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

A PEL Company

PROJECT TITLE:	***AIR QUALITY IMPACT ASSESSMENT: APPIN MINE AREA 7 GAS DRAINAGE PROJECT***
JOB NUMBER:	**3275**
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DOCUMENT CONTROL

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

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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.

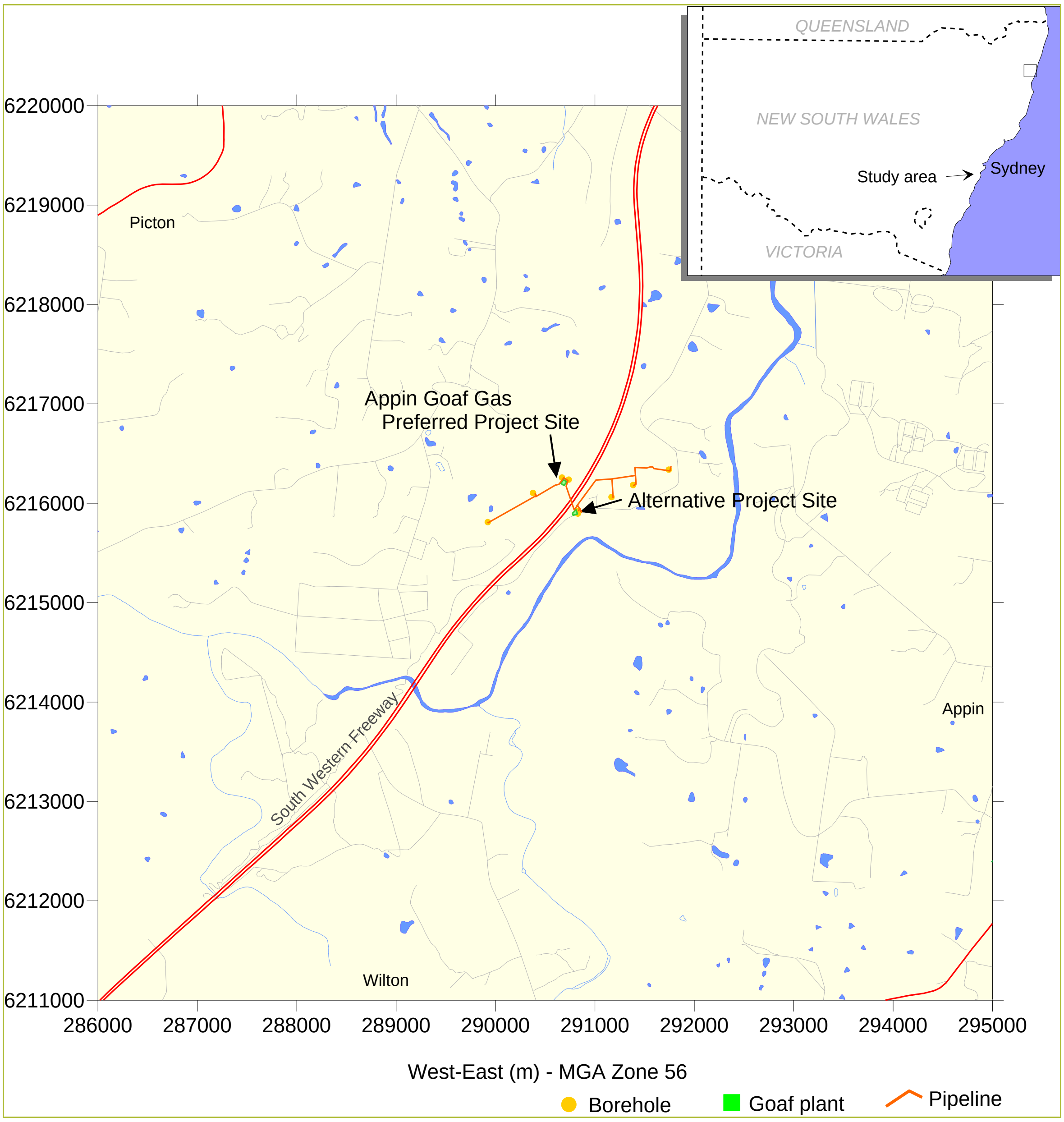


Figure 2.1: Location of study area

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.

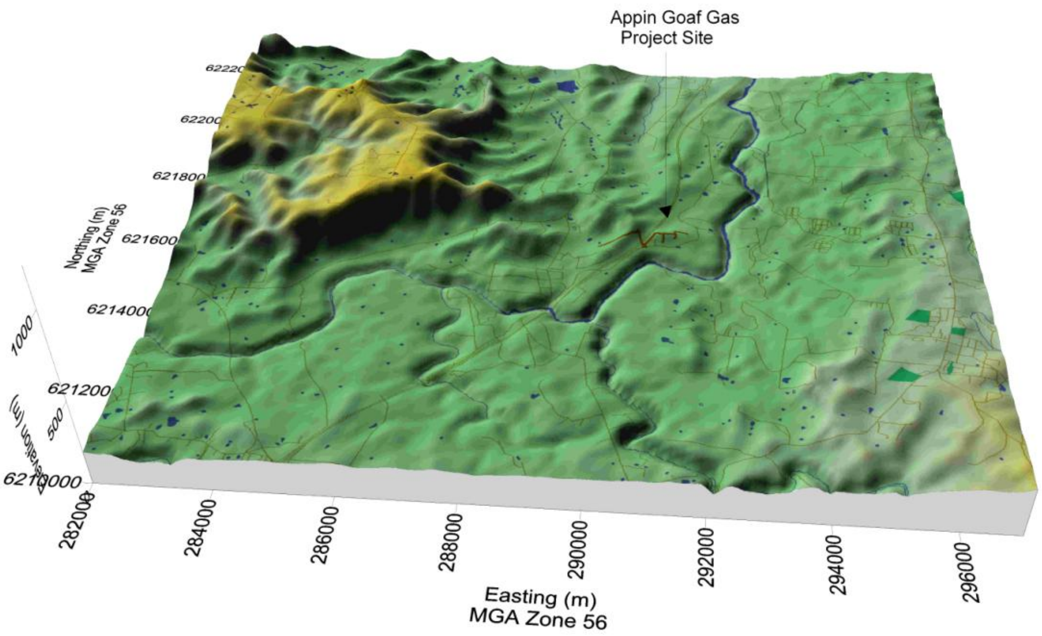


Figure 2.2: Topography of local area

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.

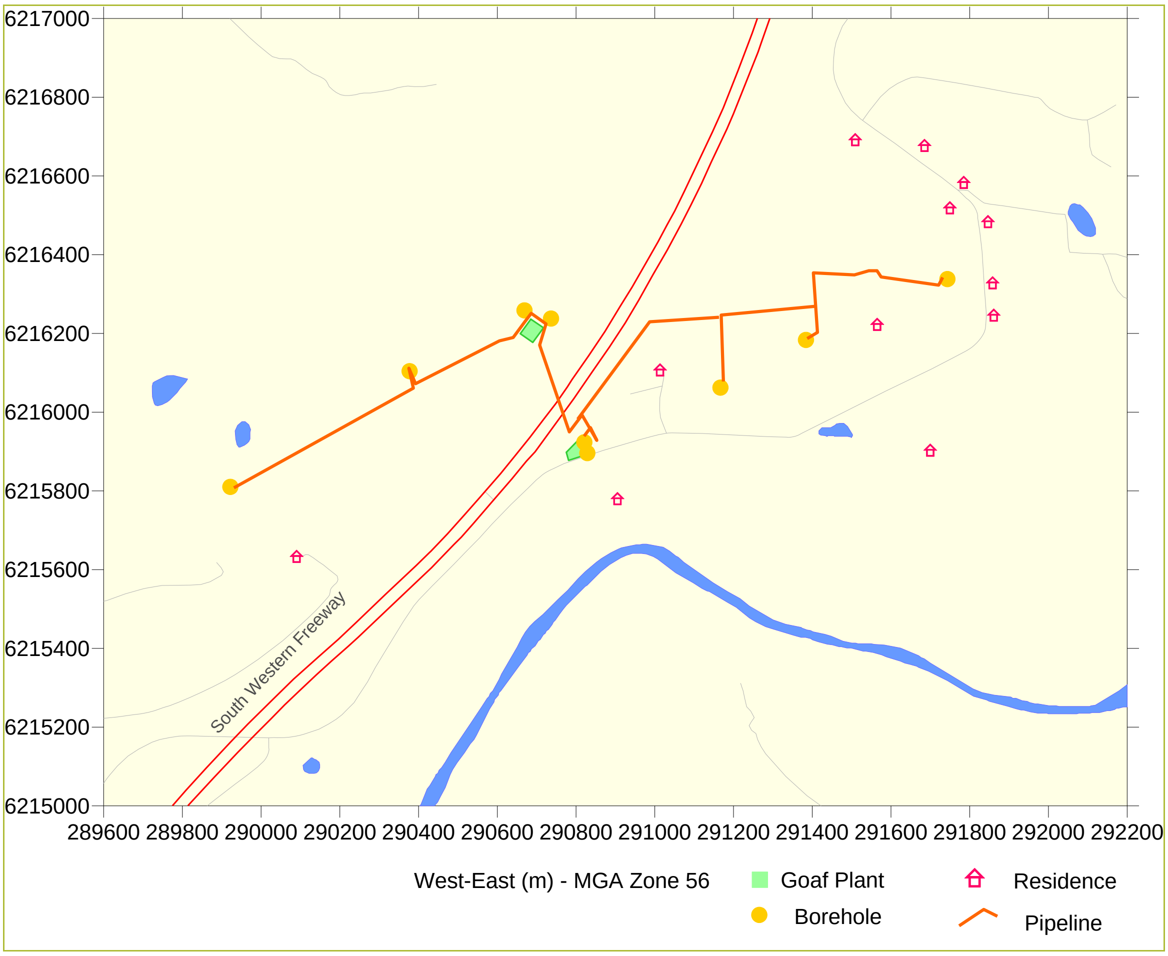


Figure 2.3: Location of nearest residences

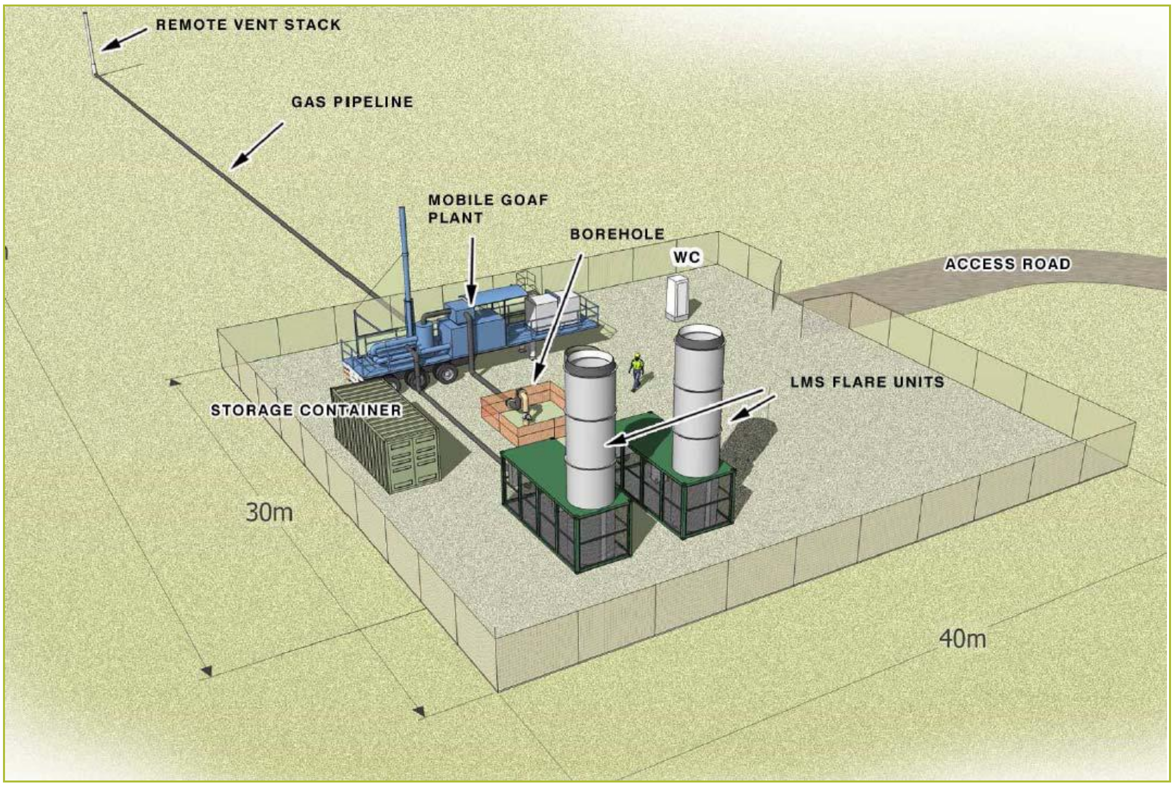
Maximum goaf gas flows are predicted to be of the order of 800 litres per second (L/s). The goaf gas will be utilised at the EDL power stations located at Appin West pit top and Appin No 1 shaft.

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 99th 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 99th 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 99th percentile)
Rural single residence (≤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 $\mu g/m^3$	Annual mean	National Health & Medical Research Council
Particulate matter < 10 μm (PM_{10})	50 $\mu g/m^3$	24-hour maximum	DECC
	30 $\mu g/m^3$	Annual mean	DECC long-term reporting goal
	50 $\mu g/m^3$	(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 g/m^2/month	4 g/m^2/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_x). NO_x is comprised of nitric oxide (NO) and nitrogen dioxide (NO_2) however NO is much less harmful to humans than NO_2 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_2. The air quality criteria relate to the total burden of NO_2 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_2)	0.12 ppm or 246 $\mu g/m^3$ 0.03 ppm or 62 $\mu g/m^3$	1-hour maximum Annual mean	DECC 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_2. 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^3

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[a] and mixing height[b]. 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.

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[a] 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.

[b] 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 ≥ 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_2. **Table 4:3** shows the measured NO_2 concentrations for the most recent year of data available (1997).

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

Month	Measured NO_2 concentration ($\mu g/m^3$)	
	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
Maximum	**90**	**-**
Average	**-**	**9**
DECC criteria	**246**	**62**

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

The monitoring data show that the area experiences NO_2 concentrations below the DECC ambient air quality criteria. The maximum 1-hour average NO_2 concentration in 1997 was 90 $\mu g/m^3$ and the annual average was 9 $\mu g/m^3$.

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_{10}). 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_{10} concentrations for the Appin area are estimated to be of the order of 15 $\mu g/m^3$ consistent with a relatively clean semi-rural environment. The 24-hour average PM_{10} concentrations will be highly variable and, in many parts of NSW, it is common for the DECC's 50 $\mu g/m^3$ 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^3
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^3/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^2)	0.05	10.3	0.01
Flow rate coalmine gas (Nl/s)	800	800	-
Flow rate total gas (Am^3/s)	-	-	0.67
Temperature (deg C)	25	1050	300
Exit velocity (m/s)	16	9.05	28
Pollutant emissions (g/s)			
PM_{10}	-	-	0.0294
CO	0.005	10.92	0.0923
NO_x	-	32.75	0.4155
Odour emissions ($OU.m^3/s$)			
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
Total emissions (kg)	-	0	**41,756**	**114**

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_{10}) and NO_x 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_{10} and NO_x, 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 99th 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 $PM_{2.5}$, 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:

- $PM_{2.5}$ (FP) is 4.7% of the TSP;
- $PM_{2.5-10}$ (CM) is 34.4% of TSP; and
- PM_{10-30} (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 $PM_{2.5}$ 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_{10} 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_x 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_x. The remaining 5% will be mostly NO_2. Ultimately, however, all nitric oxides emitted into the atmosphere are oxidised to NO_2 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_2.

For the purposes of this report it was conservatively assumed that 20% of the NO_x was NO_2 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 99th percentile (**DEC, 2006**). **Figure 7.1** shows that odour levels at the most affected residence are around 5 odour units at the 99th 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.

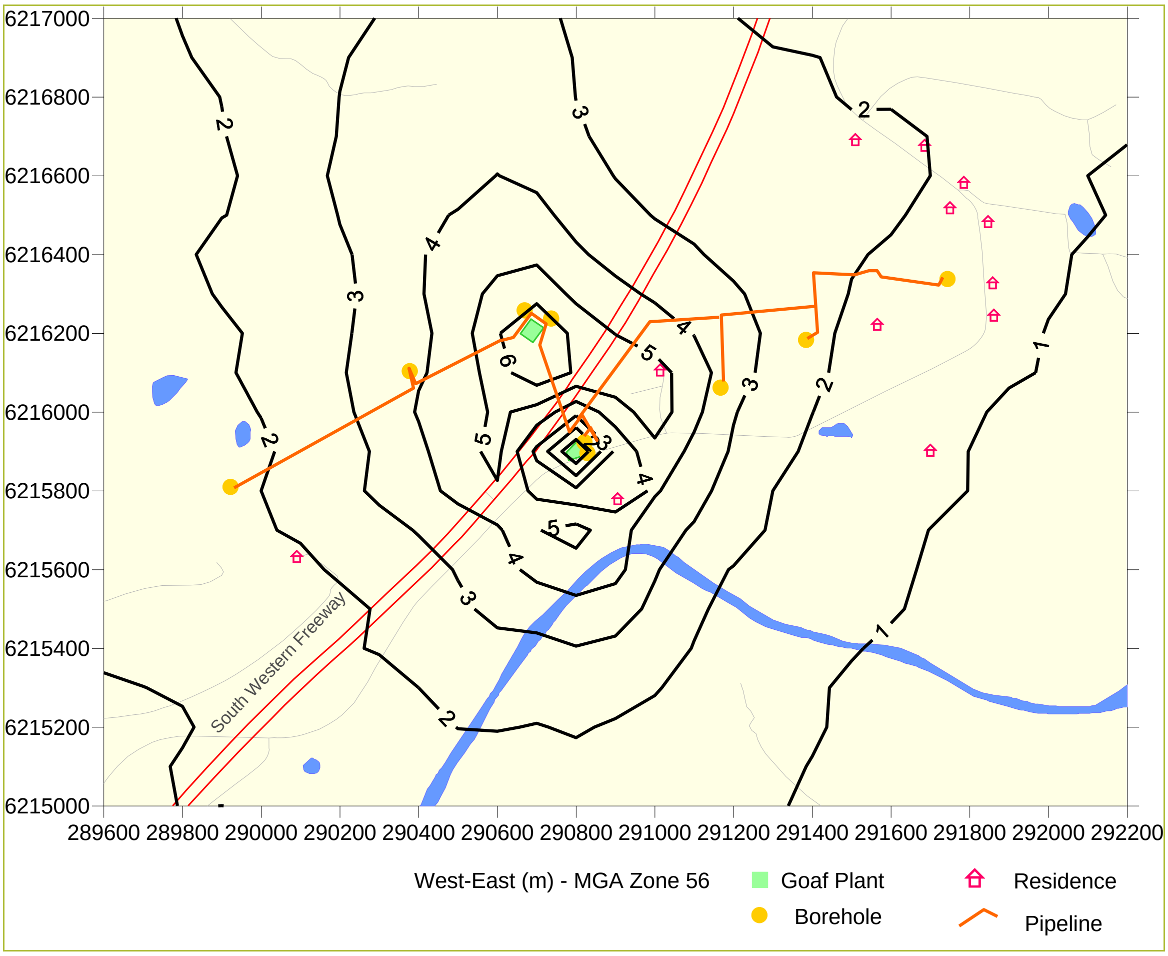


Figure 7.1: Odour contours from vent stack at 99th percentile, in odour units

7.2 Dust

Figure 7.2 shows the predicted maximum 24-hour average PM_{10} 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 $\mu g/m^3$, which represents the contribution from all sources of dust, not just the contribution from the modelled sources. Background PM_{10} concentration should be considered when examining the results in **Figure 7.2**.

It can be seen from **Figure 7.2** that the 50 $\mu g/m^3$ 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_{10} concentrations are estimated to be of the order of 15 $\mu g/m^3$. The PM_{10} concentrations will vary from day to day however for the purpose of this assessment it has been assumed that the background level is 15 $\mu g/m^3$ for the days of maximum 24-hour average PM_{10} predictions. This means that the allowable contribution from site activity emissions would be 35 $\mu g/m^3$ before the 50 $\mu g/m^3$ criterion is reached. The 35 $\mu g/m^3$ 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_{10} 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.

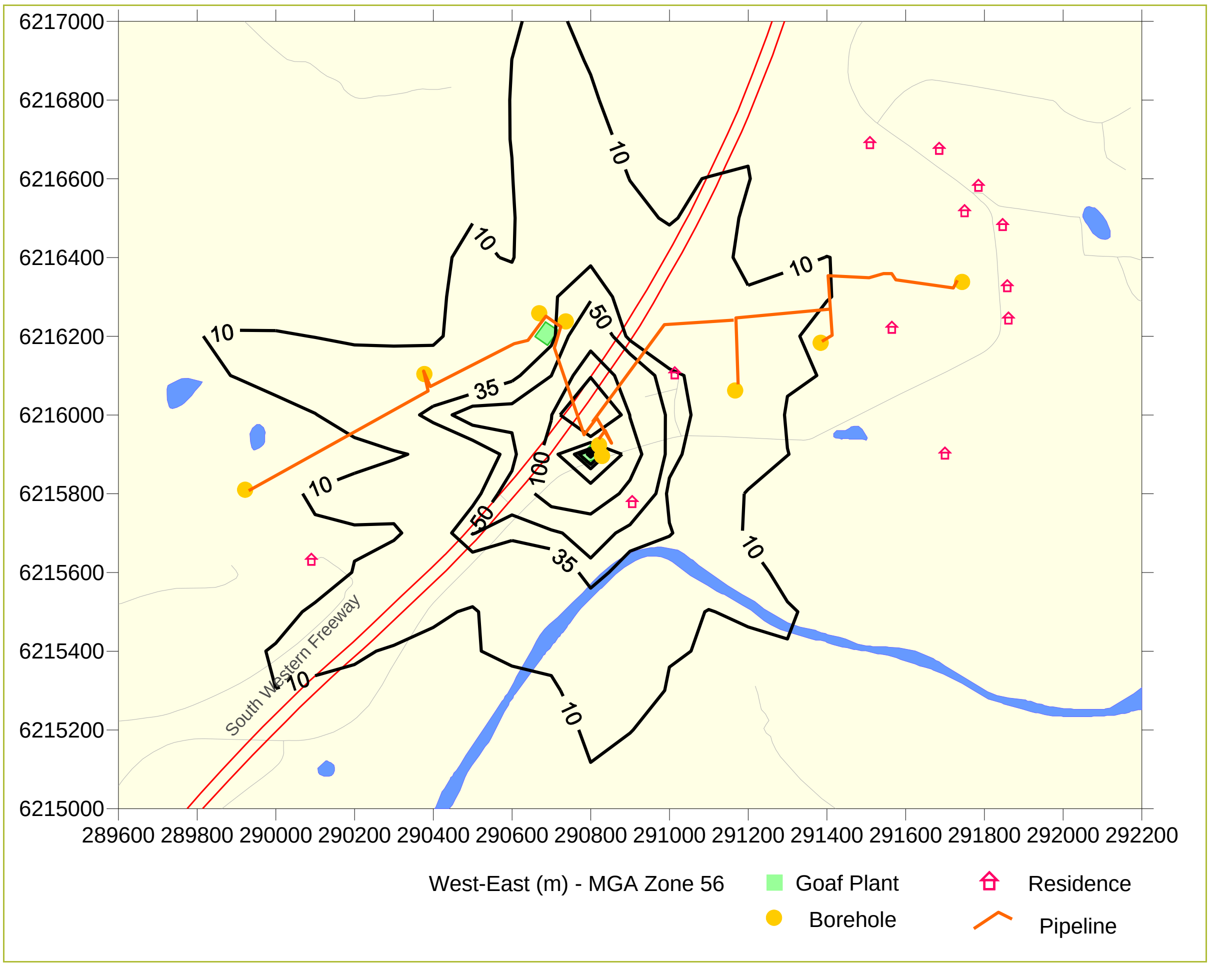
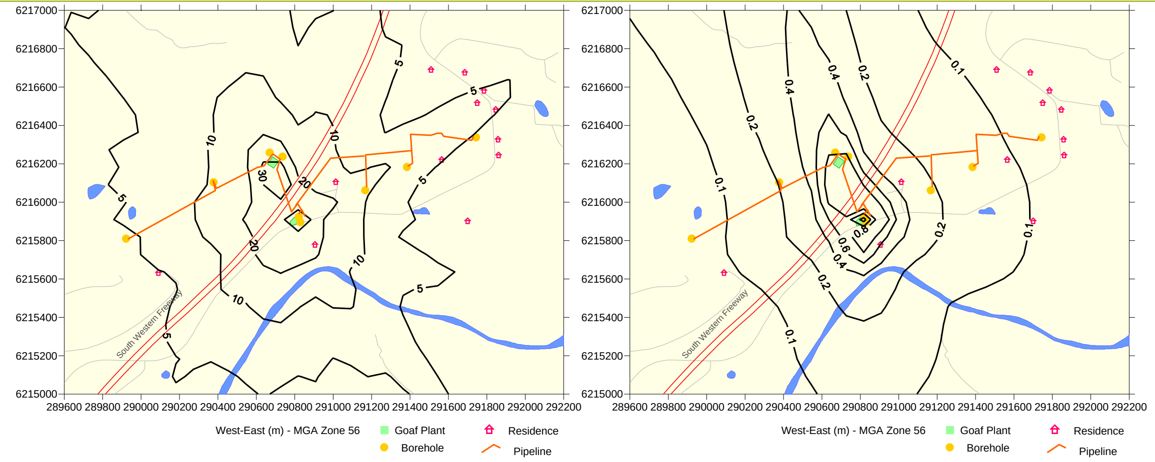


Figure 7.2: 24-hour maximum PM_{10} contours from construction activity, $\mu g/m^3$

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 µg/m^3 for both the 20% and 50% heat loss scenarios, significantly less than the criteria of 246 µg/m^3 for nitrogen dioxide. When background levels of around 90 µg/m^3 are included (see **Section 4.3**), these predicted concentrations are still within the DECC criteria.

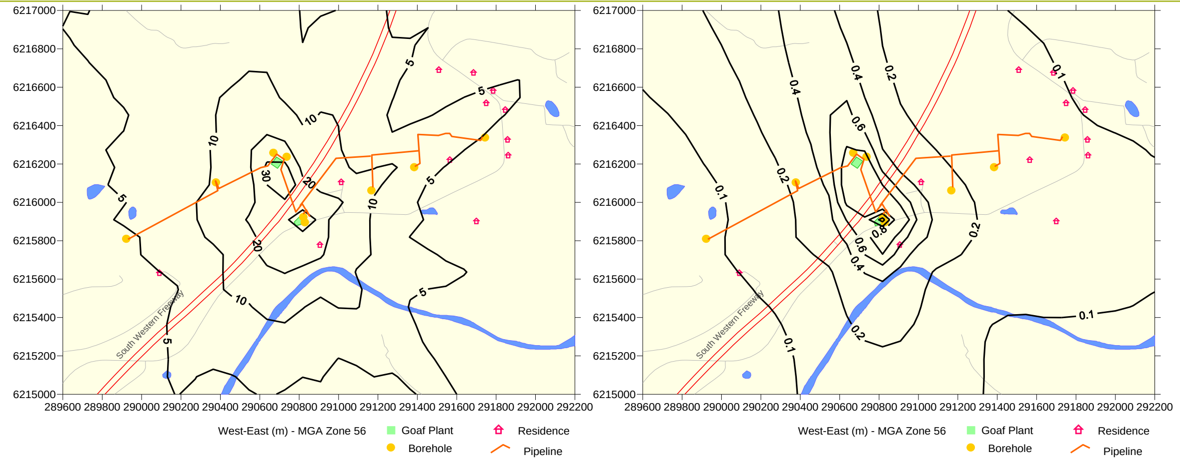
The results for the annual average for both the 20% and 50% heat loss scenarios are also shown in **Figure 7.2** and **Figure 7.3**. They show a predicted maximum of approximately 0.6 µg/m^3 at the most affected residence, significantly lower than the criteria of 64 µg/m^3, even when background levels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



1 hour maximum, μg/m^3

annual average, μg/m^3

Figure 7.3: NO$_2$ contours from flaring, assuming 20% heat loss



1 hour maximum, μg/m^3

annual average, μg/m^3

Figure 7.4: NO$_2$ contours from diesel generator and flare stack, assuming 50% heat loss

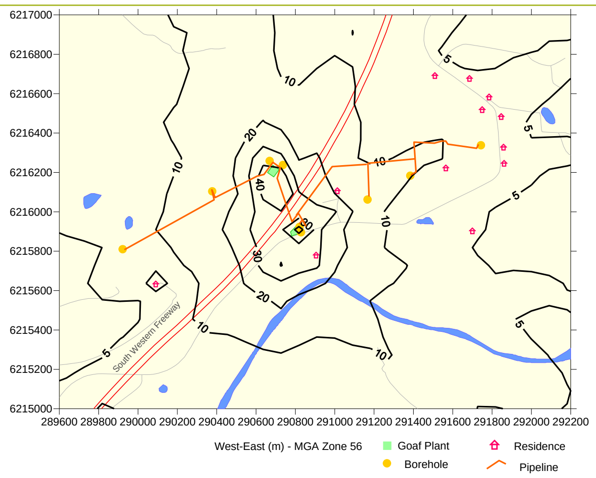
7.4 Carbon Monoxide

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.

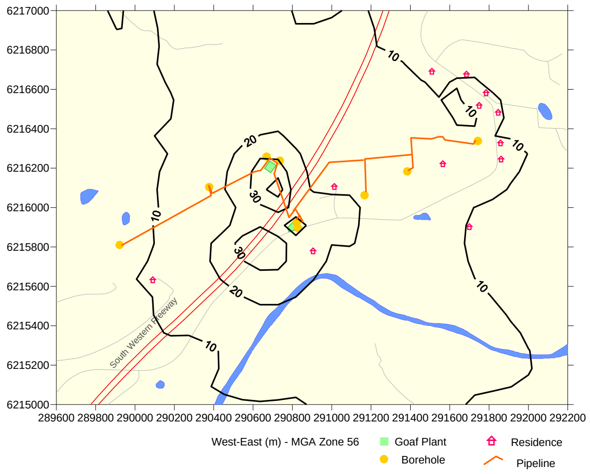
The results show predicted carbon monoxide levels for 15-minute, 1-hour and 8-hour averaging times for comparison with the DECC criteria.

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

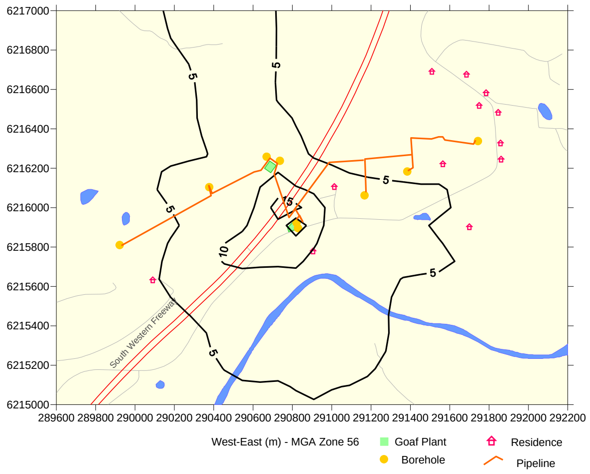
For both scenarios the impact at the residences most affected by the flaring activities were below the DECC criteria (see **Section 4.3**). The 15-minute ground level concentrations for the 20% and 50% heat loss cases show predicted levels at the most affected residence to be approximately 31 µg/m^3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



15-minute maximum, µg/m^3

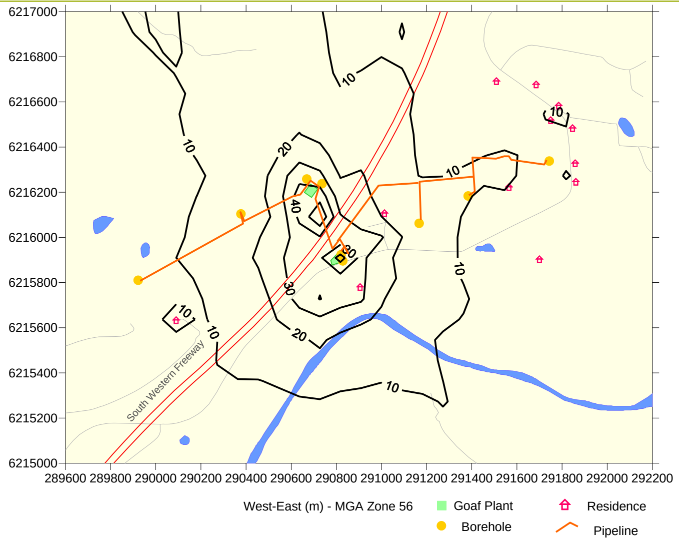


1-hour maximum, µg/m^3

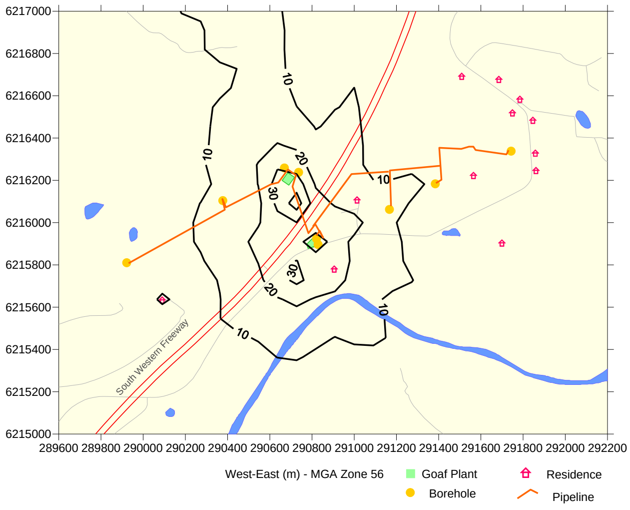


8-hour maximum, µg/m^3

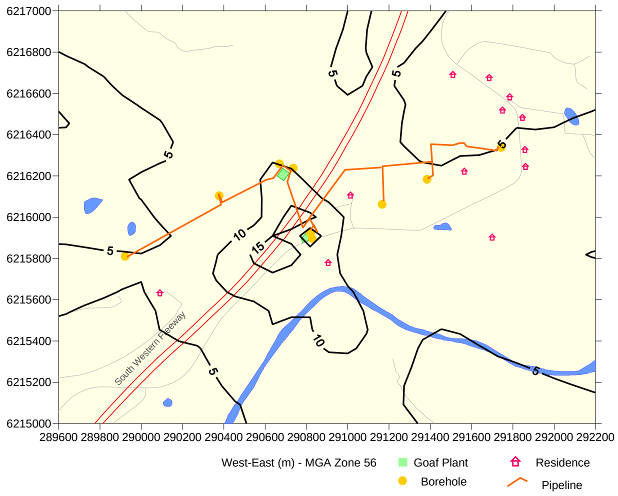
Figure 7.5: CO contours from flaring, assuming 20% heat loss



15-minute maximum, µg/m^3



1-hour maximum, µg/m^3



8-hour maximum, µg/m^3

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_{10}, CO and NO_x 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_2 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

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)**

APPENDIX B

Joint wind speed, wind direction and stability class frequency tables

```
STATISTICS FOR FILE:  C:\Jobs\WestCliff\metdata\appin_1995.aus
MONTHS: All
HOURS : All
OPTION: Frequency

                     PASQUILL STABILITY CLASS 'A'

                        Wind Speed Class (m/s)

            0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND        TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR      1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   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 Speed Class (m/s)

             0.50      1.50      3.00      4.50      6.00      7.50      9.00   GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO      THAN
SECTOR       1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL
-----------------------------------------------------------------------------------------

   NNE    0.000370 0.001849 0.000863 0.000123 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 0.002096
   ENE    0.000123 0.000740 0.000616 0.000123 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 0.001356
   ESE    0.000000 0.000863 0.000247 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 0.001972
   SSE    0.001109 0.001233 0.000616 0.000123 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 0.004068
   SSW    0.001233 0.001109 0.000616 0.000123 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 0.004068
   WSW    0.000616 0.000986 0.000986 0.000247 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 0.005301
   WNW    0.001479 0.001233 0.000370 0.000123 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 0.002589
   NNW    0.001479 0.003698 0.001109 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 0.008506

  CALM                                                                            0.000863
-----------------------------------------------------------------------------------------
  TOTAL   0.013930 0.024162 0.014670 0.001603 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 Speed Class (m/s)

             0.50      1.50      3.00      4.50      6.00      7.50      9.00   GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO      THAN
SECTOR       1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL
-----------------------------------------------------------------------------------------

   NNE    0.000616 0.001726 0.003821 0.000247 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 0.003082
   ENE    0.000370 0.000740 0.001233 0.001109 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 0.005547
   ESE    0.000493 0.000740 0.001233 0.002342 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 0.005671
   SSE    0.001233 0.002096 0.001109 0.000247 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 0.007520
   SSW    0.000740 0.002219 0.003452 0.000986 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 0.006903
   WSW    0.000740 0.001972 0.002959 0.002219 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 0.011218
   WNW    0.001479 0.001356 0.001972 0.003082 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 0.003328
   NNW    0.000247 0.006657 0.003945 0.000740 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 0.015902

  CALM                                                                            0.000370
-----------------------------------------------------------------------------------------
  TOTAL   0.011464 0.032298 0.043762 0.025764 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 Speed Class  (m/s)

             0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND         TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR       1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   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 Speed Class  (m/s)

             0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND         TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR       1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   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 Speed Class (m/s)

            0.50     1.50     3.00     4.50     6.00     7.50     9.00   GREATER
 WIND        TO       TO       TO       TO       TO       TO       TO      THAN
SECTOR      1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50     TOTAL
-----------------------------------------------------------------------------------------

   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)

            0.50     1.50     3.00     4.50     6.00     7.50     9.00   GREATER
 WIND        TO       TO       TO       TO       TO       TO       TO      THAN
SECTOR      1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50     TOTAL
-----------------------------------------------------------------------------------------

   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
```

```
-------------------------------------------
FREQUENCY OF OCCURENCE OF STABILITY CLASSES
-------------------------------------------
  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
```

```
--------------------------------
STABILITY CLASS BY MIXING HEIGHT
--------------------------------
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

----------------------------
MIXING HEIGHT BY HOUR OF DAY
----------------------------
       0000  0100  0200  0400  0800  1600  Greater
        to    to    to    to    to    to   than
Hour   0100  0200  0400  0800  1600  3200  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
```

APPENDIX C

AUSPLUME model output

```
1             ____________________________________________________

                Appin Surace Gas Drainage - flare emissions. NOx

              ____________________________________________________

 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                  Stability Class
     Category        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

 _____________________________________________________________________________
```

```
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)

 ____________________________________________________________________________


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

  Rank     Value   Time Recorded         Coordinates
                     hour,date        (* 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)
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   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

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_r = net heat release (J/s)

g = acceleration due to gravity (9.81 m/s^2)

C_p = specific heat of air (1004 J/kg K)

ρ = density of air (1.2 kg/m^3)

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

Equation 2

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

Where,

F = buoyancy flux from a stack

g = acceleration due to gravity (9.81 m/s^2)

V_s = exit velocity (m/s)

r_s = stack inner radius (m)

T_s = stack exit temperature (K)

Dimensions of the stack:

V_s = 9.05 m/sec

T_s = 1323 K (1050°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 $H_r = 2.57 \times 10^7$ J/s.

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

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

$H_{r50\%} = 2.06 \times 10^7$ 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 = <u>3.33m</u>

50% reduction; the diameter of the stack = <u>2.63 m</u>