

**Annex H**

# **H. Air Quality Assessment**



## **AIR QUALITY IMPACT ASSESSMENT**

### **AIR QUALITY IMPACT ASSESSMENT: APPIN MINE AREA 7 GOAF GAS DRAINAGE PROJECT**

**BHPBilliton**

**Job No: 3275**

**May 2009**

**PROJECT TITLE:** ***AIR QUALITY IMPACT ASSESSMENT:  
APPIN MINE AREA 7 GAS DRAINAGE  
PROJECT***

**JOB NUMBER:** **3275**

**PREPARED FOR:** Mr Peter Chudleigh  
CARDNO FORBES RIGBY PTY LTD

**PREPARED BY:** Cynthia Isley

**QA PROCEDURES CHECKED BY:** Kerry Holmes

**APPROVED FOR RELEASE BY:** Kerry Holmes

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VERSION	DATE	PREPARED BY	REVIEWED BY
Draft	28/4/09	Cynthia Isley	Kerry Holmes
Revision	7/5/09	Cynthia Isley	Kerry Holmes

Queensland Environment Pty Ltd trading as  
**PAEHolmes** ABN 86 127 101 642

**SYDNEY:**

Suite 2B, 14 Glen Street  
Eastwood NSW 2122  
Ph: +61 2 9874 8644  
Fax: +61 2 9874 8904

**BRISBANE:**

Level 1, La Melba, 59 Melbourne Street South Brisbane Qld 4101  
PO Box 3306 South Brisbane Qld 4101  
Ph: +61 7 3004 6400  
Fax: +61 7 3844 5858

Email: [info@paeholmes.com](mailto:info@paeholmes.com)

Website: [www.paeholmes.com](http://www.paeholmes.com)

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## 1 INTRODUCTION

This report has been prepared by PAEHolmes for Cardno Forbes Rigby Pty Ltd on behalf of BHPBilliton-Illawarra Coal (BHPBIC). As part of the ongoing operations of the Appin Mine, BHPBIC plans to implement a program to extract gas from the goaf area remaining after longwall extraction has occurred. The goaf area is defined as the void left after extraction in an underground longwall coal mine has finished. The gas extraction program is referred to as the Appin Mine Area 7 Goaf Gas Drainage Project (the "Project"). Cardno Forbes Rigby are preparing the Environmental Assessment (EA). The purpose of this report is to quantitatively assess the air quality impacts of the Project.

This air quality assessment is based on the use of a computer-based dispersion model, AUSPLUME, to predict off-site impacts due to the proposed site operations. To assess the effect the potential pollutants have on existing air quality, the dispersion model predictions have been compared to relevant regulatory air quality criteria.

The assessment is based on a conventional approach following the procedures outlined in the NSW Department of Environment and Climate Change's (DECC) document titled "Approved Methods for the Modelling and Assessment in NSW" (**DECC, 2005**).

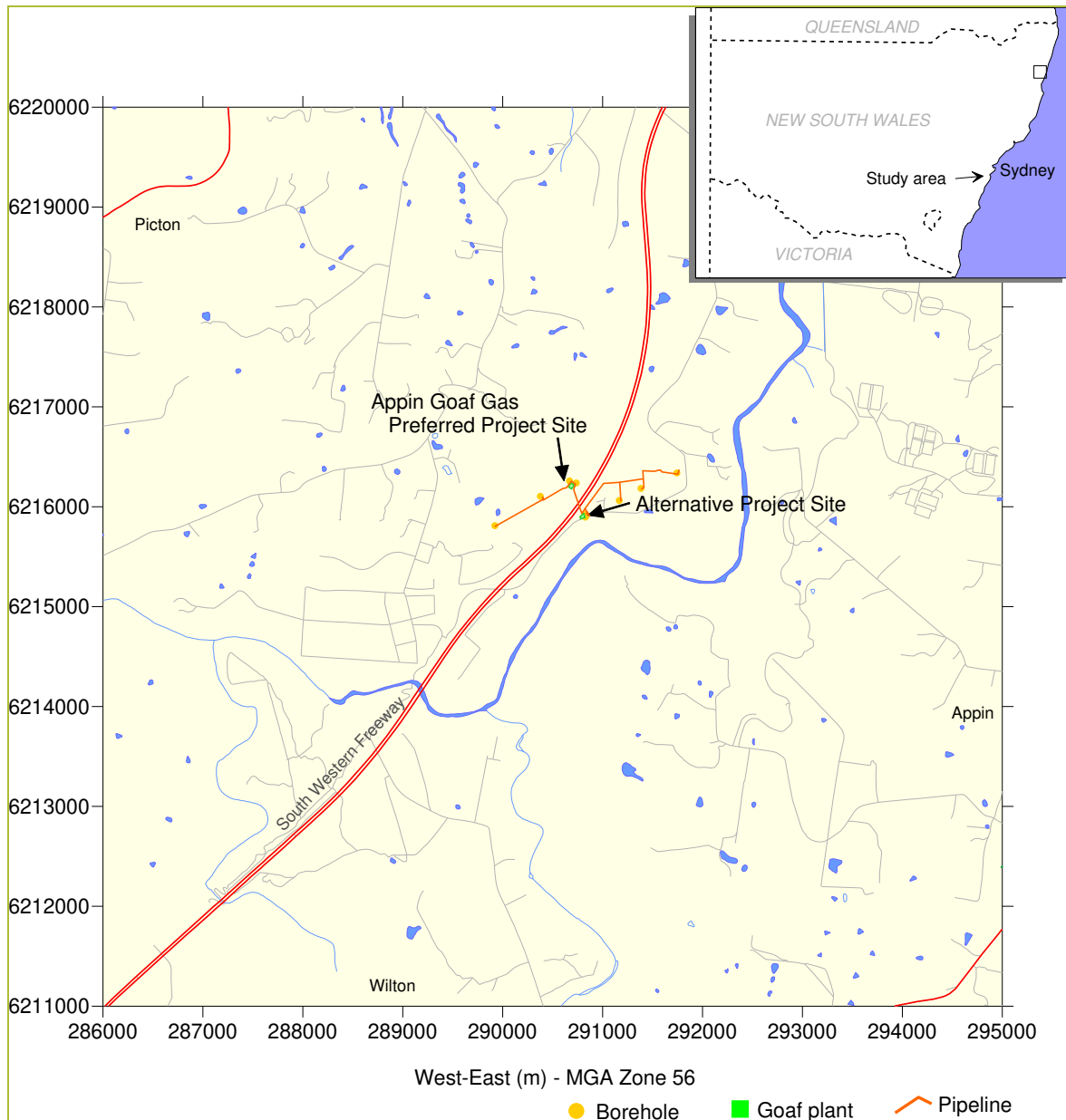
In summary, this report provides information on the following:

- Proposed surface activities related to the Appin Area 7 Goaf Gas Drainage Project;
- Air quality criteria relevant for the Project;
- Climatic and meteorological conditions in the area;
- Existing air quality;
- Emissions to air, including odour and dust;
- Methods used to predict off-site pollution levels from expected emissions from the site; and
- Expected dispersion patterns and predicted impacts.

## 2 PROJECT DESCRIPTION

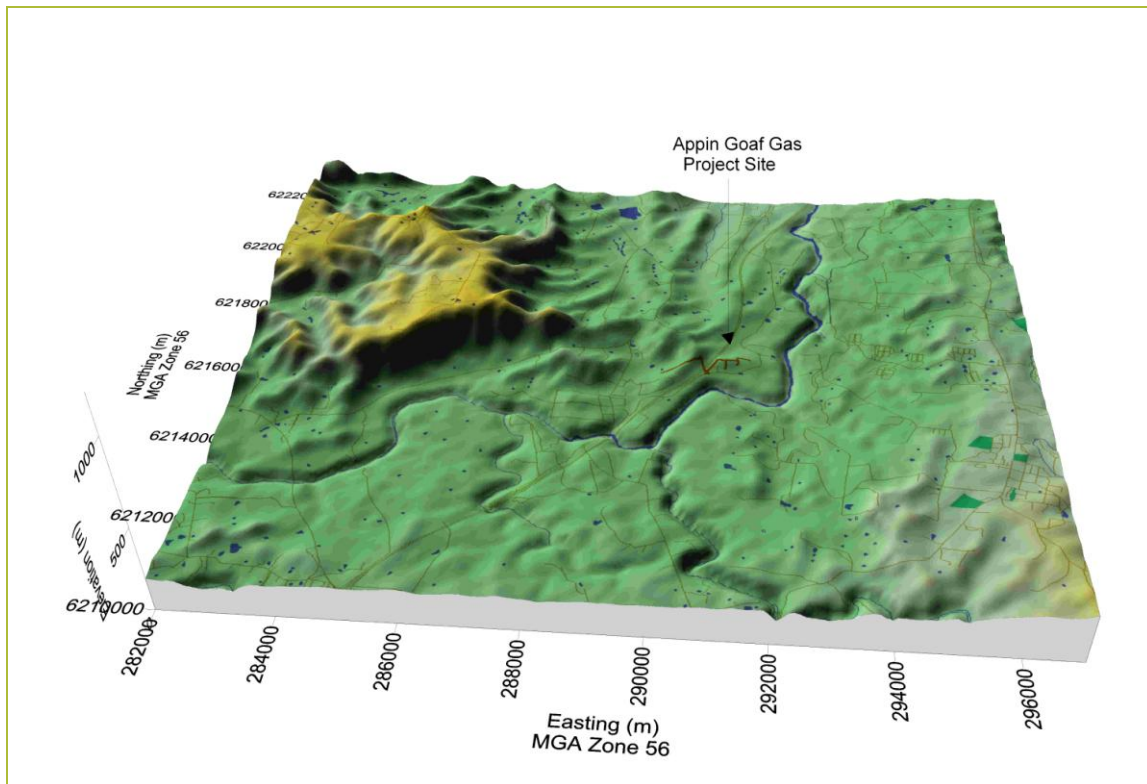
### 2.1 The Site

**Figure 2.1** shows the location of the study area, showing the preferred and alternative Goaf Plant locations.



**Figure 2.1: Location of study area**

Land use in the study area consists of agriculture (grazing and farming) and scattered rural residential properties. The closest township is Douglas Park. Local topography (see **Figure 2.2**) shows that the area comprises rolling hills.



**Figure 2.2: Topography of local area**

## 2.2 Proposed development

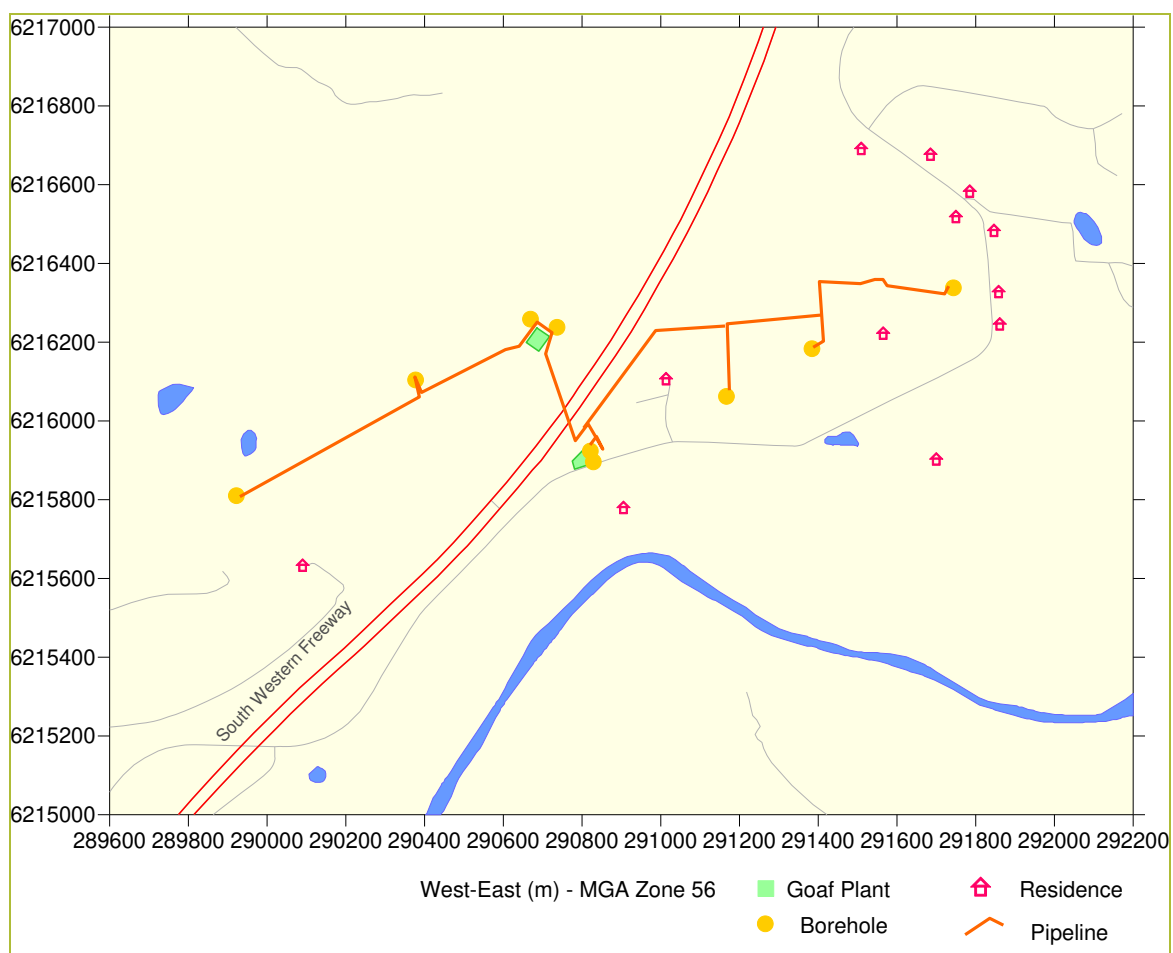
BHPBIC are proposing to extract gas from the goaf area remaining after longwall mining has occurred. Gas will be transferred to the surface via several cased boreholes installed prior to mining. Once at the surface, one or more of the following scenarios will occur (in order of priority):

- gas will be utilised at Appin West or Appin Power Station (operated by Energy Developments Ltd (EDL)) for use in power generation where air emissions must comply with the requirements of Environment Protection Licences No. 5482 and No. 5357. EDL currently have excess capacity available to utilise the goaf gas collected by this Project. The supply of the goaf gas from Appin Area 7 will not increase air emissions above the already permitted air pollutant load and concentration limits specified in their Environment Protection Licences; or
- gas may be flared adjacent to the on-site goaf plants if it cannot be utilised by the EDL power stations for extended periods; and
- gas will be vented to the atmosphere.

The Project involves the installation and operation of 8 boreholes over Appin Area 7 Longwalls 703 – 704 in order to extract gas from the goaf. The gas will be collected in a reticulation system and directed underground to be incorporated into the pipe range supplying gas to the EDL power stations.

The locations of the goaf gas drainage infrastructure and the nearest privately-owned residential properties are shown in **Figure 2.3**.

The proposed extraction plant will be in a centralised location remote from the individual well heads. The plant may draw gas from multiple wells that are connected by a reticulation system as required by the mining operation. There will be a diesel-powered generator (175 kVA) to generate the power necessary to operate the equipment. Where goaf gas cannot be reticulated underground for incorporation into the pipe range to supply EDL power stations, a 9 m high vent stack will be used to emit gas to the atmosphere to ensure the safe operation of the system. This circumstance will only occur rarely during operational emergency stoppage of the underground gas range infrastructure, equipment failures and the like. If goaf gas cannot be continuously supplied to the underground pipe range, Illawarra Coal will investigate the use of on-site flares to abate the greenhouse gas contribution of methane emissions to the atmosphere. It has been conservatively assumed in this study that a diesel generator will operate continuously.



**Figure 2.3: Location of nearest residences**

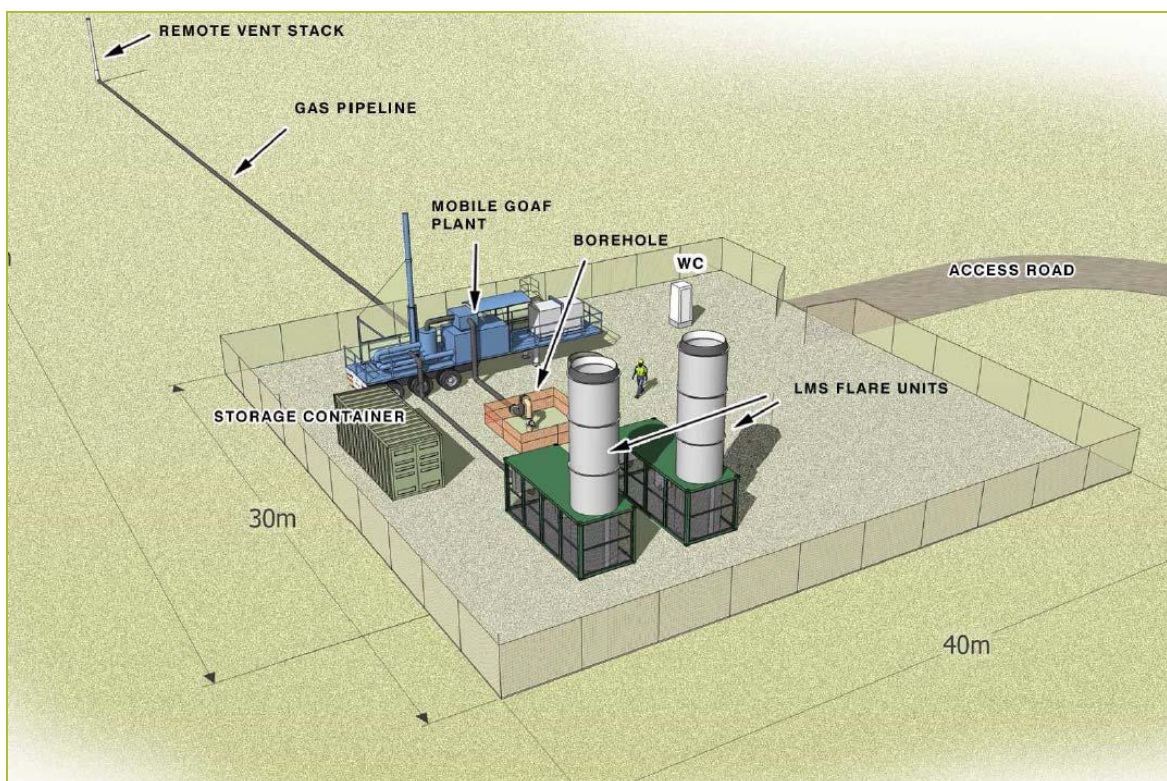
Maximum goaf gas flows are predicted to be of the order of 800 litres per second (L/s). The goaf gas will be utilised at the EDL power stations located at Appin West pit top and Appin No 1 shaft.

Flaring units which can process up to 800 L/s of gas may be considered if the proposed EDL utilisation management system is not effective or cannot be maintained routinely. An artist's impression of a typical goaf gas management compound is shown in **Figure 2.4**.

The potential air quality impacts of the Project are identified as follows:

- Emissions from the flaring stacks;
- Odour from the gas vent stacks;
- Dust generated during the construction phase; and
- Pollutant emissions from the diesel generator.

The items listed above are the focus of this air quality assessment.



Source: Maurice Hayler & Associates Architects

**Figure 2.4: Artist's impression of a typical goaf gas management compound**

## 3 AIR QUALITY ISSUES

### 3.1 Odour

This section evaluates odour in terms of measurement and air quality criteria that relate to odour. There is still considerable debate in the scientific community about appropriate odour criteria as determined by dispersion modelling.

### 3.1.1 Measurement of Odour

Odour is measured using panels of people who are presented with samples of odorous gas diluted with decreasing quantities of clean odour-free air. The panellists then note when the smell becomes detectable. Odour in the air is then quantified in terms of odour units which is the number of dilutions required to bring the odour to a level at which 50% of the panellists can just detect the odour. This process is known as olfactometry.

Olfactometry can involve a "forced-choice" end point or a "free choice" endpoint. The "forced-choice" method is where panellists identify from multiple sniffing ports, the one port where odour is detected, regardless of whether they are sure they can detect odour. The "free choice" endpoint is a "yes/no" decision where panellists are required to say whether or not they can detect odour from one sniffing port. Forced-choice olfactometry generally detects lower odour levels than free choice olfactometry.

In both the "forced-choice" and "free choice" cases, odorous air is presented to the panellists in increasing concentrations. For the forced-choice method, where there are multiple ports for each panellist, the concentration is increased until all panellists consistently distinguish the port with the sample from the blanks. For a yes/no olfactometer (which has only one sniffing port) one method used is to increase the concentration of odour in the sample until all panellists respond. The sample is then shut off and once all panellists cease to respond, the sample is introduced again at random dilutions and the panellists are asked whether they can detect the odour.

There are variations in the literature in the terminology for odour thresholds. The DECC has used the definition of the **detection** threshold as the lowest concentration which will elicit a response, but where the panellist is essentially guessing correctly. This corresponds to the first end point in the forced-choice olfactometry method. The odour **recognition** threshold is, by definition, the minimum concentration at which the panellist is certain they can detect the odour. This is also referred to as the certainty threshold and is the second endpoint in forced-choice olfactometry and similar to the first end point in yes/no olfactometry.

An Australian Standard (AS/NZS 4323.3.2001) for olfactometry has been developed which is consistent with the European Standard, CEN. This enables results between laboratories to be more uniform. These standards have adopted the certainty threshold as the odour standard and referencing this to a concentration of butanol (40 ppb). The odour levels referred to in this report are the certainty odour levels (odour detected by 50% of panellists using the recognition threshold).

As with all sensory methods of identification there is variability between individuals. Consequently the results of odour measurements depend on the way in which the panel is selected and the way in which the panel responses are interpreted. The process by which these imprecise measurements are translated into regulatory criteria is still being refined. However, the DECC has recently published a Technical Framework for the assessment of odour from stationary sources, which includes recommendations for odour criteria (**DEC, 2006**). These are explained below and have been used for this assessment.

### 3.1.2 Odour Criteria

The determination of air quality criteria for odour and their use in the assessment of odour impact is recognised as a difficult topic in air pollution science. The topic has received

considerable attention in recent years and the procedures for assessing odour impacts using dispersion models have been refined considerably.

The DECC has in recent times refined odour criteria and the way in which they should be applied with dispersion models to assess the likelihood of nuisance impact arising from the emission of odour. However, as discussed above these procedures are still being developed and odour criteria are likely to be revised in the future.

There are two factors that need to be considered:

1. what "level of exposure" to odour is considered acceptable to meet current community standards in NSW and
2. how can dispersion models be used to determine if a source of odour meets the criteria which are based on this acceptable level of exposure.

The term "level of exposure" has been used to reflect the fact that odour impacts are determined by several factors. The most important factors (the so-called **FIDOL** factors) are:

- the **F**requency of the exposure
- the **I**ntensity of the odour
- the **D**uration of the odour episodes
- the **O**ffensiveness of the odour, and
- the **L**ocation of the source

In determining the offensiveness of an odour it needs to be recognised that for most odours the context in which an odour is perceived is also relevant. Some odours, for example the smell of sewage, hydrogen sulfide, butyric acid, landfill gas etc., are likely to be judged offensive regardless of the context in which they occur. Other odours such as the smell of jet fuel may be acceptable at an airport, but not in a house, and diesel exhaust may be acceptable near a busy road, but not in a restaurant.

In summary, whether or not an individual considers an odour to be a nuisance will depend on the FIDOL factors outlined above and although it is possible to derive formulae for assessing odour annoyance in a community, the response of any individual to an odour is still unpredictable. Odour criteria need to take account of these factors.

The DECC Technical Framework includes some recommendations for odour criteria. The criteria have been refined by DECC to take account of population density in the area. **Table 3:1** lists the odour certainty thresholds, to be exceeded not more than 1% of the time, for different population densities.

The difference between odour criteria is based on considerations of risk of odour impact rather than differences in odour acceptability between urban and rural areas. For a given odour level there will be a wide range of responses in the population exposed to the odour. In a densely populated area there will therefore be a greater risk that some individuals within the community will find the odour unacceptable than in a sparsely populated area.

The criteria assume that 7 odour units at the 99<sup>th</sup> percentile would be acceptable to the average person, but as the number of exposed people increases there is a chance that sensitive individuals would be exposed. The criterion of 2 odour units at the 99<sup>th</sup> percentile is considered to be acceptable for the whole population.

**Table 3:1: DECC odour assessment criteria**

Population of affected community	Odour performance criteria (nose response odour certainty units at the 99 <sup>th</sup> percentile)
Rural single residence ( $\leq 2$ )	7
~10	6
~30	5
~125	4
~500	3
Urban (>2000) and/or schools and hospitals	2

It is common practice to use dispersion models to determine compliance with odour criteria. This introduces a complication because Gaussian dispersion models are only able to directly predict concentrations over an averaging period of 3-minutes or greater. The human nose, however, responds to odours over periods of the order of a second or so. During a 3-minute period, odour levels can fluctuate significantly above and below the mean depending on the nature of the source.

To determine more rigorously the ratio between the one-second peak concentrations and three-minute and longer period average concentrations (referred to as the peak-to-mean ratio) that might be predicted by a Gaussian dispersion model, the DECC (then EPA) commissioned a study by Katestone Scientific Pty Ltd (see **Katestone 1995** and **1998**). This study recommended peak-to-mean ratios for a range of source types. The ratio is also dependent on atmospheric stability and the distance from the source. A summary table of these ratios is presented in **Appendix A**.

The DECC Technical Framework (**DEC, 2006**) takes account of this peaking factor and the criteria shown in **Table 3:1** are based on nose-response time.

## 3.2 Dust

**Table 3:2** summarises the air quality assessment criteria for dust concentration. The air quality criteria relate to the total dust burden in the air and not just the dust from the project. In other words, some consideration of background levels needs to be made when using these criteria to assess impacts. The estimation of appropriate background levels will be discussed further in **Section 4.3**.

**Table 3:2 : DECC criteria for particulate matter concentrations**

Pollutant	Criteria	Averaging period	Agency
Total suspended particulate matter (TSP)	90 $\mu\text{g}/\text{m}^3$	Annual mean	National Health & Medical Research Council
Particulate matter < 10 $\mu\text{m}$ (PM <sub>10</sub> )	50 $\mu\text{g}/\text{m}^3$	24-hour maximum	DECC
	30 $\mu\text{g}/\text{m}^3$	Annual mean	DECC long-term reporting goal
	50 $\mu\text{g}/\text{m}^3$	(24-hour average, 5 exceedances permitted per year)	National Environment Protection Council

In addition to health impacts, airborne dust also has the potential to cause nuisance impacts by depositing on surfaces. **Table 3:3** shows the maximum acceptable increase in dust deposition over the existing dust levels. The criteria for dust fallout levels are set to protect against nuisance impacts (**DEC, 2005**).

**Table 3:3: DECC criteria for dust fallout**

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 $\text{g}/\text{m}^2/\text{month}$	4 $\text{g}/\text{m}^2/\text{month}$

### 3.3 Oxides of Nitrogen

The key pollutant released, both from flaring of the goaf gas and from the diesel-powered generator will be oxides of nitrogen (NO<sub>x</sub>). NO<sub>x</sub> is comprised of nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) however NO is much less harmful to humans than NO<sub>2</sub> and is not generally considered a pollutant with health impacts at the concentrations normally found in urban environments. **Table 3:4** shows the DECC air quality assessment criteria for NO<sub>2</sub>. The air quality criteria relate to the total burden of NO<sub>2</sub> in the air and not just that from the sources being modelled.

**Table 3:4 : DECC criteria for nitrogen dioxide**

Pollutant	Criterion*	Averaging period	Agency
Nitrogen dioxide (NO <sub>2</sub> )	0.12 ppm or 246 $\mu\text{g}/\text{m}^3$	1-hour maximum	DECC
	0.03 ppm or 62 $\mu\text{g}/\text{m}^3$	Annual mean	DECC

\* ppm = parts per million.

### 3.4 Carbon Monoxide

CO is another combustion product that will be released both from flaring of the goaf gas and from the diesel-powered generator. **Table 3:5** shows the DECC air quality assessment criteria

for NO<sub>2</sub>. The air quality criteria relate to the total burden of CO in the air and not just that from the sources being modelled.

**Table 3:5: DECC criteria for carbon monoxide µg/m<sup>3</sup>**

Pollutant	Criteria	Averaging period	Agency
Carbon monoxide (CO)	100 000	15 minutes	DECC
	30 000	1 hour	DECC
	10 000	8 hours	DECC

## 4 EXISTING ENVIRONMENT

This section describes the dispersion meteorology, local climatic conditions and existing air quality in the Project area.

### 4.1 Dispersion Meteorology

The Gaussian dispersion model used for this assessment (AUSPLUME) requires information about the dispersion characteristics of the area. In particular, data are required on wind speed, wind direction, atmospheric stability class<sup>a</sup> and mixing height<sup>b</sup>. Suitable meteorological data, from 1995, are available from a weather station operated by the DECC at Appin. The station was approximately six kilometres to the east of the Project area but has since been decommissioned. Data for 2008 has also been made available by Energy Development Limited at Appin, approximately 5 km southeast of the Project area.

**Figure 4.1** shows the annual and seasonal wind roses for Appin from 1995 and 2008.

The Appin data included hourly records of temperature, wind speed, wind direction and sigma-theta (the standard deviation of the horizontal wind direction) and have been processed into a form suitable for the AUSPLUME dispersion model.

For both 1995 and 2008, winds were predominantly from the south-southeast and this wind direction is present in all seasons. Annually, calm conditions (winds less than or equal to 0.5 m/s) were measured for 3.4% of the time in 1995 and for 0.0% of the time in 2008. Airborne pollutants disperse more slowly in calm conditions, therefore it would be anticipated that the 1995 data may return a more conservative prediction of ground level pollutant concentrations than the 2008 data.

<sup>a</sup> In dispersion modelling, stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford stability class assignment scheme, as used in this study, there are six stability classes A through to F. Class A relates to unstable conditions such as might be found on a sunny day with light winds. In such conditions plumes will spread rapidly. Class F relates to stable conditions, such as occur when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

<sup>b</sup> 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.

A screening analysis was conducted, using AUSPLUME, with both sets of meteorological data (1995 and 2008); it was found that the 1995 data returned a more conservative prediction of ground level pollutant concentrations and therefore would be more appropriate for use in the modelling of the Project.

DECC have specified the requirements for meteorological data that are used for air dispersion modelling in their *Approved Methods (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.

For the data collected in 1995, there were 8,112 hours available which represents a 93% data recovery.

As described above, to use the wind data to assess dispersion, it is necessary to also have available data on atmospheric stability. A stability class was assigned to each hour of the meteorological data using sigma-theta according to the method recommended by the US EPA (**US EPA, 1986**). **Error! Reference source not found.** shows the frequency of occurrence of the stability categories expected in the area.

The most common stability class was determined to be D class. This suggests that the dispersion conditions are such that air emissions disperse rapidly for a significant proportion of the time.

**Table 4:1 : Frequency of occurrence of stability classes in the study area**

Stability Class	Appin, 1995 (%)	Appin, 2008 (%)
A	9.4	8.9
B	5.5	7.5
C	11.4	10.9
D	44.5	52.1
E	15.1	10
F	14.1	10.6
Total	100	100

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.

Joint wind speed, wind direction and stability class frequency tables for the Appin 1995 data are provided in **Appendix B**. The Appin data are considered to satisfy the requirements of the DECC.

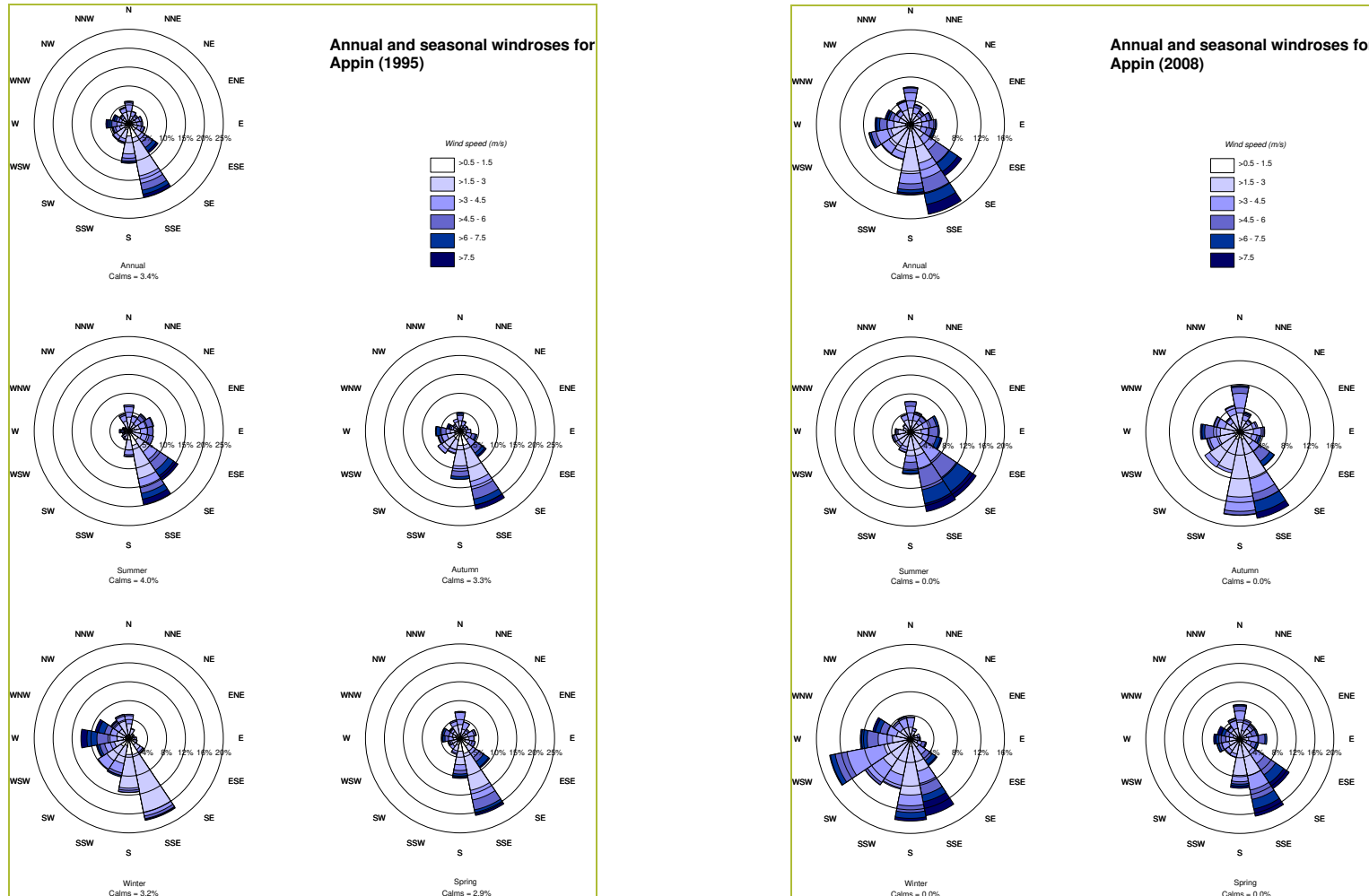


Figure 4.1 Windroses for Appin

## 4.2 Local Climatic Conditions

The Bureau of Meteorology (BoM) also collects climatic information in the vicinity of the study area. The closest BoM station to the Project site is Picton, located approximately 11 km to the west. A range of climatic information collected from Picton are presented in **Table 4:2 (Bureau of Meteorology, 2009)**.

Temperature and humidity data consist of monthly averages of 9 am and 3 pm readings. Also presented are monthly averages of maximum and minimum temperatures. Rainfall data consist of mean monthly rainfall and the average number of rain days per month.

**Table 4:2 : Climate information for Picton**

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean 9 am dry-bulb temperature (deg C)	21.8	21.5	19.9	16.8	12.2	9.4	7.7	10.4	14	17.3	19	21	15.9
Mean 3 pm dry-bulb temperature (deg C)	26.4	25.4	24.5	22.5	18.3	15.7	15.6	16.2	19	21.3	23.1	25.6	21.1
Mean daily maximum temperature (deg C)	29.3	28.6	27	23.7	20.2	17.3	16.8	18.2	21.4	24	26.3	28.5	23.4
Mean daily minimum temperature (deg C)	15.2	15.4	13.1	9.2	5.7	3.2	1.7	2.9	5.2	8.8	11.5	14	8.8
Mean rainfall (mm)	87.5	89	88.1	69.6	57.7	65.3	50.8	44.9	44.8	65.2	71.9	70.2	804.9
Mean number of rain days $\geq$ 1 mm	6.9	6.9	7.2	5.7	5	5.4	4.6	4.9	5.2	6.3	6.7	6.5	71.3

*Climate averages for Station: 'PICTON COUNCIL DEPOT' [068052], Commenced: 1880; Last record: 2009. Latitude (deg S): -34.17; Longitude (deg E): 150.61; State: NSW. Source: **Bureau of Meteorology (2009)** website.*

Temperature data show that January is typically the warmest month with a mean daily maximum of 29.3°C. July is the coldest month with a mean daily minimum of 1.7°C.

Rainfall data collected at Picton show that February is the wettest month with a mean rainfall of 89 mm over 7 rain days. Annually the area experiences, on average, 805 mm of rain.

### 4.3 Existing Air Quality

The DECC have previously operated an air quality monitoring station at Appin which measured NO<sub>2</sub>. **Table 4:3** shows the measured NO<sub>2</sub> concentrations for the most recent year of data available (1997).

**Table 4:3 : Monitoring of nitrogen dioxide at Appin in 1997**

Month	Measured NO <sub>2</sub> concentration (µg/m <sup>3</sup> )	
	Maximum 1-hour average	Average
Jan-97	55	6
Feb-97	35	10
Mar-97	53	8
Apr-97	78	12
May-97	66	8
Jun-97	90	12
Jul-97	62	8
Aug-97	49	8
Sep-97	53	6
Oct-97	53	10
Nov-97	33	8
Dec-97	70	10
<b>Maximum</b>	<b>90</b>	<b>-</b>
<b>Average</b>	<b>-</b>	<b>9</b>
<b>DECC criteria</b>	<b>246</b>	<b>62</b>

Source: EPA quarterly air quality monitoring reports for 1997 (**EPA, 1997**)

The monitoring data show that the area experiences NO<sub>2</sub> concentrations below the DECC ambient air quality criteria. The maximum 1-hour average NO<sub>2</sub> concentration in 1997 was 90 µg/m<sup>3</sup> and the annual average was 9 µg/m<sup>3</sup>.

There are no known air quality monitoring stations close to the study area that can be used to determine the existing concentrations of oxides of nitrogen, carbon monoxide and particulate matter (PM<sub>10</sub>). The DECC operate an extensive air quality monitoring network in NSW however their closest monitoring station to the site would be Macarthur (Campbelltown), approximately 20 km to the north.

Existing annual average PM<sub>10</sub> concentrations for the Appin area are estimated to be of the order of 15 µg/m<sup>3</sup> consistent with a relatively clean semi-rural environment. The 24-hour average PM<sub>10</sub> concentrations will be highly variable and, in many parts of NSW, it is common for the DECC's 50 µg/m<sup>3</sup> criteria to be exceeded on several occasions each year due to widespread events such as bushfires or dust storms.

## 5 ESTIMATED EMISSIONS

The potential air quality impacts of the Project are identified as follows:

- Pollutant emissions from gas flaring stacks;
- Pollutant emissions from the diesel generator;
- Odour and pollutant emissions from the gas vent stacks; and
- Dust generated during the construction phase.

For stack sources, the AUSPLUME dispersion model requires information on the source location, the source height, internal source tip diameter, temperature of emissions, exit velocity of emissions and the mass emission rate of the pollutants to be assessed. Temperature, exit velocity and mass emission rates can be provided to the model as hourly records for an entire year (variable emissions) or as constant emissions.

**Table 5:2** summarises the stack characteristics and expected emissions for the different scenarios.

### 5.1 Flare Systems

In this assessment, the flaring system is modelled as a point source. Stack dimensions are listed in **Table 5:2**.

Plume emissions from flares differ from conventional stacks because of the significant amount of heat released from the stack tip and heat lost due to radiation. In conventional plumes, it is assumed all the available heat is assumed to be available for buoyancy of the plume. The AUSPLUME model used in this assessment does not accurately account for the radiative heat lost from a flare and tends to over-predict the buoyancy of the plume and hence the plume rise from the stack.

In this assessment, the heat lost through the flaring process has been calculated from the flare specifications provided by the manufacturer. Adjustments assuming approximately 20% and 50% heat loss due to flaring have been factored into the diameter of the stack. Details of calculations are provided in **Appendix C (Schultze, 1977)**. The different stack diameters modelled for the 20% and 50% heat loss are 3.33 m and 2.63 m respectively.

**Table 5:1** lists conservative estimates of emissions for the flaring unit, provided by the manufacturer (Energen), assuming flaring of coalmine methane gas with 90-98 percent methane content.

**Table 5:1 Expected concentrations of emissions from flaring unit**

Pollutant	Emission mg/Nm <sup>3</sup>
NOx	150
CO	50

To provide a conservative estimate of the predicted emissions from this flare, it has been assumed that the flare will operate at all hours continuously and that all coalmine gas will be flared.

## 5.2 Diesel Generator

Emissions from the diesel-powered generator, listed in Table 5:2, were estimated using the NPI Emission Estimation Technique Manual for Combustion Engines (**NPI, 2008**). It was assumed that the generator is classed as an uncontrolled stationary diesel engine. Calculations are based on estimated diesel fuel usage of 3500 L/week and assume that the generator will operate continuously.

## 5.3 Vent Stack

There are limited odour emission data from gas extraction vents associated with underground mining operations. EML Air Pty Ltd were however commissioned by BHPBIC to measure odour emission rates from the Dendrobium underground mine ventilation shaft (**Holmes Air Sciences, 2005**). The measured odour emission rate was 4,600 ou.m<sup>3</sup>/s and while this may not be representative of the odour in the gas extraction vents, it provides an indicative estimate for the purposes of this assessment. Vent stack characteristics and emissions are listed in **Table 5:2**.

**Table 5:2 : Stack characteristics and emissions for modelling of stack sources**

	Vent stack	Flaring stack	Diesel generator*
Assumed stack location (easting and northing in MGA)	290800, 6215900	290800, 6215900	290790, 6215895
Alternate stack location	290680, 6216210	290680, 6216210	290695, 6216210
Height (m)	9	8	3.3
Diameter (m)	0.25	3.63	0.12
Stack cross-section (m <sup>2</sup> )	0.05	10.3	0.01
Flow rate coalmine gas (NI/s)	800	800	-
Flow rate total gas (Am <sup>3</sup> /s)	-	-	0.67
Temperature (deg C)	25	1050	300
Exit velocity (m/s)	16	9.05	28
<b>Pollutant emissions (g/s)</b>			
PM <sub>10</sub>	-	-	0.0294
CO	0.005	10.92	0.0923
NO <sub>x</sub>	-	32.75	0.4155
<b>Odour emissions (OU.m<sup>3</sup>/s)</b>			
Odour emission rate	4,600	-	-
OER (Stabilities A,B,C)	55,200	-	-
OER (Stabilities D,E,F)	115,000	-	-

\* Flow rate, exhaust temperature and exhaust velocity have been estimated from an equivalent size CAT diesel-powered generator:

<http://www.cat.com/cda/components/fullArticle/?m=39280&x=7&id=538612&languageId=7>

\*\* The vent stack will be located near to the extraction plant, the exact location has not yet been determined.

## 5.4 Dust

Dust will be generated during the construction stage of the Project.

Dust generating activities anticipated during the construction stage of the project are:

- Levelling of the extraction plant site;
- Trenching works for the surface pipeline reticulation system including underboring of the Hume Highway and Main Southern Rail Line;
- Work pad construction for drilling of the boreholes; and
- Drilling of 6 vertical boreholes, 2 medium radius drilled (MRD) boreholes and one downhole (to allow gas to be directed to the EDL power station).

A 13 or 30 t excavator will be used for these activities as well as to dig the drill cuttings sump and prepare any access roads if they are required. Typical site and access road preparation time is less than 5 days and these activities will be constrained to within 7 am and 5 pm.

The total length of trenching works for the surface pipeline is 2445m. It is anticipated that trenching works will proceed at the rate of around 250m/d. Trench digging will progress in a linear way over a two week period. Stockpiles of topsoil and subsoil will be replaced as soon as practicable and stabilised if necessary.

Underboring of the Hume Highway and Main Southern Rail Line will require approximately 280m of boring and is anticipated to take 4 days to complete. Underboring is done where an open trench is not possible (for example under a road) and is not a major source of dust emissions.

Vertical boreholes will be drilled during daylight hours 6 days per week. It is estimated that each borehole will take up to 2 weeks to complete. Two MRD boreholes will be also be drilled 24 hours per day, 7 days per week. It is anticipated that each MRD borehole will require 3 weeks to complete. Dust from borehole drilling will be suppressed with watersprays.

The two major dust generating activities are identified as the stripping of topsoil and general construction work by excavators and drill rigs and wind erosion from exposed areas. An estimate of the dust emissions due to these activities has been made and the calculations are provided below in **Table 5.3**.

**Table 5.3 : Estimated dust emissions during construction**

Activity	Intensity	Emission factor	TSP (kg/y)	TSP (kg/d)
Stripping topsoil and general construction work.	8 h/d	14.0 kg/h	40,880	112
Wind erosion from exposed areas of site	0.3 ha	0.4 kg/ha/h	876	2.4
<b>Total emissions (kg)</b>	-	0	<b>41,756</b>	<b>114</b>

The dust emissions presented above are conservative estimates as they assume that an excavator will be working for 8 hours per day and emitting at a rate equivalent to bulldozers (14 kg/h). Therefore, it is estimated that up to 114 kg of dust would be generated per day due to construction activities.

## 6 APPROACH TO ASSESSMENT

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

This assessment focuses on odour, dust (PM<sub>10</sub>) and NO<sub>x</sub> concentrations arising from goaf well activities and concentrations of these pollutants have been predicted using AUSPLUME. AUSPLUME (Version 6.0) is an advanced Gaussian dispersion model developed on behalf of the Victorian EPA (**VEPA, 1986**) and is based on the United States Environmental Protection Agency's Industrial Source Complex (ISC) model. It is widely used throughout Australia and is regarded as a "state-of-the-art" model. AUSPLUME is the model required for use by the DECC unless project characteristics dictate otherwise (**DEC, 2005**).

Odour, PM<sub>10</sub> and NO<sub>x</sub> levels have been modelled over an area of 9 km by 11 km, however a smaller area of predictions, approximately 2 km by 2.6 km, is displayed in this report. The modelling has considered activities at one surface goaf well location and one extraction plant location, on the property described as Lot 7 DP250231; the extent of the predicted impact zone has been taken to be representative of the impact zone around each of the other surface goaf well locations. This location has been used in the modelling as it is closer to most nearby residences and therefore provides a conservative estimate of impacts.

The modelling has been performed using the meteorological data discussed in **Section 4** and the emission estimates from **Section 5**. Model predictions have also been made at 16 discrete receptors around the emission source.

## 6.1 Odour

The way in which the model has been used in the odour assessment has been to predict the maximum 1-hour average odour levels corrected to nose response times (expressed in odour units) at each receptor. 1-hour averaging times have been used for consistency with the DECC odour criteria and odour levels at the 99<sup>th</sup> percentile have been presented to relate to these criteria.

## 6.2 Dust

This section is provided so that technical reviewers can appreciate how the modelling of different particle size categories was carried out.

The modelling has been based on the use of three particle-size categories (0 to 2.5 µm - referred to as PM<sub>2.5</sub>, 2.5 to 10 µm - referred to as CM (coarse matter) and 10 to 30 µm - referred to as the Rest). Emission rates of TSP have been calculated using emission factors developed both within NSW and by the US EPA.

The distribution of particles has been derived from measurements published by the **SPCC (1986)**. The distribution of particles in each particle size range is as follows:

- PM<sub>2.5</sub> (FP) is 4.7% of the TSP;
- PM<sub>2.5-10</sub> (CM) is 34.4% of TSP; and
- PM<sub>10-30</sub> (Rest) is 60.9% of TSP.

Modelling was done using three AUSPLUME source groups with each group corresponding to a particle size category. Each source in the group was assumed to emit at the full TSP emission rate and to deposit from the plume in accordance with the deposition rate appropriate for particles with an aerodynamic diameter equal to the geometric mean of the limits of the particle

size range, except for the PM<sub>2.5</sub> group, which was assumed to have a particle size of 1 µm. The predicted concentration in the three output files for each group were then combined according to the weightings in the dot points above to determine the concentration of PM<sub>10</sub> and TSP.

The AUSPLUME model also has the capacity to take into account dust emissions that vary in time, or with meteorological conditions. This has proved particularly useful for simulating emissions at operations where wind speed is an important factor in determining the rate at which dust is generated.

For the current study, the construction activities for a particular site were represented by a volume source. Estimates of emissions were developed on an hourly time-step taking into account the activities that would take place at that location.

Wind erosion was modelled for 24 hours per day, while other activities were modelled between 7 am and 5 pm. The dust modelling is considered to be worst-case since emissions were simulated for every day in the meteorological data file and the worst-case day for each receptor was extracted, even though the construction activities will only occur for a limited period.

### **6.3 Oxides of Nitrogen**

Maximum 1-hour average NO<sub>x</sub> concentrations have been predicted due to emissions from the diesel-powered generator and flaring stack.

Generally, at the point of emission NO will comprise the greatest proportion of the emission with 95% by volume of the NO<sub>x</sub>. The remaining 5% will be mostly NO<sub>2</sub>. Ultimately, however, all nitric oxides emitted into the atmosphere are oxidised to NO<sub>2</sub> and then further to other higher oxides of nitrogen. Generally, for plumes impacting close to the source, the time interval for oxidation is not sufficient to have converted a large proportion of the plume to the more harmful NO<sub>2</sub>.

For the purposes of this report it was conservatively assumed that 20% of the NO<sub>x</sub> was NO<sub>2</sub> at the point of maximum ground-level concentration.

### **6.4 Carbon Monoxide**

Maximum 1-hour average and maximum 8-hour average CO concentrations have been predicted due to emissions from the diesel-powered generator and flaring stack.

## 7 ASSESSMENT OF IMPACTS

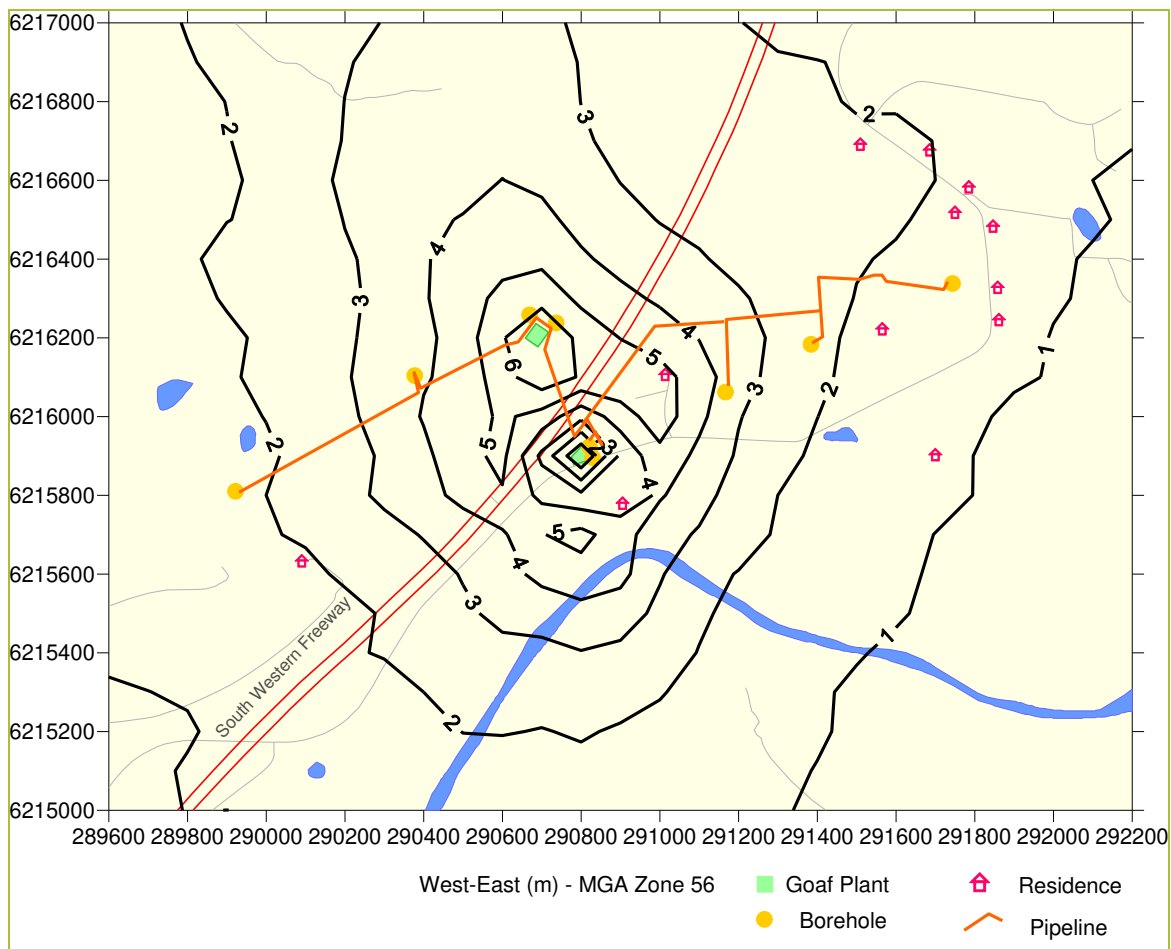
### 7.1 Odour

**Figure 7.1** shows the predicted maximum ground-level odour levels (corrected for nose response times), assuming the extraction plant to be located on the property described as Lot 7 DP250231.

The extraction plant location modelled is the closest of the two extraction plant options to residences, therefore odour levels at the most-affected residences would be expected to be less than those shown in **Figure 7.1** if the goaf plant were in the preferred location (Lot 2 DP576136).

For a single rural residence (that is, with population of 2 or less) the relevant odour criterion is 7 odour units at the 99<sup>th</sup> percentile (**DEC, 2006**). **Figure 7.1** shows that odour levels at the most affected residence are around 5 odour units at the 99<sup>th</sup> percentile. This complies with the DEC goal.

It is important to recognise also the uncertainty associated with the odour emissions data used in the modelling. The assumptions used for this assessment could be confirmed with odour emission measurements from the gas vent stacks, although considering that gases will only be vented when the underground connection to the EDL Power Station or flaring stacks fail to operate or during maintenance periods, impacts are expected to be low.



**Figure 7.1: Odour contours from vent stack at 99<sup>th</sup> percentile, in odour units**

## 7.2 Dust

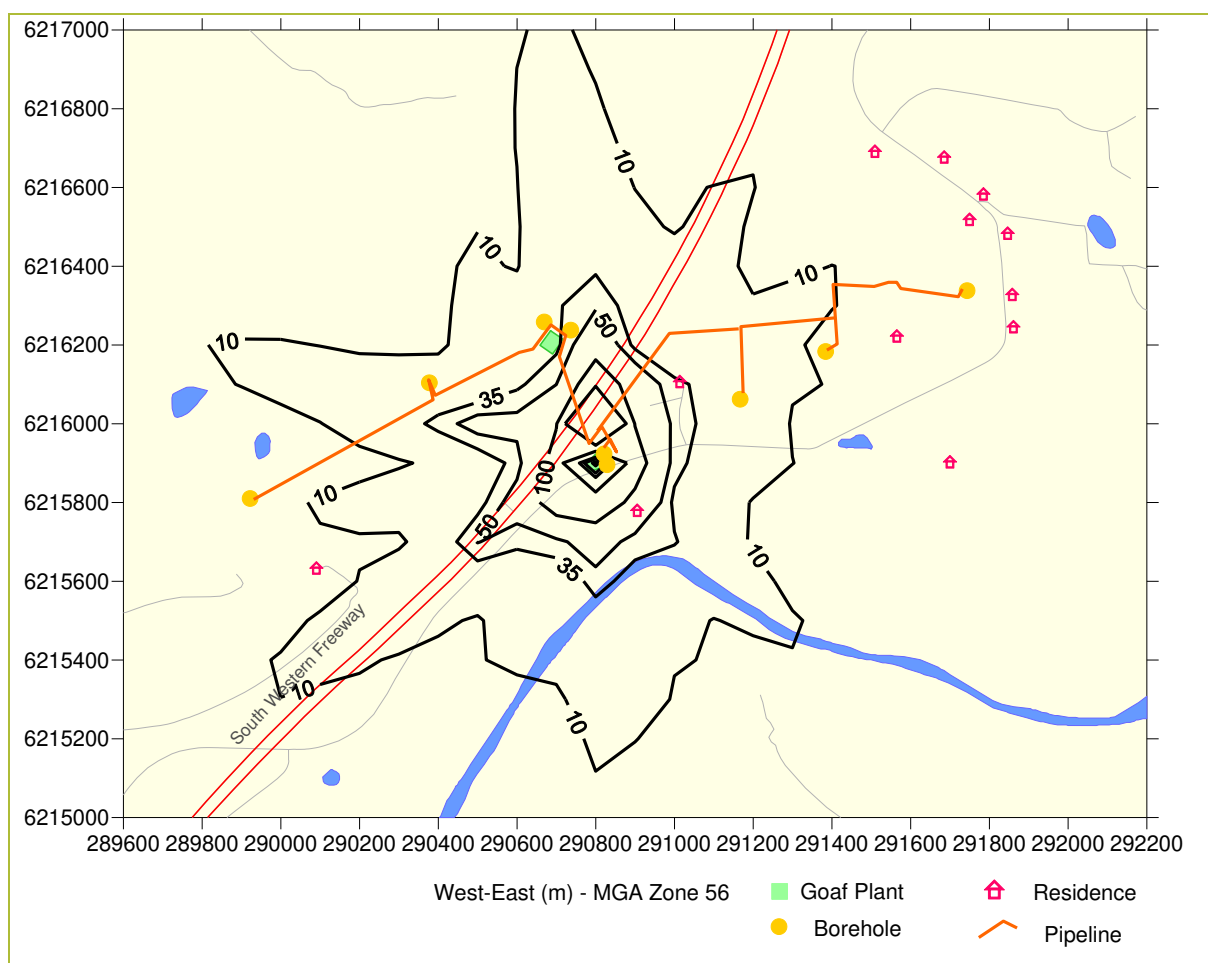
**Figure 7.2** shows the predicted maximum 24-hour average PM<sub>10</sub> concentrations due to construction activities, assuming the extraction plant to be located on the property described as Lot 7 DP250231. The DECC criterion is 50 µg/m<sup>3</sup>, which represents the contribution from all sources of dust, not just the contribution from the modelled sources. Background PM<sub>10</sub> concentration should be considered when examining the results in **Figure 7.2**.

It can be seen from **Figure 7.2** that the 50 µg/m<sup>3</sup> contour is predicted to extend between 200 to 400 m in each direction from the centre of site activities.

As discussed in **Section 4.3**, average PM<sub>10</sub> concentrations are estimated to be of the order of 15 µg/m<sup>3</sup>. The PM<sub>10</sub> concentrations will vary from day to day however for the purpose of this assessment it has been assumed that the background level is 15 µg/m<sup>3</sup> for the days of maximum 24-hour average PM<sub>10</sub> predictions. This means that the allowable contribution from site activity emissions would be 35 µg/m<sup>3</sup> before the 50 µg/m<sup>3</sup> criterion is reached. The 35 µg/m<sup>3</sup> contour extends between 220 m and 430 m in each direction from the centre of site activities. Approximately 8 out of the 9 boreholes are within 400 m of the nearest residences.

Given the conservative nature of the dust emission estimates and the short-term nature of construction activities, adverse PM<sub>10</sub> concentrations are unlikely to be observed and the activities would not be a significant dust source. However, the following measures will ensure that dust emissions are subject to a high level of control:

- Exposed areas will be watered to prevent dust emissions;
- Dust from borehole drilling will be suppressed with water sprays;
- Stockpiles of topsoil and subsoil will be replaced as soon as practicable. Re-vegetating or stabilising disturbed areas where necessary will prevent or minimise wind-blown dust; and
- If necessary, dust-generating activities will be modified during periods of high wind.

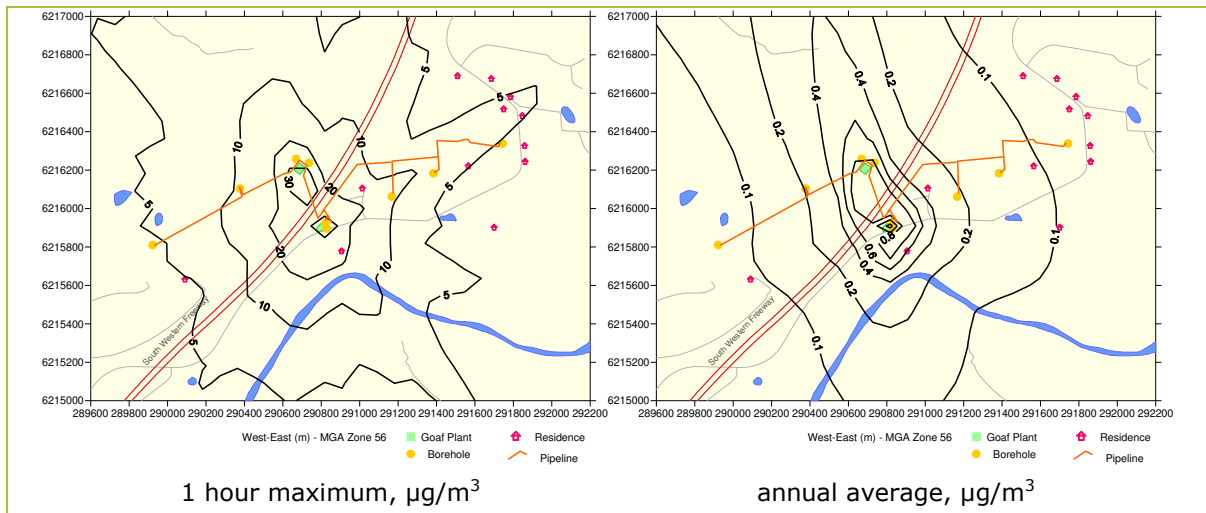


**Figure 7.2: 24-hour maximum PM<sub>10</sub> contours from construction activity, µg/m<sup>3</sup>**

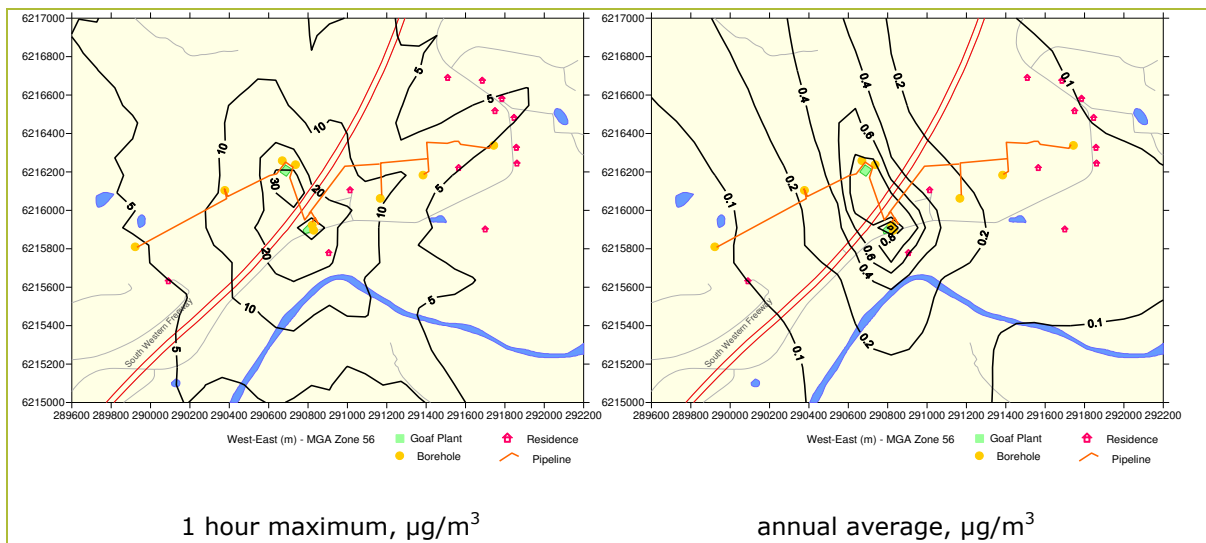
### 7.3 Oxides of Nitrogen

Results from the dispersion modelling for oxides of nitrogen are presented as contour plots in **Figure 7.2** and **Figure 7.3**. The predicted levels are shown as the 1-hour maximum and annual averages. The maximum 1-hour average predicted at the most affected residence is approximately  $22 \mu\text{g}/\text{m}^3$  for both the 20% and 50% heat loss scenarios, significantly less than the criteria of  $246 \mu\text{g}/\text{m}^3$  for nitrogen dioxide. When background levels of around  $90 \mu\text{g}/\text{m}^3$  are included (see **Section 4.3**), these predicted concentrations are still within the DECC criteria.

The results for the annual average for both the 20% and 50% heat loss scenarios are also shown in **Figure 7.2** and **Figure 7.3**. They show a predicted maximum of approximately  $0.6 \mu\text{g}/\text{m}^3$  at the most affected residence, significantly lower than the criteria of  $64 \mu\text{g}/\text{m}^3$ , even when background levels of  $9 \mu\text{g}/\text{m}^3$  (see **Section 4.3**) are included.



**Figure 7.3: NO<sub>2</sub> contours from flaring, assuming 20% heat loss**



**Figure 7.4: NO<sub>2</sub> contours from diesel generator and flare stack, assuming 50% heat loss**

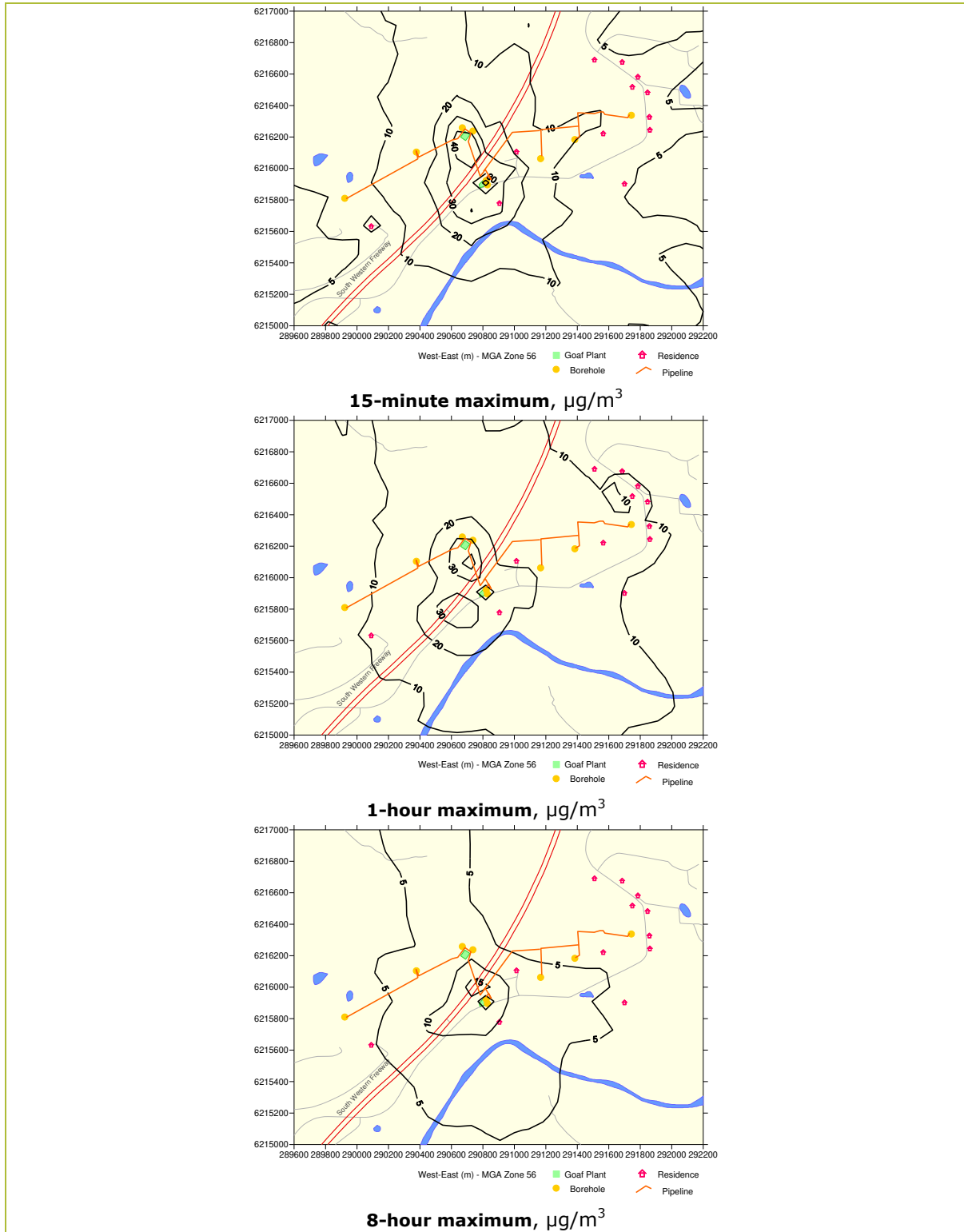
## 7.4 Carbon Monoxide

The dispersion model results are presented in **Figure 7.5** and **Figure 7.6**. The results show predicted carbon monoxide levels for 15-minute, 1-hour and 8-hour averaging times for comparison with the DECC criteria.

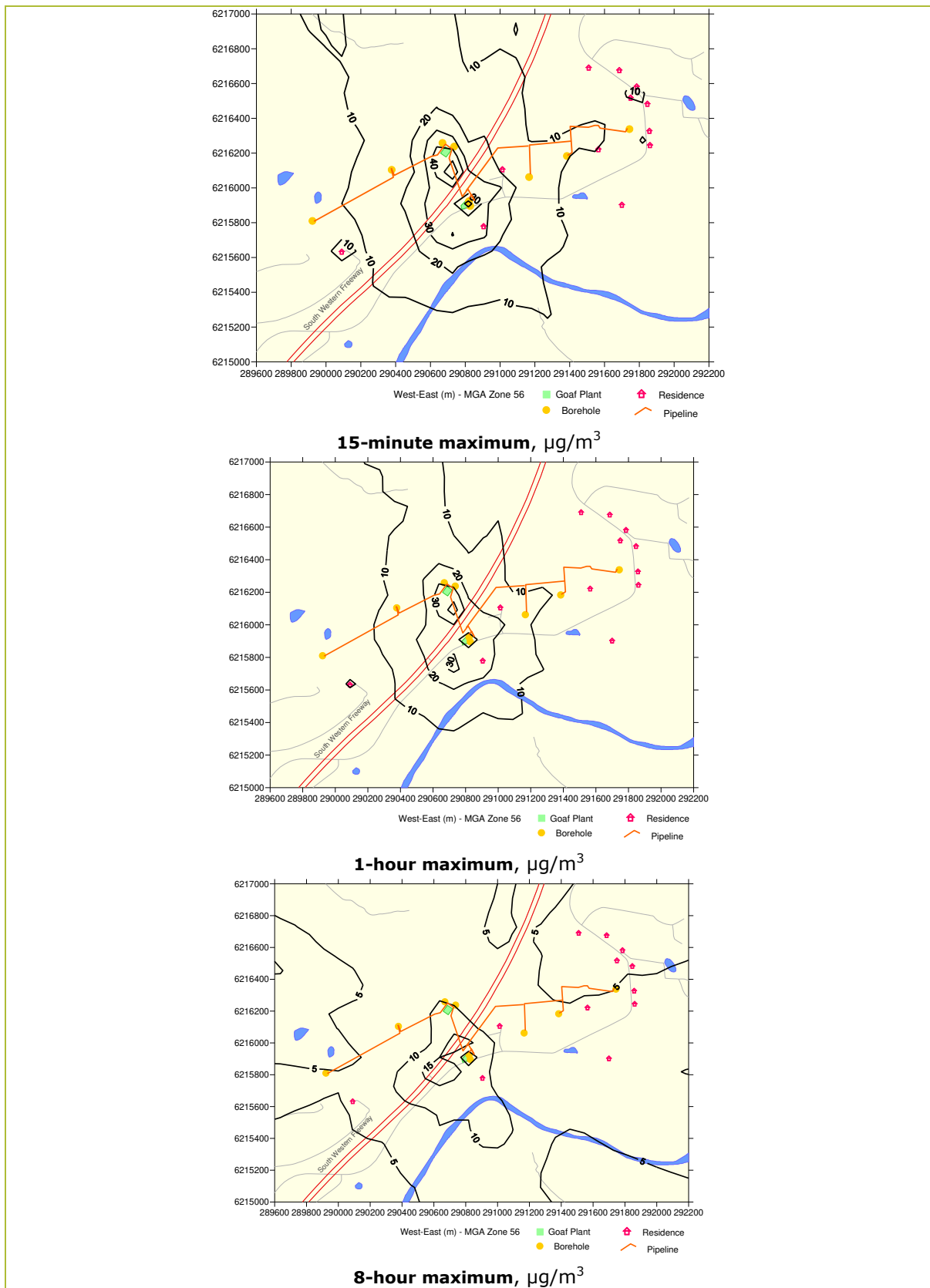
The results show predicted carbon monoxide levels for 15-minute, 1-hour and 8-hour averaging times for comparison with the DECC criteria.

**Figure 7.5** presents results assuming the 20% heat loss due to the flare and **Figure 7.6** presents the 50% heat loss case.

For both scenarios the impact at the residences most affected by the flaring activities were below the DECC criteria (see **Section 4.3**). The 15-minute ground level concentrations for the 20% and 50% heat loss cases show predicted levels at the most affected residence to be approximately 31  $\mu\text{g}/\text{m}^3$  and 30  $\mu\text{g}/\text{m}^3$  respectively. These predictions are well below the criteria of 100  $\text{mg}/\text{m}^3$  (100 000  $\mu\text{g}/\text{m}^3$ ). The 1-hour and 8-hour impacts are also well below the criteria with predictions of approximately 24  $\mu\text{g}/\text{m}^3$  and 11  $\mu\text{g}/\text{m}^3$  (20% heat loss); 24  $\mu\text{g}/\text{m}^3$  and 10  $\mu\text{g}/\text{m}^3$  (50% heat loss).



**Figure 7.5: CO contours from flaring, assuming 20% heat loss**



**Figure 7.6: CO contours from flaring, assuming 50% heat loss**

## 7.5 Alternative goaf plant location

If the extraction plant was to be located on the property described as Lot 2 DP576136, as shown in **Figure 2.1**, no significant difference in impacts at nearby residences is anticipated, especially as this extraction plant location is further from most residences than the location modelled.

## 7.6 Emissions from EDL Power Stations

The Project aims to capture goaf gas and reticulate it to the underground gas drainage range that provides mine gas to the EDL power stations at Appin West pit top and Appin No 1 Shaft. The EDL plants are currently operating below capacity. The EDL power stations are required to operate in accordance with their Environment Protection Licences which prescribe strict emission load and concentration limits and monitoring requirements. No change to the EDL operations or permitted environmental impacts will occur. No change to the Environment Protection Licences is required to accommodate the Appin Area 7 Goaf Gas Drainage Project. The EDL Environment Protection Licences are available at:

- <http://www.environment.nsw.gov.au/prpoeo/licences/L5357.pdf> (for Appin West pit top)
- <http://www.environment.nsw.gov.au/prpoeo/licences/L5482.pdf> (for Appin No 1 Shaft)

## 8 CONCLUSIONS

This report has assessed the air quality impacts of the Appin Mine Area 7 Goaf Gas Drainage Project. Dispersion modelling has been used to predict odour, PM<sub>10</sub>, CO and NO<sub>x</sub> levels due to activities taking place at the proposed boreholes and the extraction plant/s.

The conclusions of the assessment are as follows:

- Predicted odour levels from vent gasses at nearest residences are within DECC criteria.
- Compliance with dust concentration criteria is predicted during the construction stage of the Project. Dust mitigation measures will ensure that dust emissions are subject to a high level of control.
- NO<sub>2</sub> and CO concentrations at nearby residences will be below the DECC criteria.
- Emissions at the EDL power stations will continue to comply with the existing requirements of their Environment Protection Licences.

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## **APPENDIX A**

### **Peak to mean table**

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**Table A1 : Recommended factors for estimating peak concentrations for different source types, distances and stabilities**

Source type	Stability	Near field				Far field			p
		$i_{max}$	$x_{max}$	P/M 60	P/M 3	i	P/M 60	P/M 3	
Area	Neutral, Convective	0.5	500 – 1000	2.5	1.9	0.4	2.3	1.7	0.15
	Stable	0.5	300 – 800	2.3	1.7	0.3	1.9	1.4	0.10
Line	Neutral, Convective	1.0	350	6	2.8	0.75	6	2.8	0.25
	Stable	1.0	250	6	2.8	0.65	6	2.8	0.25
Surface point	Neutral	2.5	200	25	10	1.2	5 - 7	3	0.2
	Stable	2.5	200	25	10	1.2	5 - 7	3	0.2
	Convective	2	1000	12	7	0.6	3 - 4	2.5	0.15
Tall point	Neutral, Stable	4.5	5 h	35	8	1.0	6	1.3	0.5
	Convective	2.3	2.5 h	17	4	0.5	3	1.1	0.5
Wake affected point	Neutral, Convective	0.4	-	2.3	1.4	-	2.3	1.4	0.1
Volume	Neutral, Convective	0.4	-	2.3	1.4	-	2.3	1.4	0.1

$i_{max}$  is maximum centreline intensity of concentration

$x_{max}$  is the approximation location of  $i_{max}$  in metres

P/M 60 is the peak-to-mean ratio for long averaging times (typically 1 hour), at a probability of  $10^{-3}$

P/M 3 is the best estimates of the peak-to-mean ratio for 3 minute averages, at probability  $10^{-3}$

p is the averaging time power law exponent

h is stack height

Source: **Katestone Scientific (1998)**

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Air Quality Impact Assessment:

Appin Mine Area 7 Goaf Gas Drainage Project

Cardno Forgbes Rigby Pty Ltd | PAEHolmes Job 3275[Category]

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## **APPENDIX B**

### **Joint wind speed, wind direction and stability class frequency tables**

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STATISTICS FOR FILE: C:\Jobs\WestCliff\metdata\appin\_1995.aus  
 MONTHS: All  
 HOURS : All  
 OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

WIND SECTOR	Wind Speed Class (m/s)								TOTAL
	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	
NNE	0.001233	0.001603	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
NE	0.001109	0.001356	0.000616	0.000123	0.000000	0.000000	0.000000	0.000000	0.003205
ENE	0.001849	0.000740	0.000493	0.000247	0.000000	0.000000	0.000000	0.000000	0.003328
E	0.000740	0.000740	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001479
ESE	0.000493	0.001233	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.001849
SE	0.001972	0.000986	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
SSE	0.004191	0.001603	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.006164
S	0.006040	0.001726	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.008013
SSW	0.002465	0.000740	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
SW	0.001972	0.000986	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002959
WSW	0.002835	0.000616	0.000000	0.000123	0.000000	0.000000	0.000000	0.000000	0.003575
W	0.004438	0.000863	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.005671
WNW	0.003205	0.003698	0.000616	0.000000	0.000000	0.000000	0.000000	0.000000	0.007520
NW	0.005794	0.003205	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.009122
NNW	0.003575	0.005547	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.009369
N	0.003945	0.006780	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.011095
CALM									0.011218
TOTAL	0.045858	0.032421	0.004191	0.000493	0.000000	0.000000	0.000000	0.000000	0.094181

MEAN WIND SPEED (m/s) = 1.49  
 NUMBER OF OBSERVATIONS = 764

PASQUILL STABILITY CLASS 'B'

WIND SECTOR	Wind Speed Class (m/s)									TOTAL
	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		
NNE	0.000370	0.001849	0.000863	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
NE	0.000493	0.000616	0.000863	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.002096
ENE	0.000123	0.000740	0.000616	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.001603
E	0.000123	0.000616	0.000616	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001356
ESE	0.000000	0.000863	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001109
SE	0.000863	0.000740	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001972
SSE	0.001109	0.001233	0.000616	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.003082
S	0.002096	0.001109	0.000740	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.004068
SSW	0.001233	0.001109	0.000616	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.003082
SW	0.001109	0.001972	0.000863	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.004068
WSW	0.000616	0.000986	0.000986	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.002835
W	0.001233	0.001603	0.002219	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.005301
WNW	0.001479	0.001233	0.000370	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
NW	0.000863	0.001233	0.000370	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.002589
NNW	0.001479	0.003698	0.001109	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006287
N	0.000740	0.004561	0.003205	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008506
CALM										0.000863
TOTAL	0.013930	0.024162	0.014670	0.001603	0.000000	0.000000	0.000000	0.000000	0.000000	0.055227

MEAN WIND SPEED (m/s) = 2.41  
NUMBER OF OBSERVATIONS = 448

PASQUILL STABILITY CLASS 'C'

WIND SECTOR	Wind Speed Class (m/s)									TOTAL
	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		
NNE	0.000616	0.001726	0.003821	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.006410
NE	0.000370	0.000616	0.001479	0.000616	0.000000	0.000000	0.000000	0.000000	0.000000	0.003082
ENE	0.000370	0.000740	0.001233	0.001109	0.000000	0.000000	0.000000	0.000000	0.000000	0.003452
E	0.000247	0.000986	0.001849	0.002465	0.000000	0.000000	0.000000	0.000000	0.000000	0.005547
ESE	0.000493	0.000740	0.001233	0.002342	0.000000	0.000000	0.000000	0.000000	0.000000	0.004808
SE	0.000616	0.000740	0.002835	0.001479	0.000000	0.000000	0.000000	0.000000	0.000000	0.005671
SSE	0.001233	0.002096	0.001109	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.004684
S	0.001109	0.002712	0.001972	0.001726	0.000000	0.000000	0.000000	0.000000	0.000000	0.007520
SSW	0.000740	0.002219	0.003452	0.000986	0.000000	0.000000	0.000000	0.000000	0.000000	0.007396
SW	0.000616	0.003452	0.002465	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.006903
WSW	0.000740	0.001972	0.002959	0.002219	0.000000	0.000000	0.000000	0.000000	0.000000	0.007890
W	0.001972	0.001479	0.001972	0.005794	0.000000	0.000000	0.000000	0.000000	0.000000	0.011218
WNW	0.001479	0.001356	0.001972	0.003082	0.000000	0.000000	0.000000	0.000000	0.000000	0.007890
NW	0.000616	0.001109	0.000986	0.000616	0.000000	0.000000	0.000000	0.000000	0.000000	0.003328
NNW	0.000247	0.006657	0.003945	0.000740	0.000000	0.000000	0.000000	0.000000	0.000000	0.011588
N	0.000000	0.003698	0.010478	0.001726	0.000000	0.000000	0.000000	0.000000	0.000000	0.015902
CALM										0.000370
TOTAL	0.011464	0.032298	0.043762	0.025764	0.000000	0.000000	0.000000	0.000000	0.000000	0.113659

MEAN WIND SPEED (m/s) = 3.43  
NUMBER OF OBSERVATIONS = 922

PASQUILL STABILITY CLASS 'D'

WIND SECTOR	Wind Speed Class (m/s)								TOTAL
	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	
NNE	0.000863	0.006657	0.006534	0.000863	0.000000	0.000000	0.000000	0.000000	0.014916
NE	0.001726	0.003328	0.004191	0.003575	0.000616	0.000000	0.000000	0.000000	0.013437
ENE	0.001233	0.004808	0.008259	0.004438	0.000863	0.000123	0.000000	0.000000	0.019724
E	0.001726	0.006534	0.008383	0.001726	0.000247	0.000000	0.000000	0.000000	0.018614
ESE	0.002835	0.005671	0.008136	0.005054	0.001479	0.000000	0.000123	0.000000	0.023299
SE	0.004931	0.009615	0.010602	0.015656	0.010725	0.004068	0.001479	0.000247	0.057322
SSE	0.011834	0.029832	0.012081	0.017382	0.010848	0.005178	0.002589	0.000616	0.090360
S	0.004315	0.019847	0.006657	0.005917	0.004315	0.000863	0.000000	0.000000	0.041913
SSW	0.001233	0.012574	0.005424	0.001972	0.000740	0.000000	0.000000	0.000000	0.021943
SW	0.000616	0.013314	0.008136	0.000123	0.000000	0.000000	0.000000	0.000000	0.022189
WSW	0.000247	0.008752	0.007396	0.003328	0.002342	0.000986	0.000247	0.000000	0.023299
W	0.000370	0.002342	0.006903	0.007396	0.010232	0.004191	0.001109	0.000000	0.032544
WNW	0.000247	0.002959	0.004068	0.004315	0.005671	0.002712	0.001603	0.000123	0.021696
NW	0.000370	0.003082	0.003452	0.002219	0.000616	0.000740	0.000123	0.000000	0.010602
NNW	0.000616	0.005547	0.004931	0.001726	0.000247	0.000123	0.000000	0.000000	0.013190
N	0.001233	0.006780	0.008013	0.001603	0.001479	0.000000	0.000000	0.000000	0.019107
CALM									0.000370
TOTAL	0.034393	0.141642	0.113166	0.077293	0.050419	0.018984	0.007273	0.000986	0.444527

MEAN WIND SPEED (m/s) = 4.00  
NUMBER OF OBSERVATIONS = 3606

PASQUILL STABILITY CLASS 'E'

WIND SECTOR	Wind Speed Class (m/s)								TOTAL
	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	
NNE	0.000863	0.002096	0.000247	0.000123	0.000000	0.000000	0.000000	0.000000	0.003328
NE	0.000863	0.002835	0.000616	0.000000	0.000000	0.000000	0.000000	0.000000	0.004315
ENE	0.001356	0.001603	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
E	0.001972	0.001603	0.000740	0.000000	0.000000	0.000000	0.000000	0.000000	0.004315
ESE	0.002589	0.004561	0.000740	0.000000	0.000000	0.000000	0.000000	0.000000	0.007890
SE	0.004068	0.005794	0.003945	0.000740	0.000000	0.000000	0.000000	0.000000	0.014546
SSE	0.008876	0.043393	0.005671	0.000986	0.000000	0.000000	0.000000	0.000000	0.058925
S	0.004931	0.015409	0.001849	0.000370	0.000000	0.000000	0.000000	0.000000	0.022559
SSW	0.002342	0.005178	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007520
SW	0.002959	0.005424	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008383
WSW	0.000986	0.002219	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
W	0.000616	0.001726	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002342
WNW	0.000247	0.001233	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.001849
NW	0.000370	0.000986	0.001356	0.000123	0.000000	0.000000	0.000000	0.000000	0.002835
NNW	0.000370	0.000740	0.000740	0.000123	0.000000	0.000000	0.000000	0.000000	0.001972
N	0.001479	0.001603	0.000247	0.000000	0.000000	0.000000	0.000000	0.000000	0.003328
CALM									0.000740
TOTAL	0.034887	0.096400	0.016765	0.002465	0.000000	0.000000	0.000000	0.000000	0.151257

MEAN WIND SPEED (m/s) = 2.13  
NUMBER OF OBSERVATIONS = 1227

PASQUILL STABILITY CLASS 'F'

WIND SECTOR	Wind Speed Class (m/s)								TOTAL
	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	
NNE	0.002835	0.000616	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003452
NE	0.002712	0.000616	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003328
ENE	0.004191	0.000370	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004561
E	0.003945	0.000986	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004931
ESE	0.003698	0.000123	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003821
SE	0.008999	0.000863	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009862
SSE	0.010848	0.024038	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.034887
S	0.013560	0.006534	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.020094
SSW	0.007520	0.002835	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.010355
SW	0.006657	0.000986	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007643
WSW	0.003945	0.001479	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005424
W	0.002219	0.001356	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003575
WNW	0.001603	0.000740	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002342
NW	0.001479	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001479
NNW	0.001849	0.001233	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003082
N	0.001603	0.000740	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002342
CALM									0.019970
TOTAL	0.077663	0.043516	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.141149

MEAN WIND SPEED (m/s) = 1.28  
 NUMBER OF OBSERVATIONS = 1145

ALL PASQUILL STABILITY CLASSES  
 Wind Speed Class (m/s)

WIND SECTOR	Wind Speed Class (m/s)								TOTAL
	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	
NNE	0.006780	0.014546	0.011834	0.001356	0.000000	0.000000	0.000000	0.000000	0.034517
NE	0.007273	0.009369	0.007766	0.004438	0.000616	0.000000	0.000000	0.000000	0.029463
ENE	0.009122	0.008999	0.010848	0.005917	0.000863	0.000123	0.000000	0.000000	0.035873
E	0.008752	0.011464	0.011588	0.004191	0.000247	0.000000	0.000000	0.000000	0.036243
ESE	0.010108	0.013190	0.010478	0.007396	0.001479	0.000000	0.000123	0.000000	0.042776
SE	0.021450	0.018738	0.017998	0.017875	0.010725	0.004068	0.001479	0.000247	0.092579
SSE	0.038092	0.102194	0.019847	0.018738	0.010848	0.005178	0.002589	0.000616	0.198102
S	0.032051	0.047337	0.011464	0.008136	0.004315	0.000863	0.000000	0.000000	0.104167
SSW	0.015533	0.024655	0.009492	0.003082	0.000740	0.000000	0.000000	0.000000	0.053501
SW	0.013930	0.026134	0.011464	0.000616	0.000000	0.000000	0.000000	0.000000	0.052145
WSW	0.009369	0.016026	0.011341	0.005917	0.002342	0.000986	0.000247	0.000000	0.046228
W	0.010848	0.009369	0.011464	0.013437	0.010232	0.004191	0.001109	0.000000	0.060651
WNW	0.008259	0.011218	0.007396	0.007520	0.005671	0.002712	0.001603	0.000123	0.044502
NW	0.009492	0.009615	0.006287	0.003082	0.000616	0.000740	0.000123	0.000000	0.029956
NNW	0.008136	0.023422	0.010971	0.002589	0.000247	0.000123	0.000000	0.000000	0.045488
N	0.008999	0.024162	0.022313	0.003328	0.001479	0.000000	0.000000	0.000000	0.060281
CALM									0.033531
TOTAL	0.218195	0.370439	0.192554	0.107618	0.050419	0.018984	0.007273	0.000986	1.000000

MEAN WIND SPEED (m/s) = 2.94  
 NUMBER OF OBSERVATIONS = 8112

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 FREQUENCY OF OCCURENCE OF STABILITY CLASSES  
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A : 9.4%  
 B : 5.5%  
 C : 11.4%  
 D : 44.5%  
 E : 15.1%  
 F : 14.1%

-----  
 STABILITY CLASS BY HOUR OF DAY  
 -----

Hour	A	B	C	D	E	F
01	0000	0000	0000	0138	0099	0101
02	0000	0000	0000	0134	0101	0103
03	0000	0000	0000	0129	0110	0099
04	0000	0000	0000	0120	0100	0118
05	0000	0000	0000	0125	0105	0108
06	0008	0006	0010	0137	0090	0087
07	0040	0016	0029	0150	0047	0056
08	0079	0032	0044	0160	0010	0013
09	0094	0051	0079	0114	0000	0000
10	0096	0048	0105	0089	0000	0000
11	0092	0046	0113	0087	0000	0000
12	0088	0056	0098	0096	0000	0000
13	0078	0046	0110	0104	0000	0000
14	0080	0049	0096	0113	0000	0000
15	0064	0047	0092	0135	0000	0000
16	0038	0035	0089	0160	0005	0011
17	0005	0012	0047	0238	0019	0017
18	0002	0004	0010	0275	0035	0012
19	0000	0000	0000	0271	0049	0018
20	0000	0000	0000	0222	0076	0040
21	0000	0000	0000	0172	0083	0083
22	0000	0000	0000	0151	0101	0086
23	0000	0000	0000	0149	0099	0090
24	0000	0000	0000	0137	0098	0103

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 STABILITY CLASS BY MIXING HEIGHT  
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Mixing height	A	B	C	D	E	F
<=500 m	0128	0063	0121	0614	1206	1120
<=1000 m	0348	0185	0369	1220	0008	0015
<=1500 m	0288	0200	0432	1360	0013	0010
<=2000 m	0000	0000	0000	0262	0000	0000
<=3000 m	0000	0000	0000	0139	0000	0000
>3000 m	0000	0000	0000	0011	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	0081	0107	0024	0048	0066	0012	0000
02	0082	0113	0018	0042	0066	0017	0000
03	0082	0113	0024	0044	0056	0018	0001
04	0100	0104	0018	0047	0053	0015	0001
05	0129	0100	0015	0039	0044	0011	0000
06	0093	0118	0071	0029	0019	0008	0000
07	0090	0059	0102	0077	0007	0003	0000
08	0000	0074	0103	0161	0000	0000	0000
09	0000	0000	0099	0165	0074	0000	0000
10	0000	0000	0000	0216	0122	0000	0000
11	0000	0000	0000	0133	0205	0000	0000
12	0000	0000	0000	0085	0253	0000	0000
13	0000	0000	0000	0020	0318	0000	0000
14	0000	0000	0000	0000	0338	0000	0000
15	0000	0000	0000	0000	0338	0000	0000
16	0000	0000	0000	0000	0338	0000	0000
17	0004	0008	0005	0005	0294	0022	0000
18	0011	0015	0014	0015	0244	0039	0000
19	0016	0031	0020	0024	0187	0060	0000
20	0036	0053	0028	0034	0136	0051	0000
21	0066	0077	0024	0049	0092	0029	0001
22	0077	0096	0019	0050	0074	0022	0000
23	0072	0103	0018	0054	0070	0021	0000
24	0079	0108	0019	0045	0062	0025	0000



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## **APPENDIX C**

### **AUSPLUME model output**

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1

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Appin Surace Gas Drainage - flare emissions. NOx

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Concentration or deposition	Concentration
Emission rate units	grams/second
Concentration units	microgram/m3
Units conversion factor	1.00E+06
Constant background concentration	0.00E+00
Terrain effects	Egan method
Smooth stability class changes?	No
Other stability class adjustments ("urban modes")	None
Ignore building wake effects?	No
Decay coefficient (unless overridden by met. file)	0.000
Anemometer height	10 m
Roughness height at the wind vane site	0.400 m
Averaging time for sigma-theta values	60 min.

DISPERSION CURVES

Horizontal dispersion curves for sources <100m high	Sigma-theta
Vertical dispersion curves for sources <100m high	Pasquill-Gifford
Horizontal dispersion curves for sources >100m high	Briggs Rural
Vertical dispersion curves for sources >100m high	Briggs Rural
Enhance horizontal plume spreads for buoyancy?	Yes
Enhance vertical plume spreads for buoyancy?	Yes
Adjust horizontal P-G formulae for roughness height?	Yes
Adjust vertical P-G formulae for roughness height?	Yes
Roughness height	0.400m
Adjustment for wind directional shear	None

PLUME RISE OPTIONS

Gradual plume rise?	Yes
Stack-tip downwash included?	Yes
Building downwash algorithm:	Schulman-Scire method.
Entrainment coeff. for neutral & stable lapse rates	0.60,0.60
Partial penetration of elevated inversions?	No
Disregard temp. gradients in the hourly met. file?	No

and in the absence of boundary-layer potential temperature gradients given by the hourly met. file, a value from the following table (in K/m) is used:

Wind Speed Category	Stability Class					
	A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

WIND SPEED CATEGORIES

Boundaries between categories (in m/s) are: 1.54, 3.09, 5.14, 8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Rural" values (unless overridden by met. file)

AVERAGING TIMES

1 hour

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1

Appin Surace Gas Drainage - flare emissions. NOx

SOURCE CHARACTERISTICS

STACK SOURCE: GEN1

X (m)	Y (m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
290790	6215895	125m	3m	0.12m	300C	20.0m/s

No building wake effects.  
 (Constant) emission rate = 4.15E-01 grams/second  
 No gravitational settling or scavenging.

STACK SOURCE: FLARE1

X (m)	Y (m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
290800	6215900	125m	8m	2.63m	1000C	9.1m/s

No building wake effects.  
 (Constant) emission rate = 1.40E+01 grams/second  
 No gravitational settling or scavenging.

1

Appin Surace Gas Drainage - flare emissions. NOx

RECEPTOR LOCATIONS

The Cartesian receptor grid has the following x-values (or eastings):

286000.m 286100.m 286200.m 286300.m 286400.m 286500.m 286600.m  
 286700.m 286800.m 286900.m 287000.m 287100.m 287200.m 287300.m  
 287400.m 287500.m 287600.m 287700.m 287800.m 287900.m 288000.m  
 288100.m 288200.m 288300.m 288400.m 288500.m 288600.m 288700.m  
 288800.m 288900.m 289000.m 289100.m 289200.m 289300.m 289400.m  
 289500.m 289600.m 289700.m 289800.m 289900.m 290000.m 290100.m  
 290200.m 290300.m 290400.m 290500.m 290600.m 290700.m 290800.m  
 290900.m 291000.m 291100.m 291200.m 291300.m 291400.m 291500.m  
 291600.m 291700.m 291800.m 291900.m 292000.m 292100.m 292200.m  
 292300.m 292400.m 292500.m 292600.m 292700.m 292800.m 292900.m  
 293000.m 293100.m 293200.m 293300.m 293400.m 293500.m 293600.m  
 293700.m 293800.m 293900.m 294000.m 294100.m 294200.m 294300.m  
 294400.m 294500.m 294600.m 294700.m 294800.m 294900.m 295000.m

and these y-values (or northings):

6211000.m 6211100.m 6211200.m 6211300.m 6211400.m 6211500.m 6211600.m  
 6211700.m 6211800.m 6211900.m 6212000.m 6212100.m 6212200.m 6212300.m  
 6212400.m 6212500.m 6212600.m 6212700.m 6212800.m 6212900.m 6213000.m  
 6213100.m 6213200.m 6213300.m 6213400.m 6213500.m 6213600.m 6213700.m  
 6213800.m 6213900.m 6214000.m 6214100.m 6214200.m 6214300.m 6214400.m  
 6214500.m 6214600.m 6214700.m 6214800.m 6214900.m 6215000.m 6215100.m  
 6215200.m 6215300.m 6215400.m 6215500.m 6215600.m 6215700.m 6215800.m  
 6215900.m 6216000.m 6216100.m 6216200.m 6216300.m 6216400.m 6216500.m  
 6216600.m 6216700.m 6216800.m 6216900.m 6217000.m 6217100.m 6217200.m  
 6217300.m 6217400.m 6217500.m 6217600.m 6217700.m 6217800.m 6217900.m  
 6218000.m 6218100.m 6218200.m 6218300.m 6218400.m 6218500.m 6218600.m  
 6218700.m 6218800.m 6218900.m 6219000.m 6219100.m 6219200.m 6219300.m  
 6219400.m 6219500.m 6219600.m 6219700.m 6219800.m 6219900.m 6220000.m

DISCRETE RECEPTOR LOCATIONS (in metres)

No.	X	Y	ELEVN	HEIGHT	No.	X	Y	ELEVN	HEIGHT
1	290905	6215780	120.0	0.0	9	291685	6216677	130.0	0.0
2	291861	6216246	130.0	0.0	10	291784	6216583	130.0	0.0
3	291858	6216328	130.0	0.0	11	290090	6215633	130.0	0.0
4	291846	6216484	130.0	0.0	12	289383	6215812	140.0	0.0
5	291699	6215903	120.0	0.0	13	289453	6216114	120.0	0.0
6	291564	6216223	130.0	0.0	14	289500	6216273	120.0	0.0
7	291749	6216519	130.0	0.0	15	289911	6217092	120.0	0.0
8	291509	6216692	130.0	0.0	16	291013	6216107	125.0	0.0

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METEOROLOGICAL DATA : AUS to AUS Extended records (Met MANAGER)

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1 Peak values for the 100 worst cases (in microgram/m3)  
Averaging time = 1 hour

Rank	Value	Time Recorded hour,date	Coordinates (* denotes polar)
1	2.50E+02	07,22/02/95	(290700, 6216100, 0.0)
2	1.75E+02	07,16/10/95	(290700, 6216200, 0.0)
3	1.66E+02	07,05/10/95	(290700, 6216200, 0.0)
4	1.62E+02	09,12/08/95	(290700, 6216200, 0.0)
5	1.61E+02	08,12/03/95	(290700, 6216100, 0.0)
6	1.61E+02	08,12/05/95	(290700, 6216200, 0.0)
7	1.58E+02	07,28/09/95	(290700, 6216200, 0.0)
8	1.54E+02	08,11/10/95	(290700, 6216100, 0.0)
9	1.54E+02	09,25/08/95	(290700, 6215700, 0.0)
10	1.53E+02	07,09/02/95	(290700, 6216200, 0.0)
11	1.52E+02	06,07/12/95	(290700, 6216200, 0.0)
12	1.51E+02	10,10/06/95	(290700, 6215800, 0.0)
13	1.51E+02	08,30/04/95	(290700, 6216100, 0.0)
14	1.45E+02	06,16/01/95	(290700, 6216100, 0.0)
15	1.44E+02	08,20/08/95	(290700, 6216200, 0.0)
16	1.43E+02	09,25/07/95	(290800, 6216000, 0.0)
17	1.43E+02	08,21/07/95	(290800, 6216000, 0.0)
18	1.42E+02	09,21/07/95	(290800, 6216000, 0.0)
19	1.41E+02	09,26/04/95	(290700, 6216200, 0.0)
20	1.41E+02	21,19/09/95	(290800, 6215800, 0.0)
21	1.38E+02	09,13/08/95	(290700, 6216200, 0.0)
22	1.37E+02	08,22/09/95	(290800, 6216000, 0.0)
23	1.36E+02	06,03/01/95	(290600, 6216200, 0.0)
24	1.35E+02	08,11/05/95	(290700, 6216100, 0.0)
25	1.35E+02	09,07/07/95	(290800, 6216000, 0.0)
26	1.33E+02	07,04/01/95	(290700, 6216100, 0.0)
27	1.31E+02	24,08/02/95	(290700, 6216000, 0.0)
28	1.31E+02	01,10/05/95	(290700, 6215800, 0.0)
29	1.30E+02	23,18/01/95	(290700, 6215900, 0.0)
30	1.30E+02	06,06/01/95	(290600, 6216200, 0.0)
31	1.30E+02	22,14/11/95	(290800, 6215800, 0.0)
32	1.30E+02	19,13/08/95	(290700, 6215900, 0.0)
33	1.29E+02	23,02/07/95	(290905, 6215780, 0.0)
34	1.28E+02	21,03/01/95	(290700, 6215900, 0.0)
35	1.28E+02	06,16/12/95	(290700, 6216200, 0.0)
36	1.27E+02	05,07/04/95	(290800, 6215800, 0.0)
37	1.27E+02	09,07/06/95	(290700, 6216100, 0.0)
38	1.27E+02	08,14/11/95	(290700, 6216100, 0.0)
39	1.27E+02	10,29/05/95	(290700, 6216200, 0.0)
40	1.26E+02	24,08/03/95	(290700, 6216000, 0.0)
41	1.25E+02	07,06/11/95	(290800, 6215800, 0.0)
42	1.25E+02	07,26/05/95	(290905, 6215780, 0.0)
43	1.25E+02	06,18/01/95	(290600, 6215900, 0.0)
44	1.25E+02	07,11/10/95	(290700, 6216200, 0.0)
45	1.24E+02	08,28/04/95	(290700, 6216100, 0.0)
46	1.23E+02	22,30/11/95	(290800, 6215800, 0.0)
47	1.23E+02	20,19/04/95	(290700, 6216000, 0.0)
48	1.21E+02	07,14/11/95	(290700, 6216100, 0.0)
49	1.21E+02	07,30/01/95	(290700, 6216200, 0.0)
50	1.20E+02	07,02/02/95	(290700, 6216100, 0.0)
51	1.19E+02	06,27/11/95	(290700, 6216100, 0.0)
52	1.19E+02	24,21/05/95	(290900, 6216000, 0.0)
53	1.19E+02	02,09/08/95	(290800, 6216000, 0.0)
54	1.19E+02	07,12/03/95	(290700, 6216200, 0.0)
55	1.18E+02	07,18/10/95	(290700, 6216100, 0.0)
56	1.18E+02	21,10/05/95	(290700, 6216000, 0.0)
57	1.18E+02	18,23/04/95	(290800, 6215800, 0.0)
58	1.18E+02	09,11/03/95	(290905, 6215780, 0.0)
59	1.18E+02	10,07/05/95	(290900, 6215900, 0.0)
60	1.17E+02	10,06/06/95	(290700, 6216100, 0.0)
61	1.17E+02	18,14/08/95	(290700, 6215800, 0.0)
62	1.17E+02	04,18/01/95	(290700, 6216000, 0.0)
63	1.17E+02	21,24/10/95	(290700, 6216000, 0.0)
64	1.17E+02	18,21/11/95	(290700, 6215900, 0.0)
65	1.17E+02	19,28/08/95	(290700, 6215900, 0.0)
66	1.17E+02	07,05/01/95	(290600, 6216200, 0.0)
67	1.16E+02	08,05/04/95	(290700, 6216200, 0.0)

68	1.16E+02	07,21/01/95	(290700,	6216100,	0.0)
69	1.16E+02	13,22/10/95	(290700,	6215900,	0.0)
70	1.15E+02	09,24/06/95	(290700,	6216300,	0.0)
71	1.15E+02	09,30/03/95	(290800,	6216000,	0.0)
72	1.15E+02	13,09/06/95	(290800,	6215800,	0.0)
73	1.15E+02	07,17/03/95	(290700,	6216100,	0.0)
74	1.15E+02	05,19/11/95	(290700,	6216100,	0.0)
75	1.15E+02	08,26/04/95	(290700,	6216200,	0.0)
76	1.15E+02	05,22/01/95	(290800,	6216000,	0.0)
77	1.14E+02	18,18/09/95	(290905,	6215780,	0.0)
78	1.14E+02	20,23/08/95	(290900,	6215800,	0.0)
79	1.14E+02	08,13/09/95	(290700,	6216200,	0.0)
80	1.14E+02	08,19/06/95	(290900,	6215800,	0.0)
81	1.13E+02	23,28/03/95	(290800,	6216000,	0.0)
82	1.13E+02	18,09/05/95	(290700,	6215900,	0.0)
83	1.13E+02	06,25/08/95	(290800,	6215800,	0.0)
84	1.13E+02	08,02/11/95	(290700,	6216100,	0.0)
85	1.13E+02	05,20/11/95	(290700,	6216000,	0.0)
86	1.13E+02	01,21/01/95	(290900,	6215800,	0.0)
87	1.13E+02	07,25/12/95	(290700,	6216000,	0.0)
88	1.13E+02	10,04/12/95	(290800,	6215800,	0.0)
89	1.13E+02	23,15/09/95	(290700,	6216000,	0.0)
90	1.13E+02	07,30/12/95	(290700,	6216100,	0.0)
91	1.13E+02	24,21/10/95	(290700,	6216000,	0.0)
92	1.13E+02	08,30/03/95	(290800,	6216000,	0.0)
93	1.13E+02	22,13/01/95	(290600,	6215900,	0.0)
94	1.13E+02	07,12/01/95	(290800,	6216000,	0.0)
95	1.13E+02	06,17/09/95	(290700,	6216100,	0.0)
96	1.12E+02	23,10/02/95	(290700,	6216000,	0.0)
97	1.12E+02	22,16/09/95	(290700,	6216100,	0.0)
98	1.12E+02	21,12/05/95	(290700,	6215800,	0.0)
99	1.12E+02	02,24/07/95	(290800,	6216000,	0.0)
100	1.11E+02	03,05/02/95	(290800,	6215700,	0.0)

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## **APPENDIX D**

### **Calculations**

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## Plume rise of flares (Schultze, 1977)

For the purposes of dispersion modelling, flare sources can be treated as point sources except that there are buoyancy flux adjustments associated with radiative heat and heat loss which need to be taken into account. This affects both effective stack height and stack diameter. For the purposes of this assessment, a conservative approach has been adopted in that no adjustment for stack height has been made. (Effective stack heights are higher for flares)

For this application adjustments have been made to stack diameter, taking into account radiative loss.

The effective stack radius of the flare can be determined by equating the buoyancy flux from the flare to the general buoyancy flux equation that is used by AUSPLUME.

### Equation 1

$$F = \frac{(g * H_r)}{(\pi * \rho * T * C_p)}$$

Where,

F = buoyancy flux from the flare

H<sub>r</sub> = net heat release (J/s)

g = acceleration due to gravity (9.81 m/s<sup>2</sup>)

C<sub>p</sub> = specific heat of air (1004 J/kg K)

ρ = density of air (1.2 kg/m<sup>3</sup>)

T = ambient air temperature (20°C = 293K)

### Equation 2

$$F = g * V_s * (r_s^2) * \left[ \frac{(T_s - T)}{T_s} \right]$$

Where,

F = buoyancy flux from a stack

g = acceleration due to gravity (9.81 m/s<sup>2</sup>)

V<sub>s</sub> = exit velocity (m/s)

r<sub>s</sub> = stack inner radius (m)

T<sub>s</sub> = stack exit temperature (K)

Dimensions of the stack:

$$V_s = 9.05 \text{ m/sec}$$

$$T_s = 1323 \text{ K (1050}^\circ\text{C)}$$

Calorific value of methane = 50.1 MJ/kg

Multiplying the calorific value of methane by the flow rate of methane gas from the stack, we can calculate the heat release.

We find the heat release from the flare due to the burning of methane to be  $H_r = 2.57 \times 10^7 \text{ J/s}$ .

Factoring 20% and 50% greater heat loss from the flaring process;

$$H_{r20\%} = 1.29 \times 10^7 \text{ J/s}$$

$$H_{r50\%} = 2.06 \times 10^7 \text{ J/s}$$

Setting the two equations above equal and solving for the radius of the stack, we can determine the variation to the diameter of the stack for both heat loss scenarios.

20% reduction; the diameter of the stack = 3.33m

50% reduction; the diameter of the stack = 2.63 m