Table 23.

Table 23 Predicted maximum ground-level concentrations of sulfur dioxide for the Coolimba Power Project during normal operations and assessed in isolation (in µg/m^3)

Location	Predicted range of maximum concentrations			
	1-hour average[1]		24 hour average	Annual average
	Maximum[1]	Ninth highest[2]		
Eneabba	100-200	50-100	10-30	0.5-2
Elevated terrain	100-400	75-125	15-30	0.5-1
South West	100-200	100-150	20-30	1-1.5
North West	100-200	100-125	20-60	1-2.5
Maximum on Grid	544	225	100.5	4.5
Guideline	570[3]	350[4]	230[3]	60[3]

[1] Maximum (100th percentile)
[2] 9th highest (99.9th percentile)
[3] NEPM(Air) standard
[4] Kwinana EPP

Figure 24 and Figure 25 present contour plots for the predicted maximum and ninth highest 1-hour average ground-level concentrations of SO_2 for the CPP in isolation during normal operations. Figure 26 presents the predicted maximum 24-hour average ground-level concentrations of SO_2, while Figure 27 presents the predicted annual average.

The results show the following:

- There are no exceedances predicted of the NEPM(Air) standard or Kwinana EPP guideline for the 1-hour, 24-hour and annual average ground-level concentration of SO_2 due to the proposed CPP, assessed in isolation and operating at full capacity under normal conditions, at any location within the modelled domain.

1-hour average

- The predicted maximum 1-hour average ground-level concentration of SO_2 at any location within the modelling domain, is 544 µg/m^3, which is approximately 95% of the NEPM(Air) standard of 570 µg/m^3.

- The predicted maximum 1-hour average ground-level concentration of SO_2 near sensitive receptors, is between 100 and 400 µg/m^3, which is less than 20-70% of the NEPM(Air) standard of 570 µg/m^3. The highest impacts were predicted to occur on the elevated terrain to the south west of the plant.

- The predicted maximum 1-hour average ground-level concentration of SO_2 near Eneabba, is 200 µg/m^3, which is approximately 35% of the NEPM(Air) standard of 570 µg/m^3.

24-hour average

- The predicted maximum 24-hour average ground-level concentration of SO_2 at any location within the modelling domain, is 100 µg/m^3, which is approximately 43% of the NEPM(Air) standard of 230 µg/m^3.

- The predicted maximum 24-hour average ground-level concentration of SO_2 near a sensitive receptor is between 30 and 60 µg/m^3, which is approximately 13-26% of the NEPM(Air) standard of 230 µg/m^3. The highest impacts were predicted to occur to the north west of the plant.

- The predicted maximum 24-hour average ground-level concentration of SO_2 near Eneabba is approximately 30 µg/m^3, which is approximately 13% of the NEPM(Air) standard of 230 µg/m^3.

Annual average

- The predicted maximum annual average ground-level concentration of SO_2 at any location within the modelling domain, is 4.5 µg/m^3, which is approximately 7.5% of the NEPM(Air) standard of 60 µg/m^3.

- The predicted annual average ground-level concentration of SO_2 near a sensitive receptor is between 0.5 and 2.5 µg/m^3, which is less than 4% of the NEPM(Air) standard of 62 µg/m^3. The highest impacts were predicted to occur to the north west of the plant.

- The predicted annual average ground-level concentration of SO_2 near Eneabba is approximately 2 µg/m^3, which is approximately 3% of the NEPM(Air) standard of 62 µg/m^3.

7.1.2.2 Maximum Impacts of Sulfur Dioxide during Normal Operations - Flue Gas Desulfurisation System Operating

An analysis of the meteorological conditions at the time of the ten highest ground-level concentration impacts of SO_2 across the modelling domain was also carried out. Table 24 presents the ten highest 1-hour average concentrations in decreasing order, the distance and direction from the stack, and the mean wind speed and direction for that hour. Figure 28 shows the locations of the predicted ten highest 1-hour ground-level concentration of SO_2 across the domain and the proximity of the sensitive receptors to these locations.

Table 24 Meteorological conditions at the proposed Power station under which the ten highest concentrations of SO_2 occurred

Date / Time	Stack-top Wind Speed (m/s)	Stack-top Wind Direction (degrees)	Mixing Height (m)	Maximum SO_2 Conc on Grid (µg/m³)	Direction from CPP stack	Distance from CPP stack (km)
15/11/2006 8:00	1.3	301	181	543.8	SE	14.4
15/9/2006 9:00	0.5	303	167	496.7	SE	13.3
15/9/2006 10:00	0.2	264	269	489.2	SE	11.6
10/5/2006 12:00	0.8	99	524	461.0	W	3.2
18/6/2006 12:00	2.1	73	448	435.4	W	4.1
22/1/2007 9:00	0.8	212	369	370.8	N	2.5
15/11/2006 9:00	2.3	296	300	331.5	SE	5.6
17/1/2007 1:00	10.4	153	289	316.4	NW	7.2
15/9/2006 11:00	0.6	294	429	296.8	NW	6.7
27/2/2007 12:00	4.9	281	456	284.6	E	3.0

Table 24 indicates that the highest impacts are not wind direction specific, that is, they occur during winds from any direction, and occur under a range of wind speeds, though predominantly low to moderate wind speeds with eight out of ten stack-top winds 3 m/s or below. The eighth and ninth highest hours are during wind speeds of 10.4 and 4.9 m/s respectively. Nine of the ten highest 1-hour impacts occurred between 8am and 12pm with the eighth highest occurring at 1am, while the mixing heights ranged between 167 and 524 m.

The results indicate that the highest ten hours predicted may be attributable to several key meteorological conditions. An analysis of the top ten highest concentrations of SO_2 has identified many of the elevated hours to occur under light wind speeds or were preceded by several hours of light wind speeds. There are occasions where a significant change in wind direction results in very low wind speeds as the sub-hourly change in wind direction is not adequately captured by the model and a large volume of pollutant is dispersed to the ground. Four of the top ten hours in which elevated concentrations occurred were under Stability Class A, and were preceded by light wind speeds. These highly unstable conditions are likely to create a looping effect in the plume whereby it is possible for it to touch the ground in several locations downwind. Mixing heights were typically lower on the hours on which elevated concentrations occurred, than for the average mixing height for that hour of the day. Mixing heights for the top ten concentrations have a range of 167 to 524 m compared with a maximum mixing height of up to 2,235 m. Two occasions where the mixing heights were higher than the average height for that hour of the day, elevated concentrations occurred under a change in wind direction and subsequent drop in wind speed.

7.1.2.3 Effect of Variability in the Emissions of Sulfur Dioxide

Sulfur dioxide emissions may be effected by both the variability in the coal sulfur content and the efficacy of the flue gas desulfurisation system. The stochastic modelling method assessed the probability and frequency that an exceedance of the NEPM(Air) standard for the 1-hour average of SO_2 was likely to occur due to the following variable parameters:

- Non-normal operations occurring with the flue gas desulfuisation system not operating for 1, 2 and 5% of the year
- Full distribution of coal fuel sulfur contents
- 100% capacity factor
- Full range of meteorological conditions

Figure 29, Figure 30 and Figure 31 illustrate the locations where exceedance of the NEPM(Air) standard for the 1-hour average ground-level concentration of SO_2 are predicted each year for the desulfurisation system not operating for 1, 2 and 5% of a year respectively. The results are summarised in Table 25.

Figure 32 presents the contour plot for the predicted maximum 24-hour average ground-level concentrations of PM_{10} for the CPP in isolation during normal operations.

Table 25 Number of exceedences of the NEPM(Air) standard for a 1 hour average ground-level concentration of SO_2 per year for non-normal operations of the CPP

Location	Percentage of the year desulfurisation system not operating		
	1%	2%	5%
Eneabba	<1	<1	<1
Elevated terrain	<1	<1	<1
South West	<1	<1	1
North West	<1	<1	1
Maximum on Grid	1	2	5

The results show:

Desulfurisation system not operating for 1% of the year

- An exceedence of the NEPM(Air) standard for the 1-hour average of SO_2 is likely on one hour per year in the area within approximately 3 km to the north and northeast, and approximately 5 km to the west of the CPP
- An exceedence is not predicted at the location of any nearby sensitive receptors nor at the town of Eneabba

Desulfurisation system not operating for 2% of the year

- An exceedence of the NEPM(Air) standard for the 1-hour average of SO_2 is likely on one to two hours per year within an area approximately 7 km to the north to east, and up to 10 km to the west of the CPP
- An exceedence is not predicted at the location of any nearby sensitive receptors nor at the town of Eneabba

Desulfurisation system not operating for 5% of the year

- An exceedence of the NEPM(Air) standard for the 1-hour average of SO_2 is likely on one hour per year up to 15 km from the CPP and up to five hours per year closer to the plant
- An exceedence is predicted on one hour per year at the location of any nearby sensitive receptors
- An exceedence is not predicted at the town of Eneabba

7.1.3 Particles as PM_{10}

For the CPP operating at full capacity, under normal operating conditions and assessed in isolation, the largest predicted maximum 24-hour average ground-level concentrations for PM_{10} at Eneabba, the nearby sensitive receptors and within the modelling domain for the TAPM with and without data assimilation scenarios are presented in Table 26.

Table 26 Predicted maximum 24-hour average ground-level concentrations of PM_{10} for the Coolimba Power Project during normal operations and assessed in isolation (in µg/m³)

Location	Predicted range of maximum 24 hour average concentrations
Eneabba	0.5-1.5
Elevated terrain	0.5-2.0
South West	0.5-1.0
North West	1.0-3.0
Maximum on Grid	4.1
Guideline	50
Note: NEPM(Air) standard for the 24-hour average is 50 µg/m³	

The results show the following:

- There are no exceedances predicted of the NEPM(Air) standard for the 24-hour average ground-level concentration of PM_{10} due to the proposed CPP, assessed in isolation and operating at full capacity under normal conditions, at any location within the modelled domain, and based on both data assimilated and unassimilated modelling scenarios.

- The predicted maximum 24-hour average ground-level concentration of PM_{10} at any location within the modelling domain, is 4 µg/m^3, which is approximately 8% of the NEPM(Air) standard of 50 µg/m^3.

- The predicted maximum 24-hour average ground-level concentration of PM_{10} near a receptor, is in the range 0.5 to 3.0 µg/m^3, which is approximately 1-6% of the NEPM(Air) standard of 50 µg/m^3. The highest impacts are predicted to occur to the north west of the CPP.

- The predicted maximum 24-hour average ground-level concentration of PM_{10} near Eneabba, is 1.5 µg/m^3, which is approximately 3% of the NEPM(Air) standard of 50 µg/m^3.

7.2 Vegetation

The predicted impacts to vegetation in the region for the key air pollutants NO_X, SO_2 and F have been assessed by the comparing the maximum concentrations predicted by the modelling with the relevant guidelines. Table 27 presents the highest predicted annual average ground-level concentration for oxides of nitrogen and sulfur dioxide, while Table 28 shows the highest predicted 12-hour, 24-hour, 30 day and 90 day average ground-level concentration for fluoride, within the modelling domain. The 7-day average has not been assessed as this averaging period cannot be extracted from the TAPM dispersion model.

Table 27 Predicted highest annual average for oxides of nitrogen and sulfur dioxide during normal operations within the modelling domain (in µg/m^3)

Averaging Period	Oxides of nitrogen (as NO_2)	Sulfur dioxide
Annual	0.6	4.5
Guideline	30	20

Table 28 Predicted highest 12-hour, 24-hour, 30 day and 90 day averages for fluoride during normal operations within the modelling domain (in µg/m^3)

Averaging period	General land use[1]	Specialised land use[2]	TAPM data assimilated scenario	TAPM data unassimilated scenario
12-hours	3.7	1.6	1.52	1.20
24-hours	2.9	1.5	0.58	0.36
30 days	0.84	0.4	0.14	0.11
90 days	0.5	0.25	0.09	0.06

[1] General land use values are designed to protect most of the sensitive species in the natural environment
[2] Specialised land use values are designed to protect commercially valuable plants, which are shown to be sensitive to fluoride

The results show the following:

- There are no exceedances predicted of the WHO guidelines for vegetation for the annual average ground-level concentration of NO_X and SO_2 due to the proposed CPP, assessed in isolation and operating at full capacity under normal conditions, at any location within the modelled domain, and based on both data assimilated and unassimilated modelling scenarios.

- There are no exceedances predicted of the ANZECC guidelines for vegetation for the 12-hour, 24-hour, 30 day and 90 day average ground-level concentration of fluoride due to the proposed CPP, assessed in isolation and operating at full capacity under normal conditions, at any location within the modelled domain, and based on both data assimilated and unassimilated modelling scenarios.

8. Photochemistry and the Power Station Plume

8.1 Background

The oxides of nitrogen that are emitted from large power stations have the potential to generate significant concentrations of photochemical smog (nitrogen dioxide, ozone and other oxidants) downwind from the source. The transformation of oxides of nitrogen and possible formation of ozone involves a number of chemical reactions. The power station exhaust contains no ozone and has 90-95% of oxides of nitrogen as nitric oxide. Ozone can only be formed once this nitric oxide has been transformed into nitrogen dioxide and nitrates. This is a multi-stage process. The rate at which photochemical smog is generated is a function of:

- The in-plume concentration of oxides of nitrogen
- The concentration and reactivity of volatile organic compounds (VOC) in the ambient air
- The rate of plume dispersion
- The prevailing atmospheric conditions, including temperature and solar radiation fluxes

In a rural environment, three stages of plume behaviour can generally be identified (see Figure 33 - note that not all three stages are reached on a given day, depending on conditions). The three diagrams in Figure 33 show concentrations on the vertical axis and time on the horizontal axis. In this context, time is surrogate for distance from the one edge of the plume to the other.

Stage 1 Immediately downwind of the source, where plume centreline concentrations of oxides of nitrogen are high, ozone and nitrogen oxide are rapidly converted to nitrogen dioxide through the process of titration. Radicals are scavenged through the formation of nitric acid and the whole photochemical conversion process slows (Figure 33 left); uses sulphur dioxide as a surrogate for oxides of nitrogen). At this point, the source is a net negative contributor to ozone concentration.

Stage 2 Further downwind, diffusion has mixed oxides of nitrogen at the edge of the plume with VOC in the background air mass (in rural areas, this VOC may be a result of biogenic emissions). Because Oxides of nitrogen concentrations at the plume edge are reduced relative to the plume core, and because the rural air mass is generally NO_x-limited, efficient chemical transformation at the plume periphery will lead to net ozone production, resulting in growing ozone 'wings' (Figure 33- centre).

Stage 3 Following further diffusion, plume centreline concentrations of oxides of nitrogen are reduced and mixed with the background VOC, and the region of net ozone production extends to cover the entire crosswind expanse of the plume. Net ozone production will continue until the air mass again becomes NO_x-limited, or until nightfall (Figure 33– right)

If oxides of nitrogen from a large emitter are advected into a rural environment, either a positive or a negative change in the ozone concentration may result depending upon whether photochemical smog production within the ambient air, in the absence of the oxides of nitrogen emissions, reaches NO_x-limited conditions. This in turn is dependent on the total and relative concentrations of oxides of nitrogen and VOC, and the reactivity of the VOCs within the ambient air.

From this discussion, it can be seen that the prediction of photochemical smog concentration changes in rural and urban environments as a result of oxides of nitrogen emissions from a large isolated source is a complex process and consideration must be given to the coupled process of chemical transformation and plume transport.

8.2 Modelling Methodology

The TAPM modelling, discussed in Section 6, has used the model in tracer gas mode (i.e. no photochemistry) to quantify the potential ground-level concentrations of pollutants due to the CPP. In this section, TAPM modelling has been undertaken using the GRS (Generic Reaction Set) mode (i.e photochemistry) to predict the impact that the CPP plume has on ozone levels that may occur in the region.

The GRS mode is useful as a screening tool. To allow relatively quick model run times the chemistry has been simplified. This however, can result in over estimation of ozone concentrations, particularly in close proximity to the major sources of oxides of nitrogen.

If further clarification of the magnitude of ozone levels is required a detailed photochemical modelling study using a more sophisticated photochemical model (such as TAPM-CTM) is recommended.

Photochemical modelling requires all anthropogenic and biogenic emissions to be incorporated in the modelling where possible. This includes emissions from industry, commercial and domestic activities and vegetation. The following emissions were included in this study:

- Coolimba Power Station (constant full load)
- A background concentration of 25 ppb for ozone
- An Rsmog value of 0.3 ppb

A detailed description of model setup is provided in Section 6

8.3 Interpretation of Air Quality Impacts

Table 29 presents the concentrations of ozone at sensitive receptors and at towns located some distance from the CPP. All concentrations at sensitive receptor locations are well below the NEPM standards.

Table 29 Predicted maximum 1-hour and 4-hour ground-level concentrations of ozone at sensitive receptor locations (in ppb)

Location	Distance to power station (km)	Maximum 1-hour average[1]	Maximum 4-hour average[2]
Eneabba	16	30.4	27.5
Maximum at sensitive receptor locations	2-14	37.7	29.5
Jurian Bay	43	30.6	27.0
Badgingarra	55	34.1	31.8
Leeman	23	32.5	27.1
Green Head	27	34.1	27.0
Three Springs	70	35.5	30.2
Arrino	69	34.2	28.8
NEPM(Air) standard	--	100	80

Concentration contours of maximum 1-hour and 4-hour average ground-level concentrations of ozone are presented in Figure 34 and Figure 35. The maximum concentrations occur within 1 km of the CPP. The close proximity of the high ground-level concentrations to the stack source is likely to be a result of the immediate titration of the plume. In reality, photochemical oxidation of the primary ozone-forming pollutants is likely to occur over a greater distance downwind from the stack. Due to the limitations of the TAPM GRS model, it is likely that the high concentrations of ozone in the near-field are an over-prediction, and that these higher concentrations are more likely to occur further downwind.

9. Health Risk Assessment

In addition to the criteria air pollutants, namely, NO_X, SO_2 and PM_{10}, various other air toxics have the potential to be emitted from the CPP as a result of the combustion of coal to generate electricity. These air toxics present additional risks to the environment as they can affect human health, fauna and vegetation on varying timescales, and through different pathways such as the soil, water and bioaccumulation in plants and animals. To quantify potential impacts of these air pollutants, a health risk assessment (HRA) has been conducted. Air pollutants assessed for the HRA include specific VOCs, Persistant Organic Pollutants (POPs), metals, metalloids and halogens.

Health risks in this assessment have been characterised by comparing ground-level concentrations with statutory guideline values for each individual component. The methodology used for the HRA is consistent with the enHealth (2002) HRA framework and has been discussed with the Department of Health.

9.1 Methodology

The risk assessment undertaken for this project is a screening level risk assessment as it does not attempt to calculate the actual risk but rather assumes a worst case risk for a maximum exposed individual. This method is based on the very conservative assumption that an individual is exposed to the predicted maximum concentration for their entire life time.

This assessment takes in the generic steps of a risk assessment as follows:

1. Toxicity assessment (hazard identification)
2. Exposure assessment (based on dispersion modelling)
3. Risk characterisation

Non-carcinogenic and carcinogenic health effects have been assessed for individual emissions and a cumulative assessment has been undertaken to assess the potential combined impacts assuming all components are additive.

In order to characterise the risk, dispersion modelling has been used to predict the maximum short term and long term concentration of all emissions from the power station. The modelling results have then been compared to guidelines, standards and risk factors published by organisations such as the National Environment Protection Council (NEPC), National Health and Medical Research Council (NHMRC) and the World Health Organisation (WHO). For the speciation of possible VOC the Texas Commission on Environmental Quality Toxicological Section list of Effects Screening Levels have been used in the absence of other available guidelines.

9.2 Hazard Identification\Toxicity Assessment

Table 30 presents the potential air pollutants of concern associated with the combustion of coal at the CPP. These substances are typical of the emissions from a coal-fired power station. The list of potential air pollutants was compiled by PB (see PB, 2009) in consultation with emission estimation techniques (such as NPI) and information determined from the analysis of coal extracted from the Central West Coal deposit.

The International Agency for Research on Cancer has identified six of the potential pollutants emitted from the power station as being possible or probable human carcinogens including arsenic, cadmium, some PAHs, nickel, chromium and benzene (as a possible VOC). These pollutants will be assessed using the WHO cancer unit risk to determine the level of risk. These are listed in Table 30 along with general comments in relation to each pollutant.

The assessment of risk presented by each substance has been determined from predicted ground-level concentrations estimated from the dispersion modelling and scaled according to each pollutant's emission rate (presented in kilograms per year in Table 31). The maximum short-term and long-term concentrations predicted anywhere within the modelling domain (not just at identified local sensitive receptors) have been used in this assessment. This will give a very conservative estimate of the possible maximum exposure likely at any residential location.

Table 30 Comment on the pollutants emitted from the coal-fired power station

Parameter	Carcinogenic	Comments
Sulfur Dioxide	No	Inhalation exposure for acute and chronic effects
Nitrogen dioxide	No	Inhalation exposure for acute and chronic effects
Carbon monoxide	No	Hypoxic
PM_{10}	No	Inhalation exposure for acute and chronic effects
VOC	No for all except for Benzene	Inhalation exposure for acute and chronic effects Benzene is a genotoxic carcinogen
Fluoride	No	Vegetation is more sensitive than human exposure
PAH	Yes	Genotoxic
Dioxins & Furans	Yes	Non-genotoxic
Arsenic	Yes	Genotoxic
Boron	No	Exposure through food
Cadmium	Yes	Genotoxic
Lead	No	Chronic
Mercury	No	Chronic
Selenium	No	Acute and chronic
Chromium	No	Chronic
Copper	No	Acute and chronic
Nickel	Yes	Genotoxic
Vanadium	No	Acute and chronic

Table 31 Estimated annual emissions for Coolimba Power Station

Parameter	Emission rate (kg/yr)
Sulfur dioxide	15,324,131
Nitrogen dioxide	6,419,437
Carbon monoxide	2,537,095
Particulate matter (as PM_{10})	626,896
Volatile Organic Compounds (VOC)	87,765
Fluoride	183,541
Polycyclic aromatic hydrocarbons (PAH)	39
Persistent Organic Pollutants (Dioxins & Furans)	0.003
Arsenic	269
Boron	15,714
Cadmium	52
Lead	68
Mercury	267
Selenium	1,797
Chromium	1,156
Copper	816
Nickel	2,193
Vanadium	304
Note: Annual emissions have been calculated assuming maximum emission rate for 365 days per year. Emission rates supplied by Parsons Brinckerhoff (2009)	

9.3 Exposure Assessment

Two dispersion modelling scenarios (with and without data assimilation) have been used to determine the worst case exposure due to the coal-fired power station emissions. Due to the nature of the CPP's operations and the variable nature of contaminants contained in the coal, the emissions will vary significantly. The emission rates used in the risk assessment have assumed the peak emissions are occurring 365 days a year and the maximum prediction was taken from either of the modelling scenarios to represent the maximum possible exposure. For some pollutants, such as SO_2, this is extremely conservative. Notwithstanding this, we have presented results for the 75th and 100th percentile emission rate for SO_2.

Three exposure pathways have been investigated in this risk assessment.

- Inhalation (hazard indices)
- Oral (through deposition on roofs and collection in water tanks and deposition to soil)
- Dermal (through deposition to soil)

9.4 Risk Characterisation Results

The results of the screening level risk assessment are presented in the following sections.

9.4.1 Hazard Quotients and Hazard Indices

For this risk assessment a hazard quotient (HQ) is calculated for each pollutant using the following equation.

HQ = Estimated ground level concentration / Health based air quality guideline

To quantify the total health risk of mixtures of air pollutants, it is common to sum the hazard quotients to obtain a hazard index (HI). This process assumes that the toxicological effect of each pollutant is additive. This is common practice for use in screening level health risk assessments as it is an extremely conservative assumption. The general rule when interpreting a hazard index is as follows:

- Values less than 1 present no cause for concern
- Values greater than 1 may be a cause for concern and warrant further consideration and refinement of assumptions.

For the CPP, the Acute Hazard Index (AHI) has been determined for two emission scenarios; the 75th and 100th percentiles for SO_2 emissions (assuming the flue gas desulfurisation system is operating), and are presented in Table 32 and Table 33 based on the maximum ground-level concentration within the modelling domain and at a sensitive receptor location, respectively. The assessment indicates the AHI is above 1 for the maximum concentration within the modelling domain for both the maximum and 75th percentile SO_2 emission scenarios. Notwithstanding this, the AHI is below 1 for both SO_2 emission scenarios for the predicted maximum ground-level concentration at a sensitive receptor location and the maximum 99.9th percentile concentration within the modelling domain is also below the AHI of 1. As the maximum in the domain and sensitive receptors do not co-exist, there is likely to be a low risk of health effects from acute exposure to air pollutants from the proposed power station.

The acute hazard assessment has also included fluoride with a comparison to the vegetation guidelines in the absence of available human health guidelines. WHO recommends that human health will be well protected by the vegetation guidelines. The only human health acute exposure standard found in the current literature is that recommended by the California Environment Protection Agency Air Resources Board of 240 µg/m^3 (compared to the vegetation standard of 3.7 µg/m^3). Therefore the use of the vegetation guideline is very conservative.

The Chronic Hazard Index (CHI) has been calculated for all pollutants with an annual average guideline value and is presented in Table 34. The Hazard index is well below one and therefore shows the health risk is low for chronic exposure.

Table 32 Acute Hazard Index for the maximum concentration within the modelling domain, calculated for the 75th percentile and 100th percentile SO_2 emissions for the Coolimba Power Project during normal operations

Pollutant	GLCs (µg/m^3)		Guideline/ Standard (µg/m³)	Hazard Quotients	
	Maximum	99.9th ile		Maximum	99.9th ile
SO_2 [a]	543.8	225.5	570	0.954	0.396
SO_2 [b]	765.7	317.5	570	1.343	0.557
NO_2 [c]	70.1	28.3	256	0.274	0.110
CO [d]	58.4	24.2	11250	0.005	0.002
PM_{10} [d]	4.1	1.5	50	0.082	0.030
Vanadium [e]	0.002	0.001	1	0.002	0.0007
Fluoride [e]	1.204	0.441	3.7	0.325	0.1191
Selenium	0.064	0.026	2	0.032	0.0132
Copper	0.029	0.012	10	0.003	0.0012
1,1,1-Trichloroethane	0.007	0.003	10800	0.000	0.0000
2,4-Dinitrotoluene	0.000	0.000	1.5	0.000	0.0000
2-Chloroacetophenone	0.002	0.001	3.2	0.001	0.0003
Acetaldehyde	0.194	0.080	20	0.010	0.0040
Acetophenone	0.005	0.002	490	0.000	0.0000
Acrolein	0.099	0.041	2.3	0.043	0.0178
Benzene	0.442	0.183	29	0.015	0.0063
Benzyl chloride	0.238	0.099	50	0.005	0.0020
Bis(2-ethylhexyl)phthalate (DEHP)	0.025	0.010	50	0.000	0.0002
Bromoform	0.013	0.005	50	0.000	0.0001
Carbon disulfide	0.044	0.018	30	0.001	0.0006
Chlorobenzene	0.007	0.003	460	0.000	0.0000
Chloroform	0.020	0.008	10	0.002	0.0008
Cumene	0.002	0.001	500	0.000	0.0000
Cyanide	0.849	0.352	50	0.017	0.0070
Dimethyl sulfate	0.016	0.007	5	0.003	0.0014
Ethyl benzene	0.032	0.013	2000	0.000	0.0000
Ethyl chloride	0.014	0.006	500	0.000	0.0000
Ethylene dibromide	0.000	0.000	4	0.000	0.0000
Ethylene dichloride	0.014	0.006	160	0.000	0.0000
Formaldehyde	0.082	0.034	15	0.005	0.0023
Hexane	0.023	0.009	70	0.000	0.0001
Isophorone	0.197	0.082	230	0.001	0.0004
Methyl bromide	0.054	0.023	120	0.000	0.0002
Methyl chloride	0.180	0.075	1030	0.000	0.0001
Methyl ethyl ketone	0.133	0.055	3900	0.000	0.0000
Methyl hydrazine	0.058	0.024	0.2	0.289	0.1198
Methyl methacrylate	0.007	0.003	340	0.000	0.0000

Pollutant	GLCs (µg/m^3)		Guideline/ Standard (µg/m³)	Hazard Quotients	
	Maximum	99.9th ile		Maximum	99.9th ile
Methyl tert butyl ether	0.012	0.005	450	0.000	0.0000
Methylene chloride	0.099	0.041	260	0.000	0.0002
Phenol	0.005	0.002	150	0.000	0.0000
Propionaldehyde	0.129	0.054	20	0.006	0.0027
Styrene	0.008	0.004	110	0.000	0.0000
Tetrachloroethylene	0.015	0.006	2000	0.000	0.0000
Toluene	0.082	0.034	640	0.000	0.0001
Vinyl acetate	0.003	0.001	150	0.000	0.0000
Xylenes	0.013	0.005	3700	0.000	0.0000
Acute Hazard Index [a]				**2.079**	**0.839**
Acute Hazard Index [b]				**2.468**	**1.000**

[g/ma] SO_2: 75th percentile emission rate of 1,100 mg/Nm^3
[b] SO_2: 100th percentile emission rate of 1,549 mg/Nm^3
[c] NO_2/NO_x ratio of 30% assumed
[d] 8 hour average
[e] 24 hour average

Table 33 Acute Hazard Index for the maximum concentration at a receptor, calculated for the 75th percentile and 100th percentile SO_2 emissions for the Coolimba Power Project during normal operations

Pollutant	GLCs (µg/m^3)		Guideline/ Standard (µg/m³)	Hazard Quotients	
	Maximum	99.9th ile		Maximum	99.9th ile
SO_2 [a]	213.6	128.9	570	0.375	0.226
SO_2 [b]	300.7	181.4	570	0.528	0.318
NO_2 [c]	27.0	16.6	256	0.105	0.065
CO [d]	22.9	13.8	11250	0.002	0.001
PM_{10} [d]	1.8	0.7	50	0.036	0.014
Vanadium [e]	0.002	0.001	1	0.002	0.0007
Fluoride [e]	0.529	0.199	3.7	0.143	0.0538
Selenium	0.025	0.000	2	0.013	0.0000
Copper	0.011	0.007	10	0.001	0.0007
1,1,1-Trichloroethane	0.003	0.002	10800	0.000	0.0000
2,4-Dinitrotoluene	0.000	0.000	1.5	0.000	0.0000
2-Chloroacetophenone	0.001	0.001	3.2	0.000	0.0002
Acetaldehyde	0.076	0.046	20	0.004	0.0023
Acetophenone	0.002	0.001	490	0.000	0.0000
Acrolein	0.039	0.023	2.3	0.017	0.0102
Benzene	0.173	0.105	29	0.006	0.0036
Benzyl chloride	0.093	0.056	50	0.002	0.0011
Bis(2-ethylhexyl)phthalate (DEHP)	0.010	0.006	50	0.000	0.0001
Bromoform	0.005	0.003	50	0.000	0.0001
Carbon disulfide	0.017	0.010	30	0.001	0.0003
Chlorobenzene	0.003	0.002	460	0.000	0.0000
Chloroform	0.008	0.005	10	0.001	0.0005
Cumene	0.001	0.000	500	0.000	0.0000
Cyanide	0.334	0.201	50	0.007	0.0040
Dimethyl sulfate	0.006	0.004	5	0.001	0.0008
Ethyl benzene	0.013	0.008	2000	0.000	0.0000
Ethyl chloride	0.006	0.003	500	0.000	0.0000
Ethylene dibromide	0.000	0.000	4	0.000	0.0000
Ethylene dichloride	0.005	0.003	160	0.000	0.0000
Formaldehyde	0.032	0.019	15	0.002	0.0013
Hexane	0.009	0.005	70	0.000	0.0001
Isophorone	0.077	0.047	230	0.000	0.0002
Methyl bromide	0.021	0.013	120	0.000	0.0001
Methyl chloride	0.071	0.043	1030	0.000	0.0000
Methyl ethyl ketone	0.052	0.031	3900	0.000	0.0000
Methyl hydrazine	0.023	0.014	0.2	0.113	0.0684

Pollutant	GLCs (µg/m³)		Guideline/ Standard (µg/m³)	Hazard Quotients	
	Maximum	99.9th ile		Maximum	99.9th ile
Methyl methacrylate	0.003	0.002	340	0.000	0.0000
Methyl tert butyl ether	0.005	0.003	450	0.000	0.0000
Methylene chloride	0.039	0.023	260	0.000	0.0001
Phenol	0.002	0.001	150	0.000	0.0000
Propionaldehyde	0.051	0.031	20	0.003	0.0015
Styrene	0.003	0.002	110	0.000	0.0000
Tetrachloroethylene	0.006	0.003	2000	0.000	0.0000
Toluene	0.032	0.019	640	0.000	0.0000
Vinyl acetate	0.001	0.001	150	0.000	0.0000
Xylenes	0.005	0.003	3700	0.000	0.0000
Acute Hazard Index [a]				**0.834**	**0.456**
Acute Hazard Index [b]				**0.987**	**0.548**

[a] SO_2: 75th percentile emission rate of 1,100 mg/Nm³
[b] SO_2: 100th percentile emission rate of 1,549 mg/Nm³
[c] NO_2/NO_x ratio of 30% assumed
[d] 8 hour average
[e] 24 hour average

Table 34 Chronic Hazard Index for the maximum concentration on the grid, calculated for the Coolimba Power Project during normal operations

Pollutant	Annual GLC (µg/m³)	Guideline/Standard (µg/m³)	Hazard Quotient
SO_2	4.45E+00	60	7.42E-02
NO_2	6.03E-01	60	1.01E-02
PAH	1.13E-05	0.0003	3.78E-02
Arsenic	7.81E-05	0.006	1.30E-02
Cadmium	1.50E-05	0.005	2.99E-03
Lead	1.98E-05	0.5	3.97E-05
Mercury	7.77E-05	1	7.77E-05
Selenium	5.22E-04	0.2	2.61E-03
Copper	2.37E-04	1	2.37E-04
Nickel	6.37E-04	0.02	3.19E-02
1,1,1-Trichloroethane	5.56E-05	1080	5.15E-08
2,4-Dinitrotoluene	7.79E-07	0.15	5.19E-06
2-Chloroacetophenone	1.95E-05	0.32	6.08E-05
Acetaldehyde	1.59E-03	2	7.93E-04
Acetophenone	4.17E-05	49	8.52E-07
Acrolein	8.07E-04	0.23	3.51E-03
Benzene	3.62E-03	10	3.62E-04
Benzyl chloride	1.95E-03	5	3.89E-04
Bis(2-ethylhexyl)phthalate (DEHP)	2.03E-04	5	4.06E-05

Pollutant	Annual GLC (µg/m³)	Guideline/Standard (µg/m³)	Hazard Quotient
Bromoform	1.08E-04	5	2.17E-05
Carbon disulfide	3.62E-04	3	1.21E-04
Chlorobenzene	6.12E-05	46	1.33E-06
Chloroform	1.64E-04	10	1.64E-05
Cumene	1.47E-05	50	2.95E-07
Cyanide	6.95E-03	5	1.39E-03
Dimethyl sulfate	1.34E-04	0.5	2.67E-04
Ethyl benzene	2.61E-04	200	1.31E-06
Ethyl chloride	1.17E-04	50	2.34E-06
Ethylene dibromide	3.34E-06	0.4	8.35E-06
Ethylene dichloride	1.11E-04	4	2.78E-05
Formaldehyde	6.68E-04	3.3	2.02E-04
Hexane	1.86E-04	7	2.66E-05
Isophorone	1.61E-03	23	7.01E-05
Methyl bromide	4.45E-04	12	3.71E-05
Methyl chloride	1.47E-03	130	1.13E-05
Methyl ethyl ketone	1.08E-03	390	2.78E-06
Methyl hydrazine	4.73E-04	0.02	2.36E-02
Methyl methacrylate	5.56E-05	34	1.64E-06
Methyl tert butyl ether	9.74E-05	45	2.16E-06
Methylene chloride	8.07E-04	26	3.10E-05
Phenol	4.45E-05	15	2.97E-06
Propionaldehyde	1.06E-03	2	5.29E-04
Styrene	6.95E-05	140	4.97E-07
Tetrachloroethylene	1.20E-04	26	4.60E-06
Toluene	6.68E-04	4000	1.67E-07
Vinyl acetate	2.11E-05	15	1.41E-06
Xylenes	1.03E-04	37	2.78E-06
		Chronic Hazard Index	**0.20445**
[a] SO_2 emission rate of 1100 mg/Nm^3			

9.4.2 Cancer risk

The risk associated with prolonged exposure to a carcinogenic substance is calculated as the product of the average lifetime exposure to a pollutant and its estimated carcinogenic potency, and expressed as a unit risk factor. For airborne carcinogens, the unit is generally 1 µg/m³ and depending on the nature of the data used to determine the potency, the numerical value refers to the probability of developing cancer. For example, cadmium carries a risk of 1 in 555 chance of developing cancer for a lifetime exposure to 1 µg/m³; meaning that if 555 people were exposed to 1 µg/m³ of cadmium for their lifetime then one individual may develop cancer. This probability is expressed as 0.18 in 100, or 1.8 x10^{-3} per µg/m³, written as 1.80E-03 $(\mu g/m^3)^{-1}$. The generally accepted risk criterion that has been used in this assessment is 1.0E-06, i.e. with a lifetime exposure there is one chance in a million of developing cancer.

The unit risk factors used in this assessment are based on those recommended by the WHO. Table 35 and Table 36 present the estimated inhalation cancer risk for all carcinogenic air pollutants emitted from the proposed Coolimba coal-fired plant for maximum on the modelling domain and maximum at a sensitive receptor location respectively. The assessment indicates the combined cancer risk for all carcinogenic pollutants is slightly more than one in a million for the maximum predicted annual average concentration assuming maximum emissions for an entire year. The assumption that all the PAH emissions are Benzo(a)pyrene is also very conservative as the AP42 emission factors for coal fired boilers indicates the main PAHs are naphthalene, biphenyl and phenanthrene. None of which are as toxic as benzo(a)pyrene or listed carcinogens.

The estimated cancer risk for the most exposed sensitive receptor is less than one in a million, and consequently presents a low risk of developing cancer due air emissions from the power station. Notwithstanding this low risk outcome, the very conservative assumptions applied to the assessment mean the ultimate risk associated with exposure to carcinogenic substances emitted by the CPP coal-fired plant are minimal.

Table 35 Cancer risk estimates for the Coolimba Power Project during normal operations and based on the predicted maximum ground-level concentrations anywhere on the model domain

Pollutant	Annual GLC (µg/m³)	Unit Risk Factor [d] $(\mu g/m^3)^{-1}$	Cancer Risk
Benzene [a]	3.62E-03	6.00E-06	2.17E-08
PAH [b]	1.13E-05	8.70E-02	9.86E-07
Arsenic	7.81E-05	1.50E-03	1.17E-07
Chromium (VI) [c]	1.68E-06	4.00E-02	6.72E-08
Nickel	6.37E-04	4.00E-04	2.55E-07
Cadmium	1.50E-05	1.80E-03	2.70E-08
		Cancer Risk	1.47E-06

[a] Assume component of total VOCs as estimated in AP42
[b] Assume all PAH is BaP
[c] Cr(VI) estimate of 0.5% (PB, 2009)
[d] WHO unit risk factors

Table 36 Cancer risk estimates for the maximum concentration at a receptor for the Coolimba Power Project during normal operations and based on the predicted maximum ground-level concentrations at the sensitive receptor locations

Pollutant	Annual GLC ($\mu g/m^3$)	Unit Risk Factor [d] ($(\mu g/m^3)^{-1}$)	Cancer Risk
Benzene [a]	1.22E-02	6.00E-06	7.32E-08
PAH [b]	5.42E-06	8.70E-02	4.72E-07
Arsenic	3.74E-05	1.50E-03	5.61E-08
Chromium (VI) [c]	8.04E-07	4.00E-02	3.21E-08
Nickel	3.05E-04	4.00E-04	1.22E-07
Cadmium	7.16E-06	1.80E-03	1.29E-08
		Cancer Risk	7.68E-07

[a] Assume component of total VOCs as estimated in AP42
[b] Assume all PAH is BaP
[c] Cr(VI) estimate of 0.5% (PB, 2009)
[d] WHO unit risk factors

9.5 Deposition to Soil – Oral and Dermal Pathways

The deposition of air pollutants to soil was estimated using the method detailed in the Air Toxics Hot Spot Program Guidance Manual for Preparation of Health Risk Assessments (California Environmental Protection Agency, 2003). The health risk that may be associated with the deposition of pollutants to soil was estimated using the following assumption:

- Maximum annual average concentration on modelling domain
- Maximum emissions of all pollutants assumed for entire year
- Exposure period of 70 years
- Soil mixing depth of 0.01 metres (recommended for children's playgrounds)
- Deposition rate of 0.02 m/s
- Chemical half life as recommended by Cal EPA (2003)
- Soil bulk density of 1,333 kg/m^3
- All PAH emissions are assumed to be benzo(a)pyrene

The results are presented in Table 37 and compared to the health based soil investigation levels recommended by EnHealth (2001). These soil investigation levels protect against adverse health risk associated with ingestion or dermal exposure to soil. For all pollutants the estimated deposition to soil is very low and well below the health based investigation levels.

Table 37 Deposition to soil (oral and dermal pathway) for the Coolimba Power Project during normal operations

Pollutant	Maximum Annual GLC (µg/m³)	Maximum Deposition (µg/m^2/day)	Soil Conc (mg/kg)	Ref Value [a] (mg/kg)	% of ref Value
Benzo(a)pyrene	5.42E-06	9.37E-03	5.59E-04	20	0.003%
Dioxins and Furans	4.34E-10	7.49E-07	3.42E-08	3.00E-05	0.114%
Arsenic	3.74E-05	6.46E-02	7.66E-07	100	0.000%
Cadmium	7.16E-06	1.24E-02	1.47E-07	20	0.000%
Lead	9.49E-06	1.64E-02	1.94E-07	300	0.000%
Mercury	3.72E-05	6.42E-02	7.62E-07	15	0.000%
Chromium (VI)	1.61E-04	2.78E-01	3.29E-06	100	0.000%
Nickel	3.05E-04	5.27E-01	6.25E-06	600	0.000%

[a] Health based soil investigation level EnHealth, 2001. Exposure setting A 'Standard' residential with garden/accessible sour (home grown produce contributing to less than 10% of vegetable and fruit intake; no poultry): includes child care centres, school and kindergartens.
[b] Estimated using standard approach used in Australia (see Appendix D)

9.6 Deposition to Water – Oral Pathway

The deposition to water has been estimated as the quantity of each pollutant deposited on a roof and subsequently collected in a rainwater tank. Deposition of air pollutants on roofs was estimated for each air pollutant using the method detailed in the Air Toxics Hot Spot Program Guidance Manual for Preparation of Health Risk Assessments (California Environmental Protection Agency, 2003). The quantity of air pollutants that may be deposited on roofs and transferred to rainwater tanks was estimated using the following assumptions:

- Maximum annual average concentration on modelling domain
- Maximum emissions of all pollutants assumed for entire year
- Roof surface area of 600m^2
- Rain water tank capacity of 50,000 litres
- Deposition rate of 0.02 m/s
- The material deposited on the roof is washed into the water tank
- Annual average rainfall of 505 mm
- All PAH emissions are assumed to be benzo(a)pyrene

Table 38 presents the predicted maximum concentration of each pollutant that is emitted from the power station that may be deposited on roofs and transferred to rainwater tanks. Predicted pollutant concentrations in water have been compared to the Australian Drinking Water Standards (NHMRC, 2004). These standards protect against adverse health risk associated with ingestion of affected drinking water. The results indicate that all pollutant concentrations are well below the reference values and therefore should not present any risk to human health.

Table 38 Deposition to drinking water (oral pathway) for the Coolimba Power Project during normal operations

Pollutant	Maximum Annual GLC (µg/m³)	Maximum Deposition (µg/m^2/day)	Water Concentration µg/kg/day	Reference Value [a] (µg/kg)	Percent of Reference Value
Benzo(a)pyrene	5.42E-06	9.37E-03	6.77E-03	0.01	67.7%
Dioxins and Furans	4.34E-10	7.49E-07	5.42E-07	8.20E-06 [b]	6.61%
Arsenic	3.74E-05	6.46E-02	4.67E-02	7	0.67%
Cadmium	7.16E-06	1.24E-02	8.95E-03	2	0.45%
Lead	9.49E-06	1.64E-02	1.18E-02	10	0.12%
Mercury	3.72E-05	6.42E-02	4.64E-02	1	4.64%
Chromium (VI)	1.61E-04	2.78E-01	2.01E-01	50	0.40%
Nickel	3.05E-04	5.27E-01	3.81E-01	20	1.90%
Boron	4.57E-03	7.89E+00	5.70E+00	4000	0.14%
Copper	2.37E-04	4.10E-01	2.96E-01	2000	0.01%
Selemium	5.22E-04	9.02E-01	6.52E-01	10	6.52%

[a] Australian Drinking Water Guidelines, NHMRC (2004). Note reference values have been converted from mg/L to µg/kg by multiplying by a factor of 1000.
[b] Estimated using standard approach used in Australia (see Appendix D)

10. Greenhouse Gas Emissions

10.1 Background to Greenhouse Gases

The Greenhouse Effect is the process by which the absorption of infrared (long wave) radiation by certain gases present in the atmosphere, commonly known as the greenhouse gases, will warm the Earth's surface and lower atmosphere. Greenhouse gases of particular importance are those that are found in the troposphere in substantial concentrations, and those which possess a strong radiative forcing. Important greenhouse gases include:

- Water vapour (H_2O)
- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)

Indirect greenhouse gases such as carbon monoxide (CO), nitrogen oxides other than N_2O and non-methane volatile organic compounds (NMVOCs) do not have a strong radiative forcing effect in themselves, but influence atmospheric concentrations of the direct greenhouse gases.

Water vapour is the major contributor to the greenhouse effect but is not normally considered because fluxes are dominated by the day-to-day precipitation cycle. Carbon dioxide is the next most significant greenhouse gas and the major anthropogenic contributor.

The relative importance of a greenhouse gas is measured in terms of its global warming potential (GWP), usually related to a GWP of 1 for CO_2. N_2O and CO_2 are greenhouse gases that are associated with combustion activities, such as occur in the combustion of coal and natural gas to generate electricity at the CPP. CO_2 tends to remain active for a lifetime of around 150 years and has a GWP of 1 on a 100 year timeframe. N_2O has a lifetime of 120 years and a GWP of 310 on a 100 year timeframe. CH_4 has a lifetime of 14.5 years and a GWP of 21 on a 100 year timeframe. Whilst N_2O and CH_4 have a greater potential to cause global warming, carbon dioxide is produced in far greater quantities by anthropogenic activities than N_2O and CH_4 and consequently, CO_2 is the most important greenhouse gas.

Greenhouse gas emissions are reported in terms of tonnes of CO_2 equivalent (tCO_2-e). CO_2 equivalents are calculated as the sum of the emission rate of each greenhouse gas multiplied by the global warming potential.

As follows: tCO_2-e = tonnes CO_2 x 1.0 + tonnes CH_4 x 21 + tonnes N_2O x 310.

10.2 Kyoto Protocol and the Australian Greenhouse Gas Emissions Target

In December 2007, the Australian government ratified the Kyoto Protocol, an international agreement designed to restrict the growth in the emission of greenhouse gases in developing countries to the quantity being emitted in 1990. This target was expected to be met over the five year period from 2008 – 2012.

The Kyoto Protocol was established in 1997, and to date 178 countries have ratified the agreement. Each developed country's target was negotiated and agreed internationally on an individual basis. Australia committed to monitor and report greenhouse gas emissions and has set a target level for emissions of 108% of estimated emissions for 1990 or 598.076 Mt CO_2-e.

10.3 Estimation of Greenhouse Gas Emissions

The Australian Greenhouse Office (AGO) is a part of the Commonwealth Department of Climate Change. The AGO monitors and compiles databases on anthropogenic activities that produce greenhouse gases in Australia. The AGO has published greenhouse gas emission factors for a range of anthropogenic activities. The AGO methodology for calculating greenhouse gas emissions is published in the National Greenhouse Accounts (NGA) Factors workbook (AGO 2008) and is based on Australian data. This workbook is updated regularly to reflect current compositions in fuel mixes and evolving information on emission sources. The most recent publication at the time of the preparation of this PER was released in October 2008.

10.3.1 Greenhouse Gas Generating Activities

The NGA Factors workbook broadly outlines all of the activities responsible for the generation of greenhouse gases and categorises them as direct and indirect emissions. The following excerpt from the NGA Factors workbook (AGO 2008) outlines the activities responsible for greenhouse gas generation:

> *Direct and Indirect Emissions*
>
> *Direct emissions are produced from sources within the boundary of an organisation and as a result of that organisation's activities. These emissions mainly arise from the following activities:*
>
> - *generation of energy, heat, steam and electricity, including carbon dioxide and products of incomplete combustion (methane and nitrous oxide)*
> - *manufacturing processes which produce emissions (for example, cement, aluminium and ammonia production)*
> - *transportation of materials, products, waste and people; for example, use of vehicles owned and operated by the reporting organisation*
> - *fugitive emissions: intentional or unintentional GHG releases (such as methane emissions from coal mines, natural gas leaks from joints and seals)*
> - *on-site waste management, such as emissions from landfill sites*
>
> *In this workbook, emission factors are provided as applicable, for each of the following greenhouse gases:*
>
> - *carbon dioxide*
> - *methane*
> - *nitrous dioxide*
> - *synthetic gases*
>   - *HFCs, SF_6, CF_4, C_2F_6*

All factors are standardised by being expressed as a carbon dioxide equivalents (CO2-e).

10.3.2 Emissions Factors

The workbook details a method for the calculation of an activity's greenhouse gas intensity through the use of emission factors that relate the quantity of fuel or energy consumed to a quantity of CO_2-e emitted for that fuel over a given period of time. These emission factors have been determined on an average basis, where for example, rates of CO_2 released for coal combustion have been based on the average properties of coal for each Australian state. This method is adequate if specific analysis of the coal resource has not been undertaken or if multiple coal resources are consumed by the facility. In the case of the CPP, the power station has been proposed to specifically utilise the coal resource of the CWCP. While this coal source has been analysed for the purposes of this PER and the development of the project, and estimate of the greenhouse gas intensity for coal combustion has been calculated from NGA Factors. The following excerpt from the NGA Factors workbook (AGO 2008) outlines the types of emissions associated with greenhouse gas generation:

Types of Emission Factors

Firstly, it is important to note that an emission factor is activity-specific. The activity determines the emission factor used. The scope that emissions are reported under is determined by whether the activity is within the organisation's boundary (direct—scope 1) or outside it (indirect—scope 2 and scope 3).

- *Direct (or point-source) emission factors give the kilograms of carbon dioxide equivalent (CO_2-e) emitted per unit of activity at the point of emission release (i.e. fuel use, energy use, manufacturing process activity, mining activity, on-site waste disposal, etc.). These factors are used to calculate scope 1 emissions.*

- *Indirect emission factors are used to calculate scope 2 emissions from the generation of the electricity purchased and consumed by an organisation as kilograms of CO_2-e per unit of electricity consumed. Scope 2 emissions are physically produced by the burning of fuels (coal, natural gas, etc.) at the power station.*

- *Various emission factors can be used to calculate scope 3 emissions. For ease of use, this workbook reports specific 'scope 3' emission factors for organisations that:*

  a) burn fossil fuels: to estimate their indirect emissions attributable to the extraction, production and transport of those fuels; or

  b) consume purchased electricity: to estimate their indirect emissions from the extraction, production and transport of fuel burned at generation and the indirect emissions attributable to the electricity lost in delivery in the T&D network.

The definition, methodologies and application of scope 3 factors are currently subject to international discussions.

10.3.3 Greenhouse Gas Emissions Calculation

Energy consumption related to the following activities at the CPP have been provided by Parsons Brinckerhoff based on the their design specifications:

- Combustion of coal fuel in the boiler for the coal-fired power station
- Combustion of natural gas fuel in the gas turbines for the gas-fired power station
- Combustion of automotive diesel fuel for transport associated with:
  - removal of ash and gypsum
  - delivery of limestone
  - coal and limestone stockpile management

The greenhouse gas intensity for each activity has been calculated using the simplified equation as follows:

Equation 1

$$GHG = E * EF * CF$$

Where:

GHG: Annual greenhouse gas emissions tonnes of carbon dioxide equivalents (tCO_2-e)
E: Annual fuel input energy (GJ/yr)
EF: emissions factors for CO_2, CH_4 and N_2O (kg CO_2-e /GJ) (AGO, 2008a)
CF: capacity factor (%)

The total annual CO_2-e emissions are the sum of the CO_2-e emissions for each of the various gases (CO_2, CH_4 and N_2O).

10.3.4 Greenhouse Gas Producing Activities and Emission Factors

10.3.4.1 Fuel Combustion Emissions - Solid Fuels

Table 39 presents the estimated annual CO_2-e emissions from the combustion of coal in the boiler for the coal-fired power station. Table 40 presents the estimated annual CO_2-e emissions from the calcination of limestone in the coal-fired boiler for the flue gas desulfurisation system.

Table 39 Estimated greenhouse intensity for the combustion of coal in the coal-fired power station

Parameter	Units	Value		
Electrical Energy	MW	450		
Net Plant efficiency (HHV)	%	32.8		
Coal input energy	MW	1,372		
Capacity factor	%	95		
Estimated annual fuel energy consumption	GJ/yr	41,132,175.84		
		Carbon dioxide	Methane	Nitrous oxide
Emission factor[1]	g CO_2-e /MJ	88.2	0.03	0.2
Estimated annual CO_2-e emissions by compound	t CO_2-e/yr	3,627,857.91	1,233.97	8,226.44
Estimated annual total CO_2-e emissions	t CO_2-e/yr	3,637,318.3		
[1]National Greenhouse Accounts Factors (AGO 2008a)				

Table 40 Estimated greenhouse intensity for the calcination of limestone in the flue gas desulfurisation system for the coal-fired power station

Parameter	Units	Value
Design coal sulfur content	% ad	2.26
Coal consumption (per unit)	kg/s ad	26.18
Sulfur into boiler	kg/s	0.59
Sulphur atomic weight	g/mol	32.07
Calcium atomic weight	g/mol	40.08
Carbon atomic weight	g/mol	12.01
Oxygen atomic weight	g/mol	16.00
Atomic weight of $CaCO_3$	g/mol	100.09
Ca/S mole ratio	-	1.9
$CaCO_3$ / Sulphur mass ratio	-	5.93
$CaCO_3$ injection rate	kg/s	3.51
CO_2 / CaCO3 mass ratio	-	0.44
CO_2-e generation per unit	kg/s	1.54
No. of units	-	3
CO_2-e for 3 units	kg/s	4.63
Capacity factor	%	95
Estimated annual total CO_2-e emissions	tCO_2-e/yr	138,756

10.3.4.2 Fuel Combustion Emissions –Gaseous Fuels

Table 41 presents the estimated annual CO_2-e emissions from the combustion of natural gas fuel in the gas turbines for the gas-fired power station.

Table 41 Estimated greenhouse intensity for the combustion of natural in the gas-fired power station

Parameter	Units	Value		
Nominal electrical energy	MW	179.9		
Net plant efficiency (HHV)	%	32.98		
Gas input energy	MW	541.15		
Capacity Factor	%	25		
Gas input energy	GJ/yr	4,269,342.45		
		Carbon dioxide	**Methane**	**Nitrous oxide**
Emission factor[1]	kg CO_2-e/GJ	51.2	0.1	0.03
Estimated annual CO_2-e emissions by compound	tCO_2-e/yr	218,590.33	426.93	128.08
Estimated annual total CO_2-e emissions	tCO_2-e/yr	219,145.35		

[1]National Greenhouse Accounts Factors (AGO 2008a)

10.3.4.3 Fuel Combustion Emissions - Liquid Fuels

The annual energy consumed (GJ/yr) as fuel in diesel vehicles is determined from the average vehicle engine power and annual number and duration of trips. Emission factors have been extracted from the NGA Factors workbook (AGO 2008). The most conservative emission factor relating heavy vehicle diesel oil, based on the Euro I design standard of 69.9 kg CO_2-e/GJ, has been applied. The capacity factor of 95% has also been applied to the estimated total annual energy consumption. In order to account for any margin of error in estimation, a conservative 10% margin has also been added.

Transport Fuel Emissions from the Removal and Disposal of Ash and Gypsum Waste Products from the Boiler

Table 42 presents the transportation related greenhouse gas emissions for the removal and storage of waste products from the boiler such as gypsum and ash.

Table 42 Estimated greenhouse intensity for the combustion of automotive diesel fuels used in ash and gypsum transport

Parameter	Units	Value		
Assumed truck volume	m^3	75		
Total ash mass per day	tonnes/day	2,401		
Approx bulk density	kg/m^3	1,000		
Ash volume	m^3/day	2,401		
No. trips / day	N/A	33		
Rated engine power of 785C	kW	1,085		
Average vehicle power in service	kW	500		
Average efficiency	%	30%		
Average power consumed	kW	1,666.7		
Assumed trip duration (return)	mins	60		
Estimated daily fuel energy consumption	GJ/day	198		
Estimated annual fuel energy consumption	GJ/yr	68,703.53		
		Carbon dioxide	**Methane**	**Nitrous oxide**
Emission Factors[1]	kg CO_2-e/GJ	69.2	0.2	0.5
Estimated annual CO_2-e emissions by compound	t CO_2-e/yr	4,754.284	13.741	34.352
Estimated annual total CO_2-e emissions	t CO_2-e/yr	4,802.376		
Applied margin of error	%	10		
Estimated annual total CO_2-e emissions with margin of error	t CO_2-e/yr	5,282.61		

[1] Heavy vehicles conforming to Euro design standards - Euro I diesel oil total emission factor of 69.9 kg CO_2-e/GJ

Transport Fuel Emissions from Delivery of Limestone for the Flue Gas Desulfurisation System

Table 43 presents the transportation related greenhouse gas emissions for the delivery of limestone for the flue gas desulfurisation system.

Table 43 Estimated greenhouse intensity for the combustion of automotive diesel fuels used limestone delivery

Parameter	Units	Value		
Limestone per day	t	1,070		
B-Double capacity	t	80		
Loads per day	N/A	14		
Rated engine power - Mack Titan	kW	431		
Average vehicle power in service	kW	258.6		
Average efficiency	%	30%		
Average fuel energy consumed	kW	862		
Hours per load (return)	hrs	3		
Estimated daily fuel energy consumption	GJ/day	130.3344		
Estimated annual fuel energy consumption	GJ/yr	45,224.41		
		Carbon dioxide	**Methane**	**Nitrous oxide**
Emission Factors[1]	kg CO_2-e/GJ	69.2	0.2	0.5
Estimated annual CO_2-e emissions by compound	t CO_2-e/yr	3,129.529	9.045	22.612
Estimated annual total CO_2-e emissions	t CO_2-e/yr	3,161.186		
Applied margin of error	%	10		
Estimated annual total CO_2-e emissions with margin of error	t CO_2-e/yr	3,477.30		

[1] Heavy vehicles conforming to Euro design standards - Euro i diesel oil total emission factor of 69.9 kg CO_2-e/GJ

Transport Fuel Emissions associated with Coal and Limestone Stockpile Management

Table 44 presents the transportation related greenhouse gas emissions for the management of coal and limestone stockpiles.

Table 44 Estimated greenhouse intensity for the combustion of automotive diesel fuels used in coal and limestone stockpile management

Parameter	Units	Value		
Rated engine power - Caterpillar 973C	kW	178		
No. Loaders	-	3		
Total engine power	kW	534		
Assumed average vehicle power in service	kW	373.8		
Average efficiency	%	30%		
Average fuel energy consumed	kW	1246		
Hours per day in service	hrs	12		
Estimated daily fuel energy consumption	GJ/day	53.8272		
Estimated annual fuel energy consumption	GJ/yr	18,677.37		
		Carbon dioxide	**Methane**	**Nitrous oxide**
Emission Factors[1]	kg CO_2-e/GJ	69.2	0.2	0.5
Estimated annual CO_2-e emissions by compound	t CO_2-e/yr	3,877.421	11.206	28.016
Estimated annual total CO_2-e emissions	t CO_2-e/yr	3,916.644		
Applied margin of error	%	10		
Estimated annual total CO_2-e emissions with margin of error	t CO_2-e/yr	4,308.31		

[1] Heavy vehicles conforming to Euro design standards - Euro i diesel oil total emission factor of 69.9 kg CO_2-e/GJ

10.3.4.4 Total Annual Greenhouse Gas Intensity for the Coolimba Power Project

Table 45 presents a summary of the estimated total annual greenhouse gas intensity for the CPP.

Table 45 Summary of the estimated total annual greenhouse gas intensity for the CPP

Fuel Type	Activity	GHG by Compound ($t\ CO_2$-e)			Total Annual GHG $t\ CO_2$-e
		CO_2	CH_4	N_2O	
Solid Fuels	Combustion of coal in boiler	3,627,857.91	1,233.97	8,226.44	3,637,318.31
	Limestone calcination	138,756	0	0	138,756
Gaseous Fuels	Combustion of natural gas in gas turbine	218,590.33	426.93	128.08	219,145.35
Liquid Fuels[a]	Combustion of diesel for transport of ash and gypsum	5,229.71	15.11	37.79	5,282.61
	Combustion of diesel for limestone delivery	3,442.48	9.95	24.87	3,477.30
	Combustion of diesel for coal and limestone stockpile management	4,265.16	12.33	30.82	4,308.31
Total GHG ($t\ CO_2$-e)		3,855,624.53	1,687.42	8,420.82	4,008,287.88
Total GHG ($Mt\ CO_2$-e)		3.856	0.002	0.008	4.008
[a] Includes nominal margin of error of 10%					

Australia's assigned amount of greenhouse gas emissions under the Kyoto Protocol is 108% of Australia's estimated emissions for 1990 or 598.076 $MtCO_2$-e. Total emissions from the CPP are 4.008 Mt CO_2-e or 0.67% of Australia's assigned amount under the Kyoto Protocol.

10.4 Opportunities for Future Carbon Offsets

The offsetting and abatement of greenhouse gas emissions from the generation of energy through the consumption of carbon-based fossil fuels presents one of the greatest challenges facing Australia and the world today.

Table 46 outlines some potential opportunities and actions to address the growth in greenhouse gas emissions and to offset the emissions associated with the development of the CPP.

Table 46 Opportunities and actions for the abatement and offsetting of greenhouse gas emissions

Opportunity	Action

Plant production efficiency	• Minimise/reduce energy generation inefficiencies through the following:
	  o Routine monitoring of coal boiler and gas turbine efficiency
	  o Operate plant at optimum efficiency in accordance with manufacturer's operation and maintenance
	• Implement a routine preventative maintenance and cleaning regime to maintain operation of the power station at optimal efficiency.
	• Implement a "continuous improvement approach" so that advances in technology and potential operational improvements of plant performance are adopted where practicable.

Management systems and monitoring	• Annual auditing of greenhouse gas emissions; • Fund energy efficient programs • Employment of a Greenhouse Program Officer • Undertake an annual review of state of the art mitigation measures to identify advances in technology and potential operational improvements of plant performance that are relevant for gas-turbines. Investigate the feasibility of implementing these technological or operational improvements at the CPP.
Research	• Investment into research on Carbon Capture and Storage (CCS) technology for the abatement of greenhouse gas emissions • Investment into sustainable, non-fossil fuel based energy generating technologies to provide a diversified energy production mix • Investment into research on supply side energy generating efficiency and demand side energy usage
Carbon offsetting	• Participation in a carbon trading markets • Purchasing of carbon credits • Offsetting of greenhouse gas emissions through investment into carbon sinks such as tree planting and the preservation of old growth forests

11. Conclusions

An air quality impact assessment, a health risk screening assessment and an assessment of estimated greenhouse gas intensity has been conducted for the proposed Coolimba Power Project to be located approximately 15 km south-southwest of Eneabba in Western Australia. The assessment was conducted using CSIRO's TAPMv3.0.7 dispersion model.

The air quality assessment focussed on the impacts to air quality associated with the emission of criteria air pollutants such as oxides of nitrogen, sulphur dioxide and particles as PM_{10} from the coal- and gas-fired power stations. A suite of air toxics were assessed as part of the health risk assessment, while secondary pollutants such as ozone were also assessed.

The following conclusions can be drawn from the air quality assessment for the proposed CPP:

- For emissions during normal operations –

  Human Health

  - There are no exceedances predicted of the NEPM(Air) standard for human health for the 1-hour and annual average ground-level concentration of NO_2 due to the proposed CPP, operating at full capacity under normal conditions, at any location within the modelled domain.

  - There are no exceedances predicted of the NEPM(Air) standard or Kwinana EPP guideline for the 1-hour, 24-hour and annual average ground-level concentration of SO_2 due to the proposed CPP, operating at full capacity under normal conditions, at any location within the modelled domain.

  - There are no exceedances predicted of the NEPM(Air) standard for the 24-hour average ground-level concentration of PM_{10} due to the proposed CPP, operating at full capacity under normal conditions, at any location within the modelled domain.

  Vegetation

  - There are no exceedances predicted of the WHO guidelines for vegetation for the annual average ground-level concentration of NO_X and SO_2 due to the proposed CPP, operating at full capacity under normal conditions, at any location within the modelled domain.

  - There are no exceedances predicted of the ANZECC guidelines for vegetation for the 12-hour, 24-hour, 30 day and 90 day average ground-level concentration of fluoride due to the proposed CPP, operating at full capacity under normal conditions, at any location within the modelled domain.

- For emissions during non-normal operations –

  Human Health

  - An exceedence of the NEPM(Air) standard for the 1-hour average of SO_2 is likely on one to five days per year due to non-operation of the desulfurisation unit for 1 to 5% of the year respectively.

- An exceedence of the NEPM(Air) standard for the 1-hour average of SO_2 is likely on one day per year due to non-operation of the desulfurisation unit for 5% of the year at the nearest sensitive receptor locations.

- No exceedences of the NEPM(Air) standard for the 1-hour average of SO_2 are predicted near the town of Eneabba due to non-operation of the desulfurisation unit for up to 5% of the year.

- In relation to ozone generation:

  - The maximum 1-hour average ground-level concentration of ozone at a populated town or isolated sensitive receptor predicted to be less than 40 ppb, 40% of the NEPM(Air) standard.

  - The predicted maximum 4-hour average ground-level concentration of ozone at a populated town or isolated sensitive receptor is 32 ppb at Badgingarra, approximately 40% of the NEPM(Air) standard.

- In relation to health risks from acute and chronic exposure and the risk of developing cancer from exposure to air emissions:

  - The risks to human health from acute exposure to air emissions from the CPP are low
  - The risks to human health from chronic exposure to air emissions from the CPP are low
  - The risk of developing cancer from exposure to air emissions from the CPP is low

- In relation to greenhouse gas emissions:

  - The total contribution to greenhouse gas emissions from the CPP are estimated to be 3.87 Mt CO_2-e per annum. This represents or 0.65% of Australia's assigned amount under the Kyoto Protocol.

12. References

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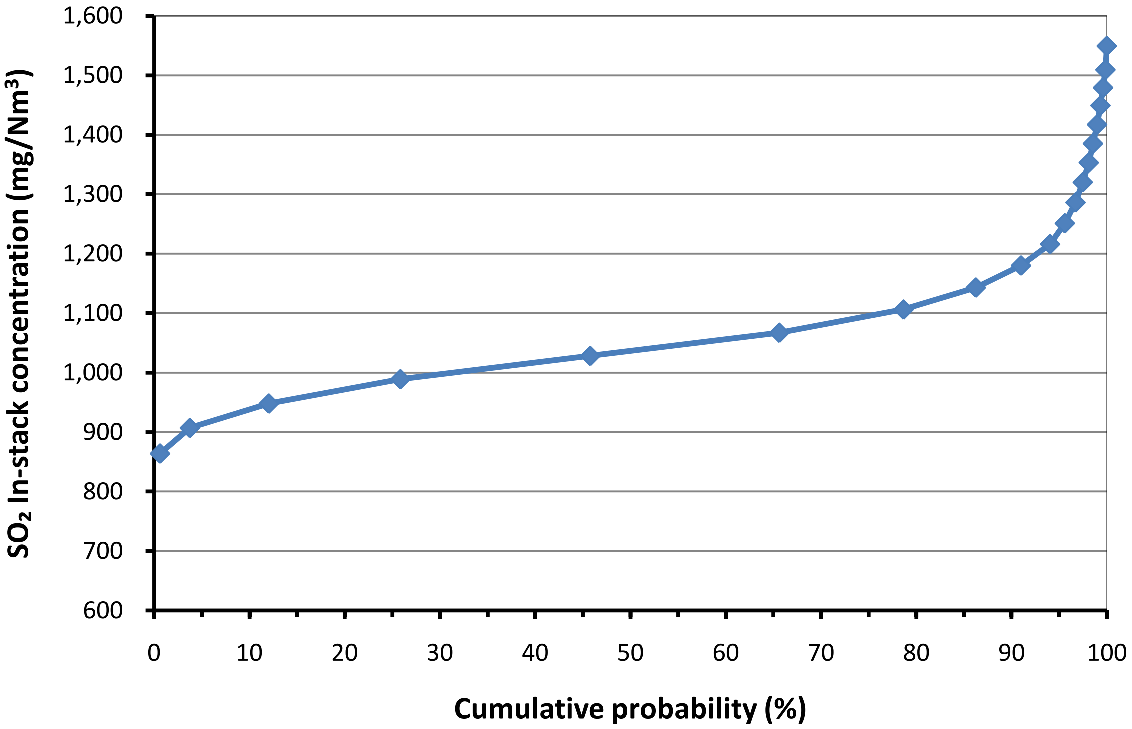

Figure 1 Cumulative distribution of in-stack SO_2 concentrations

Location: N/A	**Averaging period:** N/A	**Data source:** Emissions Spreadsheet	**Units:** % and mg/Nm^3
Type: Cumulative frequency distribution		**Prepared by:** A. Schloss	**Date:** 6/08/2008

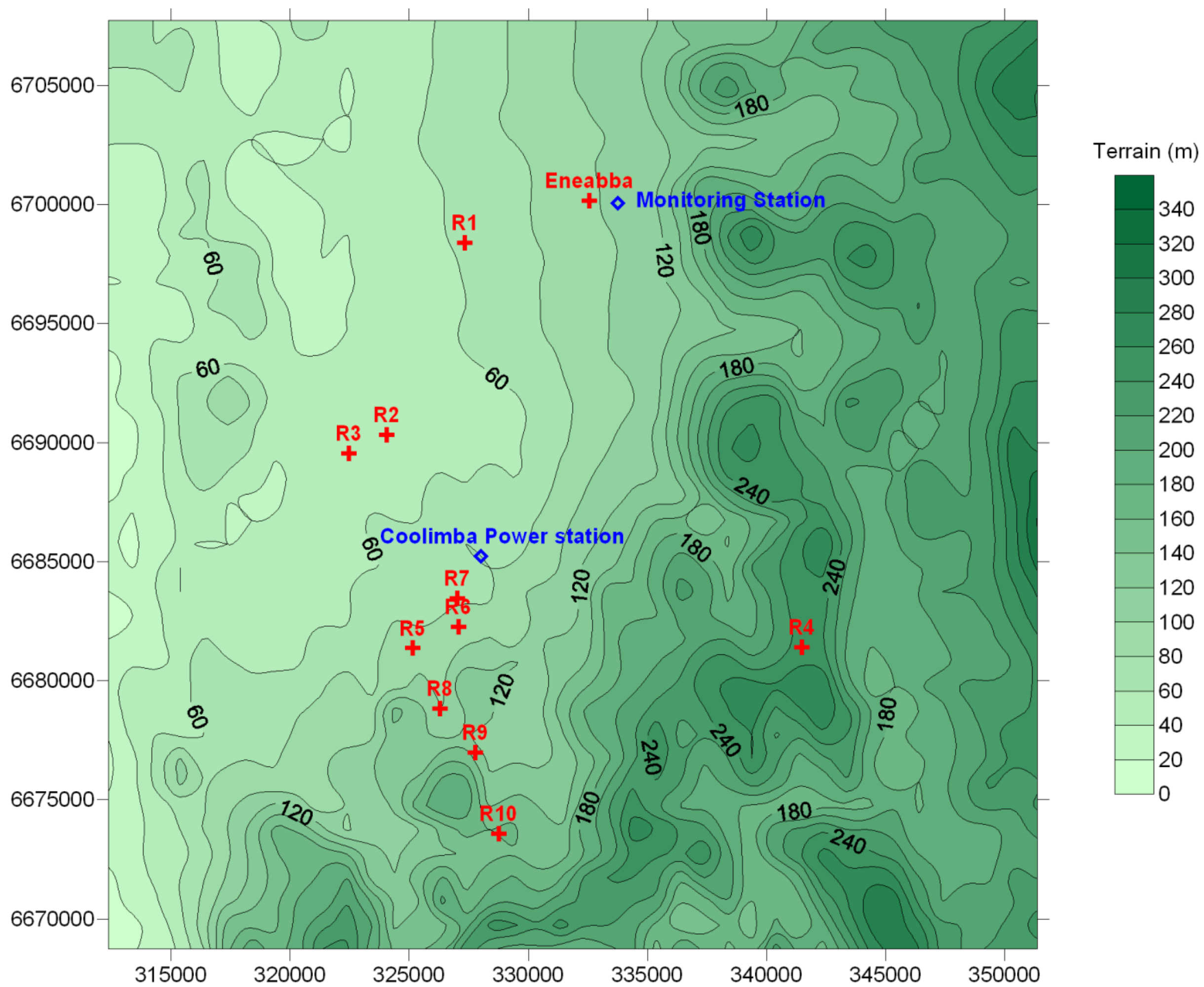

Figure 2	**Terrain contour map indicating the locations of the Coolimba Power Project, the town of Eneabba, the Iluka Resources monitoring station and the sensitive receptors**		
Location: Eneabba, W.A. region	**Period:** N/A	**Data source:**	**Units:** Australian Map Grid coordinates – GDA94
Type: Contour map		**Prepared by:** A. Schloss	**Date:** 10/10/08

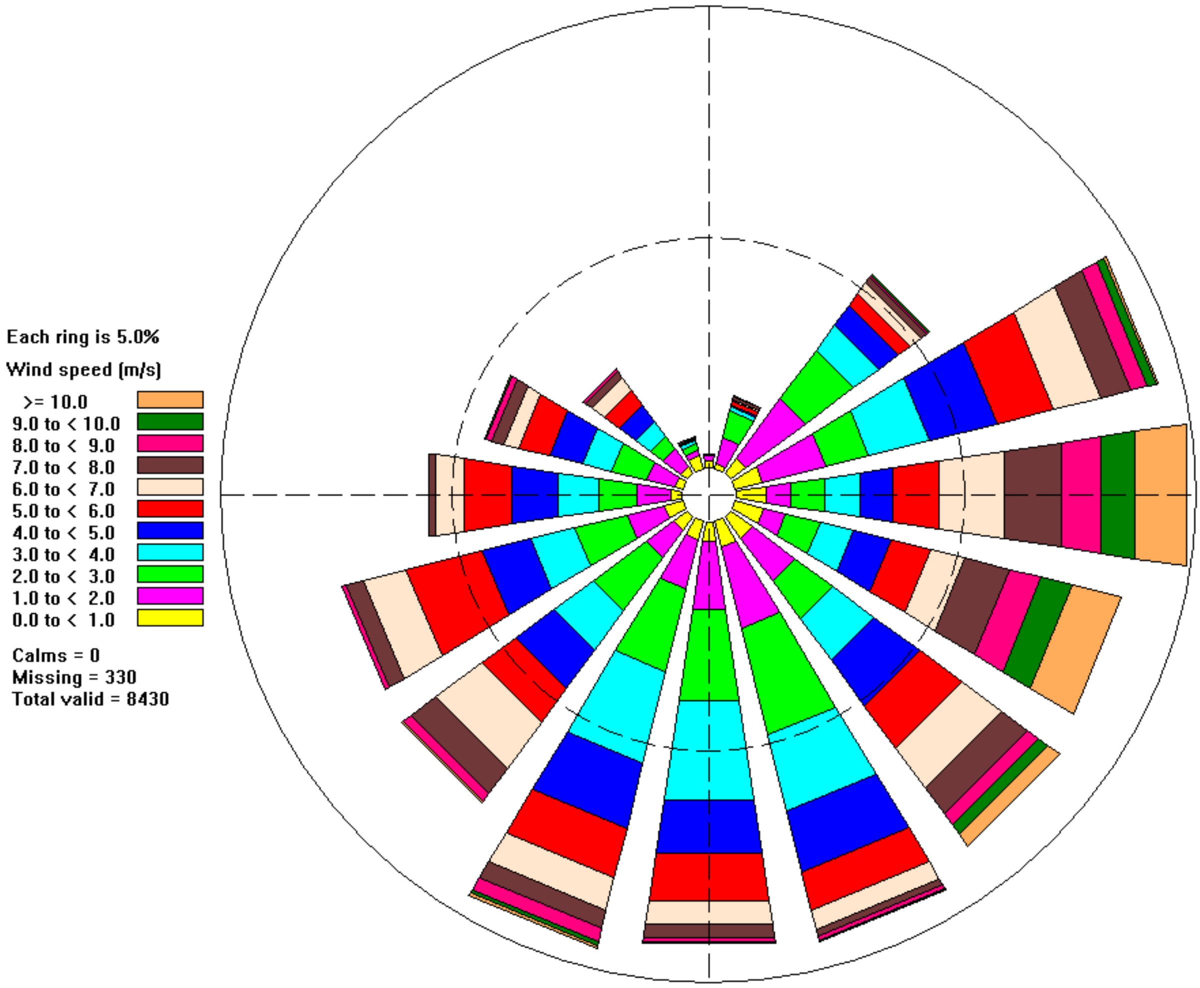

Figure 3 Annual distribution of wind speed and direction for the Iluka Resources meteorological station near Eneabba

Location: Iluka Resources meteorological station near Eneabba	**Period:** 1/05/06 – 1/05/07	**Data source:** Generated by Iluka Resources	**Units:** Degrees and metres per second
Type: Annual wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 10/10/08

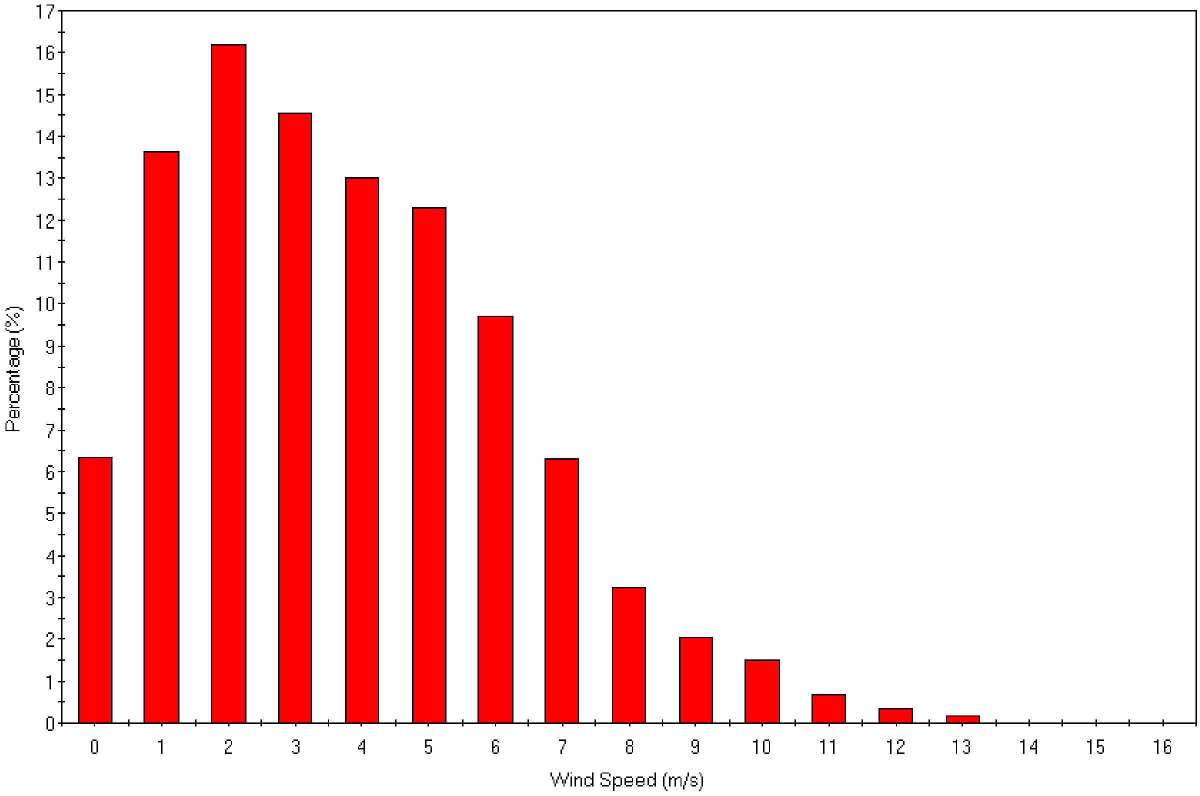

Figure 4 Frequency distribution of annual wind speed Iluka Resources meteorological station near Eneabba

Location: Iluka Resources meteorological station near Eneabba	**Period:** 1/05/06 – 1/05/07	**Data source:** Generated by Iluka Resources	**Units:** Percentage and metres per second
Type: Frequency distribution of annual wind speed	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 10/10/08

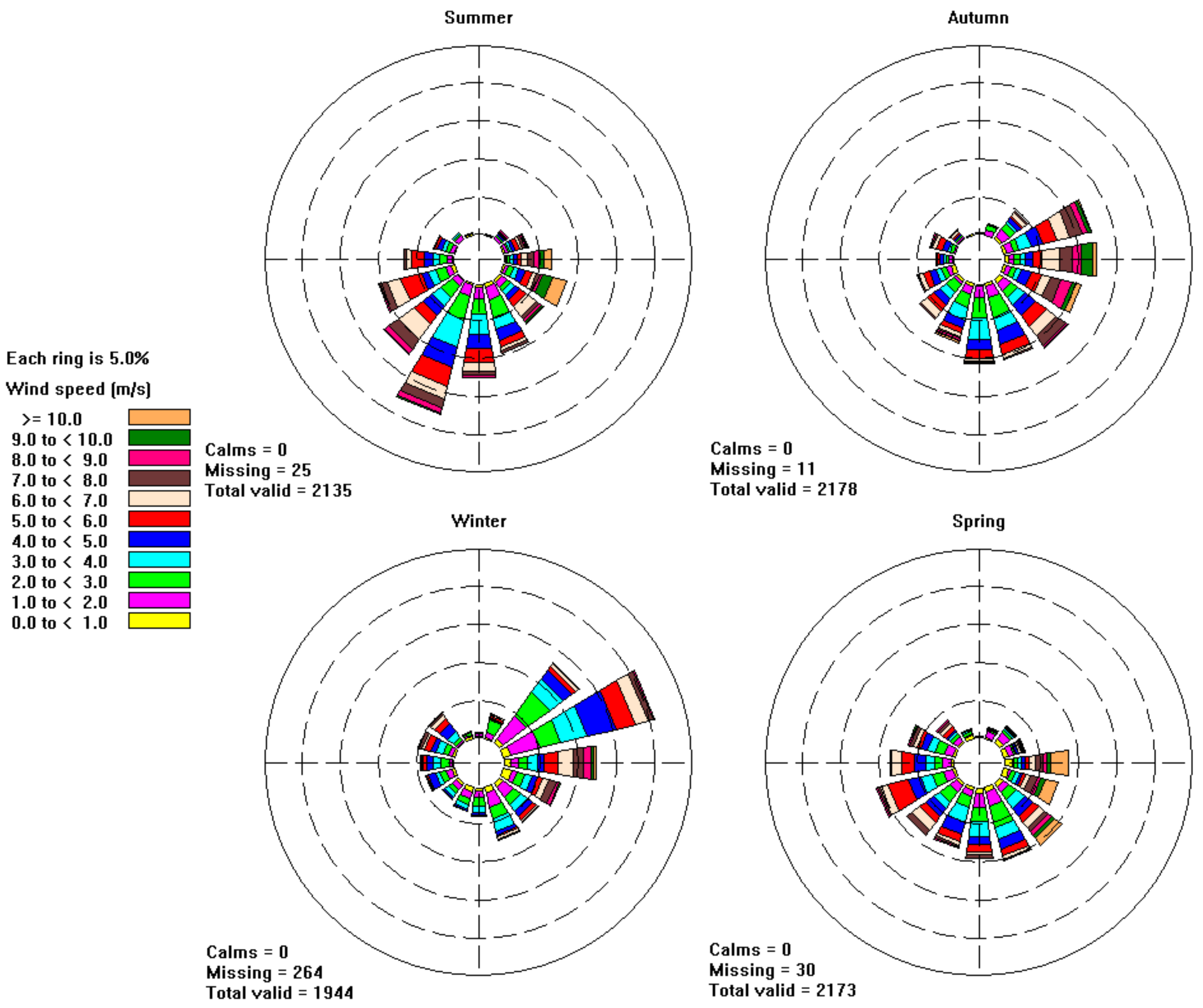

Figure 5 Seasonal distribution of wind speed and direction for the Iluka Resources meteorological station near Eneabba

Location: Iluka Resources meteorological station near Eneabba	**Period:** 1/05/06 – 1/05/07	**Data source:** Generated by Iluka Resources	**Units:** Degrees and metres per second
Type: Seasonal wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 10/10/08

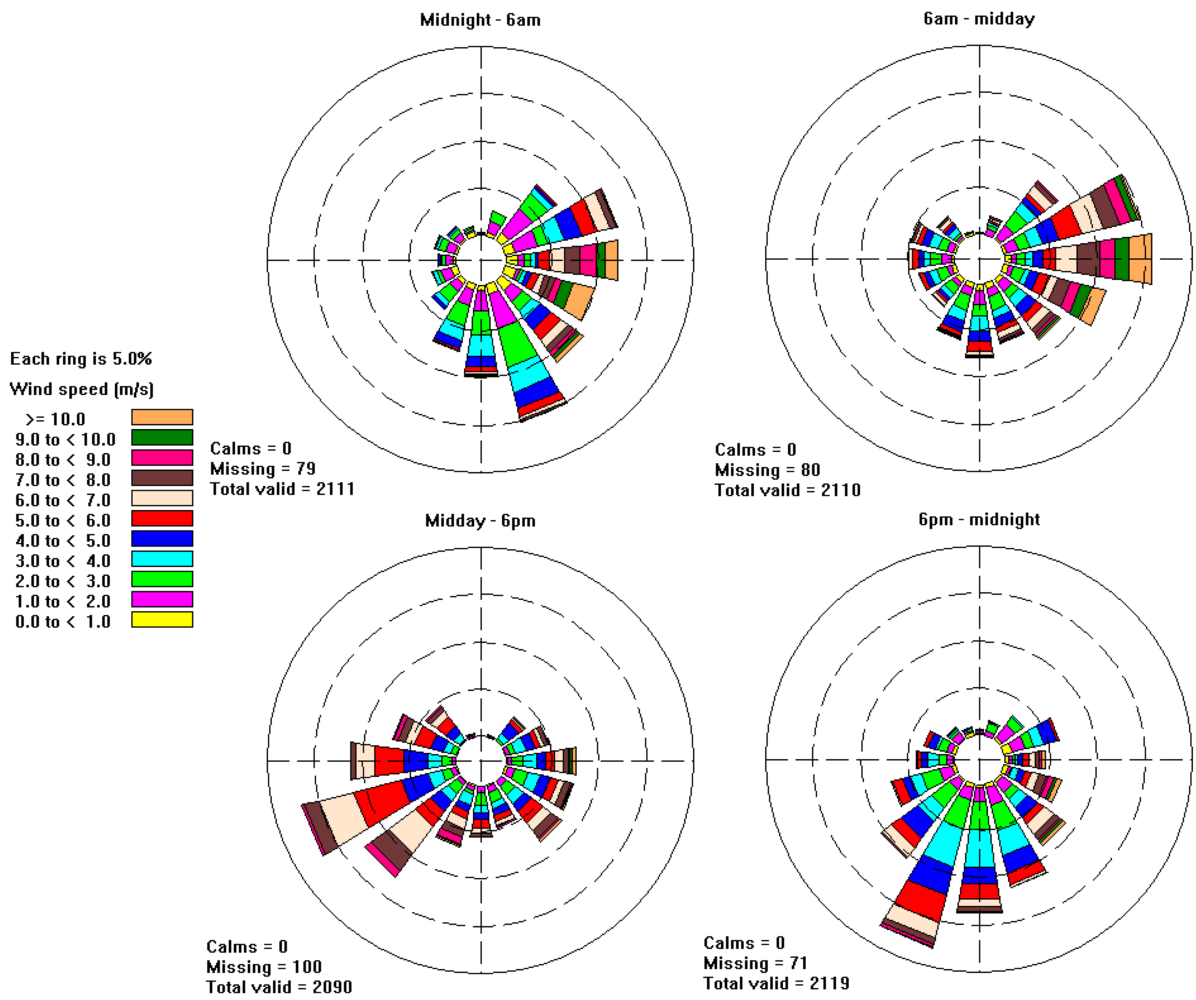

Figure 6 **Diurnal distribution of wind speed and direction for the Iluka Resources meteorological station near Eneabba**

Location: Iluka Resources meteorological station near Eneabba	**Period:** 1/05/06 – 1/05/07	**Data source:** Generated by Iluka Resources	**Units:** Degrees and metres per second
Type: Diurnal wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 10/10/08

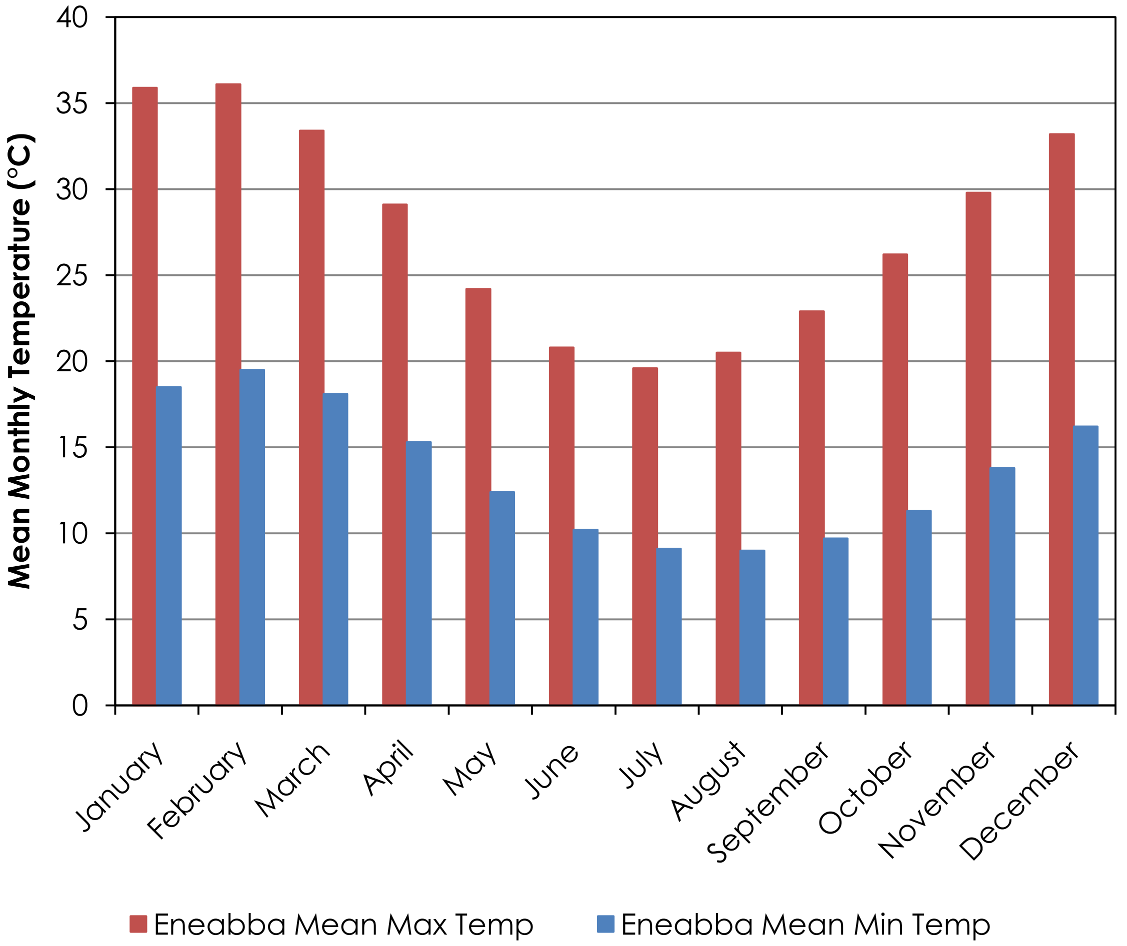

Figure 7 Mean maximum and minimum temperatures for Eneabba

Location: Eneabba	**Period:** 1972 - 2008	**Data source:** Bureau of Meteorology	**Units:** Celsius
Type: Histogram		**Prepared by:** A. Schloss	**Date:** 24/09/2008

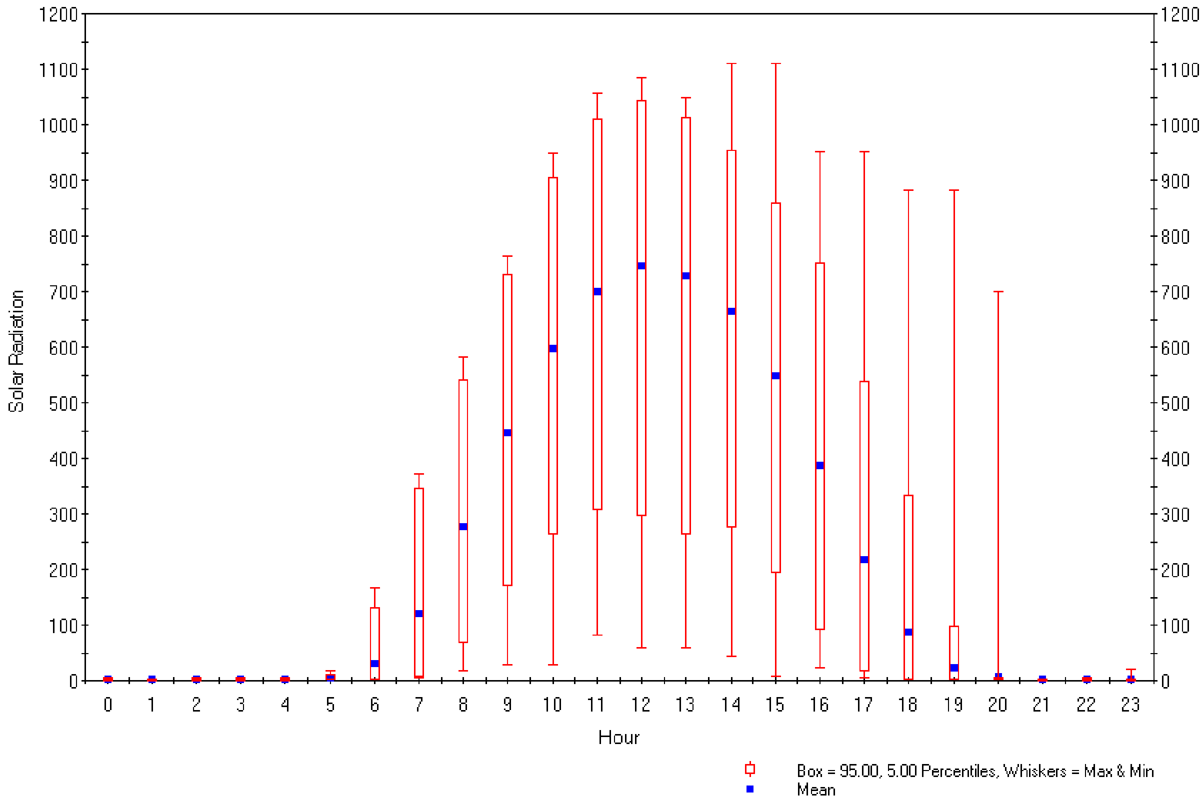

Figure 8 Mean daily solar exposure for Eneabba

Location: Eneabba	**Period:** 1/05/06 – 1/05/07	**Data source:** Iluka Resources	**Units:** Watts per square metre
Type: Box and whisker plot		**Prepared by:** A. Balch	**Date:** 10/10/2008

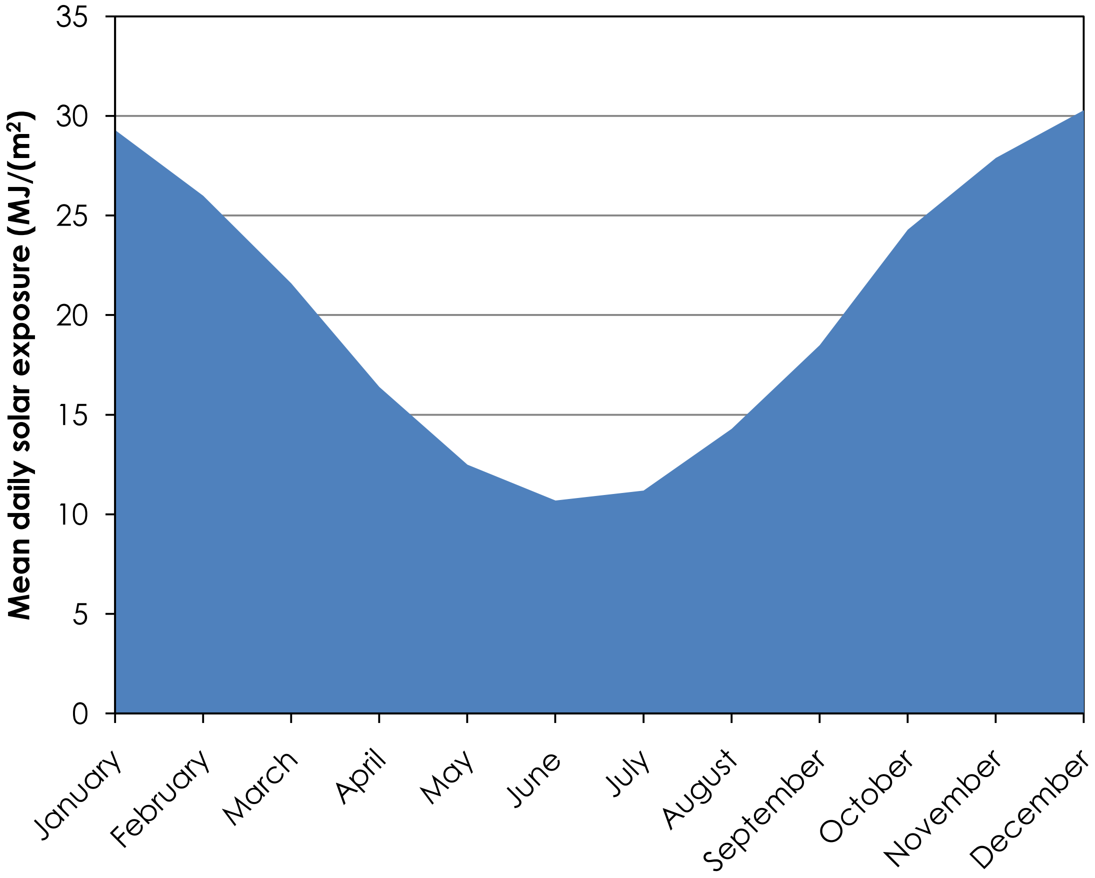

Figure 9 **Mean daily solar exposure for Eneabba**

Location: Eneabba	**Period:** 1990 - 2008	**Data source:** Bureau of Meteorology	**Units:** Megajoules per square metre
Type: Line graph		**Prepared by:** A. Schloss	**Date:** 24/09/2008

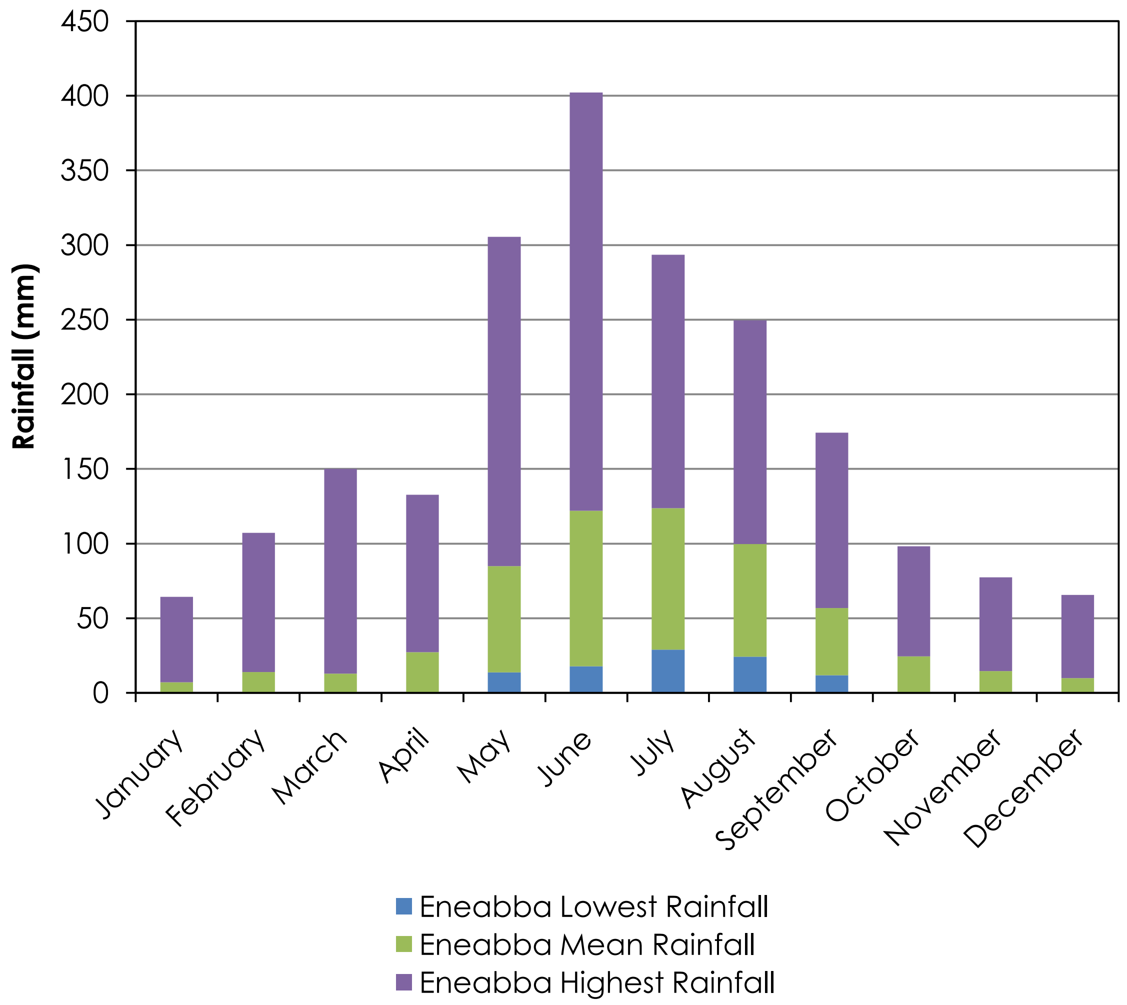

Figure 10 Range of lowest, average and highest monthly rainfall for Eneabba

Location: Eneabba	**Period:** 1964 - 2008	**Data source:** Bureau of Meteorology	**Units:** millimetres
Type: Stacked Histogram		**Prepared by:** A. Schloss	**Date:** 24/09/2008

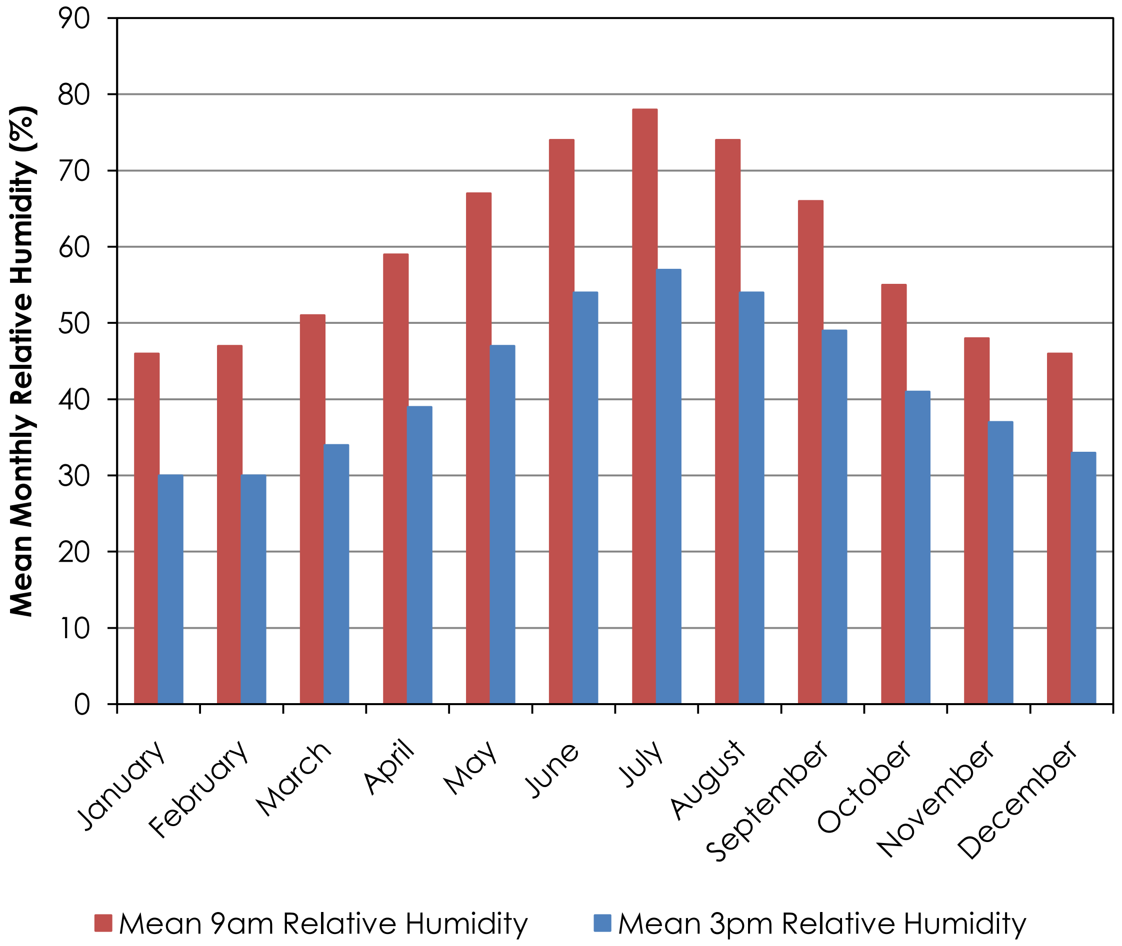

Figure 11 Mean 9am and 3pm relative humidity for Eneabba

Location: Eneabba	**Period:** 1976 - 2008	**Data source:** Bureau of Meteorology	**Units:** millimetres
Type: Stacked Histogram		**Prepared by:** A. Schloss	**Date:** 24/09/2008

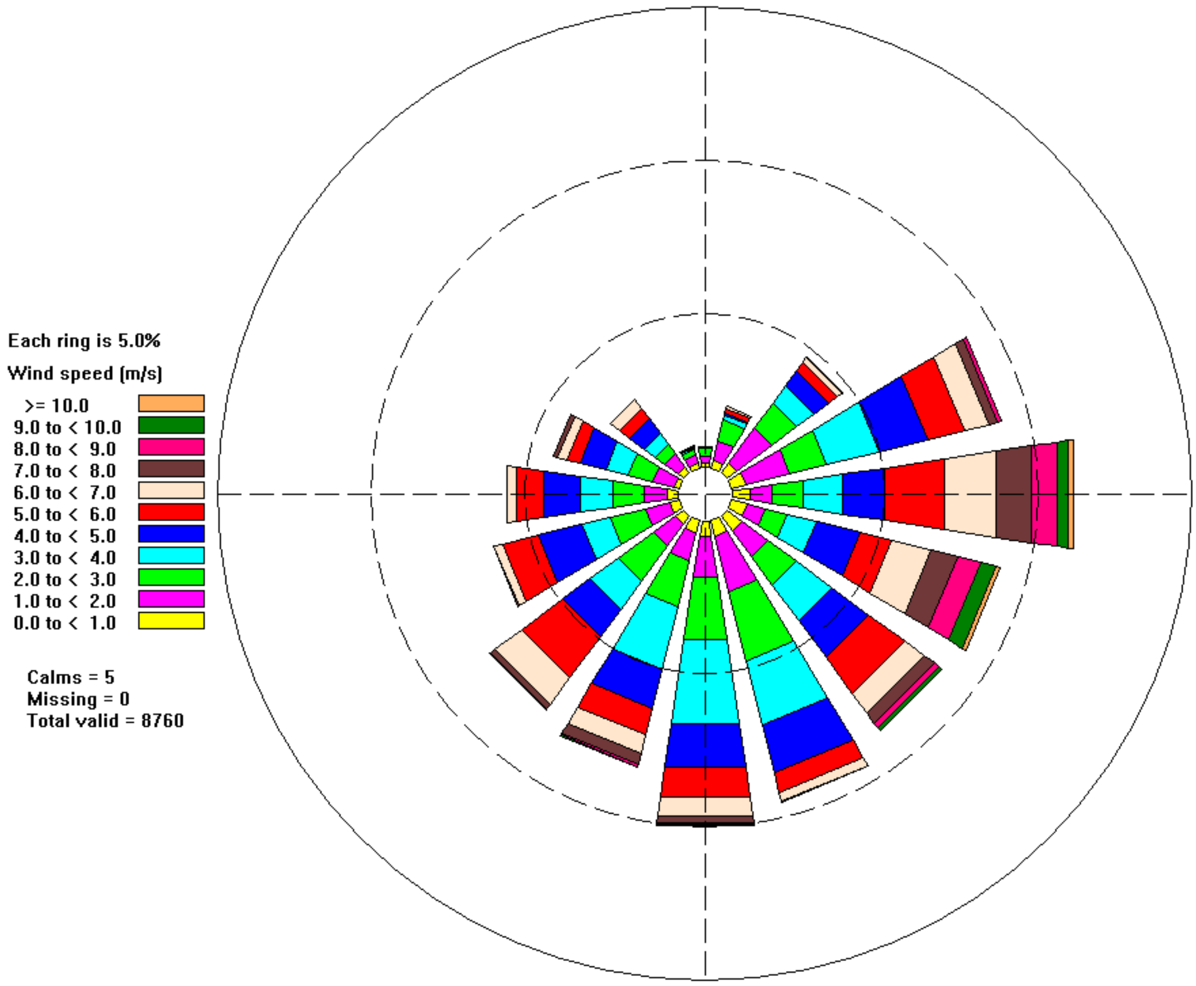

Figure 12 Predicted annual wind rose for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling with data assimilated from the Iluka Resources monitoring station

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM using data assimilation	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

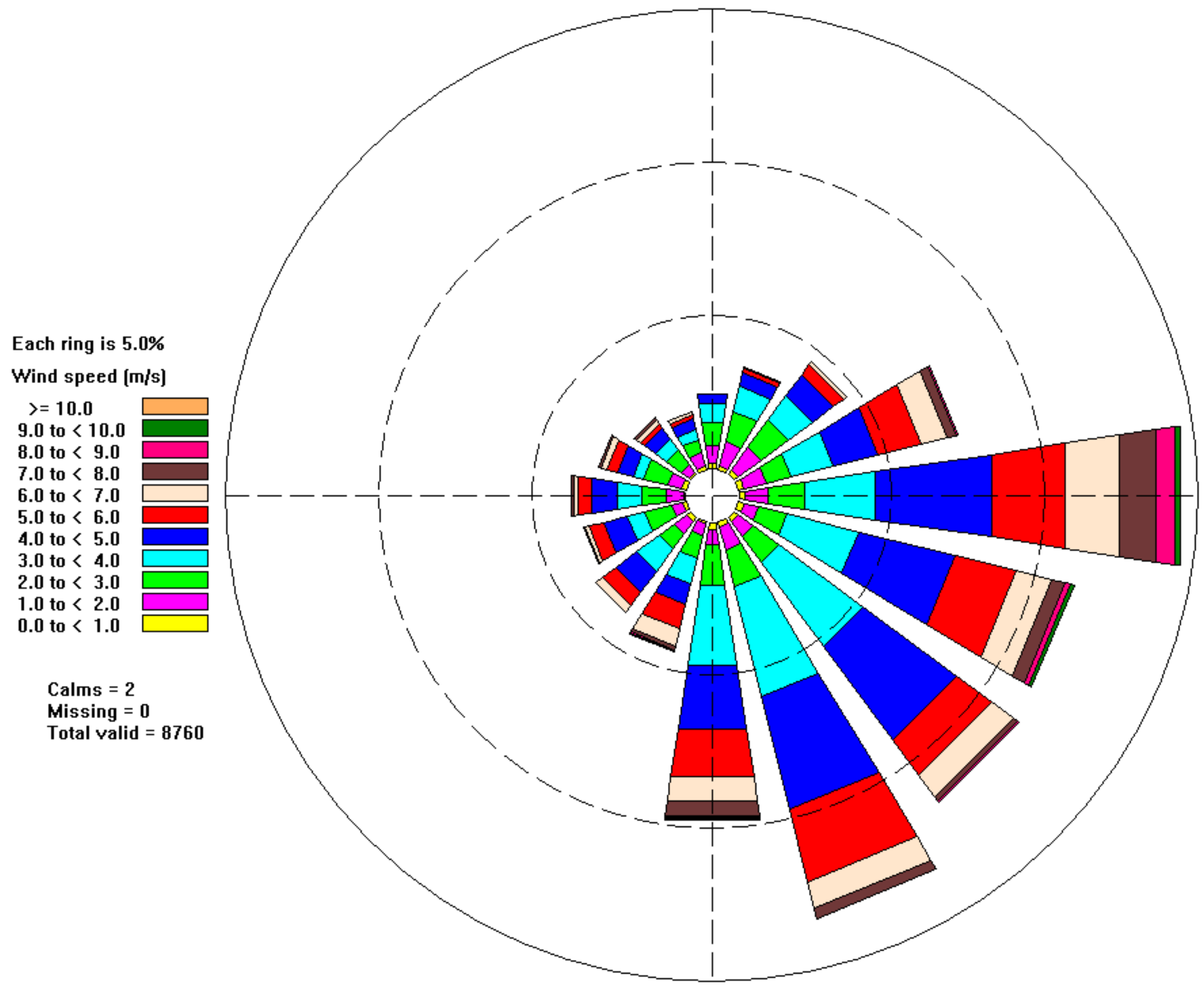

Figure 13 Predicted annual wind rose for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling without data assimilation

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM using data assimilation	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

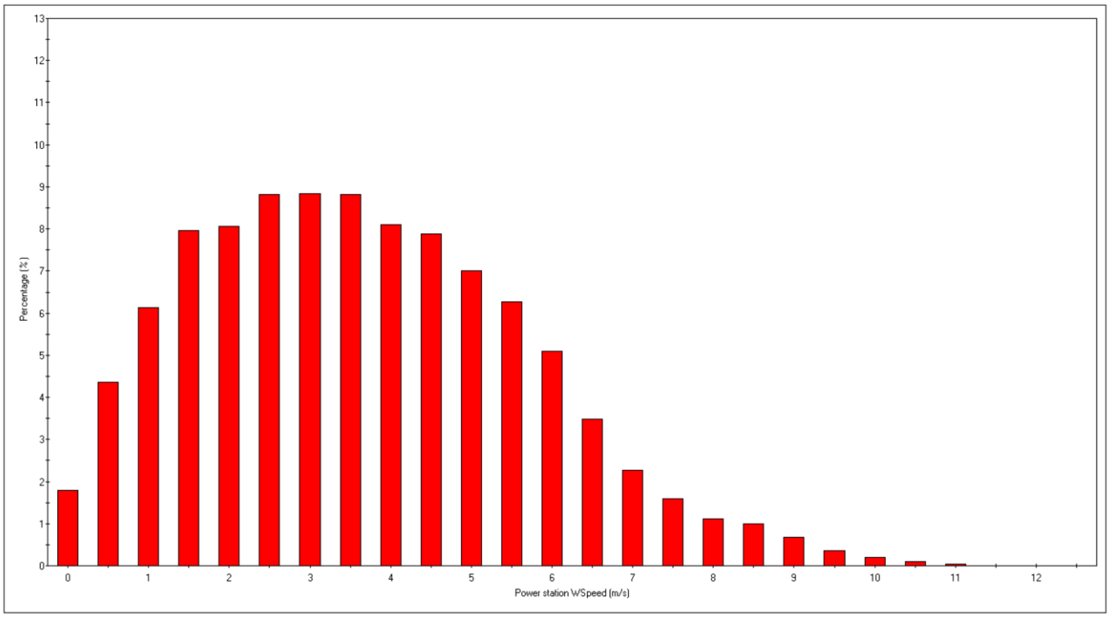

Figure 14	**Frequency distribution for TAPM predicted annual wind speeds for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling with data assimilated from the Iluka Resources monitoring station**

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second
Type: Histogram	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

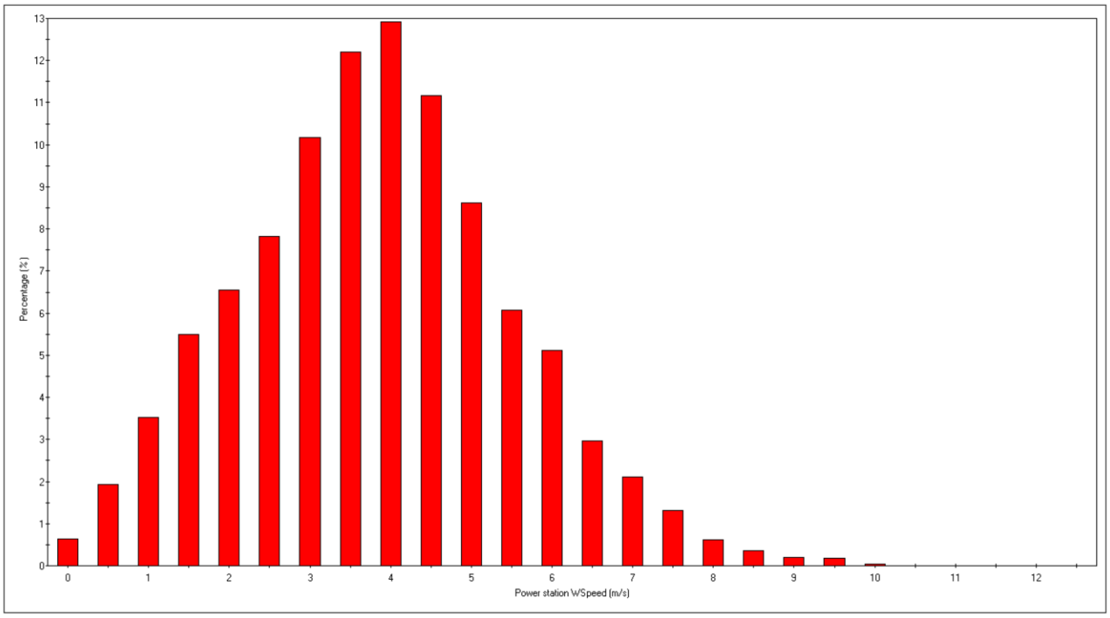

Figure 15	**Frequency distribution for TAPM predicted annual wind speeds for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling without data assimilation**

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second
Type: Histogram	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

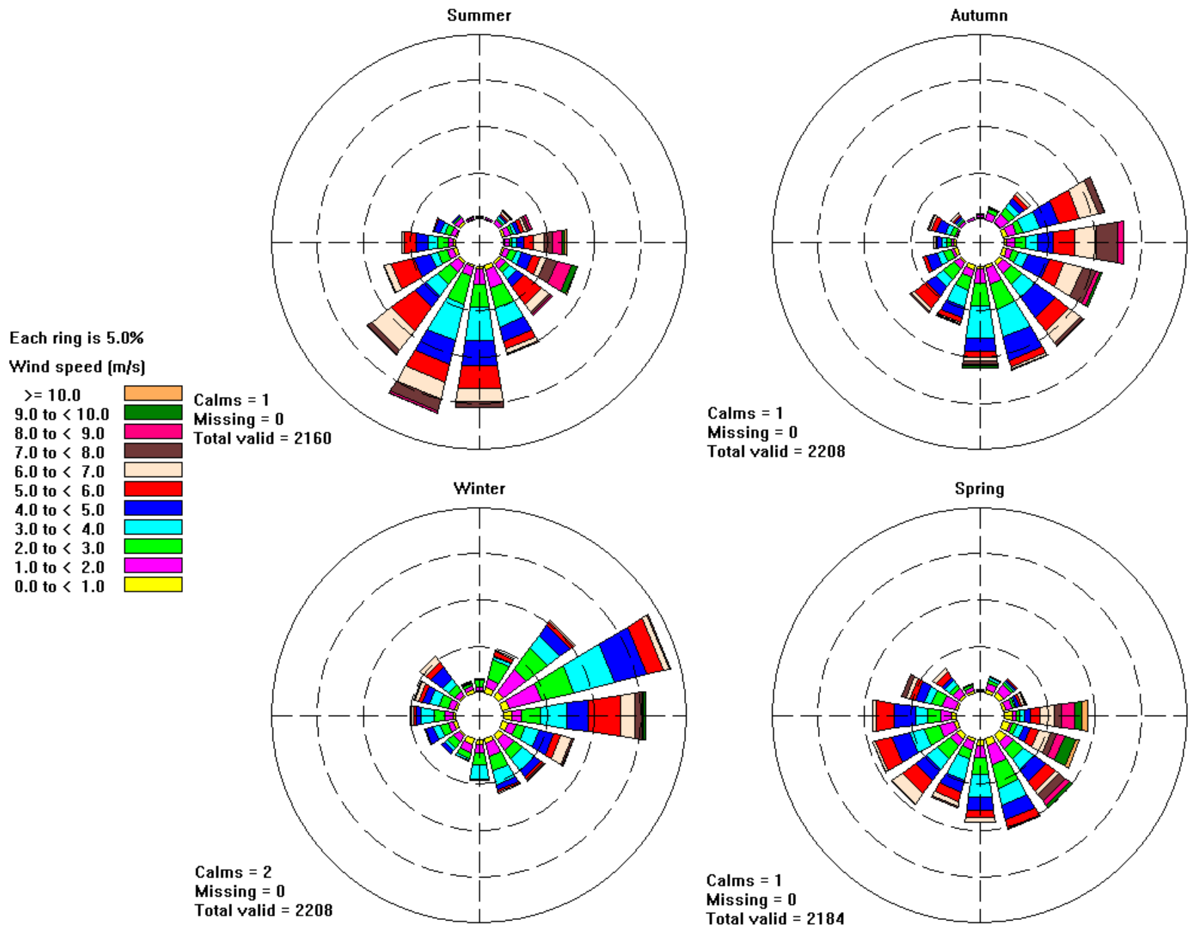

Figure 16 Predicted seasonal wind rose for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling with data assimilated from the Iluka Resources monitoring station

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

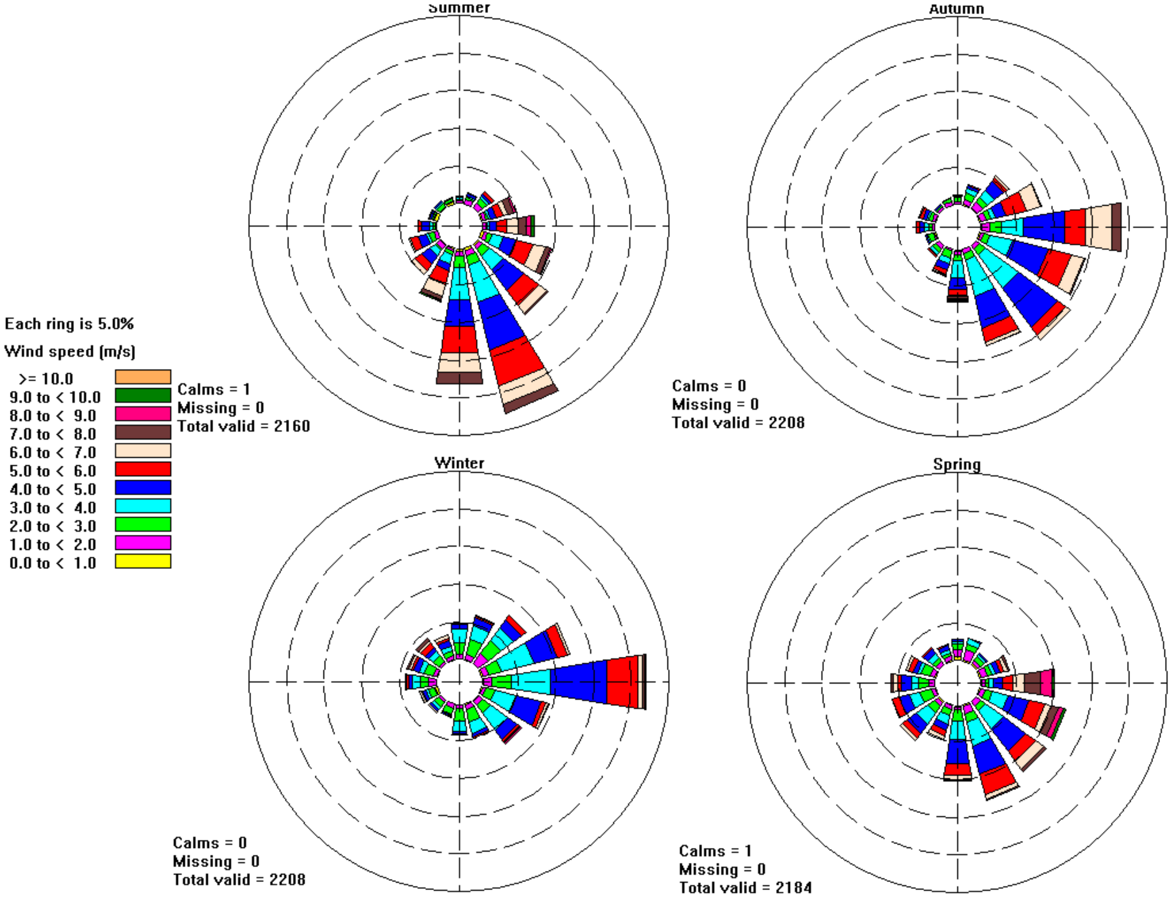

Figure 17 Predicted seasonal wind rose for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling without data assimilation

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

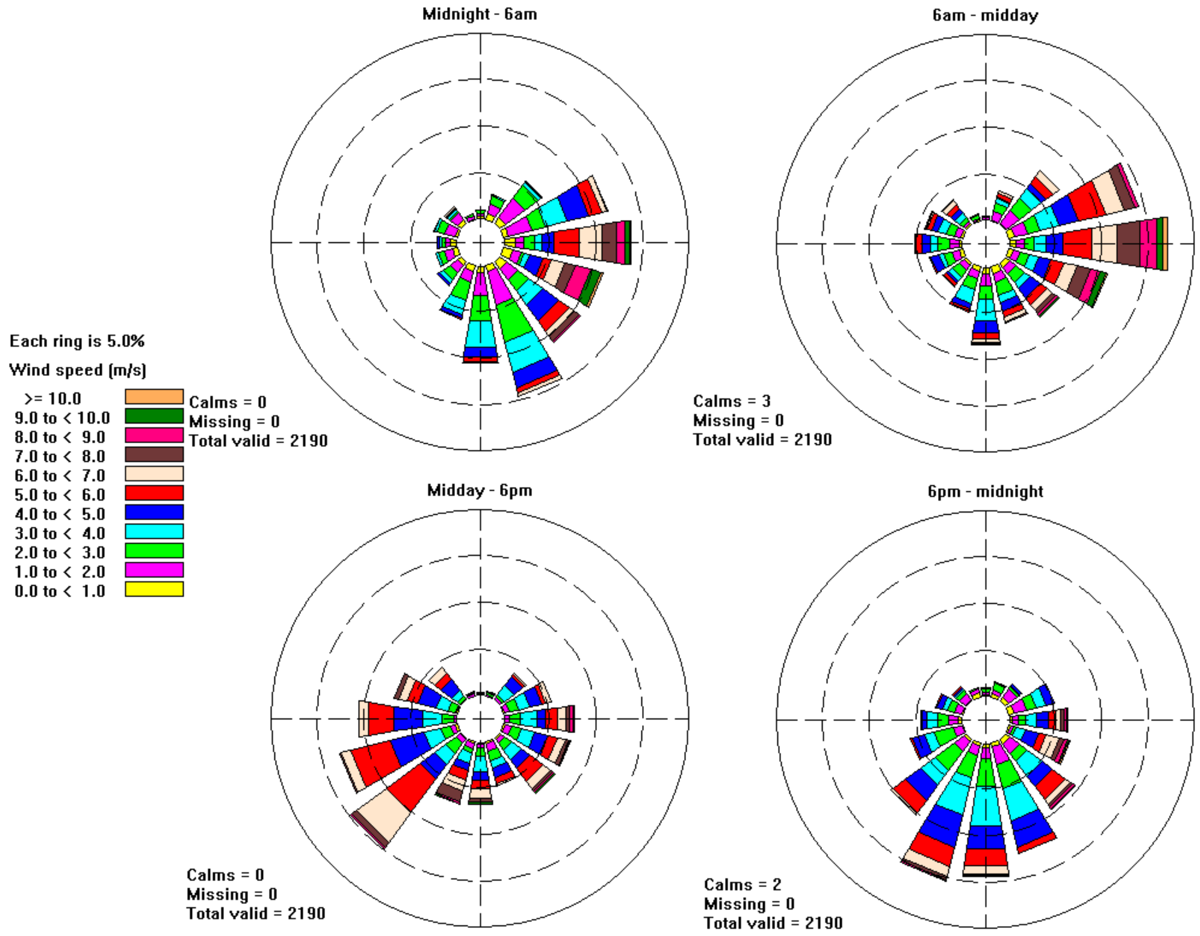

Figure 18 Predicted diurnal wind rose for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling with data assimilated from the Iluka Resources monitoring station

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

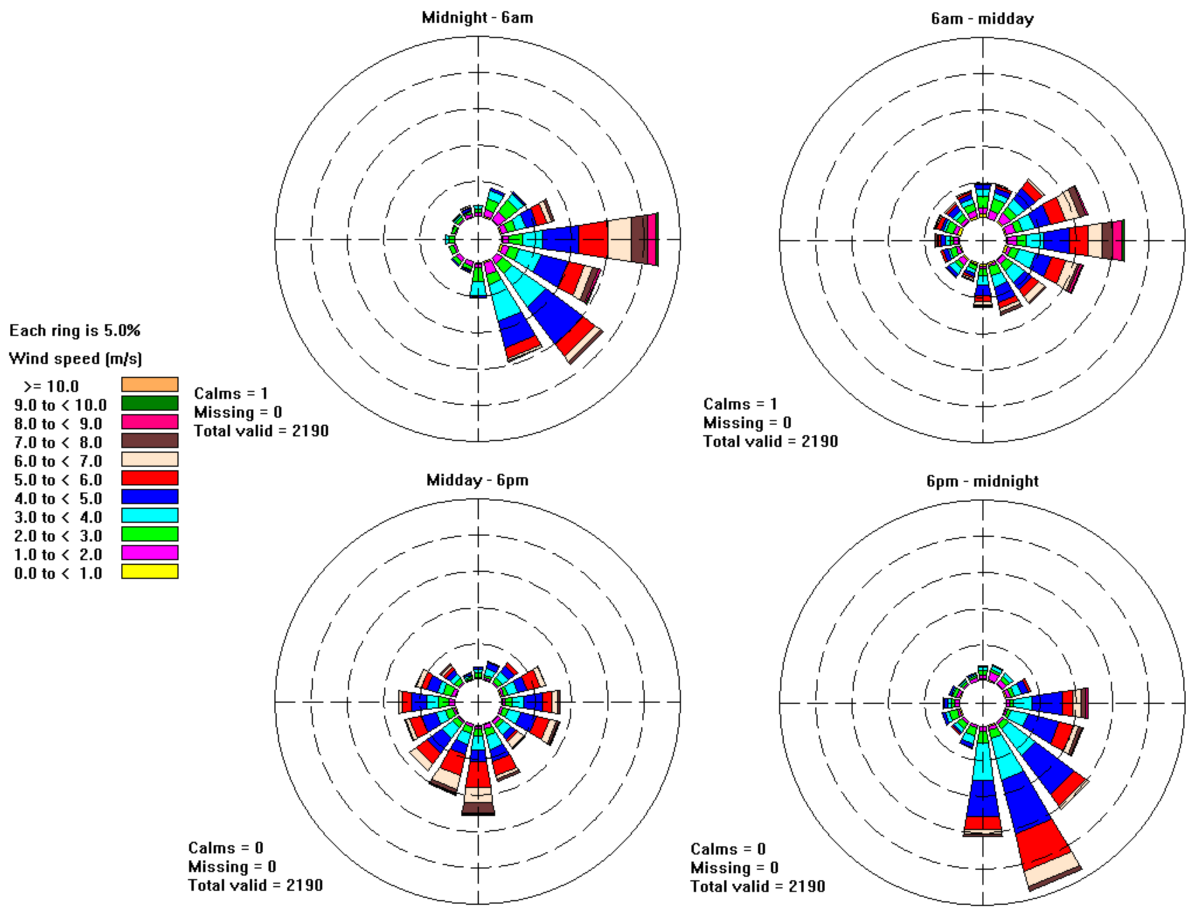

Figure 19 Predicted diurnal wind rose for the Coolimba Power Project site (at 10 m above ground), based on TAPM modelling without data assimilation

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 19/11/08

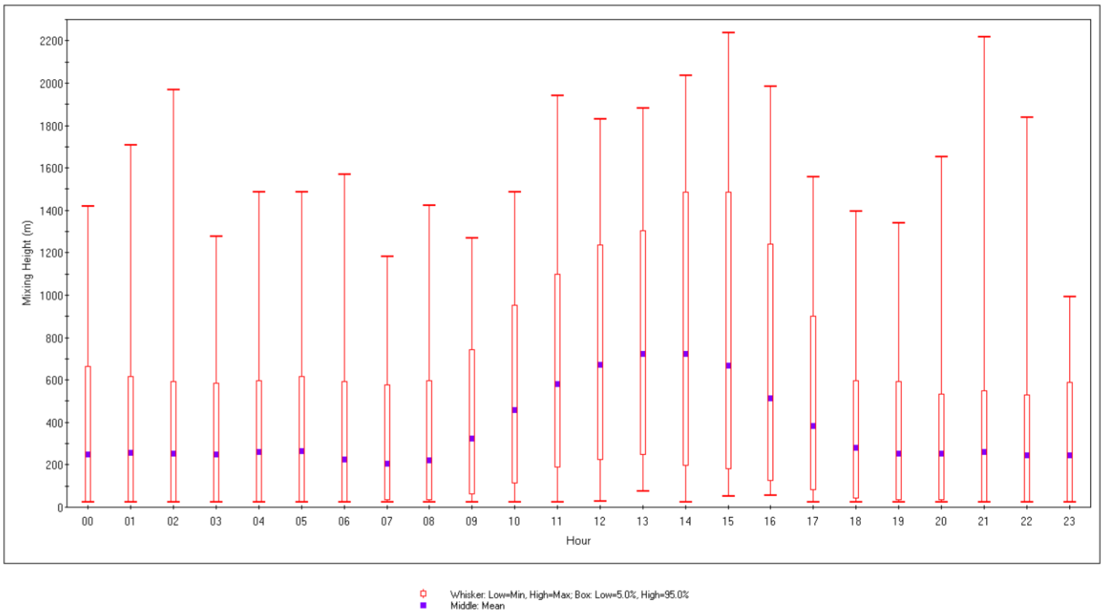

Figure 20 Predicted mixing height for the Coolimba Power Project site, for the TAPM with meteorological data assimilation scenario

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 18/11/08

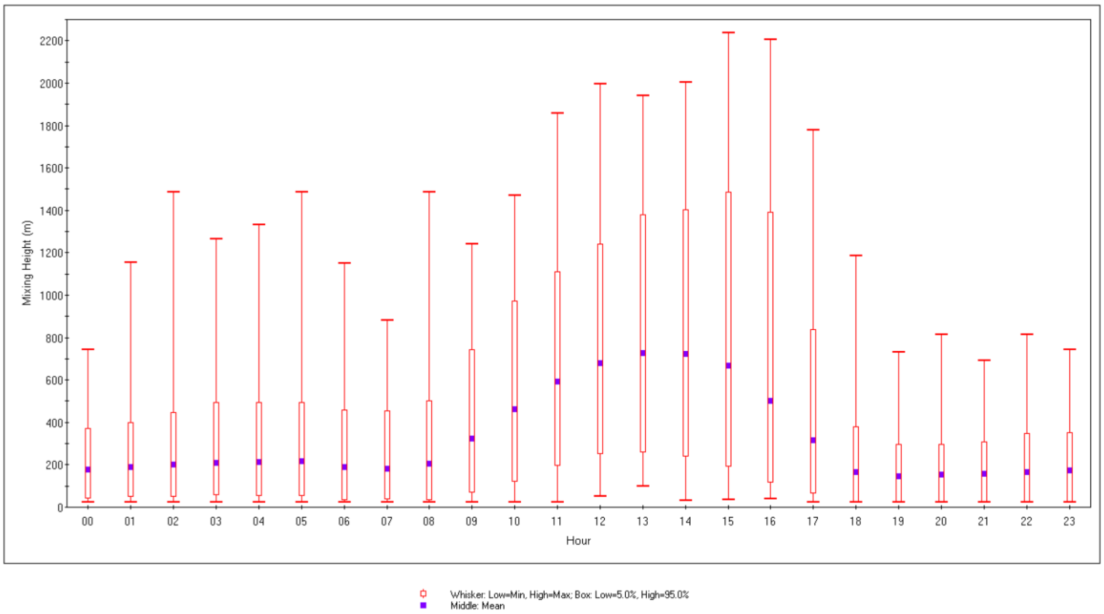

Figure 21 Predicted mixing height for the Coolimba Power Project site, for the TAPM without meteorological data assimilation scenario

Location: Coolimba Power Project site	**Period:** May 2006 – April 2007	**Data source:** Generated by TAPM	**Units:** Metres per second and degrees
Type: Wind rose	8760 hourly average records	**Prepared by:** A. Schloss	**Date:** 18/11/08

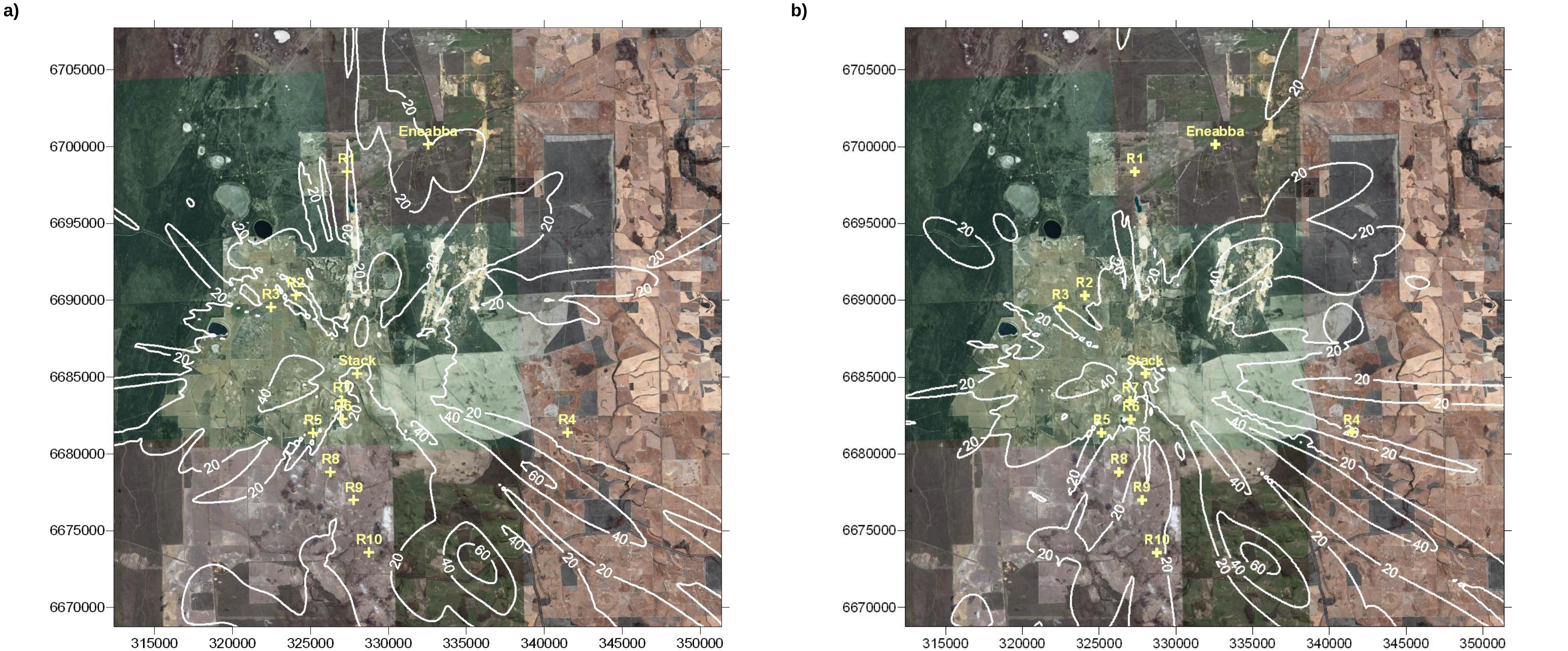

Figure 22 Predicted maximum 1-hour average ground-level concentrations of nitrogen dioxide for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** **a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	**Units:** µg/m³
Type: NO_2 maximum (100^{th} percentile) contour plot	**Standard:** 246 µg/m³	**Prepared by:** A. Schloss	**Date:** 26/11/08

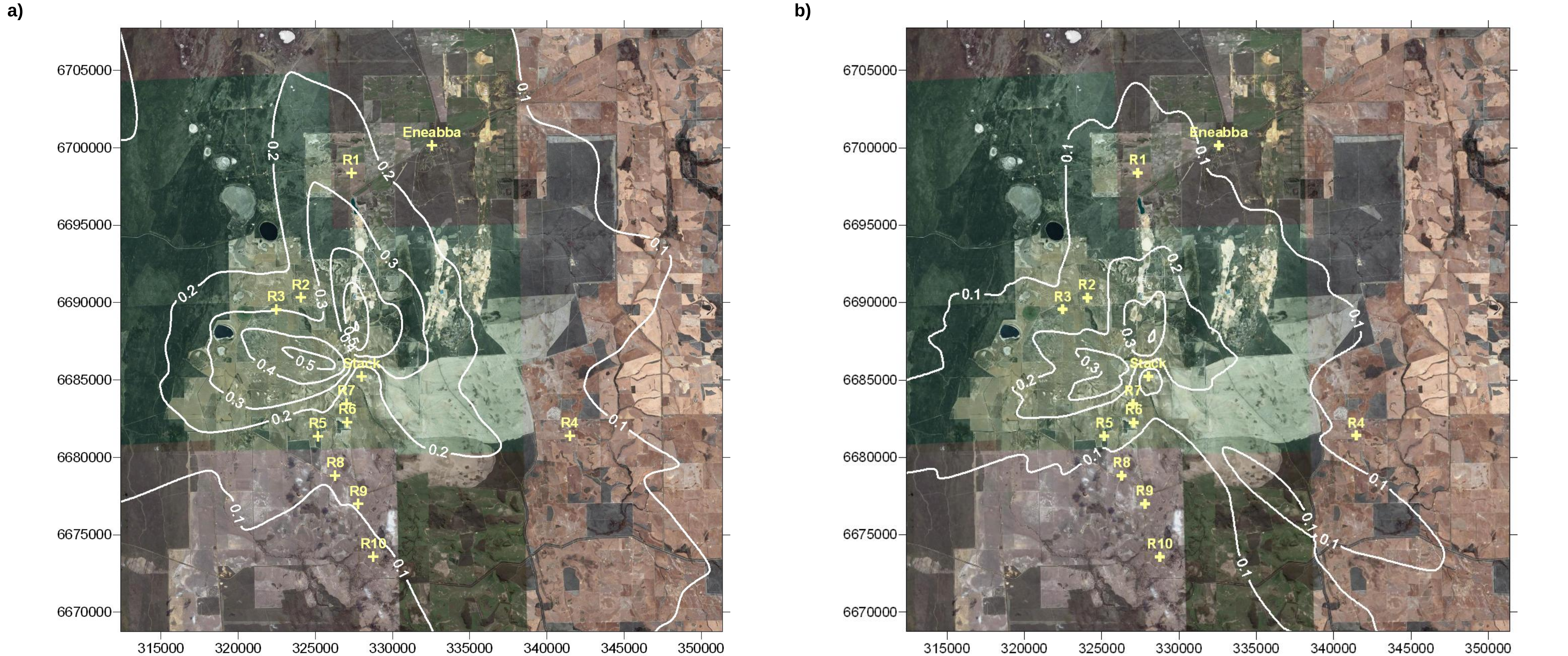

Figure 23 Predicted annual average ground-level concentrations of nitrogen dioxide for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location:	**Averaging period:**	**Data source:**	**Units:**
CPP site and Eneabba region	Annual	**a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	μg/m³
Type:	**Standard:**	**Prepared by:**	**Date:**
NO_2 contour plot	62 μg/m³	A. Schloss	26/11/08

a) b)

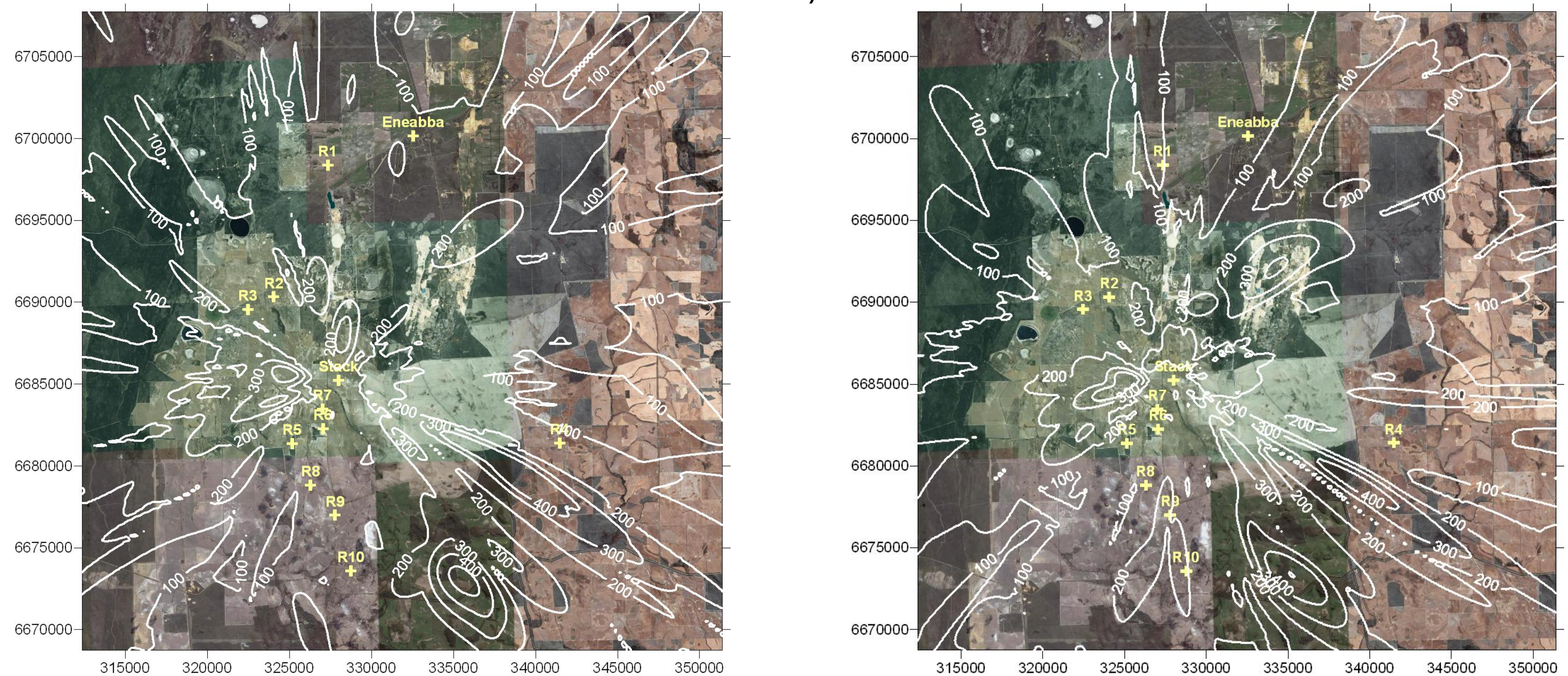

Figure 24 Predicted maximum 1-hour average ground-level concentrations of sulfur dioxide for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** **a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	**Units:** µg/m³
Type: SO_2 maximum (100th percentile) contour plot	**Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 26/11/08

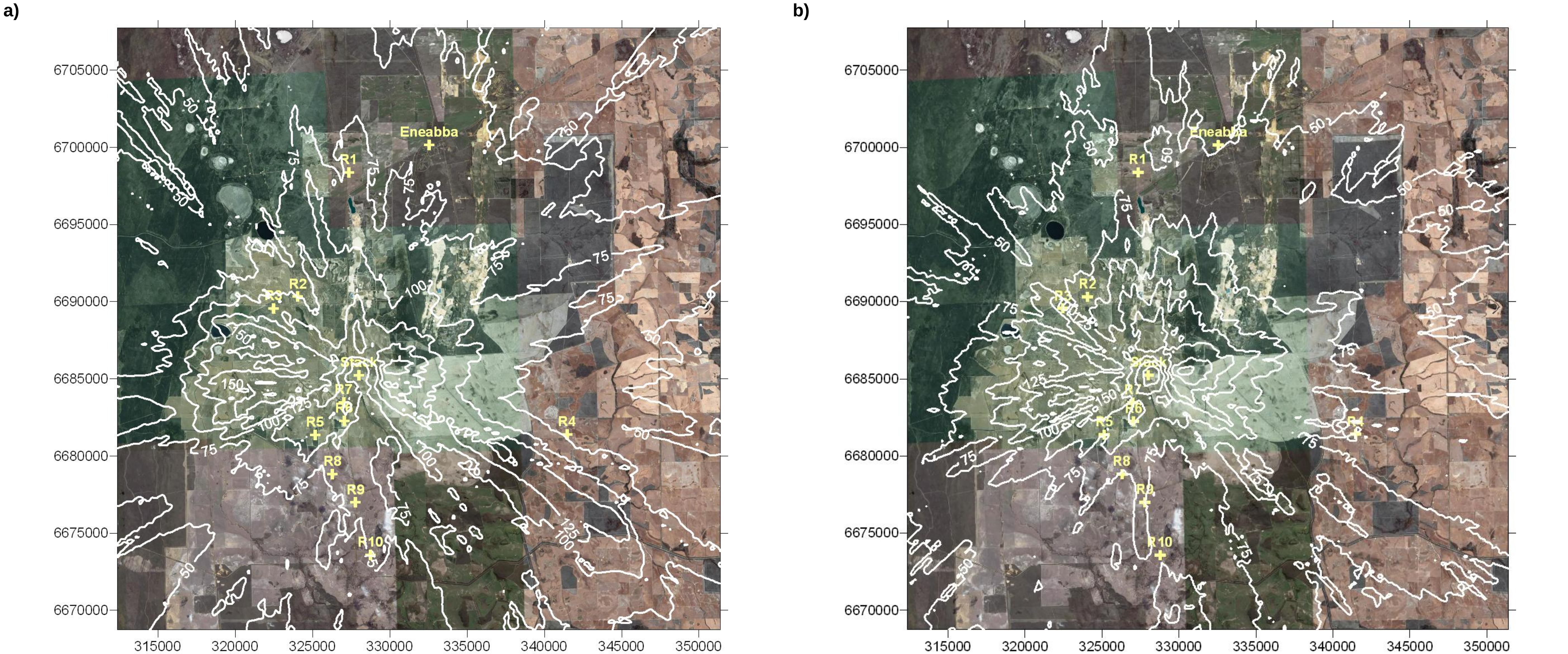

Figure 25 Predicted ninth highest 1-hour average ground-level concentrations of sulfur dioxide for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** **a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	**Units:** µg/m³
Type: SO_2 ninth highest (99.9th percentile) contour plot	**Guideline:** 350 µg/m³	**Prepared by:** A. Schloss	**Date:** 26/11/08

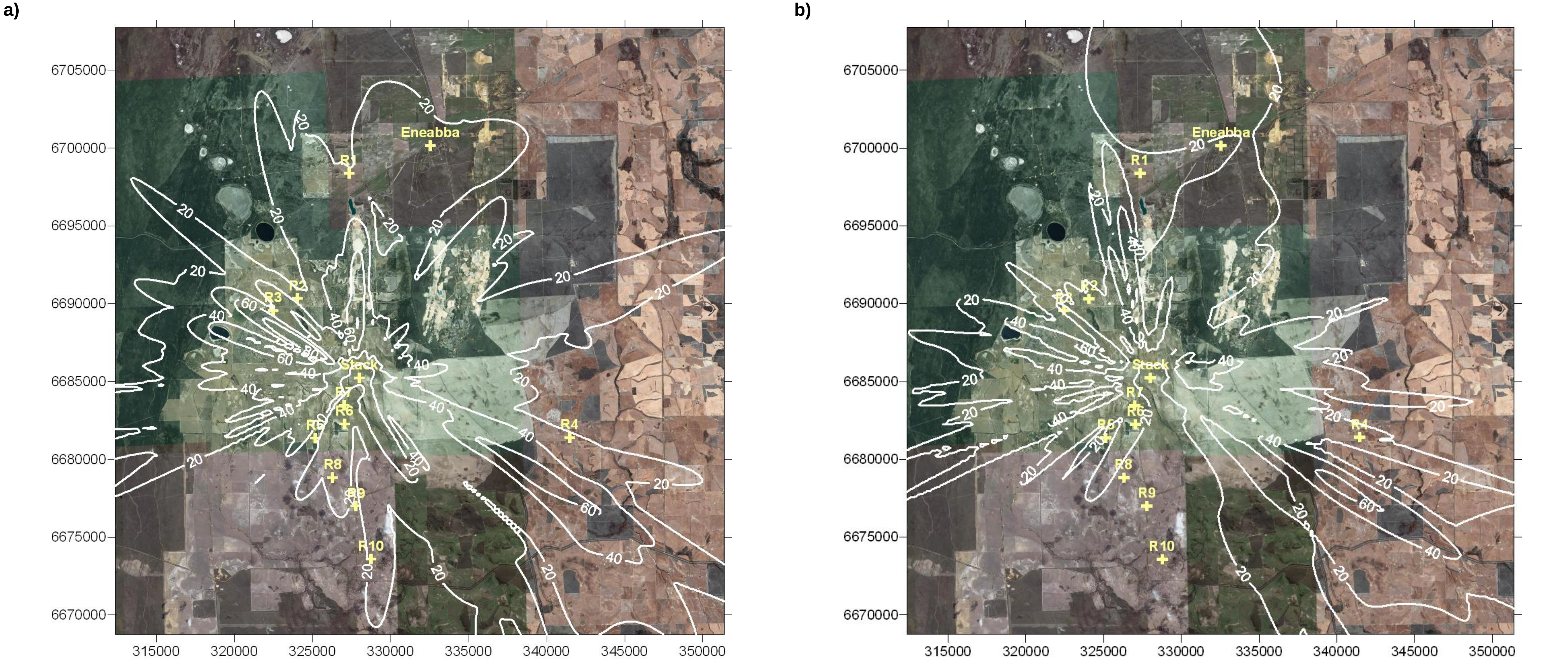

Figure 26 Predicted maximum 24-hour average ground-level concentrations of sulfur dioxide for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location: CPP site and Eneabba region	**Averaging period:** 24-hour	**Data source:** **a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	**Units:** µg/m³
Type: SO_2 maximum contour plot	**Standard:** 230 µg/m³	**Prepared by:** A. Schloss	**Date:** 26/11/08

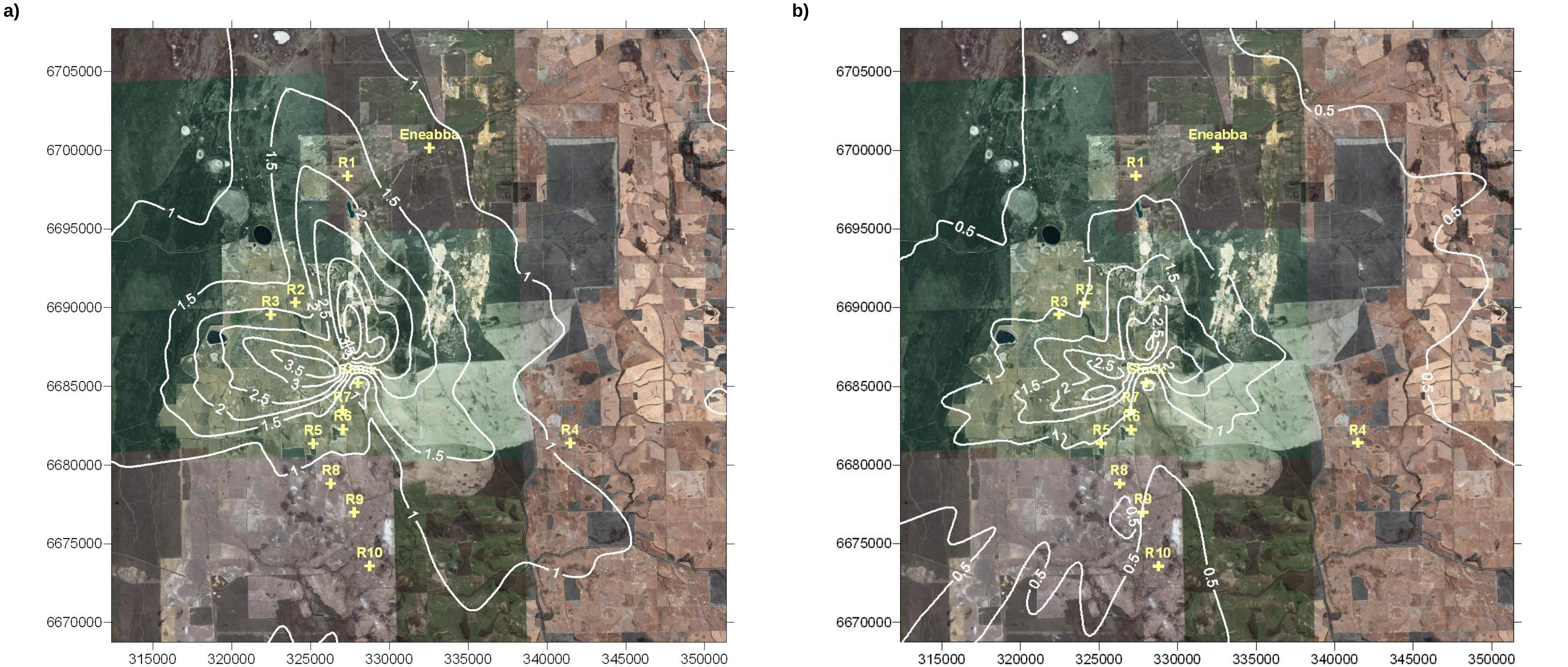

Figure 27 Predicted annual average ground-level concentrations of sulfur dioxide for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location:	**Averaging period:**	**Data source:**	**Units:**
CPP site and Eneabba region	Annual	**a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	µg/m³
Type:	**Standard:**	**Prepared by:**	**Date:**
SO_2 contour plot	60 µg/m³	A. Schloss	26/11/08

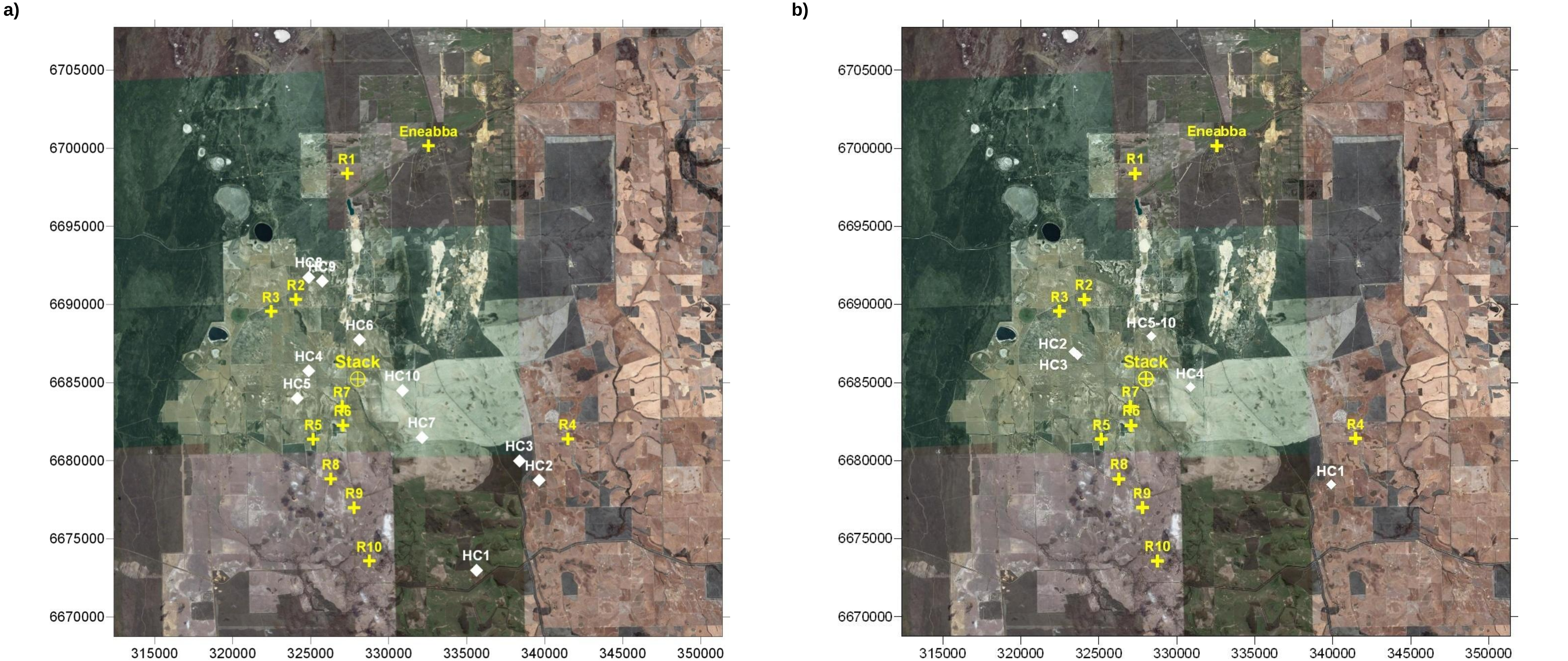

Figure 28 Locations of the ten highest 1-hour average ground-level concentrations of sulphur dioxide

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** **a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	**Units:** Number of exceedences
Type: Locations of 10 highest 1-hour average impacts plot		**Prepared by:** A. Schloss	**Date:** 24/11/08

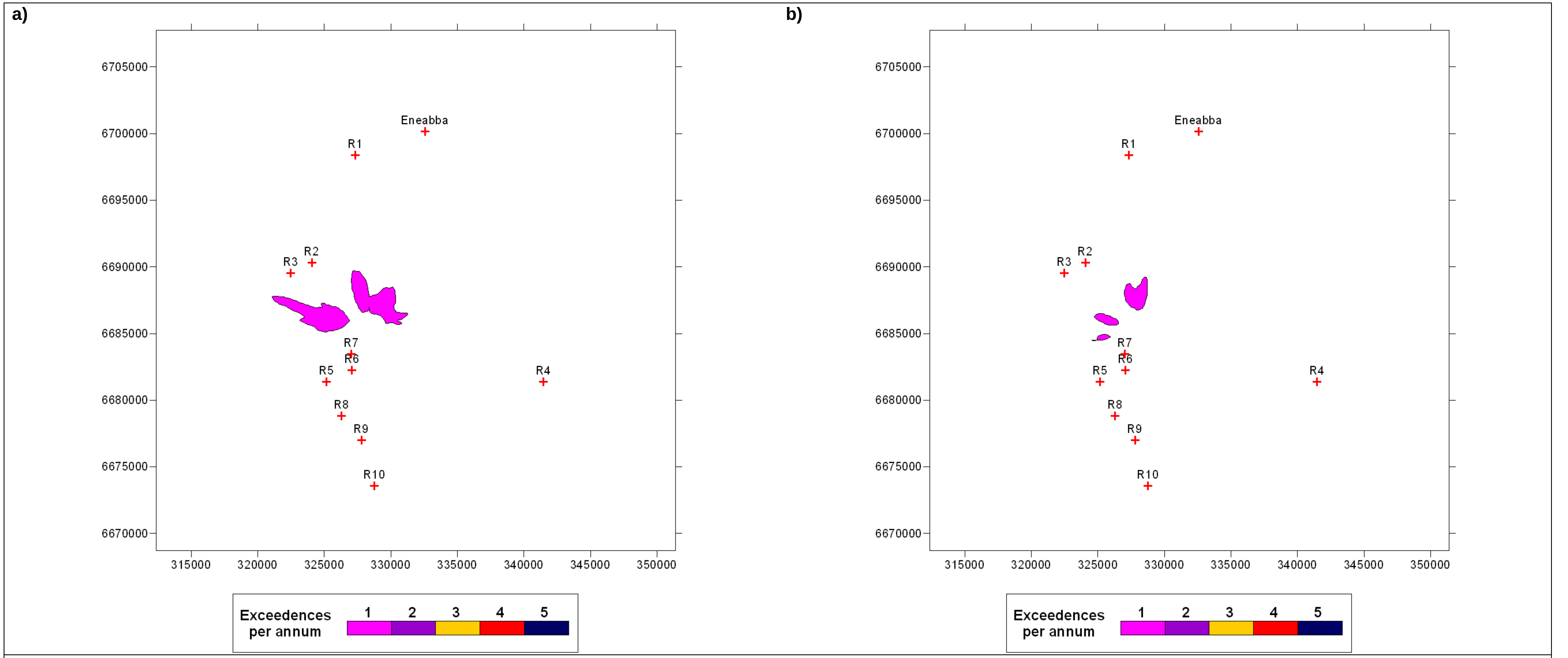

Figure 29 Locations of predicted exceedences of the NEPM(Air) standard for the 1-hour average ground-level concentration of SO_2 per year, based on operating conditions with flue-gas desulphurisation not operating for 1% of the time

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** **a)** Generated by TAPM with data assimilation and stochastic model **b)** Generated by unassimilated TAPM and stochastic model	**Units:** Number of exceedences (hours)
Type: SO_2 contour plot	**Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 21/11/08

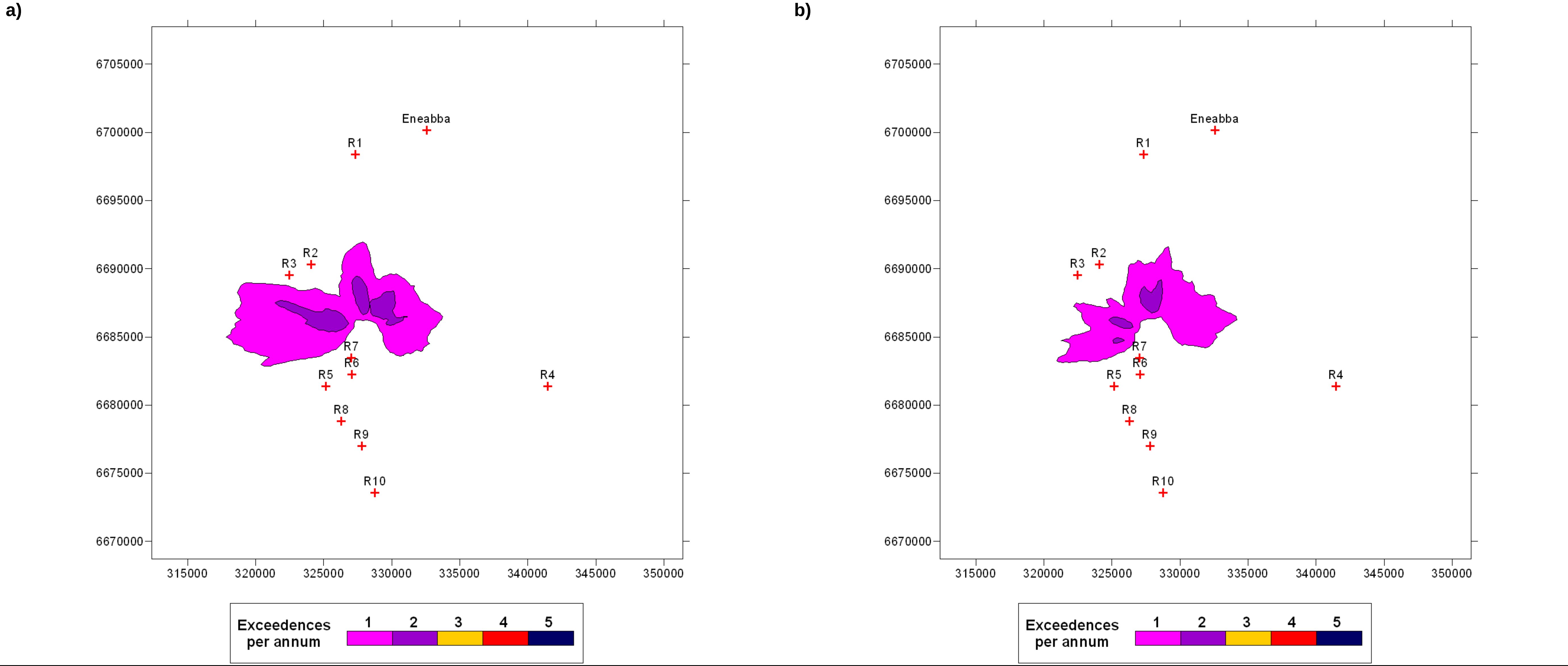

Figure 30 Locations of predicted exceedences of the NEPM(Air) standard for the 1-hour average ground-level concentration of SO_2 per year, based on operating conditions with flue-gas desulphurisation not operating for 2% of the time

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** **a)** Generated by TAPM with data assimilation and stochastic model **b)** Generated by unassimilated TAPM and stochastic model	**Units:** Number of exceedences (hours)
Type: SO_2 contour plot	**Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 21/01/09

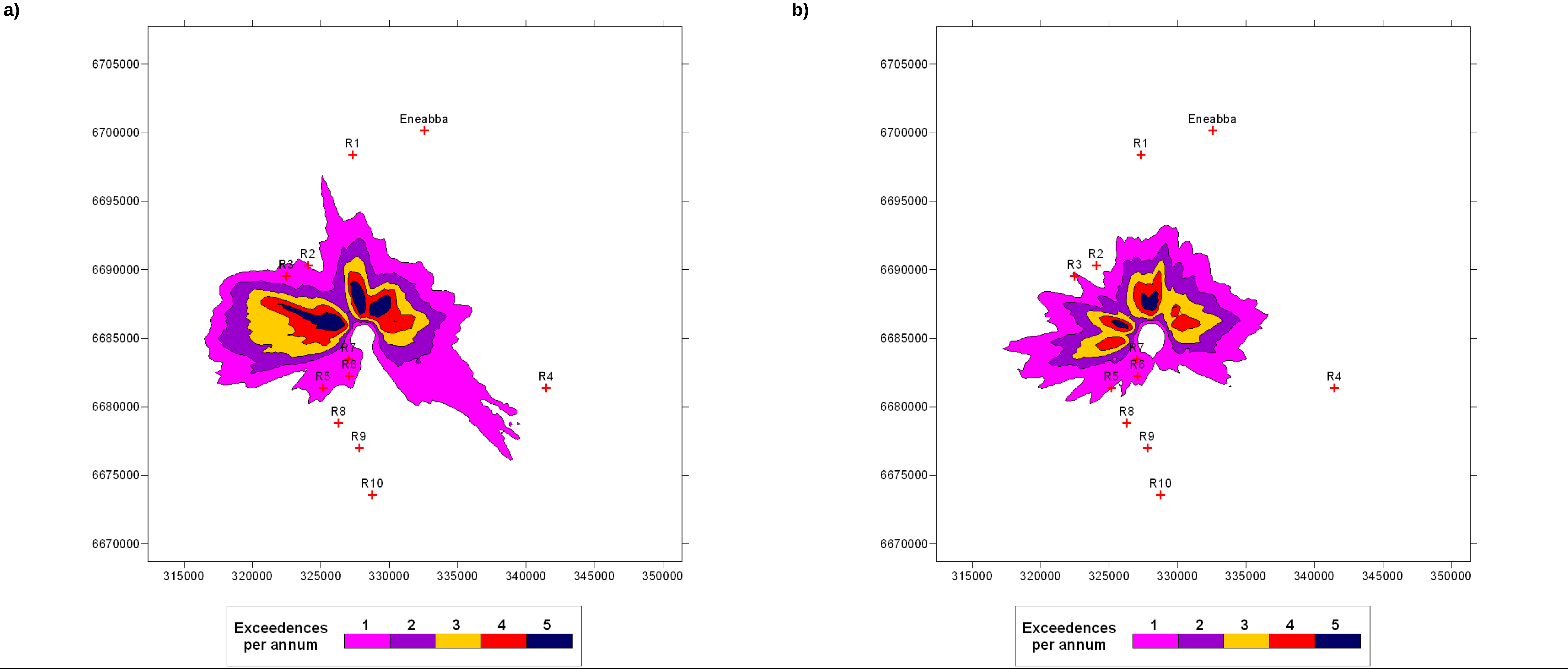

Figure 31 Locations of predicted exceedences of the NEPM(Air) standard for the 1-hour average ground-level concentration of SO_2 per year, based on operating conditions with flue-gas desulphurisation not operating for 5% of the time

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** **a)** Generated by TAPM with data assimilation and stochastic model **b)** Generated by unassimilated TAPM and stochastic model	**Units:** Number of exceedences
Type: SO_2 contour plot	**Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 21/01/09

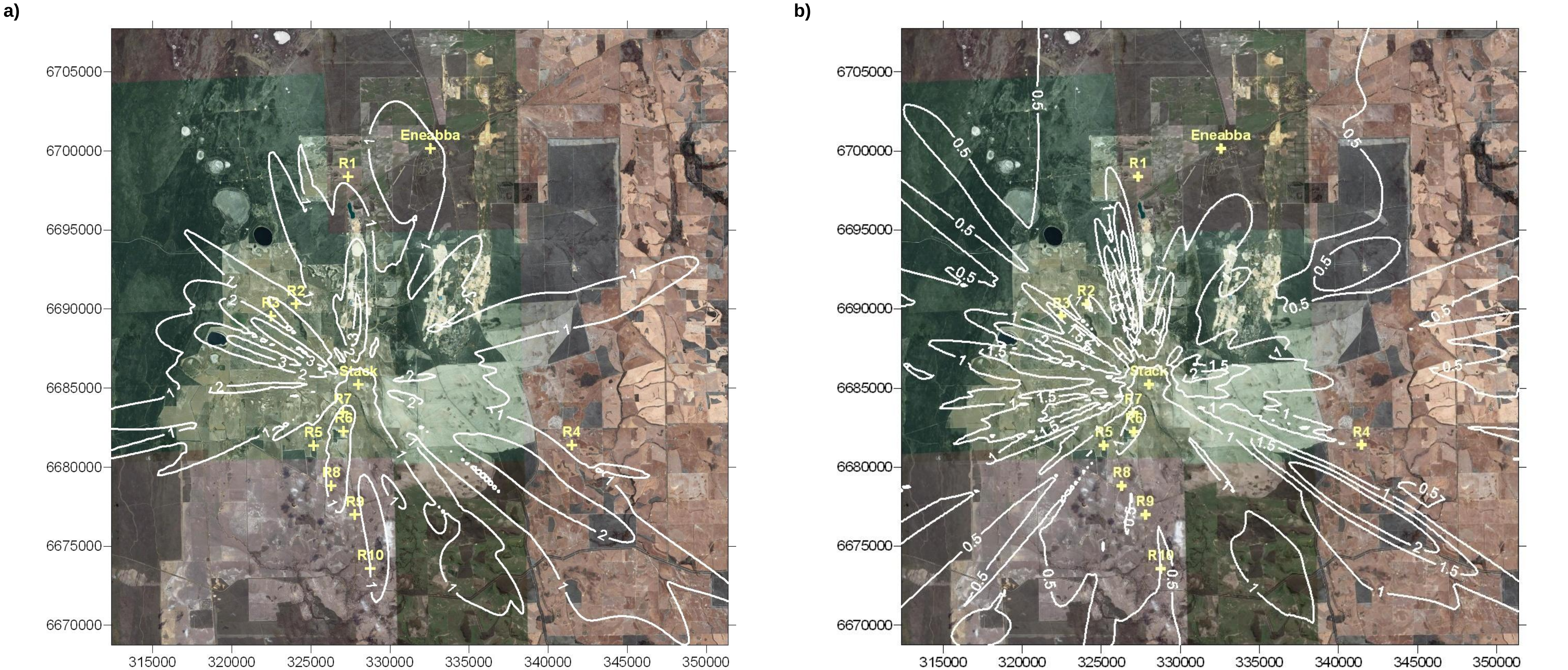

Figure 32 Predicted 24-hour average ground-level concentrations of PM_{10} for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location: CPP site and Eneabba region	**Averaging period:** 24-hour	**Data source:** **a)** Generated by TAPM with data assimilation **b)** Generated by unassimilated TAPM	**Units:** µg/m³
Type: PM_{10} contour plot	**Standard:** 50 µg/m³	**Prepared by:** A. Schloss	**Date:** 21/11/08

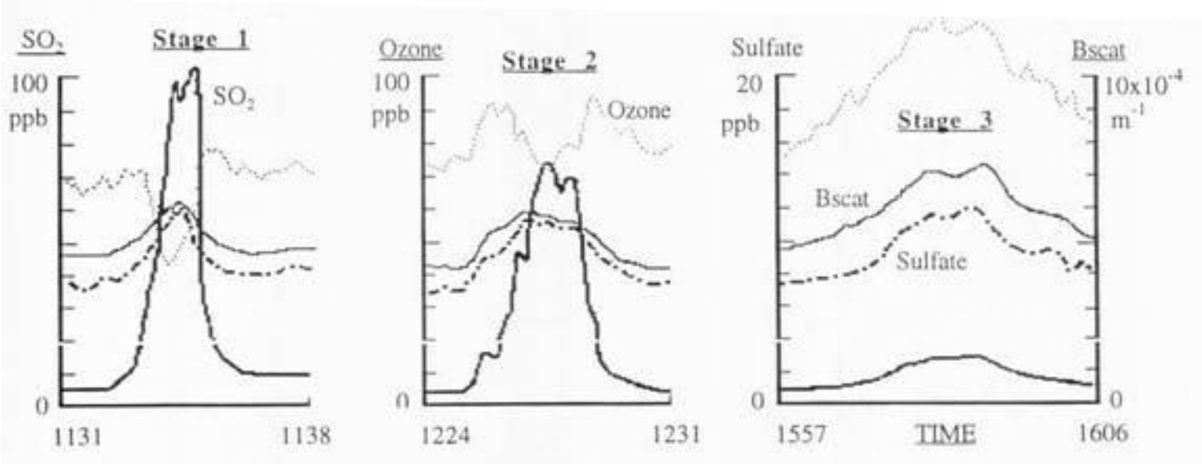

Figure 33	**Example of the three stages of plume chemical development in a large power station plume in Tennessee U.S. Data collected from aircraft traverses corresponding to travel times of approximately 4 h, 5.5 h and 8 h**

Location:	**Type:**	**Data source:**	**Units:**
Tennesse, USA	Ozone scatter plot	Gillani et al., 1981	ppb

Figure 34 Predicted 1-hour average ground-level concentrations of ozone for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity

Location: CPP site and Eneabba region	**Averaging period:** 1-hour	**Data source:** Generated by TAPM GRS	**Units:** ppb
Type: O_3 contour plot	**Guideline/Goal/ Standard:** 100 ppb	**Prepared by:** A. Schloss	**Date:** 25/11/08

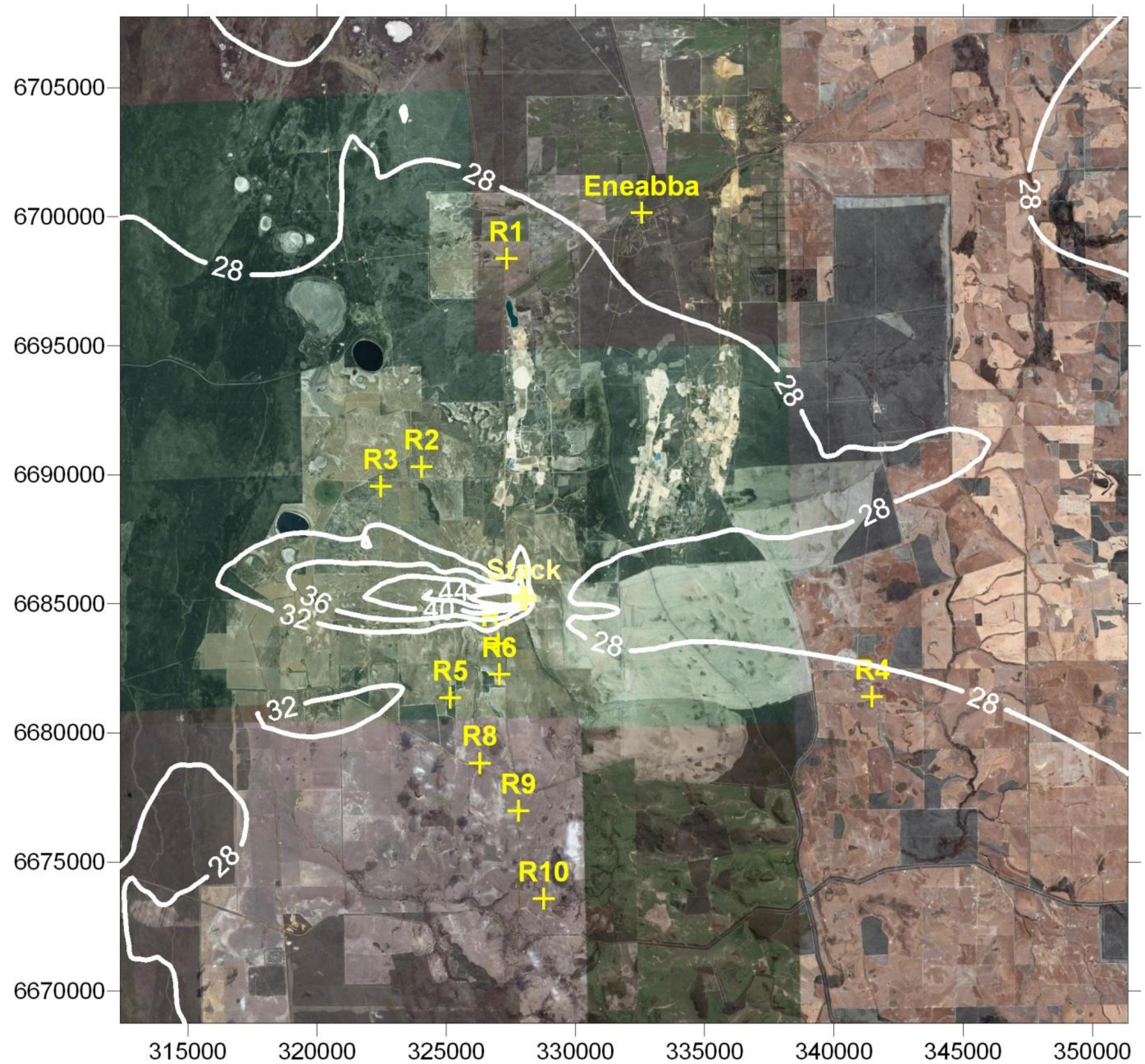

Figure 35	**Predicted 4-hour average ground-level concentrations of ozone for the Coolimba Power Project in isolation, based on normal operating conditions at full capacity**

Location: CPP site and Eneabba region	**Averaging period:** 4-hour	**Data source:** Generated by TAPM GRS	**Units:** ppb
Type: O_3 contour plot	**Guideline/Goal/ Standard:** 80 ppb	**Prepared by:** A. Schloss	**Date:** 25/11/08

APPENDIX A REPORT FROM PARSONS BRINCKERHOFF – COOLIMBA POWER STATION EMISSIONS MODELLING DATA – JANUARY 2009

Coolimba Power Station Emissions Modelling Data

January, 09

3 x 150 MWe Coal Fired
Plus
2 x 179 MWe Gas Turbines

Parsons Brinckerhoff Australia Pty Limited ABN 80 078 004 798

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Reviewer: .... Martin Ford

Signed: ....

Approved by: ....

Signed: ....

Date: ....

Distribution: ....

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1. Coal Fired Units

1.1 Plant Performance Data

Note: Performance data is representative of 3 Unit Operation at MCR

Parameter	Unit	Value
Net plant output (3 units)	MWe	450
Net plant heat rate (HHV)	kJ/kWh	10976
Stack Height (subject to results of this study)	m	130
Stack Diameter (3 x 3.45 m diameter flues in one 10 m diameter wind shield)	m	3 x 3.45
Stack exhaust temperature	ºC	130
Flue gas exit volume flow – 3 flues x 229 m^3/s each = total 687 m^3/s.	m^3/s	687
Flue gas stack exit velocity	m/s	24.4
Total flue gas normal volume flow @ operating conditions (2.38% (vol) O_2 in flue gas) [1]	Nm^3/s	465
Total flue gas normal volume flow @ standard reference conditions of 6% O_2, dry basis [1]	Nm^3/s	518

Note
1 Normal volume is referenced to 0 ºC, 1 atm (101.325 kPa A)

1.2 Emissions Data

Parameter	Unit	Operating volume flow basis [2]	6% O_2, dry basis [3]
N_2O emissions	mg/Nm^3	2.4	2.1
CH_4 emissions	mg/Nm^3	2.7	2.4
NO_2 emissions	mg/Nm^3	448	500
CO emissions	mg/Nm^3	179	200
Particulates as PM_{10}	mg/Nm^3	45	50
Volatile Organic Compounds (VOC)	mg/Nm^3	6.3	5.7
Polycyclic Aromatic Hydrocarbons (PAH)	$\mu g/Nm^3$	2.8	2.5
Total Polychlorinated dioxins	$\mu g/Nm^3$	8.4×10^{-5}	7.5×10^{-5}
Total Polychlorinated furans	$\mu g/Nm^3$	1.4×10^{-4}	1.3×10^{-4}

Notes
1 Normal volume is referenced to 0 ºC, 1 atm (101.325 kPa A)
2 The operating volume flow figures are based on 2.38% (vol) O_2 in flue gas and are to be used for dispersion modelling.
3 Figures stated at the standard reference conditions of 6% (vol) O_2, dry basis, are to be used for emissions reporting.

SO_2 Emissions

SO_2 Figures to be used for dispersion modelling

Percentage of time	SO_2 Emissions – lime injection in service (mg/Nm^3) [2]
0.64	864
3.13	907
8.29	948
13.81	989
19.92	1028
19.84	1067
13.04	1106
7.59	1143
4.74	1180
3.05	1216
1.55	1251
1.12	1286
0.76	1320
0.63	1353
0.44	1385
0.43	1417
0.36	1449
0.27	1479
0.25	1509
0.14	1549
Lime Injection System out of Service [3]	
0.12	6465
0.54	7302
0.28	8252
0.041	9669
0.015	11086
0.004	12162

Notes
1 Normal volume is referenced to 0 ºC, 1 atm (101.325 kPa A)
2 Figures are based on the operating flue gas volume flow (2.38% (vol) O_2 in flue gas) and are to be used for dispersion modelling.
3 Time distribution is based on a limestone injection system availability of 99%. This is a plant break down situation and so is included for contingency only.

SO_2 Figures to be used for Emissions Reporting

Percentage of time	SO_2 Emissions (mg/Nm^3) [2]
90	< 1100
10	1100 – 1500
Lime Injection System out of Service [3]	
0.9	5000 – 8000
0.1	8000 – 12000

Notes
1 Normal volume is referenced to 0 ºC, 1 atm (101.325 kPa A)

2 Figures are based on standard reference conditions of 6% (vol) O_2, dry basis, and are to be used for emissions reporting.
3 Time distribution is based on a limestone injection system availability of 99%. This is a plant break down situation and so is included for contingency only.

CO_2 Emissions

Emission Source	Emissions (kg/s)	Emissions @ 95% capacity factor (tpa)	CO_2-e (tpa)
CO_2			
Coal Combustion	130.8	3,920,450	3,920,450
Limestone Calcination [1]	4.63	138,760	138,760
Ash & Gypsum Transport [2]		5,290	5,290
Coal Stockpile Management [2]		1,440	1,440
Limestone Delivery [2]		3,480	3,480
CH_4			
Coal Combustion [3]	1.23×10^{-3}	37	780
N_2O			
Coal Combustion [3]	1.1×10^{-3}	33	10,200
Total			**4,080,400**

Notes
1 Limestone calcination results from lime injection to the furnace to reduce SO_x emissions
2 Mobile equipment and transport emissions
3 Figures for CO_2-e are based on “Table 5: Equipment Type Emission Factors for Non-CO_2 Greenhouse Gases” in the AGO’s “Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2005”

Trace Element Emissions

Trace element emissions to be used for dispersion modelling

Arsenic		**Boron**		**Cadmium**		**Lead**		**Mercury**		**Selenium**	
Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time
1.6	62.3	716	6.0	1.2	35.8	2.5	18.8	1.7	26.9	62	2.6
3.6	14.9	762	17.0	1.5	27.3	2.8	9.3	3.6	27.6	77	2.2
5.5	5.7	808	24.3	1.8	16.1	3.0	17.1	7.5	3.4	84	34.6
7.5	11.9	853	8.7	2.1	6.8	3.3	16.5	9.5	22.4	92	21.5
19.3	5.1	899	7.2	2.3	3.3	4.1	25.0	11.4	6.0	99	22.0
		945	12.1	2.6	5.8	4.4	0.8	13.3	1.8	106	11.9
		1036	3.3	3.4	2.2	4.7	7.4	15.3	6.8	128	5.1
		1082	12.2	3.7	2.7	4.9	5.0	19.2	5.1		
		1127	9.3								

Chromium		**Copper**		**Fluoride**		**Nickel**		**Vanadium**	
Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time	Emission ($\mu g/Nm^3$)	% of time
46	29.0	16.5	59.1	3577	17.4	20.3	47.7	12.4	8.7
50	6.0	21.2	29.2	4642	11.1	35.5	32.8	13.4	29.1
54	34.2	25.9	5.0	5708	20.8	50.7	13.6	14.5	24.1
62	11.5	30.5	5.9	6773	7.4	66.0	5.1	15.5	7.4
66	4.9	58.6	0.8	7839	4.2	157.3	0.8	17.6	21.5
74	9.4			8904	12.9			18.7	3.5
78	2.2			11035	15.3			19.7	3.4
83	2.7			12101	4.9			21.8	2.2
				13166	5.9				

Notes

1. Normal volume is referenced to 0 ºC, 1 atm (101.325 kPa A)
2. Trace element emissions are based on the operating flue gas volume flow (2.38% (vol) O_2 in flue gas) and are to be used for dispersion modelling.

2. Gas Turbine Emissions Data

Note: Data below is representative of one Alstom 13E2 Gas Turbine operation at MCR, ISO conditions. Dispersion modelling shall consider emissions of 2 x 13E2 Gas Turbines.

Performance Data

Parameter	Unit	Value
Gross plant output (1 unit)	MWe	179,900
Gross plant heat rate (HHV)	kJ/kWh	10,829
Stack Height	m	35
Stack Diameter	m	6.5
Stack exhaust temperature	ºC	510
Flue gas exit volume flow	m^3/s	1264
Flue gas normal volume flow	Nm^3/s	440.78
Flue gas stack exit velocity	m/s	38

Note
1 Normal volume is referenced to 0 ºC, 1 atm (101.325 kPa A)

Emissions Data to be used for Emissions Reporting

Parameter	Unit	Value
CO_2 emissions	kg/s (kg/MWh)	27.96 (559.5)
CO emissions [1]	ppmv dry	10
NO_x emissions [1]	ppmv dry	25

Note:
1 CO and NO_x emissions are referenced to STP conditions (0 ºC, 101.325 kPa A) and 15% O_2

Emissions data to be used for Dispersion Modelling

Parameter	Unit	Value
CO emissions	g/s	5.51
NO_x emissions	g/s	22.62

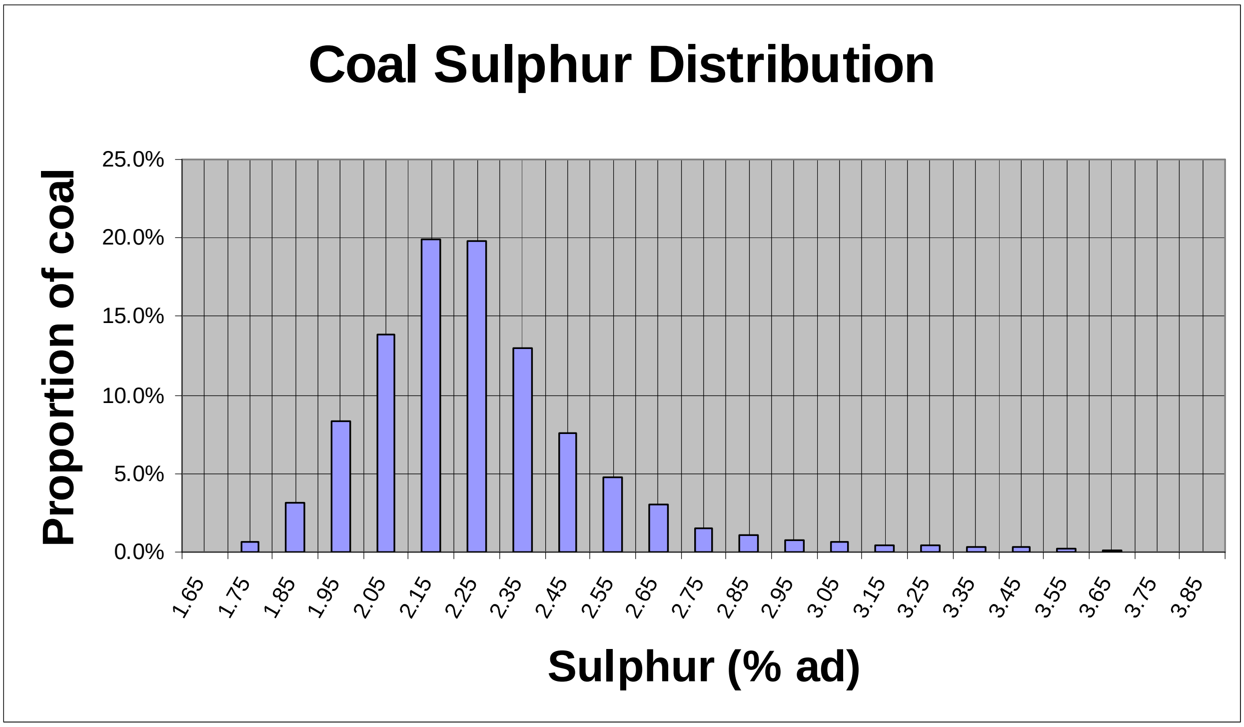
3. Basis for Gaseous Emissions Data

The purpose of this section is to outline the assumptions and methodology that has been applied to derive gaseous emissions data for the proposed Coolimba Power Station 3 x 150 MW coal fired units.

3.1 Sulphur Dioxide (SO_2) Emissions

3.1.1 Sulphur content of coal

The range of sulphur content in the coal to be received by the power station is calculated to be within the range of 1.65 % to 3.85 % (air dried basis), with an approximate distribution as shown in the following graph;



The above sulphur content range and distribution has been derived from a study done by the Central West Coal Project mining consultant Minserve. The Minserve study was based on the following data and analysis methodology;

- Coal sulphur content data throughout each of the coal seams, obtained through the coal resource drilling and sampling program
- Interpolation of coal sulphur content between drilling/sample points
- Consideration of the blending that will occur due to the mining sequence and coal stockpiling. I.e. The coal mining and stockpiling processes will provide a degree of coal blending between the coal seams being mined, which have the effect of smoothing out the peaks in the sulphur content of the coal received by the power station. The above data is based on 50 x 50 m mining blocks.

3.1.2 Desulphurisation Process

The predicted SO_2 emissions for the Coolimba Power Station are based on the use of Circulating Fluidised Bed (CFB) boilers to generate steam through coal combustion. When fuels containing sulphur are combusted, most of the sulphur is oxidized to sulphur dioxide (SO_2), which becomes a component of the flue gas. In a CFB boiler, capture of SO_2 from the flue gas can be achieved in the furnace during the combustion process. This eliminates the need for installation of a separate flue gas desulphurisation unit in the flue gas exhaust stream.

In a CFB boiler, limestone which consists of calcium carbonate ($CaCO_3$) and various impurities is injected into the boiler furnace. When limestone is added to the boiler it undergoes a transformation called calcination, as follows;

$CaCO_3 \rightarrow CaO + CO_2$

Once formed, solid CaO (lime) reacts with the gaseous sulphur dioxide and oxygen to form solid calcium sulphate ($CaSO_4$) according to the following reaction;

$SO_2 + ½\, O_2 + CaO \rightarrow CaSO_4$

The solid calcium sulphate produced through the desulphurisation process is then removed from the flue gas along with the coal combustion ash.

3.1.3 Efficiency of Desulphurisation Process

Principles

In theory the minimum Calcium to Sulphur (Ca/S) mole ratio required for a given level of sulphur removal is 1/1 (i.e. one mole of calcium carbonate injection is required to remove each mole of sulphur). This however assumes 100% limestone utilisation and reaction with SO_2, which in practical systems is impossible to attain.

In order to improve the desulphurisation efficiency, additional limestone is injected into the furnace of the boiler above what is theoretically required by the 1/1 stoichometric reactions outlined above.

The type and size of boilers being considered for the Coolimba Project can typically achieve a desulphurisation efficiency of 85% with a Ca/S mole ratio of approximately 1.9. The finally achieved removal efficiency does however depend on several variables, the most significant being;

- Sulphur content of the fuel (The higher the coal sulphur content, the lower the required Ca/S ratio for a given percentage SO_2 removal)
- Purity and reactivity of the limestone
- CFB boiler recycle rates (the greater the internal recycle rates within the CFB boiler, the greater the removal efficiency)

Coolimba Estimated Emissions

The principles outlined above have been applied in the estimation of the Coolimba SO_2 emissions.

An initial SO_2 removal efficiency for the Coolimba CFB boilers has been assumed based upon what is considered reasonable performance for a CFB boiler from available literature. The base removal efficiency has been taken to be 85% SO_2 removal, under the following operating conditions;

- 1.74 % coal sulphur content
- Ca/S ratio of 1.9

In order to account for the main variables of interest in predicting the Coolimba SO_2 emissions, correction curves have been generated to correct the above base performance for the following variables;

- Coal sulphur content
- Ca/S ratio (limestone injection rate)

Using these correction curves, the Coolimba SO_2 emissions have been predicted across the range of sulphur content in the coal, assuming that limestone will injected at a Ca/S ratio of 1.9. That is, the calculations are based on the assumption that limestone is injected in proportion to the sulphur entering the furnace (via combustion of coal), and at a rate of 90% in excess of stoichometric requirements. This has resulted in predicted removal efficiencies in the range of approximately 85 – 87.7 % across the full coal sulphur content range.

It should be noted that due to the range of complex variables associated with SO_2 removal in CFB boilers, emissions levels cannot be calculated with precision. The predicted performance is however considered to be a reasonable expectation for the boiler, and these expectations are forming the basis for discussions with prospective CFB boiler suppliers.

It should also be noted that to an extent it is possible for discrepancies between predicted SO_2 emissions and emissions from the finally installed plant to be compensated for by adjusting the rate of limestone injection (Ca/S ratio).

3.2 Trace Element Emissions

3.2.1 Trace Elements in Coal

The coal analysis for the Central West Coal Deposit has incorporated trace element analysis, with several samples being analysed for trace elements from each of the seams to be mined. The analysed trace elements are;

- Arsenic
- Boron
- Cadmium
- Lead
- Mercury
- Selenium
- Chromium

- Copper
- Fluoride
- Nickel
- Vanadium

For each trace element, the concentration distribution across the full range of analysed concentrations was processed as follows;

- The full range of concentrations between the minimum and maximum analysed values were divided into 10 x 10% bands
- The number of samples falling into each 10% band was counted, and calculated as a percentage of the total number of samples
- The mid-point of each 10% band was taken as the average concentration of all samples lying with the band

3.2.2 Trace Element Penetration

The trace elements that naturally exist in the coal are liberated into the flue gas upon coal combustion. The majority of the trace elements do not however remain entrained in the flue gas, but are captured by particulate removal equipment and exit along with the boiler ash.

The degree of trace element penetration through the particulate control equipment varies and cannot be calculated with precision. The most reliable and practical guide to the penetration of trace elements is experimental data from other coal fired power plants, and has therefore been used in the prediction of trace element emissions for Coolimba. Trace element penetration factors that have been used in conjunction with the coal trace element data to predict Coolimba emissions are based on the results of the study; *A Comprehensive Assessment of Toxic Emissions from Coal-Fired Power Plants: Phase I Results from the U.S Department of Energy Study.*

(http://www.netl.doe.gov/technologies/coalpower/ewr/mercury/pubs/toxicreport.pdf)

This study reports penetration factors from nine U.S power stations for all of the trace elements under consideration. Since there is variation in penetration factors between sites, the penetration factors selected for the Coolimba analysis lean towards the conservative end of the range, and are listed in the table below;

Trace Element	Penetration Factor assumed for Coolimba
Arsenic	0.6 %
Boron	10.0 %
Cadmium	3.0 %
Lead	0.2 %
Mercury	85.0 %
Selenium	15.0 %

Chromium	1.0 %
Copper	0.4 %
Fluoride	45.0 %
Nickel	1.5 %
Vanadium	0.2 %

3.2.3 Chromium VI

Chromium species introduced into a combustion environment have been shown to partition into toxic hexavalent chromium (VI), and other relatively non-toxic species, predominantly trivalent chromium (III). Due to the toxicity of Chromium (VI) it is of particular interest in evaluating plant emissions.

The proportions of Chromium (III) and Chromium (VI) from combustion systems cannot be calculated with precision, however will be dominated by Chromium (III).

A significant factor in the reduction of the predicted proportion of Chromium (VI) for the Coolimba project as compared to generic emissions factors is the presence of sulphur in the fuel, which acts to convert Chromium (VI) to Chromium (III).

The U.S Patent application “Minimizing emission of hexavalent chromium from combustion sources” (http://www.freepatentsonline.com/5972301.html) advises that, “The equilibrium prediction and data also indicate that the presence of sulfur greatly inhibits the formation of hexavalent chromium species. With sulfur addition, the data indicate that less than 0.5% of the total chromium is partitioned to hexavalent chromium species.”

The blended coal received by the Coolimba Power Station will have a sulphur content in the range of 1.5 – 3.3 % (15000 – 33000 ppm), whereas the above document advises that, “In order to minimize the amount of hexavalent chromium in exhaust gases from combustion and incineration, sulfur in amounts ranging from about 100 to about 10,000 ppm is added to the mixture to be burned.”

It is therefore expected that the sulphur naturally present in the coal will act to minimise the formation of hexavalent chromium. On the basis of the above it has been assumed that approximately 0.5 % of the total chromium will be partitioned into Chromium (VI). This value has therefore been taken as the basis for Coolimba emissions modelling.

3.3 Other Gaseous Emissions

3.3.1 Nitrous Oxide (N_2O) Emissions

The predicted Coolimba N_2O emissions were based upon an emission factor of 0.8 t N_2O/PJ. This is the emission factor for black coal as prescribed in Table 5 of the Australian Government Dept of Climate Change report *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006 – Energy (Stationary Sources).*

(http://www.climatechange.gov.au/inventory/methodology/pubs/methodology-stationary2006.pdf)

3.3.2 Methane (CH_4) Emissions

The predicted Coolimba CH_4 emissions were based upon an emission factor of 0.9 t CH_4/PJ. This is the emission factor for black coal as prescribed in Table 5 of the Australian Government Dept of Climate Change report *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006 – Energy (Stationary Sources).*

3.3.3 NO_2 Emissions

The NO_2 emissions limit of 500 mg/Nm^3 (6% O_2, dry basis) has been set for the Coolimba project in consideration of the following;

- *Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants* has a current limit for large existing boilers (> 500 MW thermal) of 500 mg/Nm^3.
- A limit of 500 mg/Nm^3 NO_2 is comparable and actually slightly more stringent than limits approved for other recent coal fired power stations in Western Australia.
- This limit is achievable with CFB boilers (CFB boilers inherently produce lower NO_x levels than pulverised coal boilers due to the lower combustion temperatures involved)

3.3.4 CO Emissions

The CO emissions limit of 200 mg/Nm^3 (6% O_2, dry basis) has been set for the Coolimba project in consideration of the following;

- This limit is technically achievable.
- A limit of 200 mg/Nm^3 CO is more stringent than limits approved for other recent coal fired power stations in Western Australia.

3.3.5 Particulates as PM_{10}

The particulate emissions limit of 50 mg/Nm^3 (6% O_2, dry basis) has been set for the Coolimba project in consideration of the following factors;

- *Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants* has a current limit for large existing boilers (> 500 MW thermal) of 50 mg/Nm^3.
- A limit 50 mg/Nm^3 is consistent with approved limits for other recent coal fired power stations in Western Australia.
- This limit is achievable with standard particulate control equipment.

3.3.6 Volatile Organic Compounds (VOC)

The VOC emission factor for black coal prescribed in the *NPI Emission Estimation Technique for Combustion in Boilers, Version 3.1* is 0.03 kg VOC/t coal. A margin has been added to this value in the calculation of Coolimba VOC emissions.

3.3.7 Polycyclic Aromatic Hydrocarbons (PAH)

The PAH emission factor for black coal prescribed in the *NPI Emission Estimation Technique for Combustion in Boilers, Version 3.1* is 9.50×10^{-6} kg PAH/t coal. A margin has been added to this value in the calculation of Coolimba PAH emissions.

3.3.8 Total Polychlorinated dioxins and furans

The total polychlorinated dioxins and furans emission factor for black coal prescribed in the *NPI Emission Estimation Technique for Combustion in Boilers, Version 3.1* is 9.12×10^{-10} kg TPD/t coal. A margin has been added to this value in the calculation of Coolimba total polychlorinated dioxins and furans emissions, however a split between dioxins and furans was also included on the basis of emissions factors prescribed in a previous edition of the above NPI document.

APPENDIX B - METEOROLOGICAL ASSESSMENT FOR THE ENEABBA REGION

Contents

Tables

Figures

B1. Introduction

The methodology used to assess the impact on air quality associated with the proposed Coolimba Power Project (CPP) comprised a comprehensive atmospheric dispersion modelling study. To develop the dispersion model, a detailed validation study was carried out to assess the performance of a range of model configurations and input parameters. This report provides a summary of the variations in the methodology adopted for the TAPM meteorological and dispersion modelling study and presents a detailed statistical analysis to compare the outcomes of the different model configurations.

The aim of the TAPM validation study was to improve the performance of the model without the assimilation of local meteorological observations from the monitoring station located near Eneabba. Once the performance of the model without data assimilation was validated with observed data, the observed data could be assimilated for the dispersion modelling. The following variations in the model configuration were assessed for this study:

- TAPM meteorological modelling for the period May 2006 – April 2007
- A domain centred over the monitoring station location with a 40 cell by 40 cell grid
- Terrain resolution to 300 m by increasing the number of nested grids from four to five (cell resolutions - 30 km, 10 km, 3 km, 1 km and 300 m)
- Modifications to monthly soil moisture content to promote the development of the sea breeze

The best performed meteorological simulation, determined through this validation study, was then used with local data assimilation included for Eneabba and the Power Station locations, to assess the impacts of emissions from the CPP. Dispersion modelling was also conducted using TAPM.

B2. Considerations for the TAPM Validation Study

The initial TAPM simulation Katestone Environmental (2008) performed for the Eneabba region near the proposed CPP highlighted a number of areas where the model did not adequately predict certain meteorological conditions that are important for the dispersion of air pollutants and the prediction of ground-level impacts. Consideration was given to the development of suitable wind fields in the region to adequately simulate plume dispersion for both gaseous emissions from the coal- and gas-fired Power Station stacks and dust emissions from the mine. After presentation of the initial modelling outcomes and consultation with Dr. Ken Rayner from the Department of Environment and Conservation in Western Australia, the following comments by Dr. Rayner were considered in the set up of the TAPM model for the validation study:

- The acceptability of the performance of TAPM to predict certain meteorological conditions important to dispersion will be different for the assessments of gaseous emissions from tall stacks and dust emissions from ground-level area sources
- The under-prediction of high wind speeds by TAPM will be significant for the modelling of dust emissions from the mine
- Stable light wind conditions should not be important in the context of predicting ground-level impacts from the Power Station stack, and therefore the significance of TAPM under-estimating light winds is yet to be determined
- The discrepancy between the observed and predicted wind direction statistics may be influenced by terrain but is more likely to be a result of TAPM's failure to simulate the sea breeze
- The statistics for wind direction indicate that TAPM has performed poorly
- The difference between unassimilated TAPM predictions at the Eneabba monitoring station and the proposed Power Station location is an increased frequency of south-easterly winds at the latter. This may be due to terrain influences and are likely to affect pollution predictions to the northwest of the Power Station.

B3. Location of sensitive receptors

The locations of the nearest sensitive receptors are presented below in Table B1 and also in Figure B1. The direction to the CPP has been included in this table to help identify the most important wind directions that may result in emissions from the CPP being taken over each of the sensitive receptor locations. For example, winds from the south-southwest would be required to take emissions from the CPP over the township of Eneabba.

Table B1 Location of sensitive receptors

Name	Easting	Northing	Direction to power station	Distance to power station (km)
R1	327337	6698388	S	13.2
R2	324051	6690326	SSE	6.5
R3	322465	6689554	SE	7
R4	326866	6687358	SSE	2.4
R5	325159	6681369	NE	4.8
R6	327062	6682264	NE	3.1
R7	327019	6683467	NE	2
R8	326287	6678839	NNE	6.6
R9	327783	6676991	N	8.2
R10	328760	6673579	N	11.7
R11	341480	6681401	WNW	14
Eneabba	332559	6700166	SSW	15.6

B4. Methodology

B4.1 Changes to TAPM Configuration

The DEC's responses to the initial TAPM modelling simulations, as discussed in Section 2.1, have been addressed by Katestone Environmental in the following changes to the configuration of TAPM.

To analyse the model's sensitivity to terrain effects in the region the resolution of the modelling domain has been increased to 300m with the addition of a fifth nested grid. Important terrain effects include drainage flows in a westerly direction from the elevated terrain to the east of the site. Terrain data supplied with the TAPM database had also been replaced by Geoscience Australia 9-second Digital Elevation Model (DEM) terrain data. A contour map of the terrain and the 1000m and 300m modelling domains are presented in Figure B1.

To improve TAPM's ability to simulate the sea breeze, adjustable parameters within the TAPM model that are sensitive to the meteorological characteristics that influence the sea breeze were analysed. The sea breeze is a function of the difference in atmospheric pressure between the air above the ocean and the air above the land. To stimulate the development of a sea breeze, particularly during the spring and summer months when TAPM was under-predicting winds from the southwest, adjustments were made to the monthly deep soil moisture content in TAPM.

A review of rainfall data collected by the Bureau of Meteorology (BoM) for Eneabba identified the spring and summer period of October to February as having below average rainfall, while June, July and August were the wettest months of the year. The default soil moisture content in the area in TAPM is 0.15%. This value has been adjusted to reflect variations in the annual rainfall profile based on BoM measurements. The monthly deep soil moisture content values used in TAPM are presented in Table B2.

By decreasing the soil moisture content during the spring/summer period to reflect the below average rainfall observed, the change in the Bowen ratio affected the surface heating of the air and subsequently the atmospheric pressure. This created a larger differential in air pressure between the air above the ocean and the air above the land, stimulating the sea breeze.

Table B2 Deep Soil Moisture Content used in TAPM

Month	Deep Soil Moisture Volumetric Content (%)
January	0.05
February	0.05
March	0.15
April	0.15
May	0.15
June	0.25
July	0.25
August	0.25
September	0.15
October	0.05
November	0.05
December	0.05

In summary, the following points have been addressed in the TAPM sensitivity analysis:

- 40 x 40 grid point domain with an outer grid of 30 kilometres and nesting grids of 10 kilometres, 3 kilometres, 1 kilometre and 300 metres
- Grid centred near the monitoring station site (latitude –29° 49', longitude 115°16')
- Geoscience Australia 9 second DEM terrain data
- Modification to the deep soil volumetric moisture content
- The synoptic data used in the simulation is for the period May 2006 to April 2007

B5. Results

B5.1 Modelling Scenarios Analysed

To determine the optimal TAPM configuration for this assessment, a sensitivity analysis was conducted for the following model setups. This analysis was designed to supplement the analysis presented in Katestone Environmental (2008).

Initial TAPM configuration

- TAPM with no data assimilation; four nested grids of 30 km, 10 km, 3 km, 1 km; default settings for soil moisture content; modelling period 1 May 2006 to 30 April 2007

Revised TAPM configuration

- TAPM with no data assimilation; four nested grids of 30 km, 10 km, 3 km, 1 km; soil moisture content values adjusted for observed rainfall data; modelling period 1 May 2006 to 30 April 2007
- TAPM with no data assimilation; five nested grids of 30 km, 10 km, 3 km, 1 km, 300 m; soil moisture content values adjusted for observed rainfall data; modelling period 1 May 2006 to 30 April 2007

B5.2 Comparison of Observed and TAPM Wind Fields with 300 m and 1,000 m Grid Resolution

The analysis of the modelled period between May 2006 and April 2007 has been conducted for four periods of the day, night time (00:00 to 05:59), morning (06:00 to 11:59), afternoon (12:00 to 17:59) and evening (18:00 to 23:59) hours. Descriptive statistics including mean wind speed and mean U and V vector components for the observations and TAPM modelling for the 300 m and 1,000 m scenarios for the four periods are presented in Table B3 - Table B6 . Correlation statistics between TAPM predictions at a resolution of 300 m and 1,000 m and observed data are presented in Table B7 - Table B10 . The correlations are described using various statistical functions including the Pearson Correlation Coefficient (RCOR), Index Of Agreement (IOA), the Mean Absolute Error (MAE) and a Complex Vector Correlation (CVC) that provides a comparison of the vector magnitude and phase angle. The relationship between the observed wind speed and direction and the TAPM predictions at a resolution of 300 m and 1,000 m are also presented graphically as Probability Density Function (PDF) in Figure B2 – B17. A description of the statistical methods used in this report is included in Appendix 1.

All statistical analysis and plots for both observed TAPM predicted data present wind speed and wind directions at a height above ground level of ten metres.

Table B3 Statistics for the monitoring station for observed (OBS) data and TAPM at 300 m and 1000 m resolution for the night time hours

Statistics	Configuration	WSpeed (m/s)	U	V
Average	OBS	3.73	-2.09	1.17
	TAPM 300 m	4.45	-3.35	0.20
	TAPM 1000 m	4.41	-3.33	0.31
Standard Deviation	OBS	2.75	3.31	2.19
	TAPM 300 m	2.16	2.88	2.21
	TAPM 1000 m	2.05	2.82	2.13

Table B4 Statistics for the monitoring station for observed (OBS) data and TAPM at 300m and 1000m resolution for the morning

Statistics	Configuration	WSpeed (m/s)	U	V
Average	OBS	4.70	-2.35	0.60
	TAPM 300m	4.39	-2.21	-0.16
	TAPM 1000m	4.39	-2.24	-0.11
Standard Deviation	OBS	2.78	4.12	2.64
	TAPM 300m	2.19	3.52	2.60
	TAPM 1000m	2.12	3.49	2.56

Table B5 Statistics for the monitoring station for observed (OBS) data and TAPM at 300m and 1000m resolution for the afternoon

Statistics	Configuration	WSpeed (m/s)	U	V
Average	OBS	4.96	1.25	1.44
	TAPM 300m	4.32	-0.11	1.36
	TAPM 1000m	4.29	-0.10	1.33
Standard Deviation	OBS	2.00	4.14	2.80
	TAPM 300m	1.66	3.43	2.80
	TAPM 1000m	1.63	3.41	2.77

Table B6 Statistics for the monitoring station for observed (OBS) data and TAPM at 300m and 1000m resolution for the evening

Statistics	Configuration	WSpeed (m/s)	U	V
Average	OBS	3.77	-0.18	2.11
	TAPM 300m	4.00	-2.11	1.42
	TAPM 1000m	3.96	-2.06	1.47
Standard Deviation	OBS	2.10	2.98	2.29
	TAPM 300m	1.59	2.63	2.26
	TAPM 1000m	1.52	2.60	2.20

Table B7 Correlations between TAPM predicted and observed data at the monitoring station for the night time hours

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	TAPM 300m and OBS	0.801	0.863	1.42	n/a
	TAPM 1000m and OBS	0.804	0.860	1.41	n/a
WDir	TAPM 300m and OBS	n/a	n/a	n/a	0.850, 19.5[1]
	TAPM 1000m and OBS	n/a	n/a	n/a	0.846, 18.8[1]
U	TAPM 300m and OBS	0.797	0.856	1.85	n/a
	TAPM 1000m and OBS	0.791	0.852	1.86	n/a
V	TAPM 300m and OBS	0.729	0.812	1.43	n/a
	TAPM 1000m and OBS	0.722	0.815	1.38	n/a
[1] Vector Correlation Coefficient					

Table B8 Correlations between TAPM predicted and observed data at the monitoring station for the morning

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	TAPM 300m and OBS	0.794	0.872	1.32	n/a
	TAPM 1000m and OBS	0.797	0.870	1.32	n/a
WDir	TAPM 300m and OBS	n/a	n/a	n/a	0.879, 11.9[1]
	TAPM 1000m and OBS	n/a	n/a	n/a	0.879, 11.3[1]
U	TAPM 300m and OBS	0.864	0.923	1.55	n/a
	TAPM 1000m and OBS	0.865	0.923	1.56	n/a
V	TAPM 300m and OBS	0.789	0.868	1.40	n/a
	TAPM 1000m and OBS	0.788	0.869	1.38	n/a
[1] Vector Correlation Coefficient					

Table B9 Correlations between TAPM predicted and observed data at the monitoring station for the afternoon

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	TAPM 300m and OBS	0.641	0.769	1.32	n/a
	TAPM 1000m and OBS	0.642	0.766	1.33	n/a
WDir	TAPM 300m and OBS	n/a	n/a	n/a	0.857, 19.3[1]
	TAPM 1000m and OBS	n/a	n/a	n/a	0.858, 18.9[1]
U	TAPM 300m and OBS	0.847	0.884	1.98	n/a
	TAPM 1000m and OBS	0.850	0.885	1.97	n/a
V	TAPM 300m and OBS	0.790	0.886	1.39	n/a
	TAPM 1000m and OBS	0.791	0.887	1.38	n/a
[1] Vector Correlation Coefficient					

Table B10 Correlations between TAPM predicted and observed data at the monitoring station for the evening

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	TAPM 300m and OBS	0.644	0.781	1.32	n/a
	TAPM 1000m and OBS	0.653	0.781	1.29	n/a
WDir	TAPM 300m and OBS	n/a	n/a	n/a	0.824, 27.9 [1]
	TAPM 1000m and OBS	n/a	n/a	n/a	0.825, 27.3 [1]
U	TAPM 300m and OBS	0.787	0.794	2.27	n/a
	TAPM 1000m and OBS	0.789	0.798	2.22	n/a
V	TAPM 300m and OBS	0.766	0.853	1.27	n/a
	TAPM 1000m and OBS	0.761	0.851	1.27	n/a

[1] Vector Correlation Coefficient

The results of the TAPM modelling indicate the following:

- The analyses presented in the above tables indicate there is no significant difference in the predicted wind speed and direction for the TAPM 300 m and 1,000 m grid resolution scenarios.

- The PDF scatter plots presented in Figure B2 – B5. indicate there is no significant difference in predicted wind speed and wind direction for the TAPM 300 m and 1,000 m grid resolution scenarios.

The comparative analysis of TAPM for the 300 m and 1,000 m scenarios indicates there is not a significant improvement in the model's performance with the increase in grid resolution and the related terrain profile. Consequently, in order to model a large region the 1,000 m grid resolution scenario was used for the pollution dispersion modelling and the remainder of the meteorological analyses.

B5.3 Comparison of Observed Data and Revised TAPM Predicted Wind Fields with 1,000 metre Grid Resolution at the Eneabba Monitoring Station

A correlation analysis of wind speed and direction for the observed data and unassimilated TAPM predictions, for the 1,000 m grid resolution scenario, is presented using descriptive statistics, probability density functions and wind roses.

The monthly distribution of wind speed and direction for the modelling period as generated by TAPM for the 1,000 m resolution scenario and the observed data are presented as wind roses in Figure B6 – B17. The diurnal distribution of wind speed and direction for the modelling period as generated by TAPM for the 1,000 m resolution scenario by month are presented as wind roses in Figure B18 to Figure B29.

The results of the TAPM modelling indicate the following:

- There is a significant difference between the observed wind speed and the TAPM (1,000 m resolution) predicted wind speed including
    - For the night: TAPM under-predicts wind speeds less than 3 m/s and above 9.5 m/s while it over-predicts wind speeds between 3 – 9.5 m/s

- For the morning: TAPM under-predicts wind speeds between 2.5 – 6 m/s, while it over-predicts wind speeds below 1.5 m/s and above 7.5 m/s
- For the afternoon: TAPM slightly under-predicts wind speeds below 2 m/s and significantly under-predicts wind speeds between 2 - 5.5 m/s, while significantly over-predicting wind speeds above 5.5 m/s
- For the evening: TAPM significantly under-predicts wind speeds below 3.3 m/s and significantly over-predicts wind speeds between 3.3 – 5.4 m/s. TAPM slightly under-predicts wind speeds above 5.4 m/s

- There is a significant difference between the observed wind direction and the TAPM (1,000 m resolution) predicted wind direction including

  - For the night: TAPM significantly over-predicts the frequency of winds from the east and southeast while significantly under-predicting the frequency of winds from between the south-southeast and west
  - For the morning: TAPM over-predicts the frequency of winds from the north and northwest and under-predicts the frequency of winds from the south and southwest
  - For the afternoon: TAPM significantly over-predicts the frequency of winds from the north and northeast and from between the southeast and southwest while significantly under-predicting the frequency of winds from between the southwest and northwest
  - For the evening: TAPM significantly over-predicts the frequency of winds from between the east-northeast and south while significantly under-predicting the frequency of winds from between the south and northwest

- This indicates that the changes to the TAPM configuration has not significantly improved the model's ability to simulate the sea breeze

B5.4 Comparison of Wind Fields Between Observed Data and Various TAPM Scenario Predictions at the Eneabba Monitoring Station

The observed data has been compared with predictions at the monitoring station site for three TAPM configuration scenarios. The analysis is based on the diurnal profile, and is presented graphically as a series of PDF plots in Figure B30 – B34. Correlation statistics including RCOR, IOA, MAE and CVC (Magnitude and Phase) are presented for the annual profile in Table B11 , and for the diurnal profiles in Table B12 - Table B15. The three configurations are described as follows:

- Scenario A - Previous unassimilated TAPM modelling – configuration based on TAPM run presented in Katestone Environmental report *Aviva – Preliminary Assessment of Meteorology at Eneabba, Draft Report, June 2008.* Configuration setup: TAPM with no data assimilation; four nested grids of 30 km, 10 km, 3 km, 1 km; default settings for soil moisture content; modelling period 1 May 2006 to 30 April 2007

- Scenario B - Revised unassimilated TAPM modelling – TAPM with no data assimilation; four nested grids of 30 km, 10 km, 3 km, 1 km; soil moisture content values adjusted for observed rainfall data; modelling period 1 May 2006 to 30 April 2007

- Scenario C - Revised assimilated TAPM modelling – TAPM with data assimilation; four nested grids of 30 km, 10 km, 3 km, 1 km; soil moisture content values adjusted for observed rainfall data; modelling period 1 May 2006 to 30 April 2007

Table B11 **Correlations between TAPM predicted and observed data at the monitoring station for all hours**

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	Scenario A	0.6987	0.8109	1.4185	n/a
	Scenario B	0.7315	0.8334	1.3378	n/a
	Scenario C	0.9860	0.9779	0.4972	n/a
WDir	Scenario A	n/a	n/a	n/a	0.8331, 19.6073
	Scenario B	n/a	n/a	n/a	0.8480, 18.2526
	Scenario C	n/a	n/a	n/a	0.9928, 2.1829
U	Scenario A	0.8211	0.8698	2.0330	n/a
	Scenario B	0.8366	0.8865	1.9003	n/a
	Scenario C	0.9937	0.9925	0.4530	n/a
V	Scenario A	0.7704	0.8581	1.3680	n/a
	Scenario B	0.7773	0.8678	1.3489	n/a
	Scenario C	0.9861	0.9902	0.3175	n/a

Table B12 **Correlations between TAPM predicted and observed data at the monitoring station for the night time hours**

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	Scenario A	0.7931	0.8442	1.4788	n/a
	Scenario B	0.804	0.8598	1.4126	n/a
	Scenario C	0.9891	0.9822	0.4486	n/a
WDir	Scenario A	n/a	n/a	n/a	0.8333, 20.3592
	Scenario B	n/a	n/a	n/a	0.8464, 18.8141
	Scenario C	n/a	n/a	n/a	0.9910, 2.1854
U	Scenario A	0.7578	0.8295	2.0143	n/a
	Scenario B	0.7905	0.852	1.859	n/a
	Scenario C	0.9907	0.9891	0.4188	n/a
V	Scenario A	0.7111	0.8036	1.3989	n/a
	Scenario B	0.7221	0.8147	1.3774	n/a
	Scenario C	0.9795	0.9866	0.2889	n/a

Table B13 Correlations between TAPM predicted and observed data at the monitoring station for the morning hours

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	Scenario A	0.7898	0.8615	1.3675	n/a
	Scenario B	0.7967	0.8698	1.3205	n/a
	Scenario C	0.9878	0.9759	0.6039	n/a
WDir	Scenario A	n/a	n/a	n/a	0.8775, 11.9017
	Scenario B	n/a	n/a	n/a	0.8794, 11.3004
	Scenario C	n/a	n/a	n/a	0.9938, 1.7573
U	Scenario A	0.8583	0.9159	1.6375	n/a
	Scenario B	0.8649	0.9226	1.5562	n/a
	Scenario C	0.9943	0.9905	0.5504	n/a
V	Scenario A	0.7829	0.8687	1.3707	n/a
	Scenario B	0.7877	0.869	1.3754	n/a
	Scenario C	0.9868	0.9901	0.3343	n/a

Table B14 Correlations between TAPM predicted and observed data at the monitoring station for the afternoon hours

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	Scenario A	0.5995	0.7214	1.4886	n/a
	Scenario B	0.642	0.7661	1.3265	n/a
	Scenario C	0.9758	0.9661	0.5459	n/a
WDir	Scenario A	n/a	n/a	n/a	0.8400, 19.9653
	Scenario B	n/a	n/a	n/a	0.8576, 18.9462
	Scenario C	n/a	n/a	n/a	0.9938, 2.6442
U	Scenario A	0.8414	0.8664	2.1136	n/a
	Scenario B	0.8497	0.8851	1.9685	n/a
	Scenario C	0.9942	0.9929	0.515	n/a
V	Scenario A	0.7903	0.8815	1.3564	n/a
	Scenario B	0.791	0.8868	1.3805	n/a
	Scenario C	0.9884	0.9917	0.3493	n/a

Table B15 Correlations between TAPM predicted and observed data at the monitoring station for the evening hours

Correlations Between		Statistics			
		RCOR	IOA	MAE	Magnitude, Phase
WSpeed	Scenario A	0.6206	0.7623	1.3399	n/a
	Scenario B	0.6531	0.7814	1.2916	n/a
	Scenario C	0.9844	0.9796	0.3915	n/a
WDir	Scenario A	n/a	n/a	n/a	0.8068, 30.3505
	Scenario B	n/a	n/a	n/a	0.8253, 27.3437
	Scenario C	n/a	n/a	n/a	0.9921, 2.1425
U	Scenario A	0.7651	0.7783	2.3658	n/a
	Scenario B	0.7893	0.798	2.2168	n/a
	Scenario C	0.9912	0.9923	0.3291	n/a
V	Scenario A	0.7397	0.8251	1.3461	n/a
	Scenario B	0.7606	0.8514	1.2629	n/a
	Scenario C	0.9853	0.9888	0.2977	n/a

B6. Conclusion

Katestone Environmental has conducted an assessment of the performance of TAPM to simulate the wind speed and wind direction in the Eneabba region in Western Australia. Meteorological observations collected by Iluka at Eneabba for the period 1 May 2006 to 30 April 2007 have been compared with four TAPM modelling scenarios for the same period, and are summarised as follows:

- TAPM unassimilated; 1,000 m grid resolution and terrain; default settings for soil moisture content
- TAPM unassimilated; 1,000 m grid resolution and terrain; revised settings for soil moisture content based on BoM rainfall data
- TAPM unassimilated; 300 m grid resolution and terrain; revised settings for soil moisture content based on BoM rainfall data
- TAPM assimilated; 1,000 m grid resolution and terrain; revised settings for soil moisture content based on BoM rainfall data

The following conclusions can be drawn from the assessment.

In relation to the TAPM grid resolution:

- There is no significant improvement in the performance of TAPM in predicting wind speed and wind direction in the region by increasing the modelling grid resolution and the related terrain profile from 1,000 m to 300 m.

In relation to the general model performance based on statistical correlations for the 1,000 m grid resolution scenario:

- In general, the correlations between the TAPM predictions and the observations at Eneabba are good for both wind speed and directions.
- The model performed best during the night and morning periods (i.e. from midnight to midday).
- The changes in soil moisture parameters increased the performance of the model.

In relation to the prediction of wind speed for the 1,000 m grid resolution scenario:

- In general, TAPM tends to under-predict the frequency of winds below 3 m/s.
- In general, TAPM tends to over-predict the frequency of winds in the range between 3 – 6 m/s.
- In general, TAPM tends to under-predict the frequency of winds above 6 m/s.

In relation to the prediction of wind direction for the 1,000 m grid resolution scenario:

- In general, TAPM tends to over-predict the frequency of winds from the north.
- In general, TAPM tends to over-predict the frequency of winds from between the east and southeast.
- In general, TAPM tends to under-predict the frequency of winds from between the south and northwest.
- Flows from the southwest during the afternoon, and particularly during the spring and summer months, are generally associated with the sea breeze.
- Flows from the southeast and east at night are generally associated with terrain induced drainage flows.

- The adjustment of the soil moisture content parameter within the TAPM configuration has not significantly improved TAPM's ability to simulate the sea breeze.
- TAPM's ability to simulate terrain induced drainage flows has not significantly changed with the adjustment of model configuration, with regard to soil moisture content parameterisation or grid resolution.

The performance of TAPM in predicting the wind patterns in the Eneabba region can be improved by the use of local data assimilation. Therefore we recommend the use of TAPM (100 m grid resolution and adjusted soil moisture content) with assimilated local data for predicting the dispersion of pollutants from the proposed Coolimba Power Project.

B7. References

Katestone Environmental, 2008. *Aviva – Preliminary Assessment of Meteorology at Eneabba, Draft Report, June 2008*.

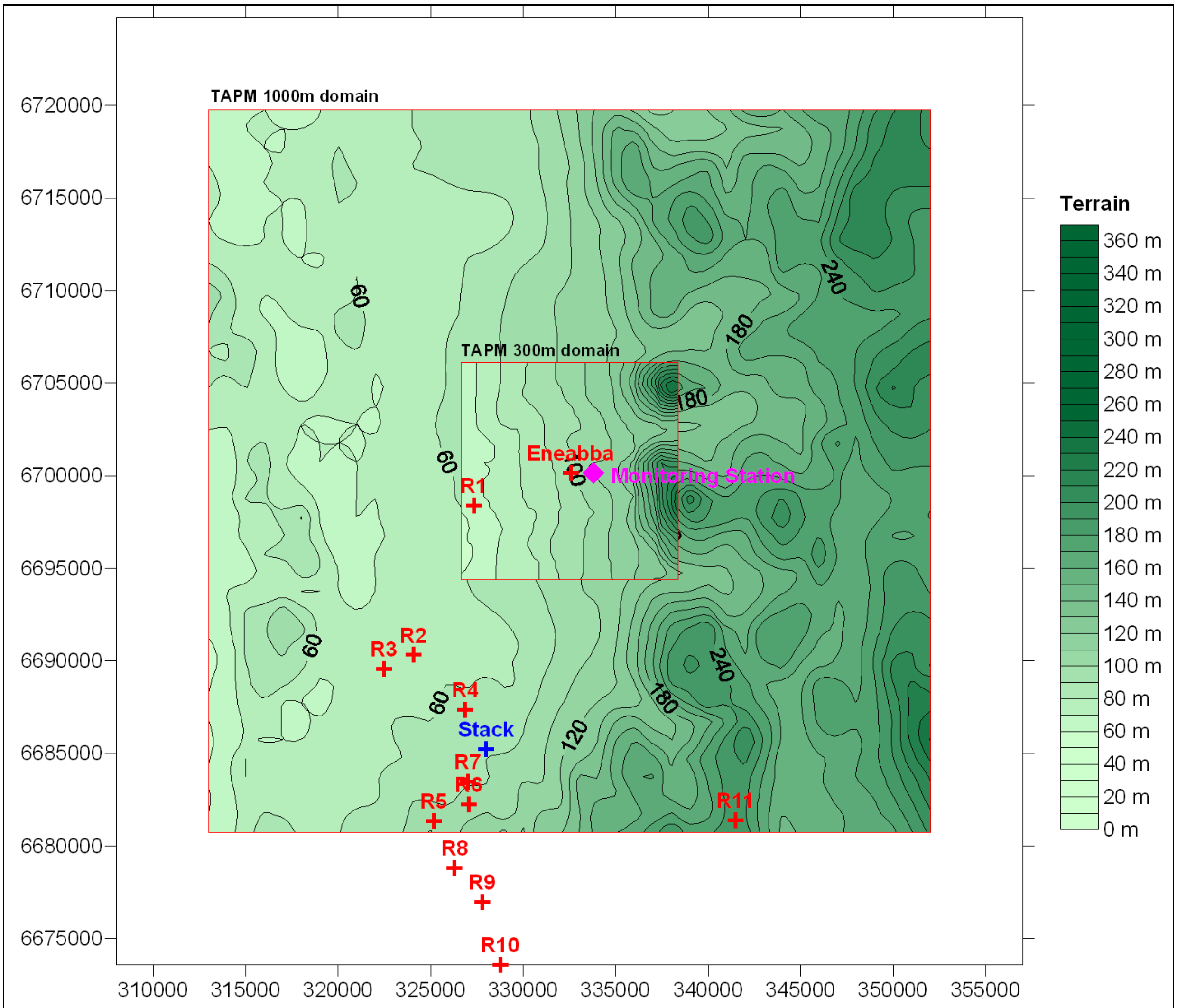
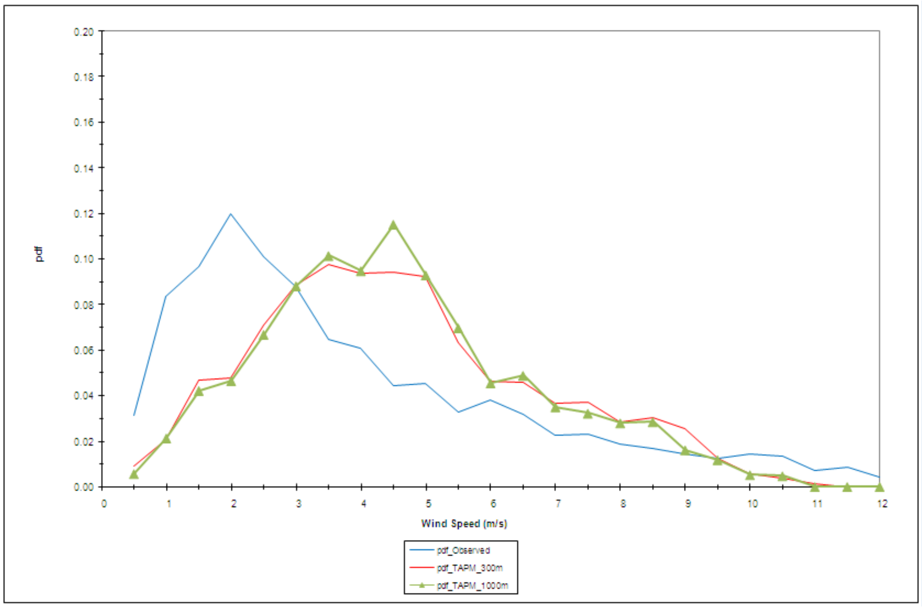


Figure B1	**TAPM modelling domains at 1000 metre and 300 metre resolution showing the location of sensitive receptors, monitoring site and stack location**		
Location: Eneabba		**Data source:** TAPM	**Units:** Australian Map Grid coordinates – MGA94
Type: Aerial Map		**Prepared by:** A. Schloss	**Date:** 8 August 2008

a)



b)

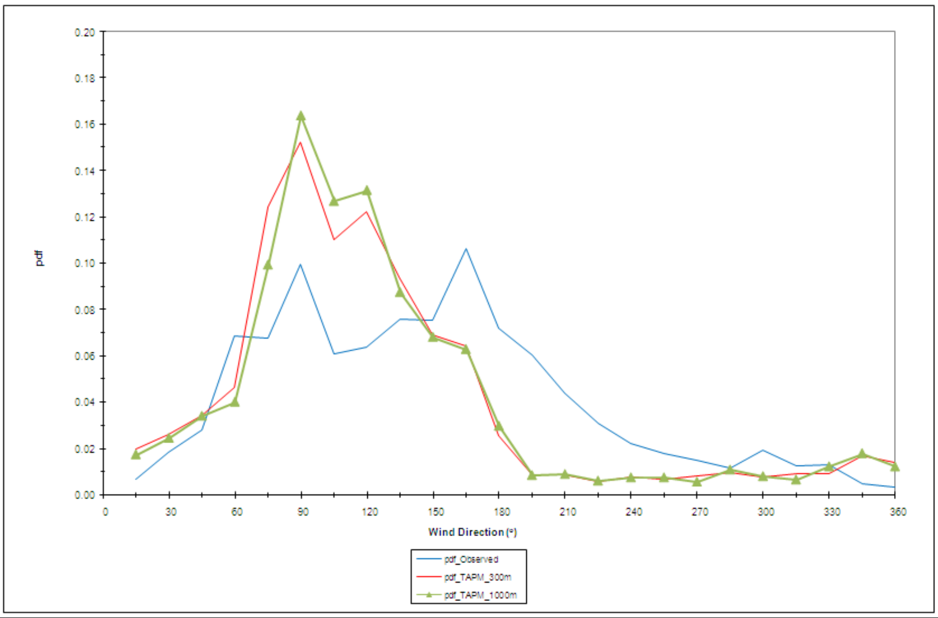
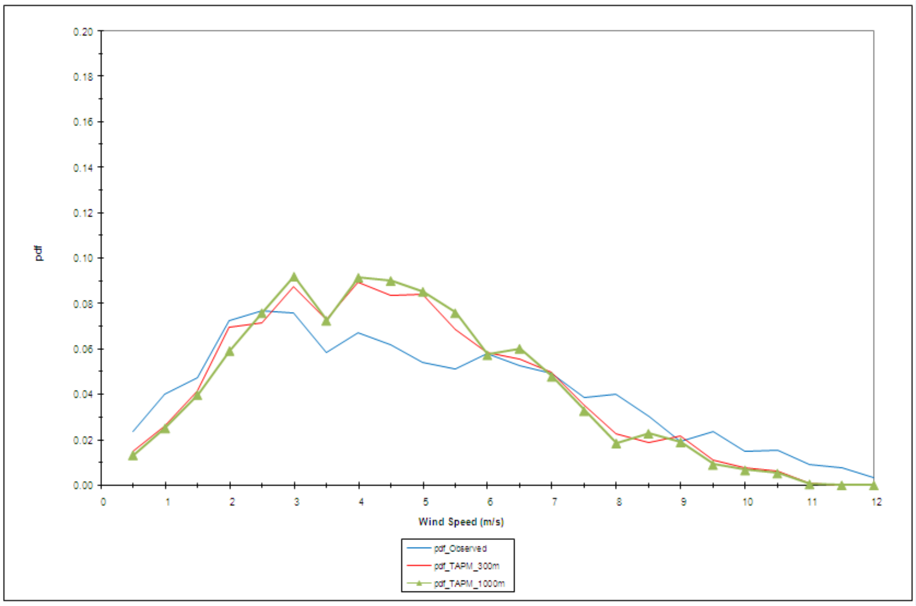


Figure B2 **Probability density function at the monitoring site for TAPM 300m domain, TAPM 1000m domain and Observed data for the night for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°**

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2111 hourly average records	**Prepared by:** A. Schloss	**Date:** 18 July 2008

a)



b)

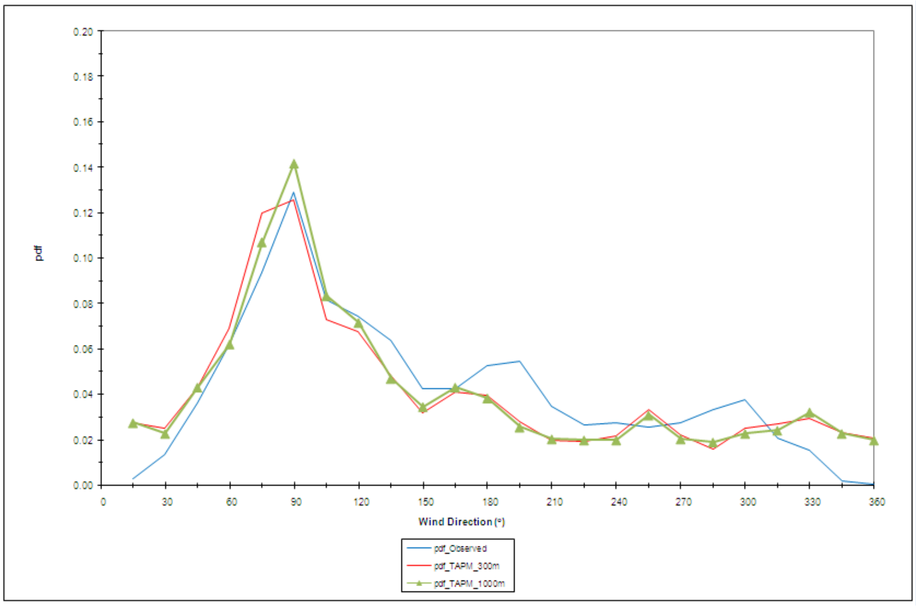
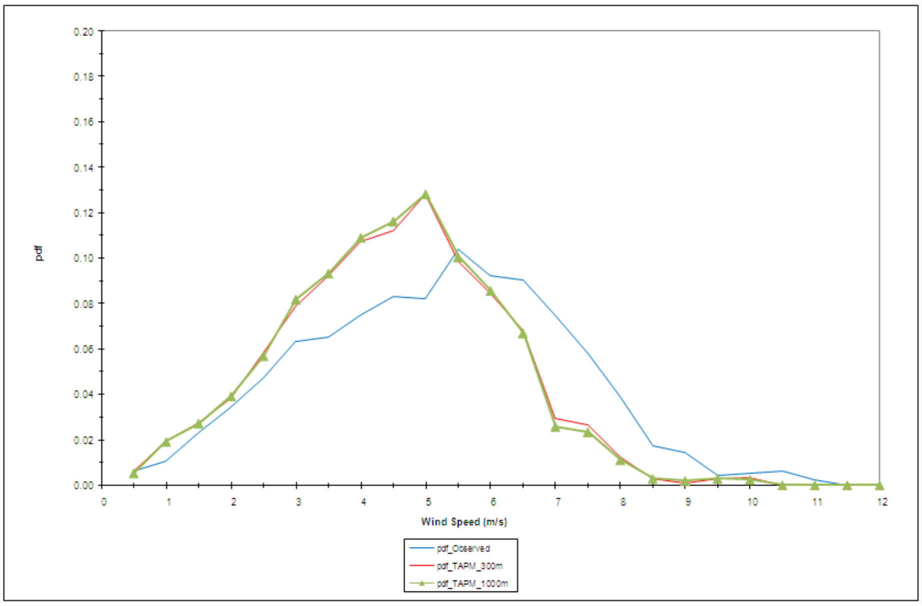


Figure B3 **Probability density function at the monitoring site for TAPM 300m domain, TAPM 1000m domain and Observed data for the morning for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°**

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2110 hourly average records	**Prepared by:** A. Schloss	**Date:** 18 July 2008

a)



b)

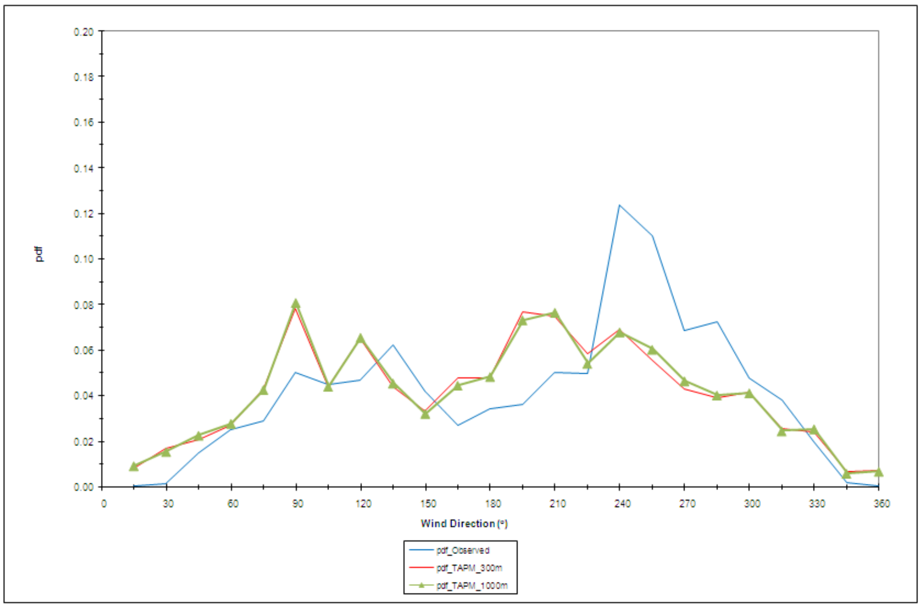
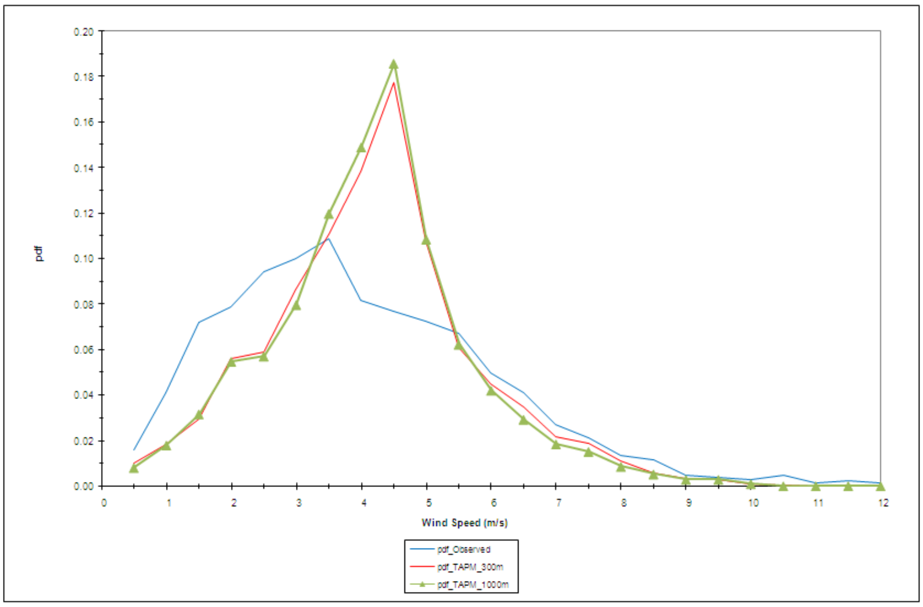


Figure B4	**Probability density function at the monitoring site for TAPM 300m domain, TAPM 1000m domain and Observed data for the afternoon for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°**

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2090 hourly average records	**Prepared by:** A. Schloss	**Date:** 18 July 2008

a)



b)

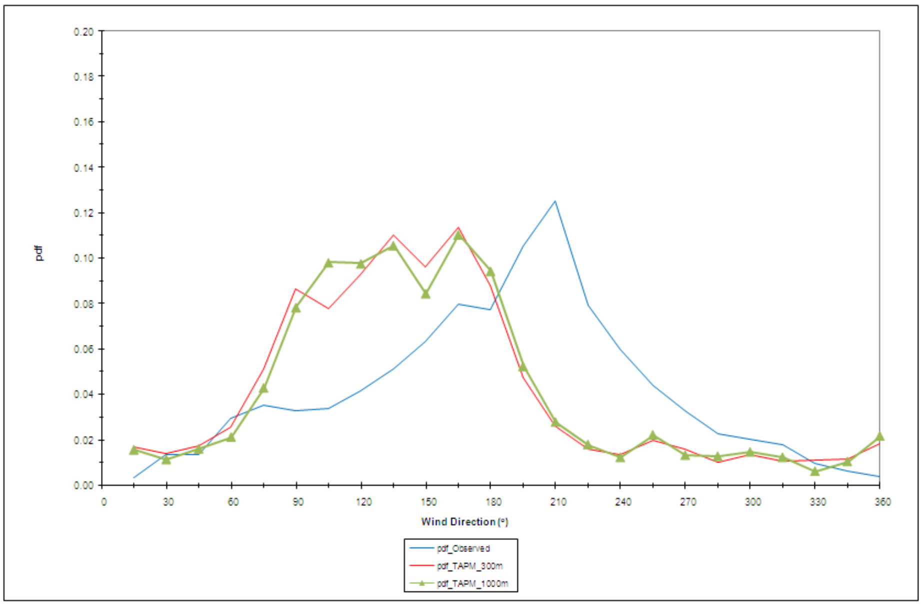


Figure B5	**Probability density function at the monitoring site for TAPM 300m domain, TAPM 1000m domain and Observed data for the evening for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°**		
Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2119 hourly average records	**Prepared by:** A. Schloss	**Date:** 18 July 2008

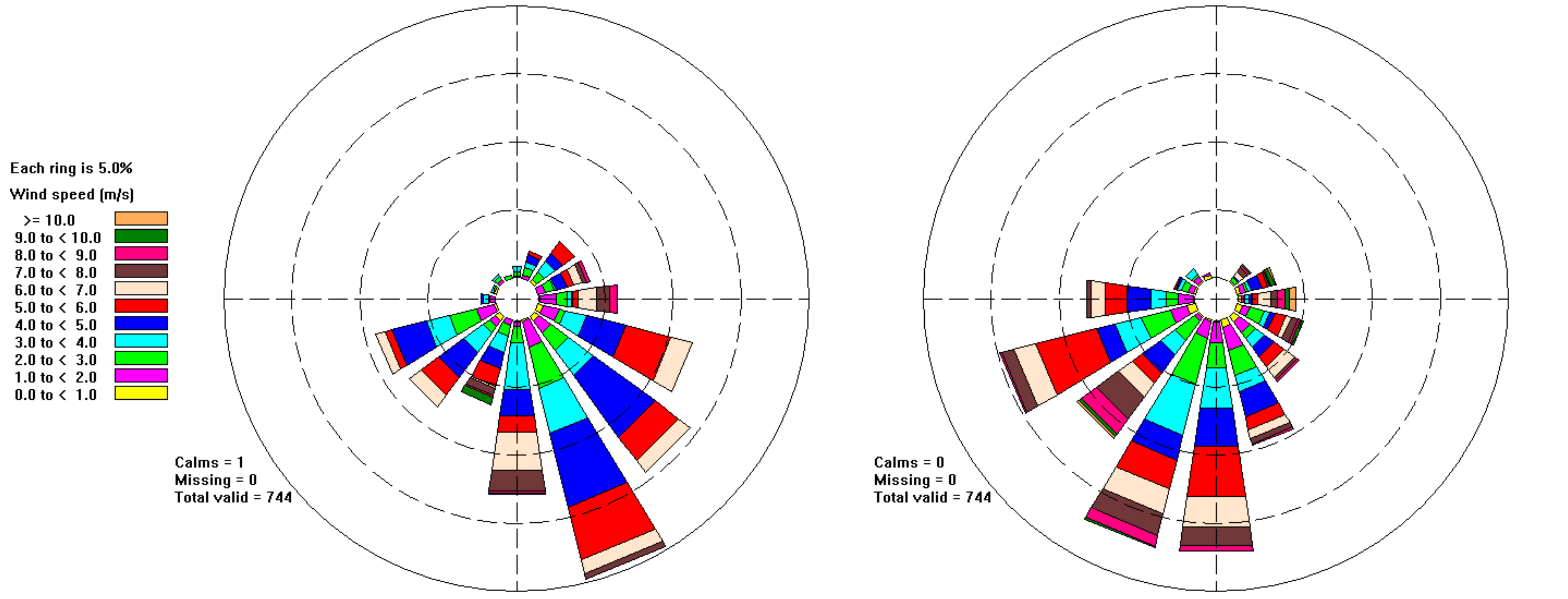


Figure B6 Wind roses for January for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/01/07 00:00 to 31/01/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

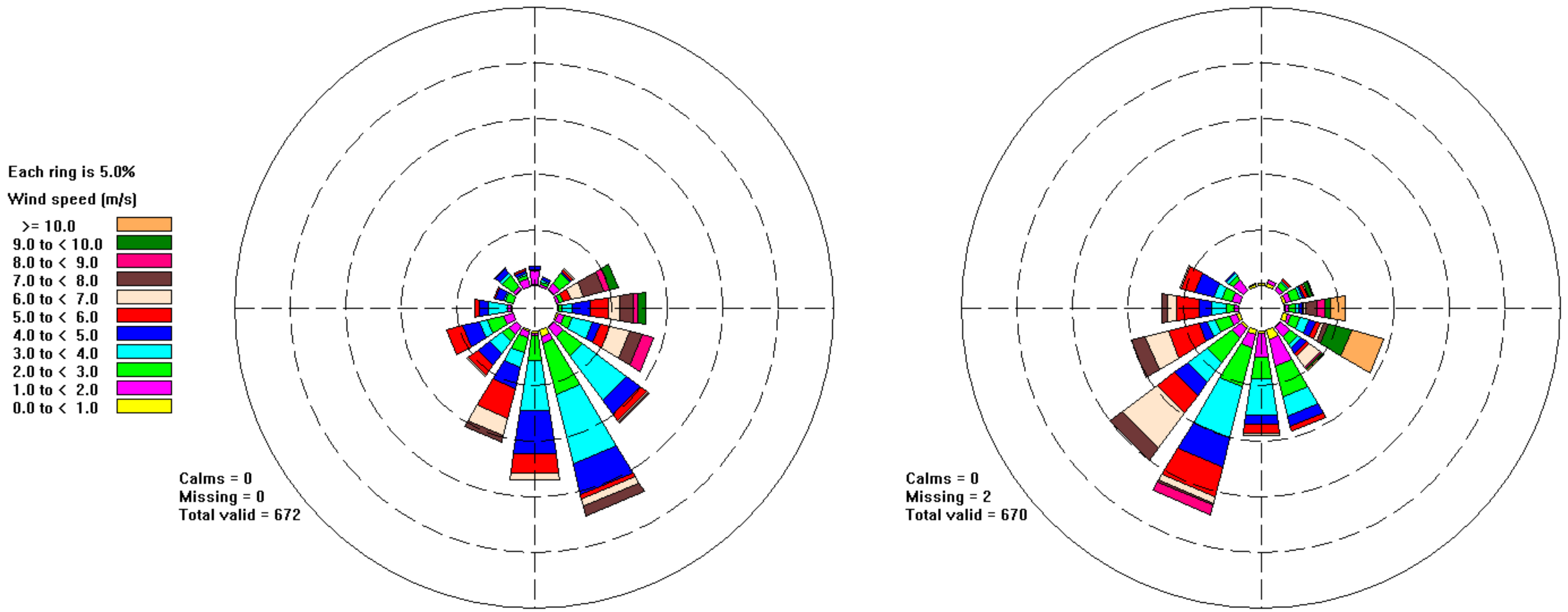


Figure B7 **Wind roses for February for TAPM (LHS) and Observed (RHS)**

Location: Monitoring station, Eneabba	**Period:** 01/02/07 00:00 to 28/02/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	672 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

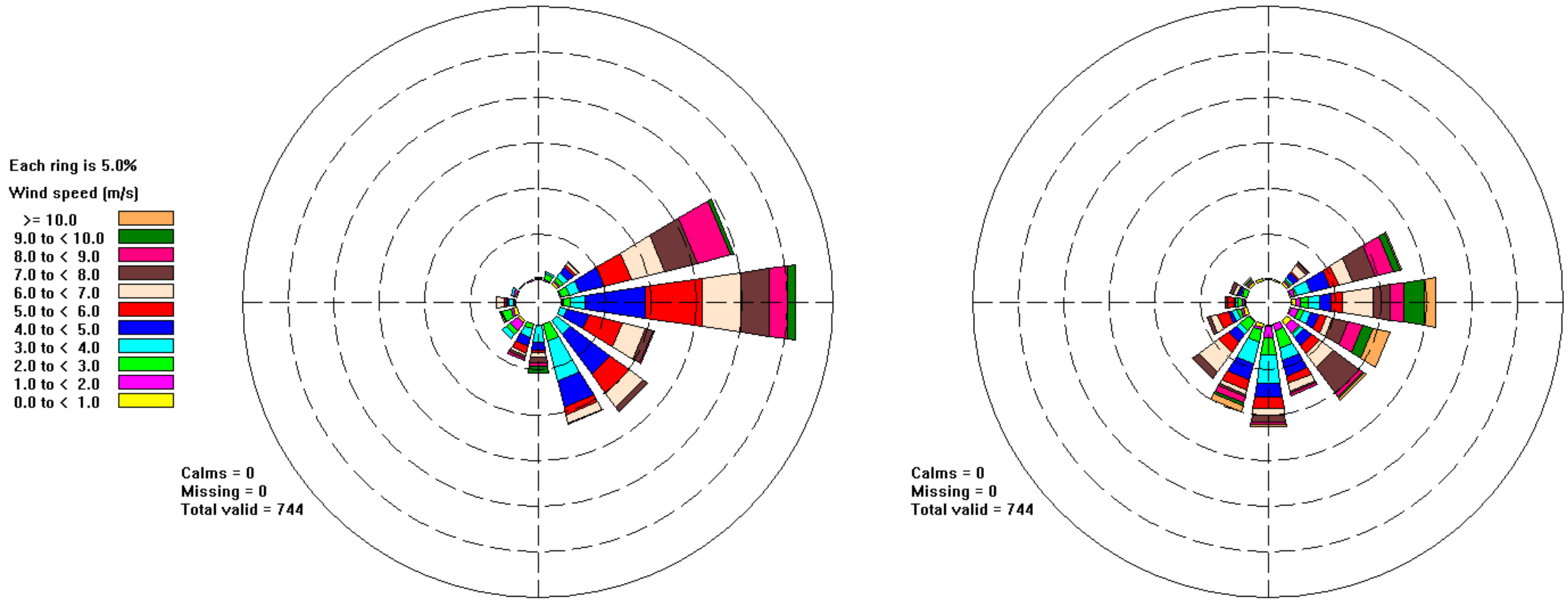


Figure B8 Wind roses for March for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/03/07 00:00 to 31/03/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

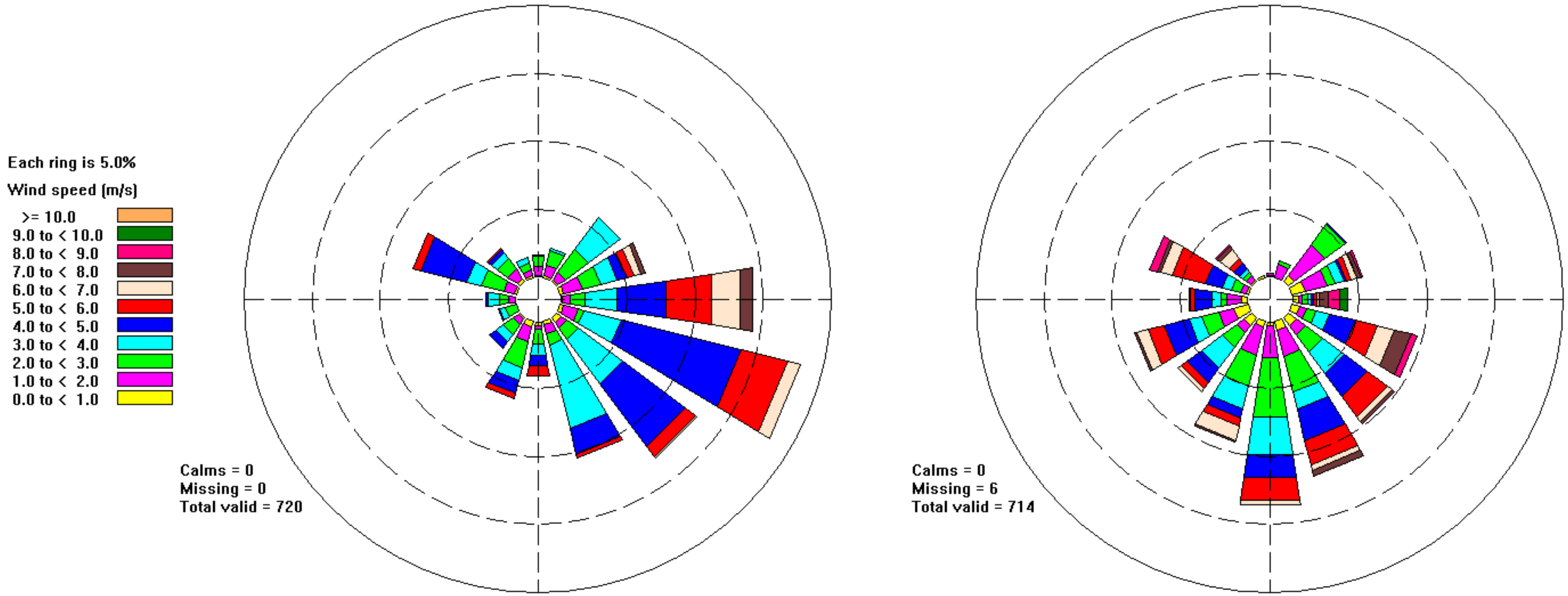


Figure B9 Wind roses for April for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/04/07 00:00 to 30/04/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

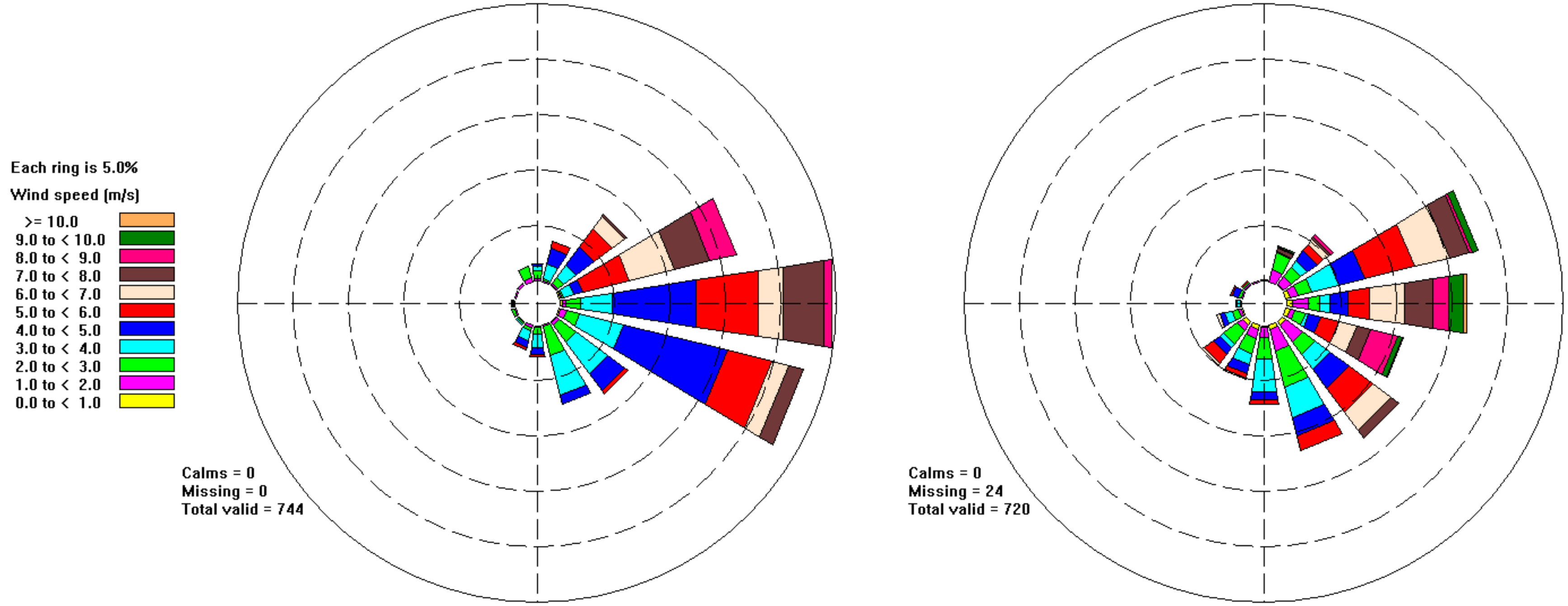


Figure B10 Wind roses for May for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/05/06 00:00 to 31/05/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

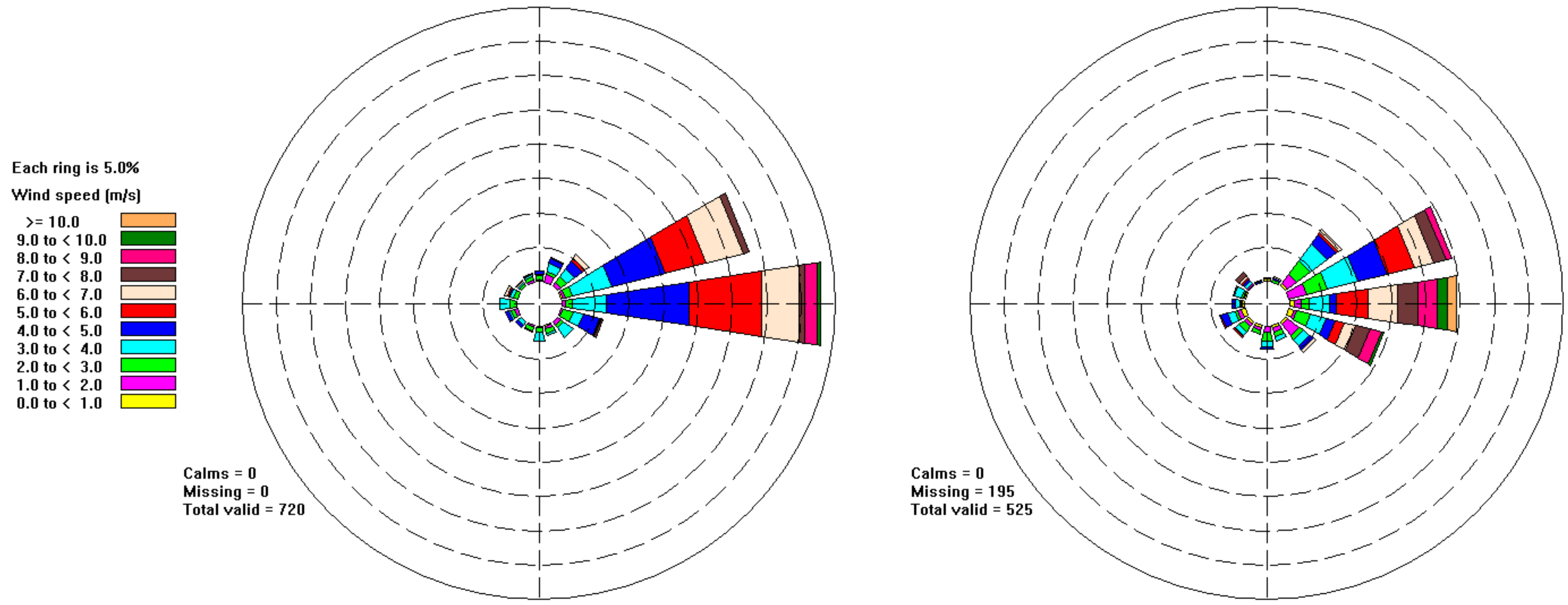


Figure B11 Wind roses for June for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/06/06 00:00 to 30/06/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

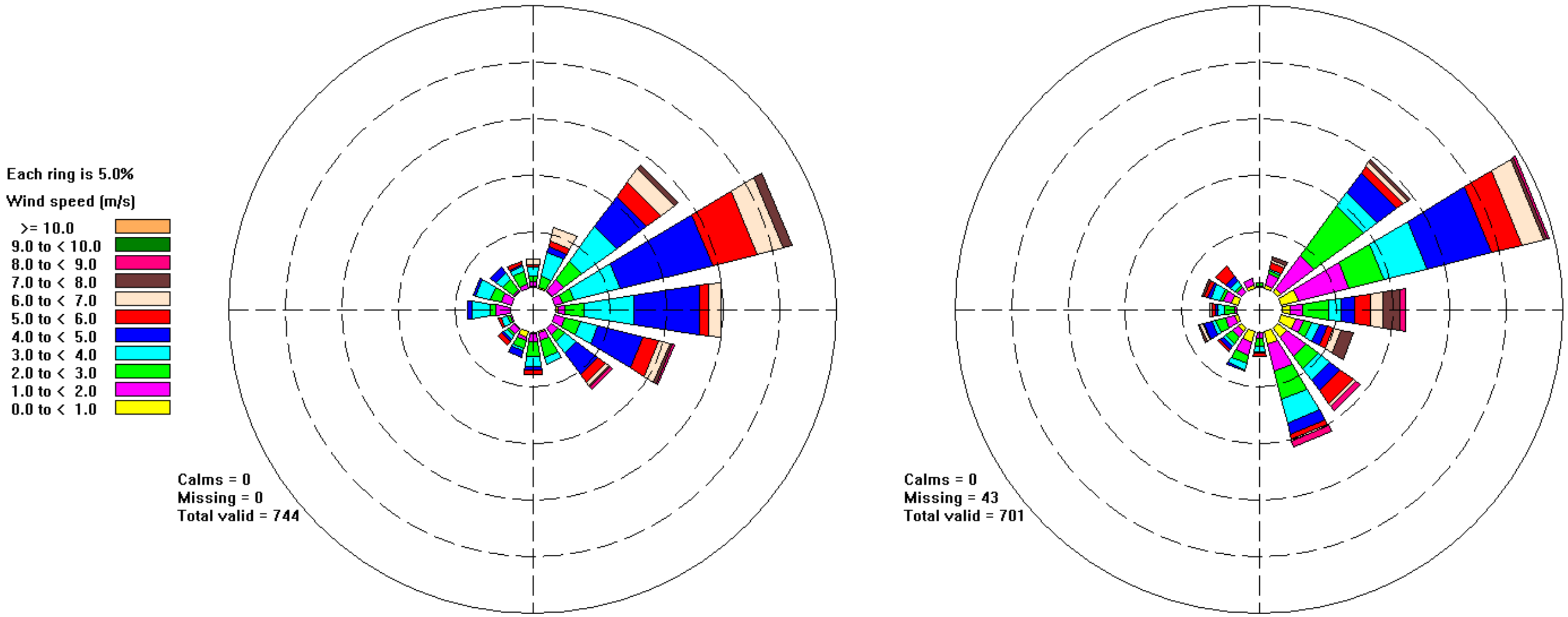


Figure B12 **Wind roses for July for TAPM (LHS) and Observed (RHS)**

Location: Monitoring station, Eneabba	**Period:** 01/07/06 00:00 to 31/07/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

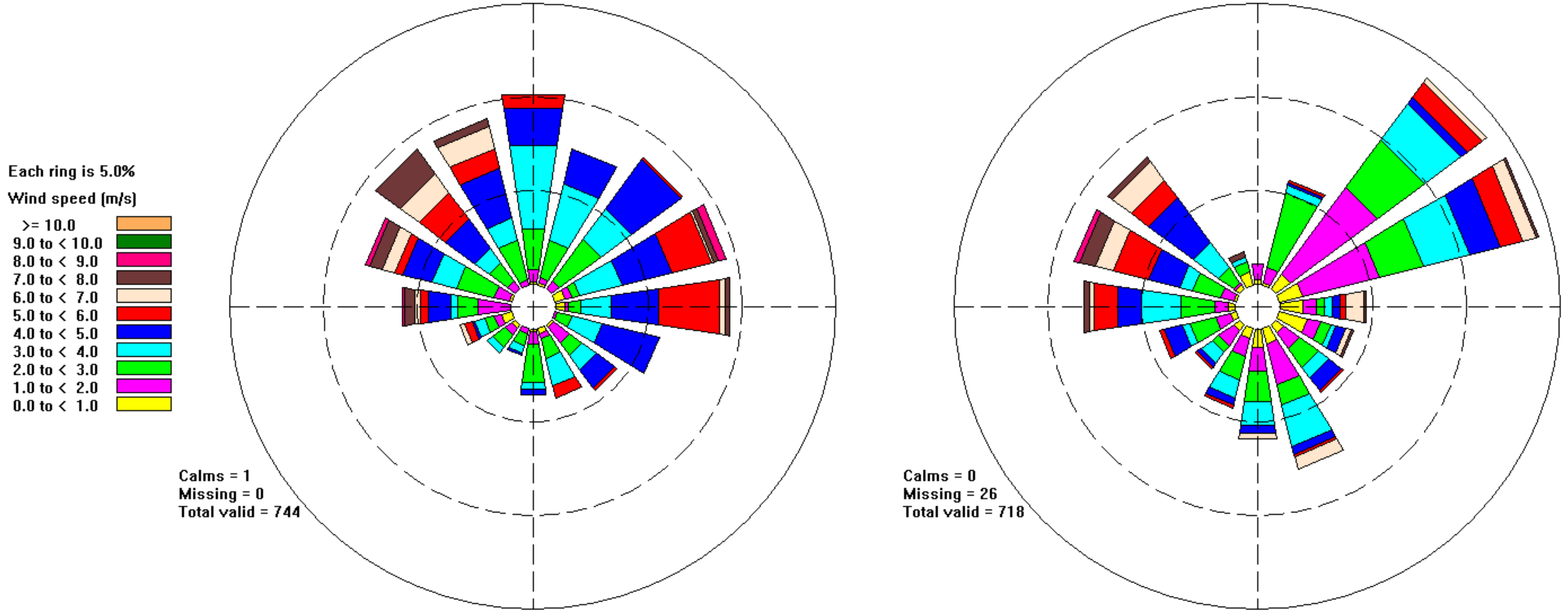


Figure B13 Wind roses for August for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/08/06 00:00 to 31/08/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

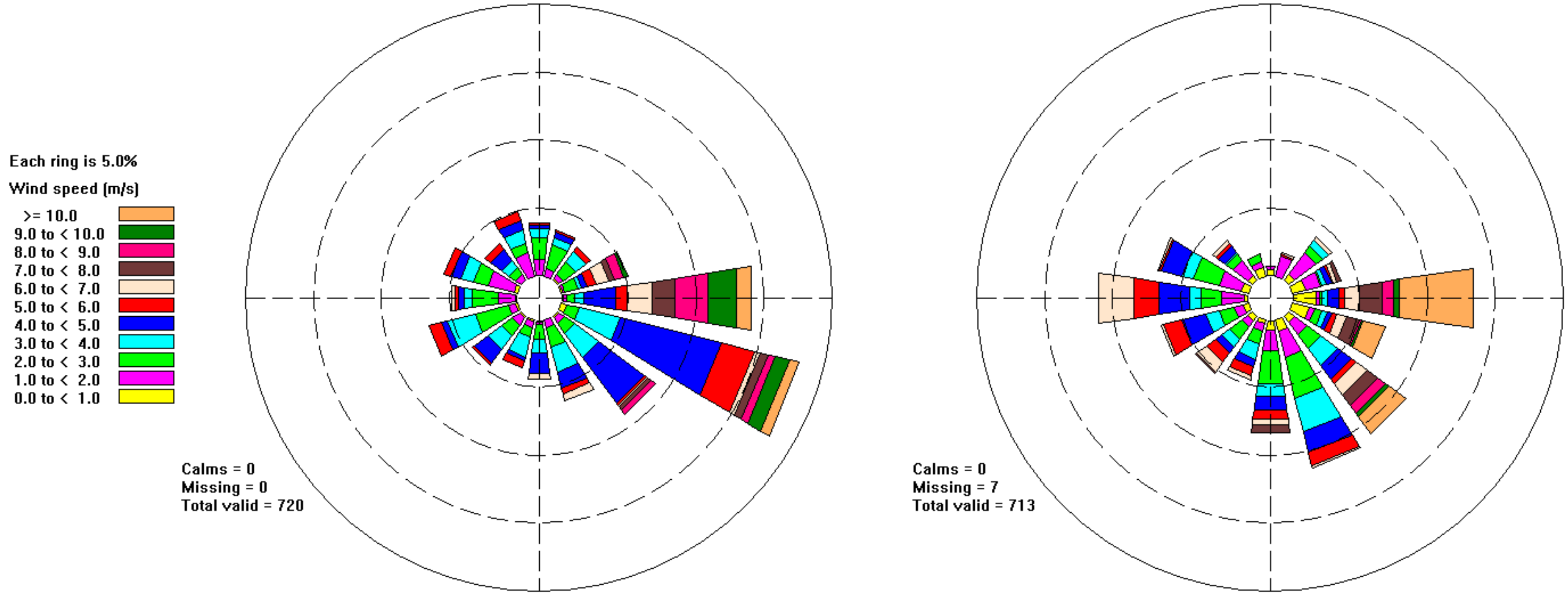


Figure B14 Wind roses for September for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/09/06 00:00 to 30/09/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

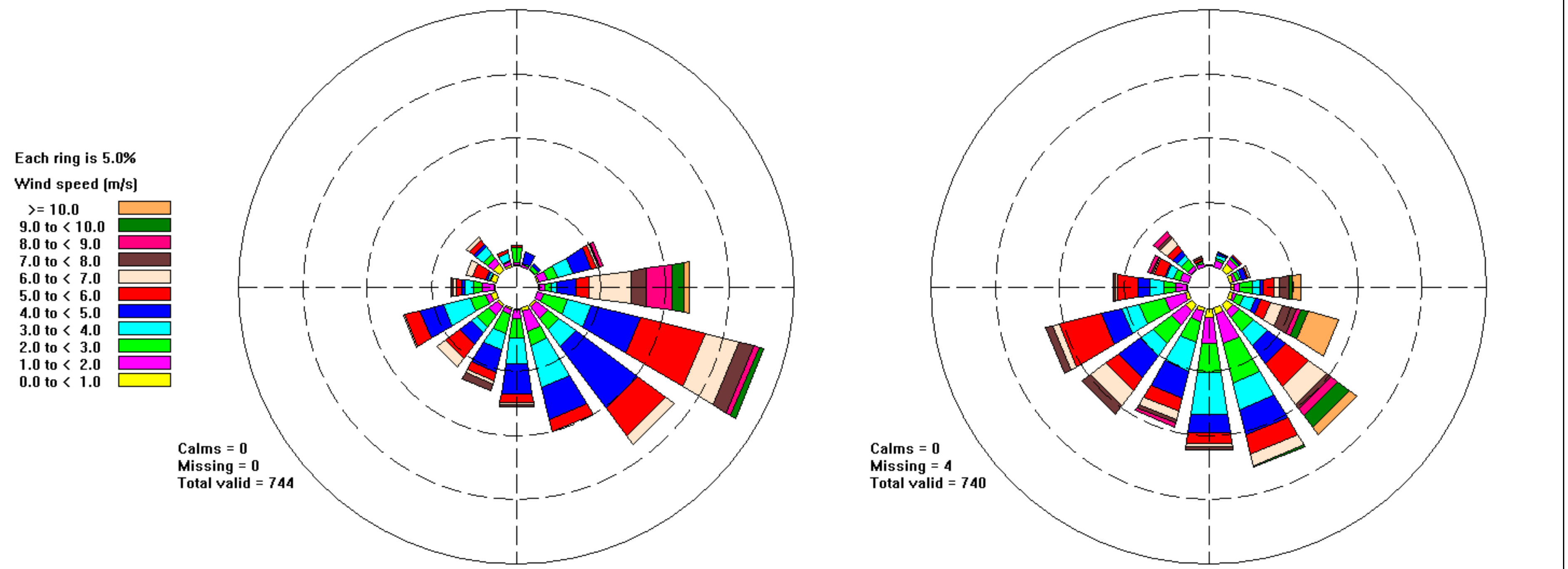


Figure B15 Wind roses for October for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/10/06 00:00 to 31/10/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

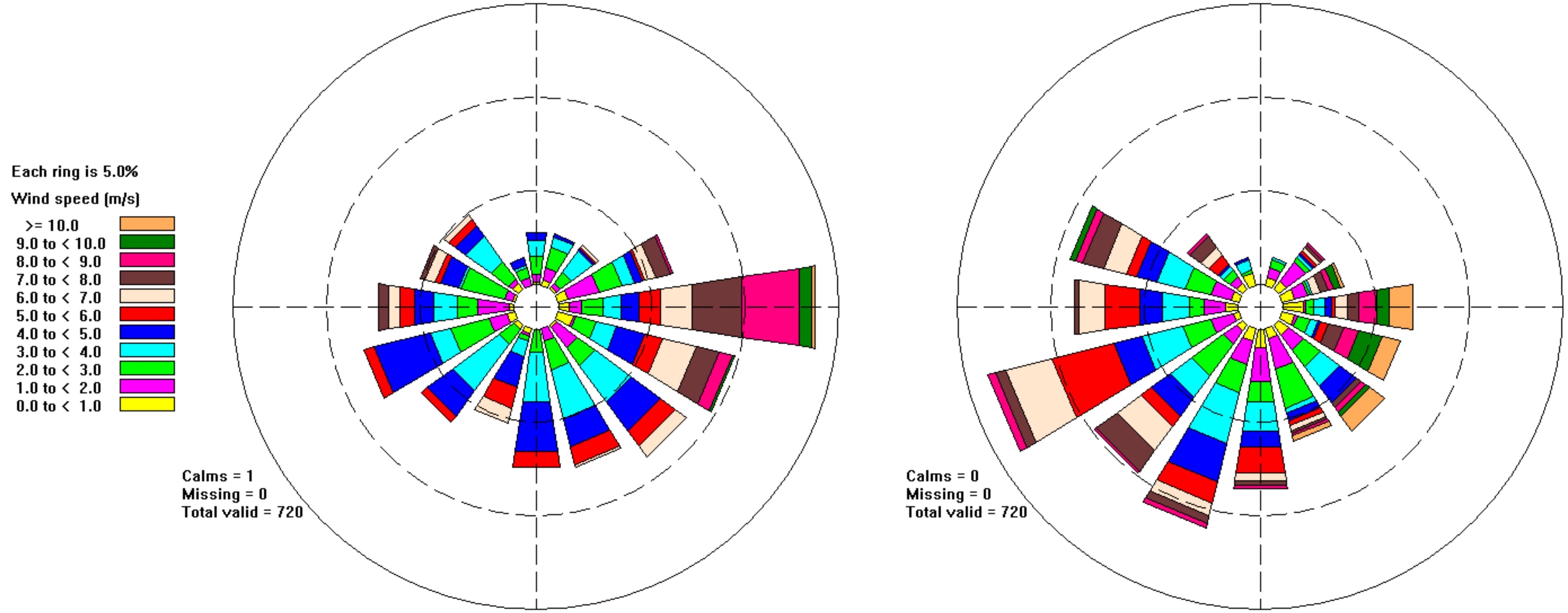


Figure B16 Wind roses for November for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/11/06 00:00 to 30/11/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

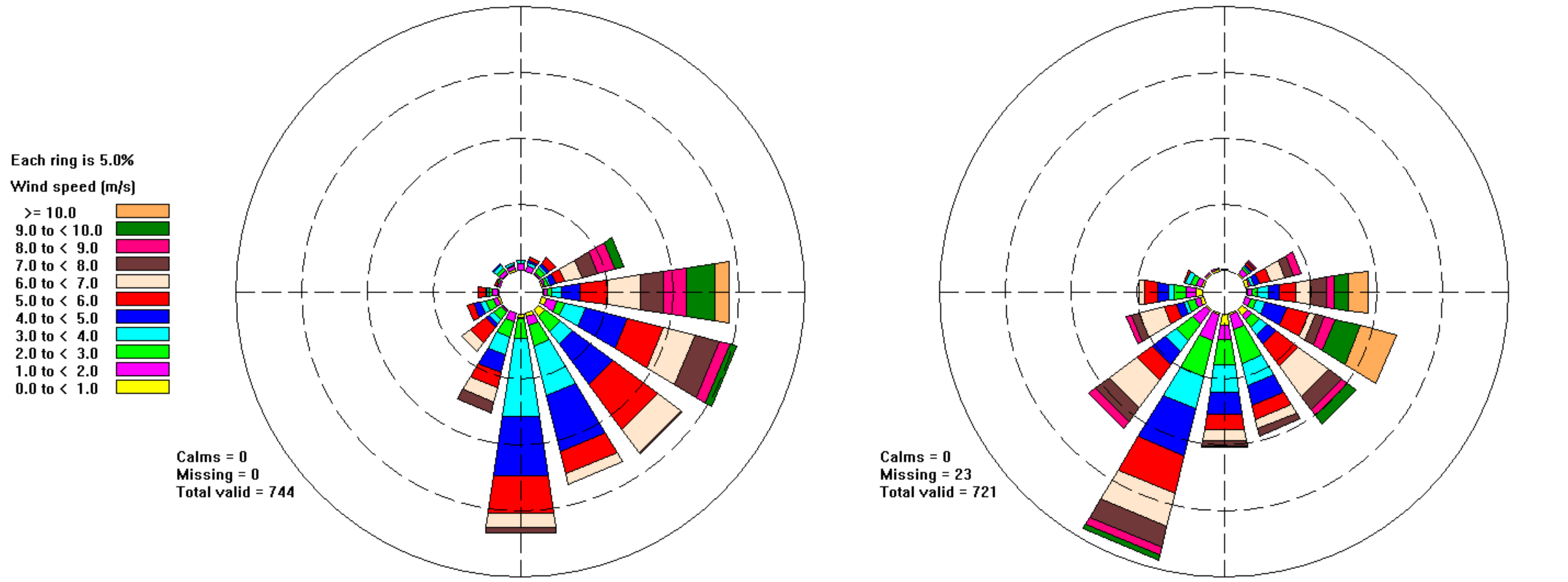


Figure B17 Wind roses for December for TAPM (LHS) and Observed (RHS)

Location: Monitoring station, Eneabba	**Period:** 01/12/06 00:00 to 31/12/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 16 July 2008

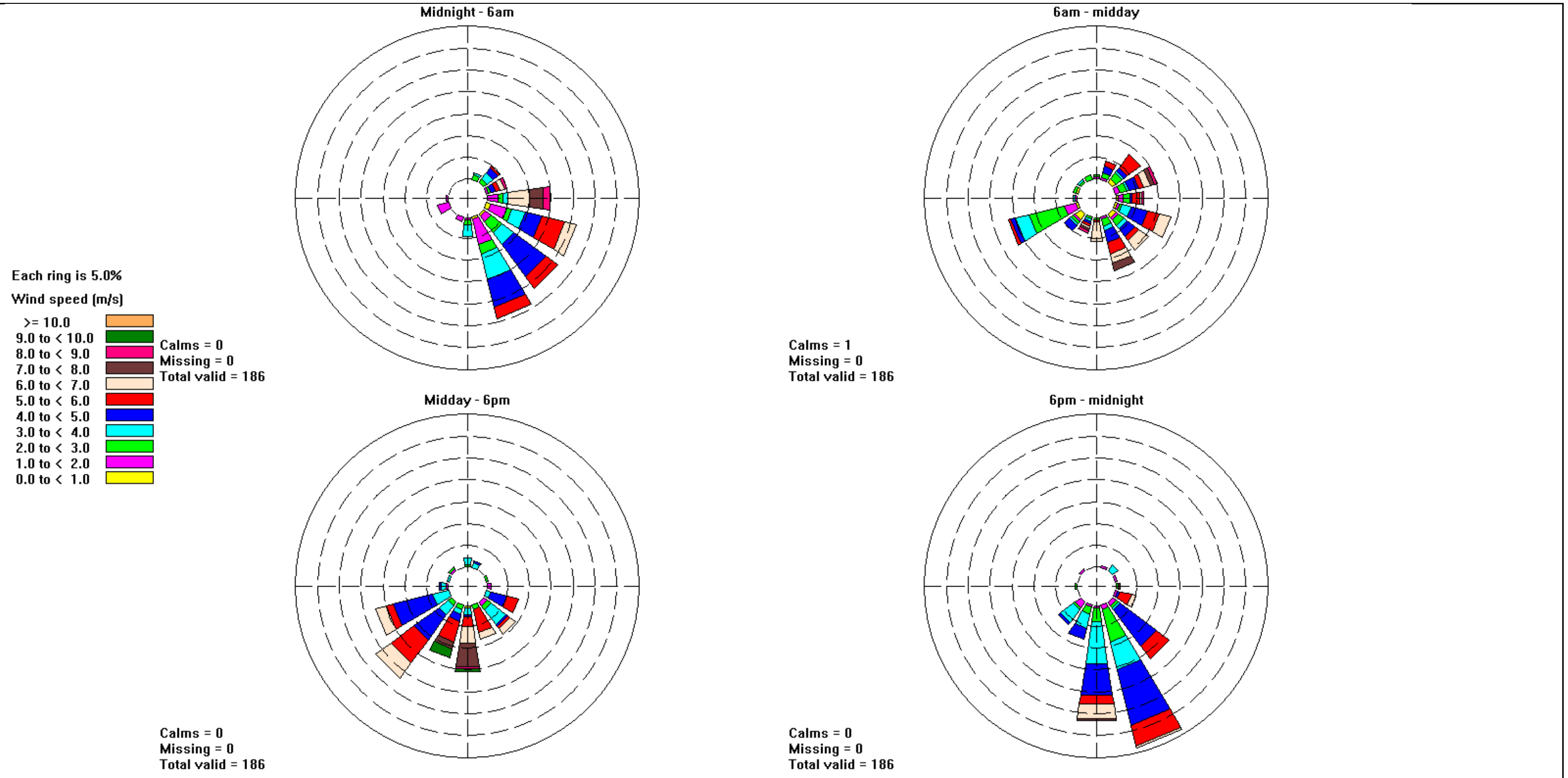


Figure B18 TAPM daily wind roses for January

Location: Monitoring station, Eneabba	**Period:** 01/01/07 00:00 to 31/01/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

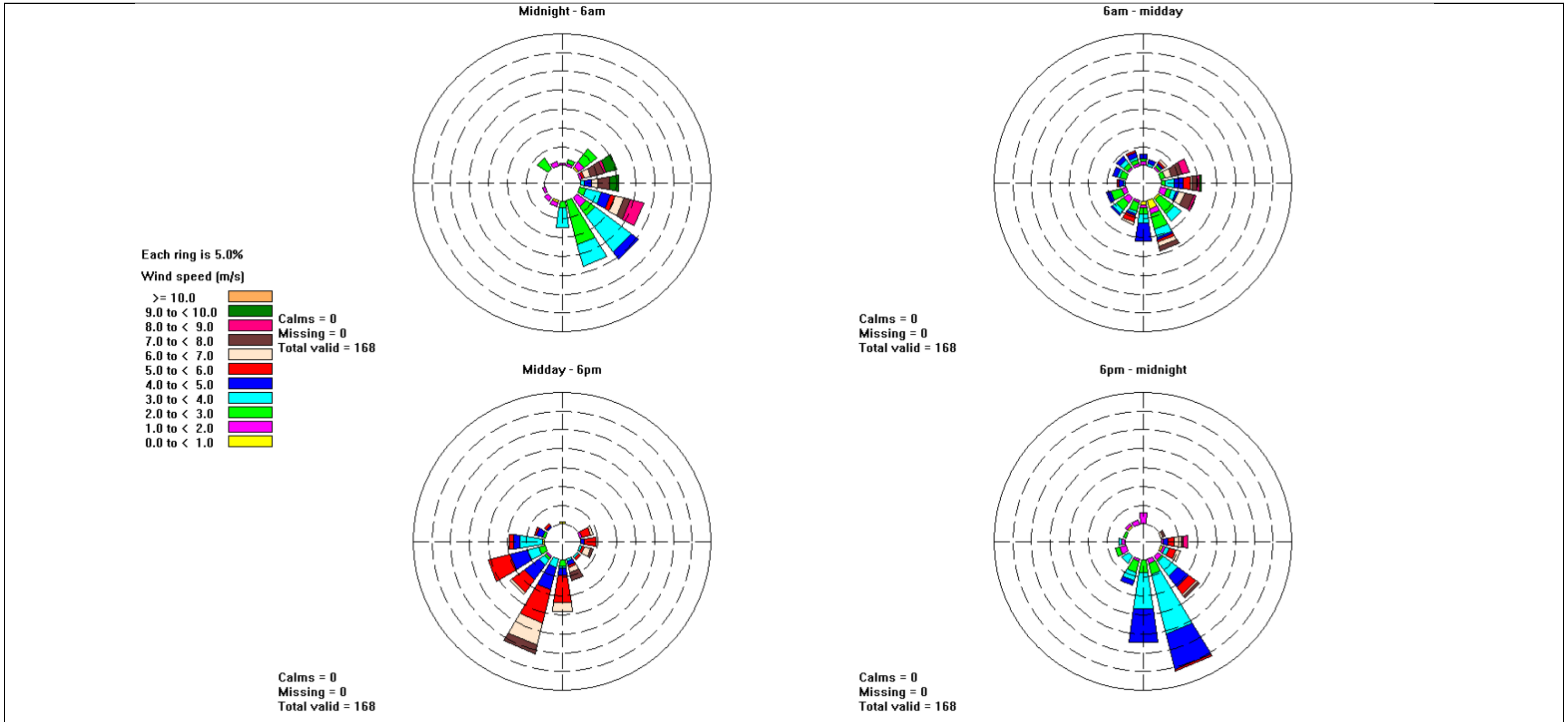


Figure B19 TAPM daily wind roses for February

Location: Monitoring station, Eneabba	**Period:** 01/02/07 00:00 to 28/02/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	672 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

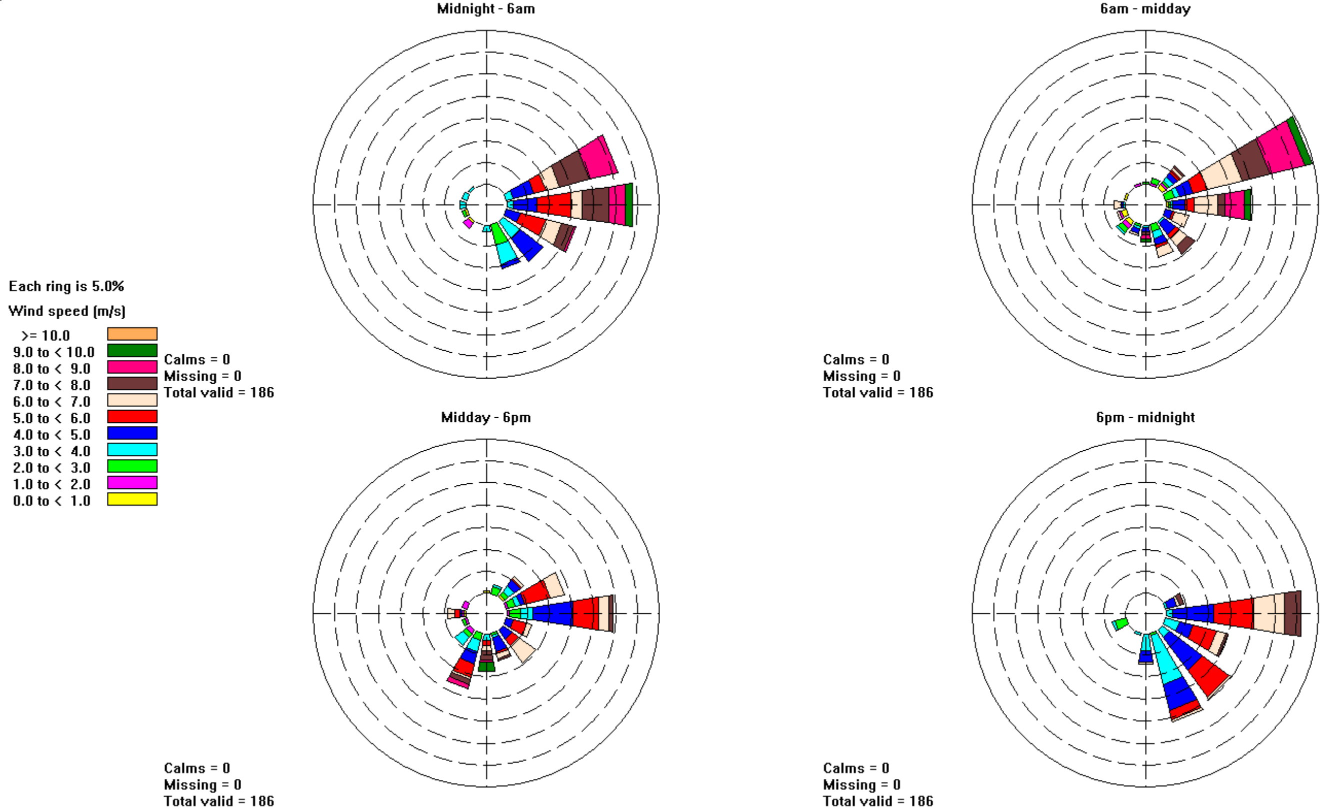


Figure B20 TAPM daily wind roses for March

Location: Monitoring station, Eneabba	**Period:** 01/03/07 00:00 to 31/03/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

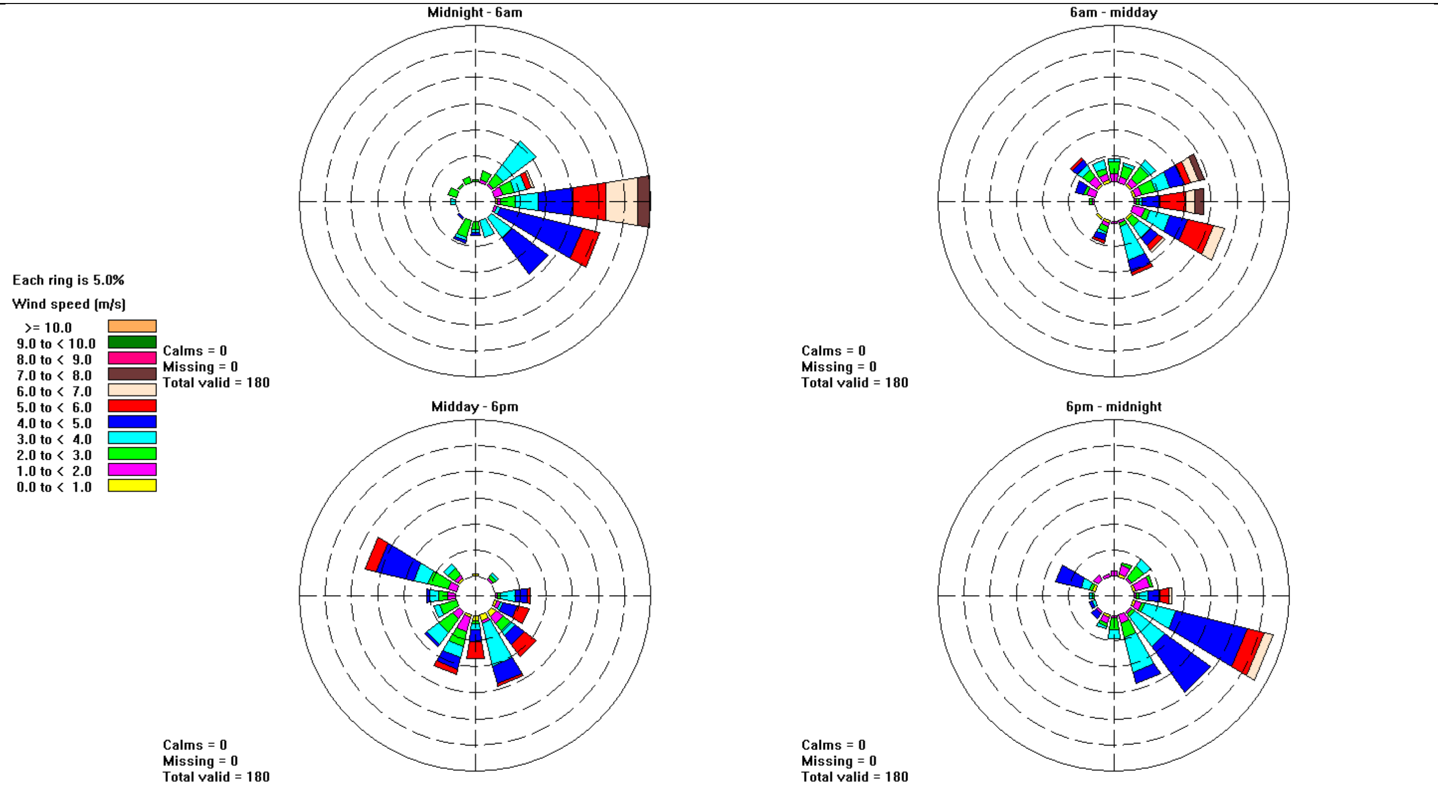


Figure B21 TAPM daily wind roses for April

Location: Monitoring station, Eneabba	**Period:** 01/04/07 00:00 to 30/04/07 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

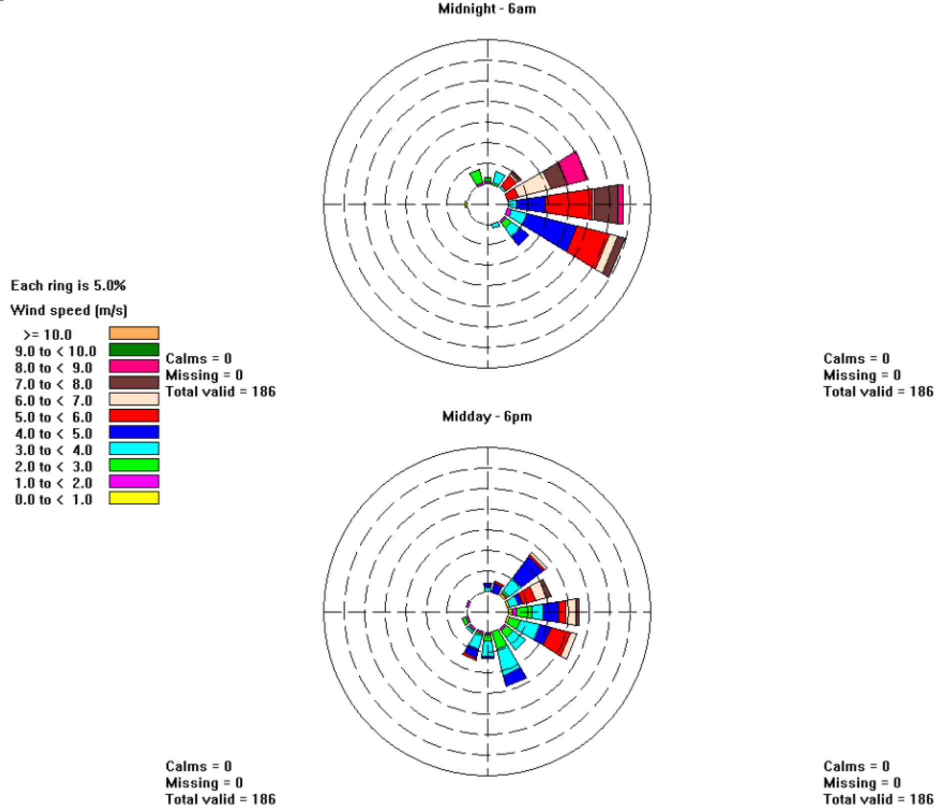


Figure B22 TAPM daily wind roses for May

Location: Monitoring station, Eneabba	**Period:** 01/05/06 00:00 to 31/05/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

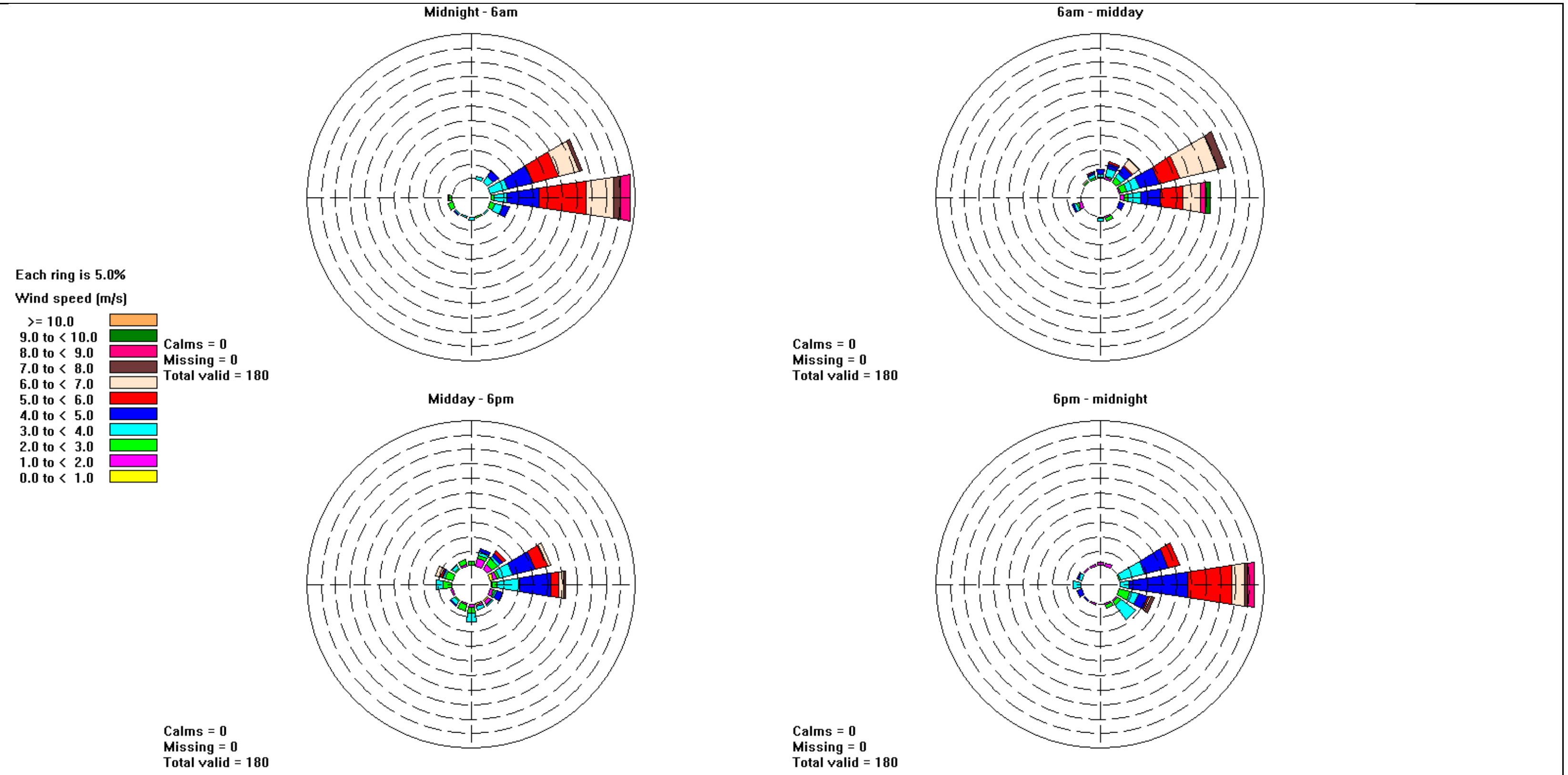


Figure B23 TAPM daily wind roses for June

Location: Monitoring station, Eneabba	**Period:** 01/06/06 00:00 to 30/06/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

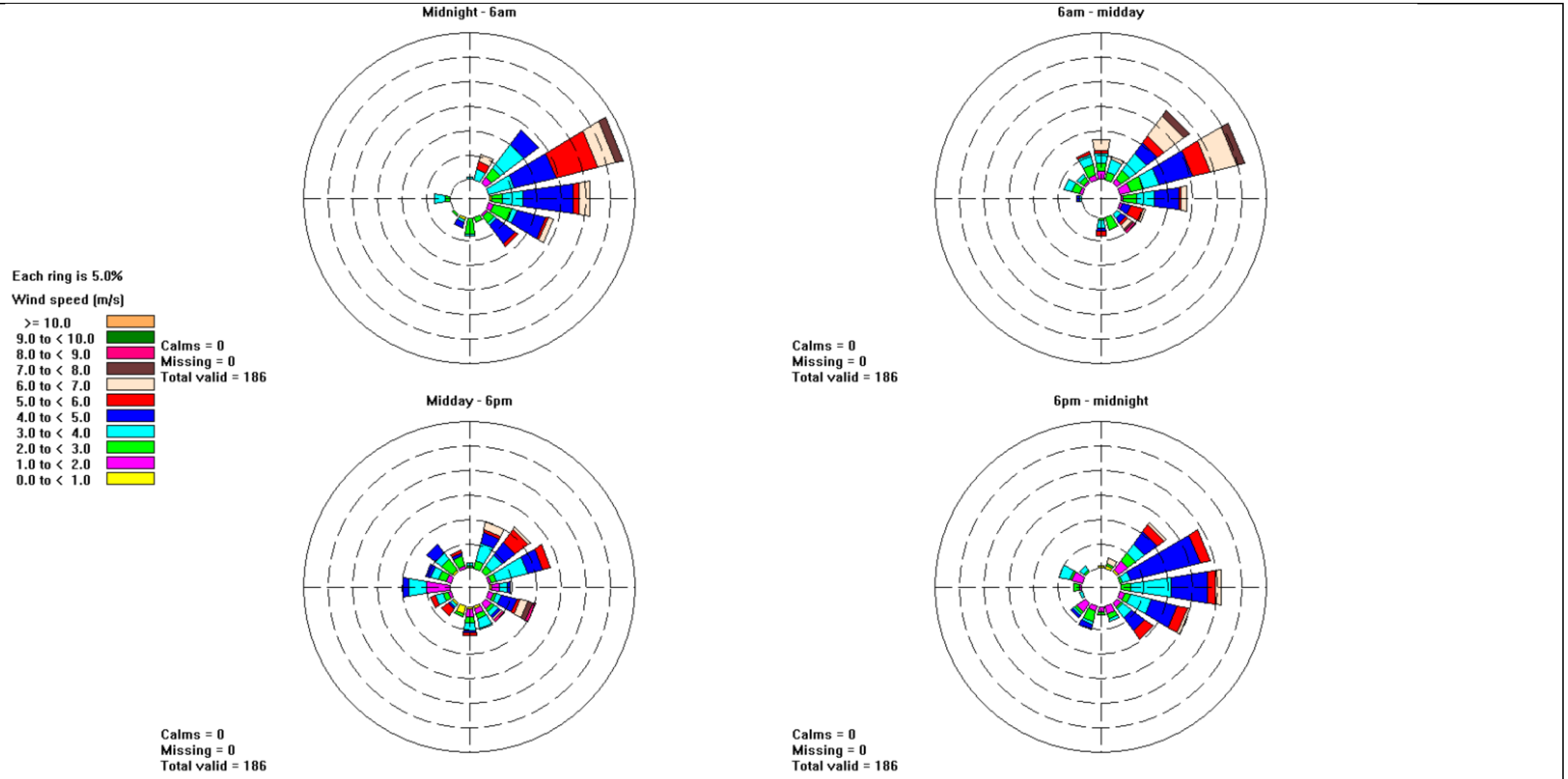


Figure B24 TAPM daily wind roses for July

Location: Monitoring station, Eneabba	**Period:** 01/07/06 00:00 to 31/07/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

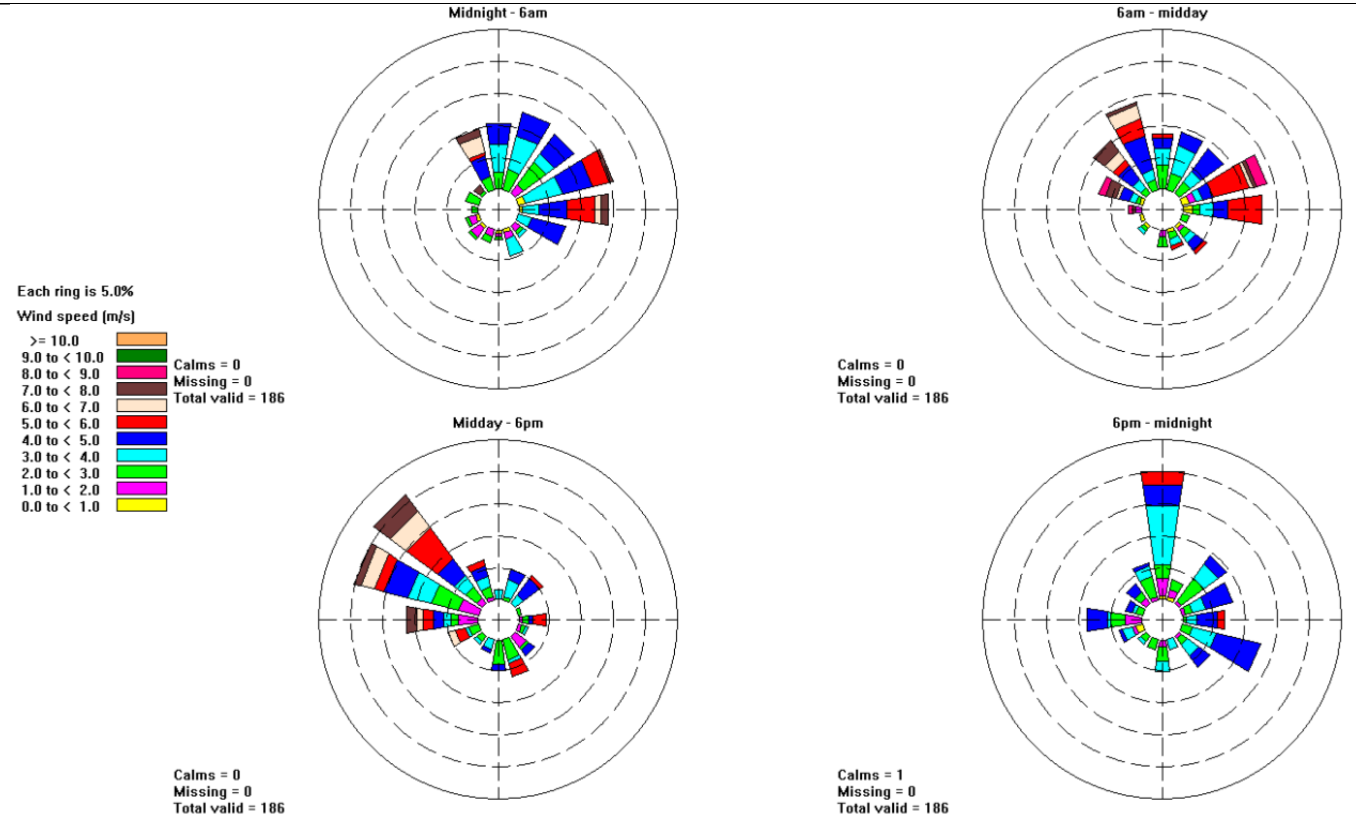


Figure B25 TAPM daily wind roses for August

Location: Monitoring station, Eneabba	**Period:** 01/08/06 00:00 to 31/08/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

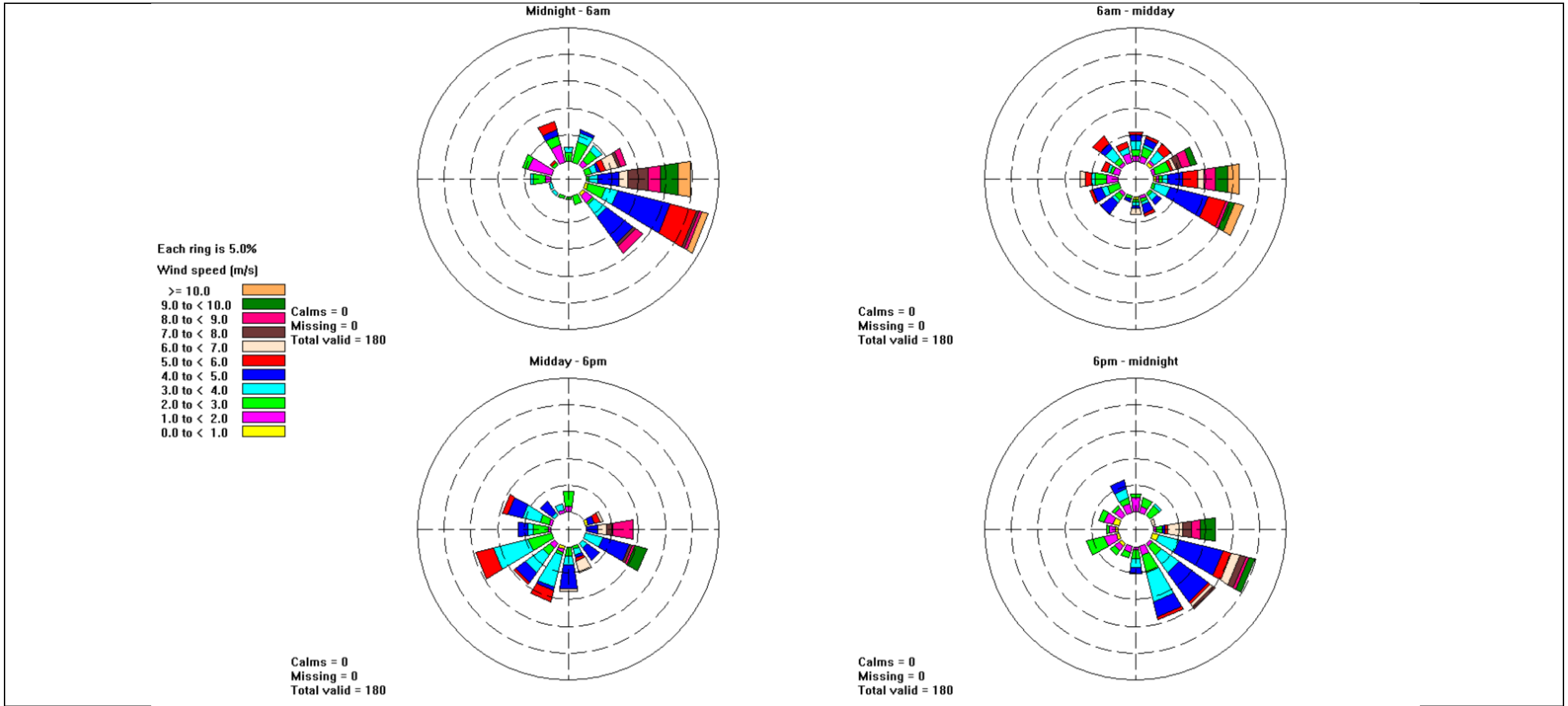


Figure B26 TAPM daily wind roses for September

Location: Monitoring station, Eneabba	**Period:** 01/09/06 00:00 to 30/09/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

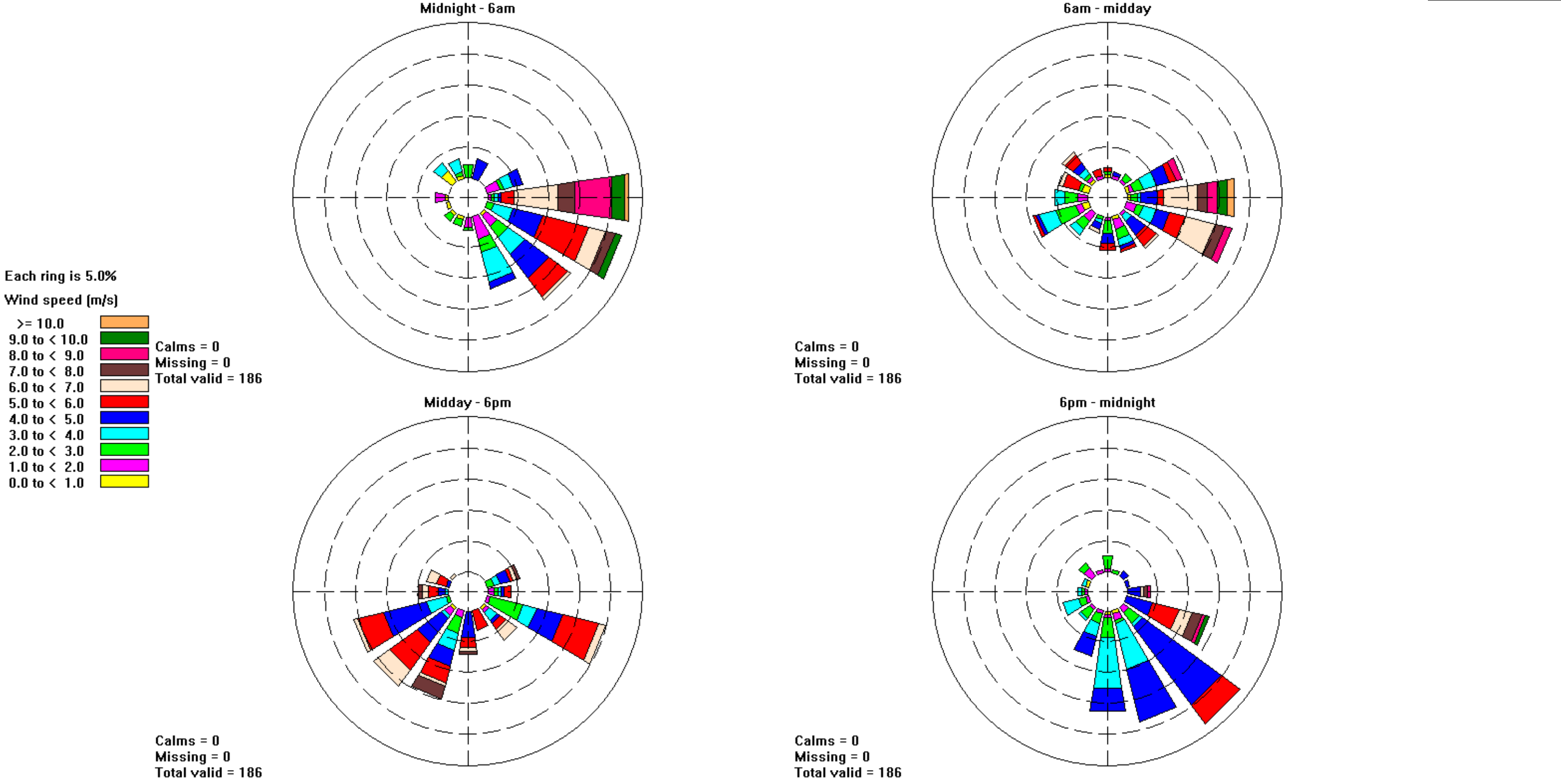


Figure B27 **TAPM daily wind roses for October**

Location: Monitoring station, Eneabba	**Period:** 01/10/06 00:00 to 31/10/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

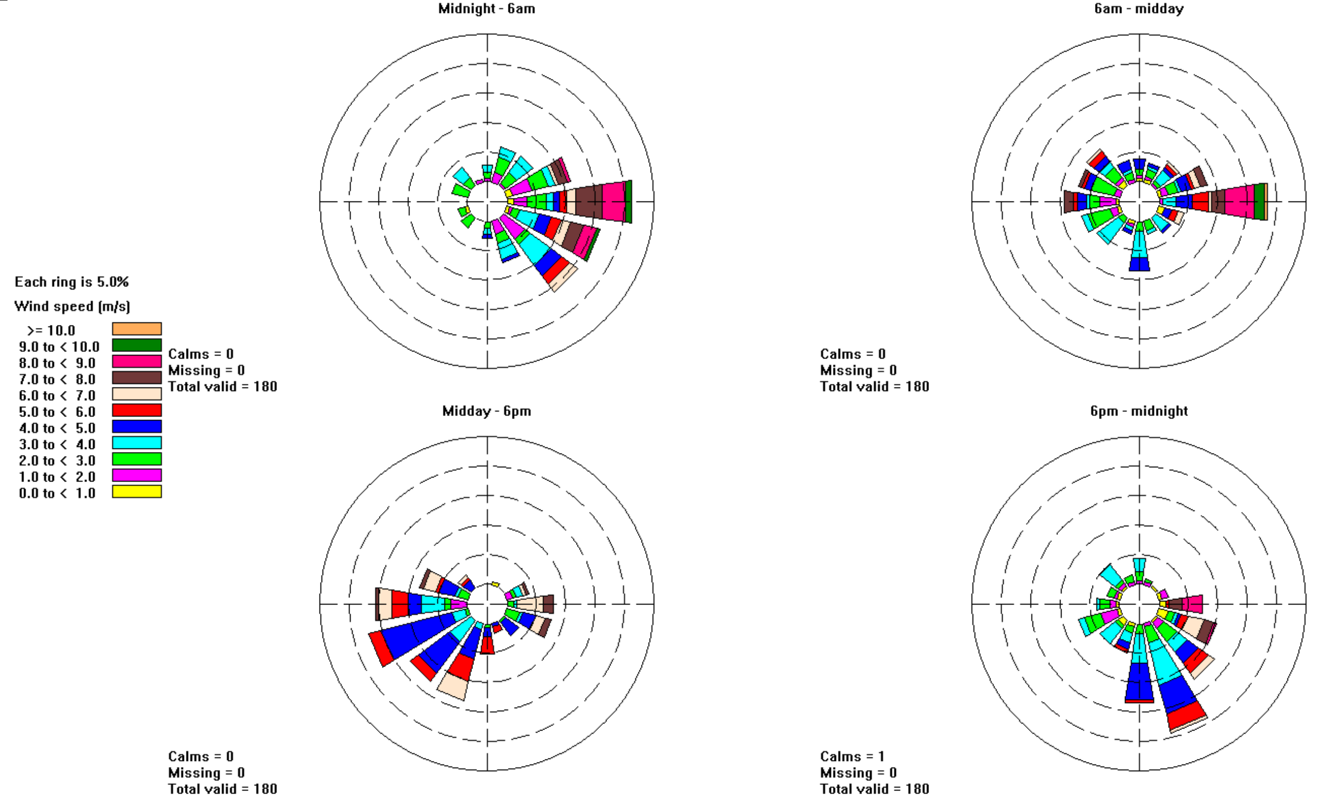


Figure B28 TAPM daily wind roses for November

Location: Monitoring station, Eneabba	**Period:** 01/11/06 00:00 to 30/11/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	720 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

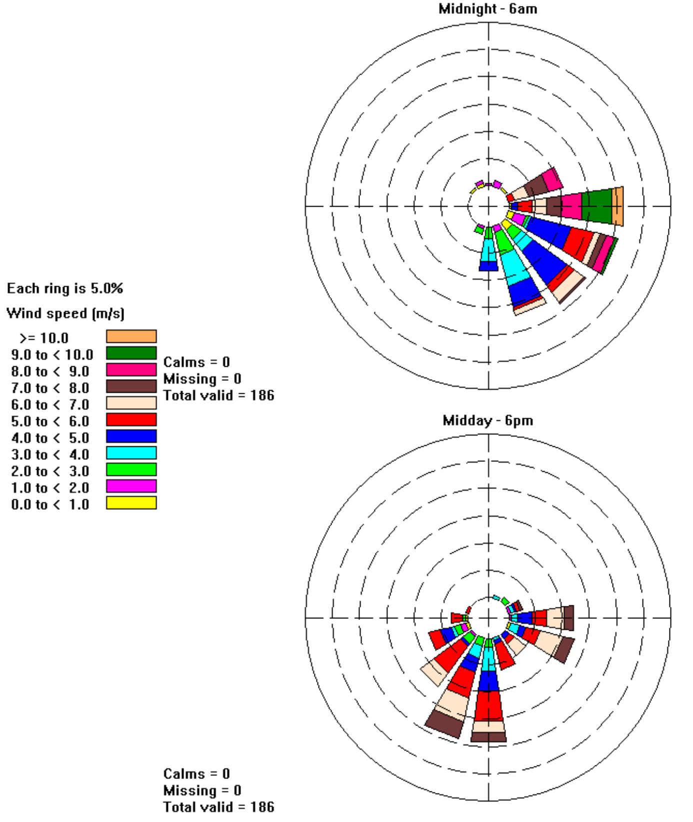
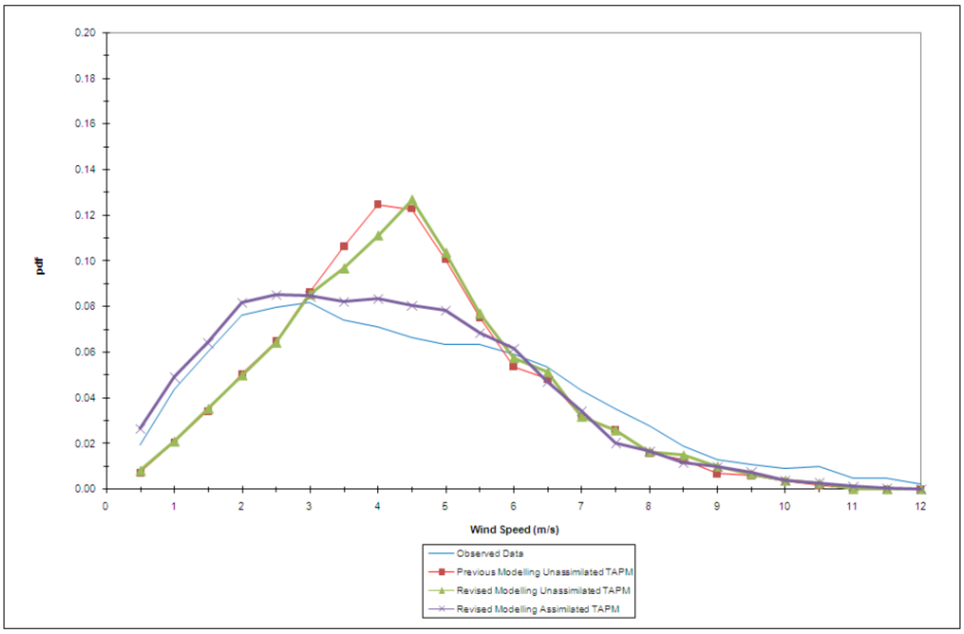


Figure B29 TAPM daily wind roses for December

Location: Monitoring station, Eneabba	**Period:** 01/12/06 00:00 to 31/12/06 23:00	**Data source:** Generated by TAPM from 1000m domain	**Units:** Metres per second
Type: Wind rose	744 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

a)



b)

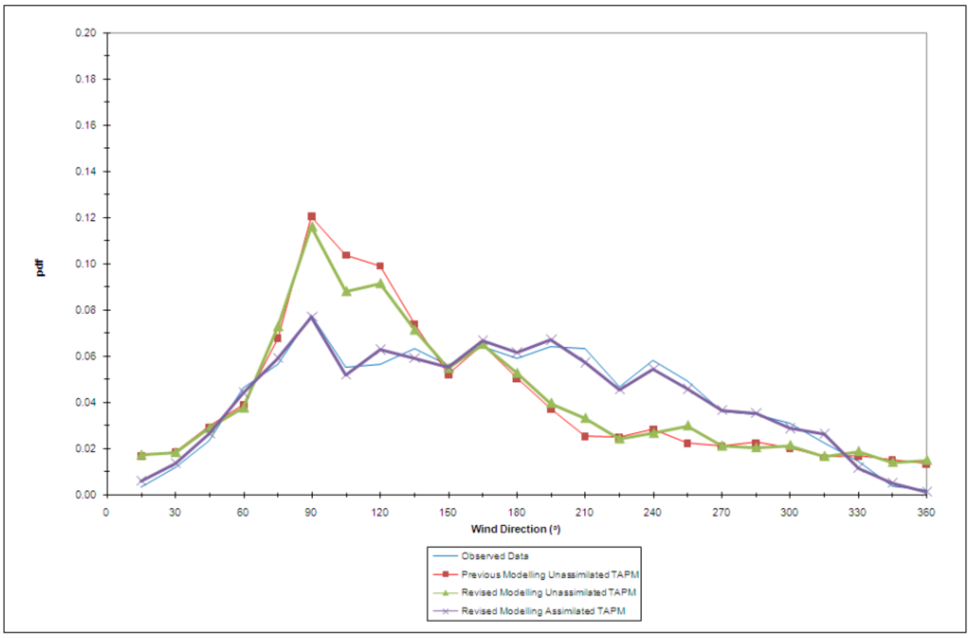
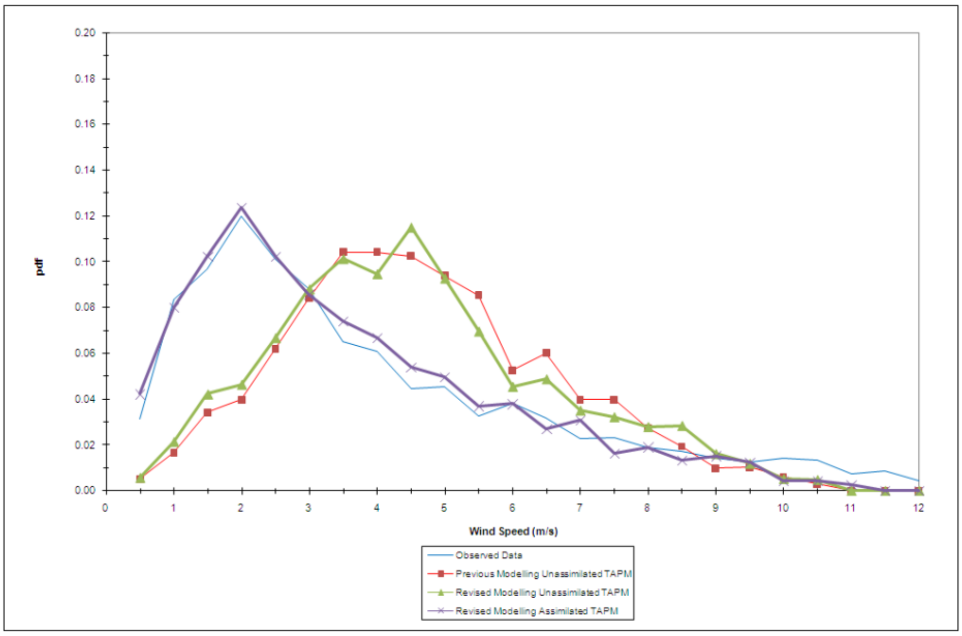


Figure B30 Probability density function comparison at the monitoring site for unassimilated TAPM (1000 m domain) for the initial and revised modelling, the assimilated TAPM (1000 m domain) and the observed data for all hours for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007 (all-hours)	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2090 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

a)



b)

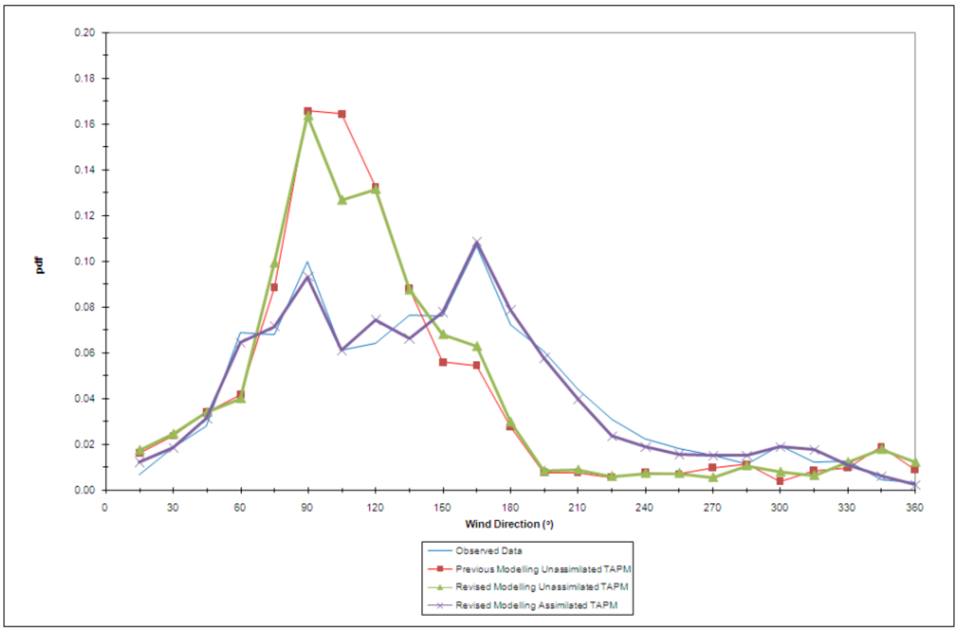
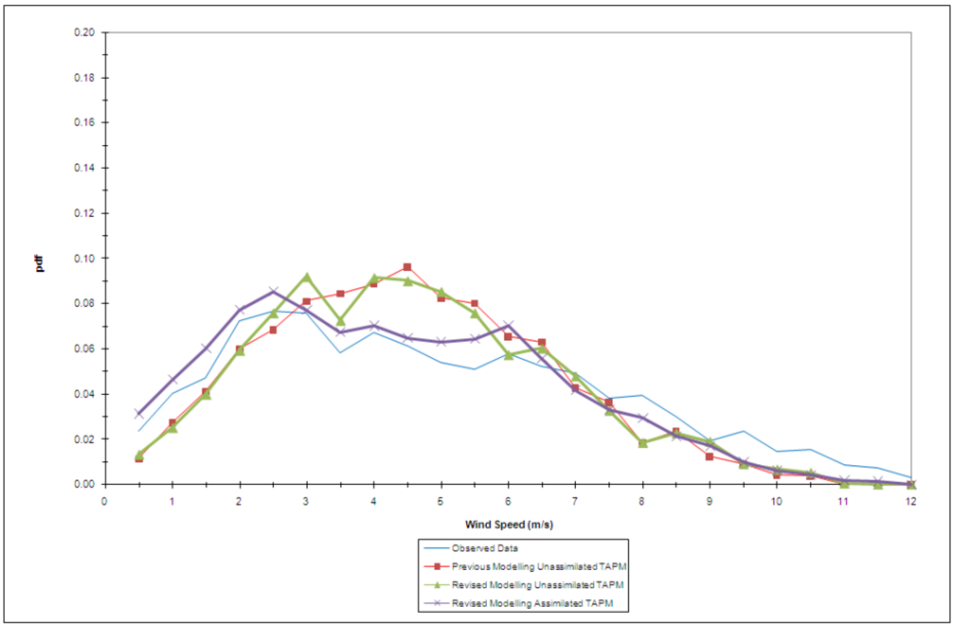


Figure B31 Probability density function comparison at the monitoring site for unassimilated TAPM (1000 m domain) for the initial and revised modelling, the assimilated TAPM (1000 m domain) and the observed data for the night for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007 night-time	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2090 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

a)



b)

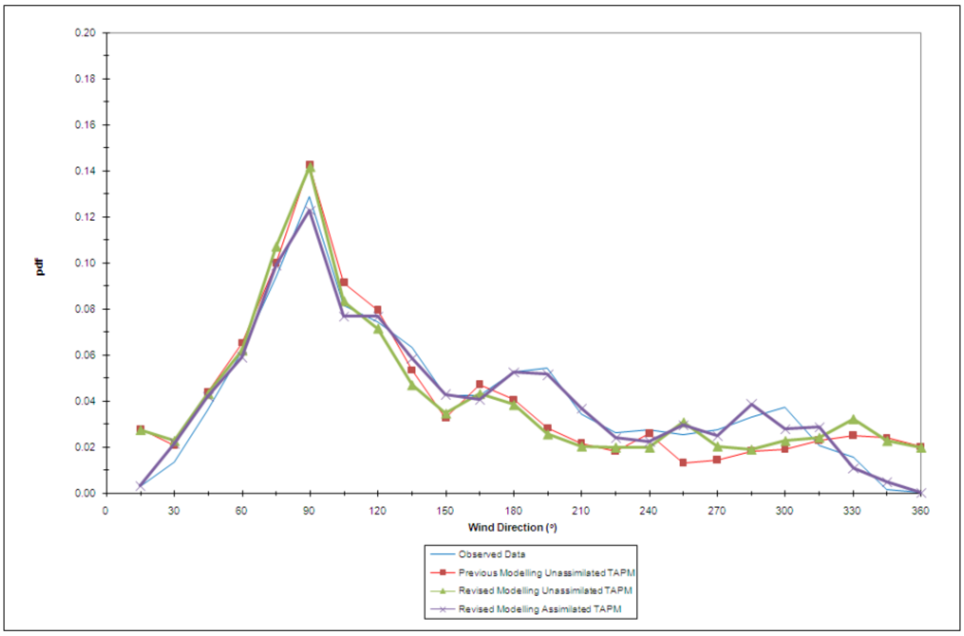
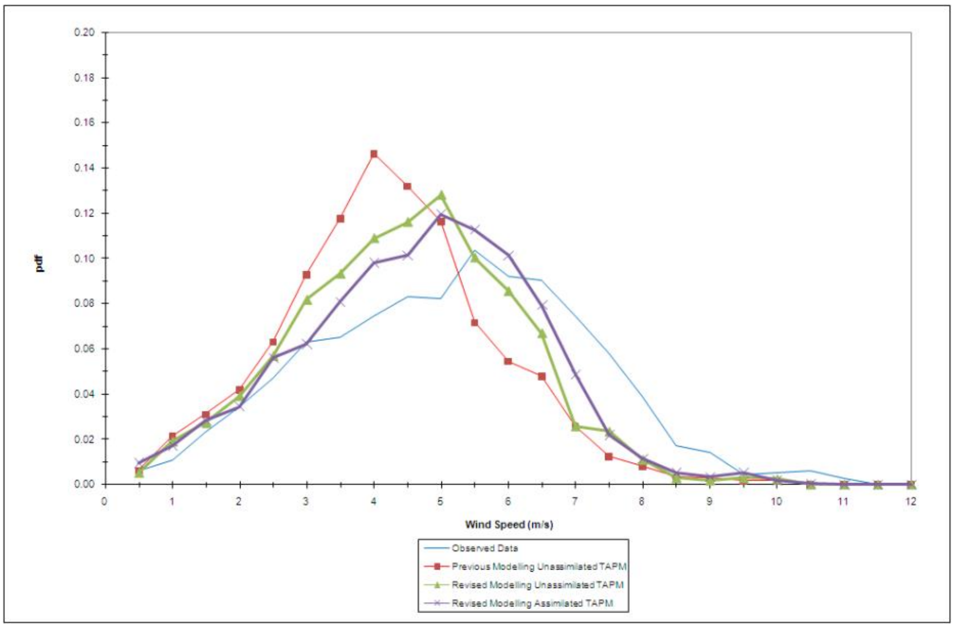


Figure B32 **Probability density function comparison at the monitoring site for unassimilated TAPM (1000 m domain) for the initial and revised modelling, the assimilated TAPM (1000 m domain) and the observed data for the morning for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°**

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007 (morning)	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2090 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

a)



b)

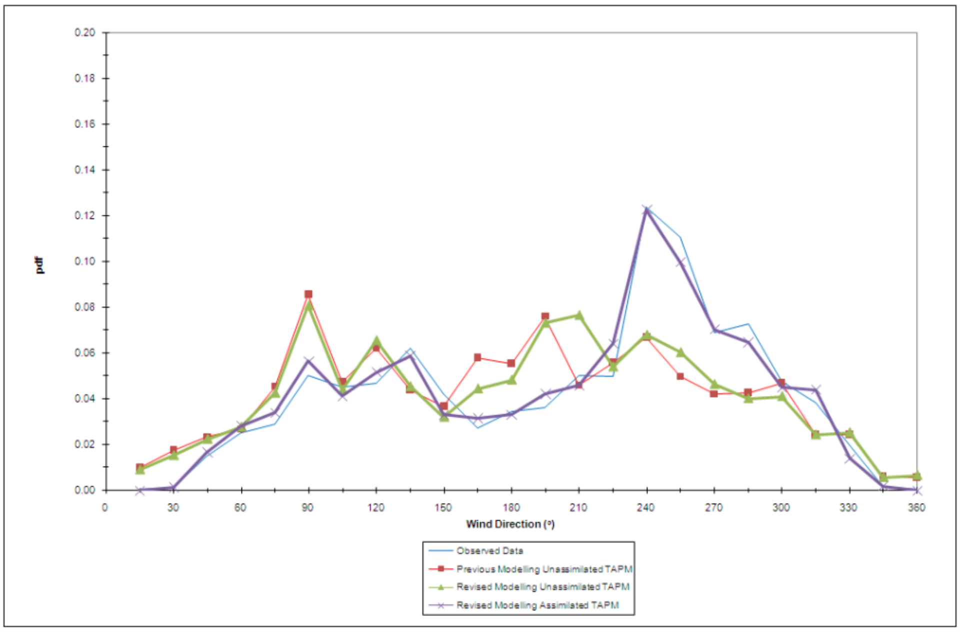
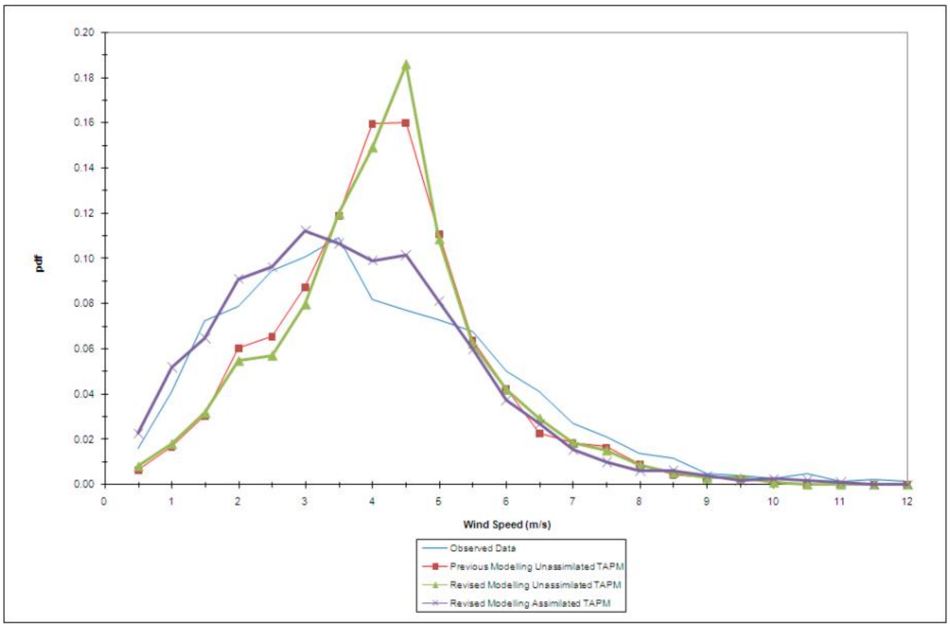


Figure B33 Probability density function comparison at the monitoring site for unassimilated TAPM (1000 m domain) for the initial and revised modelling, the assimilated TAPM (1000 m domain) and the observed data for the afternoon for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007 (afternoon)	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2090 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

a)



b)

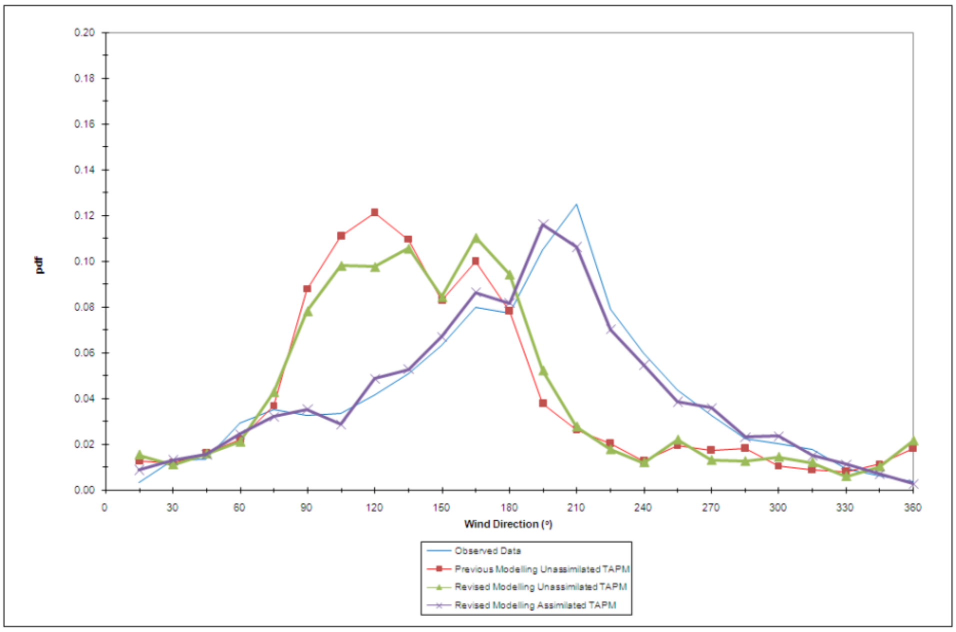


Figure B34 **Probability density function comparison at the monitoring site for unassimilated TAPM (1000 m domain) for the initial and revised modelling, the assimilated TAPM (1000 m domain) and the observed data for the evening hours for a) wind speed binned every 0.5 m/s and b) wind direction binned every 15°**

Location: Monitoring station, Eneabba	**Period:** May 2006 – April 2007 (evening)	**Data source:** Validation_Sheet.xlsx	**Units:** m/s and °
Type: PDF Scatter plot	2090 hourly average records	**Prepared by:** A. Schloss	**Date:** 6 August 2008

APPENDIX B1 – STATISTICAL METHODS

Pearson Correlation Coefficient

The Pearson Correlation Coefficient (RCOR) is a measure of the strength of the linear relationship between the predicted and observed measurements (defined in Equation 1). The closer this value is to unity the stronger the relationship.

$$r = \frac{N\left(\sum_{i=1}^{N} O_i P_i\right) - \left(\sum_{i=1}^{N} O_i\right)\left(\sum_{i=1}^{N} P_i\right)}{\sqrt{\left[N\left(\sum_{i=1}^{N} O_i^2\right) - \left(\sum_{i=1}^{N} O_i\right)^2\right]\left[N\left(\sum_{i=1}^{N} P_i^2\right) - \left(\sum_{i=1}^{N} P_i\right)^2\right]}}$$

Equation 1. Pearson Correlation Coefficient

Where *N* is the number of samples in the dataset, P_i is the hourly predictions and O_i is the hourly observations.

Index of Agreement

The IOA is a measure the match between the departure of the departure of each prediction from the observed mean and the departure of each observation from the observed mean. The Index Of Agreement (IOA) is defined in Equation 2 and gives an index from 0-1 (1 representing strong agreement).

$$1OA = 1 \frac{\sum_{i=1}^{N}(P_i - 0_i)^2}{\sum_{i=1}^{N}(|P_i - O_{mean}| + |O_i - O_{mean}|)^2}$$

Equation 2. Index of Agreement

Where O_{mean} is the observed mean

Mean Absolute Error

The Mean Absolute Error (MAE) measures the average magnitude of the error of a set of predictions in reference to the observed quantity. It is a relatively simple difference statistic defined by Wilmott (1982) as,

$$MAE = N^{-1}\sum_{i=1}^{N}\left|P_i - O_i\right|$$

Equation 3. Mean Absolute Error

The MAE is a good overall measure of model performance as it summarizes the mean difference between the predicted and the observed in the relative units of *O* and *P* (i.e. an MAE of 1.2 for wind speed is read as 1.2 m/s).

Complex Vector Correlation

A vector requires both magnitude and phase to define the relationship between two sets of vector quantities. Wind direction is a vector as well as a circular function with a cross over point at 0º and 360º. Thus negating any attempt to characterise the relationship between predicted and observed wind direction measurements using standard linear correlation techniques. However vectors can be represented by their scalar components in a Cartesian or Spherical coordinate system. In the case of wind direction this decomposition results in the scalar quantities of *u* (east-west) and *v* (north-south) thereby allowing independent statistical analyses to take place. Scalar decomposition however, is limited by confining the analysis to individual scalar components not the vector as a whole, as well as, its inherent reliance on the subjective choice of coordinate system used in the decomposition process (Crosby, Breaker and Gemmill 1993). An alternative method is to incorporate the effects of magnitude and direction directly thereby yielding a scalar quantity defining the degree of association between the two datasets (Kundu 1976). The complex correlation coefficient is presented as Equation 4, following the methods described in Kundu (1976),

$$p = \frac{\langle u_1 u_2 + v_1 v_2 \rangle}{\langle u_1{}^2 + v_1{}^2 \rangle^{1/2} \langle u_2{}^2 + v_2{}^2 \rangle^{1/2}} + i \frac{\langle u_1 v_2 - u_2 v_1 \rangle}{\langle u_1{}^2 + v_1{}^2 \rangle^{1/2} \langle u_2{}^2 + v_2{}^2 \rangle^{1/2}}$$

Equation 4. Complex Correlation Coefficient

where *u* and *v* are the scalar components of the vector and *i* = $\sqrt{-1}$ yielding the complex conjugate of the vector components. Therefore, the complex correlation coefficient (*p*) can be defined as the normalised inner product between the two vector quantities. The phase angle is then defined by

$$\alpha_{av} = \tan^{-1} \frac{\langle u_1 v_2 - v_1 u_2 \rangle}{\langle u_1 u_2 + v_1 v_2 \rangle}$$

Equation 5. Phase Angle

Where the resulting quantities are independent of coordinate system and a complex number whose magnitude gives the measure of correlation and whose phase angle gives the average counter clockwise angle of the second vector in relation to the first. Of course phase angle is only meaningful if the correlation coefficient is high. The magnitudes of the instantaneous vectors are used to weight the averaging process in order to estimate the mean angular displacement between the two datasets.

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APPENDIX C - AIR QUALITY IMPACT ASSESSMENT FOR THE COOLIMBA POWER PROJECT 400 MW COAL-FIRED PLANT SCENARIO

Contents

Tables

Figures

C1. Introduction

In November 2007, Aviva Corporation (Aviva) commissioned Katestone Environmental to undertake an air quality impact assessment for a combined coal- and gas fired Power Station proposed to be constructed and operated near Eneabba in Western Australia. The Power Station is located to utilise the proven coal resource in the Central West Coal Project (CWCP). At the inception of the environmental assessment process and the commencement of the air quality impact assessment study the project, known as the Coolimba Power Project (CPP), comprised the following capacity

- 2 x 200 MW unit coal-fired base load Power Station with a total capacity of 400 MW
- 2 x 165 MW unit gas-fired Peaking Plant with a total capacity of 330 MW.

The coal-fired plant design is to consist of a single stack 130 m in height, with the gaseous emissions associated with each boiler unit being emitted through separate flues. Use of a lime injection system is proposed to assist in flue gas desulphurisation to suppress the generation of sulfur dioxide in the boilers through the combustion of sulphur-containing coal in an oxygen-rich environment. The two coal-fired units will provide base load power. The CPP's electricity generation mix will also include two open cycle gas turbines to provide additional peak load power. Each gas turbine will have a stack height of 40 m and capacity of 165 MW.

Since the inception of the project, the proposed design of the coal-fired Power Station has been augmented. As described in the main section of this report, *Katestone Environmental, Air Quality Impact Assessment for the Proposed Coolimba Power Project, Western Australia*, the initial coal-fired plant capacity of 400 MW has been increased to 450 MW, comprising three 150 MW boiler units with gaseous emissions emitted from a single 130 m stack containing three flues, one for each boiler unit.

C2. Project Infrastructure

The initial design scenario for the coal-fired plant comprised a 400 MW coal-fired power plant comprising of two coal-fired steam turbo alternators, each with a nominal output of 200 MW. Table 1 outlines the key characteristics of the coal- and gas-fired Power Stations.

Table C1 Key characteristics of the Power Station design options

Element	Coal-fired	Gas-fired
Nominal turbine electrical output	400 MW net	330 MW net
Number of generating units	2	2
Nominal net unit output	200 MW	165 MW net
Net plant efficiency	36%	36 % (LHV)
Load profile	Base load	Peaking load
Main fuel	Coal from Central West Coal Project	Gas from Dampier to Bunbury Pipeline or Parmelia Natural Gas Pipeline
Annual fuel consumption	Approximately 2.3 Mtpa of coal	11 PJ of natural gas
Capacity factor	98%	25%
Start up fuel	Natural gas	Natural gas
Condenser cooling	Water cooled (with possible hybrid optimisations)	N/A
Energy generator type	Circulating fluidised bed boiler	Open cycle gas turbines
Emission controls	SO_2 - Flue gas desulphurisation, PM_{10} - Bag filters	N/A
Operating life of Power Station (excluding construction and closure activities)	Approximately 30 years	N/A
Note: Information provided by URS		

C3. Stack and emission characteristics

The stack and emission characteristics included in the modelling are presented in Table C2 , while the concentration and emission rate for oxides of nitrogen and sulfur dioxide, used in the dispersion modelling, are presented in Table C3. Table C4 presents the predicted range of variability in SO_2 emission rates due to variability in sulfur content of the coal fuel during normal operations, when the lime injection desulfurisation system is operating. A cumulative frequency distribution of in-stack SO_2 concentrations during normal operations is presented in Figure C1. Table C5 presents the predicted range of variability in SO_2 emission rates during non-normal operations, when the lime injection desulfurisation system is not operating (expected for less than 1% of the time).

Table C2 Stack and emission characteristics for the proposed Coolimba Power Project

Parameter	Units	Coal-fired plant	Gas-fired plant
Number of stacks	-	1	2
Number of flues	-	2	1
Location	AMG (mN, mE)	327955, 6685106	327989, 6685084 328032, 6685084
Stack height	m	130	40
Stack diameter	m	5.37[1]	6.34[2]
Volume flow (per stack)	Nm³/s (6% O_2) Am³/s	421 556	441 1,264
Exit velocity	m/s	24.5	40.0
Temperature	°C	130	510

[1]Effective stack diameter for 2 x 3.8 m diameter flues.
[2] Diameter for each stack

Table C3 Concentration and emission rate for oxides of nitrogen and sulfur dioxide for the proposed Coolimba Power Station

Pollutant	Concentration (mg/Nm³)	Emission rate (g/s)
Coal-fired Power Station		
Oxides of nitrogen (as NO_2)	448 mg/Nm^3	168.9
Sulfur dioxide	800 mg/Nm^3	301.6[1]
Gas-turbine		
Oxides of nitrogen (as NO_2)	25 ppm	22.6

[1]A constant SO_2 emission level of 301.6 g/s has been modelled to represent the 75th percentile emission level under normal operations.

Table C4 Expected variability in fuel sulfur content, in order of increasing SO_2 emissions for normal operations

Percentage (%)	Cumulative Percentage (%)	SO_2 concentration (mg/Nm^3) – Normal operations	Emission Rate (g/s)
0.64	0.64	631	237.9
3.13	3.77	663	250.0
8.29	12.06	693	261.3
13.81	25.87	723	272.6
19.92	45.79	752	283.5
19.84	65.63	780	294.1
13.04	78.67	808	304.6
7.59	86.26	835	314.8
4.74	91.00	861	324.6
3.05	94.05	886	334.0
1.55	95.60	911	343.4
1.12	96.72	934	352.1
0.76	97.48	957	360.8
0.63	98.11	980	369.5
0.44	98.55	1,001	377.4
0.43	98.98	1,021	384.9
0.36	99.34	1,041	392.5
0.27	99.61	1,059	399.2
0.25	99.86	1,077	406.0
0.14	100.00	1,100	414.7

Table C5 Expected variability in fuel sulphur content, in order of increasing SO_2 emissions for non-normal operations

Percentage (%)	Cumulative Percentage (%)	SO_2 Emissions (mg/Nm^3) – Non-normal operations	Emission Rate (g/s)
0.12	0.120	6,469	2,438.8
0.54	0.660	7,307	2,754.7
0.28	0.940	8,258	3,113.3
0.041	0.981	9,676	3,647.9
0.015	0.996	11,094	4,182.4
0.004	1.000	12,171	4,588.5

C4. Assessment Methodology

C4.1 Dispersion Modelling

Air dispersion modelling was conducted using the CSIRO prognostic model TAPM v3.0.7 (Hurley 2005). The TAPM configuration developed for this air quality assessment and a validation of the predicted dispersion meteorology is described in detail in *Appendix B - Meteorological Validation Assessment Report*.

TAPM has been configured using default settings with the following adjustments:

- 40 x 40 grid point domain with an outer grid of 30 kilometres and nesting grids of 10 kilometres, 3 kilometres and 1 kilometre
- Nested pollution grid down to 250 m resolution
- Grid centred near the monitoring station site (latitude –29° 49', longitude 115°16')
- Geoscience Australia 9 second DEM terrain data
- Modification to the deep soil volumetric moisture content
- The synoptic data used in the simulation is for the period May 2006 to April 2007
- 25 vertical levels
- Data assimilation from observations at Eneabba assimilated at Power Station and Eneabba
- Run in Lagrangian mode
- Building dimensions included for the incorporation of building wake affects

Meteorological observations obtained from an automatic weather station operated by Iluka Resources near Eneabba have been assimilated into the TAPM run. These observations have been assimilated in two locations, at the site near Eneabba and at the proposed CPP itself. A radius of influence of 10 km over three vertical levels has been used for both locations in order to create an overlap between the locations and to minimise the influence of the observations in the areas of elevated terrain in the eastern region of the modelling domain.

C4.2 Stochastic Modelling

Stochastic modelling has been conducted using the methods outlined in Heuff *et al.* (2007). And the emissions profile as presented in Table C4 and Table C5 .

C5. Results

For this assessment, ground-level concentrations of pollutants due to the contribution of the CPP have been presented in isolation. All concentrations of modelled pollutants are low and the addition of a background concentration is unlikely to cause an exceedance of the relevant standards.

A map displaying the location of the nearest sensitive receptors to the proposed CPP is shown in Figure C2. Maximum ground-level concentrations of NO_2 and SO_2 across the modelling domain and at each of these locations have been calculated, with a summary presented in Table C6 .

Table C6 Predicted ground-level concentrations (µg/m³) of nitrogen dioxide and sulfur dioxide for the proposed Coolimba coal-fired power station

Receptor	Nitrogen dioxide[1]		Sulfur dioxide			
	1hr max	Annual	1hr max	1hr 99.9th	24hr max	Annual
R1	16.2	0.2	86.7	51.1	13.6	1.2
R2	17.8	0.2	91.6	64.6	22.4	1.2
R3	20.1	0.3	105.4	75.1	30.9	1.4
R4	13.0	0.1	75.5	43.8	13.3	0.6
R5	21.2	0.2	112.5	74.0	12.6	0.8
R6	18.4	0.2	101.0	72.4	21.5	0.8
R7	21.3	0.2	125.3	84.6	19.0	1.0
R8	15.0	0.1	84.1	56.1	18.6	0.5
R9	16.0	0.1	80.3	51.4	10.5	0.5
R10	18.3	0.1	105.4	56.8	16.8	0.4
Eneabba	19.5	0.1	113.8	39.5	16.1	0.7
Maximum on Grid	59.2	0.6	351.8	133.6	65.4	3.1
NEPM(Air) standard	246	62	570	350	228	60
Note[1] 30% NO_2/NO_x ratio applied						

Ground-level concentrations for NO_2 and SO_2 are presented in Figure C3 to Figure C8 for the following averaging periods:

- Nitrogen dioxide:
  - 1 hour, maximum (100th percentile)
  - Annual
- Sulfur dioxide:
  - 1 hour, maximum
  - 1 hour, 99.9th percentile
  - 24 hour maximum
  - Annual

The hourly distribution for ground-level concentrations of SO_2 at sensitive receptor locations is presented in Figure C9 to Figure C19.

The results of the TAPM dispersion modelling for NO_2 indicate the following:

- Predicted ground-level concentrations across the modelling domain including all sensitive receptor locations are well below the NEPM(Air) standards

- The highest predicted ground-level concentrations generally occur during the day

- The predicted maximum 1-hour average ground-level concentration across the modelling domain is 59.2 µg/m^3, which is 24.1% of the NEPM standard of 246 µg/m^3

- The predicted maximum 1-hour average ground-level concentration at a sensitive receptor location is 21.3 µg/m^3 at Receptor 7 (R7), which is 8.6% of the NEPM standard of 246 µg/m^3

The results of the TAPM dispersion modelling for SO_2 indicate the following:

- Predicted ground-level concentrations across the modelling domain including all sensitive receptor locations are well below the NEPM(Air) standards

- The highest predicted ground-level concentrations generally occur during the day

- The predicted maximum 1-hour average ground-level concentration across the modelling domain is 351.8 µg/m^3, which is 61.7% of the NEPM standard of 570 µg/m^3

- The predicted maximum 1-hour average ground-level concentration at a sensitive receptor location is 125.3 µg/m^3 at Receptor 7 (R7), which is 22.0% of the NEPM standard of 570 µg/m^3

C6. Discussion of Results

C6.1 Maximum Impacts of Sulfur Dioxide during Normal Operations

Aviva predicts that the lime injection system for the desulfurisation of SO_2 emissions released from the stack will be operational for 99% of the time. With desulfurisation operating, the in-stack concentration of SO_2, based on the variability of the sulfur content in the coal fuel, is estimated to be between 631 – 1,100 mg/Nm^3. This range of concentrations produces a range of emission rates of 238 – 415 g/s.

Notwithstanding this, the dispersion modelling has been conducted using an average SO_2 stack concentration of 800 mg/Nm^3 and a corresponding emission rate of 301.6 g/s. Aviva estimates the concentration is likely to be less than or equal to 800 mg/Nm^3 for approximately 78% of the time. Consequently, the predicted maximum 1-hour ground-level concentration of SO_2 in the modelling domain for an emission rate of 301.6 g/s from the CPP, assessed in isolation, is 351.8 µg/m^3, approximately 62% of the NEPM(Air) standard of 570 µg/m^3.

The minimum emission rate of SO_2 required to cause an exceedance of the NEPM(Air) standard (570 µg/m^3) anywhere in the modelling domain for the Power Station assessed in isolation is 489 g/s, calculated as follows:

$$570\ \mu g/m^3 \ /\ 351.8\ \mu g/m^3 \times 301.6\ g/s = 489\ g/s$$

As aforementioned, the estimated maximum emission rate of SO_2 during normal conditions with the lime injection system operating is 415 g/s, 85% of the of the minimum SO_2 emission rate of 489 g/s, predicted to cause an exceedence of the NEPM(Air) standard. Consequently, during normal operating conditions, an exceedance of the NEPM(Air) standard is unlikely to occur as a result of the CPP operating in isolation.

Notwithstanding this, further analysis has been conducted into the meteorology at the time of the ten highest ground-level concentration impacts of SO_2 across the modelling domain and at the sensitive receptor that experiences the highest impact, Receptor 7. Table C7 presents the ten highest predicted 1-hour ground-level concentrations of SO_2 on the grid, in decreasing order, and a summary of the associated meteorological conditions at the CPP site. The frequency distribution of the predicted 1-hour maximum ground-level concentration of SO_2 across the domain is presented in Figure C20, while Figure C21 shows the locations of the nearest sensitive receptors and their proximity to the locations of the ten highest 1-hour maximum concentrations of SO_2 across the domain.

Table C7 indicates that the highest impacts are not wind direction specific, that is, they occur during winds from any direction, and occur under a range of wind speeds, though predominantly low to moderate wind speeds with eight out of ten stack-top winds 3 m/s or below. The eighth and ninth highest hours are during wind speeds of 10.4 and 4.9 m/s respectively. Nine of the ten highest 1-hour impacts occurred between 8am and 12pm with the eighth highest occurring at 1am, while at the time the mixing height was between 181 and 554 m.

Table C7 Meteorological conditions at the proposed Power Station under which the ten highest concentrations of SO_2 occurred

Date / Time	Stack-top Wind Speed (m/s)	Stack-top Wind Direction (°)	Mixing Height (m)	Maximum SO_2 Concentration on Grid (µg/m³)	Direction from Power Station stack	Distance from Power Station stack (km)
15/09/2006 10:00	0.2	264	269	351.8	SE	9
15/11/2006 08:00	1.3	301	181	327.2	SE	14
15/09/2006 09:00	0.5	303	167	297.3	SE	13
10/05/2006 12:00	0.8	99	524	293.6	W	3
18/06/2006 12:00	2.1	73	448	268.5	SE	9
22/01/2007 09:00	0.8	212	369	250.9	SE	8-15[1]
15/11/2006 09:00	2.3	296	300	214.3	SE	8-15[1]
17/01/2007 01:00	10.4	153	289	212.0	SE	8-15[1]
27/02/2007 12:00	4.9	281	456	182.5	SE	8-15[1]
28/04/2007 11:00	3.0	245	554	182.2	SE	8-15[1]

[1] A range has been given due to the large area of similar ground-level concentrations impacts.

Figure C22 - Figure C24 present time series for wind direction, wind speed and mixing height for the three days on which the four highest predicted 1-hour ground-level concentrations of SO_2 occur. On each occasion, a circulation event has occurred whereby the wind speeds decrease in the hours leading up to the hour of highest impact before the wind direction reverses and the wind speed begins to accelerate. This effect causes the pollution emitted during the previous hours to be poorly dispersed due to the diminishing winds and then to be subsequently blown back toward the source to produce a build up with the following hour's emissions. While these conditions are entirely reasonable in the atmosphere and is likely to produce elevated ground-level concentrations, there is likely to be a degree of over-prediction by TAPM in predicting ground-level impacts.

C6.2 Sulfur Dioxide Impacts at Eneabba

The nearest population centre in the region surrounding the proposed CPP is at Eneabba. A time series of the predicted impact of SO_2 from the Power Station at Eneabba is presented in Figure C25. The highest predicted 1-hour average ground-level concentration of SO_2 at Eneabba is 113.8 µg/m^3, which is 20% of the NEPM(Air) standard of 570 µg/m^3. The second highest 1-hour average concentration is predicted to be less than 50 µg/m^3.

The relationship between the predicted 1-hour average ground-level concentrations at Eneabba and the wind speed at the top of the proposed Power Station stack generally indicates that higher concentrations are more likely to occur during lighter winds. The relationship between the predicted 1-hour average concentrations at Eneabba and wind direction at the top of the proposed Power Station stack indicates the highest ground-level concentration occurred during winds from the easterly sector. This result is similar to the meteorological conditions responsible for the highest predicted impacts in the domain, as discussed in Section C6.1, where the elevated impact was likely to be caused by a change in wind conditions from the previous hour which led to poor dispersion.

C6.3 Impacts of Sulfur Dioxide at Receptor 7

The highest impact of SO_2 at any of the nearest sensitive receptors was found to be at Receptor 7. Notwithstanding this, no exceedences of the NEPM(Air) standard are predicted at Receptor 7.

A time series of ground-level concentrations of SO_2 at Receptor 7 is presented in Figure C26. The predicted maximum 1-hour average ground-level concentration of SO_2 is 125.3 µg/m^3, 22% of the NEPM(Air) standard of 570 µg/m^3, with only three hours predicted to be greater than 100 µg/m^3.

The relationship between the predicted 1-hour average ground-level concentration of SO_2 at Receptor 7 and the wind speed and wind direction at the top of the Power Station stack indicates that SO_2 impacts between 50 and 125 µg/m^3 may occur during various wind conditions, including wind speeds from 0.5 – 6.5 m/s and wind directions from the north-northeast to northeast and from the southwest to northwest. Again, this illustrates the significance of wind changes and the recirculation of pollution to cause impacts.

C6.4 Maximum Impacts of Sulfur Dioxide during Non-normal Operations

Aviva estimate that desulfurisation with the lime injection system could be non-operational for 1% of the year. During this time the SO_2 emission rate is likely to vary between 2.4 - 4.6 kg/s due to the variability of the coal sulfur content. Stochastic modelling methods have been used to assess the impacts of SO_2 emissions from the CPP during non-normal operations.

Figure C27 shows the locations where an exceedence of the NEPM(Air) standard is likely to occur as a result of the combination of high SO_2 emissions during non-normal operations and adverse meteorological conditions. Based on the stochastic modelling technique, the probability of impacts of SO_2 have been determined based on the frequency distribution of emission rates for the variability in coal sulphur content and assuming non-normal operations for 1% of the time.

A maximum of one exceedence per year is predicted at locations between 3-5 km from the Power Station stack. An exceedence for one hour is allowable under the NEPM standard.

C7. Health Risk Assessment

The following section presents the results of the Health Risk Assessment for the proposed CPP. A detailed methodology is provided in the main Air Quality Assessment report for the Environmental Impact Assessment.

C7.1 Hazard Quotients and Hazard Indices

C7.1.1 Acute

Table C8 Acute Hazard Index calculated for 75th percentile SO_2 emissions for the Coolimba Power Station (DeSOx operating)

Pollutant	GLCs Maximum of grid (µg/m³)		Guideline/ Standard (µg/m³)	Hazard Quotients	
	Maximum	99.9th Percentile		Maximum	99.9th Percentile
SO_2 [a]	351.8	133.6	570	0.617	0.234
NO_2 [b]	59.1	22.4	256	0.231	0.088
CO	51.9	19.7	11250	0.005	0.002
PM_{10}	3.7	1.4	50	0.074	0.028
Vanadium	0.0	0.0	1	0.002	0.001
			Acute Hazard Index	0.928	0.352

Notes: [a] SO_2 emission rate of 800 mg/Nm³
[b] NO_2/NO_x ratio of 30% assumed

Table C9 Acute Hazard Index calculated for 100th percentile SO_2 emissions for the Coolimba Power Station (DeSOx operating)

Pollutant	GLCs Maximum of grid (µg/m³)		Guideline/ Standard	Hazard Quotients	
	Maximum	99.9th Percentile		Maximum	99.9th Percentile
SO_2 [a]	483.7	183.7	570	0.849	0.322
NO_2 [b]	59.1	22.4	256	0.231	0.088
CO	51.9	19.7	11250	0.005	0.002
PM_{10}	3.7	1.4	50	0.074	0.028
Vanadium	0.0	0.0	1	0.002	0.001
			Acute Hazard Index	1.159	0.440

Notes: [a] SO_2 emission rate of 1100 mg/Nm³
[b] NO_2/NO_x ratio of 30% assumed

C7.1.2 Chronic

Table C10 Chronic Hazard Index calculated for the Coolimba Power Station (normal operations)

Pollutant	Maximum Annual Ave GLC (µg/m³)	Guideline/Standard (µg/m³)	Hazard Quotient
SO_2 [a]	3.1	60	0.05167
NO_2	1.736	60	0.02893
PAH	0.00001085	0.0003	0.03617
Arsenic	7.4788E-05	0.006	0.01246
Cadmium	1.4338E-05	0.005	0.00287
Lead	1.8988E-05	0.5	0.00004
Mercury	0.0000744	1	0.00007
Selenium	0.00049988	1	0.00050
Nickel	0.00060993	0.02	0.03050
		Chronic Hazard Index	0.16321
Notes: [a] SO_2 emission rate of 800 mg/Nm^3			

C7.2 Carcinogenic risk

Table C11 Cancer risk estimates for the Coolimba Power Station (normal operations) – maximum on grid

Pollutant	Maximum Annual GLC (µg/m³)	Unit Risk Factor per µg/m^3	Cancer Risk	Notes
VOC	0.0244125	6.00E-06	1.46E-07	Assume all is benzene
PAH	0.00001085	8.70E-02	9.44E-07	Assume all is BaP
Arsenic	7.4788E-05	1.50E-03	1.12E-07	
Chromium	1.6081E-06	4.00E-02	6.43E-08	Cr(VI) estimate of 0.5%
Nickel	0.00060993	4.00E-04	2.44E-07	
		Cancer Risk	1.51E-06	

Table C12 Cancer risk estimates for the Coolimba Power Station (normal operations) – maximum sensitive receptor

Pollutant	Maximum Annual GLC (µg/m³)	Unit Risk Factor per µg/m^3	Cancer Risk	Notes
VOC	0.0149625	6.00E-06	8.98E-08	Assume all is benzene
PAH	0.00000665	8.70E-02	5.79E-07	Assume all is BaP
Arsenic	4.5838E-05	1.50E-03	6.88E-08	
Chromium	9.8563E-07	4.00E-02	3.94E-08	Cr(VI) estimate of 0.5%
Nickel	0.00037383	4.00E-04	1.50E-07	
		Cancer Risk	9.26E-07	

C7.3 Deposition to soil and water

Table C13 Deposition to soil estimates for the Coolimba Power Station (normal operations)

Pollutant	Maximum Annual GLC (µg/m³)	Maximum Deposition (mg/m²/day)	Soil Conc (mg/kg)	Ref Value (mg/kg)	% of ref Value
Benzopyrene	1.09E-05	1.87E-02	1.12E-03	20	0.006%
Dioxins and Furans	8.68E-10	1.50E-06	6.84E-08	0.00003	0.228%
Arsenic	7.48E-05	1.29E-01	1.53E-06	100	0.000%
Cadmium	1.43E-05	2.48E-02	2.94E-07	20	0.000%
Lead	1.90E-05	3.28E-02	3.89E-07	300	0.000%
Mercury	7.44E-05	1.29E-01	1.52E-06	15	0.000%
Chromium (VI)	3.22E-04	5.56E-01	6.59E-06	100	0.000%
Nickel	6.10E-04	1.05E+00	1.25E-05	600	0.000%

Table C14 Deposition to water estimates for the Coolimba Power Station (normal operations)

Pollutant	Maximum Annual GLC (µg/m³)	Maximum Deposition (mg/m²/day)	Water Conc µg/kg/day	Ref Value (µg/kg)	% of ref Value
Benzopyrene	1.09E-05	1.87E-02	0.014	0.7	1.9%
Dioxins and Furans	8.68E-10	1.50E-06	0.000001	0.0000082	13.2%
Arsenic	7.48E-05	1.29E-01	0.093	7	1.3%
Cadmium	1.43E-05	2.48E-02	0.018	2	0.9%
Lead	1.90E-05	3.28E-02	0.024	10	0.2%
Mercury	7.44E-05	1.29E-01	0.093	1	9.3%
Chromium vi	3.22E-04	5.56E-01	0.402	50	0.8%
Nickel	6.10E-04	1.05E+00	0.762	20	3.8%
Boron	4.37E-03	7.55E+00	5.459	4000	0.1%
Copper	2.27E-04	3.92E-01	0.284	2000	0.01%
Selemium	5.00E-04	8.64E-01	0.624	10	6.2%

C8. Conclusions

Katestone Environmental has conducted an air quality assessment for an alternate configuration of the proposed Coolimba Power Station near Eneabba in Western Australia. The following conclusions can be drawn from dispersion modelling study:

- There are no exceedences of the NEPM(Air) standards for SO_2 and NO_2 predicted anywhere on the modelling domain during normal operations

- A maximum of one hour per year is predicted to exceed the NEPM(Air) standard of 570 µg/m^3 for the 1-hour average of SO_2 when considering non-normal operations for 1% of the year

- The predicted maximum 1-hour average ground-level concentration of NO_2 across the modelling domain is 59.2 µg/m^3, which is 24.1% of the NEPM standard of 246 µg/m^3

- The predicted maximum 1-hour average ground-level concentration of NO_2 at a sensitive receptor location is 21.3 µg/m^3 at Receptor 7 (R7), which is 8.6% of the NEPM standard of 246 µg/m^3

- The predicted maximum 1-hour average ground-level concentration of SO_2 across the modelling domain is 351.8 µg/m^3 during normal operations, which is 61.7% of the NEPM standard of 570 µg/m^3

- The predicted maximum 1-hour average ground-level concentration of SO_2 at a sensitive receptor location is 125.3 µg/m^3 at Receptor 7 (R7) during normal operations, which is 22.0% of the NEPM standard of 570 µg/m^3

C9. References

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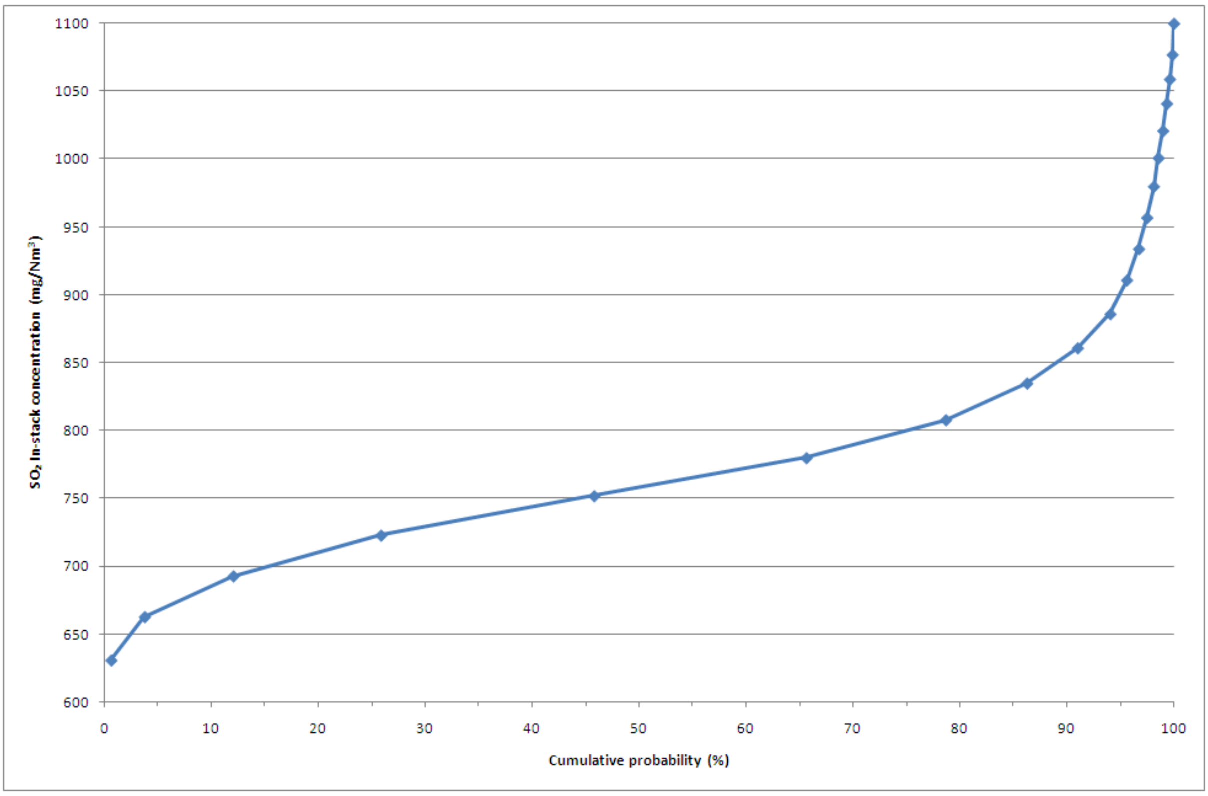

Figure C1 **Cumulative distribution of in stack SO_2 concentrations**

Location: N/A	**Averaging period:** N/A	**Data source:** Emissions Spreadsheet	**Units:** % and mg/Nm³
Type: Cumulative frequency distribution		**Prepared by:** A. Schloss	**Date:** 6/08/2008

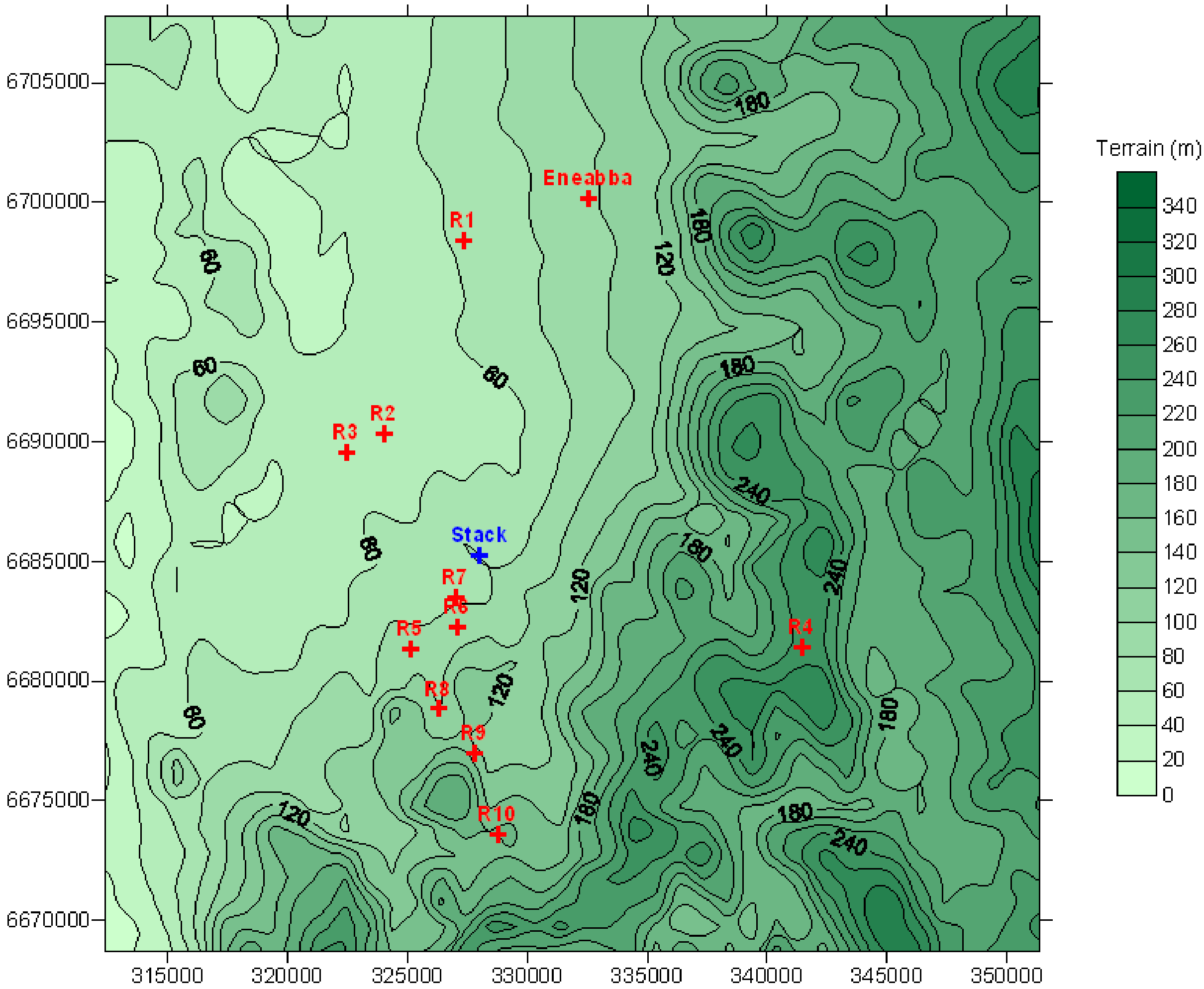

Figure C2 Terrain plot for TAPM 1000m modelling domain and sensitive receptors

Location: Eneabba	**Averaging period:** N/A	**Data source:** TAPM	**Units:** Australian Map Grid coordinates – MGA94
Type: Aerial map		**Prepared by:** A. Schloss	**Date:** 18/08/2008

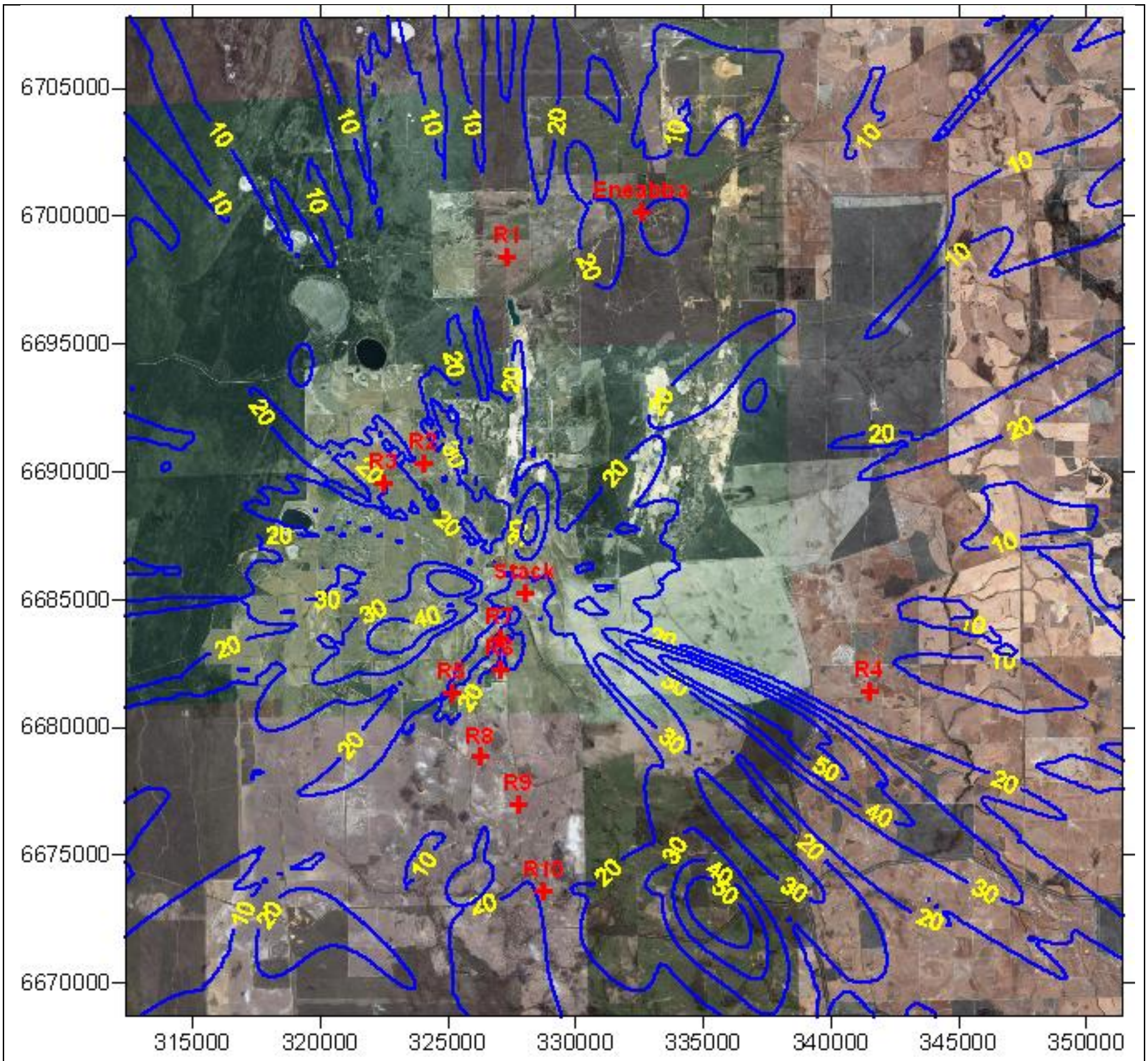

Figure C3	**Predicted maximum 1-hour average ground-level concentrations of NO_2**		
Location: Eneabba	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Contour Map 100th percentile 30% NO_2/NO_x assumed	**Standard:** 246 µg/m³	**Prepared by:** A. Schloss	**Date:** 18/08/2008

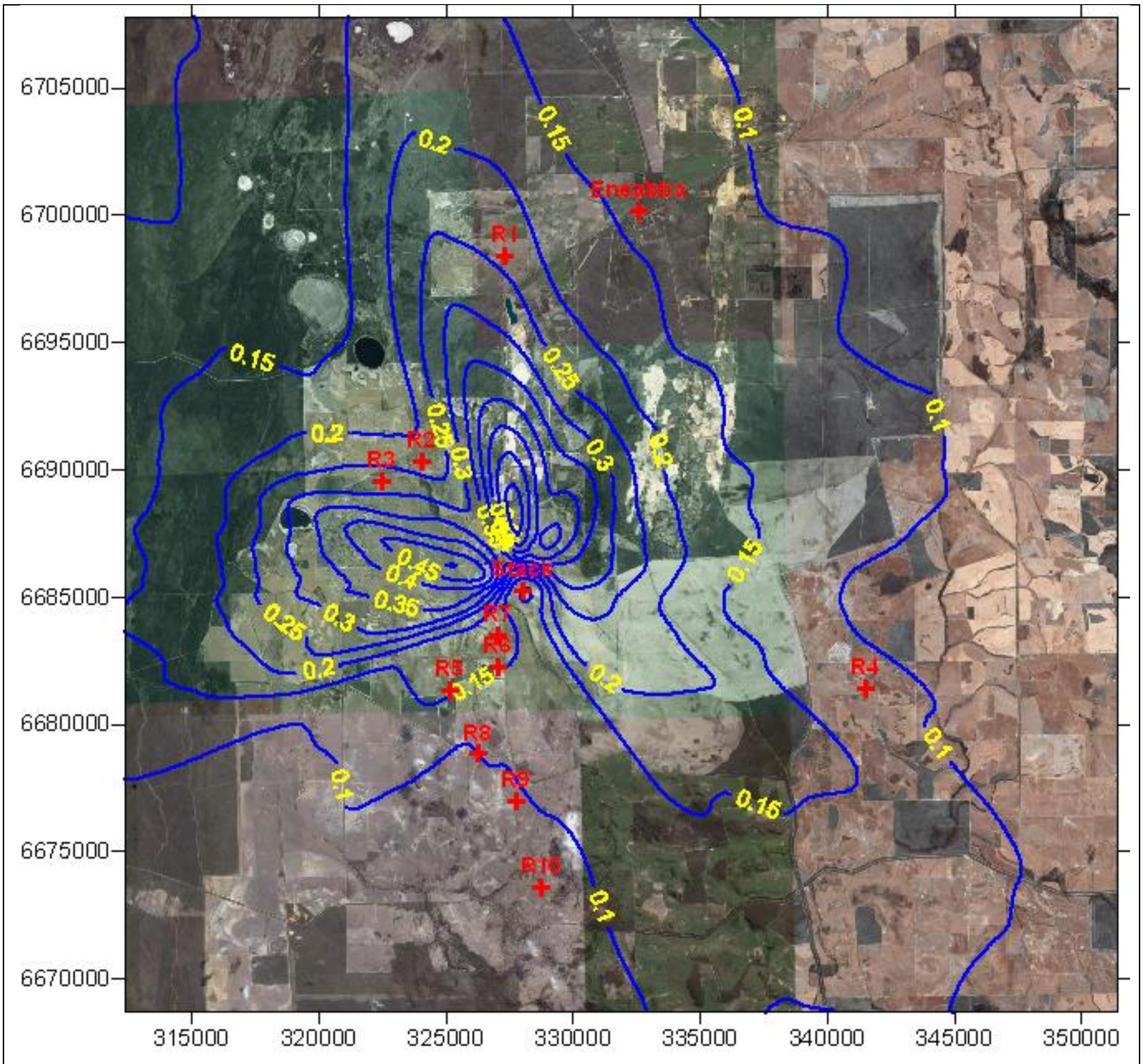

Figure C4 Predicted annual average ground-level concentrations of NO_2			
Location: Eneabba	**Averaging period:** Annual	**Data source:** TAPM	**Units:** µg/m³
Type: Contour Map 30% NO_2/NO_x assumed	**Standard:** 62 µg/m³	**Prepared by:** A. Schloss	**Date:** 18/08/2008

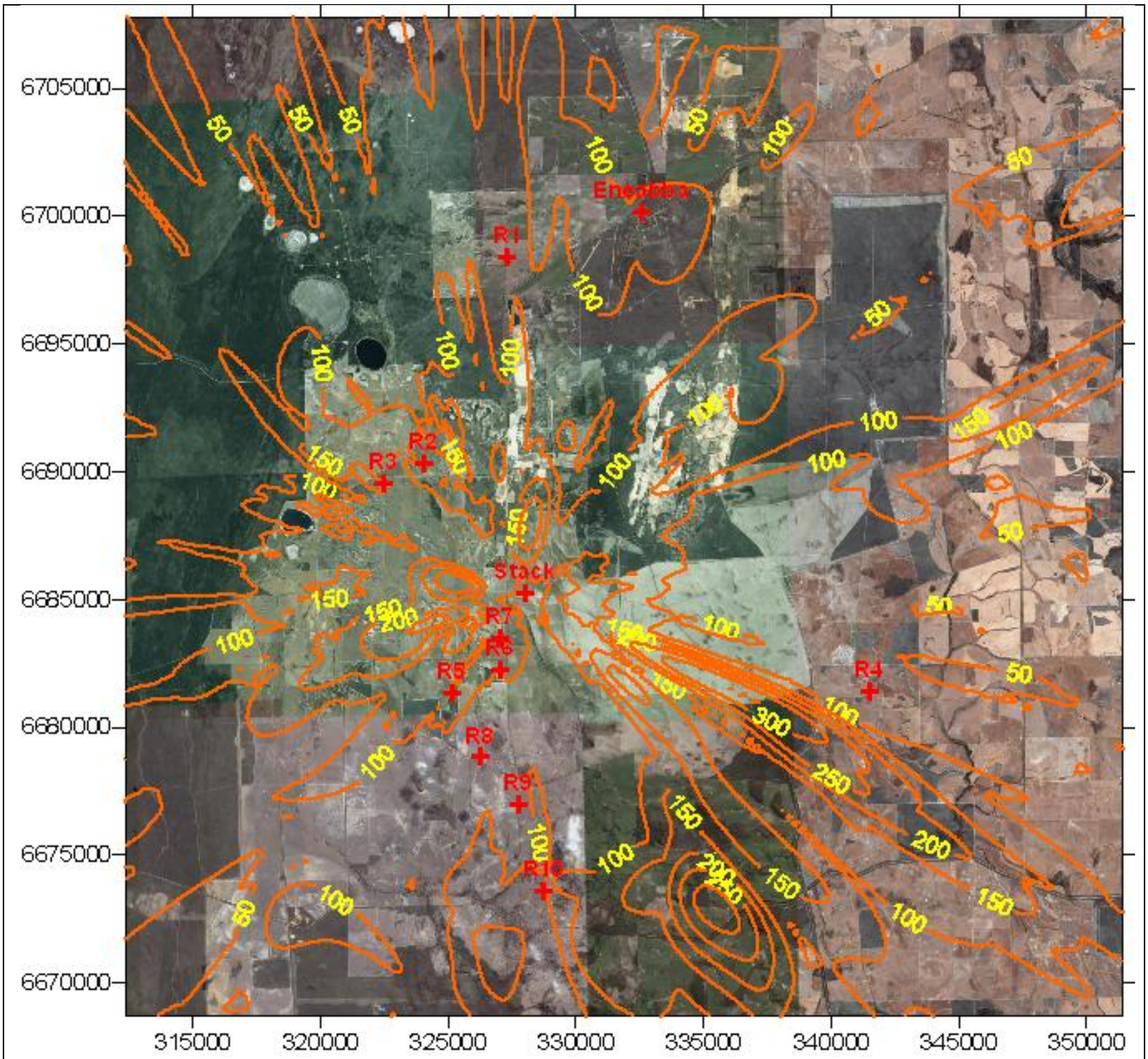

Figure C5 Predicted maximum 1-hour average ground-level concentrations of SO_2

Location: Eneabba	**Averagin g period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Contour Map 100th percentile	**Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 18/08/2008

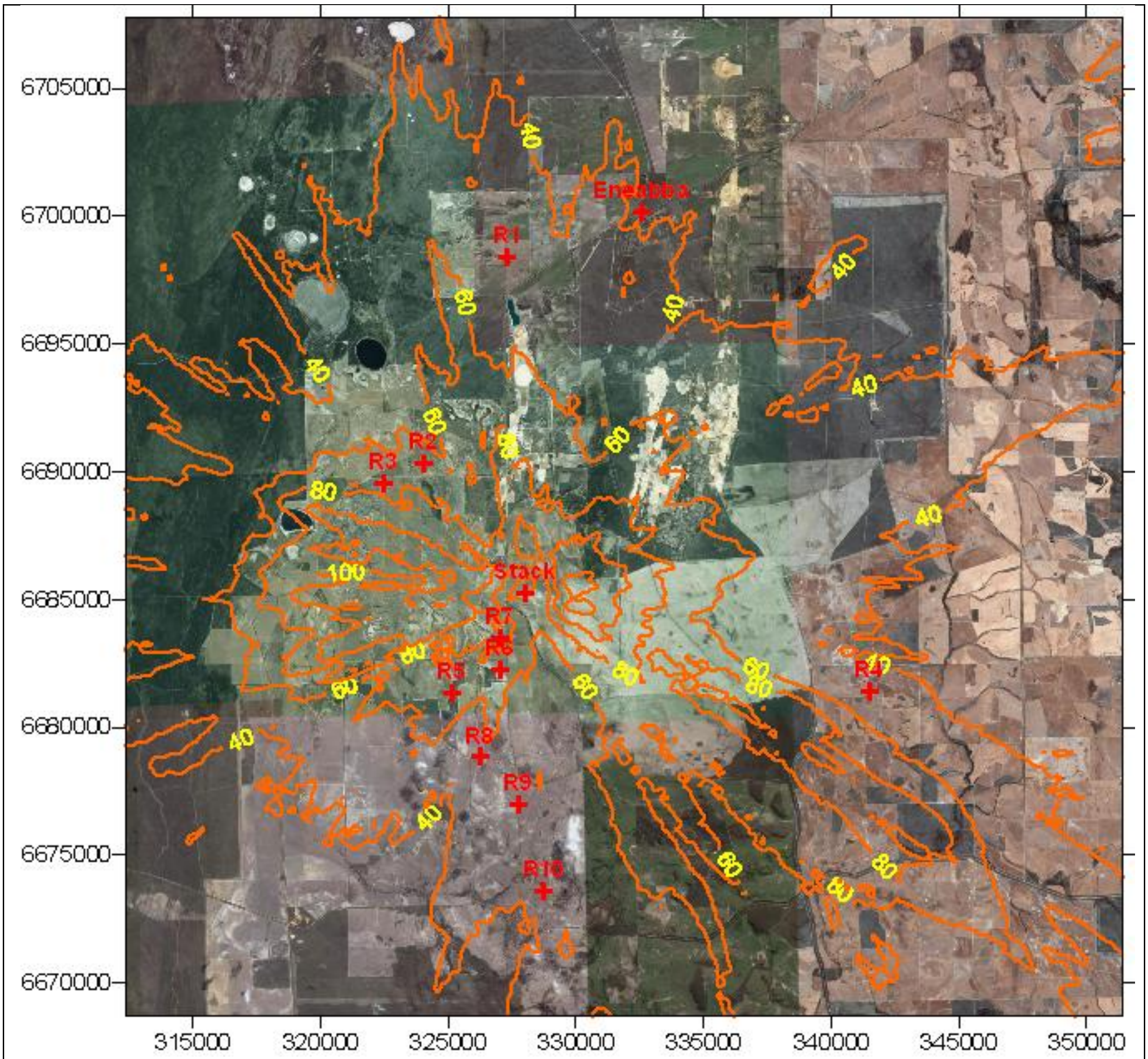

Figure C6	**Predicted 99.9th percentile 1-hour average ground-level concentrations of SO_2**		
Location: Eneabba	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Contour Map 99.9th percentile	**Standard:** 350 µg/m³	**Prepared by:** A. Schloss	**Date:** 18/08/2008

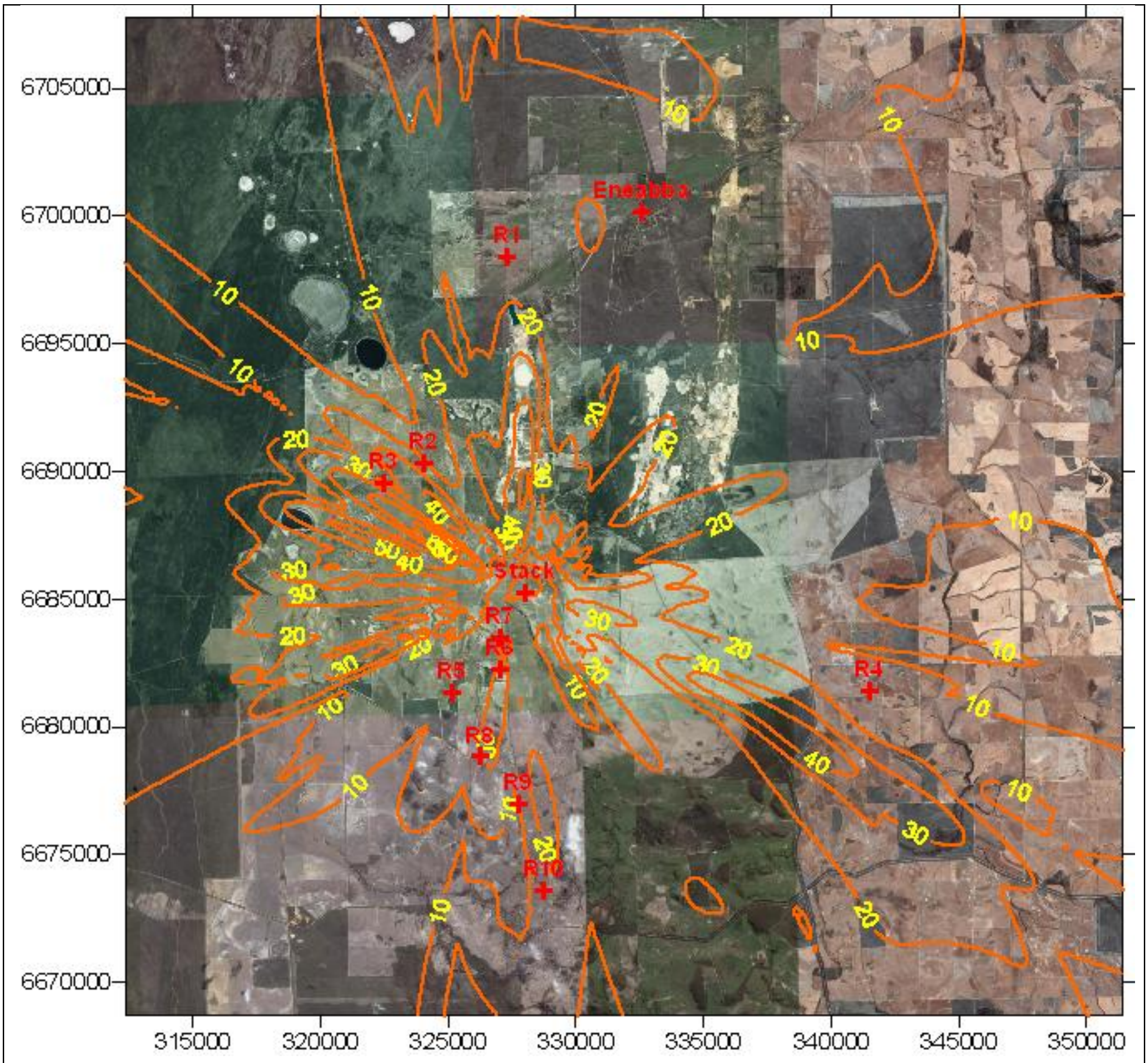

Figure C7 Predicted maximum 24-hour average ground-level concentrations of SO_2

Location: Eneabba	Averaging period: 24-hour	Data source: TAPM	Units: µg/m³
Type: Contour Map 100th percentile	**Standard:** 228 µg/m³	**Prepared by:** A. Schloss	**Date:** 18/08/2008

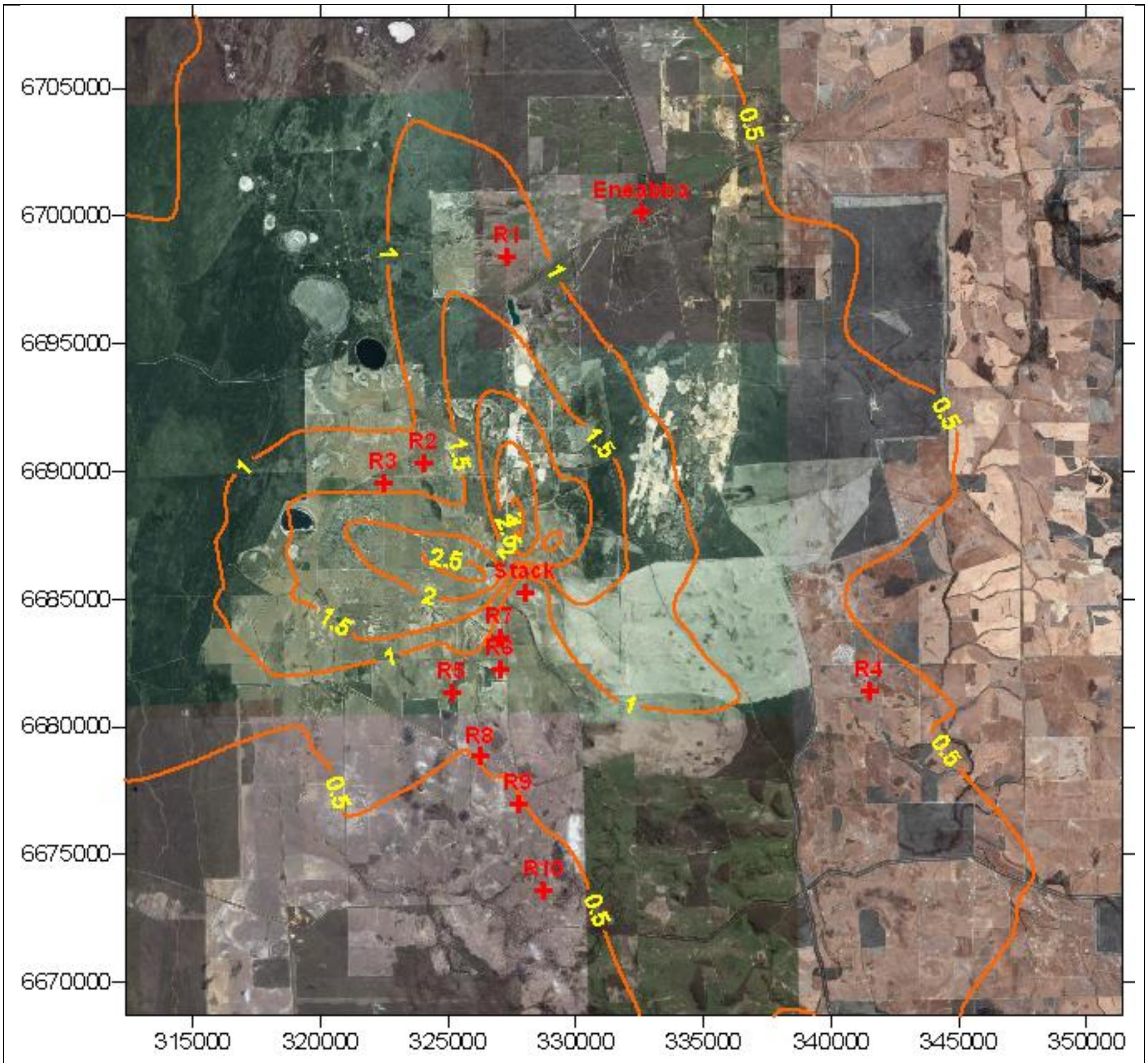

Figure C8 Predicted annual average ground-level concentrations of SO_2

Location: Eneabba	**Averaging period:** Annual	**Data source:** TAPM	**Units:** µg/m³
Type: Contour Map	**Standard:** 60 µg/m³	**Prepared by:** A. Schloss	**Date:** 18/08/2008

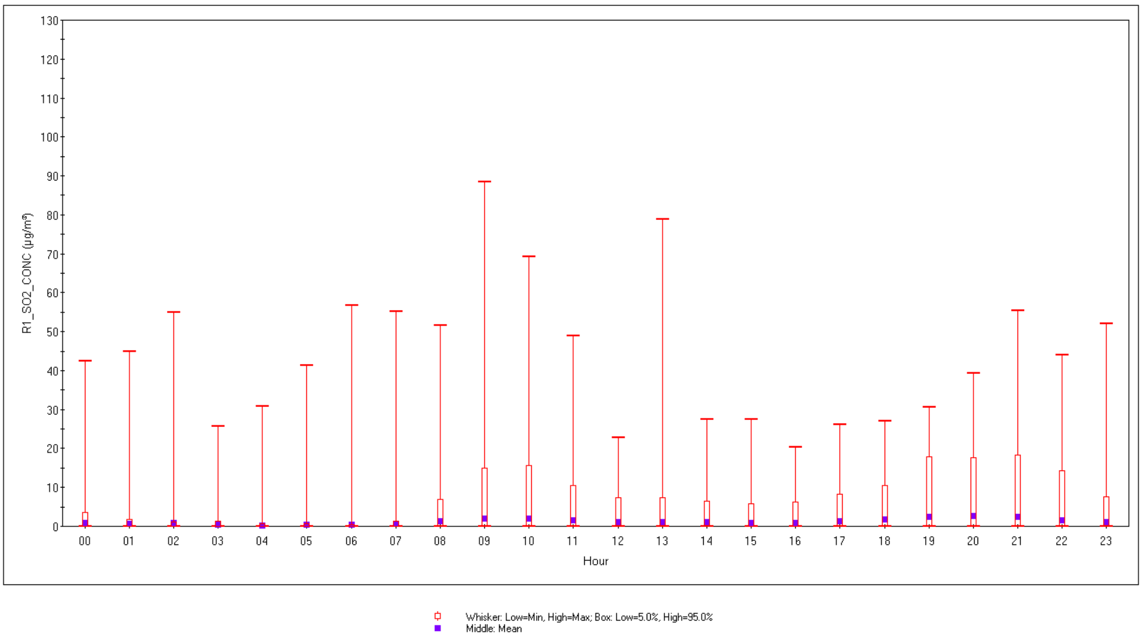

Figure C9	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R1**		
Location: R1	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

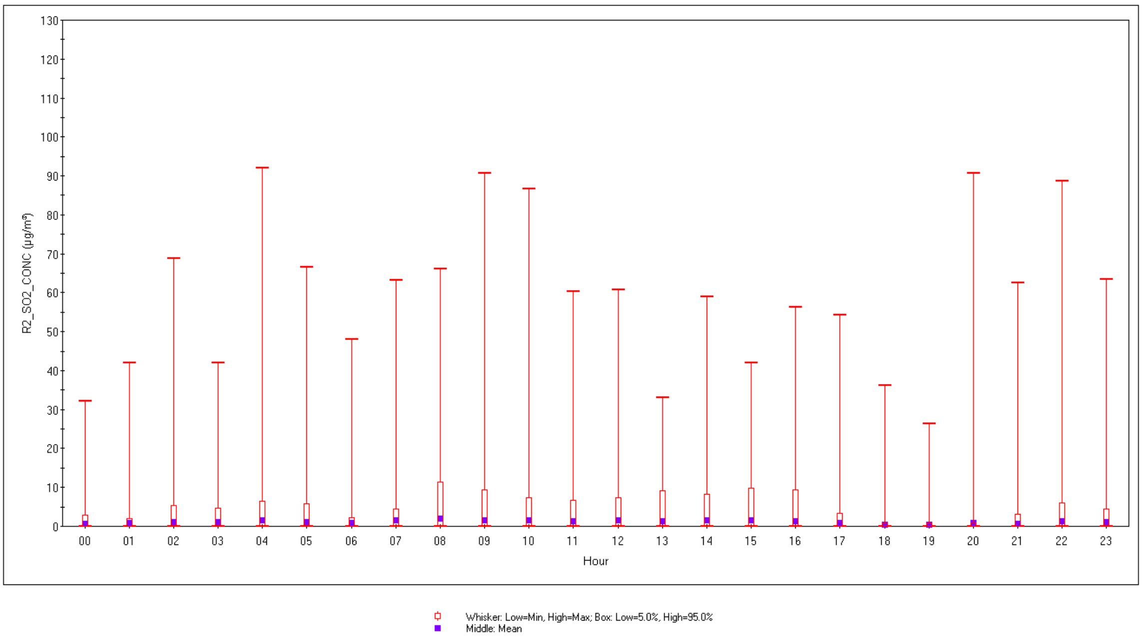

Figure C10	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R2**

Location: R2	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

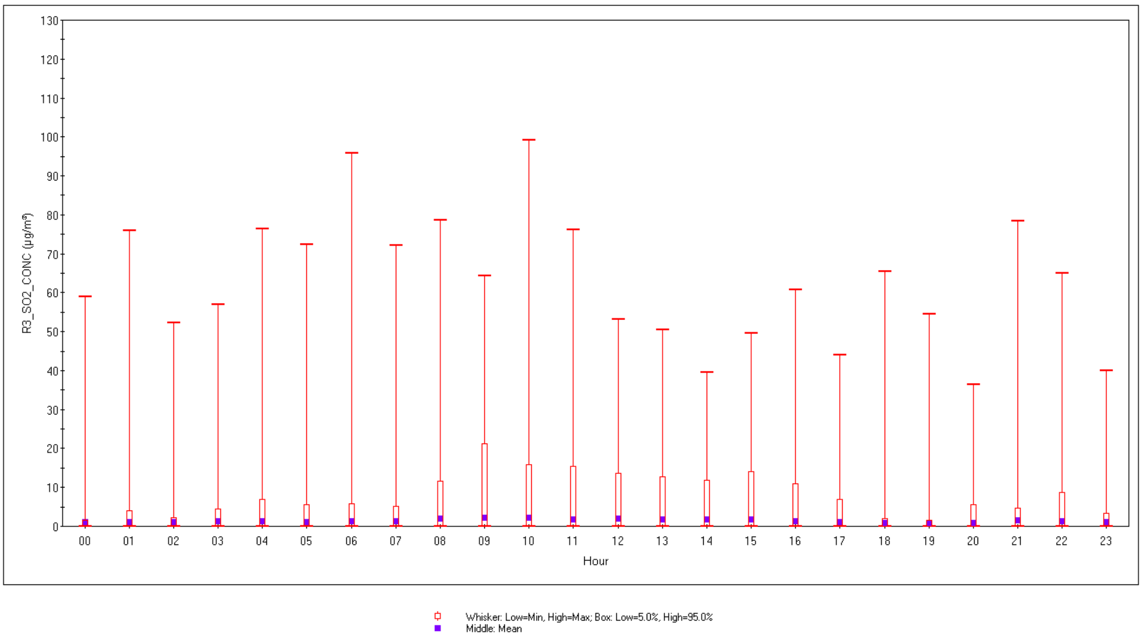

Figure C11	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R3**		
Location: R3	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

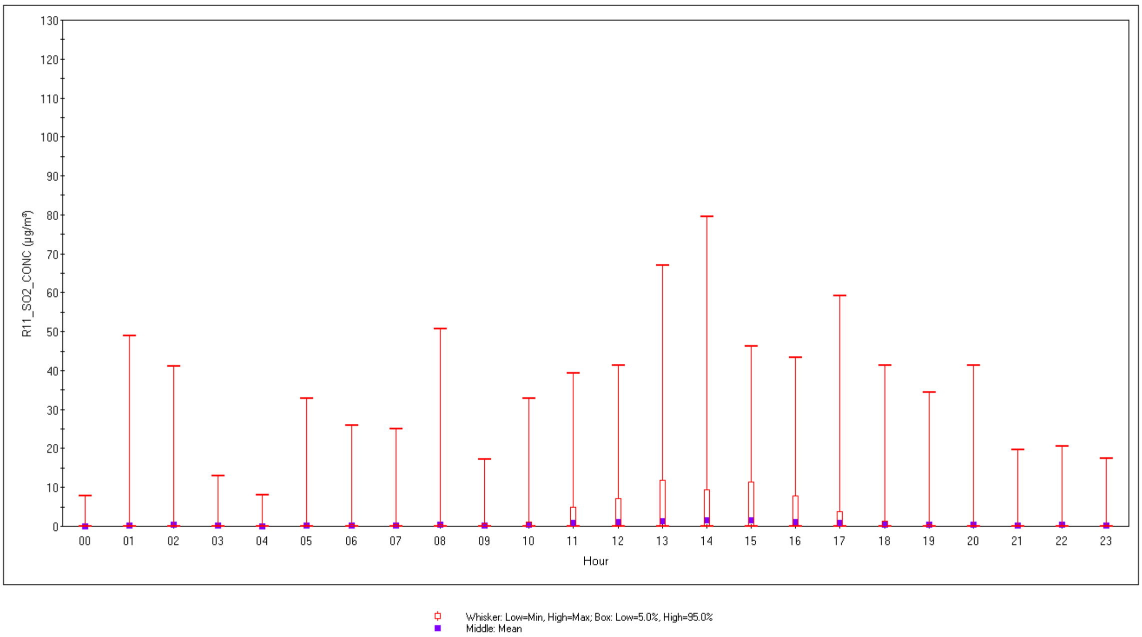

Figure C12 **Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R4**

Location: R4	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 18/08/2008

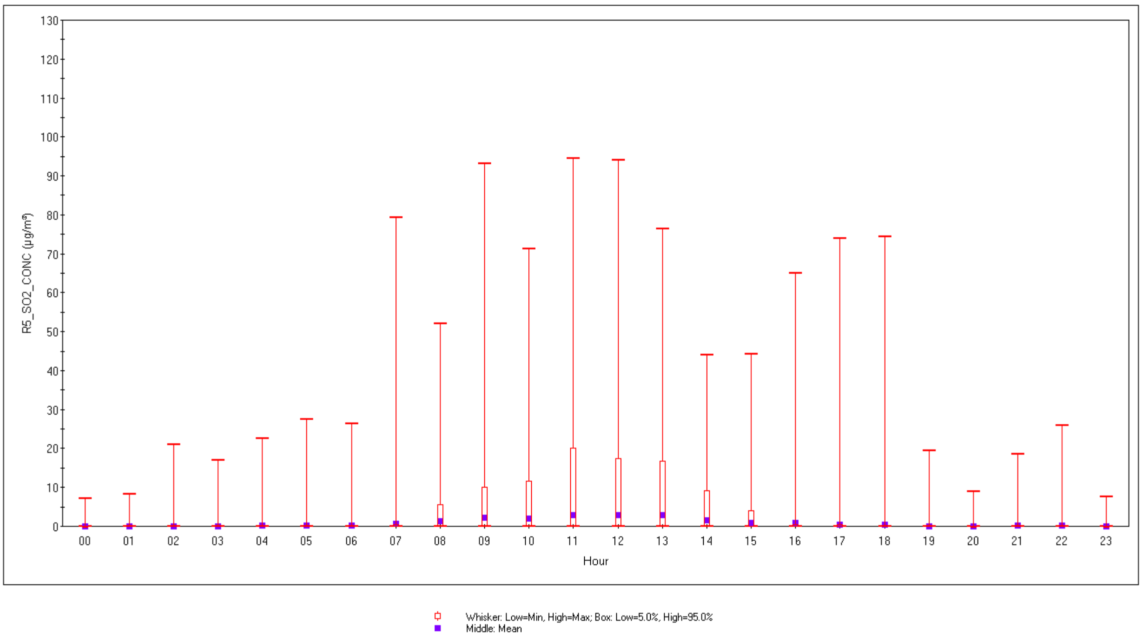

Figure C13	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R5**

Location: R5	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

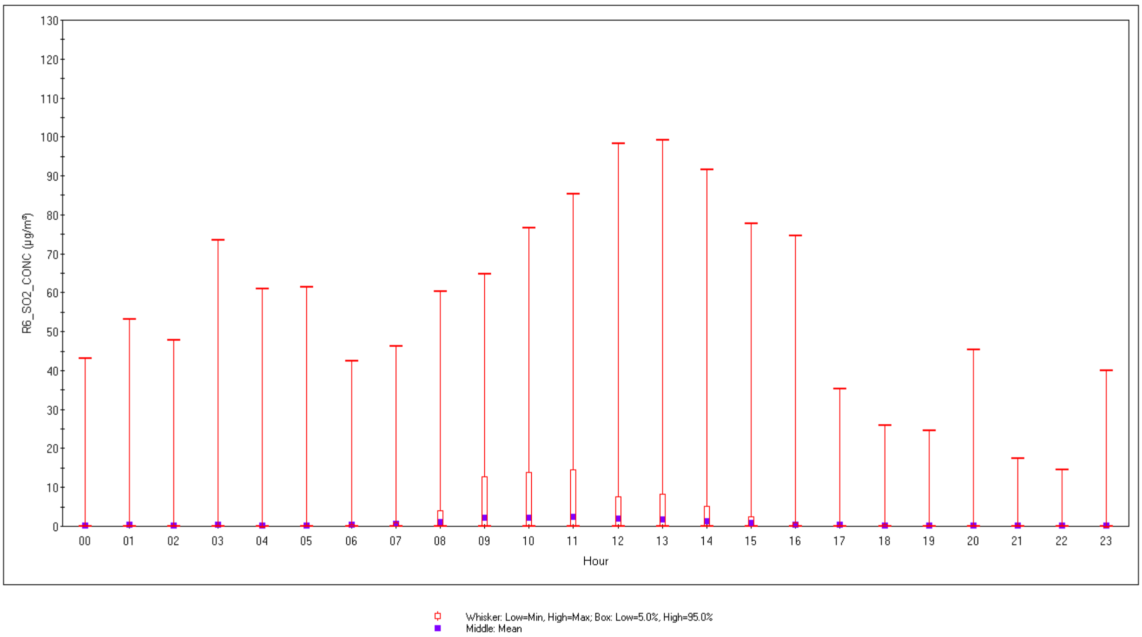

Figure C14	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R6**		
Location: R6	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

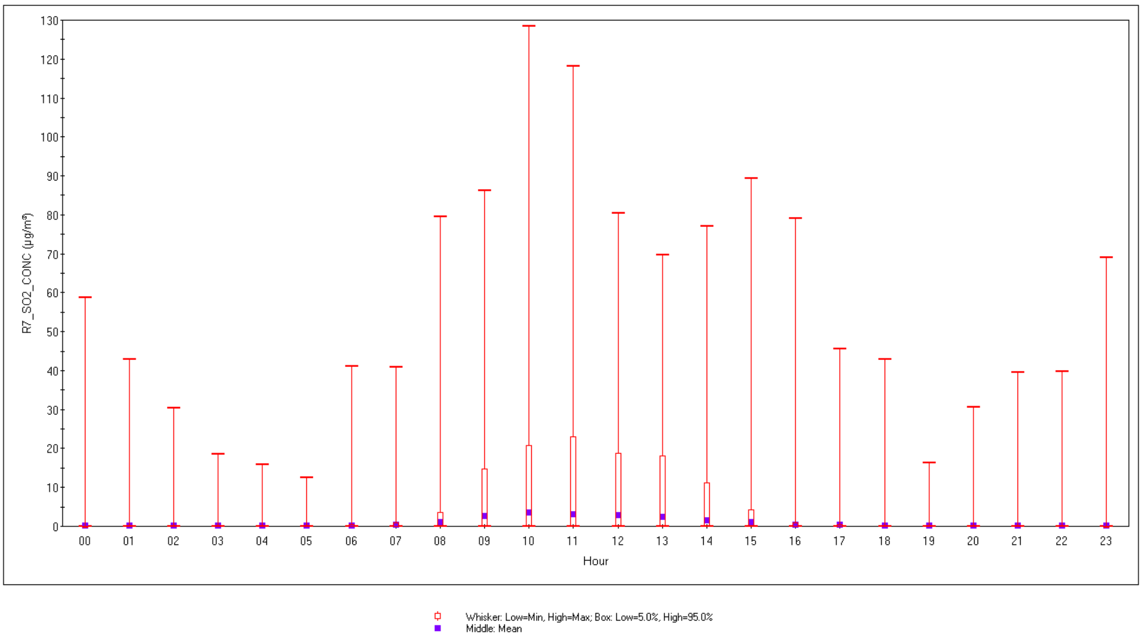

Figure C15	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R7**		
Location: R7	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

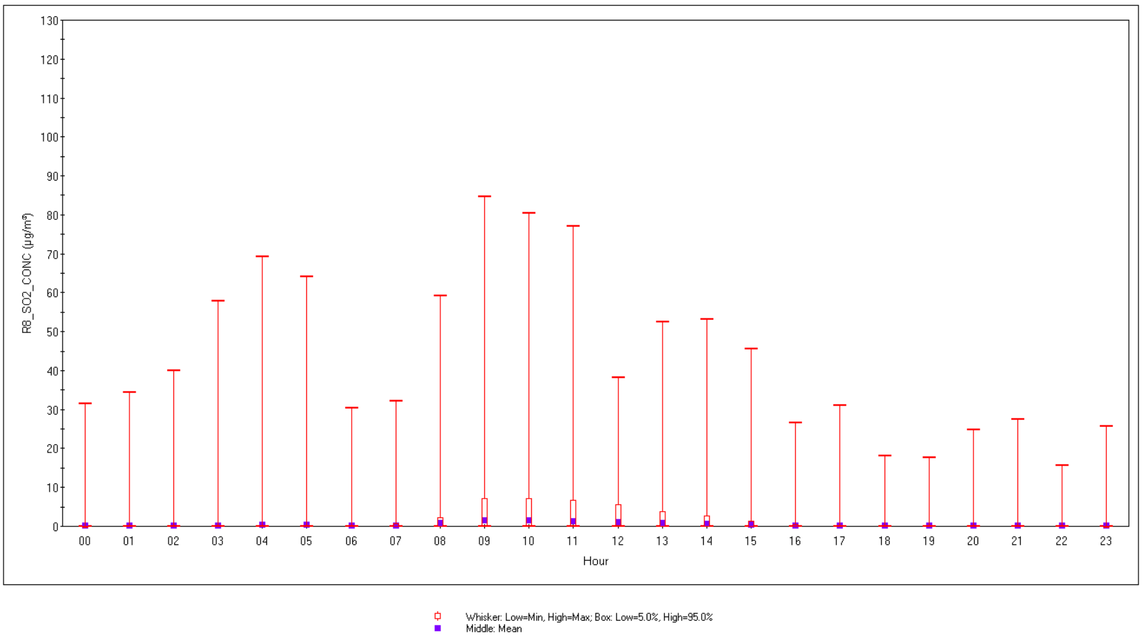

Figure C16	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R8**

Location: R8	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

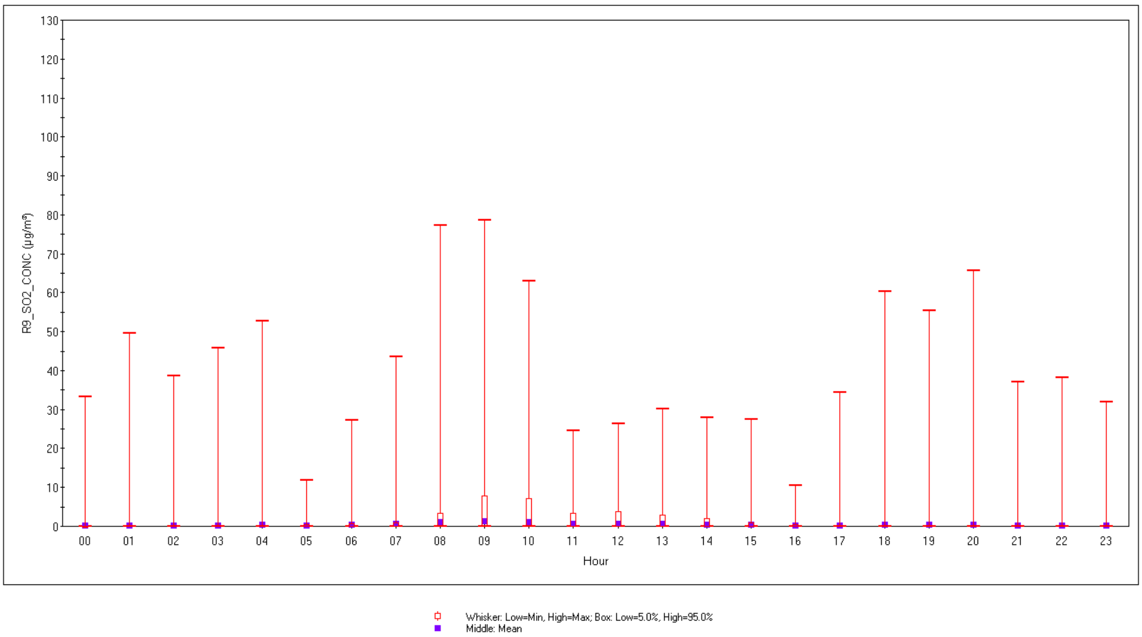

Figure C17 **Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R9**

Location: R9	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

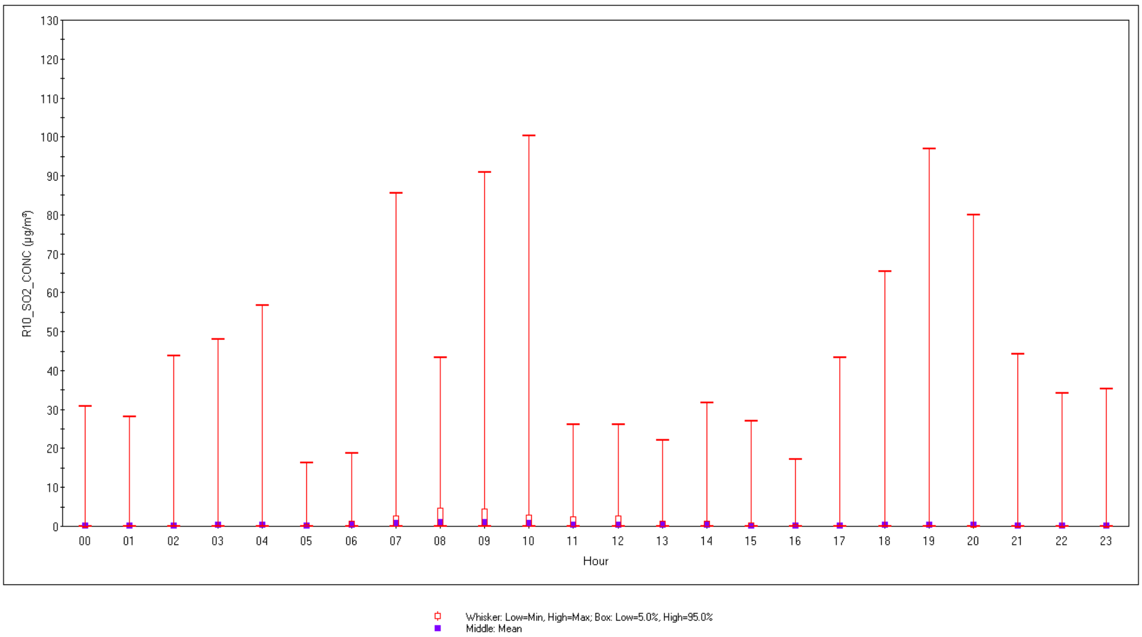

Figure C18	**Distribution of hourly averaged SO_2 concentrations throughout the day at sensitive receptor location R10**

Location: R10	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

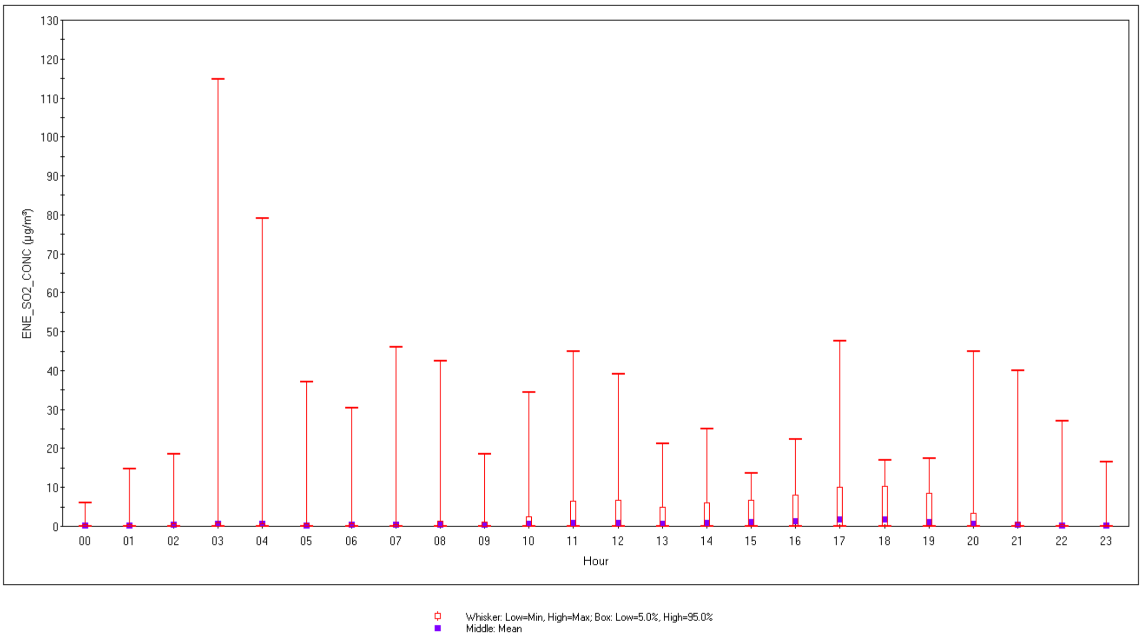

Figure C19 Distribution of hourly averaged SO_2 concentrations throughout the day at Eneabba Township

Location: Eneabba	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Box and Whisker	**Pollutant:** SO_2	**Prepared by:** A. Schloss	**Date:** 5/08/2008

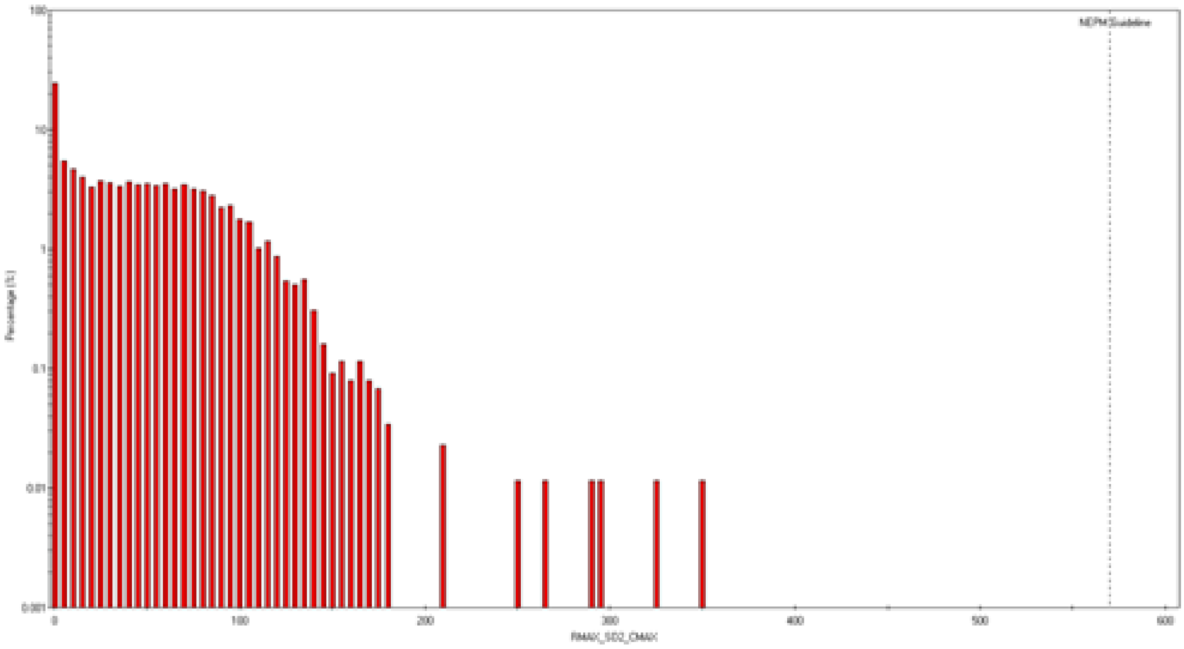

Figure C20	**Frequency distribution of maximum ground-level concentrations of SO_2 for the entire modelling domain**

Location: Across modelling domain	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Histogram	**Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 5/08/2008

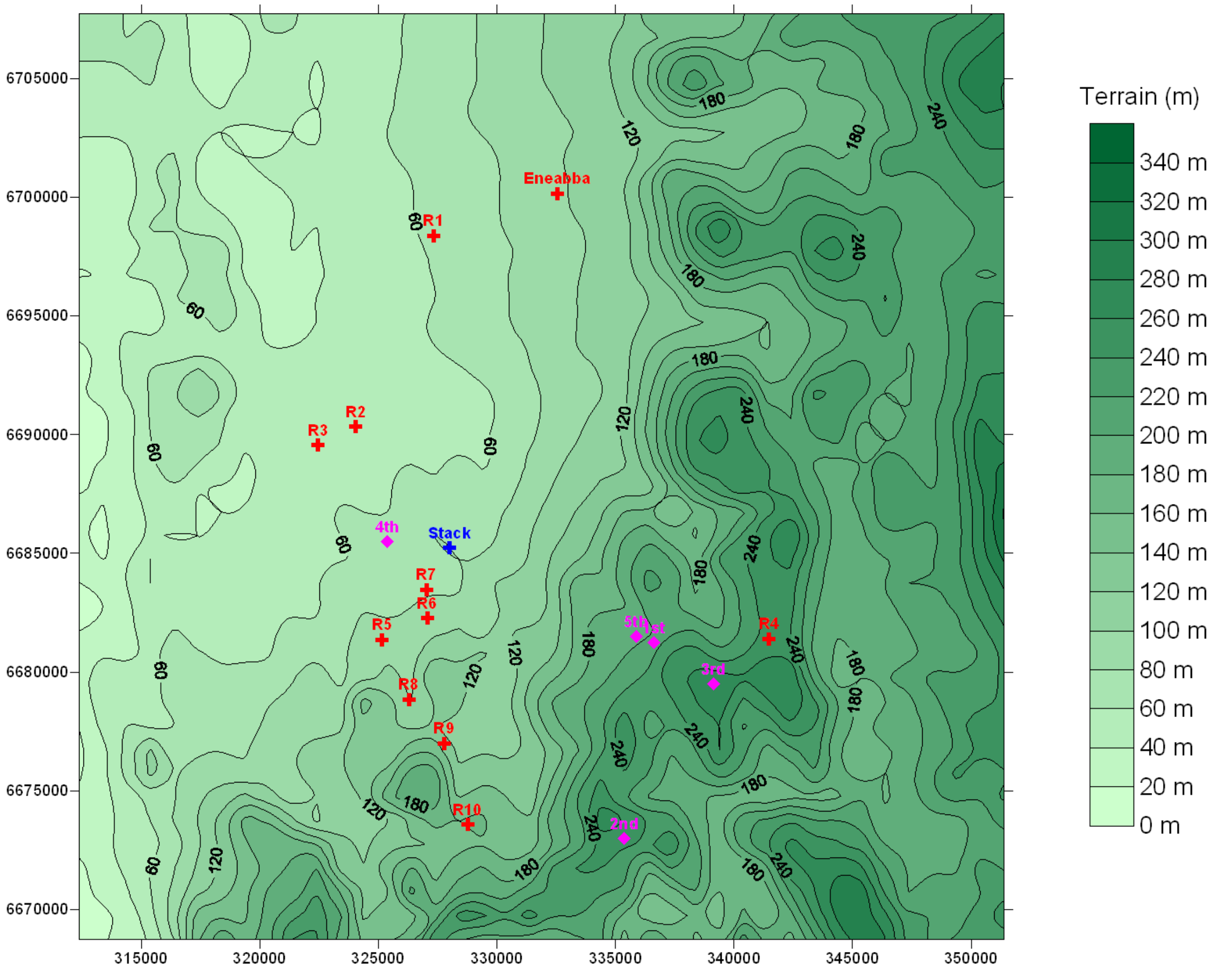

Figure C21	**Location of the five highest predicted 1-hour average concentrations of SO_2 on the modelling domain**

Location: Eneabba region	**Data source:** TAPM	**Units:** Terrain contours in metres
Type: Contour map generated from DEM data	**Prepared by:** A. Schloss	**Date:** 18/08/2008

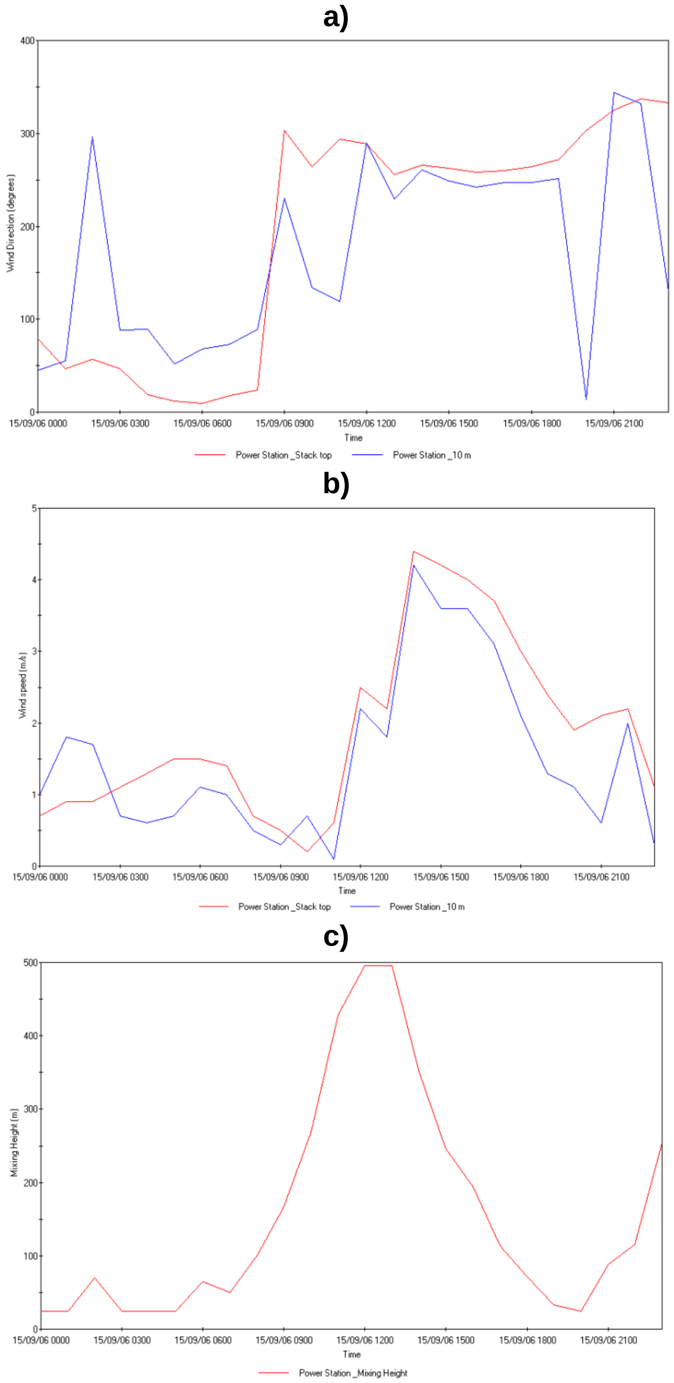

Figure C22	**Time series of hourly averaged wind direction, wind speed and mixing height for 15/09/2006. The 1st and 3rd highest predicted 1-hour concentrations of SO_2 occurred at 10am and 9am respectively. a) Wind direction, b) Wind speed, c) Mixing height**		
Location Coolimba Power Project	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** a) Degrees, b) m/s, c) m
Type: Time series		**Prepared by:** A. Balch	**Date:** 14/08/2008

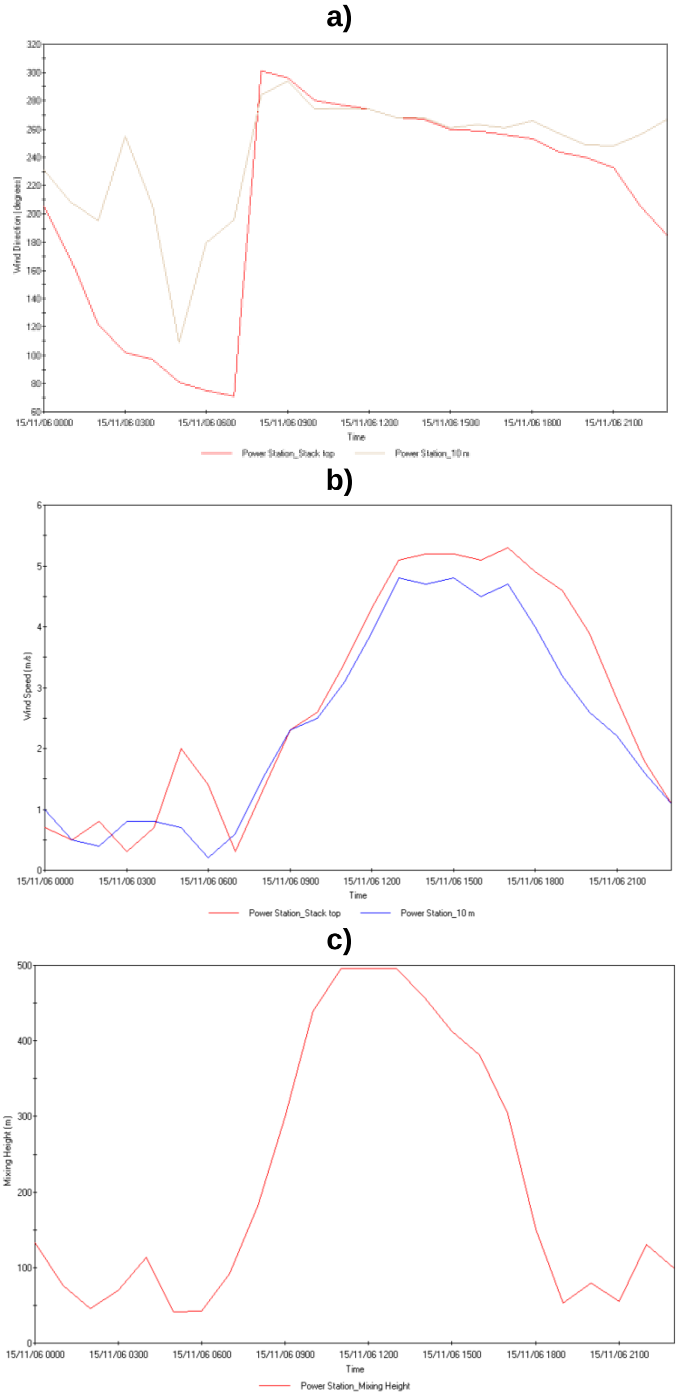

Figure C23 Time series of hourly averaged wind direction, wind speed and mixing height for 15/11/2006. The 2nd highest predicted 1-hour concentration of SO_2 occurred at 8am. a) Wind direction, b) Wind speed, c) Mixing height

Location Coolimba Power Project	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** a) Degrees, b) m/s, c) m
Type: Time series		**Prepared by:** A. Balch	**Date:** 14/08/2008

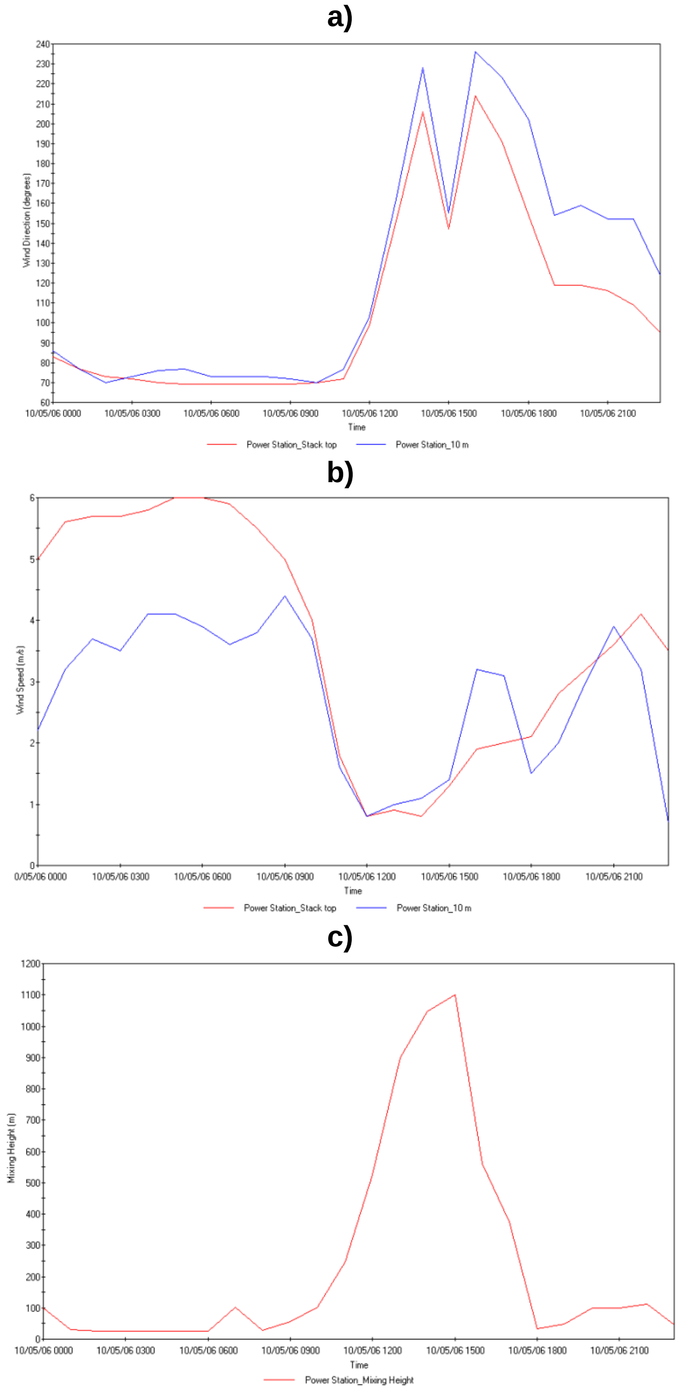

Figure C24 Time series of hourly averaged wind direction, wind speed and mixing height for 10/05/2006. The 4th highest predicted 1-hour concentration of SO_2 occurred at 12am. a) Wind direction, b) Wind speed, c) Mixing height

Location Coolimba Power Project	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** a) Degrees, b) m/s, c) m
Type: Time series		**Prepared by:** A. Balch	**Date:** 14/08/2008

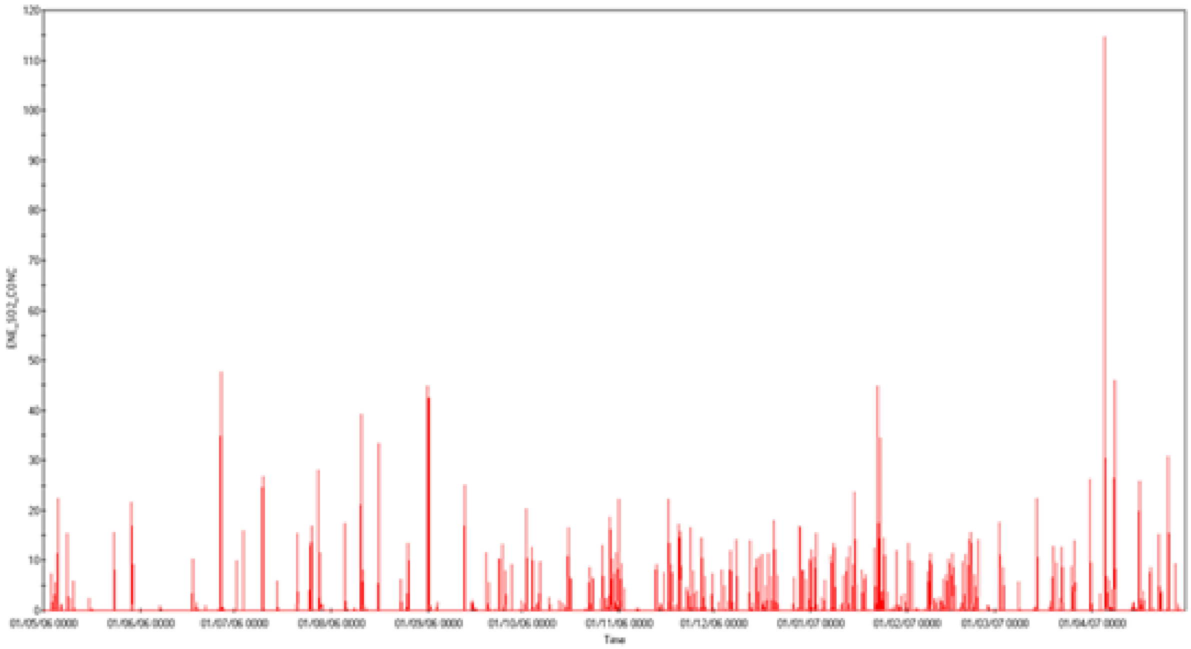

Figure C25	**Predicted hourly concentrations of SO_2 at Eneabba for the modelled period, May 2006 – April 2007**		
Location Eneabba	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Time series	**Guideline/Goal/Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 5/08/2008

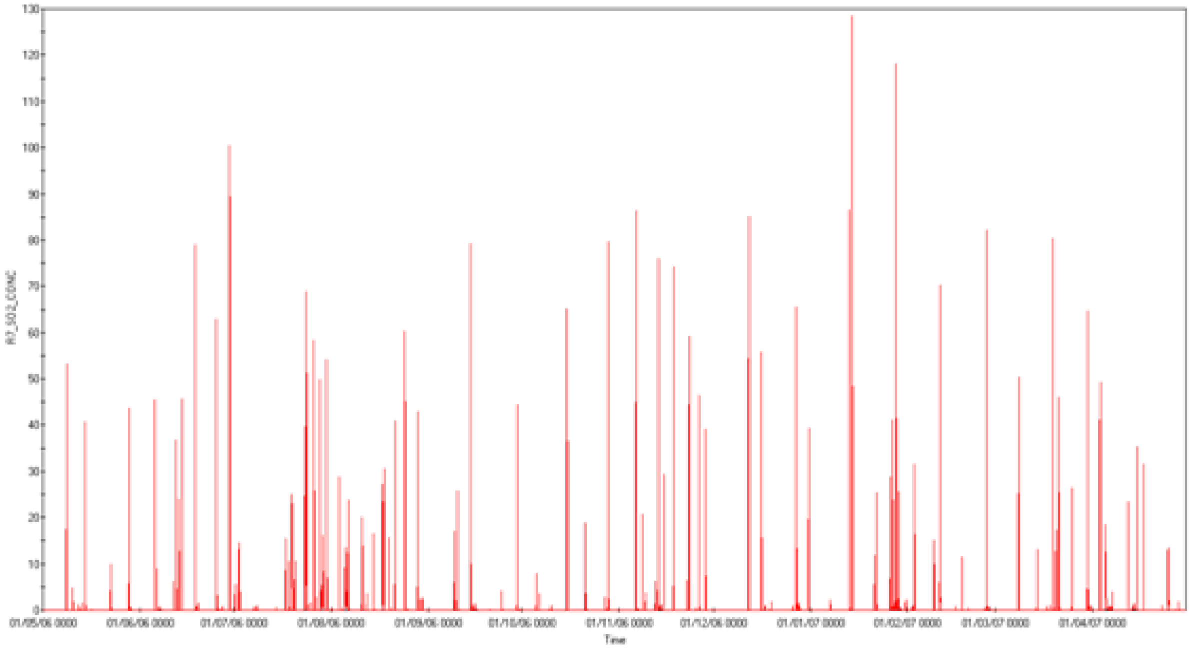

Figure C26	**Predicted hourly concentration of SO_2 at Receptor 7 for the modelled period, May 2006 – April**		
Location Receptor 7 (R7)	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** µg/m³
Type: Time series	**Guideline/Goal/Standard:** 570 µg/m³	**Prepared by:** A. Schloss	**Date:** 5/08/2008

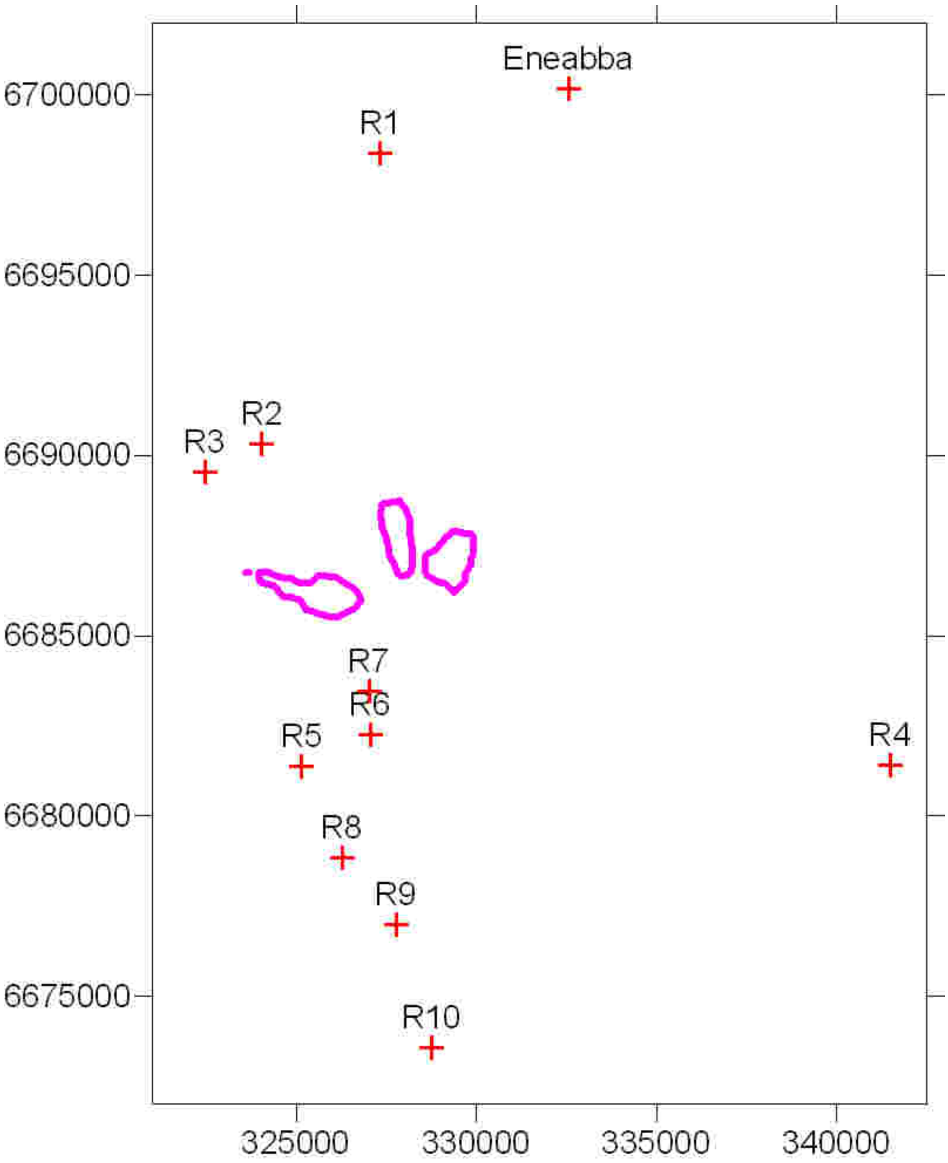

Figure C27 **Predicted areas where one exceedence of the NEPM(Air) standard for the 1-hour average ground-level concentration of SO_2 is predicted per year, during all operating conditions. The pink contour shows the location where an exceedence is predicted.**

Location:	**Averaging period:**	**Data source:**	**Units:**
Coolimba Power Project and Eneabba	1-hour	Stochastic modelling (TAPM)	Number of hours
Type:	**Standard:**	**Prepared by:**	**Date:**
Contour plot	570 µg/m³	A. Schloss	18/08/2008

APPENDIX D
ESTIMATION OF AN ACCEPTABLE LEVEL FOR DIOXINS IN SOIL AND WATER

Contents

For the purposes of this assessment estimates of tolerable levels of dioxin in soil and water will be derived using the recently published tolerable monthly intake published by the National Health and Medical Research Council (NHMRC, 2002), and established methods for setting guidelines in soil and water in Australia.

1. Tolerable concentration in soil

The default method for setting health based soil investigation levels (enHealth, 2001) is based on the method first described by Taylor (1991) as follows:

Soil concentration
(mg/kg) = TDI (mg/kg/day) x Body weight (kg) ÷ soil intake (kg/day)
= TDI (mg/kg/day) x body weight (kg) ÷ soil intake x 10^6 (mg/day)
Therefore
Soil concentration
(mg/kg) = (70 pg/kg/month x 13.2 kg x 10^{-9}) ÷ (30 x 100 mg x 10^6)
= 30 x 10^{-6} mg/kg
= 30 ng/kg
Where

- 70 pg/kg body weight per month is the tolerable monthly intake (NHMRC, 2002);
- 30 days/month used to convert to a tolerable daily intake
- 13.2 kg is the average weight of a child
- 10^{-9} is the conversion from pg to mg
  - is the proportion of total daily intake attributed to the intake from soil
- 100 mg/day is the soil ingestion rate for a child
- 106 is the conversion factor from kg to mg

2. Tolerable concentration in drinking water

An estimate of the tolerable concentration of dioxin in water derived using the method for setting drinking water guidelines used by the NHMRC (2001) as follows:

8.2 pg/L = (70 pg/kg body weight per month x 70 kg x 0.1) ÷ (2 L/day x 30 days/month)

Where:

- 70 pg/kg body weight per month is the tolerable monthly intake (NHMRC, 2002)
- 30 days/month used to convert to a tolerable daily intake
- 70 kg is the average weight of an adult
  - is the proportion of total daily intake attributable to the consumption of water
- L/day is the average amount of water consumed by an adult

References

NHMRC (2002). Dioxins: Recommendation for a Tolerable Monthly Intake for Australians
enHealth (2001). Health-based soil investigation levels.

Taylor ER (1991). How much soil do children eat. The health risk assessment and management of contaminated sites. Proceedings of a National workshop on the Health Risk Assessment and Management of Contaminated Sites. El Saadi O & Langley A (Eds). South Australian Health Commission.pp 72-83 (Appendix 1)

NHMRC/ARMCANZ (1996). Australian Drinking Water Guidelines and Framework for Management of Drinking Water Quality