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**Air Quality Assessment
Biomass Power Station, Manjimup
Babcock & Brown**

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Executive Summary

This report provides an air quality impact assessment for a proposed Biomass Power Plant, to be sited approximately 10 km south of the township of Manjimup in the south-west of Western Australia. The plant has been designed with an electrical throughput of 40 MW.

There are two major sets of pollutants that were considered, namely criteria pollutants and air toxics as outlined by the Commonwealth Environment Protection and Heritage Council in the National Environment Protection Measures:

- Criteria pollutants refer to emissions of nitrogen dioxide (NO₂), particulates as PM₁₀ (ie particles with aerodynamic diameter < 10µm), sulphur dioxide (SO₂) and carbon monoxide (CO) and lead (Pb); all these pollutants have mandatory air quality criteria. In addition to this there are also advisory guidelines levels for PM_{2.5}, which is also a criteria pollutant (ie particles with aerodynamic diameter < 2.5µm). Commonwealth legislation was used to assess the air quality impact of the criteria pollutants.
- Air toxics are defined as all pollutants other than criteria pollutants considered harmful to either human health and/or the environment; they include organic compounds. Other persistent organic pollutants and trace elements were assessed through state guidelines and International treaties/legislation.

In addition to Commonwealth legislation, International and Australian best practice guidelines were also considered, namely:

- 2001/80/EC Directive of the European Parliament on Limitation of Emission of Certain Pollutants into the Air from Large Combustion Plants
- Protection of the Environment Operations (Clean Air) Regulation, 2002
- UNEP Stockholm Convention on Persistent Organic Pollutants (POPs)
- EPHC National Action Plan for addressing Dioxins in Australia

Compliance of the plant design to best available techniques for large combustion plants was shown through the use of a bubbling fluidised bed combustion system and baghouse fabric filter emissions control system. The application of these emissions control technologies enabled compliance with directives relevant to all National and International regulatory guidelines as outlined for large combustion plants. Therefore world's best practice technology has been incorporated into the design of this facility to minimise noxious emissions.

The pollutant emissions were identified by the consideration of the elemental composition of the fuel and ash samples. The proponent provided guaranteed emissions of certain criteria pollutants including nitrogen dioxide (NO₂), particulates as PM₁₀ (i.e. particles with aerodynamic diameter < 10µm), sulphur dioxide (SO₂) and carbon monoxide (CO). In the absence of these design specific emissions for other pollutants, National Pollutant Inventory and US EPA estimation methods were used. Regional emissions of oxides of nitrogen (NO_x) and volatile organic compounds were also considered to take into account the atmospheric chemical transformation of NO_x, and to enable a worst case cumulative prediction.

The Air Pollution Model (TAPM), a prognostic meteorological and atmospheric dispersion model was used to model and predict regional and local meteorological effects as well as the dispersion of pollutants. This model was developed by CSIRO and is widely used to form air quality assessments both around Australia and internationally. TAPM was used specifically to take into account atmospheric chemical transformations, and the effects of complex terrain and land use characteristics.

TAPM was run using synoptic data for 2001 obtained from CSIRO. The reference year was shown to be representative of long term meteorological data. The TAPM generated meteorological data was compared with hourly BoM monitoring data over contemporaneous periods to show that the parameters being predicted were representative of local and regional conditions. This comparison showed that the meteorological data generated would enable the prediction of worst case pollutant ground level concentrations.

The local existing ambient air quality was measured in the townships of Bridgetown (short term) and Manjimup (full year). Similarity in ambient air concentrations was demonstrated for particulates which enabled the use of both data sets to predict cumulative ground level pollutant concentrations. In addition to the measured background concentrations of nitrogen dioxide, ambient concentrations of this compound were also predicted via the inclusion of background sources of VOCs and NO_x in a full year TAPM simulation. Cumulative nitrogen dioxide ground level concentrations were predicted using various schemes to estimate the extreme scenarios as well as more realistic methods based on atmospheric chemistry.

The following conclusions are made by assessment of the air quality model results with the relevant criteria:

- Sulphur Dioxide: Predicted concentrations are an order of magnitude below air quality standards.
- Nitrogen Dioxide: Extreme worst case scenario prediction methods show that NO₂ concentrations comply with the relevant air quality standards, whereas more realistic simulation of both emissions from the proposed facility and background sources shows that predicted levels are well below the air quality standards.
- Coarse Particulates (PM10): Ground level concentrations from the power station alone are shown to be an order of magnitude below the air quality standards. Cumulative concentrations primarily result from background concentrations in the Manjimup/Bridgetown region, and are significantly below the relevant air quality standards.
- Fine Particulates (PM2.5): Ground level concentrations from the power station alone are shown to be an order of magnitude below the air quality standards. Cumulative concentrations primarily result from background concentrations in the Manjimup/Bridgetown region. The daily averaged cumulative concentrations comply with the air quality standards while annually averaged background concentrations exceed the air quality standards (with negligible affect of concentrations due to the biomass power station).
- Carbon Monoxide and Lead: Predicted concentrations are several orders of magnitude below air quality standards.
- Persistent Organic Pollutants, Volatile Organic Compounds and Trace Elements: Predicted ground level concentrations of all compounds are well below air quality standards.

An air quality management plan has been documented to ensure that adverse impacts do not occur. This plan seeks to maintain the efficiency of best practice emissions control methods through an ongoing monitoring plan, and recommends procedural requirements in the event of plant abnormalities.

The predicted concentrations of pollutants in air were used to conduct separate expert independent human health, horticultural and viticultural risk assessments. The main conclusions from these separate studies were:

- Health Risk Assessment: It is extremely unlikely that emissions from the power plant will result in adverse effects on human health.
- Horticultural Risk Assessment: Risk of pollutant concentrations in the air on horticulture in the region from deposition of trace elements and gaseous compounds varies from being acceptable to negligible.
- Viticultural Risk Assessment: Risk of smoke taint of grapes and wine from the emissions of bound organic compounds from the Biomass Power Plant are considered to be negligible.

A comparative study shows that predicted ground level concentrations based on the current practice of open burning of plantation waste are an order of magnitude greater than the controlled combustion of this fuel in the proposed Biomass Power Plant.

In conclusion this assessment has shown that, with appropriate conditions of approval incorporated within an Air Quality Management, no adverse environmental impacts on air quality will occur as a result of emissions from the proposed development.

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Appendix A

NPI Location Report – All Sources: Shire of Manjimup, WA

Appendix B

Nitrogen Dioxide Contours – TAPM Predicted Background Levels

Appendix C

Sulphur Dioxide Contours – Non Chemistry Simulation

Appendix D

Sulphur Dioxide Contours – Chemistry Simulation

Appendix E

Nitrogen Dioxide Contours – Scenario 1 (Non-Chemistry Simulation)

Appendix F

Nitrogen Dioxide Contours – Scenario 2 (Ozone Limiting Method)

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Nitrogen Dioxide Contours – Scenario 3 (Chemistry Simulation - Biogenics/Anthropogenics)

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Nitrogen Dioxide Contours – Scenario 4 (Chemistry Simulation - Inclusion of All Sources)

Appendix I

PM10 Contours – Biomass Power Station Emissions

Appendix J

PM2.5 Contours – Biomass Power Station Emissions

Appendix K

Area Source Open Burning Daily Averaged Particulate Contours (PM10 and PM2.5)

1. Introduction

An air quality assessment has been carried out by Connell Wagner for a proposed biomass fuelled power station near Manjimup in South West Western Australia. The power station is fuelled from plantation waste fed to a boiler, with flue gas emissions controlled with a baghouse filter, and steam generated fed to a turbine to generate electrical power.

This report provides additional detail in response to the PER, and in particular responds to reviews by the Department of Environment and Conservation, the Environment Protection Authority, and independent reviews by Katestone Environmental Pty Ltd (Katestone) and Sinclair Knight Merz (SKM).

The key issues raised in these reviews cover the pollution dispersion modeling techniques and parameters, the existing environment, atmospheric chemistry, emissions control technology, the impact of pollutants on local economies, and the management plan to address these issues.

This report outlines the issues raised in the review, and in responding to these issues it covers:

- Summary of responses to the key issues raised by the DEC, EPA and peer (SKM, Katestone) reviews
- Scope of work based on the DEC (Air Quality Modelling Guidance Notes), EPA and peer reviews
- Description of the project, in terms of its location, nearby sensitive receptors, and plant technology
- Definition of the relevant State, Federal and International statutory regulations and guidelines
- Understanding of the existing environment for both meteorology and air pollution
- Definition, qualification and quantification of emissions of criteria pollutants (nitrogen dioxide, carbon monoxide, sulphur dioxide, ozone, particulates and lead), air toxics (persistent organic pollutants) and trace elements
- Description and parameters used for the air dispersion model, including a description of the method used to assess and model atmospheric chemical transformations (photochemical reactants)
- Results of air dispersion modeling and assessment of the impact of emissions from the proposed facility
- Qualification of predictions through comparison with National Pollutant Inventory (NPI) standards, comparison of other plants in similar settings and comparison of emissions from open burning of biomass
- Definition of reduction measures and the plan to manage emissions and reduction measures

2. Response to Independent Reviews

Issue	By	Detail	Response	Action	Outcome
Report Structure	SKM Katestone	Restructure and edit the air quality assessment “with the aim of assisting the reader to understand exactly what the important issues are, what has been done to assess these, how it has been done and what it means.” .	Initially the EIS was in the form of an EPS (Environment Protection Statement) which was not anticipated to have been released for public comment. The report was an then amended in a short time period to a PER (Public Environmental Review). It is recognized that in this haste, the structure of the report was not given adequate consideration.	Restructure and edit the report in response.	This report provides a stand-alone air quality assessment document, but makes reference to the air quality assessment in the PER.
Air Dispersion Model Type	Katestone SKM	Both Katestone and SKM endorse the use of TAPM for modeling the dispersion of pollutants from the power station.	Initially ISCST3 (AusPlume equivalent – a Gaussian dispersion model) was used, and later changed to TAPM (lagrangian/eulerian dispersion model) as instructed by the EPA. The issue of TAPM’s ability to accurately predict ground level wind speeds was discussed with the DEC, and it was determined that as the emissions were from an elevated stack, use of CALPUFF (better able to resolve low wind speeds at ground level) was not warranted.	The use of TAPM has not changed (but some of the parameters have changed). Validation of the use of TAPM has been included for meteorology (refer below). Validation of TAPM is included for NO2.	The outcome is affected by other settings in TAPM as noted below.
Inclusion of background data into TAPM	SKM Katestone DEC	SKM, Katestone and the DEC have queried the inclusion of background concentrations of particulates	Background concentrations of particulates were included in the run-time simulation, by applying background data to the outer grid (inflow boundary) of TAPM. This data was applied in consultation with the CSIRO, who were also consulted with	Background data for particulates have been applied as a post processing task.	Variation of background particulate concentrations is now constant across the inner grid. Minimal change to the outcome.

Issue	By	Detail	Response	Action	Outcome
			regard to the “dispersion” of background data to other grids.		
Modeling of Oxides of Nitrogen (Nox) and Ozone (O3)	SKM Katestone	SKM have queried modeling of Nox and O3, specifically the inclusion of background concentrations of VOC’s and Nox given non-linear atmospheric chemical reactions	It is recognized that VOC’s, Nox and O3 react photochemically to influence the concentration of each pollutant on a diurnal basis. TAPM was therefore run using photochemistry mode (using the GRS not CTM), In consultation with CSIRO, a conservative “background level” of VOC’s was included, but specific biogenic/anthropogenic emissions were not included. Additionally, the reaction set is NOx limited, that is, an unlimited supply of VOC’s would be unable to react to form NO2 without the supply of NOx.	Specific biogenic and anthropogenic emissions of VOC’s have been included on a grid basis as an input to TAPM. VOC’s emitted by the proposed power station were also included (as “in-plume” emissions).	Predicted ground level concentrations of NO2 have reduced from a cumulative value of about 55ppb (as noted in the PER) to about 34ppb (maximum 1 hour concentration as noted herein). Use of this approach results in lower predicted concentrations of NO2, and therefore less impact on the environment.
Background Concentration of NO2	SKM Katestone	Background concentrations of Nitrogen Dioxide by the addition of predicted concentrations with measured background concentrations. This method is fundamentally incorrect due to the non-linear nature of NOx chemistry.	NO2 was included post processing by simply adding the maximum concentration from Rolling Green (considered to provide a conservative estimate of NO2 given its rural location relative to Perth). It was recognized that a less conservative approach would be to include into TAPM, background concentrations on a grid basis, and to run TAPM in photochemistry mode.	Biogenic and anthropogenic emissions of NOx and VOCs have been included on a grid basis in TAPM using photochemistry mode (GRS). Anthropogenic emissions have been included on the inner most grid, while biogenic emissions have been included on the second most outer grid. These emissions have been applied based on the emissions listed in the NPI report for the Shire. Point source emissions from nearby major industrial sources (ie. Muja and Collie power stations) were also included (based on data acquired from	Predicted background NO2 concentrations are similar to those measured in Bridgetown (albeit with a comparison between different years). Background concentrations of NO2 are less than assumed in the PER, but comparable to the background concentrations in Bridgetown.

Issue	By	Detail	Response	Action	Outcome
				the Bluewaters Power Station assessment). Background NO2 concentrations were compared with monitoring results for Bridgetown.	
Background concentration of Ozone	SKM	The PER makes no reference to background concentrations of Ozone	As noted above, Ozone is an important contributor to the photochemical reaction set. TAPM was run with a background concentration of 20ppb which increased during the daytime to a peak of about 50ppb. This was found to be consistent with scientific observations.	No action was necessary as Ozone was already included.	Ozone has always been included, with results only changed by the inclusion of biogenic and anthropogenic emissions of NOx and VOC's. No change in the assessment outcome.
Conservativeness of TAPM GRS mode	Katestone	Comparison is required of other prediction methods for NO2 to justify the use of GRS as being reasonable and conservative	No exception is taken to this method of validation.	Model NO2 concentrations using: <ul style="list-style-type: none"> – tracer mode (without chemistry), – the ozone limiting method (OLM) – chemistry mode (GRS) with biogenic and anthropogenic area/point sources, 	A comparison of the various methods shows that chemistry mode results are similar to results using the OLM method, with both about 25% of the results using tracer mode. This is consistent with the expected concentration of NO2 from previous studies comparing measured stack emissions with measured ground level concentrations. Consideration of alternative methods to estimate photochemical transformation of nitrogen oxides achieves an outcome consistent with the original assessment as included in the PER.
Bunbury background	SKM Katestone DEC	Background data unlikely to be representative of	Bunbury data was used as it was considered to provide a conservative estimate of ambient particulate	Subsequent discussions with CSIRO revealed the availability of background data for	The data results in a marginally less conservative assessment for PM10 and about the same level of

Issue	By	Detail	Response	Action	Outcome
particulate data	DoH	Manjimup	concentrations given the increased population density and proximity to the coast (sea salt drift). Previous discussions with the EPA and DEC had not revealed the availability of other data specific to Manjimup. Clearly the meteorological conditions vary significantly between Bunbury and Manjimup.	particulates, based on a study funded by the Commonwealth DEH. Following approval from the DEH, this data has been used in the assessment.	conservatism for PM2.5. There is very little difference in the average maximum (otherwise known as the 98 th percentile) daily peak 24-hour concentration. That is, the assumption that background particulate concentrations in Bunbury would greater than in Manjimup was valid, and the use of Manjimup particulate data results in a reduced impact on the environment.
Standards	SKM	Air Toxics NEPM not cited	The Air Toxics NEPM is a guideline, and reflected in assessment criteria published by the NSW EPA.	The air toxics NEPM guideline has been included in this air quality assessment.	No change to the assessment outcomes.
Emissions of other pollutants	SKM Katestone	Detail required regarding the emission estimates for other pollutants. Background concentration of other pollutants?	Gaseous and solid pollutants were predicted on a pro-rata basis using tracer mode results for gases (NO ₂ , SO ₂) and particulates (PM ₁₀ , PM _{2.5}). It is very difficult to estimate background concentrations of other pollutants, other than through comparison of annual emissions using NPI emission estimates.	Detail provided in the air quality assessment herein has been improved in relation to the pro-rata prediction method. Additional information from the NPI reporting system was used to attempt to quantify background concentrations of other pollutants.	Improved level of detail provided. No change to the assessment outcomes.
Meteorological data	DEC Katestone	Night-time or early morning data required to assess accuracy of TAPM. Windroses on a seasonal basis recommended.	A more detailed analysis of wind statistics through consideration of wind roses and wind class frequency distributions on a seasonal, annual and diurnal basis has been included in this revision.	A comparison of BOM and TAPM predicted meteorology on a seasonal, annual and diurnal basis for the year 2002 has been carried out.	The comparison demonstrates that TAPM adequately predicts wind statistics generally, but under predicts nighttime wind speeds. Notwithstanding this, the frequency of low wind speeds, and the frequency distribution of wind direction is considered adequate to predict worst case pollutant concentrations. No

Issue	By	Detail	Response	Action	Outcome
					change in the outcome.
Comparison with other plants	SKM	Comparison of the proposed Biomass power stations emission to those with other plants in similar settings	The PER (Section 3.3) includes details of local and international examples of power stations fuelled with biomass.	A graphical comparison of biomass fuelled power stations in Europe and North America, are shown together with major wine regions (which are considered by some to be most sensitive to pollutant emissions).	Additional information provided to demonstrate the harmonious link between biomass fuelled power stations and regional agricultural activities. No change in the outcome.
Comparison with open air burning	SKM	Comparison of emissions with those from open air burning of fuel as is current practice.	A comparison of emissions with those from open air burning was carried out during the PER process.	Update the air quality assessment to include a comparison of emissions from open air burning.	Maximum daily average concentrations from open air burning exceed ground level concentrations from the power station by a factor of about 30. Ground level concentration of pollutant emissions from the current practice of open air burning exceed the NEPM criteria, with maximum concentrations occurring close to the area of burning. The biomass power station will improve regional air quality through efficient combustion practices.
Baghouse Failure	SKM Katestone DEC	Model length (1 month) insufficient	Due to time constraints in completing the PER, failure during winter was considered given the greater incidence of meteorological conditions that lead to increased ground level pollutant concentrations.	Model an entire year during which baghouse failure could occur.	An entire year was modeled with baghouse failure occurring at anytime over that period. As before and as expected, the results indicate exceedance of the assessment criteria. The proponent is committed to immediately shutting down the plant if the baghouse fails, with continuous monitoring of the baghouse efficiency to immediately alarm the operators if the baghouse fails. Failsafe measures have been incorporated

Issue	By	Detail	Response	Action	Outcome
					into the design.
Boiler Startup/Shutdown	SKM	Boiler startup with distillate firing has not been addressed in the PER. Emissions of NOX, SO2 and particulates may be higher when firing the boiler with distillate fuel.	The PER considered emissions due to baghouse failure but not startup/shutdown emissions due to the short duration of these emissions, and the difficult in estimating emissions and conditions during these events. Startup using distillate will affect only short term emissions of gaseous compounds (NO2, SO2, CO), and startup will occur for less than 1 hour.	Establish management plan to ensure shutdown procedures have minimal impact on emissions (ie. Continue forced and induced draft fans until final fuel injection is fully combusted). The type of distillate used during startup has not yet been determined.	The air quality management plan has been updated to include procedures for controlling emissions during startup and shutdown periods.
Impacts on Vegetation	SKM	Impacts on vegetation has been addressed only briefly	Given compliance with ambient air quality criteria, which are established to protect the health of humans as well as flora and fauna, a more detailed risk assessment was not carried out.	A report from the CSIRO Land & Water Division was commissioned to assess the effects on plants, and this has been provided and is included as a separate response to the PER. A report by SmartVIT (Viticulural consultant) has been provided and is included as a separate response to the PER	The report by CSIRO predicts hazards to be negligible, low, unlikely or acceptable, with the assessment based on predicted ground level concentrations and deposition of various types of pollutants. The report recommends monitoring of pollutants. The report by SmartVit assessed predicted concentrations of pollutants with the potential to taint wine. These are well below the threshold level considered likely to taint wine. Therefore the likelihood of wine taint being caused by emissions from the power station was considered to be negligible.
Impacts on Health	DoH	Impacts on human health	Given compliance with ambient air quality criteria, which are established to protect the health of humans as well as flora and fauna, a more detailed risk assessment was not carried out.	A report from Toxikos (Toxicology Consultants) was commissioned to assess health risks to humans.	The health risk assessment concludes that direct health risks from exposure to emissions from the power station is unlikely, with negligible health risks associated with Dioxin/Furans and

Issue	By	Detail	Response	Action	Outcome
					PAHs.
National Action Plan for Addressing Dioxins in Australia Stockholm convention for POPs	DEC EPA	Discussion is brief and relies heavily on NPI Emission Factors	The Stockholm Convention for Persistent Organic Pollutants (POP's) notes that for biomass-fired plants, particularly wood-fired installations, emission levels of persistent organic pollutants associated with best available techniques are generally below 0.1 ng I-TEQ/Nm ³ . Among the primary measures, control of fuel quality is a key issue (including exclusion of treated wood). Control measures for non-contaminated biomass include optimized combustion techniques and dust removal. The use of a bubbling fluidised bed boiler provides optimal combustion, while the baghouse provides a proven and reliable method for pollutant extraction. The concentration of POP's from the proposed biomass power station (0.038 ng I-TEQ/Nm ³) complies with the recommended level. This claim is further verified by the IPPC; <i>"In some biomass fired plants, especially wood-fired combustion plants, the emissions of dioxins and furans have been measured and an emission level of below 0.1 ng/Nm³ is generally regarded as achievable."</i>	Carry out additional research of POPs	Emission of POPs complies with the limit imposed by the Stockholm Convention to which Australia is a signatory. Ground level concentrations of air toxics comply with the draft NEPM criteria.
Best Available Technology	EPA	Compliance with IPPC "Best Available Technology for Large	The choice of a fluidised bed combustion boiler and baghouse are technologies that are considered best practice based on the Integrated	No action required	No change in the outcome as best available technology is employed.

Issue	By	Detail	Response	Action	Outcome
		Combustion Plants”	Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques for Large Combustion Plants (European Commission, July 2006).		
Compliance with IPCC Directive 2001/80/EC on the limitation of emissions	EPA	Further discussion as to why emissions greater than those allowed in the EU should be permitted.	Katestones endorses the proponents opinion, noting that <i>“whilst the emission guarantees for the proposed biomass power plant are higher than the emission levels specified in the European Commission report, the regulatory context and air pollution challenges in Europe are different to those of the proposed site and this should be considered in evaluating whether reductions in emissions need to be made. In our opinion, lower emission levels could only be justified if the current proposal is likely to adversely affect air quality.”</i>	EPA requires proponent to comply with IPCC Directive on emissions limits.	Compliance achieved.

3. Scope of Works

The assessment of air quality aspects associated with this proposal has been carried out in accordance with the DEC's Air Quality Modeling Guidance Notes, March 2006. The scope of works has been considered, following discussions with the DEC and the EPA.

The scope includes:

- Review the responses to the PER, together with issues raised in independent reviews undertaken by the proponent.
- Identify sensitive receivers around the site
- Understand and review the proposed facility, and assess emissions control technology with regard to Best Available Technology (reference to EPA Guidance Statement 55)
- Identify air emissions and hazards to human health, flora and fauna
- Determine appropriate assessment criteria
- Assessment of site-specific meteorology, in particular definition of mixing height, stability class, and wind speed/direction. Consider a typical annual period to be used in the air dispersion model.
- Assessment of existing ambient air pollution by consideration of monitoring results
- Definition of the proposed air dispersion model (TAPM (The Air Pollution Model) as developed by the CSIRO) to accurately account for terrain effects and land use.
- Preparation of an emissions inventory of all likely pollutants from the proposed facility
- Preparation of an emissions inventory of diffuse and industrial sources within the airshed
- Validate the accuracy of the air dispersion model by estimating background source emissions with those monitored
- Calculation of short term and long term cumulative ground level concentrations of pollutants for the proposed facility in isolation, and with background sources
- Evaluation of results with regard to the assessment criteria to determine the environmental impact
- Comparison of the emissions with those from other sources in the region (eg. Prescribed burning or open burning)
- Review impacts to sensitive receptors in the region (human health, agriculture and viticulture)
- Develop mitigation measures to reduce the impact if necessary
- Prepare an Air Quality Management Plan for construction, commissioning and operational stages.

4. Project Description

4.1 Project Site and Sensitive Receptors

The project site is currently cleared with surrounding areas vegetated with State Forest. An aerial photo of the area is shown in **Figure 4.1**. The closest rural property boundary is located approximately 1,400 m north east from the centre of the proposed plant site. The site in context with the township of Manjimup is shown in **Figure 4.3**.

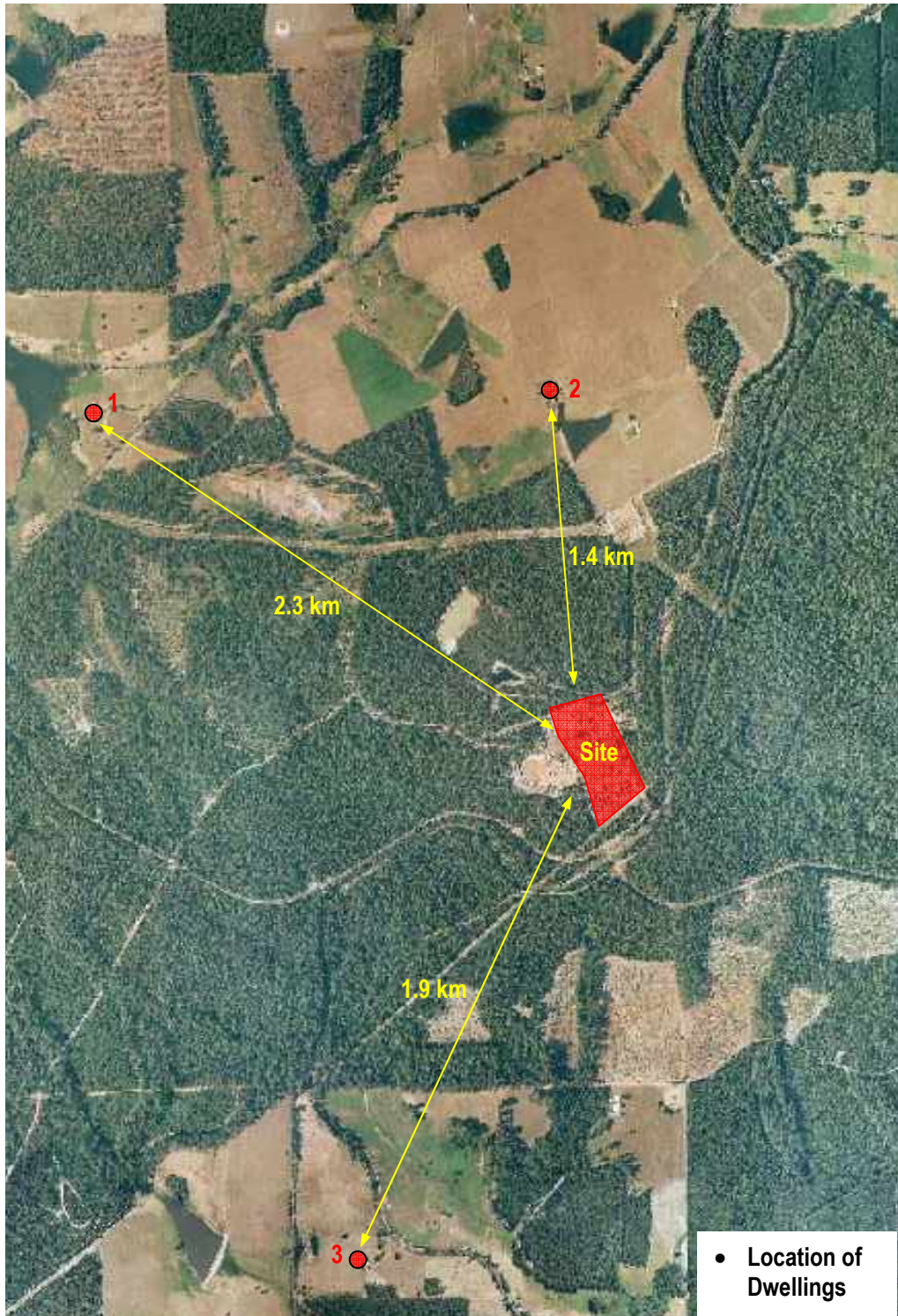


Figure 4.1 Site Location of the Proposed Power Plant.

The activities surrounding the site are largely rural, as apparent in **Figure 4.3** by there being a distinct lack of any highly urbanised areas with the exception of the township of Manjimup. The land use map, **Figure 4.2**) that was used in the pollution dispersion model also shows that the surrounding land uses are largely rural and State Forestry reserves. Agriculture in the area is mainly horticultural consisting of orchards and crops (potatoes etc), and viticultural with vineyards and wineries in the region.

Sensitive receptors therefore comprise:

- Residential dwellings
- Horticultural activities
- Viticultural activities

4.2 Proposed Development

The Power Plant has been designed to burn approximately 51 tonnes/h of plantation waste (GCV of 11.0 MJ/kg) with a rated thermal input of about 175MWth (nominal), generating 40 MWe (nominal) net plant output. Steam is to be produced at a medium pressure and used to generate electrical power by passing it through an extraction condensing steam turbine. The main items of plant are therefore:

- Boiler and auxiliaries (including emissions control technology);
- Steam turbine and auxiliaries and dry cooling system;
- Main plant electrics including, main auxiliary transformers;
- Water facilities including, water treatment, storage wastewater, and evaporation pond;
- Fuel storage, handling and supply system;
- Ash wetting and disposal system;
- Administration building and car park.

The Power Plant will operate as a base load plant and have availability factor of approximately 92%.

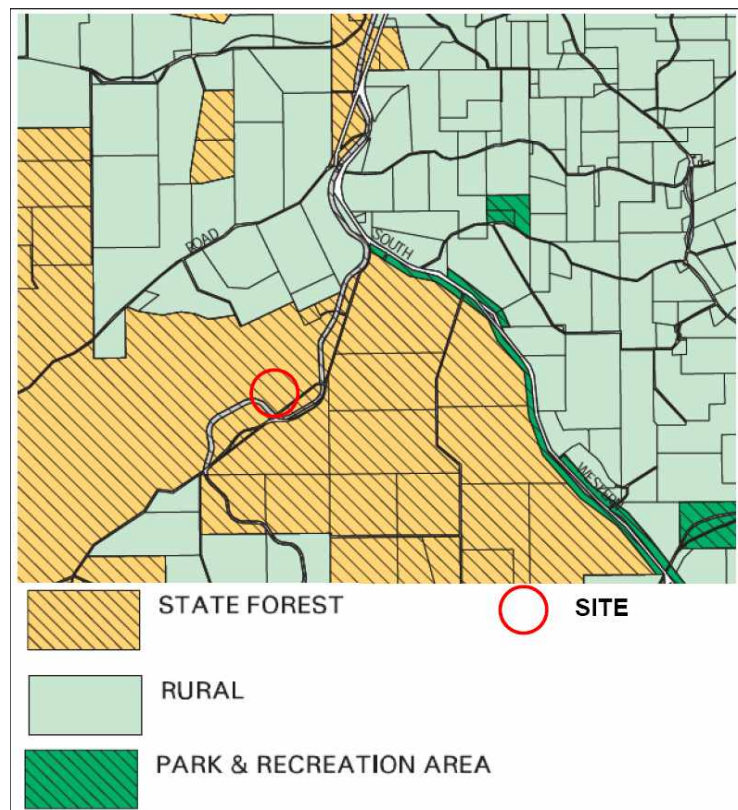


Figure 4.2 Location of the proposed plant relative to surrounding land use

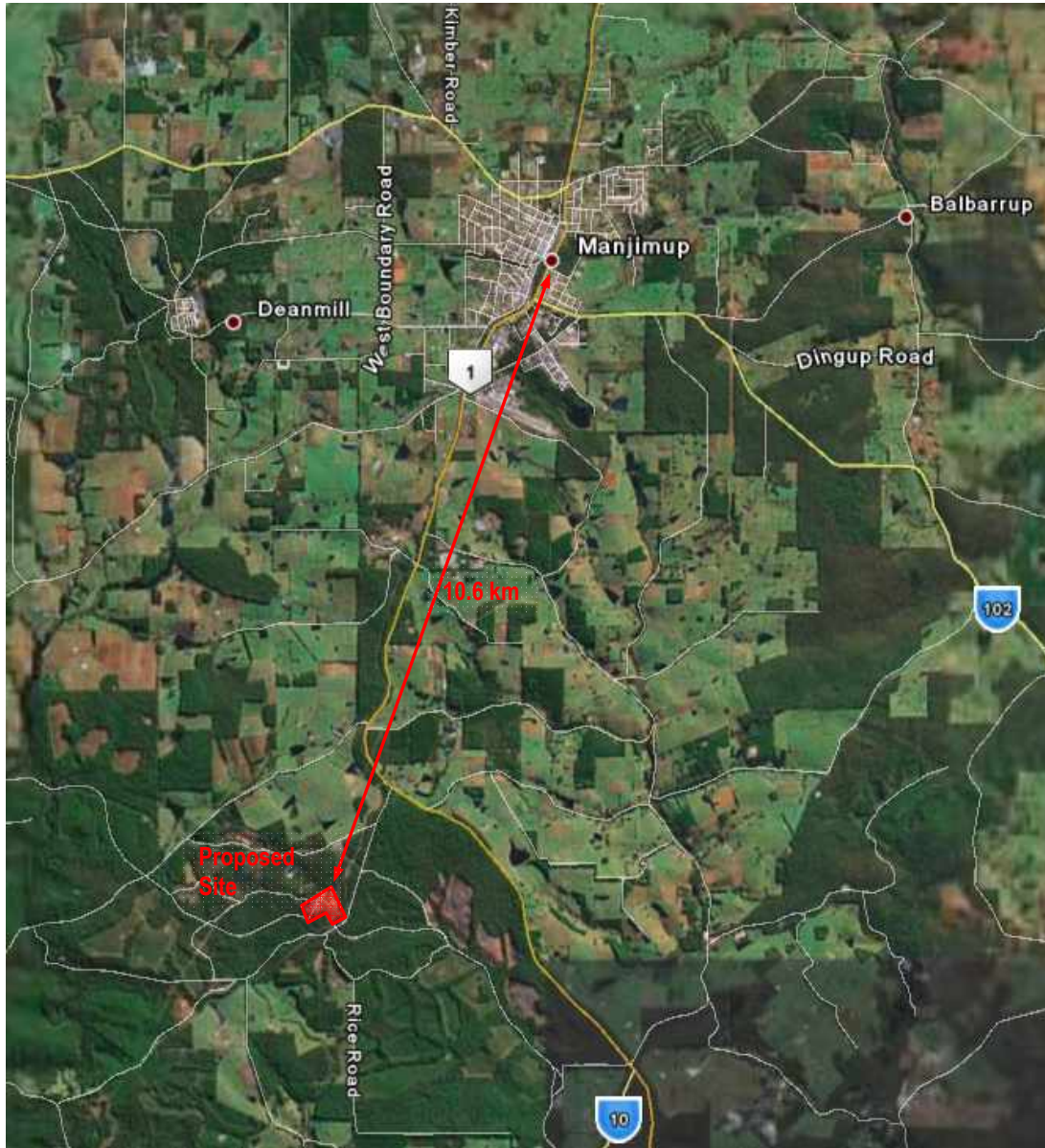


Figure 4.3 Location of the proposed site relative to Manjimup.

5. Emissions Identification

5.1 Combustion Process

Combustion can be defined as the rapid chemical combination of oxygen with the combustible elements of a fuel. This process requires a temperature high enough to ignite the constituents, good mixing or turbulence, and sufficient time for complete combustion. There are three combustible chemical elements of significance, carbon, hydrogen and sulphur.

Carbon and hydrogen, when burned to completion with oxygen are transformed to CO₂ and H₂O, with the non-combustible portion of the fuel remaining as a solid residue, or ash. CO is produced as an intermediate of the combustion process, particularly when excess oxygen levels are too low. Combustion processes are designed and operated to minimize the formation of CO, which signifies conditions of incomplete combustion and therefore reduced efficiency.

Nitrogen oxides (NO_x) are formed as a by-product during combustion, either as a result of the oxidation of atmospheric nitrogen found in combustion air, or via the conversion of nitrogen chemically bound in the fuel. There are seven known oxides of nitrogen: NO, NO₂, NO₃, N₂O, N₂O₃, N₂O₄, and N₂O₅. Of these, nitric oxide (NO) and nitrogen dioxide (NO₂) are formed in sufficient quantities to be significant in atmospheric pollution. Virtually all NO_x originates as NO, which is further oxidized in the exhaust system or later in the atmosphere, to form the more stable NO₂ molecule.

Emissions of sulphur oxides result predominantly as a result of sulphur present in the fuel and are predominantly an issue for installations burning solid or liquid fuels, or other sulphur containing industrial gases. Similarly, emissions of particulate matter, heavy metals, hydrochloric acid, hydrogen fluoride and persistent organic compounds.

Emissions can be generally classified as stack or fugitive sources. Stack emissions result from the combustion of fuels in the boiler, and these emissions will have the potential for the greatest environmental impact. Fugitive emissions arise mainly from dust generated during construction, from wind erosion of stored fuel, or from materials handling (Furnace ash).

5.2 Criteria Pollutants

Nitrogen Oxides

Nitrogen oxides (NO_x) are formed during high temperature combustion processes which use air as the oxidant. In urban areas, motor vehicle emissions are the major source of nitrogen oxides (~70%) and also coal-fired power stations.

The dominant oxides of nitrogen are nitric oxide and nitrogen dioxide of which nitrogen dioxide is known to cause adverse effects on plants and humans at concentrations above threshold levels. Some building materials and textiles can also be damaged.

Carbon monoxide

Carbon monoxide is produced by the combustion of carbon containing fuels (e.g. petrol, gas, coal and natural gas). In humans, carbon monoxide forms a stable complex with haemoglobin in red blood cells, reducing the ability of the blood to transport oxygen from the lungs throughout the body. In the atmosphere, carbon monoxide is readily oxidised to carbon dioxide therefore the potential impact of CO is significantly reduced in all other than enclosed areas.

Sulphur Dioxide

Sulphur dioxide emissions are primarily generated from mineral melting, petroleum refinery, coal burning, and motorized transport to a lesser degree. In the case of human exposure, sulphur dioxide can aggravate pre-existing lung conditions such as chronic bronchitis and asthma, causing impaired pulmonary function and increased

morbidity. Sulphur dioxide can also cause serious damage to sensitive plants and plant communities following long term exposures at elevated concentrations.

Particulate Emissions

Particulate emissions cover a wide range of particle sizes including dust, smoke, bacteria and pollen. In practice, particles are classified by size ranges. The term "total suspended particles", TSP, means all particles from 50 micrometres (μm) to the smallest ($0.1\mu\text{m}$). Particles less than $10\mu\text{m}$ (PM10) and those smaller than $2.5\mu\text{m}$ (PM2.5) are sub-categories of special interest because these are inhalants and cause respiratory effects in humans. PM2.5 is also associated with visibility reduction.

Adverse health effects associated with PM10 exposures include:

- Increases in mortality of the order of 1% for every $10\mu\text{g}/\text{m}^3$ increase in PM10 levels;
- Increases in hospital casualty and medical visits for asthma and other respiratory conditions as well as exacerbation of cardiac conditions;
- Increases in daily prevalence of respiratory symptoms and reduced activity, and
- Small decreases in the level of pulmonary function in healthy children, and in adults with obstructive airways disease.

The possible toxicity mechanisms for these effects remain uncertain though there is strong evidence that the pathogenic effects due to inhalant particles are largely caused by the fine fraction (e.g. $2.5\mu\text{m}$).

5.3 Air Toxics

5.3.1 Volatile Organic Compounds (VOCs)

General

Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. The most common VOC is methane, a greenhouse gas sometimes excluded from analysis of other VOCs using the term non-methane VOCs, or NMVOCs. Major worldwide sources of atmospheric methane include wetlands, ruminants such as cows, energy use, rice agriculture, landfills, and burning biomass such as wood. Trees are also an important biological source of VOC; it is known that they emit large amounts of VOCs, especially isoprene and terpenes.

Volatile organic compounds (VOCs) consist of a wide range of chemical structural types of which some are classified as air toxics (e.g. benzene, toluene and chlorinated hydrocarbons). Air toxins can act as irritants and induce allergic-type reactions at low levels in sensitive persons. Long-term exposure may include chronic health effects and symptoms in exposed persons. Fuel consumption, motor vehicle emissions, fuel and solvent evaporation are known sources of VOCs.

When oxides of nitrogen and reactive VOCs are present in the air in sufficient quantities, and in the presence of sunlight, chemical reactions can produce photochemical oxidants and related smog. This phenomenon is linked to large urban environments.

5.3.2 Aromatic Hydrocarbons (PAH)

General

An aromatic hydrocarbon or arene is a hydrocarbon, of which the molecular structure incorporates one or more planar sets of six carbon atoms. The term 'aromatic' was derived from the fact that many of the compounds have a sweet scent. This sweet scent actually came from impurities in the compounds (which are not actually aromatic in the sense initially described). The configuration of six carbon atoms in aromatic compounds is known as a benzene ring, after the simplest possible such hydrocarbon, benzene. Aromatic hydrocarbons can be monocyclic or polycyclic.

Monocyclic Aromatic Hydrocarbons

Benzene is the simplest AH and was recognized as the first aromatic hydrocarbon. Benzene derivatives have from one to six substituents attached to the central benzene core. Examples of benzene compounds with just one substituent are phenol, which carries a hydroxyl group and toluene with a methyl group. When there is more than one substituent present on the ring, their spatial relationship becomes important for which the arene substitution patterns ortho, meta, and para are devised. Xylenol has two methyl groups in addition to the hydroxyl group, and, for this structure, 6 isomers exist.

Guaiacol and 4-methyl Guaiacol are monoaromatic hydrocarbons, derived from Phenol. Guaiacol is present in wood smoke, resulting from the pyrolysis of lignin. It has a smoky flavour and is considered to be the source of wine taint.

Polycyclic Aromatic Hydrocarbons

Some important arenes are the polyaromatic hydrocarbons (PAH); they are also called polycyclic aromatic hydrocarbons and polynuclear aromatic hydrocarbons. They are composed of more than one aromatic ring. PAHs are colourless, white or pale yellow-green solids.

They are emitted from the stack as via adsorbance to particulate matter. They are organic compounds (carbon based). Most do not dissolve easily in water, but some readily evaporate in air. Most do not burn easily. PAHs are formed by the incomplete combustion of fossil fuels or organic material (eg. wood). They can be formed from naturally occurring fires such as uncontrolled bush or controlled forest fires. Examples include:

- Naphthalene
- Flourene

PAHs can be inhaled or consumed in food or water that has been contaminated, or absorbed through the skin on contact with products containing PAHs. Exposure can irritate the eyes, nose, throat and bronchial tubes. Skin contact can cause irritation or a skin allergy. Very high levels may cause headaches, nausea, damage the red blood cells, damage the liver and kidneys, and may cause death. A number of PAHs have been cited as being carcinogenic to humans.

Halogenated Polycyclic Aromatic Hydrocarbons

The structure of dibenzo-p-dioxin comprises two benzene rings joined by two oxygen bridges. The name dioxin formally refers to the central dioxygenated ring, which is stabilized by the two flanking benzene rings. In PCDDs, chlorine atoms are attached to this structure at any of 8 different places on the molecule. There are 75 different types of PCDD congeners (that is: related dioxin compounds). The toxicity of PCDDs depends on the number and positions of the chlorine atoms. Furans have the same structure with a mono-oxygenated central ring.

Dioxins (PCDD) and furans (PCDF) are chemically classified as halogenated aromatic hydrocarbons. In their pure form they are crystals or colourless solids. There are 75 compounds in the dioxin family and 135 compounds in the furan family, all with varying degrees of toxicity. This variance in toxicity is quantified by the inclusion of toxic equivalent (TEQ) factors.

In essence dioxins and furans are products of incomplete combustion; the emissions of these compounds are minimized by increasing the high temperature boiler resident periods and maintaining a high flue gas temperature. A high flue gas temperature also has to be maintained so as to prevent the post combustion formation of PCDD/F compounds via *de novo* synthesis. Therefore in order to avoid over conservativeness in determining emission factors for these compounds details of the combustion process and boiler type, particulate control and variation in compound toxicity have to be taken into consideration. A more detailed discussion is given in **Section 6.6.4**.

In general, these compounds have low water solubility, low vapour pressure; many are very stable and highly persistent therefore they are able to leave their imprint environmental matrices such as soil, sediment vegetation and biota.

The principle sources of dioxins are combustion or incineration (including natural fire), and chemical manufacturing and process sources such as manufacture of chlorine or chlorinated organic compounds. Dioxins and furans are

ubiquitous and can be found in a wide range of environments and organisms though normally in very small quantities.

Dioxins and furans may enter the body through breathing, ingestion or absorption through the skin. Dioxins are very toxic to certain animals. The most noted health effect is chloracne, a severe skin disease. In addition to this dioxins are a known carcinogen and have been shown to have toxic effects at very small doses including carcinogenicity, immunotoxicity, effects on lipid metabolism and biochemical effects caused by drug metabolizing enzymes.

5.4 Odour

The most important combustion products for odour impacts include NO, NO₂ and SO₂. Wood is inherently low in sulphur content as demonstrated by both NPI and US EPA AP-42 estimates and generally referenced from other Biomass Power Stations. Odour thresholds for NO and NO₂ are typically 865µg/m³ and 216µg/m³ which is equivalent to the hourly maximum NEPM limit. Compliance with the NEPM therefore ensures odour will not be an issue.

6. Plant Operating Conditions and Emissions

6.1 Fuel Analysis

The design fuel specification is tabulated in **Table 6.1**. Excessive moisture in the fuel will require a reduction in load to maintain stable combustion. Above about 53% fuel moisture and depending on the other fuel properties the boiler anticipated performance on higher moisture fuel may be changed as the combustion process is affected by these higher moisture rates. Maximum fuel size is 150mm summed from all three dimensions.

The Power Plant has been designed to fire approximately 51t/h of design plantation waste. An analysis of the fuel and ash has determined that the above fuel specification is achievable provided the fuel mix is managed subject to fuel types (eg. Pine Leaf/Twig types: Brutian, Maritime and Blue Gum Leaf/Twig/Bark). Fuel processing and haulage contract has quality control check points to ensure the fuel quality received as per the specifications.

Table 6.1 Design Fuel Specifications

Parameter	Specification
Moisture content	43.00% wt
Ash Content	1.00% wt
C	28.00% wt
H	3.25% wt
O	24.63% wt
N	0.1% wt
S	0.02% wt
Gross Calorific Value	11.0 MJ/kg
Bulk Density	400 kg/m ³

The major elements of ash were determined by CSIRO Energy Technology using a NATA certified method based on a borate fusion/TCP-AES procedure. Quality control methods will ensure the targets stated above are achieved through routine sampling and analysis of the fuel supplied. Real time in-stack monitoring of gaseous and particulate matter will also be used to qualify emissions and fuel.

The weight percent of trace elements in ash as determined are listed in **Table 6.2**. The sum of all trace elements does not equal 100% due to carbonate matter not being removed during oxidation (at 450°C).

Table 6.2 Weight percent of Ash

Trace Element	Average (wt. %)
Na	1.64
Mg	5.72
Al	0.45
Si	1.13
P	1.52
K	7.36
Ca	25.2
Ti	0.03
Mn	0.23
Fe	1.04

A flue gas analysis has not been undertaken to assess the statistical variation in flue gas composition. As noted, an ash analysis has been undertaken by CSIRO, to determine the correct fuel mix from a range of 6 samples of pine and blue gum. However the standard deviation of element composition within the ash was not determined for a range of samples for each fuel type.

6.2 Emissions Control Technology

Emissions are controlled through the use of a fluidised bed boiler in combination with a baghouse. The features and the manner in which the fluidised bed boiler, combustion process and the bag house control emissions is discussed below.

Fluidised Bed Combustion

The boiler used in this plant is a fluidised bed combustor. This combustion system has significant advantages over traditional grate fuel firing systems, including compact boiler design, higher combustion efficiency and reduced emissions of noxious pollutants including NO_x.

Fluidised beds suspend solid fuels on air jets blowing upwards through a granular solid material (a catalyst in the shape of tiny spheres), during the combustion process. If the velocities of these jets are high enough then solid fuel will become suspended and behave as though it were a fluid. This results in turbulent mixing and hence more effective chemical reactions and efficient transfer of heat.

The solid substrate (the catalytic material upon which chemical species react) material in the fluidized bed reactor is typically supported by a porous plate (the distributor). The fluid is then forced through the distributor up through the solid material. At lower fluid velocities, as in a packed bed reactor, the solids remain in place as the fluid passes through the voids in the material. As the fluid velocity is increased, the reactor will reach a stage where the force of the fluid on the solids is enough to balance the weight of the solid material. This stage is known as incipient fluidization and occurs at this minimum fluidization velocity. Once this minimum velocity is exceeded, the contents of the reactor bed reach a turbulent state and the reactor is now a fluidized bed.

Fluidised bed combustors generally fit into two general categories atmospheric and pressurised systems. As their name suggest the two types operate at atmospheric or elevated pressures, where the latter produce a high pressure gas stream at temperatures that can drive a gas turbine. In some cases, atmospheric fluidised bed uses limestone or dolomite (sorbent) to capture sulphur released by combustion (where sulphur exists in the fuel), where jets of air suspend the mixture of sorbent and the fuel.

The two main reasons for the rapid increase in the use of the fluidised bed combustors are possibility of using fuels which are difficult to burn efficiently using other systems and the ability to achieve low NO_x and SO_x emissions with the use of a limestone distributor.

Some disadvantages of fluidised bed combustion include erosion of immersed tubes, and ash removal through gravity chutes. Regular monitoring of the efficiency of ash disposal chutes is recommended in the air quality management plan.

Baghouse

The baghouse has a large baffled inlet section referred to as a "gas management inlet module". Dust laden gas enters the baghouse and hits a series of vertical baffles which are over the full 8 m length of the bags. The gas slows down to result in smooth entry onto the bags. This proven set up will avoid impingement of the high velocity gas (which could result in abrasion and/or bag swaying).

The baghouse will have one pyramid hopper (65 degree slope angle) with a large hinged door for access (flush inside, labelling on outside) and rodding point just above dust outlet. The hopper will have dual level sensors to detect (high) and alarm (high/high) ash levels in the hopper.

The hopper outlet will be fitted with a 12" rotary valve to create a gas lock. A 12" valve would be well oversized for the dust load but this is to make sure there is minimal risk of hopper bridging due to a small hopper to valve 'bottle neck'.

The baghouse pulse control will be via dedicated PLC. The advantage in PLC controlled pulsing is the maximum flexibility to optimise the pulsing regime (i.e. on demand cleaning, variable pulse frequency). The baghouse will have a pressure drop (dP) transmitter fitted for so called on demand cleaning (cleaning only started when high pressure

set point is reached). Over and above this 'on demand' cleaning a time based full pulse cycle will take place to cover low boiler load situations.

The dP tubes are prone to clogging and will be regularly cleaned via a shot of compressed air (dP transmitter will be isolated via set of solenoids during cleaning). Also each baghouse will have a pressure transmitter on the air headers. The purpose of this transmitter is to register a drop in header pressure after each pulse. If this pressure reduction is not recorded, the pulse valve is faulty and an alarm will sound.

Filter bags are nominal 8 m x 154 mm to fit a 160 mm cell plate opening. The cages are 3 piece finger jointed cages in mild steel to suit the filter bags. The expanded PTFE membrane is laminated on a so called substrate. The substrate is woven from fibreglass. The membrane results in the principle of so called surface filtration. The membrane does the filtration and no dust is penetrated into the substrate.

It also has to be noted that there is evidence showing the efficiency of fabric filters to be minimum at 99.2% for ceramic fabric filters for reducing uncontrolled emissions. Hence, when predicting the emission rates using the National Pollutant Inventory (NPI) method a baghouse efficiency of 99% was used. In addition to this it was seen from analysis of emission factors that the baghouse was seen to be marginally more efficient at reducing uncontrolled emissions of PM_{2.5} as opposed to PM₁₀.

Potential for Inefficiencies in Baghouse Operation

The possibility of inefficiencies in baghouse operation and effects are discussed in the following section. The single biggest risk arises from the fabric getting clogged with dust which would lead to numerous issues including.

- Seepage of certain unwanted dusts from dynamic pressure on fabric from flue gas flow.
- Risk of explosion or fire hazard in the fabric from rapid oxidation of large quantities of dust in baghouse (density is in the region of 50g/m³). An explosion could subsequently be sparked by either an accidental spark or flame.
- Mechanical failure of impulse generators that shake dust of fabric can also cause fabric to get clogged over time.

The occurrence of any such incidents would result in the minimum baghouse efficiency predicted not being met. Hence would increase the particulate pollutant emission rate. The predicted emission rates of both PM₁₀ and PM_{2.5} are likely to be six times greater than that otherwise used in this analysis. Therefore in order to gauge the likely impact on ground level concentrations of such a large increase in stack emission rates, a simulation for the month through which average ground level concentrations are likely to be highest, ie in winter (June) was undertaken.

It is envisaged that concentrations are likely to be highest during the winter months due to low mixing height levels, high occurrence of neutral to relatively stable meteorological conditions and in general very little mixing of air. Hence pollutants tend to accumulate resulting in higher concentrations observed. The results of this analysis are detailed under the heading Baghouse Failure **Section 13.3**.

The likelihood of such inefficiencies is low, as each baghouse includes an integral poppet damper so that each individual baghouse can be isolated. The two parallel bag filter streams, each one capable of handling 100% load, allows for on-line cleaning and maintenance of the bag filter house without effecting the power plant output. The system is designed so that if one baghouse is isolated for online replacement of bags (for up to 24-36 hrs) the emission limits can still be achieved without turndown of the load on the boiler.

Burner

Combustion air is supplied to the boiler by the forced draft fan. The forced draft fan utilizes ambient air. All of the combustion air flow is directed through the tubular air heater and then splits to supply the bed air, over fire air, burner air and fuel spout systems. Re-circulated flue gas is mixed with primary air as needed for operation before the bed air fan.

The flue gases then pass through the superheater, generating bank, economizer and air pre-heater. The gases are to be passed through the emission control equipment and are then discharged to the stack by the induced draft fan.

Preheated over fire air (OFA) located on both sidewalls is distributed through two (2) elevations of staggered nozzles. The distribution scheme is designed to create a high level of turbulence in the upper part of the combustion zone. The amount of over fire air required to each elevation varies with load and fuel characteristics for combustion and NO_x emission control performance. The over fire air enters through sets of 304 stainless steel over fire air nozzles.

Ash and Dust Handling System

Bed ash from the boiler/furnace is separated for collection in a skip, while the dust from the air heater; economizer is pneumatically conveyed to an ash storage silo for wetting and disposal by road transport:

The pneumatic conveying system uses flue gas as the conveying media and is configured as a closed loop system extracting the conveying gas, passing it through the 5 hopper ejectors and conveying the dust through a 300NB pipe to the ash silo where the dust is separated by a cyclone into the silo while the conveying gas returns through a high pressure materials handling fan. The ash silo stores the equivalent quantity of three days of plant operation and is elevated to allow road transport to pass through the support structure for ash discharge. The discharge from the ash silo will have an isolation knifegate valve and a rotary valve to feed the wetted ash from the silo. The wetted ash will be disposed of off-site as soil conditioner for agriculture purposes, retaining commercial value. Further details regarding the ash storage and handling process are provided in **Section 4.1.2**.

6.3 Emissions Guarantee

It is noted that the NSW EPA document "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" states "Manufacturers' design specifications or performance guarantees can be useful for establishing the upper bounds of likely operational variability". The Emissions Guarantees discussed below were hence used as maximum emission rates.

Particulate Emissions Guarantee

Emission of particulates will not exceed 30 mg/Nm³ of dust at 100% MCR when firing design fuel. A normal cubic meter of gas for this guarantee is defined as dry gas at 0°C, 101.3kPa and 6% O₂ conditions.

NO_x Emissions Guarantee

Emission of NO_x, will not exceed 300 mg/Nm³ at 100% MCR when firing design fuel. A normal cubic metre of gas for this guarantee is defined as dry gas at 0°C, 101.3kPa and 6% O₂ conditions.

CO Emissions Guarantee

Emission of CO will not exceed 200 mg/Nm³ at 100% MCR when firing design fuel. A normal cubic metre of gas for this guarantee is defined as dry gas at 0°C, 101.3kPa and 6% O₂ conditions.

SO₂ Emissions Guarantee

Emissions of SO₂ will not exceed 78 mg/Nm³ at 100% MCR when firing design fuel. A normal cubic metre of gas for this guarantee is defined as dry gas at 0°C, 101.3kPa and 6% O₂ conditions.

6.4 Quantification of Emissions

Table 6.3 outlines the operating characteristics applicable to the plant. The exhaust gases consist of a mixture of nitrous oxides, in particular nitrogen dioxide, water vapour, sulphur dioxide, particulates, carbon dioxide and carbon monoxide. Emissions rates for the criteria pollutants, carbon monoxide, nitrogen dioxide, sulphur dioxide and particulates, were calculated from the guaranteed flue gas emissions concentration that were provided to the authors by the proponent as part of the design specification. However only NO₂, particulate compounds as PM10 and PM2.5 and SO₂ were explicitly modelled using TAPM, CO emissions were considered to be sufficiently low to have no significant impact.

The exhaust gases will contain a mixture of nitric oxide (not a regulated pollutant) and nitrogen dioxide. The relative amount of nitrogen dioxide in the exhaust will depend upon operating conditions. However as stated previously the NO/NO_x ratio for power stations is typically 0.9. After the plume is emitted from the stack, the proportion of the NO₂

contained within the plume will increase as the NO_x combines with ambient gases such as ozone and volatile organic compounds (VOC) to form NO₂ as described in **Section 10.2**.

Table 6.3 Emissions Characteristic of the Manjimup Biomass Power Plant

Parameter	Units	Normal Operation
Number of Stacks		1
Location	GDA94 (mN, mE)	418028, 6200357
Stack Height	m	40
Stack Diameter	m	3.0
Exit Velocity ^(a)	m/s	15.0
Temperature ^(b)	K	418
Volume Flow Rate	Am ³ /s	108.3
NO _x – Guaranteed Concentration	mg/Nm ³	300
– Emission Rate	g/s	23.1
NO to NO _x ratio		0.9
Modelled:	mg/Nm ³	50
PM10 – Concentration	g/s	1.8
– Emission Rate		
Guaranteed PM10 Concentration	mg/Nm ³	30
PM2.5	g/s	1.4
PM2.5 to PM10 ratio		0.8
CO – Concentration	mg/Nm ³	200
– Emission Rate	g/s	12.0
SO ₂ – Concentration	mg/Nm ³	78
– Emission Rate	g/s	6.0

(a) Exit velocity is estimated from the flue gas flow and flue gas composition

(b) Flue gas temperature is measured at the outlet of the economiser

Emissions from stockpiles will be ignored due to the size of plantation waste, and the shielding offered by surrounding trees. Emissions from existing forestry activities would result in greater emissions of equivalent material to that contained in stockpiles.

The NPI "Emission Estimation Technique Manual for Fugitive Emissions" from stockpiles refers to the "Emissions Estimation Technique Manual for Mining" which allows prediction of emissions from Coal and Metalliferous mines. In this case stockpile material is considerably different, with material up to 150mm in size (summed from all three dimensions) stored and unlikely to be eroded. In fact, the use of wood chips and straw are commonly used to cover agricultural land to prevent erosion.

Reference is made to "Evaluating Material Properties to optimise Wood Strands for Wind Erosion Control" by the American Society of Agricultural and Biological Engineers. In this paper, emissions of particulates (PM10) are considered with respect to soil covered with wood strands (when tested in a wind tunnel). With a free stream velocity of 6.5m/s emissions were negligible, and with a free stream velocity of 18m/s peak emissions were typically under 25mg/m³. Typical wind speeds measured at Manjimup are typically no greater than 3.0m/s, therefore justifying this approach.

Fugitive emissions from discharge of ash for disposal will be enclosed and regulated as discussed in the **Section 6.2, Emissions Control Technology**.

6.5 Qualification of Emissions Guarantee

Australia's National Pollutant Inventory (NPI) was established to satisfy increasing societal pressure for greater transparency with regard to pollutant emissions to the environment. It is based on similar international inventories (e.g. US EPA AP-42). The National Pollutant Inventory (NPI) gives information on the types and amounts of 90 substances (identified as important because of their possible health and environmental effects) being emitted to the

Australian environment. The NPI program is run cooperatively by the Australian, State and Territory governments and requires industries to estimate and report their emissions annually.

The National Pollutant Inventory's (NPI) "Emissions Estimation Technique Manual for Combustion in Boilers" will be used to qualify emissions based on the fuel type, composition and consumption noted for the proposed plant herein. The NPI database has been used to express the potential health effects of pollutants emitted by the proposed plant. The National Pollutant Inventory Emission Report for the Manjimup area is provided in **Appendix A**. Emissions nominated by the proponents have been qualified by comparison with predicted emissions using the National Pollutant Inventory (NPI) estimation methods and where absent, the US EPA AP-42 methods. The NPI methods are based on those developed by the US EPA AP-42. These methods require knowledge of the fuel consumption and fuel composition, which when combined with nominal emission factors for uncontrolled emissions, and emission reduction factors (based on control technologies), allow estimates of emissions from fuel consumption.

The NSW EPA AQM document notes the "EPA's preferred methods are direct measurement for existing sources and manufacturers' design specifications for proposed sources. Emission factors are generally used when there is no other information available, or when emissions can reasonably be demonstrated to be negligible." **Table 6.4** lists emission estimates according to NPI estimation methods and factors for combustion in boiler in particular wood waste combustion. As can be seen from **Table 6.4** emission rates used in the model herein for particulates are very similar to those predicted, thus qualifying the authenticity of emissions data provided by the proponent. Emissions for NO₂ on the other hand do not qualify against that predicted in **Table 6.3**. This is most likely due to the below average Emission Factor Rating (EFR) for NO₂ (D) from the NPI (Australia) for the fluidised bed combustor. A below average EFR indicates that the emission factor developed from the US EPA and European Environment Agency (EEA) is not directly relevant to this Australian industry. Emissions for other pollutants have been considered on a pro-rata basis with results from dispersion estimates of NO₂. Further to this SO₂ emissions as predicted by the guaranteed emissions differ significantly from that predicted by NPI methods. This could be attributed to the differences in the specific fuel types and combustion conditions used to derive the respective NPI and guaranteed emission factors. As the EPA prefers direct measurement from existing sources and manufacturers design specifications for proposed sources the guaranteed emission rate was employed in all dispersion modelling involving SO₂ emissions.

Table 6.4 NPI Emission Estimates.

NPI Estimation			
Fuel		Woodwaste	
GCV (MJ/kg)		11	
Moisture (%)		43	
Consumption		51 t/hr	
NO₂			
Emission Factor (Uncontrolled)		1.19 kg/tonne	
Uncontrolled Emissions		16.9 g/s	
Particulates			
Emission Factor (Uncontrolled)		10.15 kg/tonne	
Uncontrolled Emissions		143.8 g/s	
Emission Factor (Controlled, 99% Baghouse)		1.02E-01 kg/tonne	
Controlled Emissions		1.4 g/s	
SO₂			
Emission Factor (Uncontrolled)		0.12 kg/tonne	
Uncontrolled Emissions		1.7 g/s	
TVOC			
Emission Factor (Uncontrolled)		0.13 kg/tonne	
Uncontrolled Emissions		1.9 g/s	
CO			
Emission Factor (Uncontrolled)		0.80 kg/tonne	
Uncontrolled Emissions		11.4 g/s	

6.6 Emissions of Other Pollutants

6.6.1 Trace Elements

The emissions for other pollutants, specifically trace elements are as described in **Table 6.5**. The emission factors sourced from the NPI database for wood waste combustion were uncontrolled emissions and do not take into account any particulate controls. Therefore published capture efficiencies as described in the paper by Hargis et al. (1996) for a baghouse filter system was used to determine controlled emissions of these compounds.

Table 6.5 Emissions of selected trace elements as determined from NPI factors and methods corrected for baghouse capture efficiencies (Hargis, RA, Pennline, HW, 1996).

Trace Elements	Uncontrolled Emission Factor (kg/tonne)	Control Efficiency (%)	Controlled Emissions (g/s)
Cadmium (Cd)	1.3×10^{-5}	95.9	7.42×10^{-6}
Iron (Fe)	4.7×10^{-3}	98.6	9.00×10^{-4}
Lead (Pb) *	1.8×10^{-3}	99.9	3.05×10^{-5}
Manganese (Mn)	7.5×10^{-3}	99.7	3.41×10^{-4}
Mercury (Hg)	3.1×10^{-6}	59.7	1.76×10^{-5}
Phosphorus (P)	1.3×10^{-4}	99.0	1.81×10^{-5}
Potassium (K)	1.8×10^{-1}	99.9	2.61×10^{-4}
Sodium (Na)	1.7×10^{-3}	94.7	1.27×10^{-3}
Titanium (Ti)	9.5×10^{-5}	99.9	9.37×10^{-7}

(*) Lead is a Criteria Pollutant as noted by the NEPM Ambient Air Quality Limits.

6.6.2 Volatile Organic Compounds

Table 6.6 (a) and **(b)** details the controlled and uncontrolled emission factors and emissions of speciated volatile organic compounds as listed in the NPI Combustion in Boilers Emission Factors handbook as well as the US EPA AP-42 document for wood waste combustion. The NPI listed emission factors for speciated compounds were listed as having some particulate control systems, whereas the US EPA emission factors does not take particulate control systems into account.

Table 6.6 Emissions of selected organic compounds as determined from controlled NPI factors (a) and (b) US-EPA-AP42 uncontrolled emission factors.

a)

Compound	Controlled Emissions Factor	Controlled Emissions (g/s)
Benzene	5.0×10^{-3}	7.1×10^{-2}
Benzo(a)pyrene	3.4×10^{-8}	4.8×10^{-7}
Acenaphthene	2.10×10^{-6}	2.98×10^{-5}
Fluorene	4.10×10^{-6}	5.81×10^{-5}
Phenanthrene	2.50×10^{-5}	3.54×10^{-4}
Anthracene	1.70×10^{-6}	2.41×10^{-5}
Fluoranthene	9.20×10^{-6}	1.30×10^{-4}
Benzo(a)anthracene	1.60×10^{-6}	2.27×10^{-5}
Benzo(k)fluoranthene	3.80×10^{-7}	5.38×10^{-6}
Benzo(b,k)fluoranthene	1.50×10^{-5}	2.13×10^{-4}
Benzofluoranthenes	5.40×10^{-7}	7.65×10^{-6}
Benzo(g,h,i)perylene	7.10×10^{-7}	1.01×10^{-5}
Benzo(a)phenanthrene	2.10×10^{-7}	2.98×10^{-6}
Chrysene	2.30×10^{-7}	3.26×10^{-6}
Indeno(1,2,3,c,d)pyrene	1.80×10^{-7}	2.55×10^{-6}
Acenaphthylene	2.40×10^{-5}	3.40×10^{-4}
Methyl anthracene	7.00×10^{-5}	9.92×10^{-4}
Naphthalene	1.70×10^{-3}	2.41×10^{-2}
Pyrene	8.40×10^{-6}	1.19×10^{-4}

b)

Compound	Uncontrolled Emissions Factor	Uncontrolled Emissions (g/s)
Acetaldehyde	3.92×10^{-3}	5.55×10^{-2}
Benzaldehyde	4.01×10^{-6}	5.69×10^{-5}
Crotonaldehyde	4.68×10^{-5}	6.62×10^{-4}
Formaldehyde	2.08×10^{-2}	2.94×10^{-1}
Isobutyraldehyde	5.67×10^{-5}	8.03×10^{-4}
Propionaldehyde	2.88×10^{-4}	4.08×10^{-3}
o-Tolualdehyde	3.40×10^{-5}	4.82×10^{-4}
p-Tolualdehyde	5.20×10^{-5}	7.36×10^{-4}
Dibenzo(a,h)anthracene	4.30×10^{-8}	6.09×10^{-7}
Ethyl Benzene	1.46×10^{-4}	2.07×10^{-3}
Styrene	8.97×10^{-3}	1.27×10^{-1}
Toluene	4.35×10^{-3}	6.16×10^{-2}
o-Xylene	1.18×10^{-4}	1.67×10^{-3}

6.6.3 Polycyclic Aromatic Hydrocarbons

The emission factor for polycyclic aromatic hydrocarbons were sourced from a study conducted by Leclerc, Duo and Vessey (2006) relating the pollutant concentration to excess oxygen percentage exiting a fluidised bed boiler for the combustion of salt laden wood waste. The expected oxygen content of the flue gas exiting the boiler was compared to the pollutant concentration as outlined in the paper by Leclerc et al (2005). This emission factor was considered to be more design specific than the general NPI listed emission factors for Total PAHs for wood waste combustion. This controlled emission factor and the corresponding emission rate was determined and is shown in **Table 6.7**.

Table 6.7 Emission factors and emission rates of Total PAHs.

	Controlled Emissions Factor ($\mu\text{g}/\text{m}^3$)	Controlled Emissions (g/s)
Total PAHs	21.8	2.4×10^{-3}

6.6.4 Polychlorinated Dioxins and Furans

The principal formation mechanisms of PCDD/F in industrial systems are through the high temperature pyrosynthesis (precursor formation) and the following low temperature de novo synthesis:

- The initial pyrosynthesis formation scheme occurs through the polycondensation of the PCDD/F precursors (polycyclic organo-chlorinated compounds) (Everaert K, Baeyens J., 2002). This gas phase phenomenon occurs at temperatures between 300 and 600°C. This gas phase formation can only be attributed to less than 25% of the total TEQ generated (Preto F, McCleave R, McLaughlin D, and Wang J 2005). The design specific combustion conditions of a boiler residence time of 2 seconds, freeboard temperature of between 1100 and 1200°C and a furnace exit temperature of 900°C will result in the severe inhibition of the formation of PCDD/F compounds.
- The de novo synthesis on the other hand requires the presence of carbon in the solid phase and O₂ and this process occurs in the 200 – 400°C temperature range. This process is dominant over precursor formation, and therefore the formation of PCDD/F compounds in the flue gas stream from the boiler to the ESP is a significant source. Everaert et. al. (2002) also showed that this formation is highly temperature dependant, with typical ESP operating temperatures between 180 – 280°C, leading to conditions that intensify de novo TEQ formation. At lower temperatures dioxin and furan compounds are increasingly adsorbed onto the fly ash.

Dioxins/Furans emission factors were initially sourced from the US EPA document (*Locating and Estimating Air Emissions from Sources of Dioxins and Furans*) with **Table 6.8** showing a comparison of emission factors for different boiler and fuel types measured at 12% CO₂. The higher emission factor of 3.8×10^{-2} ng/dscm I-TEQ will be used to ensure the assessment is conservatively based. This will be verified by periods of in-stack monitoring of dioxins and furans as noted in the Air Quality Management Plan detailed in **Section 17**. Both emission factors comply with the emission limit of 0.1 ng I-TEQ/dscm as stipulated by the Stockholm Convention (Geneva, 2006) further discussed at **Section 9.3.2**. This emission factor leads to the controlled emission rates as stated in **Table 6.9**.

Table 6.8 Comparison of Emission Factors for PCDD/F I-TEQ Boiler Types

Boiler Type	Emissions Control	Fuel	Emissions Factor (ng/dscm I-TEQ)
Wood Fired Boiler	ESP	Wood Waste Only	9.9×10^{-4}
Cyclone Fired Boiler	ESP	Bark Only	3.8×10^{-2}

Table 6.9 Controlled design specific PCDD/F TEQ emission factors and the corresponding controlled emission rates.

	Estimated Controlled Emissions Factor (ng I-TEQ/m ³)	Controlled Emissions (g/s)
PCDD/F (I-TEQ)	0.038	2.31×10^{-9}

6.7 Comparison with Best Available Technology

The BAT (Best Available Techniques) Reference Document (BREF) entitled 'Large Combustion Plants' covers combustion installations with a rated thermal input exceeding 50 MW. This section considers use of best available technology to limit emissions, while emission limits are discussed later in **Section 9.3**. Refer also to **Section 9.3.2**, which provides primary and secondary control measures for Persistent Organic Compounds as defined by the Stockholm Convention to which Australia is a signatory.

For the combustion of biomass, fluidised bed combustion, is considered to be BAT. The use of advanced computerised control system in order to achieve a high boiler performance with increased combustion conditions that support the reduction of emissions are also considered as BAT.

Particulates

For dedusting off-gases from biomass fired new and existing combustion plants, BAT is considered to be the use of bag-houses with fabric filters (FF) or an electrostatic precipitator (ESP). In this sense, it needs to be noted that when using low sulphur fuels such as biomass, the potential for reduction performance of ESPs is reduced with low flue-gas sulphur dioxide concentrations. In this context, the FF is the preferred technical option to reduce dust emissions.

Heavy Metals

The mineral content of the fuel includes different substances depending on its origin. Biomass has certain concentrations of trace elements, such as heavy metals. The behaviour of heavy metals in the combustion process involves complex process chemistry and physics. Basically most of the heavy metals evaporate in the combustion process and condense later in the process on the surfaces of the particulate matter (fly ash). Therefore, BAT to reduce the emissions of heavy metals from flue-gases of biomass fired combustion plants is the use of a fabric filter (reduction rate > 99.95 %) or a high performance ESP (reduction rate > 99.5 %), where the fabric filter should be seen as the first choice in the hierarchy of BAT for dedusting.

Sulphur Dioxide

The sulphur content of wood biomass contains practically no sulphur. Wood-based biomass can, therefore, be combusted in FBC without desulphurisation.

Nitrogen Oxides

In general, for biomass fired combustion plants, the reduction of nitrogen oxides (NO_x) using a combination of primary and/or secondary measures (e.g. SNCR and SCR) is considered to be BAT. The nitrogen compounds of interest are nitrogen oxide (NO) and nitrogen dioxide (NO₂), collectively referred to as NO_x, and especially for FBC boilers the emission of nitrous oxide (N₂O). In FBC boilers burning biomass, BAT is the reduction of NO_x emissions achieved by air distribution or by flue-gas recirculation.

Carbon Monoxide

BAT for the minimisation of CO emissions is complete combustion, which goes along with good furnace design, the use of high performance monitoring and process control techniques and maintenance of the combustion system.

Dioxins and Furans

In some biomass fired plants, especially wood-fired combustion plants, the emissions of dioxins and furans have been measured and an emission level of below 0.1 ng/Nm³ is generally regarded as achievable.

7. Emissions from Other Regional Sources

7.1.1 Biogenic

It is well known that biogenic VOC emissions result from vegetation, with emission rates influenced primarily by ambient temperature, vegetation type and density, and solar radiation. The biogenic emissions of volatile organic compounds (VOCs) were important to consider due to the high density of native vegetation in the area. The emission factors tabulated below are normalised to 30°C and photosynthetically active radiation of 1000 $\mu\text{mol}/\text{m}^2/\text{s}$. Based on the BEIS equations and the emission factors (reproduced in **Table 7.1**), both sourced from SKM (2003) the authors were able to develop an equivalent land use specific biogenics emissions inventory for the region under consideration.

Land Use	Emission factor ($\mu\text{g}/\text{m}^2/\text{hr}$)			
	Isoprene	Monoterpenes	Other VOCs	Total VOCs
Pasture	32.5	32.5	585	650
Crop	55	80	48	183
Broadacre	15	6	9	30
Horticulture	28	95	57	190
Settlement	409	162	201	772
Bare	0	0	0	0
Water	0	0	0	0
Native Vegetation	9,556	480	175	10,200
Regrowth	9,556	480	175	10,200
Pine Forests	79	2,380	1,295	3,750

Table 7.1 VOC Emission Factors based on Land Use (SKM, 2003)..

Biogenic NO_x emissions are products of microbial denitrification, chemical decomposition of nitrites and the oxidation of organic nitrogen compounds. There appears to be no significant emission of NO_x from either oceans or freshwaters. Biogenic emission rates for NO and NO₂ from soil range from 0.015 to 0.02 kg NO sq km/hr and 0.01 to 0.2 kg NO₂ sq km/hr. There is no significant evidence of NO_x emission from living vegetation. During decay, decomposition and ensiling of vegetation, NO_x can be formed.

Biogenic emissions of NO_x were calculated from the NPI 'all sources' report for the Shire of Manjimup, this report stated this value to be 890,000 kg/annum. These emissions of NO_x were then linearly scaled up by way of a ratio of areas between the published area of the Shire of Manjimup and the land use cover area from which these emissions were likely to originate. This was considered to be a conservative assumption as the net result is an increase in the atmospheric NO_x load.

Although the VOC emissions are several orders of magnitude greater than the likely total NO_x load in this environment the linear scaling of these NO_x emissions does not exacerbate this scenario and hence leads to conservatism in the likely ground level concentrations of NO₂ observed.

The model configuration details regarding these biogenic emissions of NO_x and VOCs are discussed in **Section 10.3**.

7.1.2 Anthropogenic

The National Pollutant Inventory has a database of pollutant emissions from various industrial facilities and diffuse sources such as small facilities, transport and households. A summary report providing emissions for all industrial and diffuse sources within the region is attached as **Appendix A**

The major industrial emission sources in the area are:

- **Sons of Gwalia**
Tantalum and lithium mining and processing activities, with major emissions to air being particulate matter (290,000kg/annum), and to a lesser extent, Carbon Monoxide, Oxides of Nitrogen and Sulphur Dioxide (about 60-75,000kg/annum each). VOC emissions total about 5,600kg/annum.
- **GUNNS (WA) Pty Ltd**
Log Sawmilling and timber processing activities, with major emissions to air being particulate matter (26,000kg/annum) and to a lesser extent Oxides of Nitrogen (8,000kg/annum) and Carbon Monoxide (5,600kg/annum).
- **Muja, Collie and Worsley Power Stations and Griffin Energy Bluewaters Refinery, Collie WA**
The township of Collie is approximately 100km due North of Manjimup and is in close proximity to the Muja, Collie and Worsley power station cluster as well as the Bluewaters refinery. The principal emissions from this source are oxides of nitrogen and sulphur dioxide. Cumulative emissions of NO_x and SO₂ from these sources total 34,740,000kg/annum and 71,130,000kg/annum respectively. Hence they are a dominant source in this region.

The anthropogenic emissions of NO_x were initialised on the 't010a' nested TAPM grid and the emissions were all sourced from the NPI emissions database for the Shire of Manjimup. It was found that most of the anthropogenic emissions were from diffuse sources such as motor vehicles and household solid fuel combustion. Based on this it was believed that most of the NO_x emissions from the shire would be centred on the township of Manjimup which was represented by the 't010a' nested grid. This assumption was also considered to be conservative due to the high emissions density.

The industrial sector consisting of the Muja, Collie and Worsley Power Stations were included as an aggregated point source. These individual facilities were not represented as individual point sources in TAPM so as to minimise computational time. Furthermore the similarity in the stack emission parameters between the individual sources justifies the validity of this assumption, as demonstrated in **Table 7.2**. The parameters were sourced from the Bluewaters Air Quality report commissioned by CSIRO. This power station cluster was seen to be the most significant source of NO_x and SO₂.

Table 7.2 Nearby source properties

Power Station	Diameter (m)	Velocity (m/s)	Temperature (deg C)	Height (m)	NO _x Emission Rate (g/s)	SO ₂ Emission Rate (g/s)
Muja	4.9	19.0	165	125	729	1142
Collie	6.3	24.4	150	170	124	444
Worsley	4.0	23.7	130	76	124	374
Bluewaters	5.0	24.0	130	100	121	296
Modelled	5.0m	20.0m/s	145 deg C	120m	1098 g/s	2256 g/s

It is therefore apparent from **Table 10.5** that the emissions from this point source are several orders of magnitude larger than the maximum emissions expected from the proposed facility. Hence any prevailing southerly wind would result in these emissions affecting the atmospheric NO_x and SO₂ load in the Manjimup region. Therefore in order to justify the cumulative nature of the results it was believed that it was necessary to include this source in the simulation. The impact of all the above gridded and point source emissions on the cumulative ground level SO₂ and NO₂ concentration around Manjimup will be discussed further in **Section 13.1**.

8. National Pollutant Inventory Reporting

Annual emissions from the proposed power plant compared with those from nearby facilities are shown in **Table 8.1** (data obtained from the National Pollutant Inventory). Diffuse source emissions from urban and industrial activities in the Shire of Manjimup were considered via the inclusion of gridded anthropogenic emissions of NO_x. A significant source of SO₂ and NO_x, being the power stations around Collie as well as the Bluewater refinery were also included as an aggregated point source (described in **Section 7.1.2**). Emissions from diffuse sources dominate over those predicted from the proposed Power Plant, as demonstrated by the data from the Shire of Manjimup and the Bunbury Air Shed.

- NO_x: Diffuse sources are predominantly generated from biogenics. These were included in the assessment as a gridded source. Annual emissions from the Biomass Power Plant are estimated to be about half of the emissions from the Shire of Manjimup but a small percentage of the total NO_x emissions from the Bunbury air shed.
- PM10: Diffuse sources from paved/unpaved road transport dominate over industrial source emissions. Note that emissions of particulates from prescribed burning have not been included.
- SO₂: The proposed biomass power plant is expected to be the most significant source of the compound within the Shire of Manjimup. However they are insignificant when compared to the emissions published by the NPI for the Bunbury air shed.
- VOCs: Diffuse sources are predominantly generated from biogenics and dominate over industrial source emissions. Emissions from the Biomass Power Station are insignificant in comparison to those from the Shire of Manjimup.
- CO: Diffuse sources dominate with emissions from motor vehicles, burning and wood fires major contributors. Emissions from the proposed Biomass Power Plant are not a significant contributor when compared to that of the Shire of Manjimup.
- PAHs: Emissions are dominated by diffuse sources resulting from domestic solid fuel burning. Emissions from the proposed Power Plant will not be a significant contributor to the emissions of these compounds in the Shire of Manjimup.
- Dioxins/Furans: Annualised emissions of TEQ dioxins and furans are seen to be a fraction of the total emissions from the Shire of Manjimup.
- Trace Elements: Diffuse sources from paved/unpaved road transport (Manganese) and from Agricultural activities (Phosphorus) significantly dominate over industrial source emissions.

Table 8.1 Per Annum pollutant emission rates of Criteria Pollutants from industrial and diffuse sources.

Pollutant (kg/yr)	Sources		
	Biomass Power Plant	Shire of Manjimup	Bunbury Air Shed
NO _x	850,000	1,400,000	66,000,000
PM10	56,700	16,000,000	170,000,000
SO ₂	189,200	20,000	70,000,000
CO	360,000	5,300,000	130,000,000
Lead	0.96	51,000	410,000
VOCs	58,700	12,000,000	140,000,000
Dioxins/Furans	0.00007	0.00026	0.0051
PAH	74	3,100	70,000
Trace Elements			
Manganese	10.8	58,800	510,000
Iron	28.6		
Phosphorus	0.57	n/a	360,000
Potassium	8.23	n/a	
Sodium	40.1	n/a	
Titanium	0.03		

9. Assessment Criteria

9.1 State

The EPA is preparing to develop a draft Environmental Protection Policy (EPP) for Ambient Air Quality in accordance with prior commitments to implement the Ambient Air Quality National Environment Protection Measure (NEPM). These NEPM standards are applicable to the State of Western Australia through the provisions of the National Environment Protection Council (Western Australia) Act 1996. Section 7 of the Act requires WA to 'implement, by such laws and other arrangements as necessary, [the] national environment protection measure', i.e. to put in place the means to ensure that compliance with the NEPM standards is achieved within the ten year goal. In accordance with such requirements the Western Australian Government agreed to achieve this via an Environmental Protection Policy (EPP). This Policy has not yet been enacted.

9.2 Federal

9.2.1 NEPM – Criteria Pollutants

The Environment Protection & Heritage Council (EPHC) incorporates the National Environment Protection Council (NEPC). The EPHC/NEPC has developed National Environmental Protection Measures (NEPMs), which outline agreed national objectives for protecting and managing aspects of the environment. The appropriate NEPM standards and goals for air emissions associated with the proposed facility are outlined in **Table 9.1**.

Western Australia has enacted the National Environment Protection (Ambient Air Quality) Measure (Air NEPM) as the required standard for six common pollutants: carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, lead, and particulate matter as PM10. The Air NEPM sets standards and goals at levels that protect human health and wellbeing, aesthetic enjoyment and local amenity.

The standards are defined as concentrations either in parts per million (ppm) or, for particulate matter, micrograms per cubic metre ($\mu\text{g}/\text{m}^3$). The goals in the Air NEPM specify a maximum permissible number of days per year when the standards may be exceeded and a timeframe of 10 years (1998–2008) within which these goals must be met.

Table 9.1 Environment Protection (Air Quality) Policy

Pollutant	Averaging Period	Maximum Concentration		Maximum Allowable Exceedances (days/yr)
		ppm	$\mu\text{g}/\text{m}^3$ @ STP (*)	
Nitrogen Dioxide	1 hour	0.12	226	1
	Annual	0.03	58	-
Carbon Monoxide	8 hours	9.0	1100	1
Sulphur Dioxide	1 hour	0.2	525	1
	1 day	0.08	210	1
	1 year	0.02	53	-
Coarse Particulates (PM10)	1 day		50	5

(*) The guideline defines STP as 25°C and at an absolute pressure of one atmosphere.

In May 2003, the NEPC made the Variation to the Ambient Air Quality NEPM which strengthens air quality standards to help protect Australians from the adverse health impacts of small pollutant particles. The Variation introduces advisory reporting standards for fine particles 2.5 micrometres or less in size (known as PM2.5). The advisory reporting standards will assist in gathering sufficient data nationally on fine particles, with the information used to inform the review process for the Ambient Air Quality NEPM.

Table 9.2 Environment Protection (Air Quality) Policy Amendment (Investigative Level)

Pollutant	Averaging Period	Maximum Concentration		Maximum Allowable Exceedances (days/yr)
		ppm	µg/m ³ @ STP (*)	
Fine Particulates (PM2.5)	1 day		25	Not established
	1 year		8	

(*) The guideline defines STP as 25°C and at an absolute pressure of one atmosphere.

9.2.2 NEPM – Air Toxics

The Air Toxics Measure is primarily concerned with the collection of data on ambient (i.e. outdoor) levels of formaldehyde, toluene, xylene, benzene and polycyclic aromatic hydrocarbons (PAH) at locations where elevated levels are expected to occur and there is a likelihood that significant population exposure could occur.

Air toxics exist in relatively low concentrations in ambient air. Elevated levels of the air toxics included in the Air Toxics NEPM are associated with locations that are close to specific sources. Sources include clusters of industrial sites, heavily trafficked or congested roads and areas affected by wood smoke.

States and territories have a range of programs in place to control industrial emissions of air toxics and to reduce emissions of air toxics from domestic wood heating. More stringent national fuel quality standards and new Australian Design Rules for motor vehicles have been introduced that are expected to reduce air toxic emissions from motor vehicles.

The aim of the Air Toxics Measure is to provide a framework for monitoring, assessing and reporting on ambient levels of five air toxics, benzene, formaldehyde, toluene, xylenes and PAHs, which will assist in the collection of information for the future development of national air quality standards for these pollutants.

Table 9.3 Monitoring Investigation Levels

Pollutant	Averaging Period	Monitoring Investigation Level		Goal
		ppm	µg/m ³	
Benzene	Annual average*	0.003 ppm	10 µg/m ³	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Benzo(a)pyrene as a marker for Polycyclic Aromatic Hydrocarbons (PAHs)	Annual average	0.3 ng/m ³	0.3x10 ⁻³ µg/m ³	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Formaldehyde	24 hours	0.04 ppm	49 µg/m ³	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Toluene	24 hours Annual average*	1 ppm 0.1 ppm	3763 µg/m ³ 376 µg/m ³	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Xylenes (as total of ortho, meta and para isomers)	24 hours Annual average*	0.25 ppm 0.2 ppm	1084 µg/m ³ 867 µg/m ³	8-year goal is to gather sufficient data nationally to facilitate development of a standard.

9.3 International

9.3.1 Criteria Pollutants

“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” applies to combustion plants, the rated thermal input of which is equal to or greater than 50 MW, irrespective of the type of fuel used (solid, liquid or gaseous). The rated thermal input proposed is about 175 MWth (nominal), and therefore accordingly Annex VII of the Directive, emission limits are:

- Dust to 30 mg/Nm³ (O₂ content 6%) for new plants and 100 mg/Nm³ for existing plants, this compares to 50 mg/Nm³ for that proposed; and
- NO_x (as NO₂) to 300 mg/Nm³ (O₂ content 6%) for new plants and 600 mg/Nm³ for existing plants. This compares to 350 mg/Nm³ for that proposed.

Emissions guarantees by the proponent are compliant with EC limits for new plants for both NO_x as NO₂ and dust (with reference to 6% O₂ content). Therefore world's best practice technology is put in place as part of the design of the proposed facility.

9.3.2 Air Toxics

Stockholm Convention on Persistent Organic Compounds (POPs)

The Stockholm Convention on Persistent Organic Pollutants came into force on 17 May 2004, with Australia ratifying the Convention on 20 May 2004 and becoming a Party on 18 August 2004.

The Convention aims to protect human health and the environment from the effects of persistent organic pollutants (POPs) with a range of control measures to reduce and, where feasible, eliminate POPs releases, including emissions of unintentionally produced POPs such as dioxins. The Convention also aims to ensure the sound management of stockpiles and wastes that contain POPs.

There are currently twelve POPs listed in Annexes to the Convention (refer to **Table 9.4**). Article 7 of the Stockholm Convention requires each Party to develop, and endeavour to put into practice, a plan setting out how it will implement its obligations under the Convention. Australia is well positioned in implementing its obligations under the Stockholm Convention, with much of the work already done or under way. The Australian Government has developed Australia's National Implementation Plan (NIP), which outlines the actions that Australia has undertaken to date and will undertake in the future.

The Stockholm Convention Best Available Techniques and Best Environmental Practices guidance for new facilities and for existing facilities Best available techniques to reduce PCDD/PCDF emissions may include the following relevant measures (Nussbaumer and Hasler 1998):

Primary Measures

1. Control of fuel quality (e.g. calorific value, water content, contaminants);
2. Optimized combustion technology: Improved burnout of gases and fly ash and reduction of dust content:
 - Optimize excess air ratio to < 1.5–2, though care must be taken as any changes made to the air ratio can also affect the amount of other emissions;
 - Good mixing quality of gas and air (high turbulence);
 - Sufficient residence time in the hot zone;
 - Minimal disturbance of the glow bed and homogeneous distribution of the primary air;
 - Optional integration of selective non-catalytic reduction for NO_x reduction;
3. Measures in the boiler:
 - Minimal residence time in the temperature range 180° and 500° C and minimal dust deposition ability;
4. Optimized plant operation:
 - Application of advanced combustion control technologies to ensure optimal burnout in practice;
 - Stationary operation, no on/off operation and prevention of rapid changes of heat and demand;

- Cleaning of the hot zone of flue gases at regular intervals.

Secondary Measures

- Optimized gas cleaning:
 - Rapid quench of combustion gases (< 200° C) before passing through filters in order to avoid the de novo reformation (or synthesis) window;
 - PCDD/PCDF separation in dust separators (electrostatic precipitators, fabric filters) in combination with sorbent injection (if necessary);
- Optional destruction of PCDD/PCDF by catalytic oxidation, i.e., in combination with selective catalytic reduction for NOx reduction.

For biomass-fired plants, particularly wood-fired installations, emission levels associated with best available techniques are generally below 0.1 ng I-TEQ/m³.

Table 9.4 Australia's action on the 12 POPs listed under the Convention

POP	Description	Production, use and importation restrictions
Aldrin	Pesticide	Final registration cancelled 1992 and importation prohibited.
Dieldrin	Pesticide	Final registration cancelled 1988 and importation prohibited.
DDT (pp'- DDT)	Pesticide	Final registration cancelled 1987 and importation prohibited.
Endrin	Pesticide	Final registration cancelled 1987 and importation prohibited.
Chlordane	Pesticide	Final registration cancelled 1997 and importation prohibited.
Hexachloro-benzene (HCB)	Pesticide, Industrial by-product	Final registration cancelled 1980 and importation prohibited. National strategy for HCB waste provides for management and destruction of stockpile.
Mirex	Pesticide	Final registration cancelled 2007. Prohibited import.
Toxaphene	Pesticide	Final registration cancelled 1987.
Heptachlor	Pesticide	Final registration cancelled 1997 and importation prohibited.
Polychlorinated biphenyls (PCB)	Industrial by-product	Importation of PCBs is banned unless explicit permission is granted by the Minister for Customs. National strategy proposes to remove and destroy all PCBs by end 2009.
Polychlorinated dibenzodioxins and dibenzofurans	By-product	No federal emission standards but most states have some regulations. Reporting under National Pollutant Inventory.

Almost all of the primary and secondary measures have been included in the design of the proposed facility. Quenching is not included per se, however controlled reduction of the temperature of flue gas from the boiler is provided by the heat exchange between flue gas exit from the boiler and combustion air entry to the boiler.

National Action Plan for Addressing Dioxins in Australia

In the 2001-02 Federal Budget, the Australian Government announced the four year National Dioxins Programme to reduce dioxins and dioxin-like substances in the environment.

A priority for the programme was to improve our knowledge about dioxin levels in Australia. The Australian Government undertook a range of studies from 2001 to 2004, to measure emissions from sources such as bushfires, and dioxin levels in the environment, food and population. The findings of these studies were used to determine the risk dioxins pose to our health and the environment. Because of a range of actions taken by governments and industry over the past decade or so, Australia's dioxin levels are generally low, as are the risks to human health and the environment.

Measures to ensure that levels remain low, and where feasible are eliminated, are outlined in the National Action Plan for Addressing Dioxins in Australia. At its 12th meeting on 29 October 2005, this plan was endorsed by the Environment Protection and Heritage Council as the guiding document for addressing dioxins in Australia as required under Article 5 of the Stockholm Convention on Persistent Organic Pollutants (POPs).

The National Action Plan notes emissions of Dioxins from Biomass Burning (that is open burning of biomass) is the greatest emitter. This highlights the benefits of the proposed development as opposed to the current practice of open air burning of plantation waste. Instead, with the proposed Biomass Power Station, plantation waste will be burnt in a controlled manner within the boiler (utilizing fluidized bed technology to maximize combustion efficiency) at a controlled temperature to minimize formation of Dioxins, with any formation of Dioxins in the flue gas from the boiler formed on fly-ash that is later captured in the fabric filters of the baghouse. The Biomass Power Station will result in reduced emissions of Dioxins assisting with compliance with the Stockholm Convention.

Actions specific to air emissions from combustion facilities include:

- Governments to adopt or reaffirm 0.1 ng TEQ/m³ as a guideline emission level for new combustion facilities and for existing combustion facilities when they are upgraded.
- Governments to use recommendations in the Stockholm Convention Best Available Techniques and Best Environmental Practices guidance for new facilities and for existing facilities when they are upgraded.

Table 9.5 Top 25 Emissions Estimates of Dioxins

Source Category	Annual Estimated Release (g TEQ/annum)			
	Air	Water	Land	Total ^a
Biomass burning (includes prescribed burning)	240	0	1,020	1,270
Pulp and paper production	0.4	0.2	103	104
Waste burning and accidental fires	88	0	8.7	97
Zinc production	50	0	0	50
Fossil fuel power plants	14.3	0	27.7	42.0
Aluminium production	4.45	0	31.80	36.26
Sewage and sewage treatment	0	0.9	33	34
Metal ore sintering	32	0	0	32
Medical waste incineration	6.39	0.36	21.9	28.7
Household heating and cooking with biomass	20.2	0	1.6	21.8
Iron and steel production plants	20.3	0	0.03	20.3
Copper production	1	0	13	14
Composting	0	0	7.3	7.3
Diesel engines	5.4	0	0	5.4
Other non-ferrous metal production	4	0	0	4
Heavy oil fired engines	3	0	0	3
Domestic heating and cooking with fossil fuels	0.4	0	2.5	2.9
Open water dumping	0	1.5	0	1.5
Ceramics production	1	0	0	1
Lead production	0.5	0	0	0.5
Cement production	0.48	0	0	0.48
Crematoria	0.3	0	0.15	0.46
4-Stroke Engines	0.3	0	0	0.3
Landfills and waste dumps	0	0.2	0	0.2
2-Stroke engines	0.2	0	0	0.2
Other	0.06	0.05	0.7	0.9
Total	500	3.2	1,271	1,778

10. Air Dispersion Model

10.1 Analytical Model

TAPM (The Air Pollution Model) a CSIRO developed meteorological and dispersion model was used to accurately account for complex terrain effects in this region and the development of the preprocessing spatially varying hourly meteorological data. The TAPM model produces meteorological data, upper air information and temperature profiles for the simulation period in three dimensions for all the grid points across the domain. The gridded meteorological data generated by TAPM is calculated from the synoptic information determined from the six hour interval limited area prediction system (LAPS) (Puri K, Les L, Davidson N, Naughton M, 1998). This final meteorological data is representative of the local topography, land use, surface roughness and temperature effects caused by water bodies.

The TAPM nesting grid or mesh was determined for this model via the consideration of the required terrain resolution in the radius of influence (approximately 20km). Due to the gentle, 'rolling' gradient of the hills the required terrain resolution was achieved via the use of nested grid with a minimum spacing of 600m. The dispersion grid was modelled with still smaller a grid spacing due to the fact that good near field source resolution was required; the nearest receiver being only 1.4km from the site. When running the TAPM dispersion model the hybrid Lagrangian/Eulerian mathematical option was selected. This was done so as to allow for more accurate near field resolution (<1 km). However due to the increased computational expense involved with the Lagrangian model and the fact that these two models converge in the far field the hybrid option was selected.

10.2 Modelling of Atmospheric Chemistry

Sulphur dioxide, nitrogen dioxide and ozone all undergo complex chemical transformations in the atmosphere that leads to the production and destruction of the stated compounds. This section seeks to briefly describe these complex processes as well as explain the manner in which the simulation tool takes these factors into account.

Oxides of nitrogen consisting of nitric oxide (NO) and nitrogen dioxide (NO₂) are formed in the combustion process within the power station boiler in the prevailing high temperature environment. Typically the ratio of NO to NO_x production in power station combustion systems is 0.9, i.e. 90% of the stack emissions consists of nitric oxide. Following the emission of these compounds into the environment NO is oxidised via reactions with oxygen and highly reactive peroxyacetyl radicals. This radical pool (RP) is formed via the photochemical reactions between volatile organic compounds (VOCs) in the presence of sunlight ($h\nu$) (Eq. (1),). TAPM uses the R_{smog} parameter to describe emissions of VOCs within the modelling domain, the R_{smog} emission rate is defined as the product of the calculated VOC emission and a numerical factor of 0.0067. This radical pool (RP) then reacts with NO to produce NO₂ (Eq. (2)). Following the cycle NO₂ then photodissociates to NO and ozone (O₃), leading to the production of O₃ in the atmosphere. The ozone then becomes a reactant in a further chemical reaction producing NO₂ via the process described in Eq. (4) of . These reactions are not instantaneous but occur over several hours through the course of the day. Furthermore as some of these reactions are photolytic, the reaction rates are hence more significant through different periods of the day. Other reactions involving NO₂ shown in , (ie Eq. (6) and (7)) lead to the destruction of NO₂ in the presence of the highly reactive radical pool and lead to the the formation of stable non-gaseous nitrogen compounds. The reactions described so far form the generic reaction set that is used by TAPM to take into account the production and destruction of nitrogen dioxide, nitric oxide and ozone in the atmosphere.

However if the simulation is run in the mode that includes emissions of sources of sulphur dioxide (SO₂) with chemistry, then up to ten reactions involving thirteen different species take place. SO₂ is reduced by the radical pool and in the presence of hydrogen peroxide to stable non-gaseous sulphur compounds (- Eq (5),(8) and (9)). In addition ozone also reduces sulphur dioxide to these non-gaseous (particulate) sulphur compounds (SNGS). It is important to run the simulation in this mode to determine the cumulative impact of the power station in the local environment. With the inclusion of current established sources the total pollutant load in the atmosphere will increase; hence in order to determine the synergetic chemical affects of this increased pollutant load it is important that these chemical reactions be taken into account in an atmospheric dispersion simulation. However the next two paragraphs will explain situations where such a detailed analysis is not always necessary.

Table 10.1 Generic Reaction Set (GRS) chemical reactions.

Eq. No.	Reactions
1	$R_{\text{smog}} + h\nu \rightarrow \text{RP} + R_{\text{smog}} + \text{SNGOC}$
2	$\text{RP} + \text{NO} \rightarrow \text{NO}_2$
3	$\text{NO}_2 + h\nu \rightarrow \text{NO} + \text{O}_3$
4	$\text{NO} + \text{O}_3 \rightarrow \text{NO}_2$
5	$\text{RP} + \text{RP} \rightarrow \text{RP} + \alpha\text{H}_2\text{O}_2$
6	$\text{RP} + \text{NO}_2 \rightarrow \text{SGN}$
7	$\text{RP} + \text{NO}_2 \rightarrow \text{SNGN}$
8	$\text{RP} + \text{SO}_2 \rightarrow \text{SNGS}$
9	$\text{H}_2\text{O}_2 + \text{SO}_2 \rightarrow \text{SNGS}$
10	$\text{O}_3 + \text{SO}_2 \rightarrow \text{SNGS}$

(1) RP – radical pool

(2) SNGS – stable non-gaseous sulphur products

(3) SNGN – stable non-gaseous nitrogen products

(4) SNGOC – stable non-gaseous organic carbon

Several methods were employed in the analysis of cumulative ground level concentrations of SO₂ and NO₂ for the proposed facility. Sulphur dioxide ground level concentrations were initially predicted without taking into account the chemical transformations described above. However if it can be reasonably justified that emissions are sufficiently low to suffice not performing the detailed photochemical modelling the described non-chemistry mode will predict worst-case impacts with good accuracy. This is an attractive option as it is computationally inexpensive. However chemistry and non-chemistry runs were completed for the analysis of both pollutants, the results of which are discussed in **Section 13.1.1**.

There are several methodologies used to predict NO₂ levels other than the simple non-chemistry option. The chemistry method is not always necessary to accurately determine the amount of NO and NO₂ within the plume at any time, because simpler methods have been found to be adequate in most situations. The simplest is to assume that all of the NO_x emitted from the Power Plant is NO₂. This is an extreme case and is unlikely to ever occur for an extended period of time in practice. Several methodologies were adopted in this case, including the simplest method described, the ozone limiting method, and two scenarios of the generic reaction set chemistry method (described in more detail in **Section 13.1.2**). The ozone limiting method developed by the US EPA assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the O₃ or all of the NO is exhausted. One fallacy of this method is that the atmospheric reaction is assumed to be instantaneous, but in reality these reactions take place over several hours. In order to calculate the total NO₂ concentrations from the OLM method one has to assume background levels of O₃ and NO₂, as well as predict the maximum NO_x concentration in the atmosphere, which can be done through simulation. The equation below describes the calculation of ground level NO₂ concentrations using the OLM method.

$$[NO_2]_{\text{total}} = \{0.1 \times [NO_x]_{\text{pred.}}\} + \text{MIN}\{(0.9) \times [NO_x]_{\text{pred.}} \text{ or } (46/48) \times [O_3]_{\text{bkgd.}}\} + [NO_2]_{\text{bkgd.}}$$

(Subscripts pred = predicted, bkgd = background)

The above is a brief introduction to the atmospheric chemical processes that have been modelled and an introduction to different methodologies that are employed to accurately predict worst-case cumulative ground level concentrations of compounds such as NO₂ and SO₂ which are significantly affected by atmospheric chemical transformations.

10.3 Model Configuration

A basic summary of the data and parameters used in both the meteorological and dispersion parts of the TAPM model are shown in **Table 10.2**. The parameters for the proposed stack emissions as configured within TAPM are shown below in **Table 10.3**.

Table 10.2 TAPM Biomass Power Station input parameters

Location (Grid Centre)	(418028,6200357)	
Dates	2001 (GMT +7.7)	
	Meteorology	Dispersion
Grid	41 x 41 x 25 (nx x ny x nz)	73 x 73 (nx x ny)
Nesting	20 – 5 – 1.8 – 0.6 km	10 – 2.5 – 0.9 – 0.3 km
Chemistry Mode (*)	Rsmog = 0.3 ppb, Ozone = 20 ppb (**)	

(*) Relevant to modes run with atmospheric chemistry only.

(**) Refer to **Section 12** on existing air quality

Table 10.3 TAPM point source input parameters for the proposed Biomass Power Station

Location (UTM Zone: 50)	(418028,6200357)
Stack height	40m
Stack Diameter	3.0 m
NO-NO_x Ratio	0.9
Exit Velocity	15 m/s
Exit Temperature	418 K
NO_x Emission Rate	26.9 g/s
SO₂ Emission Rate	6 g/s
PM10 E mission Rate	1.8g/s
PM2.5	1.4g/s
Computation	Eulerian/Lagrangian Grid Mode

In addition to these parameters several scenarios of the pollution model were run in TAPM with both the GRS chemistry and 'tracer' non-chemistry runs. Furthermore to achieve cumulative results, ie those that take into account the presence of pre-existing environmental and anthropogenic sources of nitrogen oxides and sulphur dioxide an industrial point source and gridded source emissions of biogenic and anthropogenic source emission files were included. These biogenic/anthropogenic gridded source emissions and major established industrial point sources were discussed in detail in **Section 7** and their configuration in TAPM are detailed below in **Table 10.4** and **Table 10.5**.

Table 10.4 TAPM gridded source emissions parameters

Emissions	Initialisation Grid	NO_x Emission Rate (g/s/grid point)	VOCs Emission Rate (g/s/grid point)
Biogenic	t100a	0.1	0.24
Anthropogenic	t010a	0.01	0.0

Table 10.5 TAPM point source input parameters for Collie industrial NO_x emissions.

Location (UTM Zone: 50)	(435785, 6298979)
Stack height	120 m
Stack Diameter	5.0 m
NO-NO_x Ratio	0.9
Exit Velocity	20 m/s
Exit Temperature	418 K
NO_x Emission Rate	1098 g/s
SO₂ Emission Rate	2256 g/s
Computation	Eulerian Grid Mode

10.4 Background Concentration

Background concentrations of pollutants are included using the following methods:

- **Nitrogen Dioxide:** Background concentrations were calculated within TAPM based on gridded biogenic and anthropogenic emissions, as well as nearby point sources (ie. Collie region). These were compared with the background concentrations measured in Bridgetown (refer to **Section 12.1**), with the maximum statistical value used in the OLM method. Background concentrations were also predicted from regional emissions included within TAPM and modelled using GRS mode.
- **Ozone:** Peak background concentrations for Ozone, were predicted from regional emissions and the proposed plant emissions, included within TAPM and modelled using GRS mode. The statistical values were checked by comparison with background concentrations as measured by the Department of Environment and Conservation (DEC) as part of compliance testing for NEPM criteria for a similar setting (ie. Rolling Green).
- **Sulphur Dioxide:** Background concentrations were predicted using the GRS mode within TAPM, as the most significant regional sources are power stations located at Collie.
- **Particulates:** Background concentrations of particulates have been monitored in the environment by the CSIRO (refer to **Section 12.2**). Statistics from these measurements were simply added to the predicted ground level concentrations from the power station, as particulates undergo no chemical transformation.

10.5 Model Verification

Various validation studies have been carried out for TAPM, many of which have been located in Western Australia, demonstrating the accuracy to predict climate conditions (Hurley, PJ, Physick, WL, Cope, ME, 2004). These previous studies provide verification of The Air Pollution Model (TAPM) for a number of laboratory experiments of dispersion, for two US tracer experiments (Kincaid and Indianapolis) used internationally for model intercomparison studies, and for meteorology and/or dispersion in various regions throughout Australia (Anglesea, Kwinana, Kalgoorlie, the Pilbara and Melbourne).

The meteorological results show that TAPM performs well in a variety of regions throughout Australia (e.g., coastal, inland and generally complex terrain for sub-tropical to mid-latitude conditions). The pollution results show that TAPM performs well for a range of important phenomena (e.g. concentration variance and fluctuation intensity; building wakes; nocturnal inversion break-up fumigation; stable, neutral, and convective dispersion; shoreline fumigation; and general dispersion in complex rural and urban conditions). In particular, TAPM performs very well for the prediction of extreme pollution statistics, important for environmental impact assessments, for both non-reactive (tracer) and reactive (nitrogen dioxide, ozone and particulate) pollutants for a variety of sources (e.g. industrial stacks and/or general surface or urban emissions).

11. Meteorology

Ground-level concentrations resulting from a constant discharge of contaminants change according to the weather (particularly the wind and stability) conditions at the time. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the dilution effect of the atmosphere. Therefore, it is important that meteorology is carefully considered when modelling plume dispersion.

Plume rise at the release point is affected by ambient temperature and relative humidity at the release point. Plume dispersion over distance is affected by:

- Wind speed, profile and turbulence intensity (which are affected by terrain);
- Temperature gradient which is determined from atmospheric stability (which in itself is determined from wind speed, cloud cover and solar radiation); and
- Mixing height.

Pollutant concentrations are also affected by atmospheric chemistry through photochemical reactions, therefore solar radiation is also a consideration. Wet deposition of pollutants is affected by rainfall.

Measured meteorological conditions were simulated for a full year, with 2001 selected as the test year. An assessment of the appropriateness for using 2001 as the test year follows through comparison with the closest Bureau of Meteorology (BOM) Automatic Weather Station (AWS) to the site, located at Manjimup. The long term average meteorological data (BoM) for this site is presented in **Table 11.1** and discussed in the sections to follow.

11.1 General Meteorology

The mean maximum and minimum monthly temperatures for 2001 are compared to the long term meteorological data in **Figure 11.1** and **Figure 11.2**. The averaged monthly minimum and maximum temperature profiles for 2001 are well correlated with the respective long term average, and do not indicate that 2001 was an unusual year.

Humidity is recorded at 9am and 3 pm. While humidity does not have a significant impact on air quality dispersion models, the comparison of long term averaged mean monthly 9 am and 3 pm data presented in Figure 11.3 and Figure 11.4 with 2001 data shows good correlation with the exception for April which may have been a dry month resulting in potentially increased concentrations.

The long term averaged mean monthly number of cloudy days relative to 2001 data is presented in Figure 11.5, and does not show any abnormal differences to between the two data sets. However August, September and December show an increased number of cloudy days which may reduce solar radiation and lead to increased atmospheric stability resulting in increased pollutant concentrations.

The long term averaged monthly rainfall relative to 2001 data is presented in Figure 11.6, and suggests that rainfall for 2001 was generally below the long term average. This will likely result in less wet deposition than otherwise, potentially resulting in increased airborne concentrations.

Table 11.1 Long Term Meteorological Data for Manjimup

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temperature (°C)	27.0	26.9	4.7	21.0	17.5	15.2	14.3	14.9	16.4	18.7	21.8	24.8
Mean daily minimum temperature (°C)	13.0	13.3	12.5	10.7	8.9	7.4	6.4	6.5	7.2	8.2	10.1	11.6
Mean 9am relative humidity (%)	65	67	78	84	88	88	85	79	72	67	64	75
Mean 3pm relative humidity (%)	43	42	47	57	65	71	71	67	63	55	51	45
Mean monthly rainfall (mm)	19.5	19.2	30.8	60.3	132.6	166.5	175.7	148.7	109.2	77.9	46.6	24.4
Mean no of rain days	3.4	3.2	5.0	8.2	13.7	16.8	18.6	17.0	14.3	11.3	7.3	4.6
Mean no. cloudy days	7.2	8.2	10.6	13.5	14.8	14.6	15.1	15.0	15.0	14.8	14.2	10.2

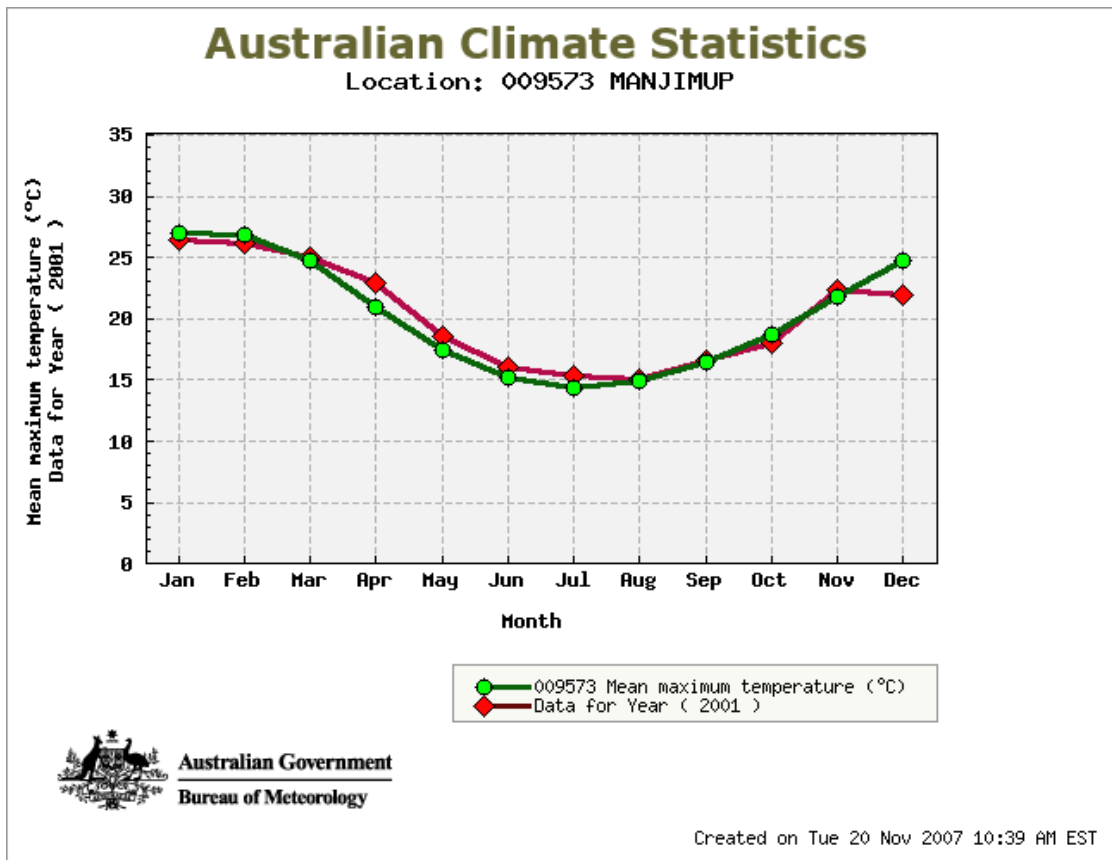


Figure 11.1 Mean maximum temperature compared to mean maximum temperature for 2001.

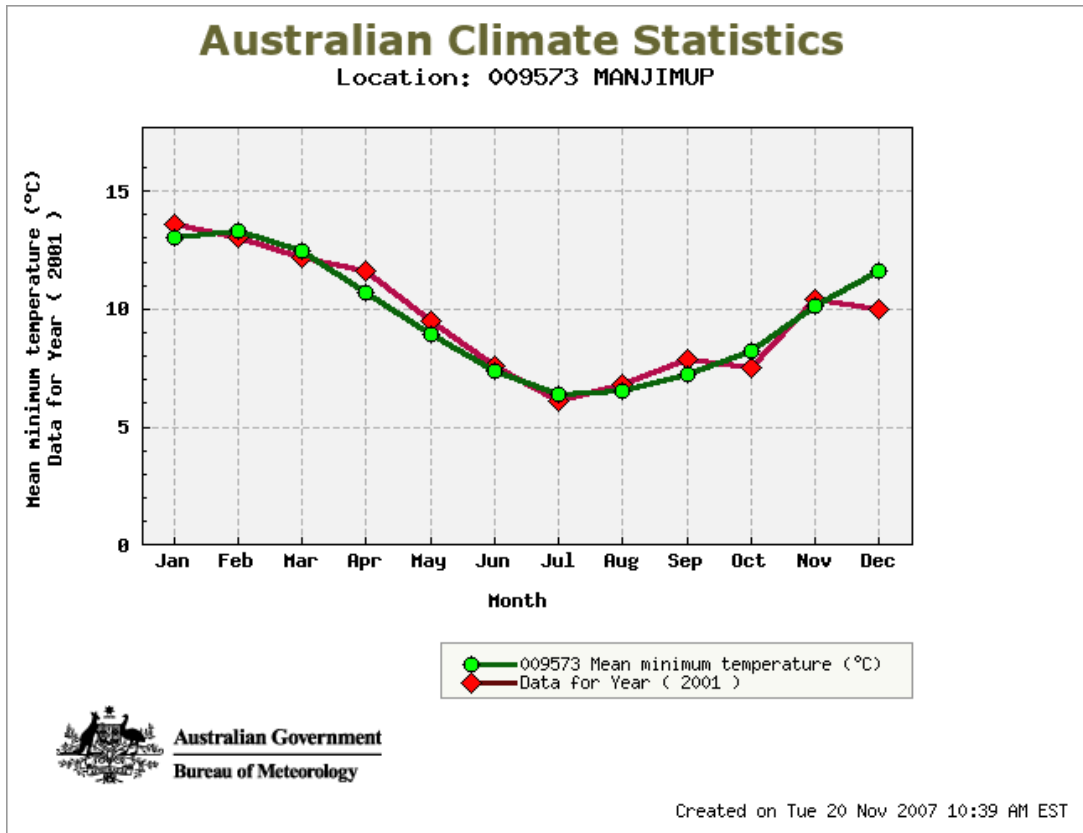


Figure 11.2 Mean minimum temperature compared to mean minimum temperature for 2001.

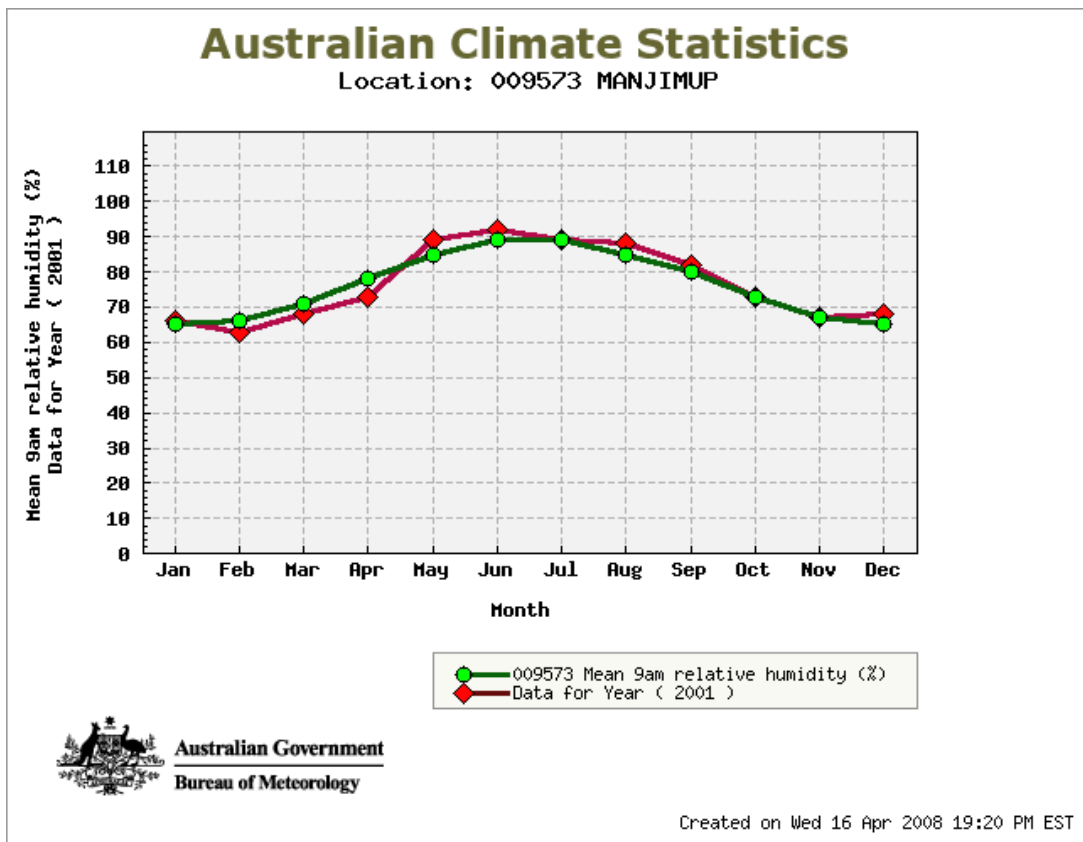


Figure 11.3 Mean long term averaged 9 am relative humidity compared to that for 2001.

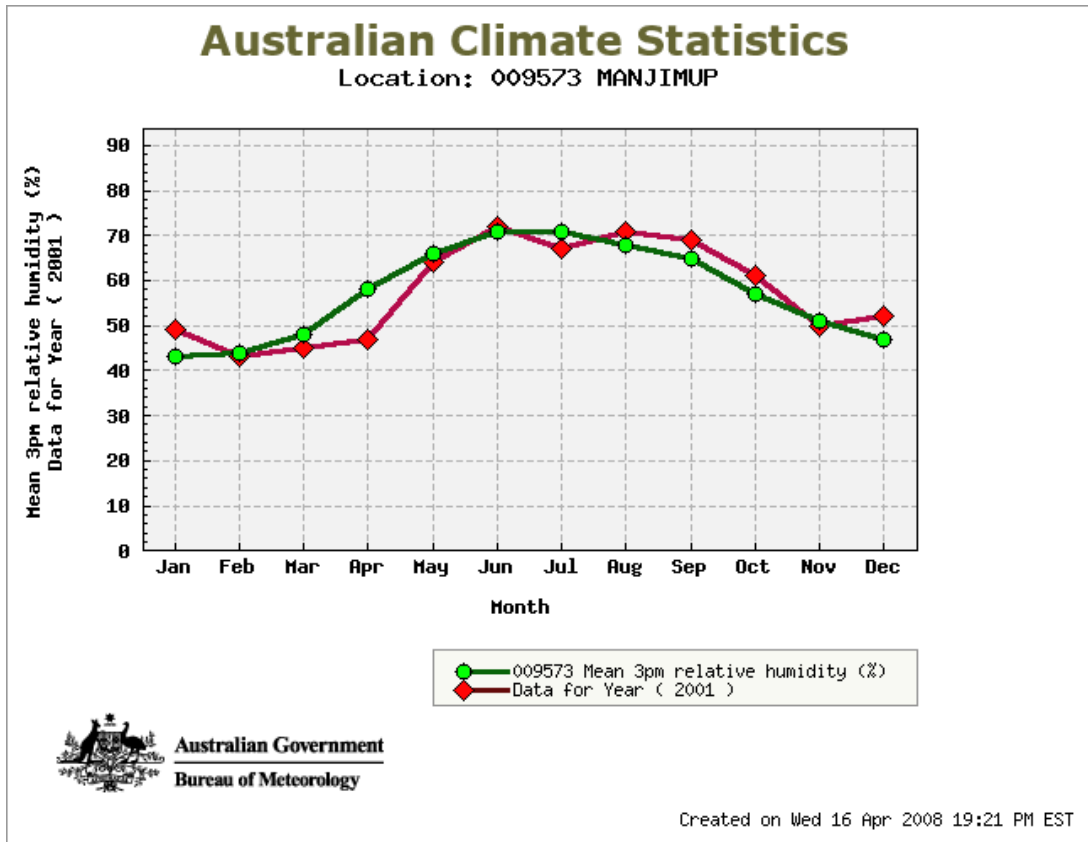


Figure 11.4 Mean long term averaged 3 pm relative humidity compared to that for 2001.

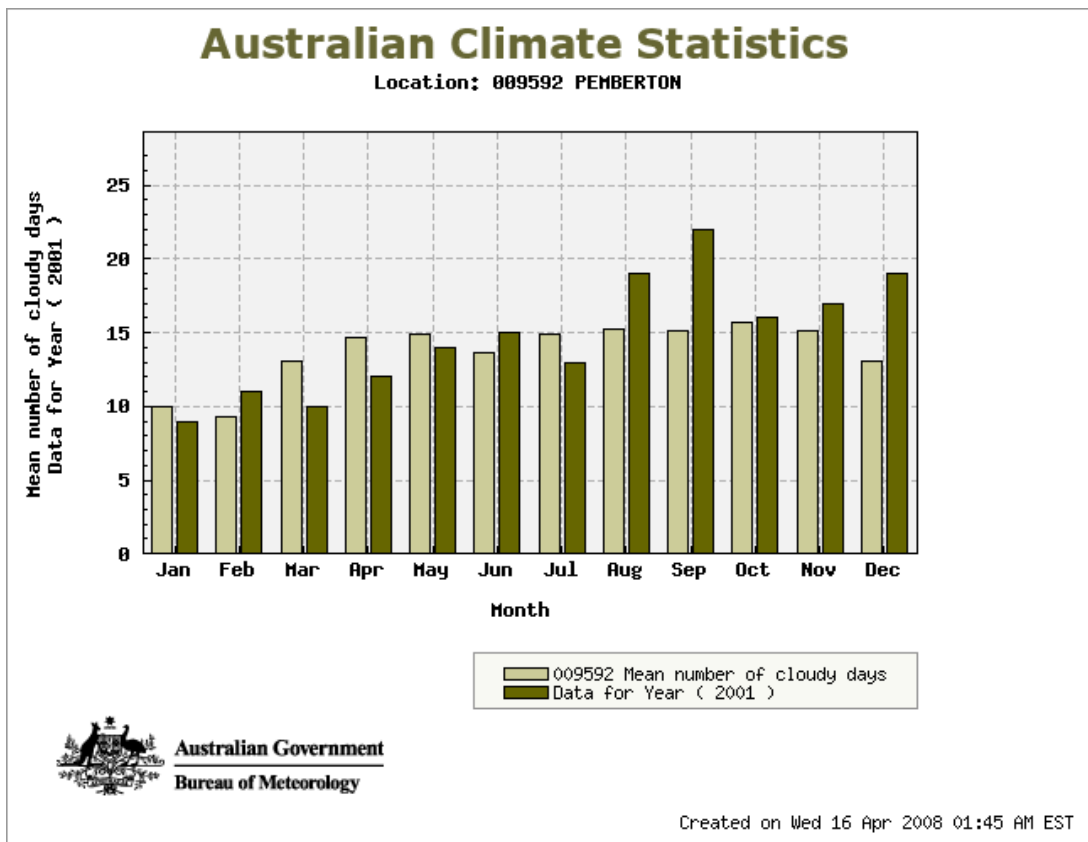


Figure 11.5 Cloud cover for year 2001 compared with the long term average.

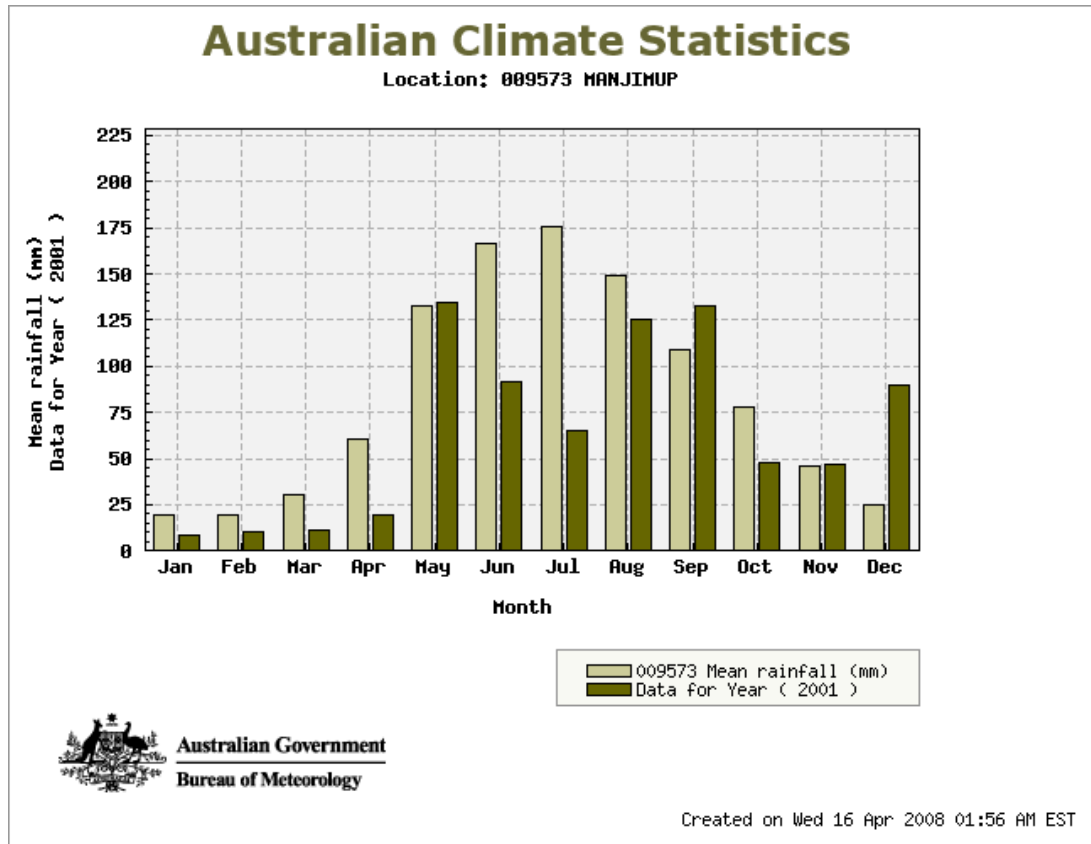


Figure 11.6 Monthly rainfall for year 2001 compared with the long term average.

11.2 Wind

It is normal to measure wind speed at a height of 10m, and adjust the wind speed with height based on the terrain category according to formula used to model the atmospheric boundary layer. In October of 2000, the wind speed measurements were changed from ground level observations, to 30m mast head automated measurements at Manjimup. Hence BOM data for the year 2001 has been amended using the relevant factor from AS1170 to correct for the mean wind speed ratio between 30m and 3m. BOM data for 2001 for Manjimup was also affected by a large number of missing hours at night-time; hence 2002 was used to evaluate the accuracy of TAPM at predicting meteorological conditions.

Data for both 9 am and 3 pm are presented in **Figure 11.7** and **Figure 11.8** with the corrected 30m 2001 BOM data showing good correlation with the long term trend. Hence 2001 can be said to be a representative year. Winds affecting WA are influenced by Tropical Cyclone activity in the North of the state. The long term average number of cyclones is 4, with 5 noted in 2000-01 and 6 in 2001-02, therefore providing some further justification for the use of 2001 as a representative year.

Notwithstanding this, it is also necessary to evaluate:

- wind statistics given the joint probability of wind speed and direction; and
- TAPM's ability to accurately model these statistics

Synoptic data for the South-West of Western Australia was obtained from the BOM and used to configure TAPM to predict meteorological parameters for the year 2002 (given some inadequacies in BOM data for 2001 as measured at Manjimup). The sections below compare TAPM's predicted data with BOM measured data to evaluate the accuracy of TAPM at predicting wind conditions important to ensure a worst case assessment.

11.2.1 Seasonal Conditions

Table 11.2 and **Table 11.3** provide wind roses for all seasons for a comparison between BOM and TAPM:

- Summer : BOM data shows winds are predominantly from the south-east quadrant. Good correlation for both wind direction and wind speeds is obtained
- Autumn : BOM data shows winds are predominantly from the north and east. Reasonable correlation in wind direction with a strong northerly component not predicted by TAPM. The frequency of low wind speeds is underpredicted by TAPM
- Winter : BOM data shows winds are predominantly from the north-west quadrant. Good correlation for both wind direction and wind speeds is obtained
- Spring : BOM data shows winds are predominantly from the west. Reasonable correlation in wind direction with a strong westerly component not predicted by TAPM. The frequency of low wind speeds is underpredicted by TAPM.

Annual wind roses are provided in **Table 11.4** for a comparison between BOM and TAPM. BOM data shows strong north and south components not predicted by TAPM, however other wind directions show a reasonable correlation. The frequency of low wind speeds is underpredicted by TAPM. The annual wind class frequency distribution is shown in **Figure 11.9**, with TAPM data skewed towards higher wind speeds, but notwithstanding this, TAPM provides a reasonable frequency of low wind speeds to enable worst case meteorological conditions for pollutant accumulation.

11.2.2 Diurnal Conditions

Table 11.4 provides wind roses showing variations in diurnal conditions for comparison between BOM and TAPM. Also shown in **Figure 11.10** and **Figure 11.11** are the wind class frequency distributions for daytime and nighttime hours respectively. The annual wind rose in the same Table shows that annual statistics are very similar to for both daytime and nighttime wind direction statistics. However a larger frequency of low wind speeds is observed for nighttime conditions, which TAPM does not predict well.

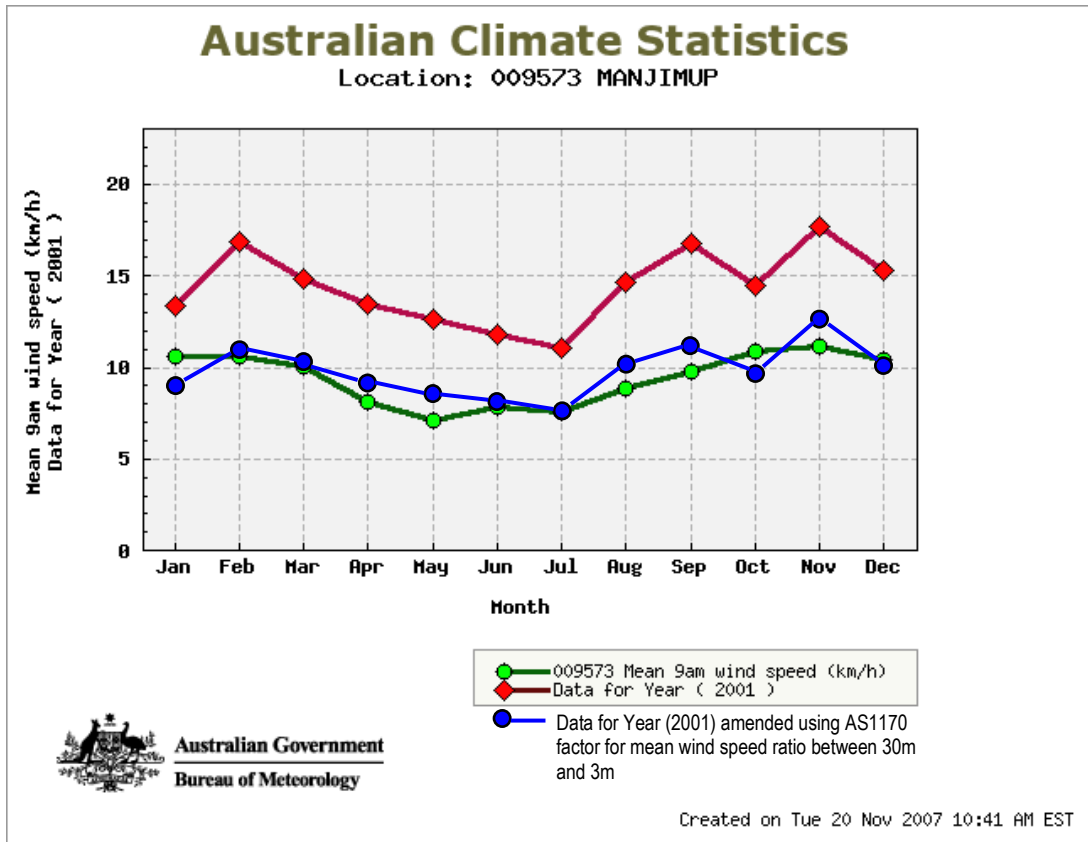


Figure 11.7 Mean 9 am wind speed compared with 2001 data.

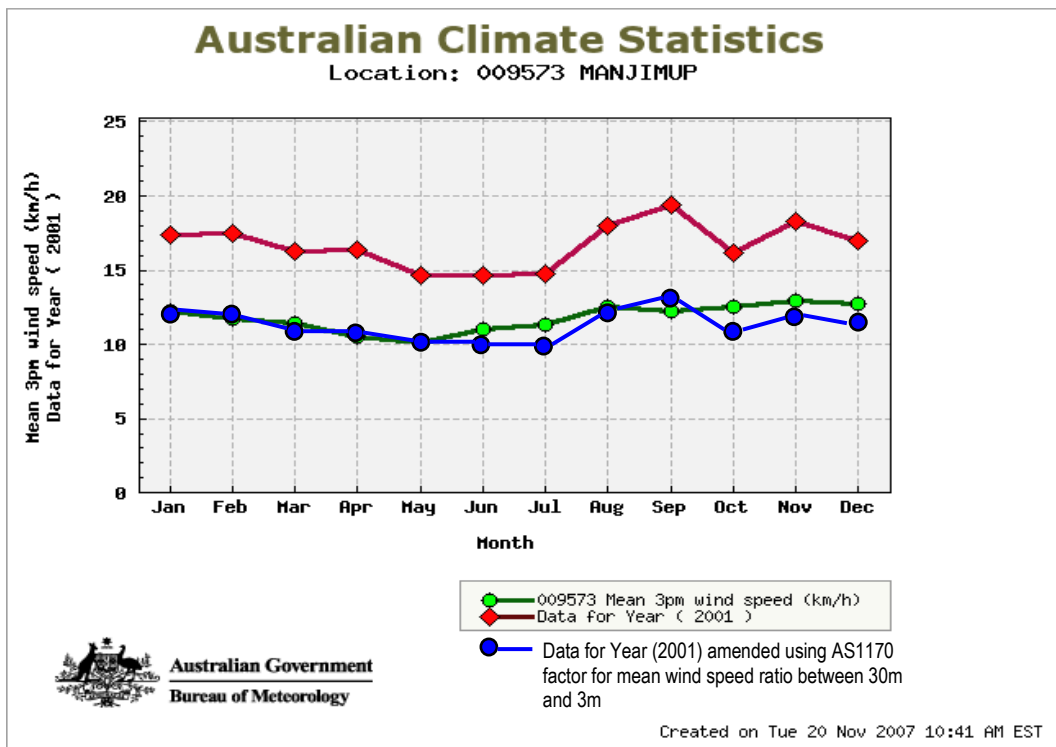
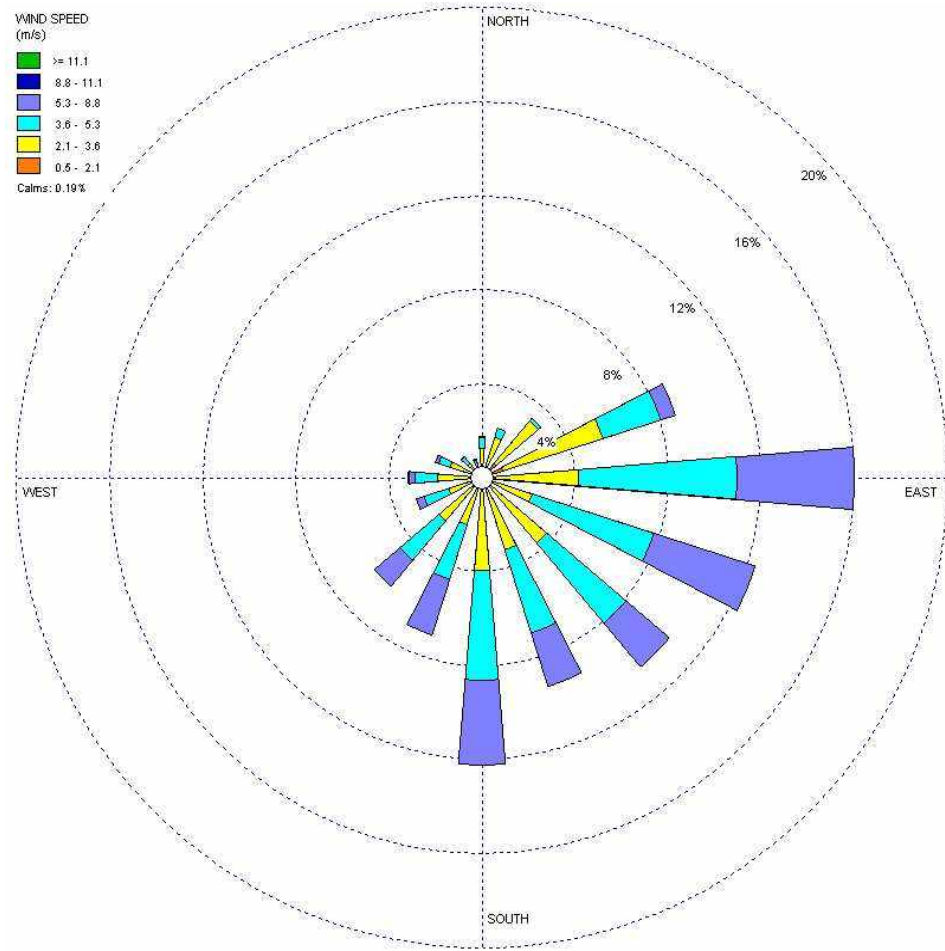


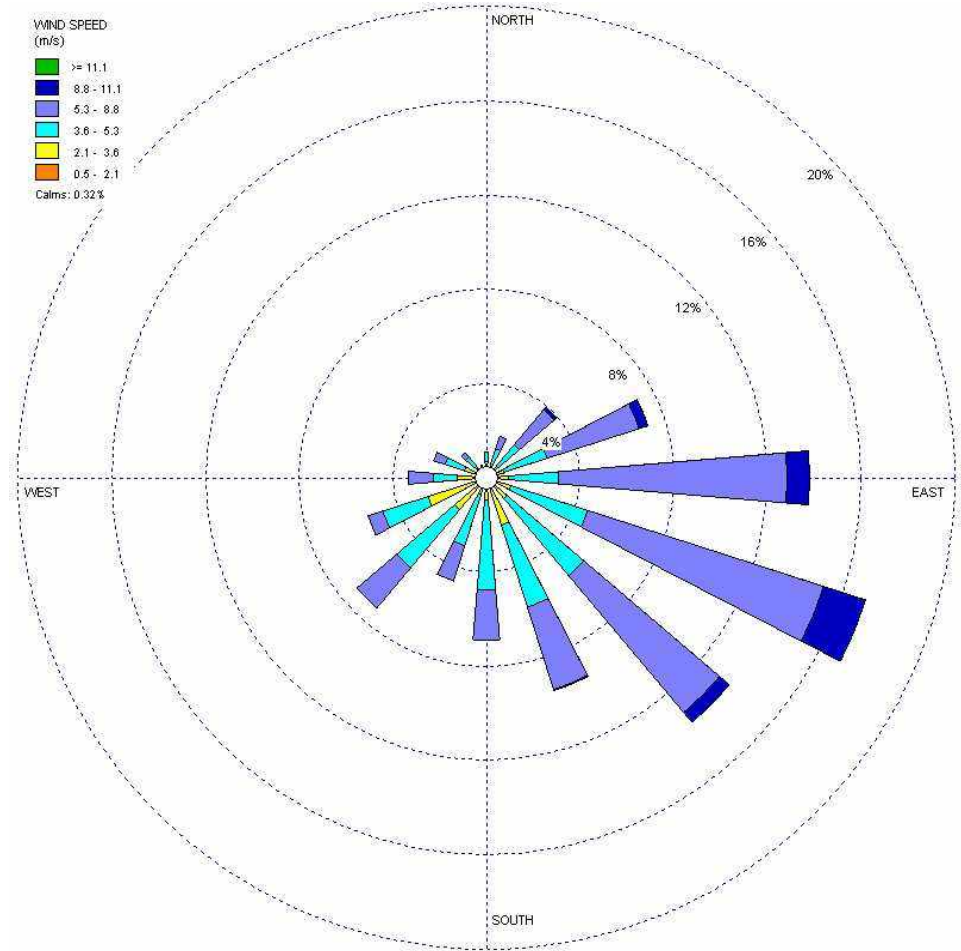
Figure 11.8 Mean 3 pm wind speed compared with 2001 data

Table 11.2 Seasonal Wind Rose Comparison (2002)

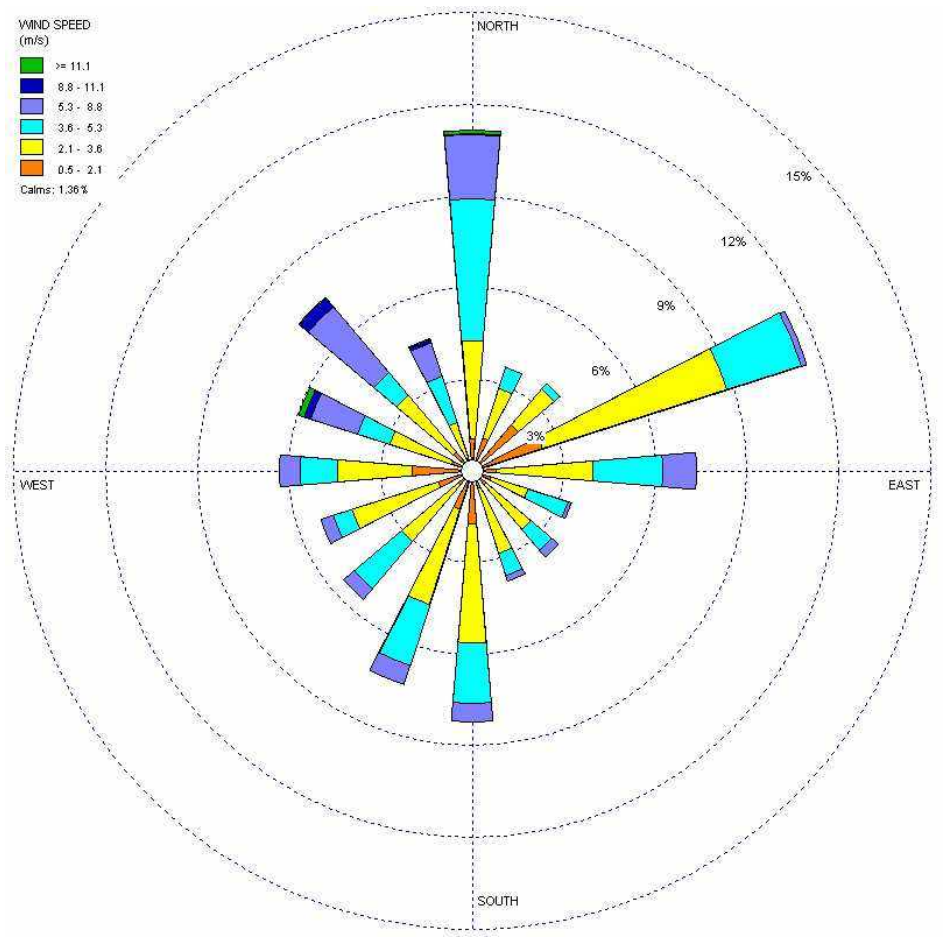
Summer-BOM



Summer-TAPM



Autumn-BOM



Autumn-TAPM

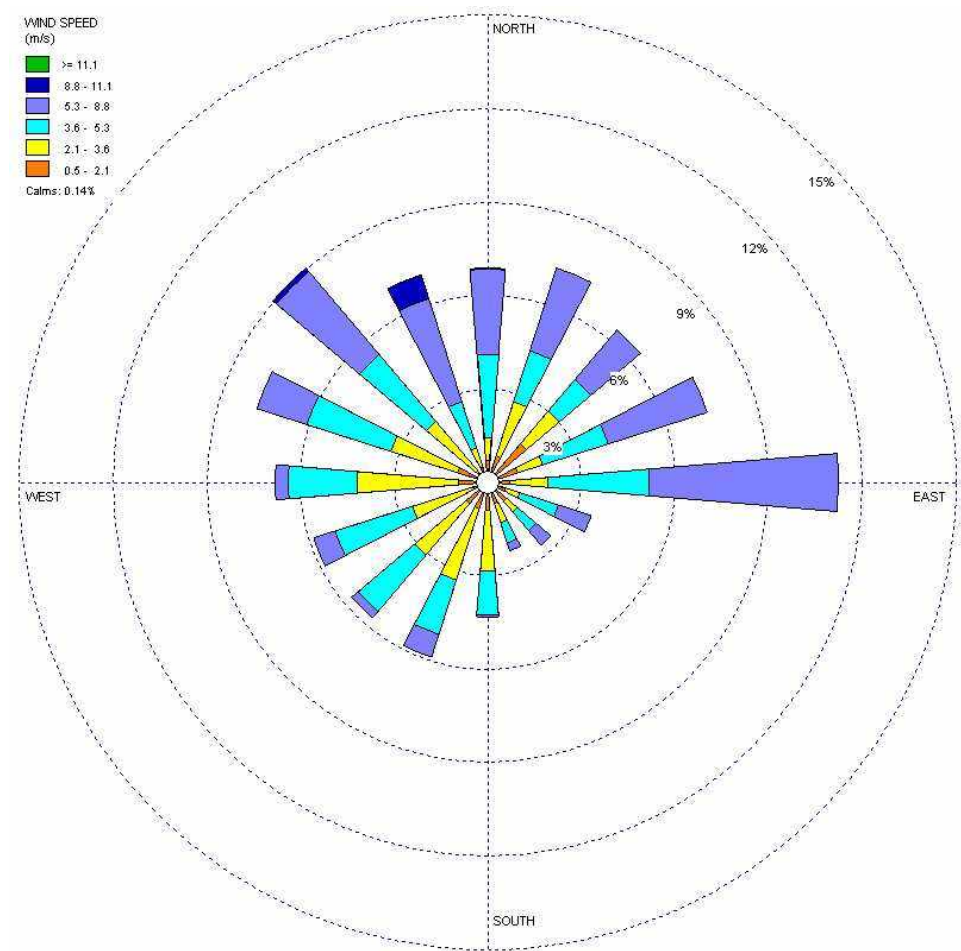
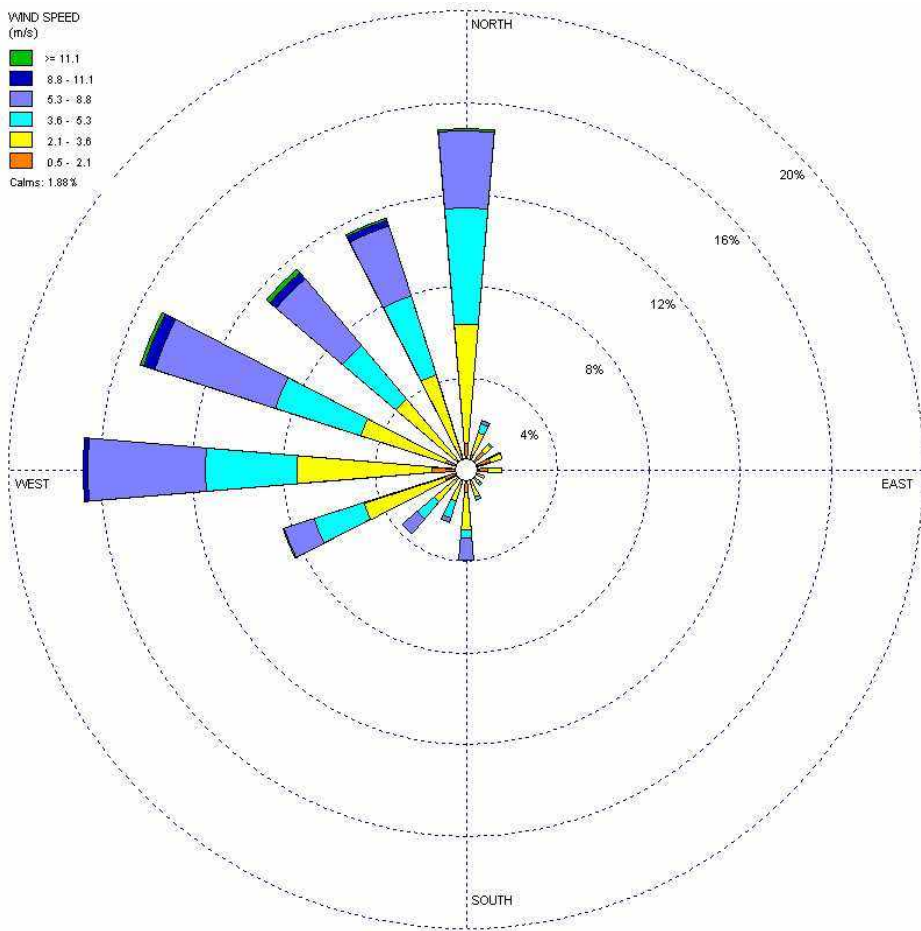
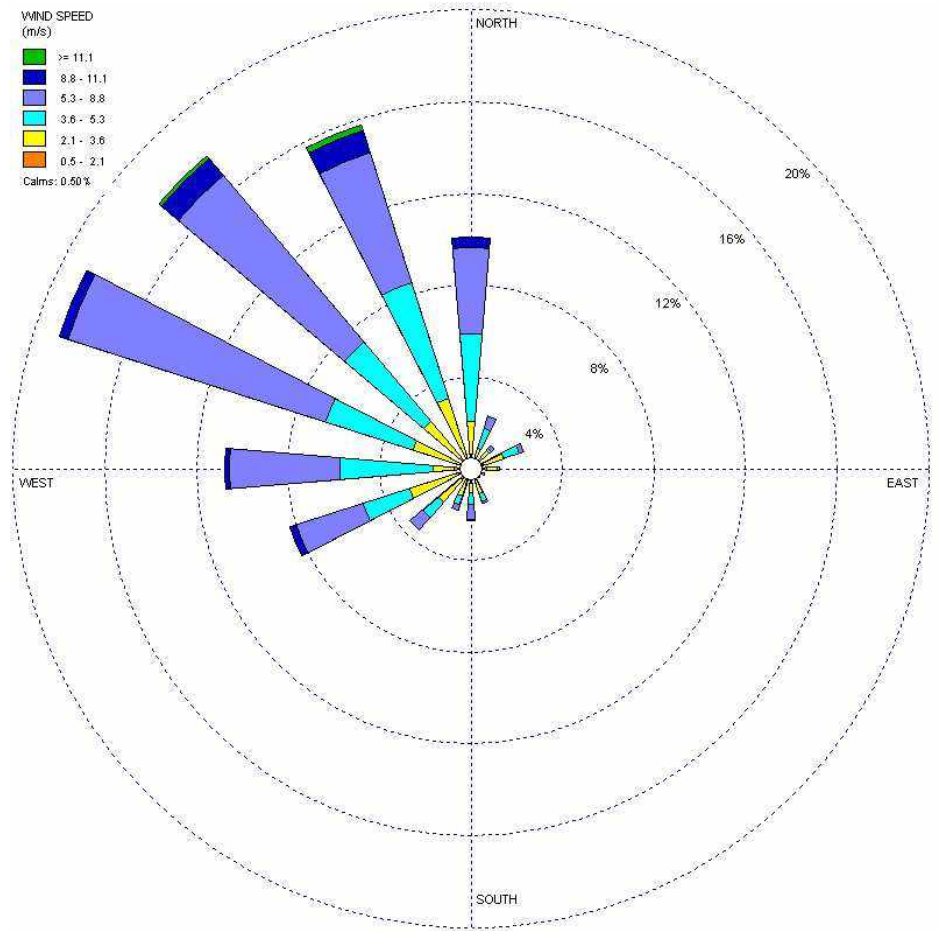


Table 11.3 Seasonal Wind Rose Comparison (2002)

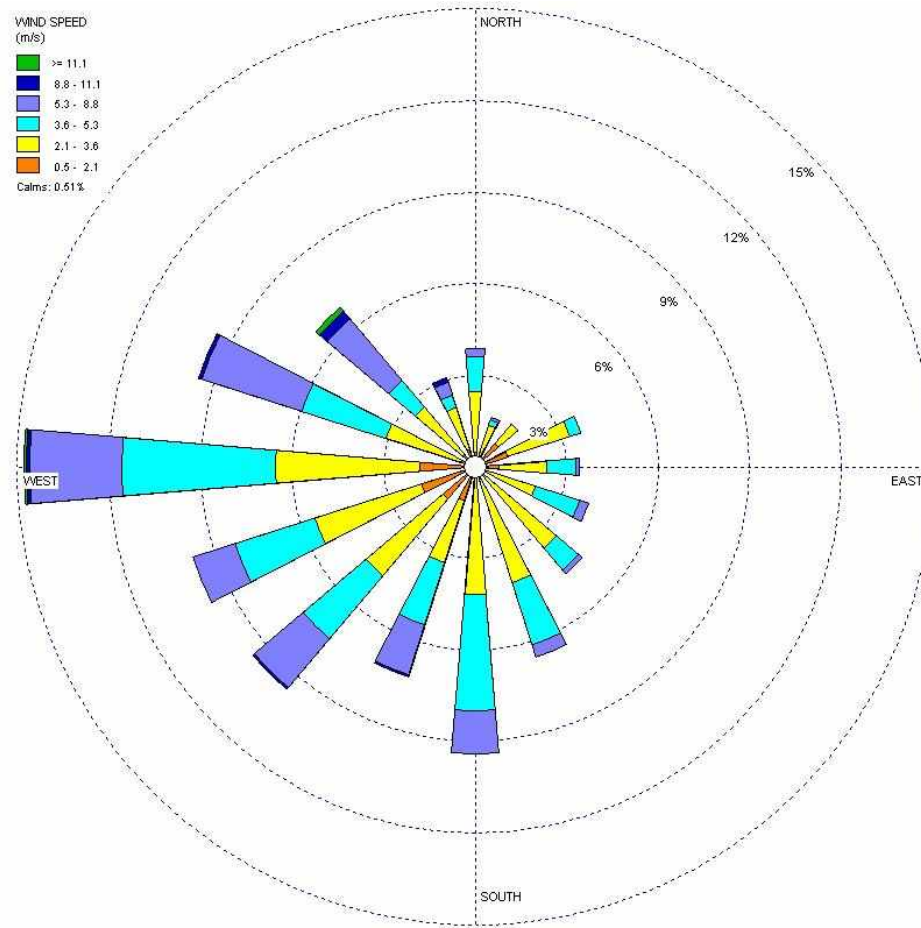
Winter-BOM



Winter-TAPM



Spring-BOM



Spring-TAPM

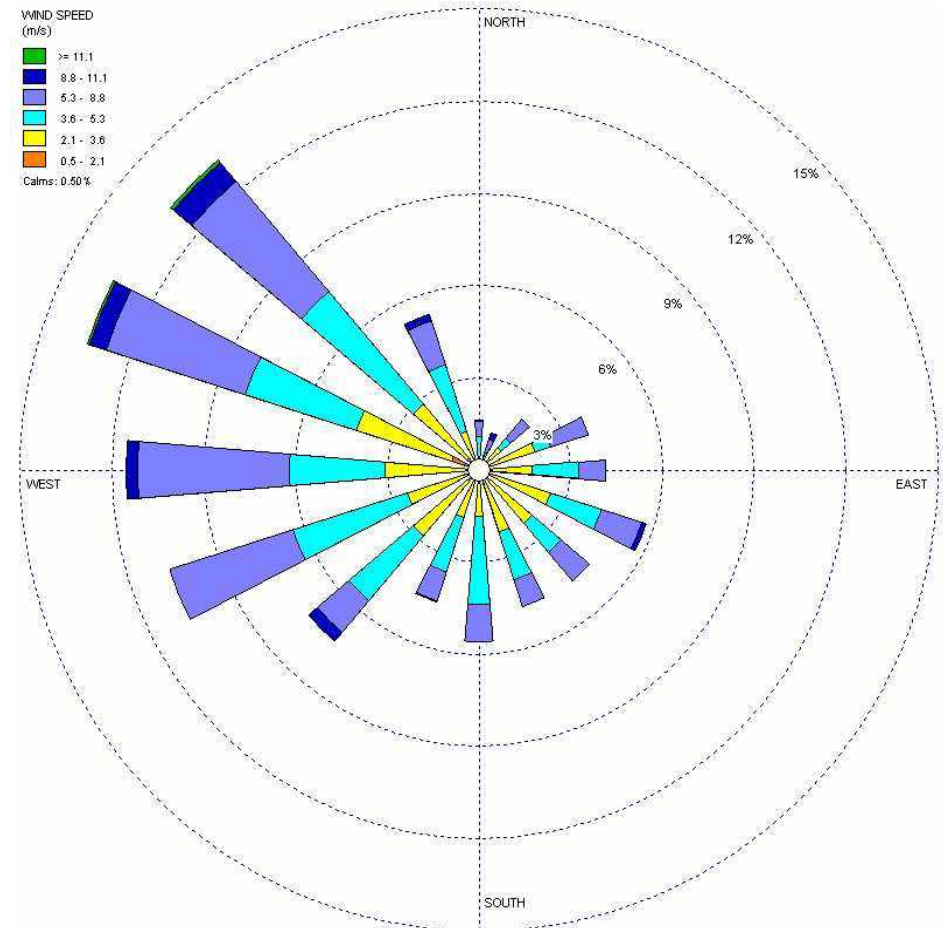
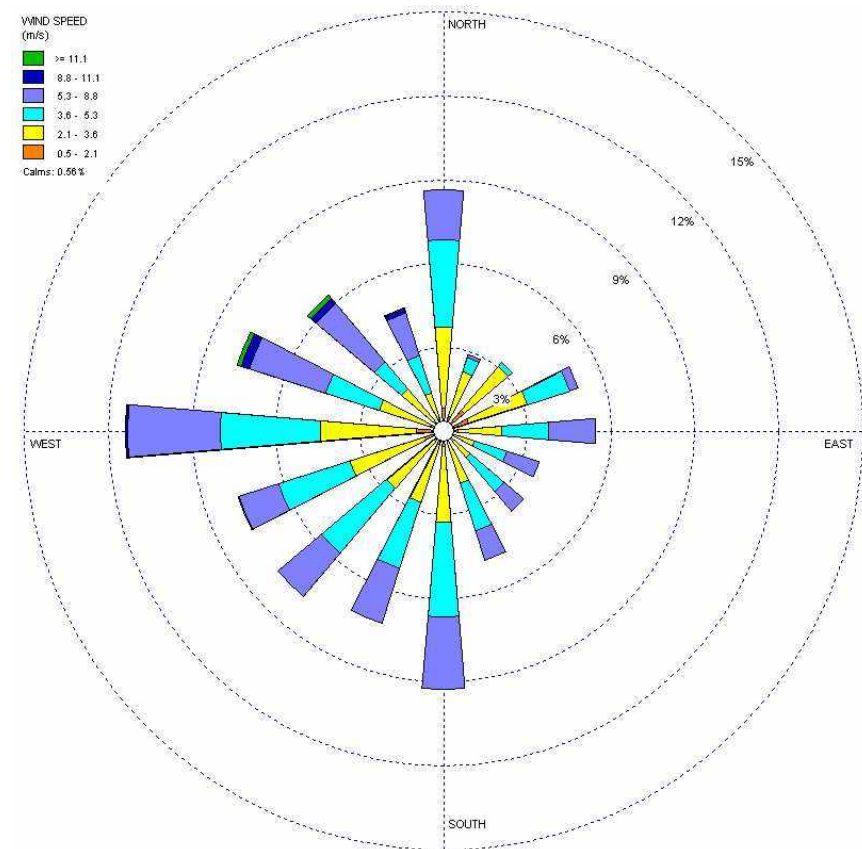
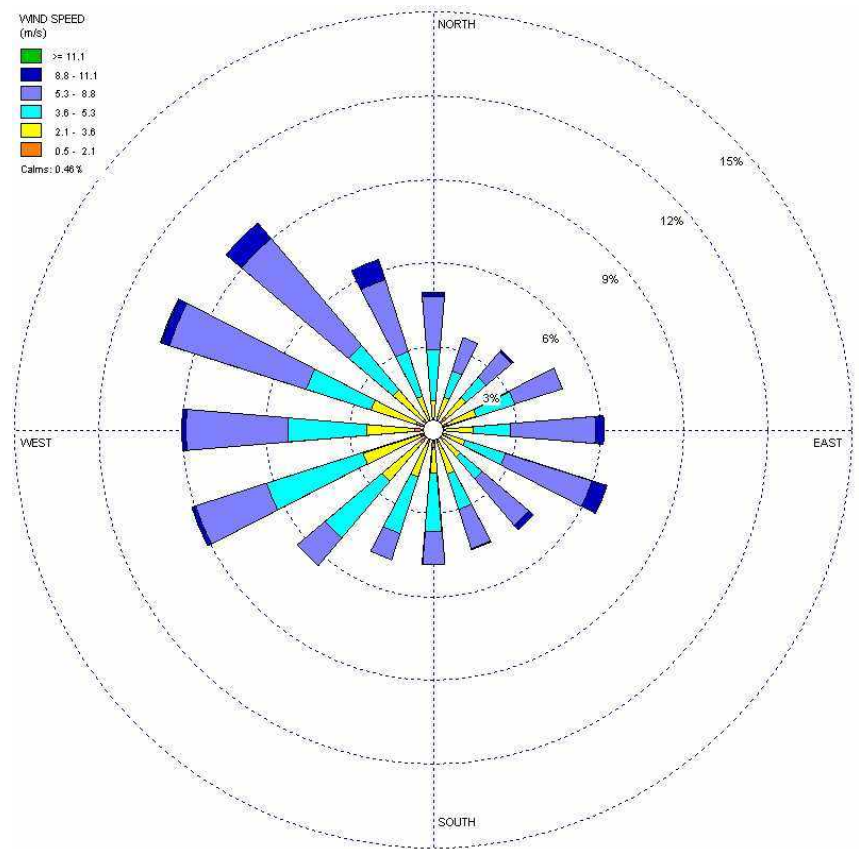


Table 11.4 Comparison of Wind Roses for Daytime (7 am - 7 pm), Nighttime (8 pm – 6 am) and Annual (2002)

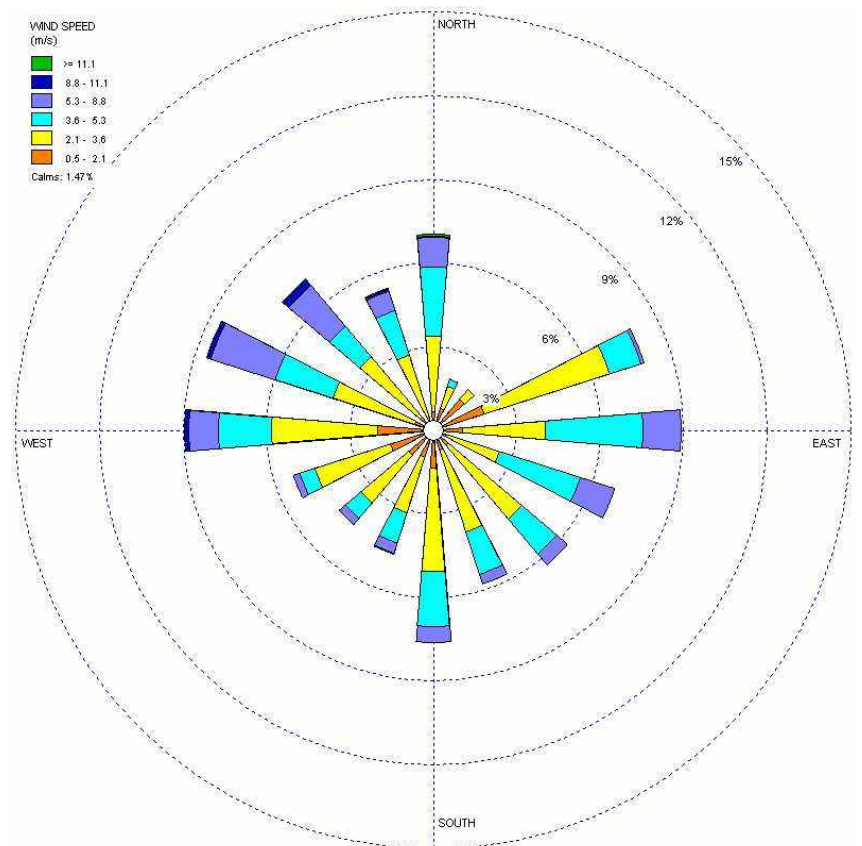
Daytime-BOM



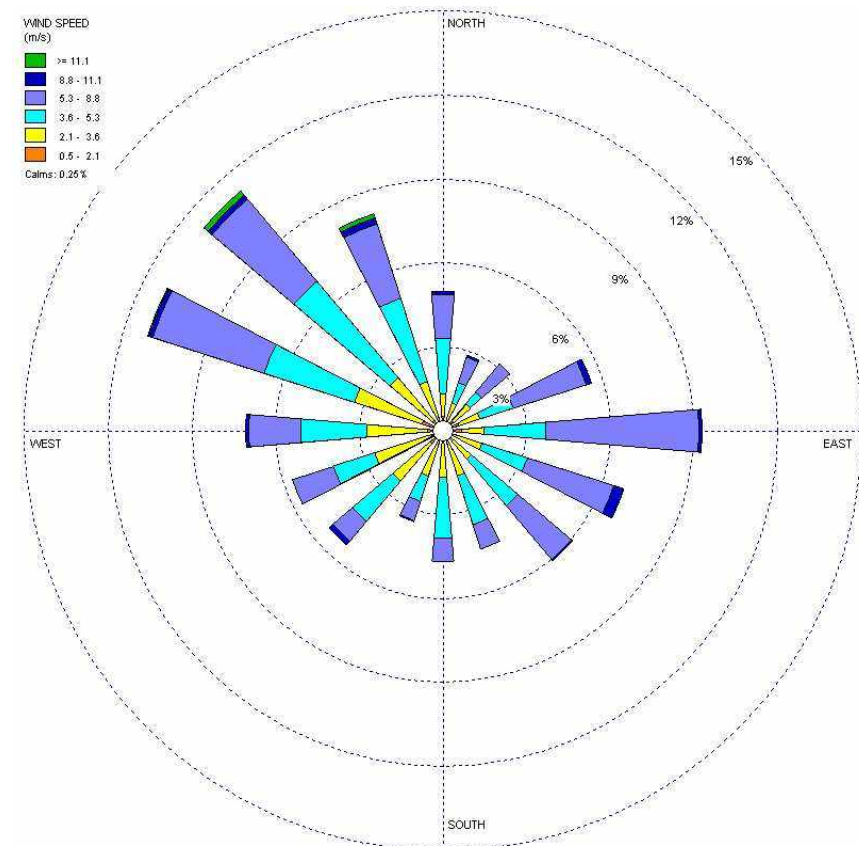
Daytime-TAPM



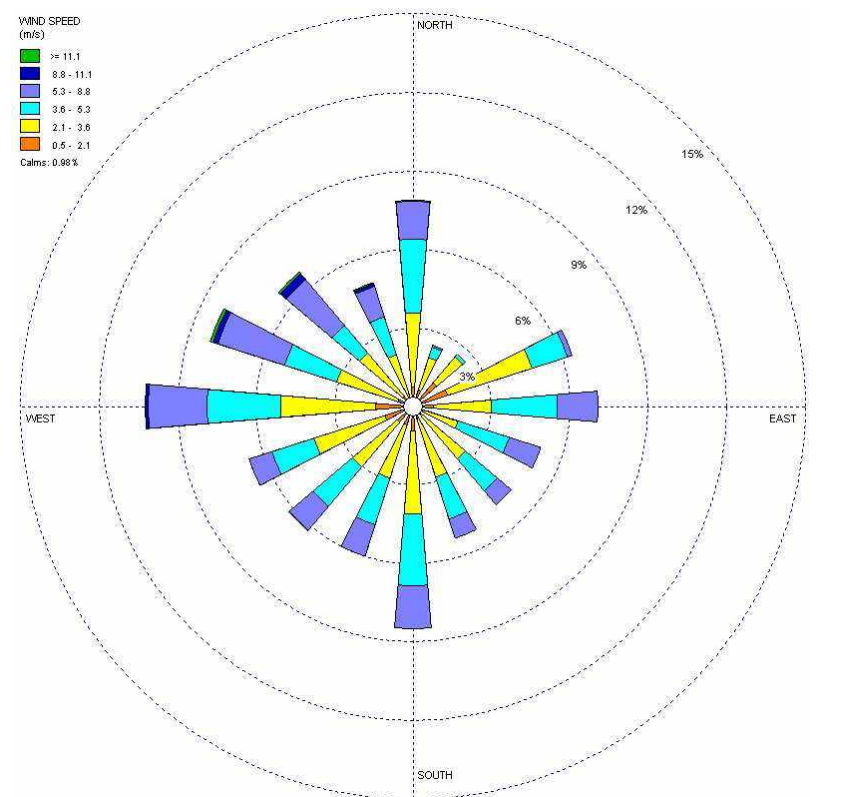
Nighttime-BOM



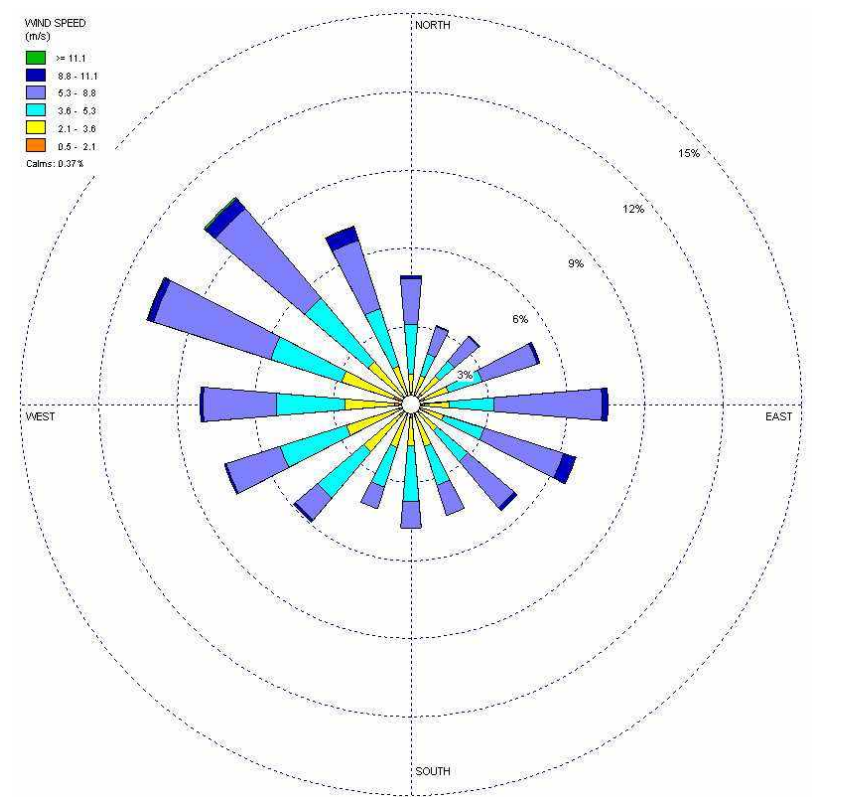
Nighttime-TAPM



Annual-BOM



Annual-TAPM



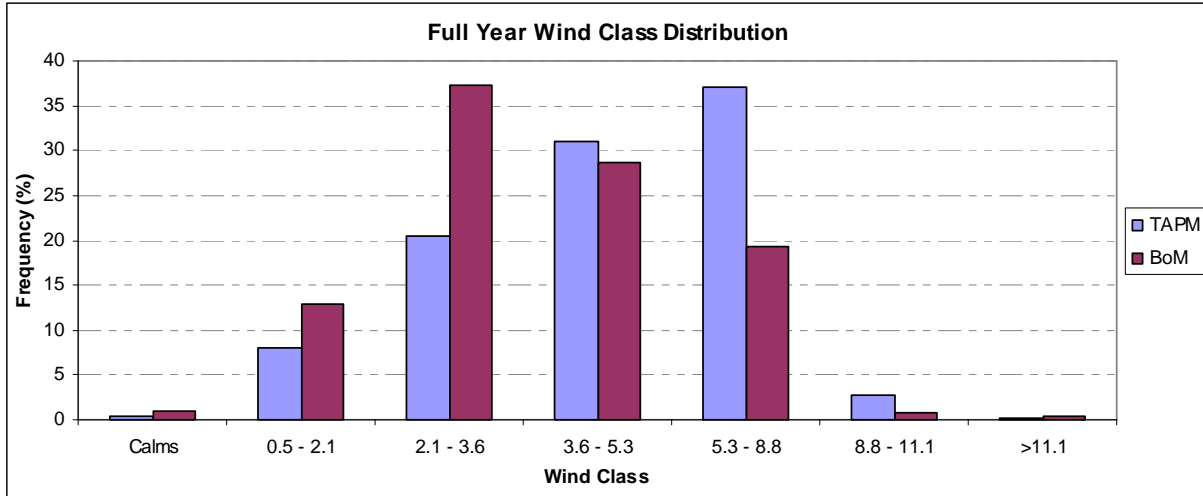


Figure 11.9 Annual wind class distribution comparison between TAPM and BOM

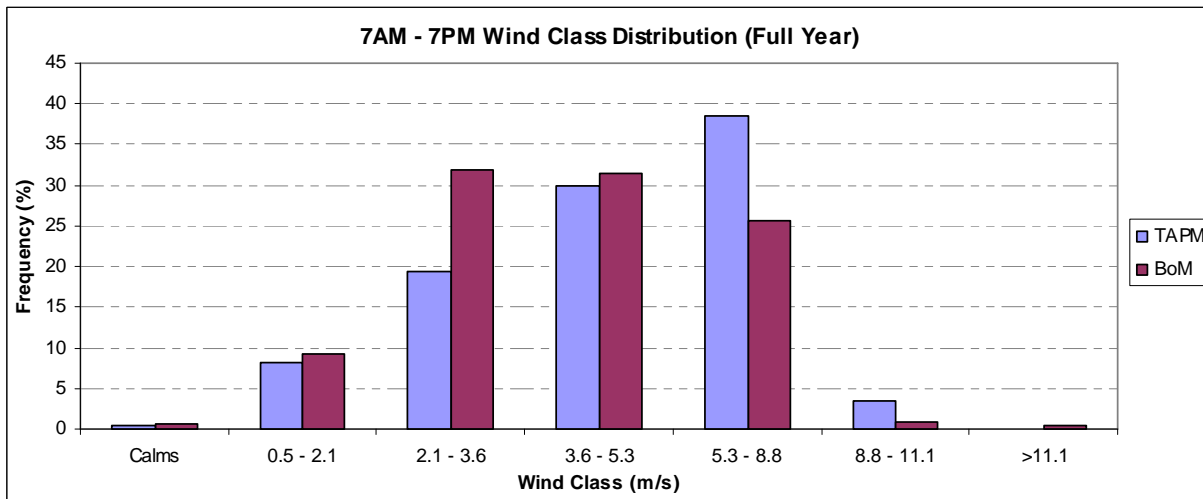


Figure 11.10 Daytime wind class distribution comparison between TAPM and BOM

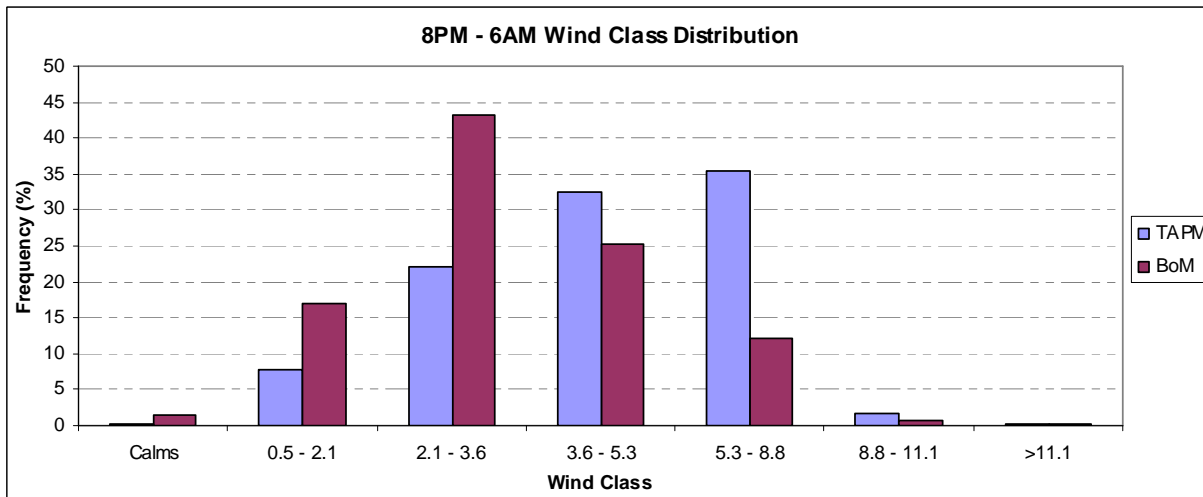


Figure 11.11 Night-time wind class distribution comparison between TAPM and BOM

11.3 Atmospheric Stability

The degree of stability in the atmosphere is determined by the temperature difference between an “air parcel” and the air surrounding it. This difference can cause the “air parcel” to move vertically, and this movement is characterised by four basic conditions that describe the general stability of the atmosphere. In **stable** conditions, this vertical movement is discouraged, whereas in **unstable** conditions the “air parcel” tends to move upward or downward and to continue that movement. When conditions neither encourage nor discourage that movement beyond the rate of adiabatic heating or cooling they are considered **neutral**. When conditions are extremely stable, cooler air near the surface is trapped by a layer of warmer air above it, with this condition being called an **inversion** which results in virtually no vertical air motion.

The Pasquill-Gifford (P-G) stability category scheme is normally used. Stability class under the P-G scheme is designated a letter from A-F (and sometime G), ranging from highly unstable to extremely stable. There are a number of methods for determining stability classes, with Turner’s method the most common. This method estimates the effects of net radiation on stability from solar altitude, total cloud cover and ceiling height. The stability class is estimated as a function of wind speed and net radiation as is apparent in **Table 11.5**.

Table 11.5 Stability Categories

Wind Speed ^a (m/s)	Day-time incoming Solar radiation (mW/cm ²)				1 hour before sunset or after sunrise	Night-time Cloud cover (octas)		
	>60	30-60	<30	Overcast		0-3	4-7	8
< 1.5	A	A-B	B	C	D	F or G ^b	F	D
2.0 – 2.5	A-B	B	C	C	D	F	E	D
3.0 – 4.5	B	B-C	C	C	D	E	D	D
5.0 – 6.0	C	C-D	D	D	D	D	D	D
> 6.0	D	D	D	D	D	D	D	D

^a Wind speed is measured to the nearest 0.5m/s.

^b Category G is restricted to night-time with less than 1 octa of cloud and a wind speed less than 0.5m/s.

The stability class rose together with the frequency distribution of stability class for the sites are shown in **Figure 11.12** and **Figure 11.13** respectively. As can be seen from this data, this area is dominated by neutral and stable conditions, with stability class D being significantly dominant. The high occurrence of relatively stable meteorological conditions is due to the low wind speeds in the area. Significant cloud cover in the area resulting in minimal solar radiation has also causes minimal heating or cooling of the surface, leading to neutral conditions.

The frequency distribution of stability class with time of day is shown in **Table 11.6**. Neutral and stable stability classes are observed through the nighttime, as expected. Throughout the day however the stability class shifts from neutral-stable to neutral-unstable due to the convective nature of the boundary layer. The convection arises from the solar irradiation of the earth’s surface, resulting in enhanced mixing.

Table 11.7 displays the frequency distribution of stability versus wind speed. The wind speeds are observed to follow the expected outcome with stability class. The processed surface data appears to provide reliable data based on Stability Class.

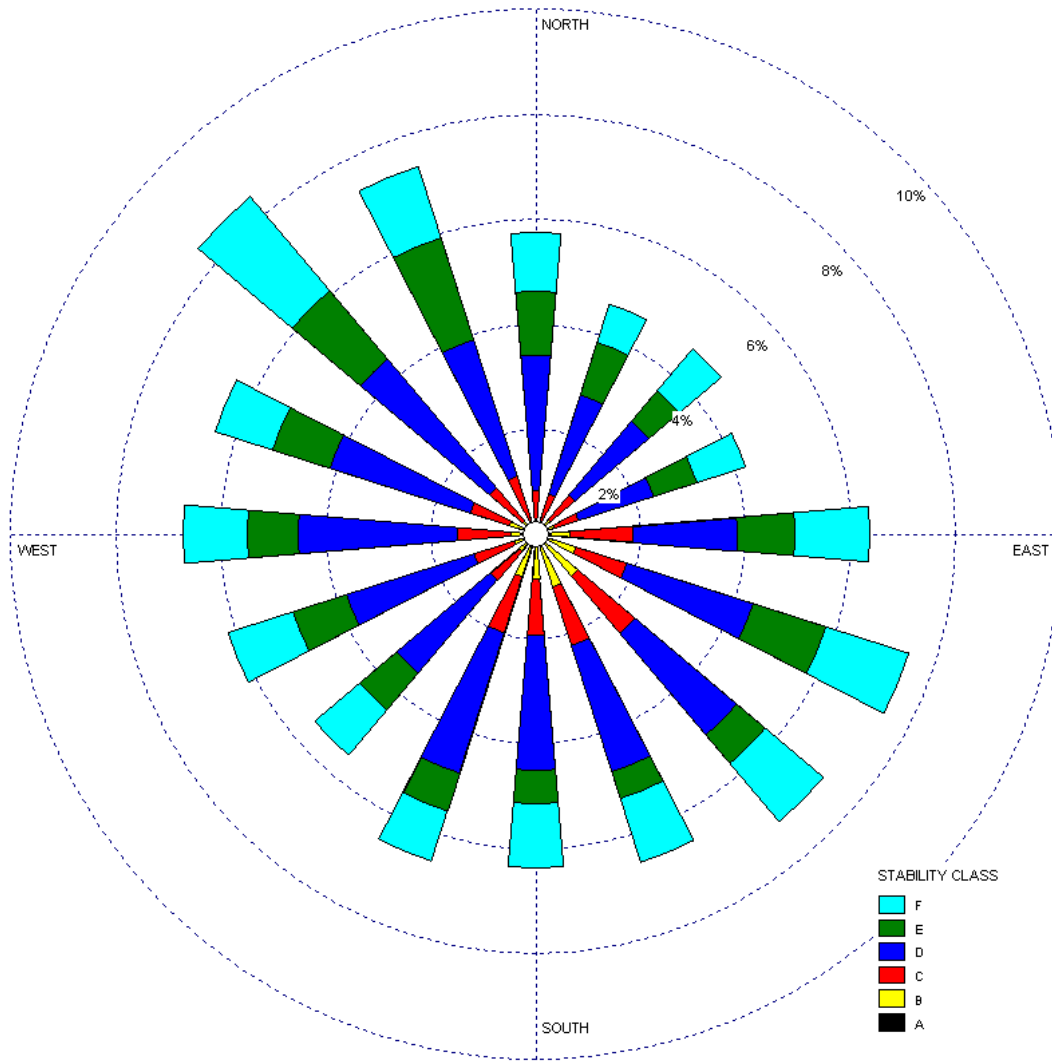


Figure 11.12 Stability class rose.

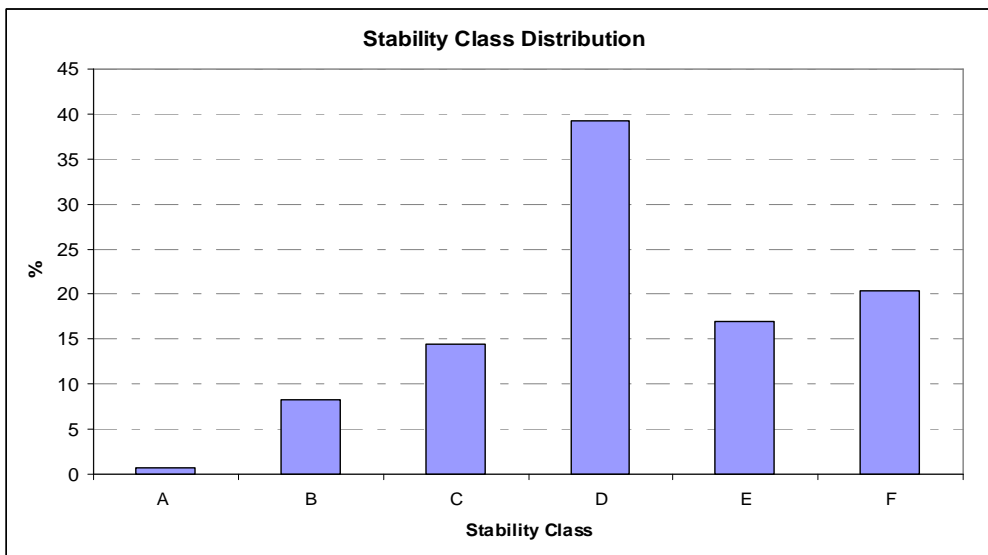


Figure 11.13 Stability class frequency distribution

Table 11.6 Frequency distribution of Stability Class versus Time of Day

Hour of Day	Stability Class					
	A	B	C	D	E	F
1	0	0	0	78	152	135
2	0	0	0	89	147	129
3	0	0	0	93	146	126
4	0	0	0	104	138	123
5	0	0	0	131	131	103
6	0	0	0	233	77	55
7	0	0	58	264	30	13
8	0	38	125	202	0	0
9	9	79	134	143	0	0
10	22	85	152	106	0	0
11	27	87	150	101	0	0
12	21	101	130	113	0	0
13	16	91	133	125	0	0
14	8	77	144	136	0	0
15	5	55	147	161	0	0
16	0	28	135	203	0	0
17	0	7	105	255	0	0
18	0	0	24	267	28	47
19	0	0	0	184	75	106
20	0	0	0	63	121	181
21	0	0	0	64	116	185
22	0	0	0	64	123	178
23	0	0	0	64	134	167
24	0	0	0	75	144	14

Table 11.7 Frequency distribution of Stability Class versus Wind Speed

Speed (m/s)	A	B	C	D	E	F	G
0-2.0	40	135	135	644	217	280	0
2.0-4.0	20	466	555	1513	740	1459	0
4.0-6.0	0	99	427	821	448	0	0
6.0-8.0	0	0	30	271	0	0	0
8.0-10.0	0	0	0	6	0	0	0

11.4 Mixing Height

The mixing height is the height of the turbulent boundary layer of air near the earth's surface, into which ground level emissions will be rapidly mixed. A plume emitted above this height will remain isolated from the ground until the mixing height reaches the height of the plume. A plume emitted below this height will be mixed subject to the stability class and wind climate. The height of the mixing layer is controlled by convection (resulting from solar heating of the ground during the day) and by mechanically generated turbulence as the wind blows over rough ground (hence the importance of land use data).

The mixing height at the power plant site was estimated using gridded surface and upper air meteorological data that was generated by TAPM. TAPM is able to generate detailed, three dimensional gridded (in x, y and z) meteorological data up to a level of 8 km above sea level from preprocessed synoptic meteorological data.

The estimated mixing height for this site rises very quickly in the early morning from just after sunrise until mid afternoon, at which point the mixing height remains at a relatively stable value until returning to a lower level early in the evening, refer **Figure 11.14** This diurnal variation of atmospheric structure is consistent and expected with that

found at similar sites. Large values for mixing height occur in the summer months as expected due to the greater convective effects. The main change throughout the year is the length of the period of strong convection and the wind variation.

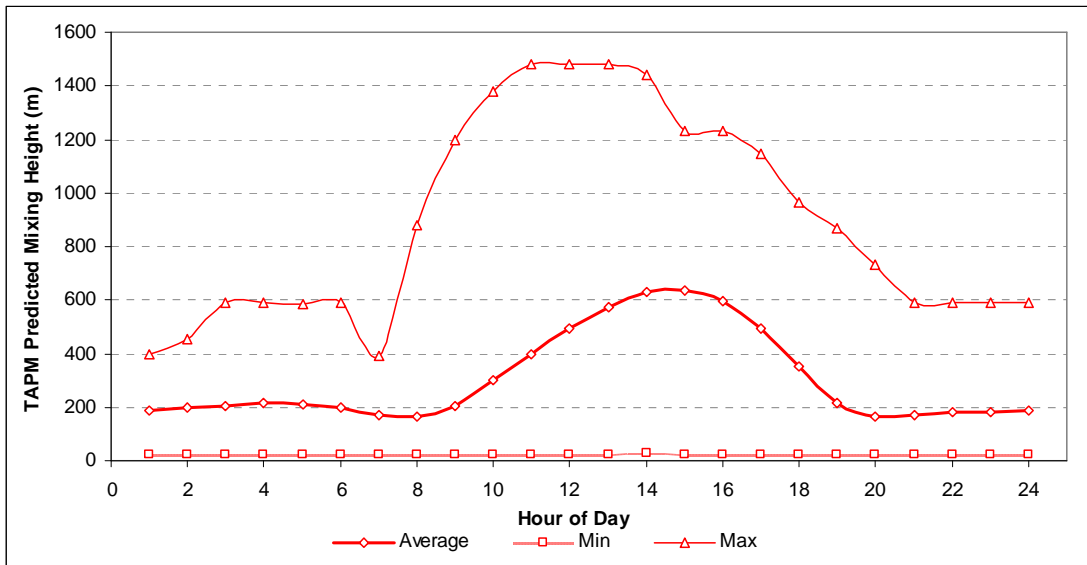


Figure 11.14 Hourly variation of mixing height over a period of a year

12. Existing Air Quality

A monitoring program was undertaken in Bridgetown (a nearby township similar to Manjimup) to assess background concentrations of PM₁₀, PM_{2.5}, NO and NO₂. The monitoring facility was located within the centre of town (see **Figure 12.1**). Monitoring data from Bridgetown is considered to be representative of that recorded in Manjimup due to their geographic similarities and close proximity, resulting in similar synoptic conditions prevailing within both these localities. This postulation is supported by the two independent bodies that reviewed the PER, SKM and Katestone. Notwithstanding this, ambient air quality monitoring data was obtained from the CSIRO for Manjimup. CSIRO's data is understood to be conservative as their research was related to emissions from prescribed burning. The data from CSIRO is for PM_{2.5} concentrations.

Oxides of Nitrogen were analysed using chemiluminescence. Particulate concentrations were measured using a TEOM (Tapered Element Oscillating Microbalance). The NPI database for the Shire of Bridgetown (or Manjimup) notes that oxides of Nitrogen result primarily from biogenic sources, motor vehicles and fuel combustion (and metal ore mining in the case of Bridgetown). While particulate emissions can be primarily attributed to dust from paved/unpaved roads, with other sources being wind blown dust and domestic solid fuel combustion (and metal ore mining in the case of Bridgetown).

Australian Standards for monitoring meteorology and pollutants were not strictly complied with as worst case concentrations of pollutants were required. This required monitoring within the township of Bridgetown in close proximity to surrounding buildings. Surrounding buildings generally emitted pollutants which had the potential to elevate concentrations of pollutants (due to wake effects), therefore increasing measured concentrations and resulting in a conservative (i.e. likely worst case) assessment.



Figure 12.1 Ambient Air Quality Monitoring Location.

The results of monitoring are shown the sections to follow for ambient particulate and nitrogen dioxide levels respectively. The monitoring period was from 15 June to the 15th September 2007 for NO_x and PM₁₀ and from 15th July to 15th October 2007 for PM 2.5. Monitoring data at Bridgetown was compared with monitoring results from a study by CSIRO of PM_{2.5} levels in Manjimup over the majority of 2007 (ie Nov 2006 – Dec 2007).

12.1 Nitrogen Dioxide

The nitrogen dioxide monitoring profile is shown in **Figure 12.2**. This monitoring data is compared to background data predicted via simulation of pollutant dispersal (as per the configuration outlined in **Section 10.3**) so as to seek to evaluate the pollution model within TAPM. Notwithstanding this, the comparison is made between non-contemporaneous period (i.e. 2007 for monitoring compared with 2001 for predictions). Since the monitoring period does not coincide with the TAPM run which was conducted with 2001 Synoptic Analyses, it is considered that a comparison showing similarity between relevant statistics (such as maxima, averages and percentile levels) will be sufficient to achieve a cursory form of qualification of the background sources. This comparison is given in **Table 12.2**

and suggests that all sources of NO_x were not represented in the TAPM modelling domain. The contours from the 't100a' TAPM outer grid (see **Appendix B**) with a uniform mesh size of 2500m, show that NO₂ background levels near Manjimup were between 15 – 20 ppb. The high NO₂ levels observed north of the proposed site can be attributed to the emissions from the power stations near Collie, and it can also be said that the local effects of the proposed power station are only observed around the townships of Manjimup, Pemberton and Northcliffe.

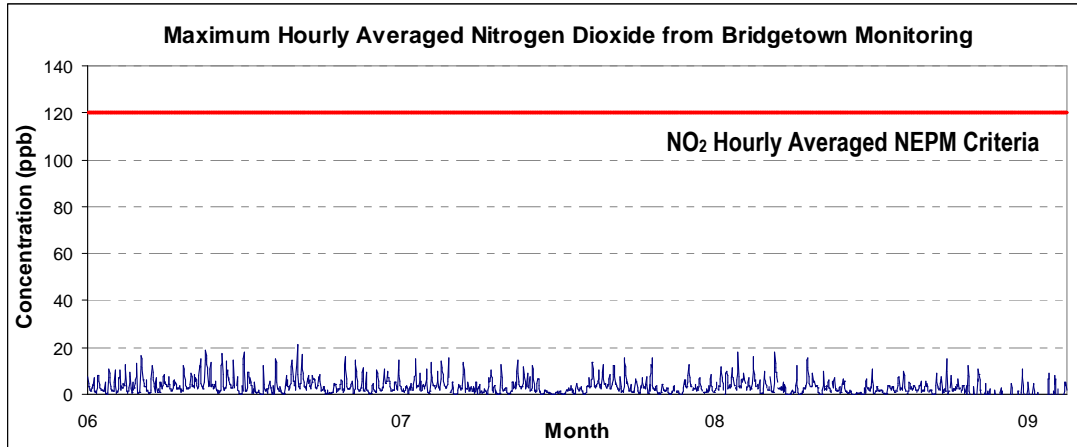


Figure 12.2 Monitoring profile of NO₂ concentrations from Bridgetown pollutant survey.

Table 12.1 Comparison of Bridgetown Survey with simulation of NO_x background emissions by TAPM.

* TAPM results output over same part of the year in 2001 (i.e. 15 July to 14 Sept) as Bridgetown monitoring.

	Hourly Averaged NO ₂ Concentration (ppb)		
	Maximum	98th Percentile	Average
Bridgetown	21.1	13.3	3.2
TAPM Background*	14.5	3.1	1.1
Criterion		120	

12.2 Other Pollutants

Ambient concentrations of ozone and VOCs in the area were also important to consider as they effect the atmospheric chemical transformation of the regional NO_x emissions. A single background value of 20 ppb of ozone was input into the TAPM model for all months of the year, which was considered reasonable as other air quality assessments in the area (Physick, WL et al. 2004) (i.e. for power stations at Collie WA) have used this level of background ozone to represent the region.

Another requirement is to assign a background level to R_{smog}, which takes into account ambient concentrations of VOCs in the region. A background concentration of between 0.2 - 0.4 ppb is considered appropriate for the rural setting of the proposed power plant. The actual value for R_{smog} used in the modelling domain was 0.3 ppb.

12.3 Particulate Matter

The particulate monitoring undertaken in Bridgetown and the full year monitoring period for Manjimup are plotted in **Figure 12.3** and **Figure 12.4**. **Figure 12.3** shows the maximum daily averaged PM₁₀ profile over the four month monitoring program in Bridgetown. These four months are expected to produce the highest concentrations due to prevalent adverse meteorological conditions that would result in pollutant accumulation (see **Section 11**). The PM₁₀ daily averaged concentrations over the monitoring period are seen to fall well below the NEPM guideline of 50 µg/m³.

Figure 12.4 shows PM_{2.5} time series daily averaged ground level concentration profile for the Bridgetown monitoring period from 11/07 to 15/10 with data from the CSIRO monitoring program for the same period overlaid. As evident, there is relatively good correlation between measurements in Bridgetown and Manjimup. This is further supported by an analysis of the statistics (refer to **Table 12.2**), although the peak levels recorded in Manjimup are significantly higher than that recorded in Bridgetown, likely due to research at Manjimup associated with prescribed burning. However

upon the comparison of the percentile levels it is clear that both the 98th and 95th percentile levels for PM_{2.5} are very similar, demonstrating the similarity in ambient air quality (and meteorology) between Bridgetown and Manjimup.

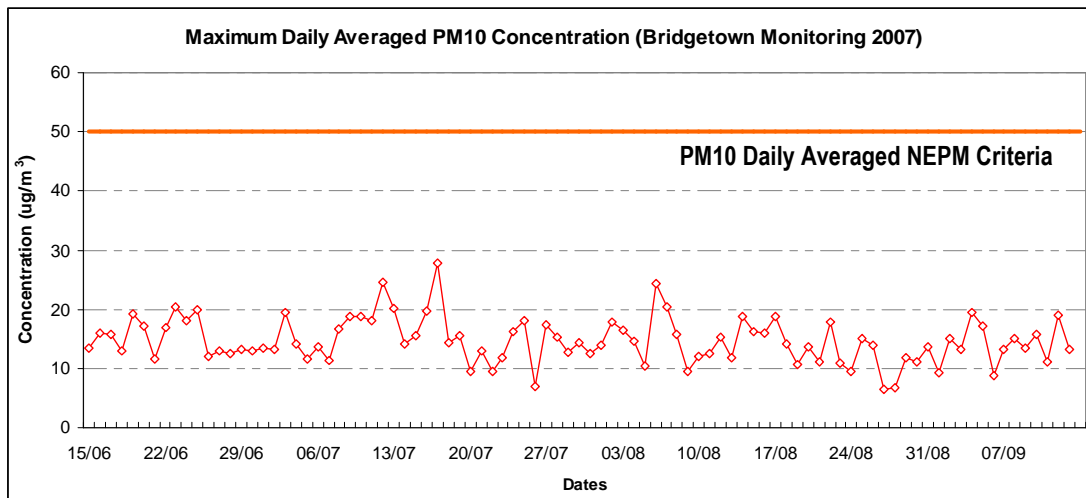


Figure 12.3 Maximum daily averaged PM₁₀ concentration from Bridgetown monitoring period from 15th June to 15th September.

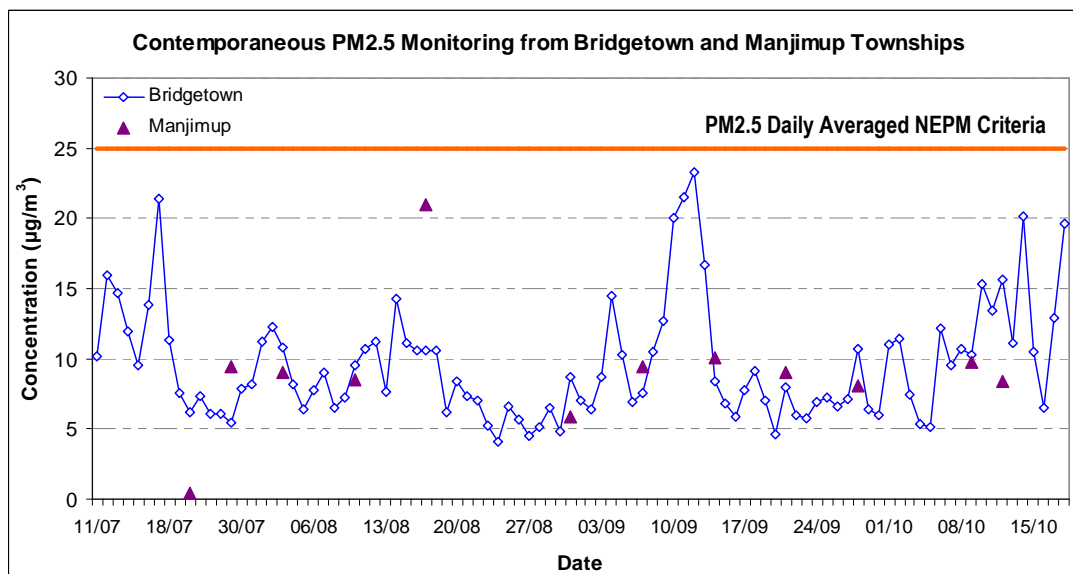


Figure 12.4 Maximum daily averaged PM_{2.5} concentrations from (a) Bridgetown monitoring (b) Manjimup monitoring.

Table 12.2 Comparison of Bridgetown and Manjimup ambient air quality for PM_{2.5} (2007 Monitoring data)

Location	PM _{2.5} Concentration (µg/m ³)			
	Maximum Hourly	Maximum Daily Average	98 th Percentile of Daily Average	95 th Percentile of Daily Average
Bridgetown	58.5	23.3	21.4	19.8
Manjimup	-	58.9	21.8	20.0

Table 12.3 Bridgetown ambient air quality for PM₁₀ (2007 Monitoring data)

Location	PM ₁₀ Concentration (µg/m ³)			
	Maximum Hourly	Maximum Daily Average	98 th Percentile of Daily Average	95 th Percentile of Daily Average
Bridgetown	214.5	27.8	24.5	20.3

13. Modelling Results and Impact Assessment

13.1 Criteria Pollutants

13.1.1 Sulphur Dioxide

As a result of the low expected emissions of sulphur dioxide (SO₂) from this facility a tracer run in the TAPM dispersion model was executed to determine the worst case local impact. Table 13.1 outlines the maximum 98th and 95th percentile ground level concentrations (GLCs) expected. It is apparent from these results that ground level concentrations of sulphur dioxide due to the emissions from the proposed facility are expected to fall well below the governing criteria for the worst case emission rate. The contours of this simulation can be seen in **Appendix C**, for one and 24 hour averaging periods. However this analysis does not take into account the cumulative affects of gridded source emissions of VOCs as well as the Collie power station cluster; this justified more detailed chemical modelling.

Table 13.1 SO₂ GLCs with no chemical transformations in the simulation and the governing NEPM criteria (ppb).

Averaging Period	Ground Level Concentrations (ppb)			NEPM Criteria (ppb)
	Maximum	98 th Percentile	95 th Percentile	
1 hour	25.1	2.17	0.57	200
24 hour	6.58	0.02		80
Annual	0.39			20

The maximum expected cumulative sulphur dioxide ground level concentrations from the chemistry simulation are detailed in Table 13.2. (Refer to **Appendix D** for the corresponding contours for one and 24 hour averaging periods). This simulation took into account the chemical transformation of SO₂ in the atmosphere as well as the inclusion of gridded biogenic sources of VOCs and the most significant source of SO₂ emissions in the region, the Collie power station cluster. The results from this simulation henceforth show that the prevalence of meteorological conditions that lead to a southerly transference of the plume from Collie leads to a statistically significant increase in the maximum predicted level. This marginal increase in the predicted level is still seen to be well below the governing criteria nevertheless and therefore not of any great concern. The profile of the predicted ground level concentrations over the modelling year shown in **Figure 13.1** illustrates that the maximum levels occur in the winter months of the year which is as expected. This is as sulphur dioxide does not undergo photochemical reactions within the generic reaction set outlined in and therefore would be influenced more significantly by meteorological parameters such as the high prevalence of temperature inversions, low mixing heights and the generally decreased degree of air mixing during the winter months.

Table 13.2 SO₂ Cumulative GLCs taking into account atmospheric chemical transformation of SO₂ in the presence of VOC compounds and sulphur dioxide emissions

Averaging Period	Ground Level Concentrations (ppb)			NEPM Criteria (ppb)
	Maximum	98 th Percentile	95 th Percentile	
1 hour	27.8	4.17	1.74	200
24 hour	6.83	0.03		80
Annual	0.58			20

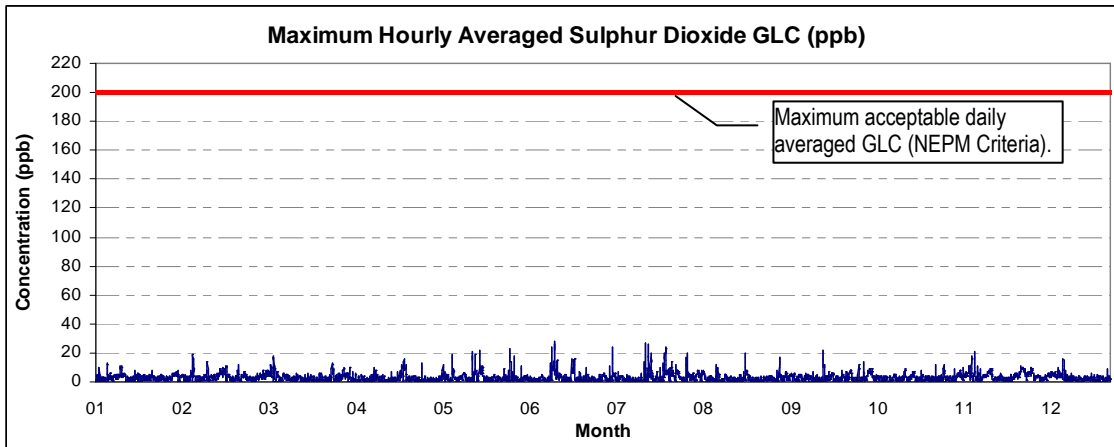


Figure 13.1 Hourly averaged profile of SO₂ GLCs over the simulation year for the GRS chemical transformation simulation.

13.1.2 Nitrogen Dioxide

To ensure a rigorous assessment of the air quality impact of the biomass power station on local nitrogen dioxide levels it was necessary to compare the procedures detailed in the NSW EPA (2005) Modelling Guidance Notes. Hence the following scenarios were modelled using the dispersion model, TAPM.

- Scenario 1: Model the emissions of NO_x emitted from the stack as being 30% NO₂. This is based on past knowledge of the likely transformation ratio of NO to NO₂ in plumes.
- Scenario 2: Calculate the expected NO₂ level with regards to the Ozone Limiting Method (OLM) as described in the NSW EPA (2005) Air Quality Modelling Guidance Notes. This requires NO_x to be modelled in tracer mode with 100% NO_x.

The NO_x emissions guarantee that was used to calculate the NO_x emission rate for the simulations conducted for Scenario 3 and 4 was 350 mg/Nm³, which is equivalent to a stack emission rate of 26.9g/s. This enables a more conservative assessment of the atmospheric transformation of NO to NO₂, but still yields more realistic results in comparison to the simulation conditions stated under Scenario 1 and 2 above.

- Scenario 3: Model NO₂ using the chemical transformation tool in the dispersion modelling software, which in the case of TAPM is the Generic Reaction Set (GRS). A more realistic ratio of NO_x to NO₂ being emitted from the stack was used (10% NO₂ is considered to be typical value for power stations). The model also included gridded biogenic and anthropogenic emissions of VOCs and NO_x (refer to **Section 7**).
- Scenario 4: Model NO₂ concentrations as per Scenario 3, but with the inclusion of a significant NO_x source in the area being the Collie power station cluster. Refer to **Section 7** for more a detailed discussion on emissions form Collie.

The results from the simulations of each of the four scenarios outlined above are summarised in **Table 13.3**.

Table 13.3 Summary of results for each modelling scenario

Averaging Period	Ground Level Concentration, 1 hour averaging period (ppb)			NEPM Criteria (ppb)	Contours Appendix
	Maximum	98 th Percentile	95 th Percentile		
Scenario 1	41.1	15.6	5.9	120	E
Scenario 2	95.4	86.9	74.1		F
Scenario 3	32.2	8.25	3.15		G
Scenario 4	34.3	8.38	3.78		H

The following observations are made with regard to the results from each modelling scenario:

- **Scenario 1:** Dispersion without accounting for atmospheric chemistry relies on past knowledge of the likely transformation ratio of NO to NO₂ in plumes. Depending on the background level of VOCs, NO_x and solar radiation, this is likely to be overly conservative, particularly in the South-West of Western Australia due to concurrent high VOC emissions from native vegetation together with high solar radiation during summer months.
- **Scenario 2:** The maximum predicted levels of NO_x as modelled without any chemical transformations was used in order to calculate the maximum ozone limiting method NO₂ ground level concentration. The other parameters assumed in this calculation include, a background (one hour averaged) peak tropospheric ozone concentration of 48.1 ppb (see **Section 13.1.3**) and a background peak nitrogen dioxide level of 35.6 ppb. The assumption regarding the peak background nitrogen dioxide level is highly conservative as this value is the sum of the predicted peak as well as the measured peak concentrations, which are non-contemporaneous events and occur at different locations. Further conservatism is applied by assuming contemporaneous peak levels being observed for tropospheric ozone and nitrogen dioxide. The OLM method also assumes instantaneous transformation from NO_x to NO₂ whereas the reality is these reactions take several hours to reach equilibrium. The peak NO₂ concentration predicted via this methodology is below the NEPM criteria level for this extremely conservative assessment.
- **Scenario 3:** The inclusion of gridded background emissions of biogenic and anthropogenic VOCs and NO_x result in a drop in the maximum expected ground level concentrations compared with the OLM method hourly averaged maxima due to the fact that the regional atmosphere is NO_x limited. In other words, the reaction mechanism that nitric oxide (NO) has to undergo to be oxidised to nitrogen dioxide is limited by the fact that the amount of NO being emitted is significantly smaller than the VOC emissions. It was postulated that this could be due to the lack of significant NO_x sources in the area or due to the non-inclusion of a significant but distant NO_x source being the power station cluster and refinery near Collie WA.
- **Scenario 4:** The inclusion of the Muja Power Station cluster near Collie, WA as well as the gridded emissions as a single point source in the area yielded results that were thought to be representative of maximum background concentrations in the Manjimup region. The results show that although the Collie power station cluster is a significant NO_x source, it has little bearing on the maximum expected ground level concentrations in the Manjimup region for the year modelled.

Scenario 4 is considered to be the most reasonable representation of likely ground level concentrations from a variety of sources due to the less conservative approach through inclusion of atmospheric chemistry. Notwithstanding this, extreme atmospheric and plant events (considered highly unlikely) have been demonstrated to comply with the assessment criteria.

For ease of reference, both annual and hourly averaged statistics of ground level concentrations of NO₂ are provided in **Table 13.4**. The NO₂ concentration profile over the full year simulation for scenario 4 is shown in **Figure 13.2**. **Figure 13.2** shows that the maximum cumulative hourly averaged ground level concentrations of nitrogen dioxide fall well below the NEPM criterion of 120 ppb.

Table 13.4 Results of Scenario 4 simulation (inclusion of gridded biogenic/anthropogenic emissions and point source representing the Collie power station cluster).

Averaging Period	Scenario 4: GLC (ppb)			NEPM Criteria (ppb)
	Maximum	98 th Percentile	95 th Percentile	
1 hour	34.3	8.38	3.78	120
Annual	1.66	-	-	30

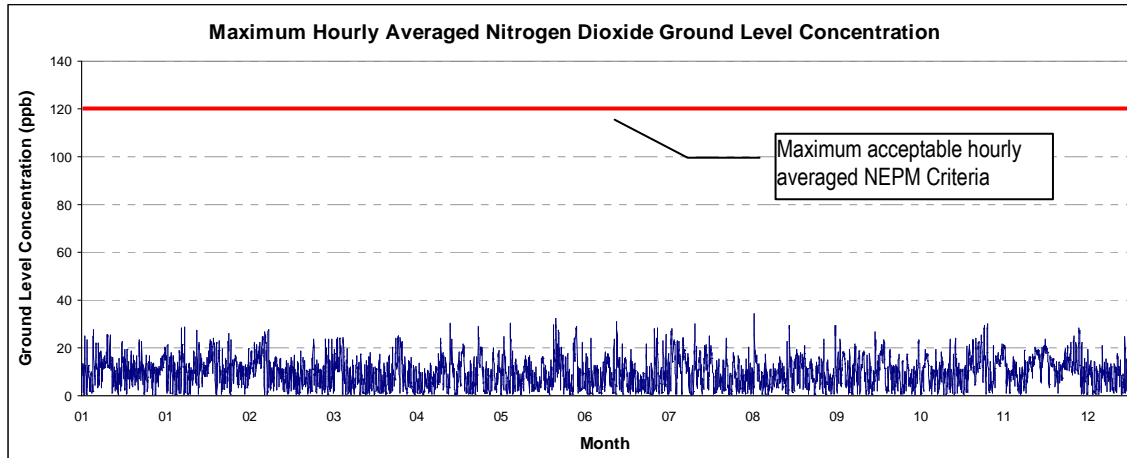


Figure 13.2 Maximum hourly NO₂ ground level concentrations from the simulation of Scenario 4, as described.

13.1.3 Ozone

Tropospheric ozone can pose air quality issues close to significant sources of oxides of nitrogen, where they become elevated through the photochemical reactions through the day. This section seeks to describe the behaviour and production of tropospheric ozone and the levels that are likely to be experienced from the presence of this power station.

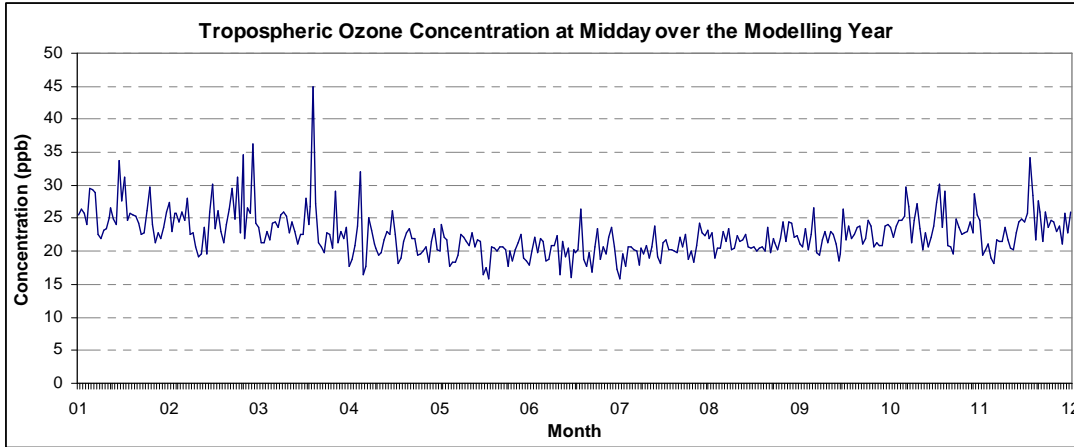
Through the course of a day, the level of tropospheric ozone increases as NO₂ reacts photochemically to produce nitric oxide and ozone. Ozone levels are seen to be maximum between 8 am and 4 pm, which is most likely due to the enhancement of the photochemical production. The low concentrations during other periods of time can be attributed to the unavailability of sunlight to induce the photochemical process as well as ozone deposition. Ozone is also known to act as a sink during night time where it reacts with nitric oxide to form NO₂ ($\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$) (Satsangi, G, Lakhani, A, Kulshrestha, P, Taneja, A, 2004).

The ground level concentrations of ozone are shown in **Table 13.5** and are seen to fall well below the stated NEPM criteria for photochemical oxidants as ozone, with maximum levels approximately half of the NEPM guideline level. The point of curiosity is the diurnal variation of O₃ concentrations over a day. It is apparent from the analysis of **Figure 13.3 (a)** and **(b)** that ozone concentrations are maximised over the summer months of the year when during which period cloud cover is minimum, therefore enhancing the photochemical production of ozone in the presence of nitrogen dioxide. The diurnal variation in concentrations can also be observed via the comparison of the two graphs in succession. The concentration profile at midday shows a significantly larger number of peaks, with consistently higher levels being observed at midday throughout the year c.f. 4 am ozone levels.

Table 13.5 Maximum tropospheric ozone ground level concentrations (ppb); sourced from the Scenario 4 simulation.

Averaging Period	Scenario 4: GLC (ppb)			NEPM Criteria (ppb)
	Maximum	98 th Percentile	95 th Percentile	
1 hour	48.1	28.3	25.8	100
4 hour	44.8	23.9	21.4	80

(a)



(b)

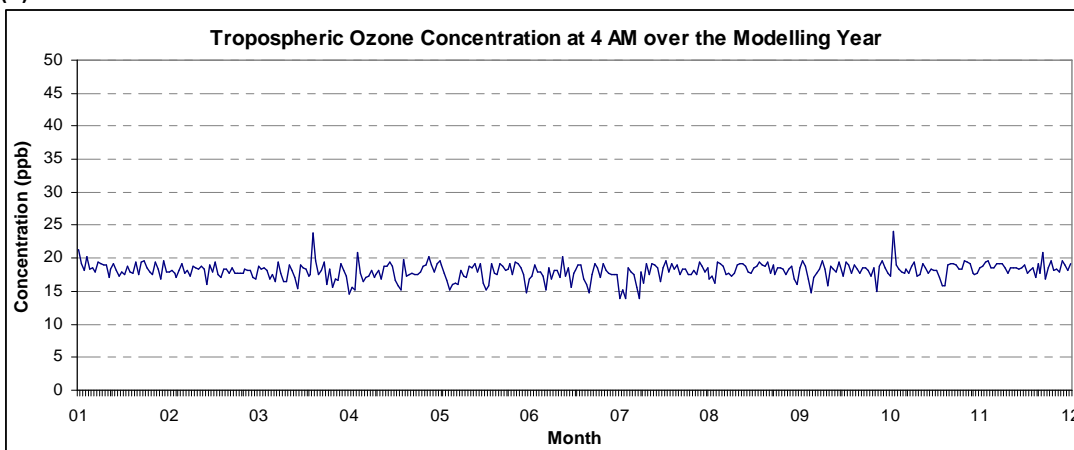


Figure 13.3 Diurnal variation of ozone concentrations with (a) Midday and (b) 4 am tropospheric ozone concentration profiles over the simulation year.

13.1.4 Particulates

The PM10 impact assessment was conducted based on an emissions concentration of 50 mg/Nm³ (6% O₂), however the guaranteed emissions concentration as stated by the proponent is 30 mg/Nm³ (6% O₂) and therefore the impact assessment below is inherently conservative. Ground level concentrations estimated from the emissions of the power station alone and the cumulative concentration estimation with the inclusion of daily averaged background emissions are presented. In the past, the EPA has accepted use of the 95th percentile ambient concentration for calculation of the cumulative ground level concentration and this has been used to assess cumulative levels in the following section also.

Monitoring in Manjimup only considered PM2.5, with the 95th percentile therefore available for the calculation of the cumulative concentration. However, the assessment of the existing environment (refer to **Section 12**) demonstrated good similarity of the ambient air quality between Manjimup and Bridgetown. Therefore given this similarity, the 95th percentile PM10 concentration for Bridgetown was used to calculate the cumulative concentration for PM10.

The maximum 24 hour averaged ground level concentrations of PM10 and PM2.5 under normal plant operating conditions for a full year simulation are shown in **Table 13.6** and **Table 13.7**. This simulation was conducted with TAPM in chemistry mode with deposition and settling. In this mode the term 'APM' represented PM10 particulates and FPM represented PM2.5 particulate matter. Emissions of oxides of nitrogen were also included in the emission rates for this pollutant and hence could have also contributed to the formation of stable non-gaseous nitrogen compounds leading to slight increases in particulate concentrations. Maximum 24 hour averaged concentrations show compliance with the assessment criteria for both PM10 and PM2.5.

With the inclusion of the 95th percentile of the monitored background data the cumulative levels are still seen to not have exceeded the NEPM criterion. **Table 13.7** also details the maximum predicted PM_{2.5} ground level concentrations for the annual averaging periods. While the ground level concentration from the power station are minor compared with the ambient concentration, the annually averaged cumulative level exceeds the criterion. It should be noted that the background annually averaged ambient concentration is higher than the criterion. The criterion is a guidance level to be used to understand the existing environment and to assess future impacts of regulatory restraint, with compliance not being mandatory.

Table 13.6 Maximum Predicted PM10 concentrations.

Note there are no criteria for 1-hour and annual concentrations

PM10	Maximum Predicted Concentration (µg/m ³)	
	24-Hour Average	
TAPM Estimate (Power station)	3.2	
Manjimup Background (95 th Percentile)	20.3	
Total	23.5	
Criterion	50 (limit of 5 exceedances/year)	

Table 13.7 Maximum Predicted PM2.5 concentration.

PM2.5	Maximum Predicted Concentration (µg/m ³)	
	24-Hour	Annual
TAPM Estimate (Power Station)	3.2	0.76
Manjimup Background (95 th Percentile)	20.0	9.8
Total	23.2	10.6
Criterion	25 (allowable number of exceedances unknown)	8

Contours for PM10 can be seen in **Appendix I**. The PM10 one hour averaged contours show that the maximum ground level concentration to occur immediately north and NNE of the proposed site. The daily averaged ground level concentration contours on the other hand show concentrations to be maximum immediately NNE of the proposed site and also in a region approximately 6 km SSW of the site.

Contours for PM2.5 can be seen in **Appendix J**. The PM2.5 one averaged contours show a pollutant concentration accumulation immediately north east of the proposed site. The daily averaged ground level concentration contours on the other hand show concentrations to be maximum immediately west of the site and approximately 7 km east of the proposed site.

13.1.5 Carbon Monoxide

Carbon monoxide was not explicitly modelled in TAPM due to the extremely low levels of guaranteed emissions from the proposed facility and was calculated using the ratio of emission rates between CO and NO₂ and the maximum predicted cumulative ground level concentration. A mathematical description of this process is shown via the equation below. The results from the tracer analysis assuming 100% NO_x to NO₂ conversion was used to determine the maximum ground level concentration of CO based on a ratio of emissions. The maximum predicted ground level concentrations of carbon monoxide are shown in **Table 13.8** and the maximum predicted concentrations are seen to fall well below the governing NEPM criteria.

$$[Conc.]_{CO} = \frac{[Emissions]_{CO}}{[Emissions]_{NO_2}} \times [MaxGLC]_{NO_2}$$

Table 13.8 Maximum predicted CO GLC (ppb) with respect to the governing NEPM criteria.

Averaging Period	Maximum Predicted Concentration (ppb)			NEPM Criteria (ppb)
	Maximum	98 th Percentile	95 th Percentile	
8 hours	29.6	16.1	12.0	900

13.1.6 Lead

Lead was considered to be a trace element and hence due to the negligible emissions of this compound once again this criteria pollutant was not explicitly modelled using TAPM. The methodology used to calculate the maximum ground level concentration of this pollutant is very similar to that described above in **Section 13.1.5**. However the emissions of lead were assumed to have a relationship with the guaranteed emission rate and maximum predicted ground level concentration of PM10 particulates via the equation presented below. Therefore based on this methodology the maximum annually averaged GLC for lead was predicted (**Table 13.9**) and is seen to be four ten thousandths of the governing NEPM criteria.

$$[Conc.]_{Pb} = \frac{[Emissions]_{Pb}}{[Emissions]_{PM10}} \times [MaxGLC]_{PM10}$$

Table 13.9 Maximum predicted CO GLC (ppb) with respect to the governing NEPM criteria.

Averaging Period (µg/m ³)	Maximum Predicted Concentration	NEPM Criteria
Annual	1.29 x 10 ⁻⁵	0.5

The prediction of lead levels was important for the Health Risk Assessment and the Horticultural risk assessment conducted by Toxikos Pty Ltd and the Land & Water division of CSIRO.

13.1.7 Sensitive Receptors

Table 13.10 details the maximum pollutant ground level concentrations at the nearest sensitive receptors with respect to the proposed power station as well as the levels expected at Manjimup Township. It is important to note that the ground level concentrations from the power station, when considered in isolation, are well below the existing ambient concentrations. All of the levels outlined in **Table 13.10** are cumulative and the sensitive receptors are as described in **Section 4.1**.

Table 13.10 Maximum particulates and NO₂ ground level concentrations (full year 2001) at sensitive receptors as described in Figure 4.3, and the township of Manjimup.

The 95th Percentile particulate background level used to derive expected cumulative concentrations (SKM, 2007).

Cumulative Maximum Ground Level Concentration		Manjimup	Receptor 1	Receptor 2	Receptor 3	Limit
NO ₂ (ppb)	1hr	17.3	19.7	16.7	23.3	120
PM2.5 (µg/m ³) (with 95 th Percentile background)	24hr	22.9	22.8	22.9	22.9	25
PM10 (µg/m ³) (with 95 th Percentile background)	24hr	23.3	23.2	23.4	23.3	50

13.2 Other Pollutants

The expected ground level concentrations of other toxins are all calculated on a pro rata basis. That is, the maximum ground level concentrations of the following pollutants (with the exception of carbon monoxide) were considered to be correlated to the emission rates and maximum expected concentrations of PM10 particulates via the following relationship for the required averaging period. This methodology ignored chemical transformation of some of the organic compounds in the atmosphere, hence is considered to be conservative. This assumption was considered appropriate as the organic and trace element compounds treated in this manner have long biological half lives.

$$[Conc.]_X = \frac{[Emissions]_X}{[Emissions]_{PM10}} \times [MaxGLC]_{PM10}$$

All the pollutant concentrations are expected to fall well below the prescribed regulatory limits (shown in brackets) as sourced from the NSW EPA Approved methods for the modeling and assessment of air pollutants (2005) and WHO

guideline levels. The justification of the likely emission factors, emissions and ground level concentrations for the following groups of compounds will be considered in turn.

- polycyclic aromatic hydrocarbons;
- polychlorinated dibenzo dioxins and furans (PCDD/F);
- volatile organic compounds;
- trace elements.

13.2.1 Polycyclic Aromatic Hydrocarbons

Based on the emission rates, the maximum predicted concentration is shown in **Table 13.11**. Comparing the maximum hourly averaged concentration against the NSW EPA regulatory criteria it is apparent that the emissions from the proposed biomass power station satisfy the guideline.

Table 13.11 Maximum predicted ground level concentrations of PAHs over a one hour averaging period.

Averaging Periods	Maximum Predicted Concentration ($\mu\text{g}/\text{m}^3$)	NSW Regulatory Criteria ($\mu\text{g}/\text{m}^3$)
1-Hour	6.96×10^{-3}	0.4

13.2.2 Dioxins/Furans

Using the pro rata methodology described at the head of this section, the maximum ground level concentrations for hourly, daily and annual averaging periods can be seen in **Table 13.12**. The hourly averaged concentrations are compared to the only available regulatory criteria, from the NSW legislature and are shown to fall several orders of magnitude below the guideline level. Following the above analysis of the controlled PCDD/F emissions from the proposed facility it can be said that the technology proposed for this facility complies with both international treaties which Australia is a signatory to as well as Australian state guidelines.

Table 13.12 Maximum predicted concentration over several averaging periods.

Averaging Periods	Maximum Predicted Concentration ($\mu\text{g}/\text{m}^3$)	NSW Regulatory Criteria ($\mu\text{g}/\text{m}^3$)
1-Hour	6.81×10^{-9}	2×10^{-6}

13.2.3 Volatile Organic Compounds

The ground level concentrations of speciated VOCs are listed in **Table 13.13** (a) and (b) for the emission factors sourced from the NPI handbook for combustion in boilers and the US EPA AP-42 document for wood waste combustion.

The Air Toxics NEPM monitoring investigation levels are compared with ground level concentrations for the compounds shaded in **Table 13.13** (a) and (b). This comparison demonstrates predicted concentrations comply with guideline levels and are several orders of magnitude below the guideline levels.

Given that the compounds listed in the following two tables are pathogenic to varying degrees, a robust human Health Risk Assessment (HRA) has been carried out by Toxikos. The impact of these pollutants is hence described within the HRA, in the absence of any comparison to regulatory guidelines. A brief description of human health impacts is provided within **Section 16.1**.

Table 13.13 Controlled emission factors, emission rates, criteria (shaded and in [...]) and ground level concentrations of speciated VOCs.

(a)

Compound ($\mu\text{g}/\text{m}^3$)	Ground Level Concentration	
	Annually Averaged	Hourly Averaged
Benzene	2.99×10^{-2} [10]	2.07×10^{-1}
Benzo(a)pyrene	2.03×10^{-7} [0.3x10 ⁻³]	1.41×10^{-6}
Acenaphthene	1.26×10^{-5}	8.69×10^{-5}
Fluorene	2.45×10^{-5}	1.70×10^{-4}
Phenanthrene	1.50×10^{-4}	1.03×10^{-3}
Anthracene	1.02×10^{-5}	7.04×10^{-5}
Fluoranthene	5.50×10^{-5}	3.81×10^{-4}
Benzo(a)anthracene	9.57×10^{-6}	6.62×10^{-5}
Benzo(k)fluoranthene	2.27×10^{-6}	1.57×10^{-5}
Benzo(b,k)fluoranthene	8.97×10^{-5}	6.21×10^{-4}
Benzofluoranthenes	3.23×10^{-6}	2.24×10^{-5}
Benzo(g,h,i)perylene	2.03×10^{-7}	2.94×10^{-5}
Benzo(a)phenanthrene	4.25×10^{-6}	8.69×10^{-6}
Chrysene	1.26×10^{-6}	9.52×10^{-6}
Indeno(1,2,3,c,d)pyrene	1.38×10^{-6}	7.45×10^{-6}
Acenaphthylene	1.08×10^{-6}	9.94×10^{-4}
Methyl anthracene	1.44×10^{-4}	2.90×10^{-3}
Naphthalene	4.19×10^{-4}	7.04×10^{-2}
Pyrene	1.02×10^{-2}	3.48×10^{-4}

(b)

Compound ($\mu\text{g}/\text{m}^3$)	Ground Level Concentration	
	Daily Averaged	Annually Averaged
Acetaldehyde	9.97×10^{-2}	2.34×10^{-2}
Benzaldehyde	1.02×10^{-4}	2.40×10^{-5}
Crotonaldehyde	1.19×10^{-3}	2.80×10^{-4}
Formaldehyde	5.28×10^{-1} [49]	1.24×10^{-1}
Isobutyraldehyde	1.44×10^{-3}	3.39×10^{-4}
Propionaldehyde	7.32×10^{-3}	1.72×10^{-3}
o-Tolualdehyde	8.64×10^{-4}	2.03×10^{-4}
p-Tolualdehyde	1.32×10^{-3}	3.11×10^{-4}
Dibenzo(a,h)anthracene	1.09×10^{-6}	2.57×10^{-7}
Ethyl Benzene	3.72×10^{-3}	8.76×10^{-4}
Styrene	2.28×10^{-1}	5.37×10^{-2}
Toluene	1.10×10^{-1} [3763]	2.60×10^{-2} [376]
o-Xylene	3.00×10^{-3} [1084]	7.06×10^{-4} [867]

13.2.4 Trace Elements

The emissions of trace element compounds from the proposed facility were calculated from emission factors sourced from the NPI Combustion in Boilers Handbook (2003) for wood waste combustion. However, in order to avoid over conservativeness in the estimations of annual emissions and ground level concentrations, baghouse capture efficiencies had to be considered. These efficiencies were published by a study conducted by Hargis and Pennline (1996) for a range of trace elements. The expected ground level concentrations of selected trace elements are listed in . Guideline levels are available for only a select few of these elements, with the hourly averaged criteria from EPA NSW legislature and the annual averaged guidelines from the WHO. It can be seen from the comparison of these numbers that the emissions from the biomass power station fall well below the relevant criteria.

Table 13.14 Estimated maximum ground level concentrations of trace elements, with regulatory levels in brackets. Regulatory levels in parentheses for one hour and annually averaged results sourced from EPA NSW Legislature and WHO guidelines respectively.

Averaging Periods	Maximum Predicted Concentration ($\mu\text{g}/\text{m}^3$)	
	1-Hour	Annual
Cadmium (Cd)	2.19×10^{-5} (0.018)	3.12×10^{-6} (0.005)
Iron (Fe)	2.67×10^{-3} (90)	3.83×10^{-4}
Manganese (Mn)	1.00×10^{-3} (18)	1.44×10^{-4}
Mercury (Hg)	5.19×10^{-5} (1.8)	7.41×10^{-6} (1)
Phosphorus (P)	5.32×10^{-5}	7.63×10^{-6}
Potassium (K)	7.69×10^{-4}	1.10×10^{-4}
Sodium (Na)	3.74×10^{-3}	5.36×10^{-4}
Titanium (Ti)	2.76×10^{-6}	3.96×10^{-7}

13.3 Emissions Control Failure

In a situation where the baghouse fails or is not able to operate as specified particulate emissions from this plant will be significantly higher and may result in local ground level concentrations exceeding the criterion levels. To assess the likely worst case full year pollutant dispersion concentrations over one and 24 hour averaging periods, a full year simulation for the year 2001.

The results of this simulation are shown in Table 13.15. It can be seen that both the PM_{2.5} ($25 \mu\text{g}/\text{m}^3$) and the PM₁₀, daily averaged ground level concentration criteria ($50 \mu\text{g}/\text{m}^3$) will be exceeded with the inclusion of background monitoring data from Manjimup, as expected. It was assumed that if the baghouse were to fail particulate emissions would be ten times larger than the guaranteed emission rate, which would occur under normal plant operating conditions.

The reasoning behind the low likelihood of an event resulting in a significant decrease in baghouse efficiency is discussed under the heading **Baghouse** in **Section 6.2**.

Table 13.15 Baghouse failure particulate ground level concentrations (Full year run 2001)

Concentration ($\mu\text{g}/\text{m}^3$) (with 95 th Percentile background)	Daily Averaged Concentrations	
	Maximum	Criterion
PM _{2.5}	50.2	25
PM ₁₀	64.1	50

14. Comparative Studies

14.1 Prescribed Burning

The cumulative air quality impact of current state sponsored practice of open burning was investigated and compared to the maximum expected concentrations of combustion of wood waste in the biomass power plant. An area source modelling scheme was used in TAPM to determine the cumulative impact of 10,000 ha of wood waste being burnt in an uncontrolled manner.

Hence ten area sources of approximately 1000 ha each, burning the same quantity of fuel were placed around the Shire of Manjimup. This simulation was then run for the entire month of July. The expected maximum daily average concentrations from this analysis were compared to the maximum levels expected from the Biomass power station. These values are tabulated in **Table 14.1** and compared to the governing Federal NEPM (National Environment Protection Measure) criteria. The ground level concentration contours of the daily averaged levels showed that the maximum levels occur in the immediate region surrounding the area sources, hence they are very localised. The daily averaged PM10 and PM2.5 contours can be seen in **Appendix K**. Due to minimal plume dispersion and the distinct lack of interaction between multiple pollutant plumes, the concentrations published are not cumulative but it is believed that similar levels would be reported from the equivalent (fuel consumption of approximately 5 tonnes/hr) open combustion of 1000 ha of forested land.

Although July is a month where this open controlled burning may not be practicable due to high potential rainfalls, the pollutant dispersion during months (e.g. spring) where the practice is more likely to occur is not expected to be of any greater significance due to the fact that plume dispersion is only driven by local wind speeds. The long term average wind speeds are not seen to increase significantly between the winter and spring months of the year.

Table 14.1 Results of Open Burning simulation compared to likely daily averaged maximum particulate emissions from proposed Biomass power station.

Daily Averaged Maxima µg/m ³	Biomass Power Station	Open Burning	Criteria
PM2.5	3.20	82.9	25
PM10	3.23	99.9	50

The validity of these results were reviewed by comparison with results from monitoring stations during prescribed burns (by the DEC). In April 2004, the DEC conducted controlled burns in the South-West of Western Australia (at Collie, Manjimup, Pemberton, Harvey, Kirup and Nannup). The wind trajectory caused elevated concentrations of particulates at the Bunbury monitoring station, with concentrations of PM10 and PM2.5 of 99.5 µg/m³ and 94.8 µg/m³ respectively. These concentrations substantiate the predictions given in **Table 14.1**.

The discussion above compares worst case ground level concentrations of particulates between emissions from the proposed biomass power station with those from prescribed burning. An alternative means of comparison is to consider annual emissions themselves, rather than the resulting ground level concentrations. This has been done in part, and reported in Table 8.1, with regard to annual emissions from the proposed biomass power station. Table 14.2 includes annual emissions for prescribed burning (as estimated using the NPI emissions factors for prescribed burning) for PM10 and PM2.5 (with PM2.5 estimated as 80% of PM10 emissions). The reduced emissions from efficient combustion in the biomass power station is clearly apparent.

Table 14.2 Annual emissions of particulates for comparison of prescribed burning to biomass power station combustion

Pollutant (kg/yr)	Sources	
	Biomass Power Plant	Prescribed Burning
PM10	56,700	4,560,000
PM2.5	45,360	3,648,000

14.2 Bluewaters Power Station Proposal

Results (as shown in **Table 14.3**) from an air-pollution modelling study in the Collie mining and power-generation area, located about 150 km south-south-west of Perth were considered given its location about 100 km North of the proposed Biomass Power Station, and that regions contribution to ambient air quality in Shire of Manjimup. The proposed Bluewaters Power Station comprises 2 x 200MW coal fired power stations. The importance of this comparison is to demonstrate that despite existing excessive ambient air quality, the EPA granted conditional approval for the development of an additional power station in the Collie region. The proposed Biomass Power Station will have minimal impact on the existing environment and considerably less impact than the existing facilities at Collie.

Table 14.3 Comparison of predicted pollutant ground level concentrations between the proposed Biomass Power Station and the existing group of power stations at Collie, WA.

Power Station	PM10 (daily maximum)	NO ₂ (hourly maximum)
Collie Group	106	100
Biomass Power Station	23	34
Criterion	50 µg/m ³	120 ppb

15. Mitigation Measures

To ensure compliance with the environmental regulations, it is recommended that the following mitigation measures be implemented through an air quality management plan:

Fuel Quality

- Quality control methods and routine sampling of the fuel will be implemented to ensure the guaranteed emissions targets are achieved.

Emissions Guarantees

- Real-time in-stack monitoring of gaseous and particulate matter will be used to qualify emissions
- Proponent to ensure compliance with emissions guarantees

Ambient Air Monitoring

- A base-line monitoring program will be established prior to and during plant operation, and will be detailed in the Air Quality Management Plan
- An automatic weather station will be established to validate air dispersion model results

Audit

- Routine independent auditing of emissions and management procedures

Reporting

- Reporting commissioning results to the EPA and the community
- Ongoing reporting of emissions from monitoring (ambient and in-stack)

Maintenance of Emissions Control Technology

- Continuous monitoring and control of the combustion process
- Baghouse controls to ensure maximum collection efficiency is not compromised and standby facilities are available in the event of failure

16. Air Pollution Risks

16.1 Human Health

The proponents committed to undertaking this assessment to ensure that any likely health risk was adequately assessed. The proponent commissioned Toxikos to carry out an independent Health Risk Assessment. The Health Risk Assessment (HRA) was undertaken by Toxikos Pty Ltd according to national and international guidelines and included an assessment of acute and chronic health risks that might arise from direct inhalation exposure to individual components of the biomass power plant emissions, and the mixture of chemicals in the emissions. Also incorporated into the HRA is a quantitative evaluation of cancer risks, and a preliminary evaluation of the potential healthy risks associated with exposure of emission components through the food chain (i.e. indirect exposure pathways). The HRA takes cognisance of background exposures when these were provided.

The HRA considered health risk associated with a range of pollutants including the criteria pollutants, as well as “toxic” pollutants such as Dioxins, PAH’s etc. The HRA concludes that, based on the 98th percentile cumulative concentrations of power station emissions and background air quality; it would be very unlikely health would be adversely affected.

16.2 Horticulture

CSIRO Land and Water undertook a review the potential effects of pollutants predicted to be emitted from the proposed biomass power station on plants and agricultural crops in the surrounding area. This review concluded:

- Hazards from particulates are likely to be low, and restricted to areas very close to the plant.
- The predicted direct toxicity hazards from SO₂ emissions to plants and crops were predicted to be negligible.
- The predicted direct toxicity hazard from NO₂ emissions to plants and crops are predicted to be acceptable.
- The predicted direct toxicity hazards from emissions of dioxins/furans to agricultural crops were predicted to be acceptable.
- Monitoring of emissions will be undertaken once the plant is operating to ensure predicted emissions are in line with actual emissions, and that actual emissions are within regulatory limits.

16.3 Viticulture

Smart Viticulture was engaged to calculate the likelihood of wine taint occurring due to the proposed emissions from the biomass power station. This assessment was conducted based on the minimum sensory threshold of guaiacol and chlorophenol compounds that a wine taster can sense. This sensory threshold varies for different varieties of wine. This Viticultural Impact Assessment report authored by Smart Viticulture is attached separately with the PER Response document. The outcome of this impact assessment was based on predicted ground level concentrations in air of wine taint compounds, and it was demonstrated that the likelihood of wine taints being caused by emissions from the power station was negligible.

16.3.1 Wine Taint Compounds

Recent research assessing cork taint in wines indicates that the following compounds are associated taint [G.F. Fleet, “Wine Microbiology and Biotechnology”, 1993, CRC Press]:

- Phenols – Similar to a Benzene ring, with an attached hydroxyl (OH) group.
 - Chlorophenols: Organochloride, with a Chlorine (Cl) atom bonded to the ring.
 - Methoxyphenols: A form of phenol with a methoxy (CH₃O) compound bound to the ring (could also be considered a form of anisole with a hydroxyl group). **Guaiacol** is known to be a common cause of wine taint.
- Aldehydes - An organic compound containing a terminal carbonyl group (CHO).
 - **Vanillin**: Also a methoxyphenol, with a hydroxyl and methoxy compound bonded to the ring.
- Anisoles (methoxybenzene) – Similar to a Benzene ring, with an attached methoxy (CH₃O) group, and is thus an aromatic compound.

- Chloroanisoles: **Trichloroanisole** (TCA) is a type of Anisole with three bonded Chlorine (CL) atoms, and is generally considered the compound most responsible for cork taint.
- Alcohols – Organic compounds with any organic compound in which a hydroxyl group (-OH) is bound to a carbon atom of an alkyl.
 - **Octenol**: A secondary alcohol, and a common metabolite of mould.
- Bacteria based – The following compounds are metabolites of soil bacteria:
 - **Geosmin**: Geosmin is formed from bacteria that degrade lignin to guaiacol in the presence of vanillin. Geosmin is therefore a by product of other wine taint compounds.
 - **2-Methylisoborneol (2-MIB)**: Borneol is a bicyclic organic compound and a terpene (terpenes are formed from isoprene which are the basic constituents of lignin, and integral part of the cell walls of plants). 2-MIB is formed from bacteria reacting with terpene, and the addition of a methyl group.

As noted, these compounds are organic based, therefore it is necessary to understand organic emissions from biomass burning. Of the compounds listed above, those linked with a benzene ring (ie. Phenols, Aldehydes and Anisoles) are considered of most relevance with regard to biomass burning.

16.3.2 Emissions of Organics from Biomass Burning

Recently there has been a significant amount of research given the accelerated prevalence of wildfire globally due to anthropogenic intervention. The effects of atmospheric particulate matter, including smoke particles, on global climate is now of major concern (Simoneit, B.R.T, "Biomass burning – a review of organic tracers for smoke from incomplete combustion", 2002). Methoxyphenols makeup a significant proportion of particulate concentrations, and to a lesser extent PAHs and chlorophenols. These three compounds have been considered by SmartVit specifically given they act as a tracer for wine taint. Hence ground level concentrations of these compounds in air are predicted for use by SmartVit in their assessment of their affect on viticulture.

16.3.3 Predicted Ground Level Concentrations

The following section quantifies and qualifies the expected cumulative maximum ground level concentrations of key aromatic compounds known to taint wines, from the proposed power plant. This is based on the type of fuel used and the emissions control technology to be put in place in the power station as well as current background levels.

Phenols

Guaiacol

Hays et al ("Speciation of Gas-Phase and Fine-Particle Emissions from burning of foliar fuels", 2002), has demonstrated a relationship between airborne concentrations of fine particulate matter (PM_{2.5}) and methoxyphenols, in particular guaiacol. This assessment considers combustion of a number of pine species, to derive the mass fraction relationship between PM_{2.5} and guaiacol of 0.0013%.

Using the predicted ground level concentrations of PM_{2.5} from the biomass power station (refer to **Section 13.1.4** above), as well as current background levels in Manjimup, the guaiacol concentrations in air were predicted and are given in **Table 16.1**. This method was used to predict ground level concentrations of guaiacol based on PM_{2.5} concentrations measured during bushfires in Victoria (Victorian EPA, "Air Quality during the 2006-07 Victorian Bushfires"). The predicted guaiacol concentrations during the bushfire event were compared with measured guaiacol concentrations during a wildfire in Montana, USA (Ward, T.J. et al, "Characterisation and evaluation of smoke tracers in PM: Results from the 2003 Montana Wildfire Season", 2006), with good correlation.

Table 16.1 Maximum expected guaiacol ground level concentrations, based on PM2.5 peak GLC.

GLC (ng/m ³)	Daily Averaged	Annually Averaged
Biomass Power Station	0.04	0.01
Manjimup Background	0.26	0.13
Victorian Bushfire	0.65 (*)	

(*) Averaged over the exposure period (bushfire duration)

Chlorophenols

The emission factors for all chlorophenols listed in the US EPA AP-42 document for wood waste combustion were summed and the emission rate calculated for the design fuel. The emissions factor detailed in the US EPA document was uncontrolled whereas the proposed Biomass power plant has a baghouse emissions control technology incorporated into the design. The baghouse is known to capture a significant quantity of polychlorophenols (PCP) from the flue gas stream (as they bound to particulates). Filter efficiencies are published (Jussi-Pekka A, Jakko P, Antem V, 1996) for all chlorophenol congeners with two or more chlorine atoms, but not 2CP; hence this was estimated via linear regression using the molecular weights. The average filter efficiency was found to be 31%.

The controlled emission factor for all chlorophenols was estimated using the filter efficiency, and the daily and annually averaged ground level concentrations were calculated using the same pro-rata method as described at the head of **Section 13.2** (with PM10 used as the reference). The uncontrolled emission factor and the controlled emission rates are listed in **Table 16.2**.

Table 16.2 2-MCP Emission factors and controlled emission rates.

	Uncontrolled Emissions Factor (kg/ton)	Controlled Emissions (g/s)
Chlorophenols	5.6×10^{-7}	5.5×10^{-6}

Table 16.3 Maximum expected chlorophenol ground level concentrations, based on PM10 emission rates and peak GLC.

GLC (pg/m ³)	Daily Averaged	Annually Averaged
Chlorophenols	9.8	2.3

Polycyclic Aromatic Hydrocarbons (PAHs)

Refer to **Table 6.7** for emission factors and rates, with the predicted ground level concentrations shows below in **Table 16.4** for the daily and annually averaged concentrations.

Table 16.4 Maximum predicted ground level concentrations of PAHs over a one hour averaging period.

GLC (ng/m ³)	Daily Averaged	Annually Averaged
PAHs	4.3	1.0

17. Management Plan

Table 17.1 Air Quality Management Plan

Objective	To ensure air emissions do not adversely affect the environment or health, welfare and amenity of people and nearby land uses by meeting statutory requirements and acceptable standards.
Performance Criteria	Compliance with State and Federal guidelines and prescribed licence conditions
Management Measures	<p>Construction</p> <p>Responsibility: Project Principal</p> <ul style="list-style-type: none"> • As part of site induction and environmental awareness training, all construction staff will be informed of the environmental issues associated to the site and their obligations relating to construction activities. • Unsealed roads will be watered to suppress dust. • Restrict vehicle speed on unsealed roads to 20kph to limit dust generation. • No burning of waste materials or release to land or water. • Efficient use of construction machinery and earth moving equipment during construction • All equipment used during construction to be maintained in good working order. <p>Operation</p> <p>Responsibility: Plant Manager</p> <ul style="list-style-type: none"> • Ensure ground level concentrations of major pollutants comply with statutory guidelines. • Ensure dust and other pollutants resulting from Power Plant operations are minimised. • Base line monitoring program to be established prior to and during plant operation. Monitoring will be carried out in accordance with Australia Standards and DEC requirements • Weather station established on site in accordance with AS2923 to log meteorological conditions on and surrounding the site. • Develop and implement air quality monitoring program in accordance with DEC requirements • Quality control methods and routine sampling of fuel to be established. • Baghouse controls to ensure maximum collection efficiency is not compromised. • In the event of a baghouse failure steps should be taken based on the plant hazard and operability guidelines that there is minimal impact on the health of the surrounding residents and impact on local flora and fauna.
Monitoring & Reporting	<ul style="list-style-type: none"> • Equipment to be inspected and approved by the Project Principal prior to location on site. • Log of service and repairs to be kept by contractors and project staff. • Regular inspection of the emission control technology within the Power Plant. • Monitoring of the stack on commissioning and regular intervals thereafter of the following gaseous pollutants. <ul style="list-style-type: none"> ○ Polycyclic aromatic hydrocarbons (PAHs) ○ Volatile organic compounds ○ Polychlorinated dioxins and furans ○ Sulphur dioxide ○ Carbon monoxide

**Corrective
Action**

- Real time in-stack continuous monitoring of the following gaseous and particulate matter.
 - Nitrogen Dioxide
 - PM10
 - PM2.5
- Monitoring of plant efficiency
- Implementation of quality control methods through sampling and analysis of fuel supply.

Non-compliance is recorded and reported to the DEC.

18. Conclusions

This report has assessed the air quality impact of a proposed 40 MWe Biomass Power Plant, to be sited approximately 10 km south of the township of Manjimup in the south-west of Western Australia.

Commonwealth legislation was used to assess the air quality impact of the criteria pollutants. Other persistent organic pollutants and trace elements were assessed through state guidelines and International treaties/legislation.

Compliance of the plant design to best available techniques for large combustion plants was shown through the use of a bubbling fluidised bed combustion system and baghouse fabric filter emissions control system. The application of these emissions control technologies enabled compliance with all emission directives relevant to the Australian context and European context as outlined for large combustion plants. With regards to the European Council Directive for new large combustion plants, emissions of dust and NO_x have been guaranteed by the proponent to be at the compliance limit. Therefore ensuring the application of world's best practice technology in regards to the design of this plant.

The pollutant emissions were identified and modelled using The Air Pollution Model (TAPM), a prognostic meteorological and atmospheric dispersion model was used to model and predict regional and local meteorological effects as well as the dispersion of pollutants. TAPM was run using synoptic data for 2001 obtained from CSIRO. The reference year was shown to be representative of long term meteorological data. The TAPM generated meteorological data was compared with hourly BoM monitoring data over contemporaneous periods to show that the parameters being predicted were representative of local and regional conditions. This comparison showed that the meteorological data generated would enable the prediction of worst case pollutant ground level concentrations.

The local existing ambient air quality was measured in the townships of Bridgetown (short term) and Manjimup (full year). Similarity in ambient air concentrations was demonstrated for particulates which enabled the use of both data sets to predict cumulative ground level pollutant concentrations. In addition to the measured background concentrations of nitrogen dioxide, ambient concentrations of this compound were also predicted via the inclusion of background sources of VOCs and NO_x in a full year TAPM simulation. Cumulative nitrogen dioxide ground level concentrations were predicted using various schemes to estimate the extreme scenarios as well as more realistic methods based on atmospheric chemistry.

The following conclusions are made by assessment of the air quality model results with the relevant criteria:

- Sulphur Dioxide: Predicted concentrations are an order of magnitude below air quality standards.
- Nitrogen Dioxide: Extreme worst case scenario prediction methods show that NO₂ concentrations comply with the relevant air quality standards, whereas more realistic simulation of both emissions from the proposed facility and background sources shows that predicted levels are well below the air quality standards.
- Coarse Particulates (PM10): Ground level concentrations from the power station alone are shown to be an order of magnitude below the air quality standards. Cumulative concentrations primarily result from background concentrations in the Manjimup/Bridgetown region, and are significantly below the relevant air quality standards.
- Fine Particulates (PM2.5): Ground level concentrations from the power station alone are shown to be an order of magnitude below the air quality standards. Cumulative concentrations primarily result from background concentrations in the Manjimup/Bridgetown region. The daily averaged cumulative concentrations comply with the air quality standards while annually averaged background concentrations exceed the air quality standards (with negligible affect of concentrations due to the biomass power station).
- Carbon Monoxide and Lead: Predicted concentrations are several orders of magnitude below air quality standards.
- Persistent Organic Pollutants, Volatile Organic Compounds and Trace Elements: Predicted ground level concentrations of all compounds are well below air quality standards.

An air quality management plan has been documented to ensure that adverse impacts do not occur. This plan also seeks to maintain the efficiency of best practice emissions control methods through an ongoing monitoring plan, and recommends procedural requirements in the event of plant abnormalities.

The predicted concentrations of pollutants in air were used to conduct separate expert independent human health, horticultural and viticultural risk assessments. The main conclusions from these separate studies were:

- Health Risk Assessment: It is extremely unlikely that emissions from the power plant will result in adverse effects on human health.
- Horticultural Risk Assessment: Risk of pollutant concentrations in the air on horticulture in the region from deposition of trace elements and gaseous compounds varies from being acceptable to negligible.
- Viticultural Risk Assessment: Risk of smoke taint of grapes and wine from the emissions of bound organic compounds from the Biomass Power Plant are considered to be negligible.

A comparative study shows that predicted ground level concentrations based on the current practice of open burning of plantation waste are an order of magnitude greater than the controlled combustion of this fuel in the proposed Biomass Power Plant.

In conclusion this assessment has shown that, with appropriate conditions of approval incorporated within an Air Quality Management, no adverse environmental impacts on air quality will occur as a result of emissions from the proposed development.

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Appendix A

NPI Location Report – All Sources: Shire of Manjimup, WA

Appendix B

Nitrogen Dioxide Contours – TAPM Predicted Background Levels

Appendix C

Sulphur Dioxide Contours – Non Chemistry Simulation

Appendix D

Sulphur Dioxide Contours – Chemistry Simulation

Appendix E

Nitrogen Dioxide Contours – Scenario 1 (Non-Chemistry Simulation)

Appendix F

Nitrogen Dioxide Contours – Scenario 2 (Ozone Limiting Method)

Appendix G

Nitrogen Dioxide Contours – Scenario 3 (Chemistry Simulation - Biogenics/Anthropogenics)

Appendix H

Nitrogen Dioxide Contours – Scenario 4 (Chemistry Simulation - Inclusion of All Sources)

Appendix I

PM10 Contours – Biomass Power Station Emissions

Appendix J

PM2.5 Contours – Biomass Power Station Emissions

Appendix K

Area Source Open Burning Daily Averaged Particulate Contours
(PM10 and PM2.5)