**REPORT**

# AIR QUALITY ASSESSMENT – BELTANA POWER GENERATION PROJECT

**Beltana Highwall Mining Pty Limited**

**Job No: 3839**

**22 April 2010**

A PEL Company

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| **PROJECT TITLE:** | **AIR QUALITY ASSESSMENT – BELTANA POWER GENERATION PROJECT** |
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# ES1 EXECUTIVE SUMMARY


**Overview**

Beltana Underground Mine seeks approval to modify its existing consent (DA 376-8-2003) to allow for the capture and use of the coal seam methane through the operation of up to 25 MW of gas fired reciprocating engine power generating units and a pilot ventilation air methane (VAM) abatement system.

This study assesses the potential air quality impacts of the proposed Beltana Power Generation Project in accordance with the Department of Environment, Climate Change and Water's "*Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*".

**Dispersion Meteorology**

A meteorological station operated by Bulga Coal Mine provides information on prevailing conditions for the area and is used to characterise dispersion for this assessment. On an annual basis, the most common winds are from the east-northeast, west-northwest and south.

**Emissions and Dispersion Modelling**

Impacts are assessed for all new emissions sources for the proposed Beltana Power Generation Project, including:

- Eight coal seam gas power generation units;
- Pilot VAM abatement unit; and
- Seven flares for excess coal seam methane;

Modelling has been performed using the CALPUFF dispersion model run in screening mode. Of the potential emissions from the project, oxides of nitrogen ($NO_x$) have the largest emission potential, formed by high temperatures generated during combustion of the coal seam methane for power generation and flaring. Emissions of carbon monoxide (CO) and organic compounds can also be expected from the incomplete combustion of the fuel. Emissions of $NO_x$ from VAM abatement are low, as the oxidation of the methane occurs at temperatures below that required for thermal $NO_x$ generation.

**Predicted Impacts**

The predicted $NO_2$ concentrations were well within the impact assessment criteria at all receptor locations, even with the application of conservative modelling assumptions. The potential for cumulative impacts is also expected to be small. Incremental increases in other pollutant concentrations, including CO and VOCs are predicted to be minor.

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# 1 INTRODUCTION

Bulga Underground Operations (also known as Beltana Underground Mine (Beltana)) is an underground coal mine located approximately 12 km southwest of Singleton in the Upper Hunter Valley of NSW. Beltana forms part of the Bulga Complex managed by Bulga Coal Management Pty Limited (BCM) on behalf of the Bulga Joint Venture (BJV).

Beltana Underground Mine comprises Beltana No.1 Whybrow Seam Longwall Mine and the Blakefield South – Blakefield Seam Mine. The deeper seam being mined at Beltana contains substantial methane levels and this is currently drained through a combination of pre and post mining gas drainage and then flared or vented to atmosphere.

BCM seeks approval to modify its existing consent (DA 376-8-2003) to allow for the capture and use of the coal seam methane through:

- Installation and operation of up to 25 MW of gas fired reciprocating engine power generating units and associated infrastructure; and
- Construction and operation of a pilot ventilation air methane (VAM) abatement system.

An Environmental Assessment has been submitted as part of a Section 75W Modification Application (DA 376-8-2003 MOD 4) (**Umwelt, 2009**), which has been reviewed for adequacy by the NSW Department of Environment, Climate Change and Water (DECCW). DECCW have requested further assessment to address the potential air quality impacts of the project.

Beltana Highwall Mining P/L has commissioned PAEHolmes to prepare an Air Quality Impact Assessment for the Beltana Coal Mine Power Generation and Ventilation Air Methane Abatement Project.

## 1.1 Objectives of the Study

The objectives of the study are to address the requirements of the DECCW, as follows:

- To conduct an Air Quality Impact Assessment in accordance with the "*Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*";
- To quantify emissions to air for all proposed sources, preferably based on manufacturers performance specifications / guarantees;
- To provide a detailed description of the ambient receiving environment, with particular focus on background pollution concentrations, prevailing meteorological conditions and nearby sensitive receptors;
- To provide a cumulative impact assessment based on regulatory dispersion model predictions and representative background pollution concentrations; and
- Where emission controls are assumed as part of the air quality impact assessment, specific details pertaining to those controls should be provided.

# 2 PROJECT DESCRIPTION

The project involves the capture, treatment and use of methane drained from the underground operations at Beltana. The two key components of the project are:

- Installation and operation of up to 25 MW of gas fired reciprocating engine power generating units and associated infrastructure; and
- Construction and operation of a pilot ventilation air methane (VAM) abatement system.

The power generation component is proposed to be located on a cleared site approximately 150 m south of the No.2 Ventilation Fan site. Up to eight gas fired reciprocating engines, with an output up to 25 MW will be installed in stages as the mine progresses. Electricity produced from the power generation units will be used to power some of Beltana's infrastructure, including ventilation fans, with surplus fed back into the national power grid. A 2.5 km pipeline would be constructed to deliver gas to the power plant from the existing Blakefield South gas drainage infrastructure.

Each power generation unit will have the capacity to utilise approximately 90 L/s of methane per MW of generating capacity. With eight operational units generating 25 MW of power approximately 2250 L/s of gas would be required. Any excess gas would be flared. It is expected that the flares would have an availability of 95% with unavailability due to maintenance etc. Details of equivalent generator units are shown in **Table 2.1**.

**Table 2.1: Design Parameters for Power Generation**

| Parameter | Value |
|---|---|
| Unit Model | Energen G3094 |
| Engine | Duetz TCG2032 V16 Engine |
| Output per unit | 3.93 MW |
| Proposed Installation | Up to 8 Units (staged) |
| Total Output | Up to 25 MW |
| Methane Utilisation | 90 L/sec per MW of generating capacity |
| Proposed Project Methane Utilisation (8 Units at 25 MW) | 2,250 L/sec |
| Availability | 96 to 98 percent |

A Ventilation Mine Methane (VAM) abatement system is proposed to be sited adjacent to the Blakefield South Ventillation Fan No. 2 which is currently under construction. The system will utilise reverse flow thermal reactor (RFTR) technology (Vocsidizer, VAMOX, Corky's VAN RAB or similar) to capture and convert the dilute methane concentrations from the mine ventilation shafts to carbon dioxide ($CO_2$) and water. The pilot VAM abatement system proposed for Beltana will include one RFTR. The operational parameters for an equivalent system are shown in **Table 2.2**.

**Table 2.2: System Design Parameters for VAM Abatement**

| Parameter | Value |
|---|---|
| Mine Ventilation Air Volume | 60,000 $Nm^3$/hr |
| Mine Ventilation Air Temperature | 10-40 °C |
| Typical Ventilation Air Methane Content | 0.5% $CH_4$ @ 62,500 $Nm^3$/hr |
| Maximum deign VAM concentration | 0.8% $CH_4$ |
| Methane reduction target | 97% average reduction |

## 2.1 Local Setting

Beltana Underground Mine is located in the Upper Hunter Valley of New South Wales. The closest urban centre is Singleton, approximately 12 km to the northeast of the project. There are also a number of villages in the surrounding area which include Broke and Bulga approximately 1.0 km south and 1.5 km west of the lease area.

Land-use in the local area is dominated by coal mining, grazing, viticulture and rural residential holdings. The closest private residences to the proposed power generation project are located approximately 2.5 km to the southwest of the site. The location of the closest private receptors in relation to the power generation project and VAM abatement system are shown in **Figure 2.1**.

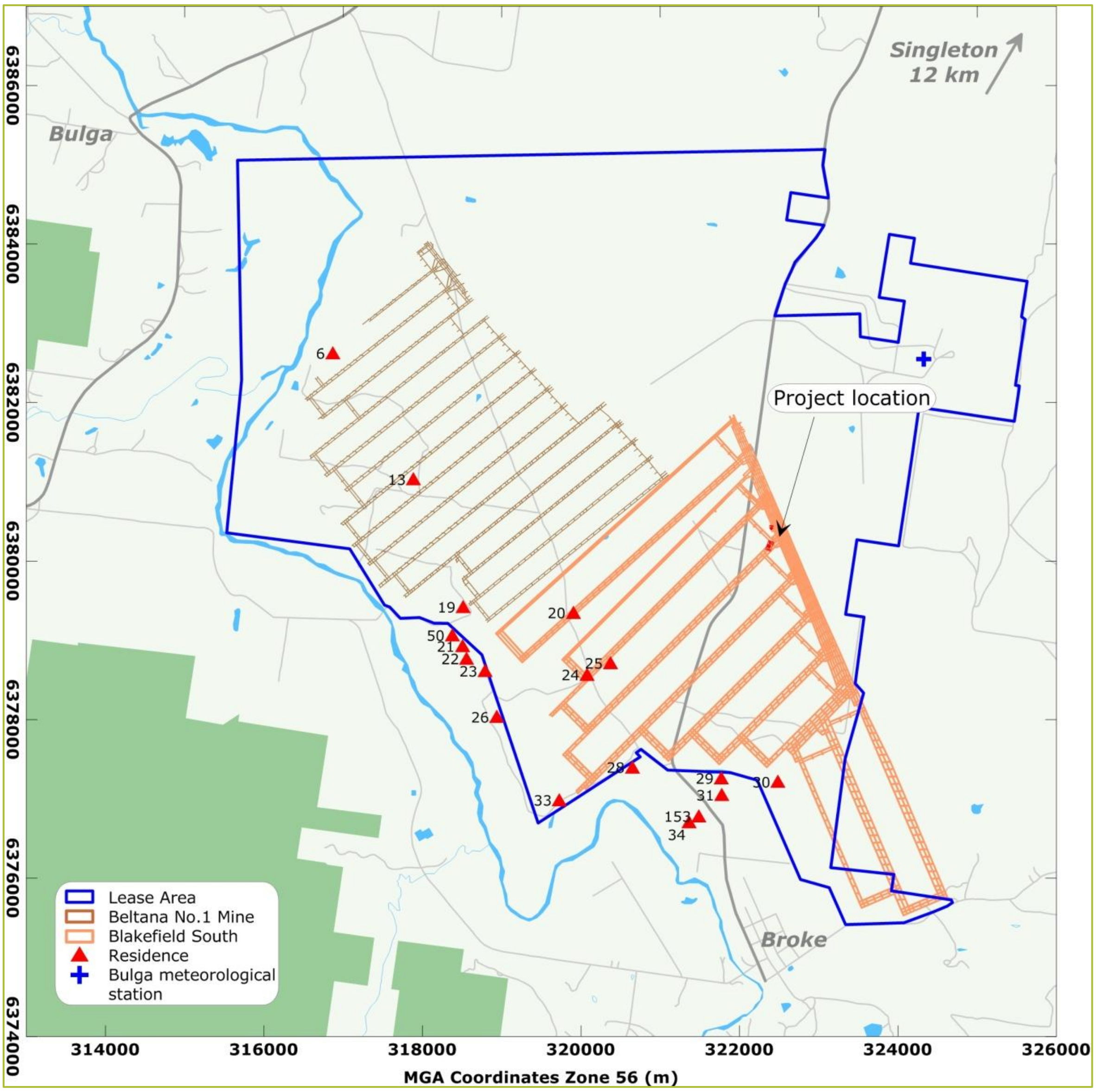



**Figure 2.1: Local Setting and Site Overview**

## 2.2 Topography

A three-dimensional representation of the regional topography is shown in **Figure 2.2**, showing the location of the proposed site in relation to the neighbouring receptor locations. Regional topography has a strong influence on prevailing meteorological conditions described in **Section 5**.

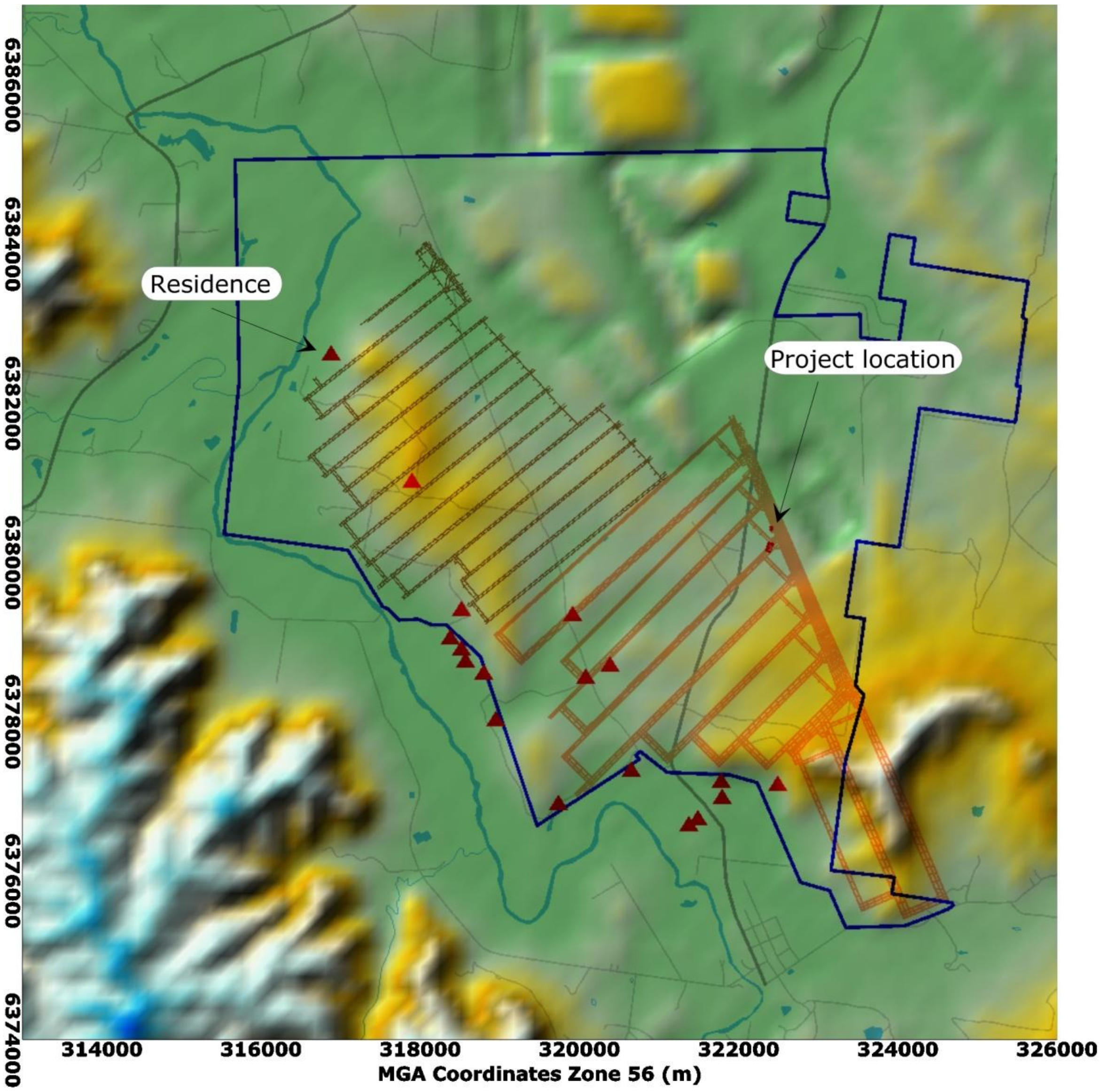



**Figure 2.2: Pseudo 3-Dimensional Representation of Regional Topography**

# 3 AIR QUALITY CRITERIA

The combustion and flaring of coal seam methane will result in emissions of Oxides of Nitrogen ($NO_x$), Carbon Monoxide (CO) and hydrocarbons. In addition, the VAM abatement system is designed to oxidise the methane, resulting in emissions of $NO_x$ and CO.

## 3.1 Oxides of Nitrogen

The key pollutant released from combustion and flaring of coal seam methane, will be oxides of nitrogen ($NO_x$). $NO_x$ is comprised of nitric oxide (NO) and nitrogen dioxide ($NO_2$), however NO is not generally considered harmful to human health and not considered an air pollutant at the concentrations that are typically found in ambient environments. Effects of $NO_2$ include respiratory infections, asthma and chronic lung disease. The NSW DECCW prescribes ambient impact assessment criteria for $NO_2$, as outlined in **Table 3.1**.

## 3.2 Carbon Monoxide

Emissions of Carbon Monoxide (CO) can be expected from the combustion and flaring of coal seam methane. Carbon monoxide is a colourless, odourless gas, formed from the incomplete or inefficient combustion of fuels containing carbon. Exposure to CO can cause a reduction in the oxygen-carrying capacity of the red blood cells, resulting in decreased oxygen supply to vital organs such as the heart and brain. The NSW DECCW prescribes ambient impact assessment criteria for CO, as outlined in **Table 3.1**.

## 3.3 Volatile Organic Compounds (VOCs)

Volatile Organic Compounds is a term given to various organic chemical components, several of which are considered air toxics, including formaldehyde which is formed from the combustion of methane. Methane itself is a common VOC but is often distinguished from other VOCs using the term non-methane VOCs or NMVOCs.

Air toxins are present in the air in low concentrations, however characteristics such as toxicity or persistence means they can be hazardous to human, plant or animal life. There is evidence that cancer, birth defects, genetic damage, immuno-deficiency, respiratory and nervous system disorders can be linked to exposure to occupational levels of air toxics.

## 3.4 Summary of Air Quality Goals

The NSW Department of Environment, Climate Change and Water (DECCW) prescribe ambient impact assessment criteria which are outlined in their "*Approved Methods for Modelling and Assessment of Air Pollutants in NSW*" (**NSW DEC, 2005**). The impact assessment criteria refer to the total pollutant load in the environment and impacts from new sources of these pollutants must be added to existing background levels for compliance assessment. **Table 3.1** summarises the air quality goals that are relevant to this study.

**Table 3.1: NSW DECCW Impact Assessment Criteria**

| Pollutant | Assessment Criteria | Averaging Period |
|---|---|---|
| Nitrogen Dioxide | 246 µg/m$^3$ | 1-Hour |
| | 62 µg/m$^3$ | Annual |
| Carbon Monoxide | 30 mg/m$^3$ | 1-Hour |
| | 10 mg/m$^3$ | 8-Hour |
| Formaldehyde | 0.02 mg/m$^3$ | 1-Hour |

# 4 EXISTING AMBIENT AIR QUALITY

Air quality standards and goals refer to pollutant levels that include the contribution from specific projects and existing sources. To fully assess impacts against all the relevant air quality standards and goals it is necessary to have information on the background concentrations to which the project is likely to contribute.

## 4.1 Nitrogen Dioxide

As a part of the Macquarie Generation (MacGen) monitoring network, measurements of $NO_2$ have been conducted since 1984 at six locations in the Hunter Valley (**Katestone, 2009**). The two closest MacGen monitoring stations are Singleton and Ravensworth, approximately 18 km northeast and 28 km north of the proposed site.

**Table 4.1** presents the 1-hour maximum and the annual average for each year since monitoring commenced in 1994.

It can be seen at the Singleton monitoring site that, in general, the maximum 1-hour average concentrations constitute less than half of the air quality goal of 246 µg/m$^3$. The only exception is during 2005 where the concentration exceeds the air quality goal. It should be noted that this monitoring station is close to a major road where vehicular exhaust would have strongly influenced measured concentrations. The annual average $NO_2$ concentrations are all well below the air quality goal of 62 µg/m$^3$.

The $NO_2$ monitoring results for the Ravensworth site are slightly higher than those experienced at the Singleton site. The maximum 1-hour average $NO_2$ concentration was 154.0 µg/m$^3$ and the annual average was 21.3 µg/m$^3$, both below the relevant air quality criterion.

The 95$^{th}$ percentile of the 1-hour average of $NO_2$ for each year at all monitoring stations are less than 60 µg/m$^3$ indicating that generally, ambient levels of $NO_2$ are less than 25% of the DECCW air quality goal (**Katestone, 2009).**

Table 4.1: $NO_2$ concentrations at Singleton and Ravensworth sites (µg/m$^3$)

| Year | Singleton | | Ravensworth | |
|---|---|---|---|---|
| | 1-hour average (maximum) | Annual average | 1-hour average (maximum) | Annual average |
| 1994 | 49.5 | 9.6 | 66.6 | 13.7 |
| 1995 | 74.4 | 14.5 | 154.0 | 17.9 |
| 1996 | 83.7 | 16.2 | 140.5 | 26.4 |
| 1997 | 117.9 | 22.0 | 104.3 | 24.0 |
| 1998 | 113.9 | 18.6 | 93.2 | 23.1 |
| 1999 | 65.8 | 12.7 | 86.7 | 19.9 |
| 2000 | 68.0 | 13.5 | 145.9 | 17.2 |
| 2001 | 113.0 | 15.3 | 96.5 | 18.9 |
| 2002 | 109.8 | 16.0 | 88.3 | 18.3 |
| 2003 | 82.3 | 16.4 | 126.3 | 22.0 |
| 2004 | 126.5 | 17.9 | 60.1 | 19.1 |
| 2005 | *339.2*[a] | 18.9 | 96.5 | 22.6 |
| 2006 | 85.5 | 17.0 | 93.7 | 26.7 |
| 2007 | 80.3 | 16.0 | 103.8 | 21.7 |
| 2008 | 78.9 | 18.5 | 99.7 | 21.1 |
| **Maximum** | **339.2** | **-** | **154.0** | **-** |
| **Average** | **-** | **16.4** | **-** | **21.3** |

[a] *High measurements at this site in 2005 have been attributed to the close proximity of the monitoring station to a major road.*

## 4.2 Carbon Monoxide

There is no information available on ambient concentrations of carbon monoxide in the Hunter Valley. However, ambient CO concentrations would be, in general, expected to be very low. Ambient air quality goals for CO are many orders of magnitude greater than $NO_2$, suggesting, based on the $NO_2$ monitoring data, that ambient levels of CO would be significantly less than the air quality goals.

# 5 PREVAILING METEOROLOGY

## 5.1 Climate data

The Bureau of meteorology collects climatic information from the monitoring station located at Jerry's Plains Post Office (Station Number 061086), approximately 27 km northwest of the Project. Data collected over a 126 year period is available providing information on the long-term average values of climatic elements such as temperature, humidity, rainfall, etc.

**Table 5.1** presents temperature, humidity and rainfall data collected at Jerry's Plains Post Office for 126 years between 1884 and 2009. Temperature and humidity data consist of monthly averages of 9am and 3pm readings. Also presented are monthly averages of maximum and minimum temperatures. Rainfall data consist of mean rainfall and the average number of raindays per month.

On average January is the hottest month with an average maximum temperature of 31.7°C. July is the coldest month, with average minimum temperature of 3.8°C. The annual average maximum and minimum temperatures experienced at Jerry's Plains Post Office are 25.2°C and 10.6°C respectively.

The annual average humidity reading collected at 9am at Jerry's Plains Post Office is 70 percent, and at 3pm the annual average is 47 percent. The month with the highest humidity on average is June with a 9am average of 80 percent, and the lowest are September, October, November and December with 3pm average of 42 percent.

Rainfall data collected at Jerry's Plains Post Office shows that January is the wettest month, with an average rainfall of 77.0 mm. The average annual rainfall is 642.1 mm with an average of 86.8 raindays.

**Table 5.1: Temperature, Humidity and Rainfall Data for Jerry's Plains Post Office**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 am Mean Dry-bulb and Wet-bulb Temperatures (ºC) and Relative Humidity (%) | | | | | | | | | | | | | |
| Dry-bulb | 23.4 | 22.7 | 21.2 | 18.0 | 13.6 | 10.6 | 9.4 | 11.4 | 15.3 | 19.0 | 21.1 | 23.0 | 17.4 |
| Humidity | 67 | 72 | 72 | 72 | 77 | 80 | 78 | 71 | 64 | 59 | 60 | 61 | 70 |
| 3 pm Mean Dry-bulb and Wet-bulb Temperatures (ºC) and Relative Humidity (%) | | | | | | | | | | | | | |
| Dry-bulb | 29.8 | 28.9 | 27.1 | 24.1 | 20.1 | 17.1 | 16.4 | 18.2 | 21.2 | 24.2 | 26.9 | 29.0 | 23.6 |
| Humidity | 47 | 50 | 49 | 49 | 52 | 54 | 51 | 45 | 42 | 42 | 42 | 42 | 47 |
| Daily Maximum Temperature (ºC) | | | | | | | | | | | | | |
| Mean | 31.7 | 30.9 | 28.9 | 25.3 | 21.3 | 18 | 17.4 | 19.4 | 22.9 | 26.3 | 29.2 | 31.3 | 25.2 |
| Daily Minimum Temperature (ºC) | | | | | | | | | | | | | |
| Mean | 17.1 | 17.1 | 15 | 10.9 | 7.5 | 5.3 | 3.8 | 4.4 | 7.0 | 10.3 | 13.2 | 15.7 | 10.6 |
| Rainfall (mm) | | | | | | | | | | | | | |
| Mean | 77.0 | 72.5 | 59.1 | 44.1 | 40.4 | 47.6 | 43.3 | 36.4 | 41.7 | 51.9 | 59.7 | 67.9 | 642.1 |
| Raindays (Number) | | | | | | | | | | | | | |
| Mean | 7.9 | 7.4 | 7.4 | 6.4 | 6.5 | 7.6 | 7.1 | 7 | 6.6 | 7.5 | 7.7 | 7.7 | 86.8 |

*Station number 061086; Commenced: 1884; Last record: 2010; Latitude (deg S): -32.50; Longitude (deg E): 150.91 (Bureau of Meteorology)*

## 5.2 Dispersion Meteorology

The dispersion model used for this assessment (see **Section 6**) requires information about the dispersion characteristics of the area. In particular, data is required for wind speed, wind direction, atmospheric stability class and mixing height.

DECCW have specified the requirements for meteorological data that are used for air dispersion modelling in their *Approved Methods* (**NSW DEC, 2005**). The requirements are as follows:

- Data must span at least one year;
- Data must be 90% complete; and
- Data must be representative of the area in which emissions are modelled.

Bulga Coal Mine owns and operates an automatic weather station (AWS) 3 km northwest of the project site. Measurements of temperature, wind speed wind direction and solar radiation are collected at 10-minute intervals, retrieving 100 % of data in 2009. Annual and seasonal wind roses prepared from data collected from the Bulga AWS for 2009 are presented in **Figure 5.1**.

On an annual basis, the most common winds are from the east, west and southern quadrants. Very few winds originate from the northern quadrant. Summer and autumn winds are dominated by winds originating from the east, east-northeast and south and winds during winter are predominantly from the west-northwest. The wind pattern in spring is an average of the seasons. The annual average wind speed is 2.15 m/s and the frequency of calms (when winds are <=0.5 m/s) is 23.2 %.

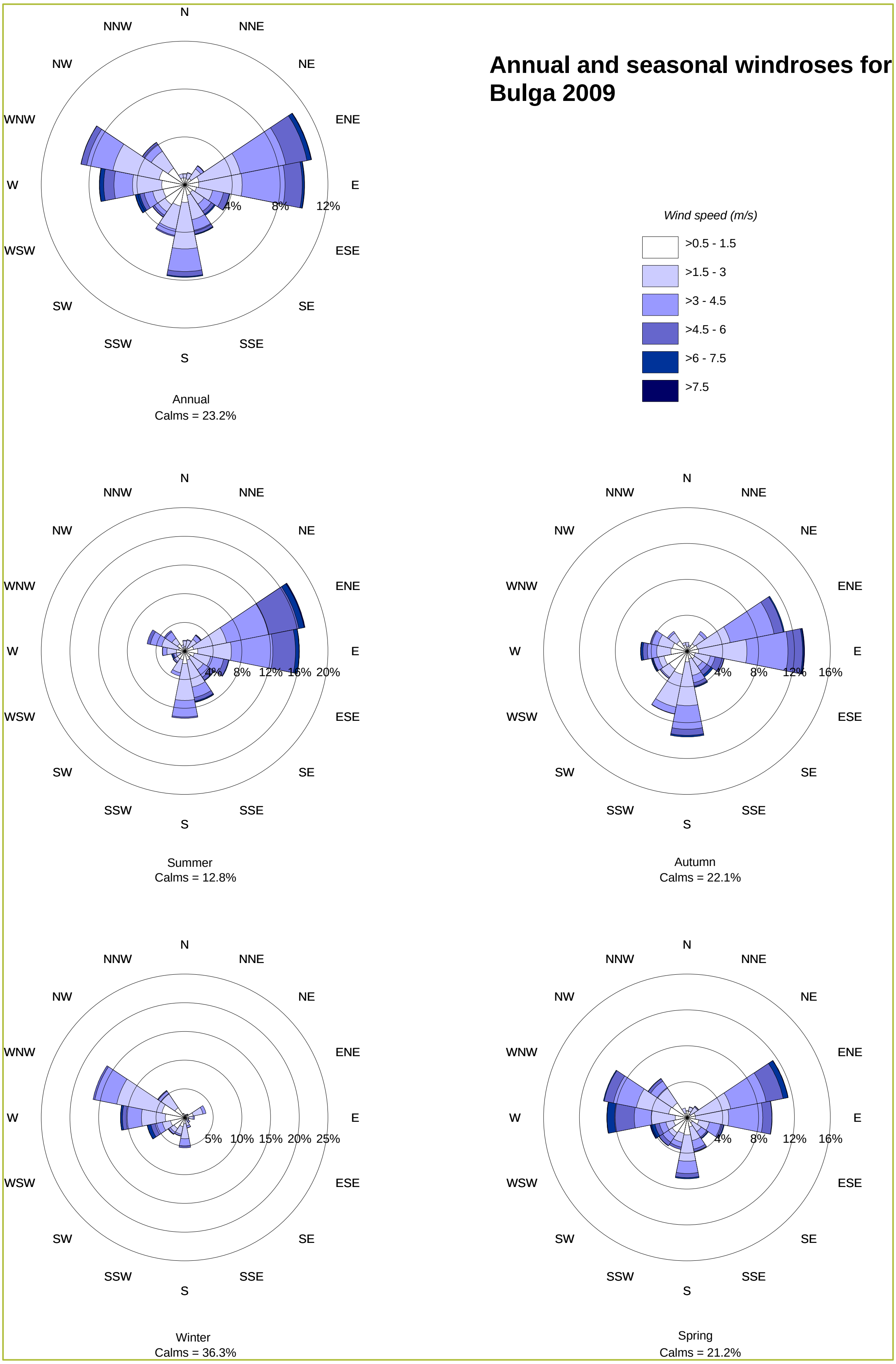



**Figure 5.1: Annual and Seasonal Windroses for Bulga 2009**

To use the wind data to assess dispersion, it is necessary to also have data on atmospheric stability, which has been determined from sigma theta measurements using the US EPA turbulence based method (**US EPA, 2000**).

The term atmospheric stability refers to the dispersive capacity of the atmosphere. In this study a classification scheme referred to as the Pasquill-Gifford scheme has been used. The Pasquill-Gifford scheme classifies the atmosphere into six (sometimes seven) classes A to F (or G in the extended scheme);

- Class A occurs in the day with light winds and strong solar radiation with strong convection; dispersion is rapid.
- Class D, also known as "neutral conditions" occurs with moderate to strong winds and/or overcast skies; again dispersion is rapid.
- Class F (and G) occurs under light winds with clear skies at night. These conditions are conducive to the formation of ground-based inversions and as such, dispersion is slow.
- Classes B and C are intermediate between A and D, and E is intermediate between D and F.

**Table 5.2** shows the frequency of occurrence of the stability categories expected in the area. Overall, stability class D occurs for the greatest proportion of time within the surrounding area, this is characterised by rapid dispersion.

**Table 5.2: Frequency of occurrence of stability classes (April 2008 to March 2009)**

| Stability Class | Percentage Frequency (%) |
|---|---|
| A | 17.2 |
| B | 9.2 |
| C | 11.9 |
| D | 28.9 |
| E | 12.3 |
| F | 20.6 |
| **Total** | **100** |

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

Mixing height was determined using a scheme defined by **Powell** (**1976**) for day-time conditions and an approach described by **Venkatram**, (**1980**) for night-time conditions. These two methods provide a good estimate of mixing height in the absence of upper air data.

# 6 APPROACH TO ASSESSMENT

## 6.1 Introduction

The assessment follows a conventional approach commonly used for air quality assessment in Australia and outlined in the NSW DECCW "*Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*".

Dispersion modelling is performed for all new emission sources for the proposed Beltana Power Generation Project. Modelling has been performed using the CALPUFF dispersion model run in screening mode.

The CALMET / CALPUFF modelling system is a multi-layer, multi-species non-steady state puff dispersion model that can simulate the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal (**Scire *et al*., 2000**). The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer-range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects. The model employs dispersion equations based on a Gaussian distribution of pollutants across the puff and takes into account the complex arrangement of emissions from point, area, volume and line sources. CALPUFF is endorsed by the US EPA, and has been extensively used in Australia.

CALPUFF screening mode uses a single meteorological input file (similar to models such as AUSPLUME) rather than using the CALMET modelling system to develop a spatially varying and three-dimensional meteorological wind field. CALPUFF run in screening mode is valid when the meteorological conditions can be assumed as spatially uniform over the modelling domain for any given hour.

To assess the potential impact from the proposed Beltana Power Generation Project, the following modelling sources have been considered.

- Eight coal seam gas power generation units;
- Pilot VAM abatement unit; and
- Seven flares for excess coal seam methane.

CALPUFF has been chosen for this assessment due to its ability to effectively model flare emissions. Modelling flare emissions differs from conventional plumes in that the buoyancy flux is affected due to radiative heat lose during plume rise. Flare emissions can be modelled using CALPUFF, replacing Briggs plume rise with numerical plume rise to allow for radiative heat loss, vertical wind shear and ambient temperature stratification, with the "no stack tip downwash" option chosen (**Robe, 2009**).

## 6.2 Emissions to Air

Of the potential emissions from the project, oxides of nitrogen ($NO_x$) have the largest emission potential, formed by high temperatures generated during combustion of the coal seam methane. Emissions of carbon monoxide (CO) and organic compounds can also be expected, formed from the incomplete combustion of the fuel. $NO_x$ emissions from the VAM abatement are minimal as the oxidation of the methane occurs at temperatures lower than what is required for thermal $NO_x$ generation.

### 6.2.1 Power Generation Units

The emission parameters adopted for the assessment, for the eight power generation units, are shown in **Table 6.1**. Emissions concentrations are taken from the manufacturer emission performance guarantees (**Deutz, 2006**), however for $NO_x$ the emissions concentrations are given as < 500 mg/Nm$^3$. The prescribed standards of concentration for stationary reciprocating internal combustion engines under the Clean Air Regulations (**POEO, 2002**) is 450 mg/Nm$^3$ and as such modelling has been performed for emissions at the regulation limit. It is noted that the engines can be tuned to comply with the regulation limit (**Umwelt, 2009**). Exhaust volumetric flow rates (used to establish mass emission rates) have been derived stoichiometrically, based on typical composition of coal seam methane and fuel flow rate.

**Table 6.1: Emission and Stack Parameters – Power Generation**

| Parameter | Value |
|---|---|
| $NO_x$ Emission Concentration | 450 mg/Nm$^3$ |
| CO Emission Concentration | 50 mg/Nm$^3$ |
| Formaldehyde Emission Concentration | 0.06 mg/Nm$^3$ |
| Stack Height | 9 m |
| Stack Diameter | 1 m |
| Exit Velocity | 20 m/s |
| Temperature | 476 $^oC$ |
| **Mass Emission Rates** | |
| $NO_x$ Emission Rate | 0.96 g/s |
| CO Emission Rate | 0.64 g/s |
| VOC Emission Rate | 0.13 g/s |

### 6.2.2 VAM Abatement Unit

The reverse flow thermal reactor (RFTR) unit consists of a single heat transfer bed filled with ceramic media. The methane laden air is directed through the porous ceramic heat exchange media and as it moves through the inlet side of the bed it gets hot enough to undergo oxidation to water vapour and $CO_2$. The thermal energy released by the oxidation is recovered by the ceramic media on the outlet side of the bed. Emissions include carbon monoxide (CO) and oxides of nitrogen ($NO_x$), however due to low temperature oxidation typical emissions are low.

The emission parameters adopted for the assessment are given in **Table 6.2**. The emission concentrations were those quoted by manufacturers of VAM abatement units (**Umwelt, 2009**). Exit velocity (m/s) and temperature $^oC$ are taken from the Air Quality Assessment for a similar VAM abatement facility at West Cliff, NSW (**Holmes Air Sciences, 2002**).

**Table 6.2: Emissions and Stack Parameters - VAM**

| Parameter | Value |
|---|---|
| $NO_x$ Emission Concentration | 10 mg/Nm$^3$ |
| CO Emission Concentration | 50 mg/Nm$^3$ |
| Stack Height | 9 m |
| Stack Diameter | 1 m |
| Exit Velocity | 4 m/s |
| Temperature | 60 °C |
| **Mass Emission Rates** | |
| $NO_x$ Emission Rate | 0.17 g/s |
| CO Emission Rate | 0.83 g/s |

### 6.2.3 Emissions from Flaring

The emission parameters adopted for the assessment are given in **Table 6.3**. Emission concentrations for the flares have been taken from the manufacturer specifications for typical emissions from flares. The effective stack height and effective stack diameter have been taken as the actual stack height and diameter. This is due to the fact that the proposed flare is enclosed within a flare stack, and the assumption is made that the flare stack dimensions will reflect, on a reasonable basis, the effective release height and plume diameter. The effective exit velocity is set to 20 m/s and the effective exit temperature is set to 1273 K in accordance with typical approaches for modelling flare emissions. The volume of flue gas formed by each flare has been derived stoichiometrically based on the excess flow of coal seam methane to flares and used to establish the mass emission rates.

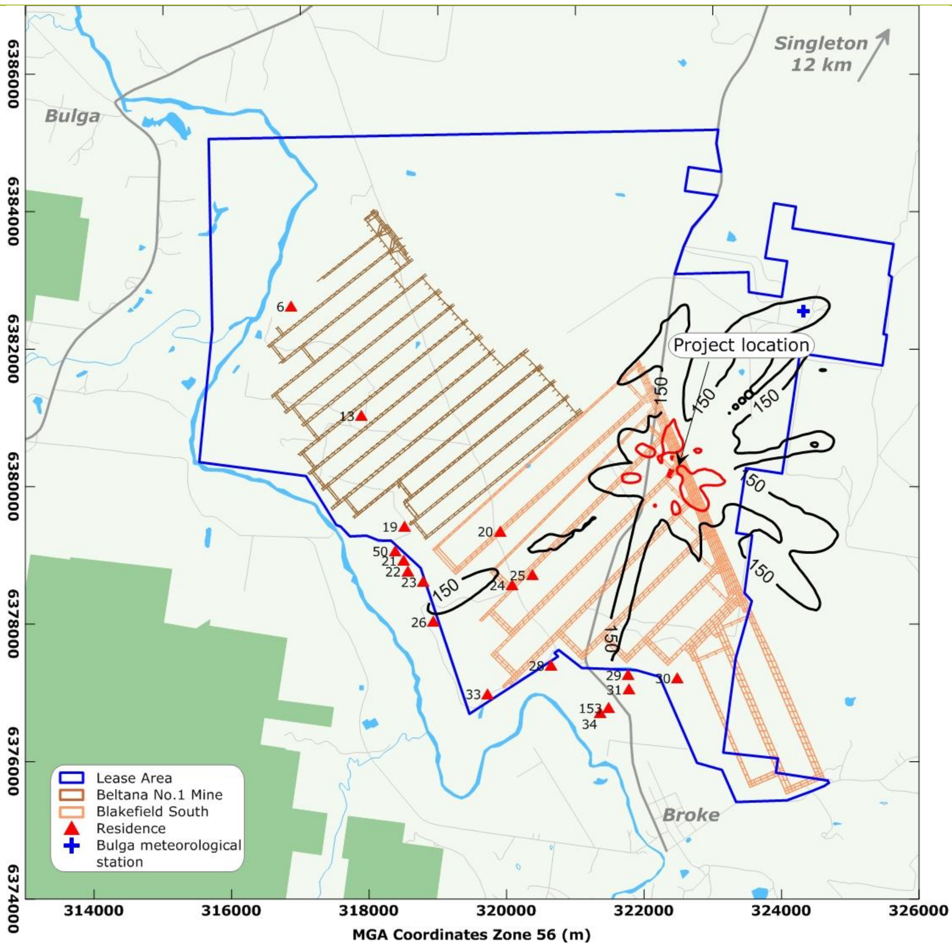
**Table 6.3: Emissions and Stack Parameters - Flares**

| Parameter | Value |
|---|---|
| $NO_x$ Emission Concentration | 150 mg/Nm$^3$ |
| CO Emission Concentration | 50 mg/Nm$^3$ |
| VOC Emission Concentration | 10 mg/m$^3$ |
| Stack Height | 9 m |
| Stack Diameter | 1 m |
| Exit Velocity | 20 m/s |
| Temperature | 1000 °C |
| **Mass Emission Rates** | |
| $NO_x$ Emission Rate | 0.38 g/s |
| CO Emission Rate | 0.13 g/s |
| VOC Emission Rate | 0.03 g/s |

# 7 MODELLING RESULTS

Emissions of $NO_x$ will consist of both nitric oxide (NO) and nitrogen dioxide ($NO_2$). $NO_2$ is the regulated oxide of nitrogen and is assessed for compliance against air quality goals. However, a conservative approach is adopted for this assessment whereby $NO_2$ is assumed as 100% $NO_x$. In reality, $NO_2$ concentrations would be expected to be between 5% and 20% of total $NO_x$ emissions. The modelling results therefore reflect a conservative over prediction of $NO_2$ concentrations.

A contour plot of the maximum predicted 1-hour $NO_x$ concentration for all sources (8 power generation units, VAM and seven flares) is presented in **Figure 7.1**. The contour plot shows that predicted $NO_2$ concentrations were within the assessment criteria of 246 µg/m$^3$ (shown by the red line) at all residences, even applying the conservative assumption that 100% of $NO_x$ emissions comprise $NO_2$.




$NO_x$.

| **Species:** | **Location:** | **Scenario:** | **Percentile:** | **Averaging Time:** |
|---|---|---|---|---|
| $NO_x$ | Beltana | Power Generation, VAM & Flaring | Maximum | 1-Hour |
| **Model Used:** | **Units:** | **Guideline:** | **Met Data:** | **Plot:** |
| CALPUFF v6.262 | µg/m$^3$ | 246 µg/m3 | 2009 Bulga | R Kellaghan |

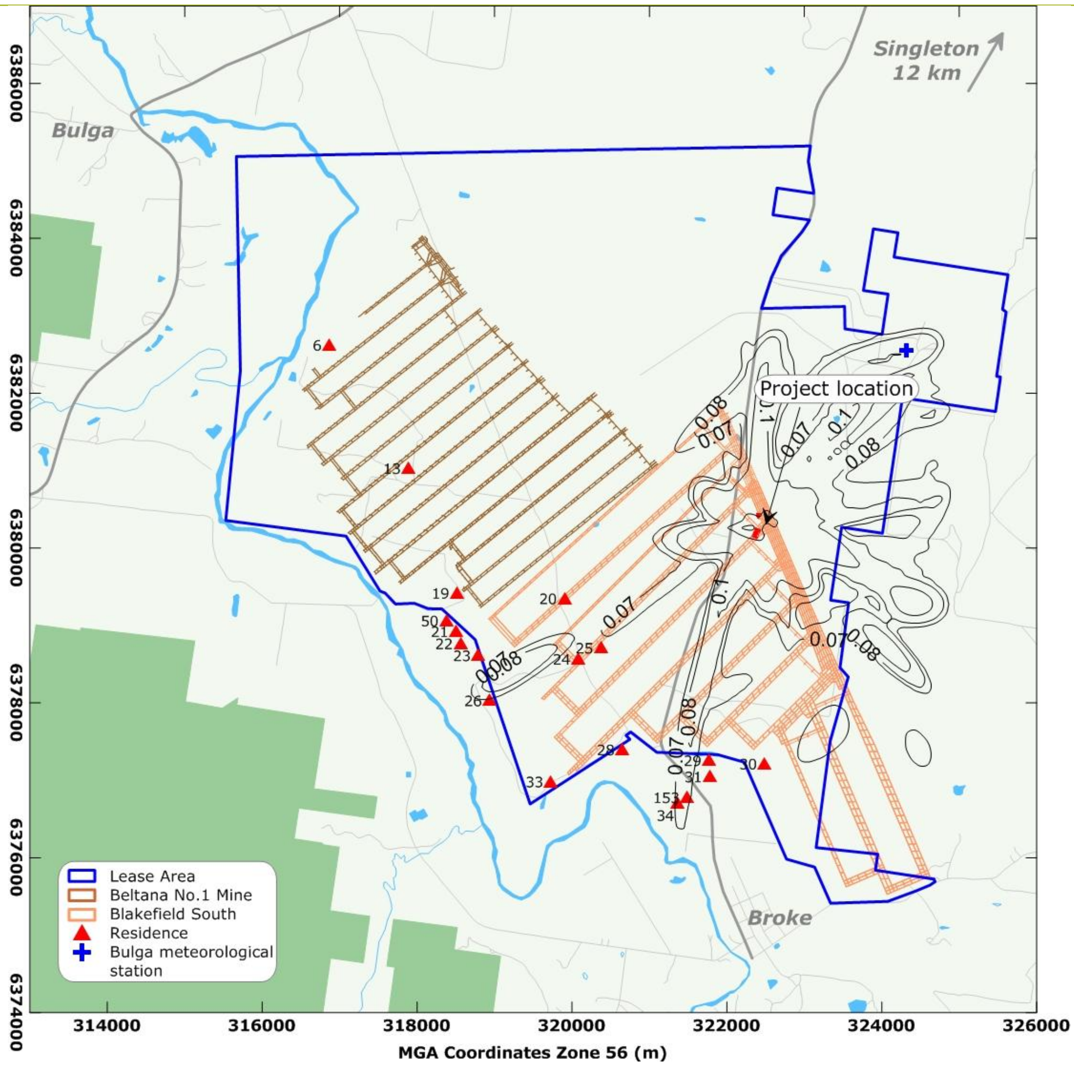
**Figure 7.1: Predicted Maximum 1-Hour $NO_x$ Concentration**

The maximum 1-hour $NO_x$ predictions at each of the residence locations shown in **Figure 2.1**, are presented in **Table 7.1**. Annual average $NO_2$ concentrations from the Power Generation Project are predicted to be less than 3% of the goal at all receptor locations.

**Table 7.1: Predicted 1-hour $NO_x$ at Receptor Locations**

| Resident ID | Maximum Predicted 1-hour $NO_x$ Concentration (ug/m$^3$) | 1-Hour $NO_2$ Goal (ug/m$^3$) |
|---|---|---|
| 6 | 65.69 | 246 |
| 13 | 88.54 | |
| 19 | 85.65 | |
| 50 | 76.32 | |
| 21 | 63.95 | |
| 22 | 74.88 | |
| 23 | 83.79 | |
| 26 | 126.59 | |
| 20 | 96.42 | |
| 24 | 100.04 | |
| 24 | 116.02 | |
| 33 | 54.87 | |
| 28 | 72.50 | |
| 34 | 133.30 | |
| 153 | 137.78 | |
| 31 | 93.69 | |
| 29 | 119.05 | |
| 30 | 105.82 | |

A contour plot of the maximum predicted 1-hour CO concentration for all sources (8 power generation units, VAM and seven flares) is presented in **Figure 7.2**. The contour plots show that incremental increases in CO concentrations from the project are minor and well below the impact assessment criteria of 30 mg/m$^3$ at all locations in the vicinity of the facility.




| Species: | Location: | Scenario: | Percentile: | Averaging Time: |
|---|---|---|---|---|
| CO | Beltana | Power Generation, VAM & Flaring | Maximum | 1-Hour |
| **Model Used:** | **Units:** | **Guideline:** | **Met Data:** | **Plot:** |
| CALPUFF v6.262 | mg/m$^3$ | 30 mg/m3 | 2009 Bulga | R Kellaghan |

**Figure 7.2: Predicted 8-Hour CO Concentration**

The maximum 1-hour CO predictions at each of the residence locations shown in **Figure 2.1** are presented in **Table 7.2**.

**Table 7.2: Predicted 1-hour CO at Receptor Locations**

| Resident ID | Maximum Predicted 1-hour CO Concentration ($mg/m^3$) | 1-Hour CO Goal ($mg/m^3$) |
|---|---|---|
| 6 | 0.03 | 30 |
| 13 | 0.04 | |
| 19 | 0.04 | |
| 50 | 0.04 | |
| 21 | 0.03 | |
| 22 | 0.03 | |
| 23 | 0.04 | |
| 26 | 0.07 | |
| 20 | 0.04 | |
| 24 | 0.05 | |
| 24 | 0.06 | |
| 33 | 0.03 | |
| 28 | 0.04 | |
| 34 | 0.07 | |
| 153 | 0.07 | |
| 31 | 0.05 | |
| 29 | 0.06 | |
| 30 | 0.06 | |

## 7.1 Volatile Organic Compounds (VOCs)

Emissions data for individual VOCs were not available, however manufacturer emission guarantees for the gas engine power generation units were provided for formaldehyde. Typical flare emissions for total VOCs were also available. A conservative modelling approach has been to add the total VOC emission from flares to the formaldehyde emissions for the gas engines and compare this to ambient impact assessment criteria for formaldehyde (as a surrogate for all VOCs).

This worst case modelling indicates that the maximum predicted formaldehyde concentration at any receptor location would be less than 0.01 $mg/m^3$ (or 50% of the air quality goal).

# 8 CUMULATIVE IMPACTS

Existing sources of $NO_x$ in the local or regional airshed include fossil fuel electricity generation (Bayswater and Liddell coal fired power stations), mining sources (mining fleets, explosives) and transport related emissions. Monitoring data collected as part of MacGen's monitoring campaign indicates that 1-hour $NO_2$ levels are generally less than 25% of the air quality goals (based on the 95$^{th}$ percentiles). The maximum 1-hour $NO_2$ concentrations are typically less than 50% of the air quality goal.

As indicated in **Table 7.1**, the incremental increase in 1-hour $NO_x$ is less than 50% of the air quality goal for $NO_2$ at all receptor locations. The actual $NO_2$ concentrations at these locations are expected to be significantly less than what was modelled, based on the conservative assumption that 100% of $NO_x$ is $NO_2$. On this basis, the cumulative impact of emissions from this project, combined with existing background levels, would not be expected to approach air quality goals.

The predicted incremental CO concentrations resulting from the project are sufficiently low to not result in any potential cumulative impacts.

# 9 CONCLUSIONS

An assessment of the potential air quality impacts from the Beltana Power Generation Project has been undertaken.

Dispersion modelling was conducted for key pollutants released from the following sources:

- Eight gas engine power generation units;
- Pilot VAM abatement unit; and
- Seven flares proposed for excess coal seam gas flow.

The modelling indicates that peak ground level $NO_2$ impacts from the Power Generation Project are well below the impact assessment criteria of 246 µg/$m^3$ at all private receptor locations in the vicinity of the site. The potential for cumulative impacts is also expected to be small, based on the predicted incremental concentrations being significantly less than 50% of the goal, and background levels shown as being typically 25% of the goal. Annual average $NO_2$ concentrations from the Power Generation Project are predicted to be negligible (less than 3% of the goal). Incremental increases in other pollutant concentrations, including CO and VOCs are also predicted to be minor.

# 10 REFERENCES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**APPENDIX A**

**Joint Wind Speed, Wind Direction and Stability Class Frequency Tables for**

**Bulga AWS 2009**

STATISTICS FOR FILE: \\Ronan\jobs\3839 Beltana Power Generation Project\Met\Bulga_2009.aus
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

Wind Speed Class (m/s)

| WIND SECTOR | 0.50 TO 1.50 | 1.50 TO 3.00 | 3.00 TO 4.50 | 4.50 TO 6.00 | 6.00 TO 7.50 | 7.50 TO 9.00 | 9.00 TO 10.50 | GREATER THAN 10.50 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NNE | 0.003311 | 0.003653 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006963 |
| NE | 0.003425 | 0.004795 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.008219 |
| ENE | 0.002740 | 0.007991 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.010731 |
| E | 0.002740 | 0.003995 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006735 |
| ESE | 0.001826 | 0.002055 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003881 |
| SE | 0.001826 | 0.001941 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003767 |
| SSE | 0.001598 | 0.001826 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003425 |
| S | 0.002626 | 0.001826 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.004452 |
| SSW | 0.002626 | 0.001256 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003881 |
| SW | 0.005023 | 0.000799 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.005822 |
| WSW | 0.004338 | 0.000685 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.005023 |
| W | 0.006279 | 0.003767 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.010046 |
| WNW | 0.009589 | 0.008219 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.017808 |
| NW | 0.010274 | 0.009247 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.019521 |
| NNW | 0.004680 | 0.002055 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006735 |
| N | 0.004224 | 0.002397 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006621 |
| CALM | | | | | | | | | 0.047945 |
| TOTAL | 0.067123 | 0.056507 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.171575 |

MEAN WIND SPEED (m/s) = 1.25
NUMBER OF OBSERVATIONS = 1503

PASQUILL STABILITY CLASS 'B'

Wind Speed Class (m/s)

| WIND SECTOR | 0.50 TO 1.50 | 1.50 TO 3.00 | 3.00 TO 4.50 | 4.50 TO 6.00 | 6.00 TO 7.50 | 7.50 TO 9.00 | 9.00 TO 10.50 | GREATER THAN 10.50 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NNE | 0.000228 | 0.000228 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000685 |
| NE | 0.000228 | 0.000913 | 0.001256 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002397 |
| ENE | 0.000799 | 0.005594 | 0.007078 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.013470 |
| E | 0.000000 | 0.001598 | 0.004452 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006050 |
| ESE | 0.000114 | 0.000571 | 0.000913 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.001598 |
| SE | 0.000114 | 0.000913 | 0.001256 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002283 |
| SSE | 0.000228 | 0.000685 | 0.000799 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.001712 |
| S | 0.000799 | 0.001941 | 0.000913 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003653 |
| SSW | 0.000457 | 0.001941 | 0.000571 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002968 |
| SW | 0.000685 | 0.000799 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.001712 |
| WSW | 0.001027 | 0.000342 | 0.000342 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.001712 |
| W | 0.001941 | 0.004452 | 0.003196 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.009589 |
| WNW | 0.001484 | 0.010959 | 0.013128 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.025571 |
| NW | 0.000571 | 0.004680 | 0.003311 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.008562 |
| NNW | 0.000000 | 0.000457 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000457 |
| N | 0.000342 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000457 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CALM | | | | | | | | | 0.008676 |
| TOTAL | 0.009018 | 0.036187 | 0.037671 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.091553 |

MEAN WIND SPEED (m/s) = 2.53
NUMBER OF OBSERVATIONS = 802

PASQUILL STABILITY CLASS 'C'

Wind Speed Class (m/s)

| WIND SECTOR | 0.50 TO 1.50 | 1.50 TO 3.00 | 3.00 TO 4.50 | 4.50 TO 6.00 | 6.00 TO 7.50 | 7.50 TO 9.00 | 9.00 TO 10.50 | GREATER THAN 10.50 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NNE | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| NE | 0.000000 | 0.000457 | 0.000685 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.001370 |
| ENE | 0.000228 | 0.003196 | 0.009932 | 0.006621 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.019977 |
| E | 0.000114 | 0.002511 | 0.007306 | 0.006279 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.016210 |
| ESE | 0.000000 | 0.000457 | 0.002511 | 0.001598 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.004566 |
| SE | 0.000342 | 0.001027 | 0.001598 | 0.000685 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003653 |
| SSE | 0.000114 | 0.002283 | 0.001598 | 0.000799 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.004795 |
| S | 0.000685 | 0.005936 | 0.005251 | 0.001256 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.013128 |
| SSW | 0.002397 | 0.007078 | 0.001826 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.011301 |
| SW | 0.001142 | 0.000571 | 0.000913 | 0.001027 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003653 |
| WSW | 0.001826 | 0.000457 | 0.002968 | 0.001598 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006849 |
| W | 0.001370 | 0.002626 | 0.006849 | 0.005251 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.016096 |
| WNW | 0.000000 | 0.001027 | 0.003311 | 0.003539 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.007877 |
| NW | 0.000342 | 0.000000 | 0.002055 | 0.001370 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003767 |
| NNW | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| N | 0.000114 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000228 |
| CALM | | | | | | | | | 0.005479 |
| TOTAL | 0.008676 | 0.027740 | 0.046804 | 0.030251 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.118950 |

MEAN WIND SPEED (m/s) = 3.51
NUMBER OF OBSERVATIONS = 1042

PASQUILL STABILITY CLASS 'D'

Wind Speed Class (m/s)

| WIND SECTOR | 0.50 TO 1.50 | 1.50 TO 3.00 | 3.00 TO 4.50 | 4.50 TO 6.00 | 6.00 TO 7.50 | 7.50 TO 9.00 | 9.00 TO 10.50 | GREATER THAN 10.50 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NNE | 0.000114 | 0.000114 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000342 |
| NE | 0.000228 | 0.001256 | 0.000913 | 0.000114 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.002626 |
| ENE | 0.002511 | 0.011986 | 0.021347 | 0.011416 | 0.003539 | 0.000457 | 0.000000 | 0.000000 | 0.051256 |
| E | 0.001370 | 0.014041 | 0.024087 | 0.008105 | 0.001712 | 0.000342 | 0.000000 | 0.000000 | 0.049658 |
| ESE | 0.001712 | 0.006507 | 0.005822 | 0.003425 | 0.000571 | 0.000000 | 0.000000 | 0.000000 | 0.018037 |
| SE | 0.000799 | 0.004452 | 0.004110 | 0.002283 | 0.001142 | 0.000000 | 0.000000 | 0.000000 | 0.012785 |
| SSE | 0.002055 | 0.009817 | 0.006279 | 0.002397 | 0.000685 | 0.000114 | 0.000000 | 0.000000 | 0.021347 |
| S | 0.003082 | 0.021461 | 0.012671 | 0.002854 | 0.000799 | 0.000000 | 0.000000 | 0.000000 | 0.040868 |
| SSW | 0.003082 | 0.004909 | 0.002626 | 0.001027 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.011644 |
| SW | 0.003539 | 0.002283 | 0.002283 | 0.000685 | 0.000114 | 0.000114 | 0.000000 | 0.000000 | 0.009018 |
| WSW | 0.003653 | 0.005023 | 0.003881 | 0.002055 | 0.003653 | 0.000342 | 0.000000 | 0.000000 | 0.018607 |
| W | 0.001598 | 0.005023 | 0.005365 | 0.003311 | 0.003425 | 0.000342 | 0.000000 | 0.000000 | 0.019064 |
| WNW | 0.000571 | 0.002283 | 0.005936 | 0.001256 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.010274 |
| NW | 0.001027 | 0.001027 | 0.001598 | 0.000342 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.004224 |
| NNW | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| N | 0.000114 | 0.000114 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000342 |
| CALM | | | | | | | | | 0.018836 |
| TOTAL | 0.025457 | 0.090297 | 0.097146 | 0.039269 | 0.016210 | 0.001712 | 0.000000 | 0.000000 | 0.288927 |

MEAN WIND SPEED (m/s) = 3.25
NUMBER OF OBSERVATIONS = 2531

PASQUILL STABILITY CLASS 'E'

Wind Speed Class (m/s)

| WIND SECTOR | 0.50 TO 1.50 | 1.50 TO 3.00 | 3.00 TO 4.50 | 4.50 TO 6.00 | 6.00 TO 7.50 | 7.50 TO 9.00 | 9.00 TO 10.50 | GREATER THAN 10.50 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NNE | 0.000228 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000457 |
| NE | 0.000913 | 0.001142 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002169 |
| ENE | 0.003082 | 0.005479 | 0.000342 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.008904 |
| E | 0.003311 | 0.010046 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.013356 |
| ESE | 0.001484 | 0.002283 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003767 |
| SE | 0.001370 | 0.001370 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002968 |
| SSE | 0.002397 | 0.003311 | 0.000342 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006050 |
| S | 0.002740 | 0.005594 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.008447 |
| SSW | 0.004795 | 0.003082 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.007991 |
| SW | 0.005479 | 0.001598 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.007306 |
| WSW | 0.003653 | 0.001027 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.004795 |
| W | 0.003653 | 0.006393 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.010160 |
| WNW | 0.004452 | 0.009361 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.013813 |
| NW | 0.001598 | 0.001256 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002968 |
| NNW | 0.000228 | 0.000342 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000571 |
| N | 0.000114 | 0.000228 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000457 |
| CALM | | | | | | | | | 0.029224 |
| TOTAL | 0.039498 | 0.052740 | 0.001941 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.123402 |

MEAN WIND SPEED (m/s) = 1.41
NUMBER OF OBSERVATIONS = 1081

PASQUILL STABILITY CLASS 'F'

Wind Speed Class (m/s)

| WIND SECTOR | 0.50 TO 1.50 | 1.50 TO 3.00 | 3.00 TO 4.50 | 4.50 TO 6.00 | 6.00 TO 7.50 | 7.50 TO 9.00 | 9.00 TO 10.50 | GREATER THAN 10.50 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NNE | 0.001256 | 0.000799 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002055 |
| NE | 0.001598 | 0.001027 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.002626 |
| ENE | 0.002740 | 0.001027 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003767 |
| E | 0.004110 | 0.004110 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.008219 |
| ESE | 0.004795 | 0.001826 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006621 |
| SE | 0.003196 | 0.002055 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.005251 |
| SSE | 0.002397 | 0.002968 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.005365 |
| S | 0.004680 | 0.002169 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006849 |
| SSW | 0.004680 | 0.001598 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006279 |
| SW | 0.003995 | 0.001027 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.005023 |
| WSW | 0.004110 | 0.001256 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.005365 |
| W | 0.004452 | 0.002169 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.006621 |
| WNW | 0.005822 | 0.007534 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.013356 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NW | 0.002968 | 0.000799 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.003767 |
| NNW | 0.001142 | 0.000571 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.001712 |
| N | 0.000799 | 0.000457 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.001256 |
| CALM | | | | | | | | | 0.121461 |
| TOTAL | 0.052740 | 0.031393 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.205594 |

MEAN WIND SPEED (m/s) = 0.85
NUMBER OF OBSERVATIONS = 1801

ALL PASQUILL STABILITY CLASSES

Wind Speed Class (m/s)

| WIND SECTOR | 0.50 TO 1.50 | 1.50 TO 3.00 | 3.00 TO 4.50 | 4.50 TO 6.00 | 6.00 TO 7.50 | 7.50 TO 9.00 | 9.00 TO 10.50 | GREATER THAN 10.50 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NNE | 0.005137 | 0.005023 | 0.000342 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.010502 |
| NE | 0.006393 | 0.009589 | 0.002968 | 0.000342 | 0.000114 | 0.000000 | 0.000000 | 0.000000 | 0.019406 |
| ENE | 0.012100 | 0.035274 | 0.038699 | 0.018037 | 0.003539 | 0.000457 | 0.000000 | 0.000000 | 0.108105 |
| E | 0.011644 | 0.036301 | 0.035845 | 0.014384 | 0.001712 | 0.000342 | 0.000000 | 0.000000 | 0.100228 |
| ESE | 0.009932 | 0.013699 | 0.009247 | 0.005023 | 0.000571 | 0.000000 | 0.000000 | 0.000000 | 0.038470 |
| SE | 0.007648 | 0.011758 | 0.007192 | 0.002968 | 0.001142 | 0.000000 | 0.000000 | 0.000000 | 0.030708 |
| SSE | 0.008790 | 0.020890 | 0.009018 | 0.003196 | 0.000685 | 0.000114 | 0.000000 | 0.000000 | 0.042694 |
| S | 0.014612 | 0.038927 | 0.018950 | 0.004110 | 0.000799 | 0.000000 | 0.000000 | 0.000000 | 0.077397 |
| SSW | 0.018037 | 0.019863 | 0.005137 | 0.001027 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.044064 |
| SW | 0.019863 | 0.007078 | 0.003653 | 0.001712 | 0.000114 | 0.000114 | 0.000000 | 0.000000 | 0.032534 |
| WSW | 0.018607 | 0.008790 | 0.007306 | 0.003653 | 0.003653 | 0.000342 | 0.000000 | 0.000000 | 0.042352 |
| W | 0.019292 | 0.024429 | 0.015525 | 0.008562 | 0.003425 | 0.000342 | 0.000000 | 0.000000 | 0.071575 |
| WNW | 0.021918 | 0.039384 | 0.022374 | 0.004795 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.088699 |
| NW | 0.016781 | 0.017009 | 0.007078 | 0.001712 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.042808 |
| NNW | 0.006050 | 0.003425 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.009475 |
| N | 0.005708 | 0.003425 | 0.000228 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.009361 |
| CALM | | | | | | | | | 0.231621 |
| TOTAL | 0.202511 | 0.294863 | 0.183562 | 0.069521 | 0.016210 | 0.001712 | 0.000000 | 0.000000 | 1.000000 |

MEAN WIND SPEED (m/s) = 2.15
NUMBER OF OBSERVATIONS = 8760

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

A : 17.2%
B : 9.2%
C : 11.9%
D : 28.9%
E : 12.3%
F : 20.6%

STABILITY CLASS BY HOUR OF DAY

| Hour | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 01 | 0000 | 0000 | 0000 | 0134 | 0080 | 0151 |
| 02 | 0000 | 0000 | 0000 | 0127 | 0095 | 0143 |
| 03 | 0000 | 0000 | 0000 | 0123 | 0102 | 0140 |
| 04 | 0000 | 0000 | 0000 | 0121 | 0079 | 0165 |
| 05 | 0000 | 0000 | 0000 | 0129 | 0088 | 0148 |
| 06 | 0020 | 0011 | 0018 | 0121 | 0062 | 0133 |
| 07 | 0067 | 0026 | 0061 | 0090 | 0035 | 0086 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 08 | 0133 | 0062 | 0113 | 0047 | 0003 | 0007 |
| 09 | 0142 | 0069 | 0123 | 0031 | 0000 | 0000 |
| 10 | 0174 | 0084 | 0089 | 0018 | 0000 | 0000 |
| 11 | 0184 | 0083 | 0076 | 0022 | 0000 | 0000 |
| 12 | 0188 | 0086 | 0074 | 0017 | 0000 | 0000 |
| 13 | 0170 | 0089 | 0088 | 0018 | 0000 | 0000 |
| 14 | 0154 | 0088 | 0106 | 0017 | 0000 | 0000 |
| 15 | 0141 | 0099 | 0099 | 0026 | 0000 | 0000 |
| 16 | 0094 | 0068 | 0116 | 0054 | 0010 | 0023 |
| 17 | 0036 | 0037 | 0079 | 0116 | 0041 | 0056 |
| 18 | 0000 | 0000 | 0000 | 0231 | 0057 | 0077 |
| 19 | 0000 | 0000 | 0000 | 0219 | 0059 | 0087 |
| 20 | 0000 | 0000 | 0000 | 0220 | 0057 | 0088 |
| 21 | 0000 | 0000 | 0000 | 0197 | 0057 | 0111 |
| 22 | 0000 | 0000 | 0000 | 0172 | 0067 | 0126 |
| 23 | 0000 | 0000 | 0000 | 0141 | 0093 | 0131 |
| 24 | 0000 | 0000 | 0000 | 0140 | 0096 | 0129 |

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STABILITY CLASS BY MIXING HEIGHT

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| Mixing height | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| <=500 m | 0241 | 0140 | 0218 | 0522 | 1033 | 1706 |
| <=1000 m | 0591 | 0348 | 0364 | 0723 | 0016 | 0039 |
| <=1500 m | 0671 | 0314 | 0460 | 0995 | 0032 | 0056 |
| <=2000 m | 0000 | 0000 | 0000 | 0236 | 0000 | 0000 |
| <=3000 m | 0000 | 0000 | 0000 | 0055 | 0000 | 0000 |
| >3000 m | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |

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MIXING HEIGHT BY HOUR OF DAY

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| Hour | 0000 to 0100 | 0100 to 0200 | 0200 to 0400 | 0400 to 0800 | 0800 to 1600 | 1600 to 3200 | Greater than 3200 |
|---|---|---|---|---|---|---|---|
| 01 | 0164 | 0082 | 0010 | 0032 | 0070 | 0007 | 0000 |
| 02 | 0165 | 0087 | 0013 | 0031 | 0063 | 0006 | 0000 |
| 03 | 0154 | 0102 | 0014 | 0031 | 0059 | 0005 | 0000 |
| 04 | 0168 | 0089 | 0013 | 0031 | 0058 | 0006 | 0000 |
| 05 | 0214 | 0062 | 0013 | 0023 | 0046 | 0007 | 0000 |
| 06 | 0152 | 0098 | 0075 | 0010 | 0026 | 0004 | 0000 |
| 07 | 0119 | 0058 | 0114 | 0072 | 0002 | 0000 | 0000 |
| 08 | 0000 | 0062 | 0129 | 0174 | 0000 | 0000 | 0000 |
| 09 | 0000 | 0000 | 0095 | 0189 | 0081 | 0000 | 0000 |
| 10 | 0000 | 0000 | 0000 | 0236 | 0129 | 0000 | 0000 |
| 11 | 0000 | 0000 | 0000 | 0138 | 0227 | 0000 | 0000 |
| 12 | 0000 | 0000 | 0000 | 0092 | 0273 | 0000 | 0000 |
| 13 | 0000 | 0000 | 0000 | 0000 | 0365 | 0000 | 0000 |
| 14 | 0000 | 0000 | 0000 | 0000 | 0365 | 0000 | 0000 |
| 15 | 0000 | 0000 | 0000 | 0000 | 0365 | 0000 | 0000 |
| 16 | 0000 | 0000 | 0000 | 0000 | 0365 | 0000 | 0000 |
| 17 | 0016 | 0014 | 0002 | 0005 | 0325 | 0003 | 0000 |
| 18 | 0051 | 0042 | 0008 | 0022 | 0232 | 0010 | 0000 |
| 19 | 0082 | 0057 | 0016 | 0022 | 0113 | 0075 | 0000 |
| 20 | 0089 | 0059 | 0008 | 0023 | 0143 | 0043 | 0000 |
| 21 | 0118 | 0054 | 0006 | 0019 | 0142 | 0026 | 0000 |
| 22 | 0134 | 0066 | 0007 | 0021 | 0122 | 0015 | 0000 |
| 23 | 0150 | 0075 | 0011 | 0027 | 0092 | 0010 | 0000 |
| 24 | 0143 | 0088 | 0014 | 0029 | 0083 | 0008 | 0000 |