

Directionality of wind roses

A comparison of the contemporaneous wind roses demonstrates a good degree of similarity between the observed and predicted datasets.

Although some compromise in the accuracy of the LMPS predicted dataset exists, there is relatively good agreeability in the directionality of the predicted wind conditions overall.

Wind class frequency distribution

Wind class frequency distributions shown in Appendix E indicated that the bulk of winds through this region are less than ~6 m/s. The TAPM simulation however has been unable to accurately represent calm conditions but has represented all other wind classes including high wind speed classes (ie >9 m/s) accurately.

The assimilation of the observed datasets into the TAPM simulation demonstrates that there is some skew towards the lower wind classes in the frequency distribution. However this enables some conservatism in the model's predictions of air quality impacts.

Atmospheric stability

The degree of stability in the atmosphere is determined by the temperature difference between an "air parcel" and the air surrounding it.

The Pasquill-Gifford (P-G) stability category scheme was used in this assessment. Although Gaussian models were previously used to develop stability profiles, TAPM models stability explicitly through turbulence intensity. The classes range from highly unstable to extremely stable, indicated by the letters A to F (and sometimes G).

Turner's method has been used in this assessment to determine stability classes. This method estimates the effects of net radiation on stability from solar altitude, total cloud cover and ceiling height and the stability class is estimated as a function of wind speed and net radiation (Table 7.14). The frequency distribution of stability class with wind speed classes is shown in Appendix E. Neutral conditions tend to occur in all wind speed brackets but stable and unstable conditions only occur in the lower wind speed brackets, predominantly those below 6 m/s. This is consistent with what is expected for this region and the empirical expectations shown in Table 7.14

A stability class rose and frequency distribution can be seen in Figure 7.9 and Figure 7.10.

The stability class rose shows that neutral and stable conditions are predicted to be dominant both to the east and west of the Munmorah site.

The frequency distribution shows that the area is dominated by neutral and stable conditions (occurring >60% of the hours analysed), with stability class E being dominant.

The high occurrence of relatively stable atmospheric conditions can be attributed to the low wind speeds in the area; with 90% of all wind speeds estimated being below 6 m/s.

Table 7.12 – Stability class frequency distribution with respect to wind speed classes

Speed (m/s)	A	B	C	D	E	F
0.5 - 2.0	65	220	220	1367	889	706
2.1 – 4.0	105	723	723	858	212	1307
4.1 – 6.0	0	268	268	459	264	0
6.0 – 8.0	0	0	0	166	0	0
> 8.0	0	0	0	27	0	0

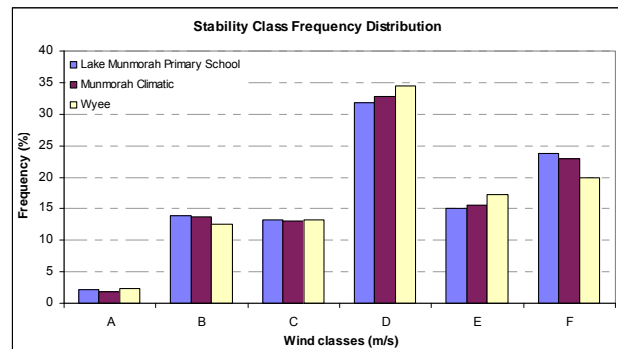


Figure 7.9 – Annual stability class frequency distribution at LMPS and Wye

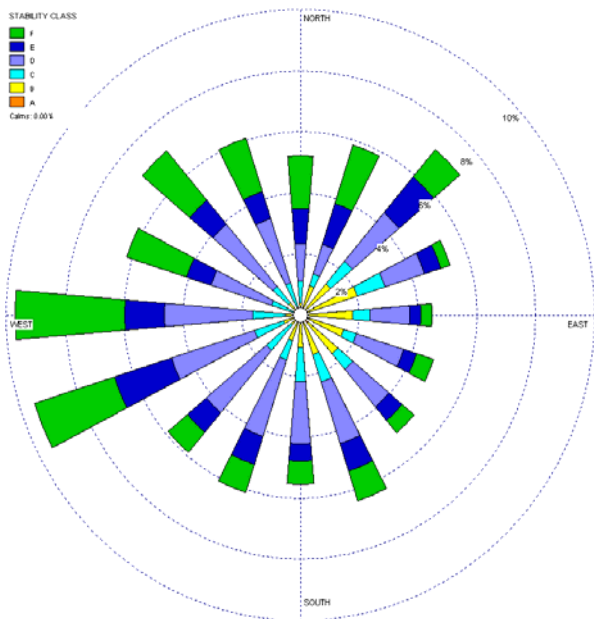


Figure 7.10 – Stability class rose

Table 7.13 – Atmospheric stability categories

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

NOTE: ⁽¹⁾ Wind speed is measured to the nearest 0.5m/s.

⁽²⁾ Category G is restricted to night-time with less than 1 octa of cloud and a wind speed less than 0.5m/s.

Stability class frequency distributions shown for each hour a day for 2004 is shown in Appendix E. These results demonstrate the high frequency of unstable meteorological conditions during the day and neutral to stable conditions prevalent during the night.

This is as expected due to the fact that mixing is enhanced during the day due to solar irradiation and mechanical mixing due to the wind. Night time mixing only occurs through mechanical means (wind) which is less pronounced compared to day time hours, resulting in more stable meteorological conditions.

Mixing Height

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

The mixing height at Munmorah Power Station was estimated using gridded surface and upper air meteorological data generated by TAPM. TAPM is able to generate meteorological data up to 8 km above sea level, therefore mixing height can be estimated with this data. The hourly mixing height profile (average, 2nd and 99th percentiles) is provided in Figure 7.11.

The estimated mixing height for this site rises very quickly in the early morning from just after sunrise until mid afternoon, at which point the mixing height remains at a relatively stable value until returning to a lower level early in the evening. This diurnal variation of atmospheric structure is consistent and expected with that found at similar sites. Large values for mixing height occur in the summer months as expected due to the greater convective effects. The main change throughout the year is the length of the period of strong convection and the wind variation.

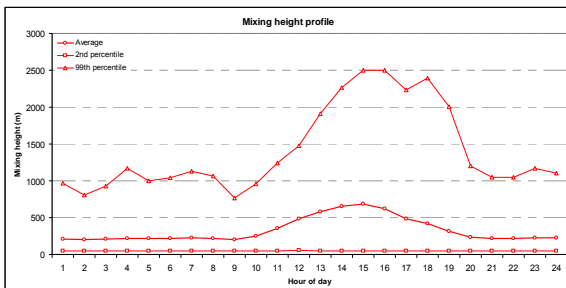


Figure 7.11 – Hourly mixing height profile at Munmorah, as predicted by the TAPM prognostic meteorological simulation

7.6.3 Air dispersion pollutant modelling

The pollutants modelled as part of the local air quality impact assessment were calculated based on the guaranteed emission limits as provided by the Delta

Electricity. The guaranteed limits are equal to the Group 6 emission standards as stipulated within the *POEO (Clean Air) Regulation*. Maximum pollutant emission rates for the rehabilitated plant configuration are listed in Table 7.15. Emission limits lower than the Group 6 standard is prescribed for fluoride and cadmium compounds, to further reduce ambient air quality impacts.

Munmorah Power Station operates with a guaranteed fuel sulfur content of 1%. Several studies commissioned by Delta Electricity recommend the adoption of coal with 0.7% sulfur content to minimise SO₂ ambient air quality impacts (ie ground level concentrations) over the 10 minute and 1 hour averaging periods.

The stack exit conditions modelled are shown in the following table.

Table 7.14 – Stack exit parameters included in dispersion model

Stack exit conditions	
Stack - height	150 m
Stack - base elevation	15 m
Diameter	7.9 m
Exit temperature	426 K
Exit velocity	19.4 m/s
Average volumetric flow rate at exit	951 m ³ /s

Table 7.15 – Emission limits and rates for pollutants modelled as part of the local air quality impact assessment

Pollutant	Rehabilitated emissions limit (mg/Nm ³ unless stated otherwise)	Munmorah rehabilitated emission rates (g/s) ⁽¹⁾
Sulfur dioxide (SO ₂)	1,663 ⁽²⁾	1,014
Oxides of nitrogen (NO _x)	500	305
Fine particulates (PM ₁₀)	50	30.5
Fluoride (modelled as HF – hydrogen fluoride)	10	6.1
Cadmium (Cd)	0.002	0.0012
Mercury (Hg)	0.2	0.122
Dioxins and furans (PCDD/F)	0.1 ng/Nm ³	6.09 x 10 ⁻⁸

NOTE: ⁽¹⁾ Emission rates are reported at standard conditions (0°, dry gas, 1 atm pressure, 7% O₂). Normalised volumetric flow rate (604.3 Nm³/s) was used to determine specific pollutant air emissions

⁽²⁾ SO₂ emission concentration at 0.7% sulfur coal

7.6.4 SO₂ background

The selected background was the peak level observed at Wyee and LMPS ambient air monitoring station in the reference year 2004.

7.6.5 NO₂ background

The second highest recorded measurement was selected as the appropriate reference for background NO₂ given the influence of a number of large diffuse air emission sources ie major carriageways (Sydney Newcastle Fwy and Pacific Hwy) and other larger industrial sources (Vales Point and Eraring Power Stations) in the locality.

DECCW prefers the 100th percentile or maximum background figure to be used in the assessment of cumulative impacts, however the second highest value is more appropriate.

In addition, the ozone limiting method (OLM) calculation (see below) included the expected influence of the Colongra gas turbine facility on the local air environment. The maximum one hour average NO_x level predicted for high emission distillate firing scenario included in the OLM calculation as part of this study was 70 µg/m³

Cumulative NO₂ impacts by OLM method

Analysis of atmospheric chemistry in air dispersion modelling is not always necessary to accurately determine the amount of NO and NO₂ within the plume at any time. Simpler methods have been found to be adequate in most situations. The simplest is to assume that all NO_x emitted from power plants is NO₂.

This is an extreme case and is unlikely to ever occur for an extended period of time in practice.

The US EPA developed the OLM which assumes that all available O₃ in the atmosphere reacts with NO in the plume until either all the O₃ or all the NO is exhausted. One disadvantage of this method is that the atmospheric reaction is assumed to be instantaneous, but in reality these reactions take place over several hours.

To calculate total NO₂ concentrations from the OLM method one has to assume background levels of O₃ and NO₂, as well as predict the maximum NO_x concentration in the atmosphere, which can be done through simulation.

The equation above describes the calculation of ground level NO₂ concentrations using the OLM method.

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

NOTE: pred = predicted and bkgd = background

7.6.6 O₃ background

It has been assumed that the background level of O₃ based on the 2004 dataset alone would not provide a reasonable characterisation of the changing nature of the air environment in the region. The VOC and NO_x emission reduction strategies implemented by the DECCW over the past decade need to be characterised as well. Therefore, an average of the

maximum levels recorded over the period from 2003-2008 at the DECCW air monitoring stations through the Lower Hunter have been used. The data was sourced from DECCW station reports for Beresfield, Newcastle and Wallsend specifically.

The adaptation of the 98th percentile NO₂ concentration and the average maximum O₃ concentration over 2003-2008 allows for a realistic yet conservative representation of the NO₂ impact from the combined influence of both the Munmorah coal, and the partially commissioned Colongra gas turbine facility upon local air quality.

7.7 Dispersion modelling results

The assessment of impacts has been undertaken in accordance with the requirements of Section 7 of the Approved Methods. The approved methods include two methods for the consideration of the contribution of background concentrations to the prediction of impacts.

A Level 1 assessment involves adding the maximum background concentration and the 100th percentile dispersion model prediction to obtain the total impact for each averaging period.. Results for the Level 1 assessment are referred to as Method 1.

A Level 2 assessment, predicts ground level concentrations by modelling at least one year of continuous ambient monitoring measurements, contemporaneous with the meteorological data used in the dispersion modelling and adding each individual dispersion model prediction to the corresponding measured background concentration to obtain hourly predictions of total impact • at each receptor. The 100th percentile total impact for the relevant averaging period at each receptor is then determined. The results of the Level 2 assessment are referred to as Method 2 in the following sections.

Local air quality impact assessment for this project is has required consideration of the impacts resulting from the upgrade of another coal fired power station in the region, as well as the effects of the nearly completed Colongra gas turbine facility.

Nonetheless, the conservative nature of the methodology adopted as part of this assessment allows for a robust characterisation of the worst case air quality impact through this region with the operation of all facilities.

7.7.1 Sulfur dioxide

The cumulative air quality impacts for SO₂ are provided in Table 7.16. Worst case cumulative impacts are shown in Figure 7.12.

The cumulative impact data demonstrates that the 24 hour and annual ground level concentrations limits listed in the Approved Methods are achieved. The 10 minute average and hourly averaged limit for SO₂ listed in the Approved Methods are however exceeded when the power station is fired with coal with 0.7% sulfur content.

Table 7.16 – Predicted first highest cumulative SO₂ GLC with 0.7% sulfur coal

	SO ₂ concentrations (ppb)				
		1 Hr methods			
Averaging period	10 min	1	2	24 hr	Ann
Predicted cumulative impact	455	318	257	60	16.7
Prediction with Munmorah alone	342	239	239	50	15.4
Air quality limit	250*	200	200	20	250*

NOTE: (*) NSW DEC guideline limit.

This assessment agrees with the 2008 CSIRO study which investigated the use of different coal sulfur contents on power stations in the Central Coast. The CSIRO assessment indicated that modelling emissions from all major coal fired power stations in the region at full load and maximum permissible coal sulfur levels (0.7% sulfur) may lead to exceedances of the 10 minutes and hourly averaged ground level concentrations (See Appendix E2).

Further analysis of the time series of the predicted data through the modelled reference year; shows:

- the 3rd highest cumulative hourly averaged GLC was 523 µg/m³. This will not exceed the NSW DEC or AAQ NEPM air quality limits.
- the 2nd highest cumulative ground level concentration was 577 µg/m³. This was 25% lower than the peak cumulative level predicted.

An analysis by Lilley et. al. (2007) shows evidence that suggests that the highest predictions of air quality models tend to over estimate impacts by as much as 50%.

Given that the explicit prediction of 10 minute average GLC is not possible through TAPM, a power law function based on historical data (CSIRO, 2007) was used to understand the likely impact over the 10 minute averaging period. This function is represented by the equation below.

$$C_{10 \text{ min}} = C_{60 \text{ min}} \left(\frac{60}{10} \right)^{0.38}$$

The peak 10 minute average concentrations are on average twice the hourly averaged ground level concentration:

$$C_{10 \text{ min}} = 1.98 C_{60 \text{ min}}$$

However the more recent CSIRO assessment of air quality impacts on the Central Coast shows that this may in fact significantly over estimate the 10 minute average concentrations. The CSIRO suggests that, as hourly averaged concentrations reach peak levels the ratio of 10 min average concentrations to hourly average concentrations tends towards unity.

$$\frac{C_{10 \text{ min}}}{C_{60 \text{ min}}} \rightarrow 1; \text{ as } C_{60 \text{ min}} = \text{peak}$$

An extrapolation of this hypothesis to the predicted cumulative air quality impacts represented in Table 7.16 demonstrates that plant operation with 0.7% sulfur coal is likely to lead to compliance with the 10

minute average NSW DECCW guideline limit ($712 \mu\text{g}/\text{m}^3$) ie 50% of $1,406 \mu\text{g}/\text{m}^3$ is equivalent to $703 \mu\text{g}/\text{m}^3$.

7.7.2 Nitrogen dioxide

The cumulative impact data represented in Table 7.17 demonstrates compliance with all air quality goals as stipulated by the NEPM and the NSW DECC.

The potential for exceedances of the NO₂ hourly averaged criterion is exemplified by the fact that the worst case cumulative prediction of hourly averaged NO₂ is equal to the prescribed air quality limit. The predicted level is however considered to be a conservative representation of the probable air quality impact for this pollutant into the future and has to be considered in this context. This is in light of the reasons outlined in the discussion relating to the apparent nature of TAPM over predicting peak levels (Lilley et al 2007).

The cumulative level is based on the assumption that Munmorah's operation at peak output is concurrent with worst case meteorological conditions, the Colongra gas turbine operating at worst case emissions and generally high background levels of NO_x in the environment (from other industrial and fugitive air emissions sources in this region). Based on this, it is highly unlikely that an exceedance of the hourly average limit would occur.

Table 7.17 – Predicted first highest cumulative GLC for NO₂

Pollutant concentrations (ppb)	NO ₂		
	1 hour		Annual
	Method 1	Method 2	
Predicted cumulative impact (NO₂)	139	116	14.8
Background air quality (NO ₂) [^]	37.7	26.7	8.3
Munmorah power station contribution (NO _x)	100	55.3	6.5
Colongra gas turbine contribution (NO _x) [*]	34.1	34.1	0.1
<i>Air quality limit</i>	120		30

[^] Background air quality represents emissions from Vales Point, Eraring Power Stations and background levels from other fugitive sources (including motor vehicle emissions).

^{*} Worst case operation assumed to be contemporaneous with worst case impact from Munmorah power station.

7.7.3 Fine particulates

The cumulative daily averaged PM₁₀ levels are shown in Table 7.18 and Figure 7.14.

Table 7.18 – Predicted first highest cumulative GLC for PM₁₀.

Averaging period	Pollutant concentrations (µg/m ³)	
	24 hour	Annual
Predicted cumulative impact	60	22.1
Number of exceedances through reference year	3	none
Prediction with Munmorah alone	4.3	1.3
Background air quality	56	20.8
Air quality limit	50	30
Allowable exceedances per year	5	None

The contribution made by Munmorah Power Station to the background PM₁₀ levels should be taken into account. This is because the background levels already exceed the AAQ NEPM. The peak contribution of emissions from Munmorah alone (4.3 µg/m³) demonstrates a contribution of <10% of the peak background level.

7.7.4 Other Pollutants

The ambient air quality impacts for all other pollutants (Fluoride compounds, Cd, Hg and dioxins and furans (PCDD/F)) have been prescribed on a non-cumulative basis, given the absence of any ambient air monitoring data to represent the background level of these pollutants.

A comparison of emission rates used in predicting the impacts for these pollutants to those recorded for Munmorah Power Station over the 2004-2006 period are shown in Table 7.19.

Table 7.19 – Comparison of modelled versus actual performance data

Pollutant	Modelled emissions	Average Munmorah performance (2004-2006) ⁽¹⁾	
	mg/m ³	Unit 3	Unit 4
Fluoride compounds ⁽²⁾	14.5	4.1	5.6
Cd compounds	0.002	0.00132	
Hg compounds	0.2	0.00030	
PCDD/F ⁽³⁾	0.1 ng/m ³	0.0013 ng/m ³	

NOTE: ⁽¹⁾ Source: Malfroy, 2007

⁽²⁾ modelled as hydrogen fluoride

⁽³⁾ Polychlorinated dibenzo-dioxin and dibenzo-furans

This comparison demonstrates a significant level of conservatism in the approach that was taken. The fact that the average levels are at a level that is either half or up to an order of magnitude below the modelled levels enables conservatism in the predictions of cumulative impacts. The performance data is shown in Figures 7.12 (SO₂), Figure 7.13 (NO₂) and Figure 7.14 (PM₁₀). These data also shows peaks in the observed data, but the average statistic is typically skewed towards the lower end of the performance range.

It is not unreasonable to assume a reduction in the ambient levels of these pollutants in the environment following the use of low sulfur coal at both Eraring and Vales Point Power Stations and with the upgrade of the combustion technology at Eraring. Improvements in the motor vehicle fuel quality and combustion technology would also contribute towards general improvements. However, it needs to be noted that these pollutants have a tendency to accumulate in the natural environment ie through deposition over soil and natural water bodies.

Table 7.20 shows the predicted cumulative impact for Cd, Hg, dioxins and furans (PCDD/F) and HF. The predicted levels of these pollutants are several orders of magnitude below the ambient air quality limit as prescribed by the NSW DECC.

Based on the discussion above, levels of fluorides in the ambient environment are also predicted to fall at levels that are at nearly half the limit prescribed.

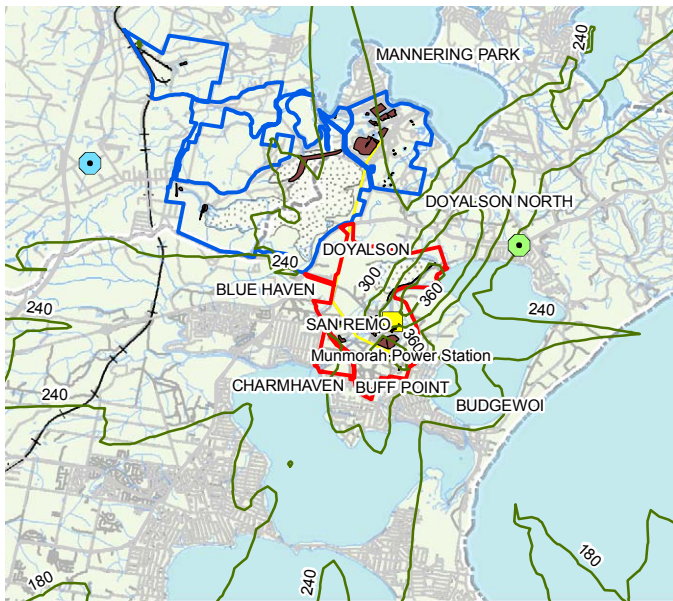


FIGURE 7.8a: SO2 10 minute average ground level concentration ($\mu\text{g}/\text{m}^3$)

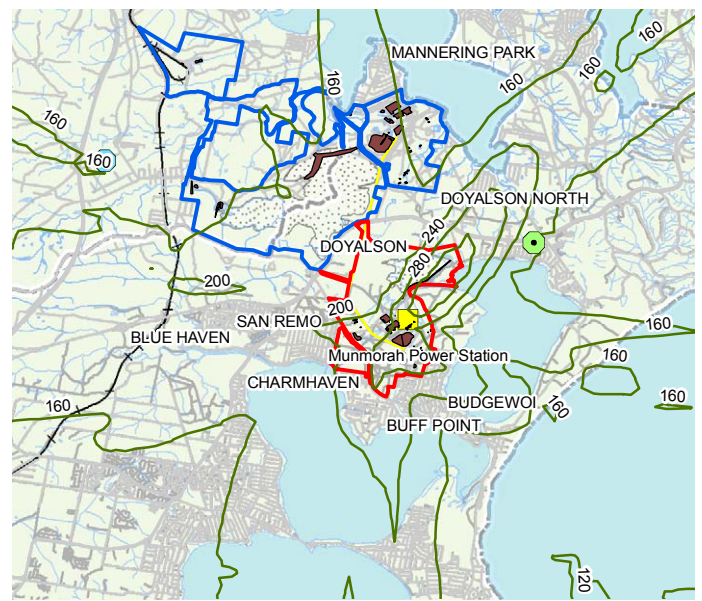


FIGURE 7.8b: SO2 hourly average ground level concentration ($\mu\text{g}/\text{m}^3$)

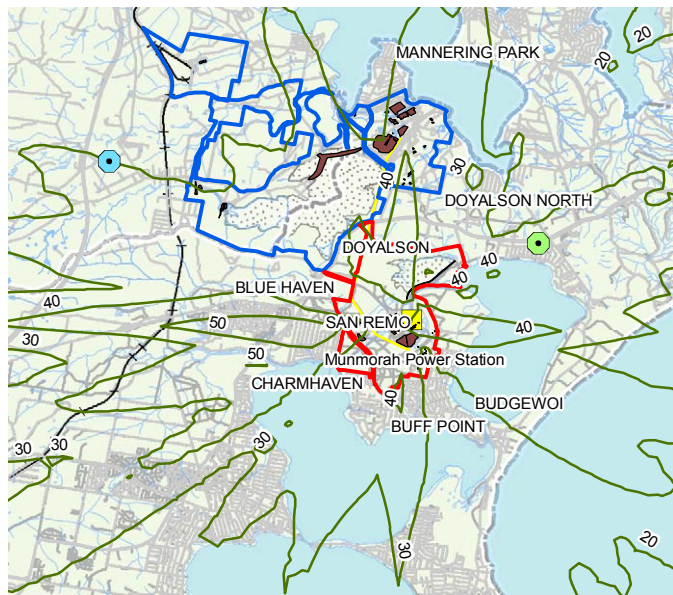


FIGURE 7.8c: SO2 daily average ground level concentration ($\mu\text{g}/\text{m}^3$)

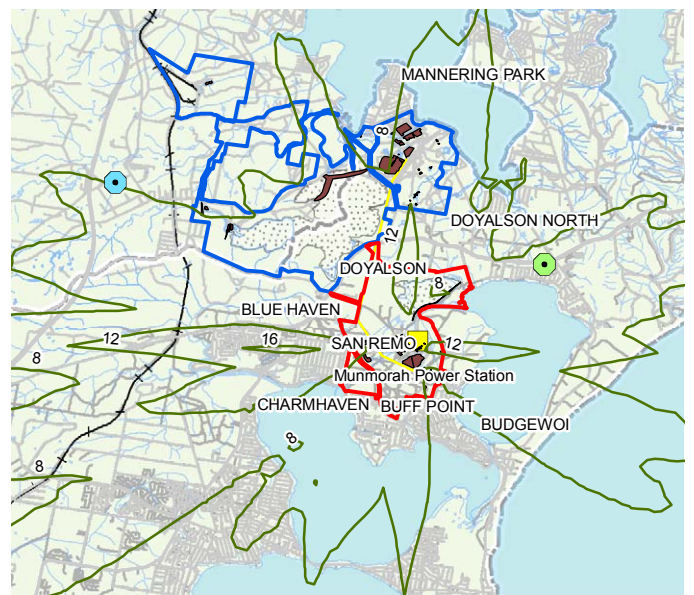


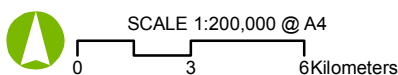
FIGURE 7.8d: SO2 annual average ground level concentration ($\mu\text{g}/\text{m}^3$)

Legend

- MV Conveyor
- SO2 contours
- Wye air monitoring station
- Lake Munmorah PS air monitoring station
- Colongra Gas Turbine Facility
- Munmorah Power Station
- Vales Point Power Station
- Buildings and Infrastructure
- Local Government Area

Source: TAPM Modelling

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Projection: MGA

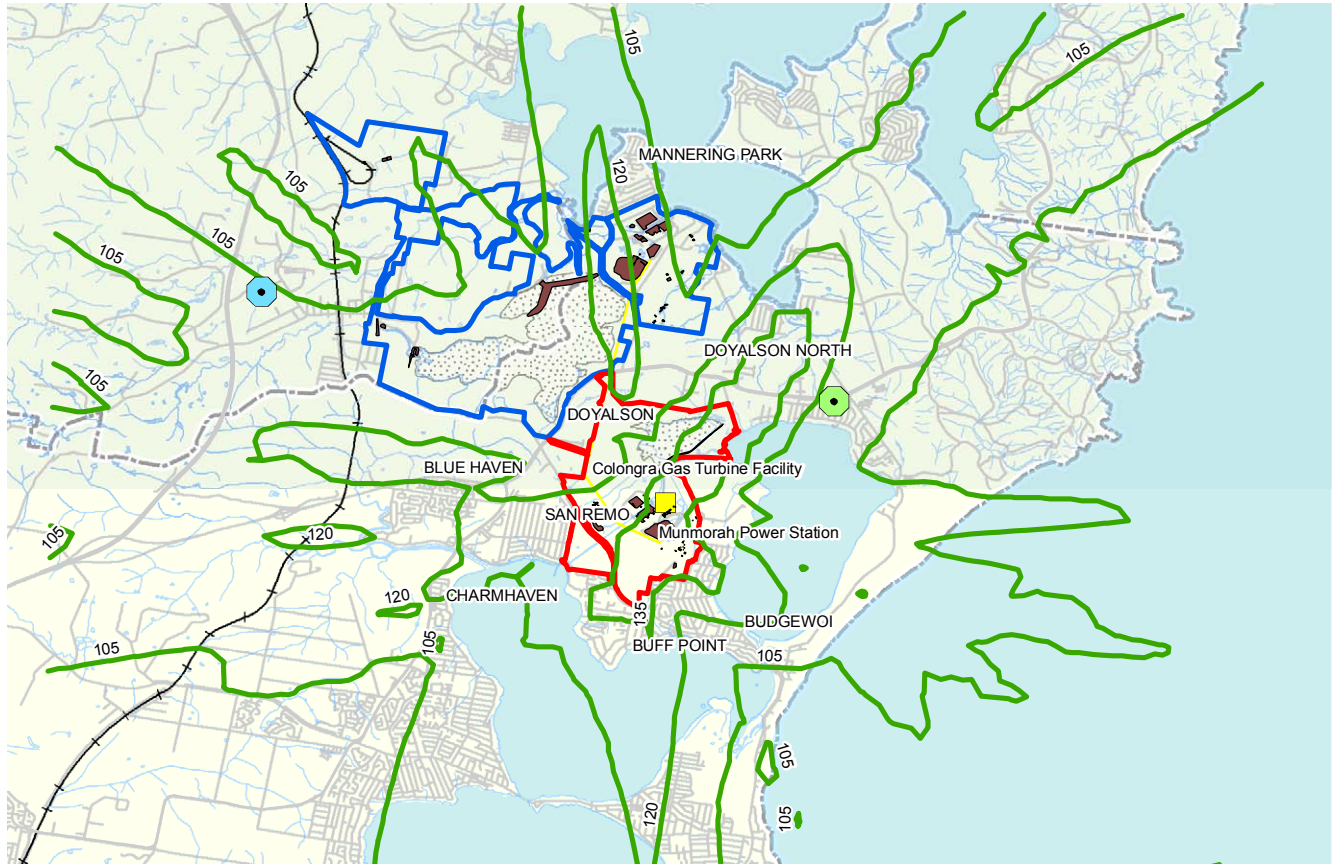


FIGURE 7.9a: NO2 hourly average ground level concentration ($\mu\text{g}/\text{m}^3$)

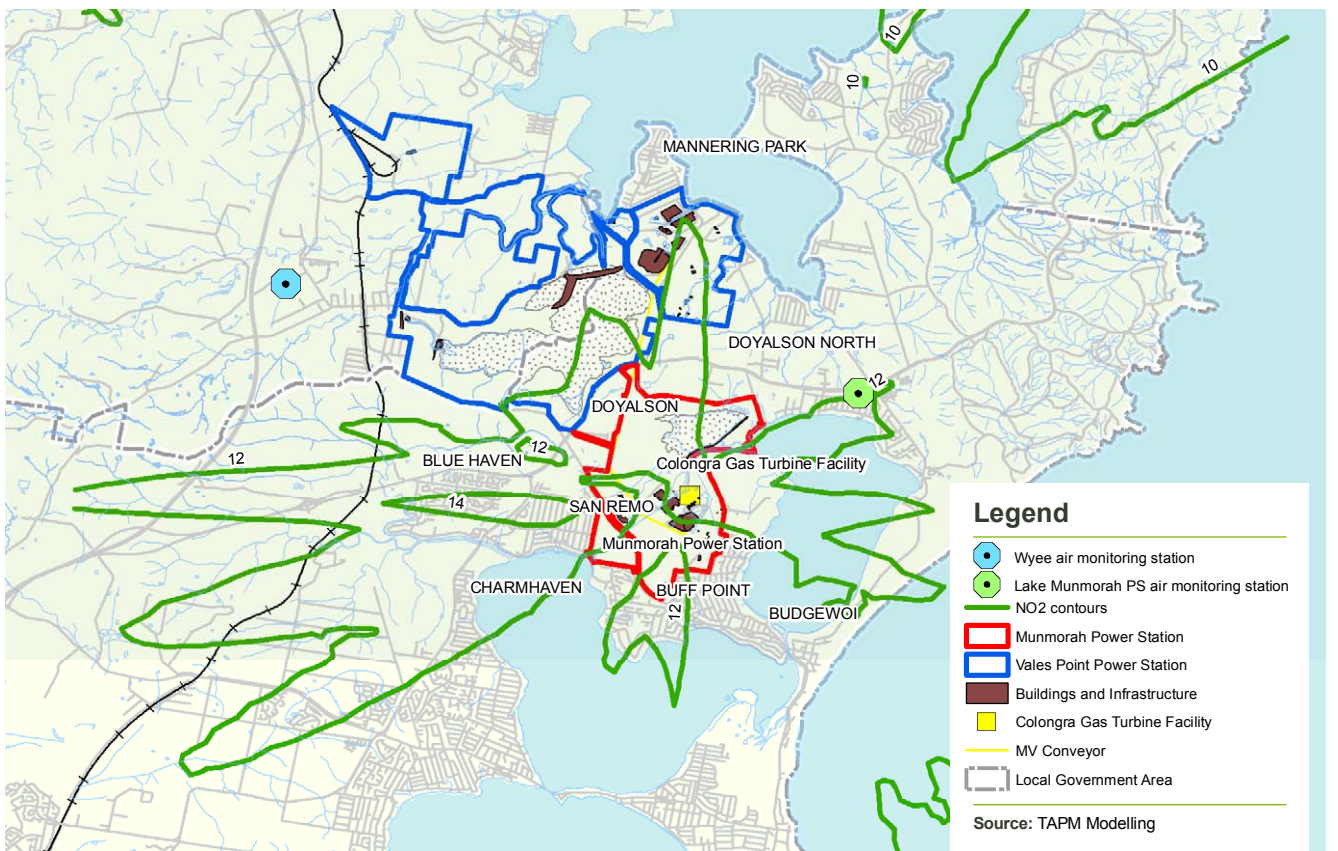


FIGURE 7.9b: NO2 annual average ground level concentration ($\mu\text{g}/\text{m}^3$)

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SCALE 1:150,000 @ A4
0 2 4 Kilometers

Projection: MGA

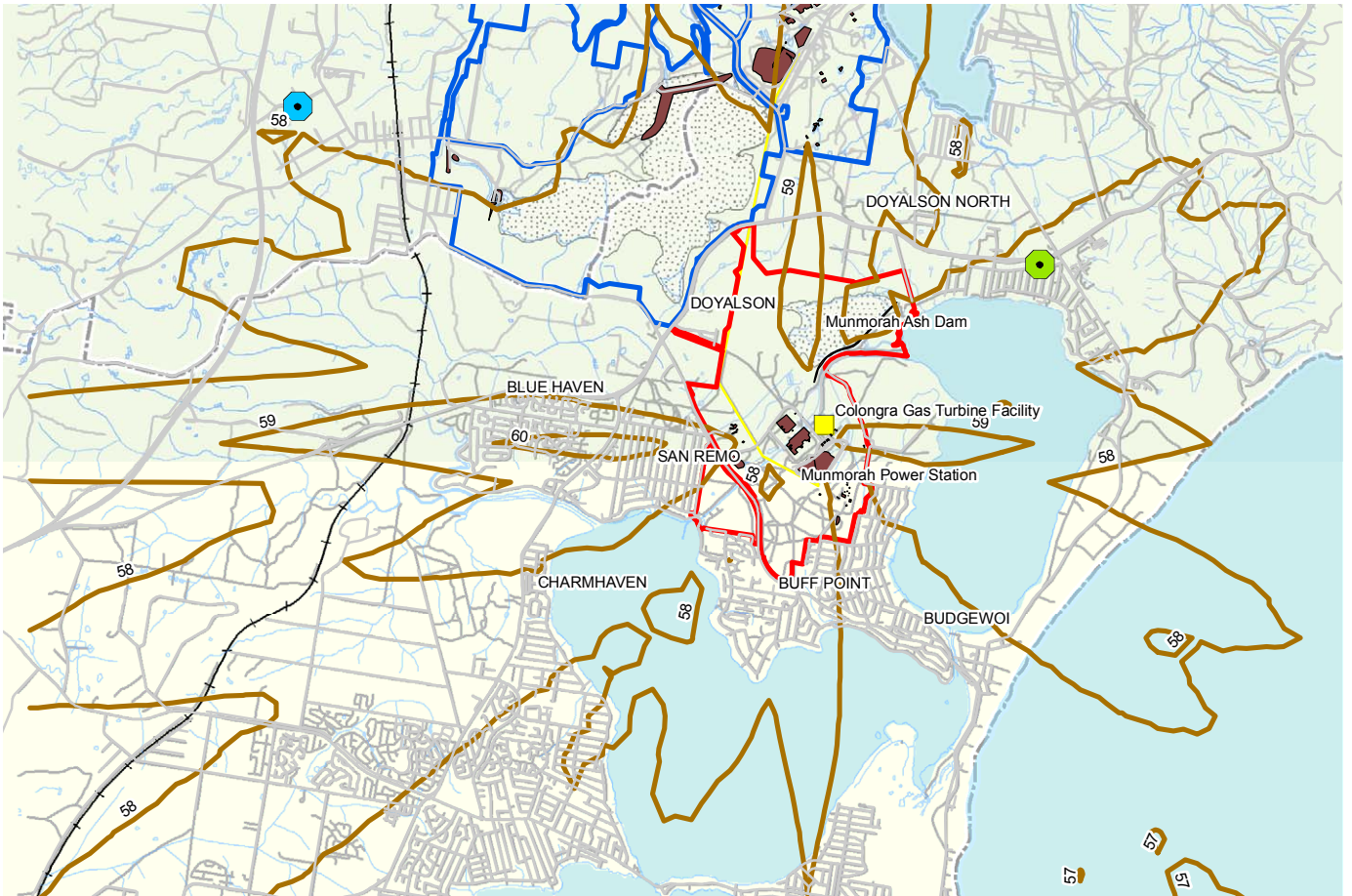


FIGURE 7.10a: PM10 daily average ground level concentration ($\mu\text{g}/\text{m}^3$)

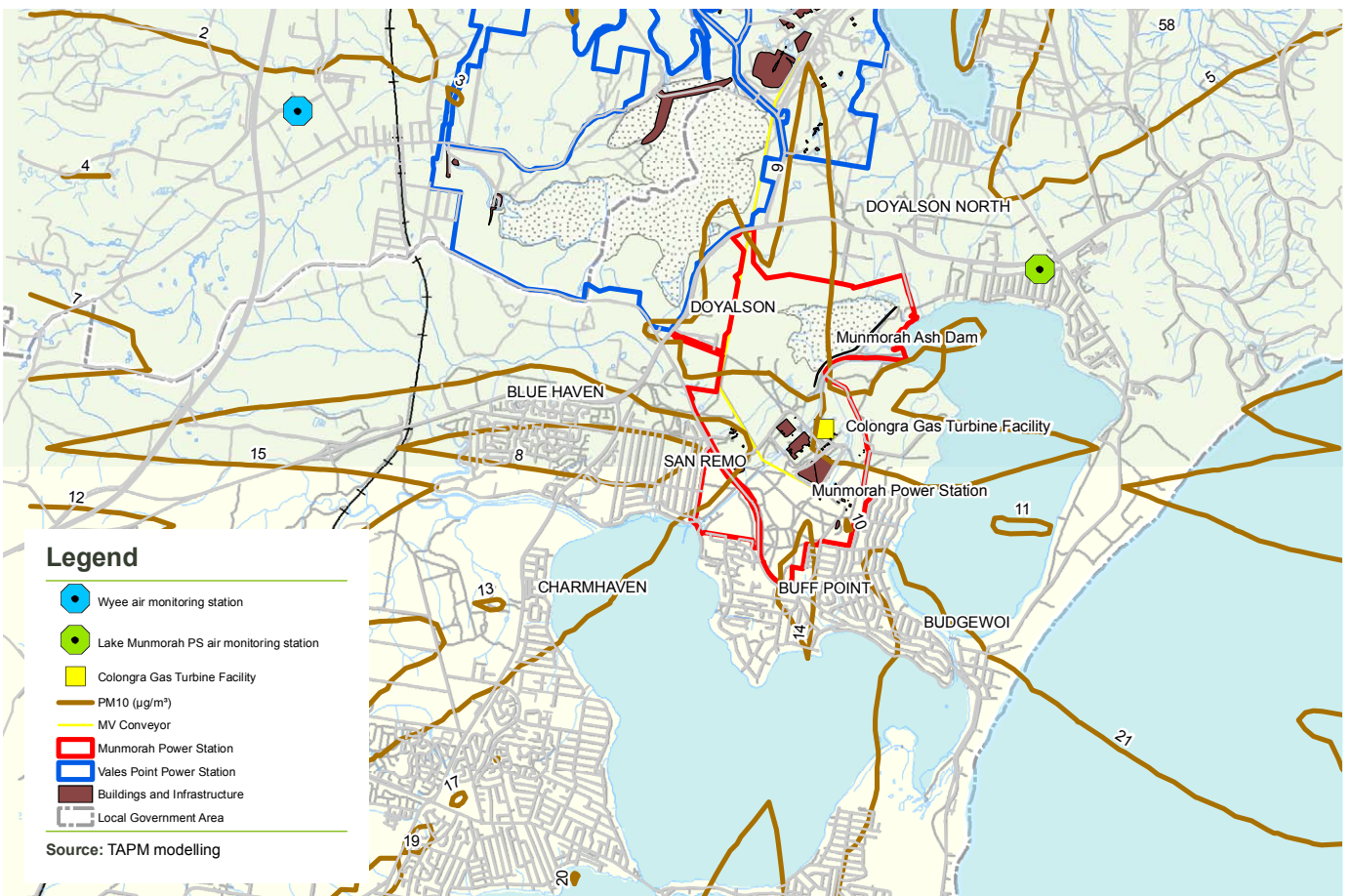
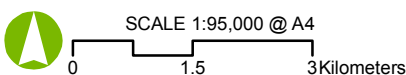


FIGURE 7.10b: PM10 annual average ground level concentration ($\mu\text{g}/\text{m}^3$)



SCALE 1:95,000 @ A4

Projection: MGA

Table 7.20 – Predicted first highest cumulative GLC for other pollutants

Pollutant concentrations	Cadmium µg/m ³	Mercury µg/m ³	PCDD/F ⁽¹⁾ µg/m ³	Fluorides (as hydrogen fluoride (HF)) µg/m ³			
				24 hr	7 days	30 days	90 days
Averaging period	1 hour	1 hour	1 hour				
Predicted cumulative impact	0.001	0.082	4.1 x 10 ⁻⁸	1.2	0.84	0.64	0.5
Air quality limit	0.018	1.8	2.0 x 10 ⁻⁶	2.9	1.7	0.84	0.5

NOTE: ⁽¹⁾ Polychlorinated dibenzo-dioxin and dibenzo-furans

7.8 Regional and Inter-Regional Impacts

The region broadly described as the NSW Central Coast and Sydney Greater Metropolitan are densely populated with numerous fugitive and industrial NO_x and anthropogenic VOC emission sources, which are precursors to O₃ formation and photochemical smog. The formation of NO₂ and O₃ in the lower atmosphere is dependent on the interaction of various organic and inorganic reagents, meteorological conditions, and the local/regional atmospheric NO_x load.

The following sections provide an assessment of the likely impact of the rehabilitated Munmorah Power Station on regional and inter-regional air quality.

7.8.1 Ozone

The CSIRO (2005) undertook a photochemical smog study for the Colongra Gas Turbine Environmental Assessment. The new turbine facility was considered a significant new NO_x emission source in this region.

The CSIRO analysis over several historically high O₃ concentration days showed that the Colongra Gas Turbine would have a negligible impact on exceedances of the NSW DECCW limits over the one hour averaging period for both NO₂ and O₃. This assessment included Munmorah Power Station operating as a two unit power station at full load.

Figure 7.15 shows isopleths for hourly averaged O₃ ground level concentrations measured over the period 11-13 March 1998 (CSIRO, 2005).

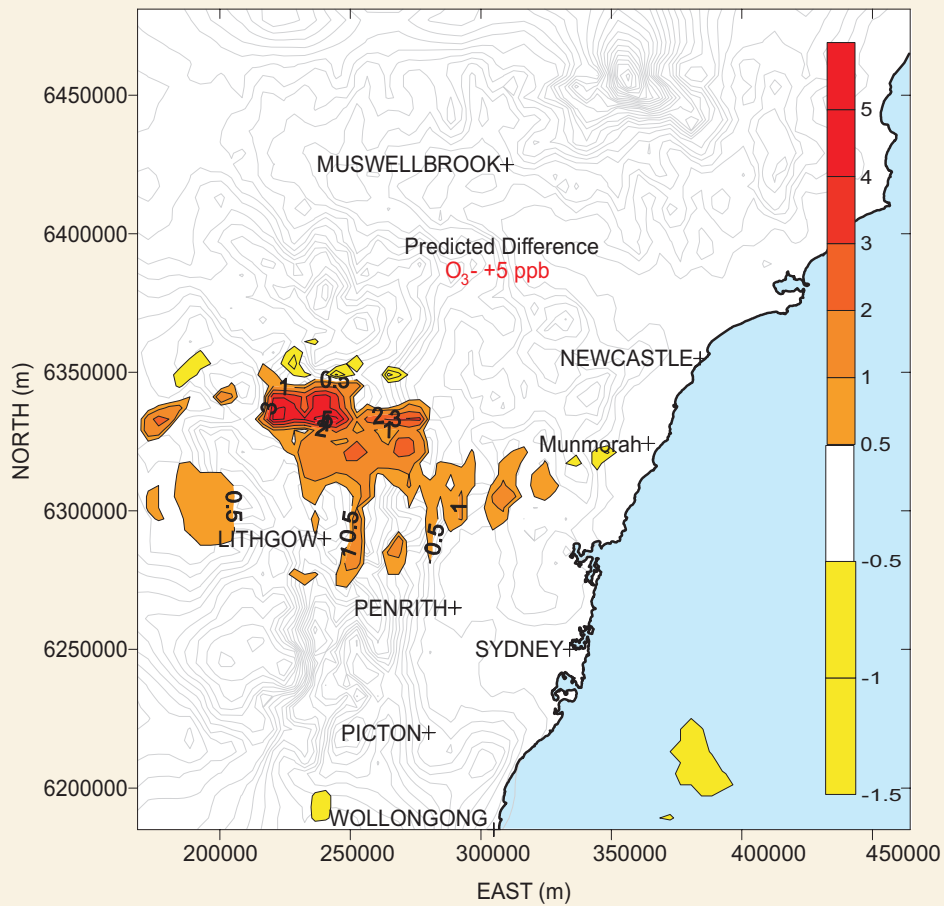
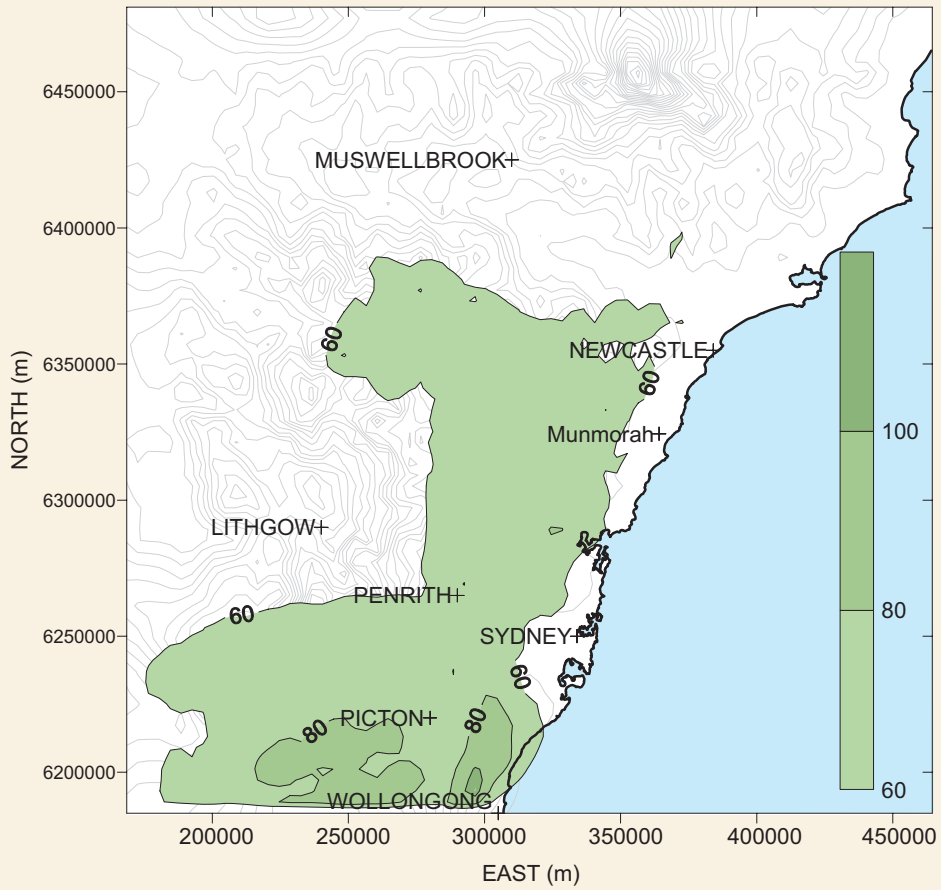
The plot on the left is the overall predicted O₃ concentration while the plot on the right is the difference between the baseline (including Munmorah Power Station emissions) and the test case (Colongra Gas Turbine emissions included).

The plots show that the highest increase in predicted concentration, once Colongra gas turbine is commissioned, is expected to occur over sparsely populated but densely forested regions north of Lithgow. These predicted increases in O₃, with Munmorah operating, were accepted and the Colongra Gas Turbine project was approved in July 2006.

The results from the CSIRO (2005) indicate that the formation of O₃ in this region is not limited by the availability of NO_x in the atmosphere but rather on the availability of AVOC (CSIRO, 2002). A similar trend is observed when the results for the other historical O₃ event days considered within this study are analysed. This trend was first outlined by Nelson (et al) (2002) (IRTAPS). The implementation of any further controls on NO_x emissions is unlikely to lead to any downward trends in the formation of photochemical oxidants (as O₃) in the wider geographical regional or inter-regional context.

The initiatives introduced by the NSW DECCW over the last decade to limit VOC emissions has assisted in creating low VOC/NO_x mixing ratios which are not conducive to O₃ formation. Low VOC/NO_x ratios have been shown to have a greater effect however over shorter term (ie one hour averaging periods) in urban environments.

The further control of industrial NO_x emissions is therefore not likely to result in any discernable reduction or change in photochemical impacts in terms of hourly averaged O₃ concentrations. NO_x emissions control of the nature proposed for Munmorah Power Station are likely to have a more significant suppressive effect on photochemical smog impacts defined in terms of four hour averaged O₃ concentration (Jin, L, et. al. 2008).



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Munmorah Power Station **Refurbishment Environmental Assessment**

FIGURE 7.15: Hourly averaged O₃ ground level concentrations - Baseline case (top) and test case (with Munmorah gas turbines (bottom) (CSIRO, 2005)



7.8.2 Nitrogen dioxide

The CSIRO (2005) also undertook an assessment of the effect of the Colongra gas turbine facility on NO₂ impacts in the regional setting. This assessment included Munmorah Power Station with two units operating at full load. This information has been used to infer the likely air quality impacts following the rehabilitation of Munmorah Power Station.

Figure 7.16 shows the hourly averaged NO₂ concentration isopleths for the base case and test case. The figures indicate that a significant addition to the atmospheric NO_x load from Colongra gas turbine does not lead to appreciable air quality impacts in the urbanised regions along the coast, but transpired to impacts in NO_x limited but BVOC rich environments north west of the facility on the photochemical smog event day (11-13 March 1998).

Although AVOC does not have as significant an impact on NO₂ concentrations as it does on O₃, the analysis suggests a NO_x rich air environment, which has passed the critical mass load even without the inclusion of a major facility such as the Colongra gas turbine. Thus a relatively minor change in the temporal anthropogenic emission structure in this region will not have any appreciable beneficial impacts on either regional or inter-regional air quality.

The predicted impacts of both Munmorah Power Station and the Colongra Gas Turbine operating were assessed and approved by the Department of Planning in consultation with the DECCW (DOP 2006).

The rehabilitation of Munmorah will decrease the intensity of NO_x emissions compared to current emissions. The effect of this change will decrease regional NO₂ or O₃ concentrations over an hourly averaged time period. The effect of a change in atmospheric mixing ratios (VOC/NO_x) varies significantly through diurnal, seasonal and weekday-weekend basis, with motor vehicle emissions being the primary driver of this system. This complexity cannot be simplified in terms of a single figure.

The CSIRO (2005) analysis also showed that chemical transport model based simulations often yield results, which bring forth questions of statistical significance. The trend in the simulations in this instance suggests that no significant changes would occur in the atmospheric environment following the reduction of NO_x emissions through the rehabilitation of Munmorah.

7.8.3 Other pollutants

Negligible changes in the emissions of other pollutants including SO₂, particulate matter, TSP, VOCs and heavy metals will have no impact on air quality in the regional or inter-regional setting.

A change in the emissions of VOCs or solid particles is inherently related to NO₂ and O₃ impacts as discussed above. These reagents are largely consumed in reactions related to the formation and destruction of O₃ and nitrogen dioxide in the troposphere.

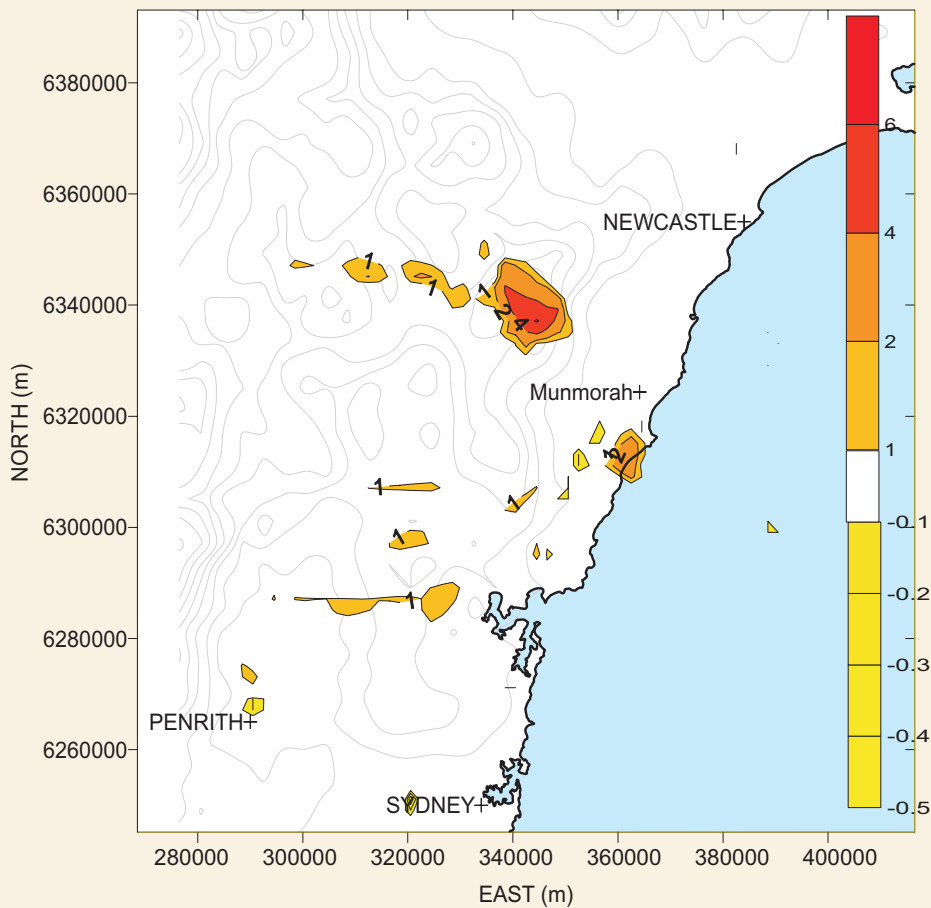
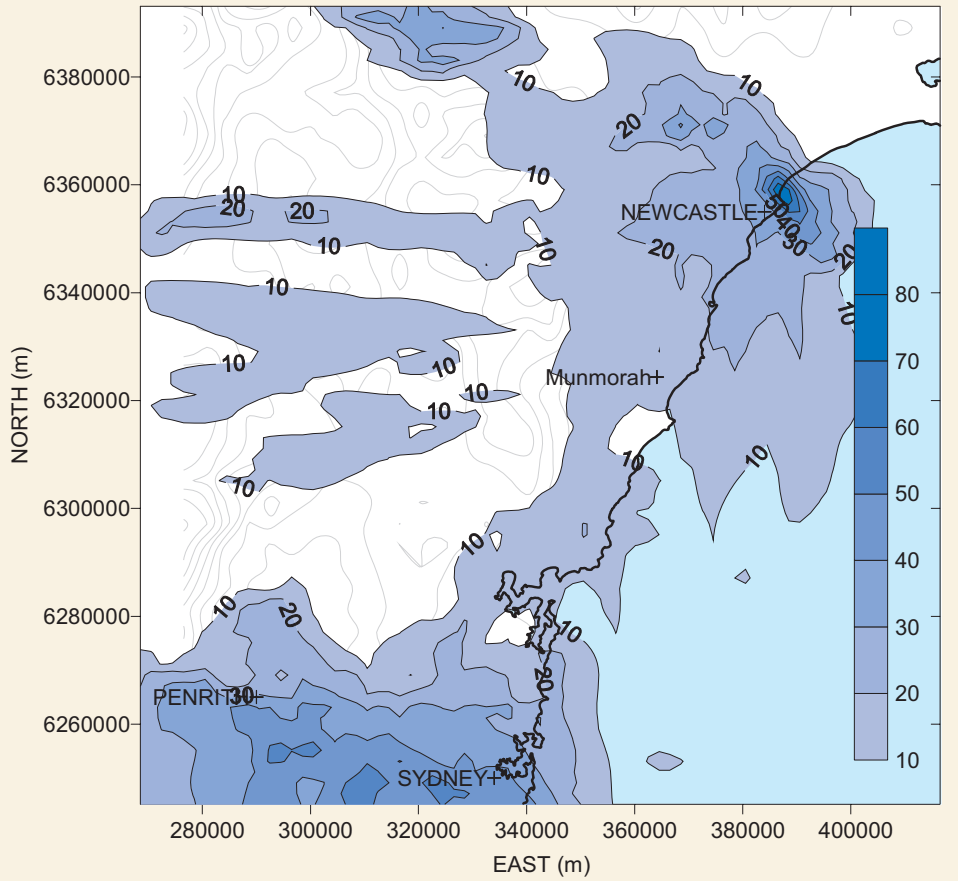
7.8.4 Deposition impacts

Depletion of NO_x and SO₂ from the atmosphere through oxidation by dry and wet deposition processes has not been assessed quantitatively for this Environmental Assessment.

Regional atmospheric NO_x load is formed through a combination of the diffuse and industrial source air emissions, with diffuse sources being the more significant contributor. Deposition of large amounts of NO_x and SO₂ can lead to the acidification of natural and manmade water bodies, as well as acidification of soils over time, which can be problematic for regions dominated by agricultural or horticultural industry. While not a serious threat, loss of crop productivity can result unless limestone is applied to correct acidification. This is normal practice in agriculture in high rainfall areas, and in areas of high productivity, where acidification is a natural process or a consequence of agricultural production activities.

Munmorah's rehabilitation could reduce the cumulative NO_x emissions by up to 20% over the proposed 20 year lifespan, while a marginal increase in the level of gross SO₂ emissions over a period of time may be observed. It is however unlikely that all the coal that is combusted will be represented by the 0.7% sulfur emissions calculated as part of the CSIRO studies (Rae et al 2007).

SO₂ emissions could tend towards zero as the plant is co-fired with increasing proportions of gas over the plant's 20 year lifespan. The combined effect of the introduction of the proposed rehabilitation program and the CPRS market infrastructure will lead to a marked reduction in the contribution that Munmorah will make to gross SO₂ and NO_x (dry and/or wet) deposition in this region. The cumulative level of acid deposition over the 20 year time period, specifically per m², will decrease.



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Munmorah Power Station **Refurbishment Environmental Assessment**

FIGURE 7.16: Hourly averaged NO₂ ground level concentrations - Baseline case (top) and test case (with Munmorah gas turbines (bottom) (CSIRO, 2005)



7.9 International Best Available Techniques

The European Council under Article 16(2) of Council Directive 96/61/EC required the Commission to organise 'an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring and developments in them', and to publish the results of the exchange.

The 'Large Combustion Plants' Best Available Techniques Reference (LCP BREF) is a document produced under this Directive. The LCP BREF covers all nature of large combustion plants and includes specific BATs applicable to coal only (no lignite) combustion plants.

The BREF is provided for comparison against the requirements made by the NSW DECCW.

7.9.1 Sulfur dioxide emissions

Removal of SO₂ from coal fired power stations can be achieved through the following (DTI, 2000):

Fuel switching

This could include switching to coal sources with lower sulfur content or making a switch to natural gas. Delta Electricity is proposing to reduce the limit of sulfur in coal from 1% to 0.7% and in addition, co-firing with natural gas will also serve to reduce the SO₂ emissions further. This discussed in more detail in Section 7.10.

Desulfurisation technologies

The following desulfurisation options are available:

- Pre-combustion: This involves removing sulfur with chemical cleaning processes; however this is not practised on a commercial scale. Gasification could be considered a pre-combustion technology (IGCC). Although commercially available, this technology is still not fully mature and is not considered feasible in the short to medium term due to high construction costs (See Section 2.3.3.).
- During combustion: This involves the addition of sorbents eg lime or limestone to the furnace during combustion. Although this technology has been used in pulverised fuel boilers, it is more applicable to fluidised bed combustion where higher residence times (between the SO₂ and sorbent) can be achieved.

- Post-combustion: This is the most common method of achieving sulfur emission reductions from conventional coal fired power stations. Flue gas desulfurisation (FGD) technologies include limestone gypsum wet scrubbing, sea water scrubbing, combined de-SO_x and de-NO_x technologies, ammonia scrubbing etc. FGD technologies generally require high levels of auxiliary power and quite often the significant energy penalty is not balanced by the relatively minor benefit in additional emission control that can be achieved.

BAT emission limits

Table 7.21 provides a list of BAT and the associated SO₂ emission limits for existing coal combustion plants.

Although Munmorah Power Station will not necessarily be compliant with the BAT stipulated for 100% coal combustion, it is within the practicable range that has been proposed by European industry bodies for existing combustion plants with thermal capacity > 300 MW_{th}.

7.9.2 NO_x emissions

Nitrogen bound in the coal and nitrogen present in the combustion air contributes to the formation of NO_x during combustion. The following mechanisms contribute to the formation of NO_x:

- Thermal NO_x results from the presence of nitrogen in combustion air reacting with oxygen at high temperatures (5-25% of total NO_x formed).
- Fuel NO_x results from the oxidation of the nitrogen in the fuel (70-80% of total NO_x formed)
- Prompt NO_x is formed at the flame front (<5% of total NO_x formed).

Investigations have shown that optimisation of the boiler can achieve up to 20% reduction in NO_x emissions. Optimisation can be achieved through balancing fuel and air flows, reducing excess air levels etc (DTI, 1997).

Combustion modification technologies include the following:

- Installation of low NO_x burners: these burners aim to reduce the temperature and oxygen availability in the flame by various means
- air and fuel staging: this technology aims to stage the supply of combustion air and fuel through the burners with ~70-90% air being supplied to the

burners and the remaining 10-30% is injected above the burners (referred to as 'overfire' air).

- reburning: this involves the staged supply of fuel and combustion air in the furnace. Stage 1 includes the primary zone where coal is burnt with excess air to produce NO_x. Stage 2 involves the addition of a secondary fuel, either natural gas, coal or oil, which is injected above the burner to create the reburn zone reducing the NO_x formed in the Stage 1 to molecular nitrogen. Stage 3 involves the injection of the remaining combustion air to ensure complete combustion. Up to 70% NO_x reduction can be achieved using this mechanism.

The first two of these are relevantly inexpensive modifications which can achieve up to 50% NO_x reduction when applied individually (DTI, 1997). However, reburning may be relatively expensive, depending on fuel costs.

A number of flue gas NO_x reduction systems are available commercially. These include:

- selective catalytic reduction (SCR) – 90% reduction achievable
- Non-selective catalytic reduction (NSCR) – 50% reduction achievable
- combined NO_x/SO_x control (DTI, 1997)

Flue gas treatment is more expensive due to high capital, operating and maintenance costs and only countries with stringent NO_x emission limits, as indicated in Table 7.22, will these technologies be feasible.

It is proposed that tangential low NO_x burners with separate overfire air technology (TLN2) will be installed during the rehabilitation. These burners will provide significant reductions and are likely to meet, or be very close to Group 6 limits (500 mg/Nm³). This emission will be achieved at a modest cost compared to the costs associated reburning or with the installation of catalytic or non-catalytic de-NO_x. Also, given that very low local NO₂ concentrations have been recorded over many years resulting in low ambient impacts, the additional costs of reburning, catalytic or non-catalytic de-NO_x is not justified.

The BAT guideline for the maximum allowable NO_x emission limits for coal and gas combustion for existing plants is provided in Table 7.22. Although the proposed facility will not be compliant with the BAT guidelines stipulated, it is within the practicable range for the oldest of the existing combustion plants with thermal capacity > 300 MW as outlined by the European Member state.

Table 7.21 – Directive 96/61/EC BAT for SO₂ emissions (existing coal and gas combustion)

Fuel	Combustion Techniques	Emission control techniques	SO ₂ emission level associated with BAT
Coal Capacity > 300 MWth	Pulverised/ bubbling/circulating fluidised bed combustion	Low sulfur fuel, pulverised combustion. Wet/dry (sorbent injection) flue-gas desulfurisation Seawater scrubbing Combined techniques for the reduction of NO _x and SO ₂ .	20-200 mg/Nm ³ ⁽¹⁾
	Bubbling/pressurised fluidised bed combustion	Low sulfur fuel Limestone injection	100-200 mg/Nm ³ ⁽²⁾
	Bubbling fluidised bed combustion	Low sulfur fuel Wet flue-gas desulfurisation	20-200 mg/Nm ³ ⁽³⁾

⁽¹⁾ Upper level of 400 mg/ Nm³, ⁽²⁾ and ⁽³⁾ Upper level of 300 mg/Nm³

These levels are proposed by Industry (EU) because they claim that better takes into account the fuel characteristics, the inlet flue-gas SO₂ concentration affects the BAT achievable levels considering the agreed wet scrubber SO₂ removal efficiencies of 85 – 98 %, the high energy consumption of such a wet scrubber system in relation with the net unit efficiency requirements, and because an optimisation is necessary between emission control technique performance (low emission levels) and related energy consumption (energy penalty).

Table 7.22 – Directive 96/61/EC BAT for NO_x emissions (for existing coal and gas combustion plant)

Fuel	Combustion Technique	NO _x emission level associated with BAT
Coal Capacity > 300 MW _{th}	Pulverised combustion Combination of primary measures to reduce NO _x (incl. air and fuel staging, low NO _x burners, reburning etc.) in combination with selective catalytic reduction or combined techniques	90-200 mg/Nm ³
Gas (new and existing gas-fired boilers) O ₂ reference level – 3%	Low NO _x burners, selective catalytic and non-catalytic reduction.	50-100 mg/ Nm ³ (upper limit – 120 mg/Nm ³)

Table 7.23 – Best available techniques emission limits for the control of dust from large existing coal fired combustion plants.

Type of fuel	Rated thermal input (MW _{th})	Emission limit values (mg/Nm ³)
Solid	≥ 500	50*
	< 500	100

* A limit value of 100 mg/Nm³ may be applied to plants with a rated thermal input greater than or equal to 500 MW_{th} burning solid fuel with a heat content of less than 5,800 kJ/kg (net calorific value), a moisture content greater than 45 % by weight, a combined moisture and ash content greater than 60% by weight and a calcium oxide content greater than 10%.

The Directive 96/61/EC states that for the European context, a strict target of 150 mg/Nm³ can be achieved in a cost effective way by a system of NO_x emission trading. However, to have maximum flexibility in the system of NO_x emission trading, a range of 100 – 650 mg/Nm³ for the existing oldest combustion plants over 300 MW, was considered more practicable.

7.9.3 Persistent organic and non-organic pollutants (Dust)

Fly ash is generated as a result of combustion of coal. The main technologies used for the removal of fly ash from coal fired power stations are:

- Electrostatic precipitation
- Electrostatic precipitation with sulfur trioxide (SO₃) conditioning
- Fabric filters

Fabric filters is the BAT for controlling particulates from large coal combustion plants. These are more efficient at controlling small particles than electrostatic precipitators. The implementation of effective management strategies is also important in maintaining the high efficiencies associated with the fabric filter. Management strategies include:

- monitoring of pressure differentials (dPs) across the fabric filters
- ensuring that the actuators shaking the dust off the fabric filters are operating properly
- ensuring the availability of spare sections through the baghouse which can be brought into service in the event of a tear in the fabric filters in another section of the bag house.

These strategies are designed to ensure filters do not become clogged with particulate matter. Fabric filters replaced the older electrostatic precipitator technology at Munmorah Power Station in the late 1980s.

The LCP BREF also provides BAT for controlling the emissions of dust, and in particular particulate bound heavy metals and VOCs. This report indicates that as it is known that metals (including mercury) and persistent organic pollutants (ie PAH) preferentially adsorb onto smaller particles (ie PM_{2.5}), it is important to apply BAT for controlling these fine particles. These pollutants have a tendency to bioaccumulate for extended periods of time in the natural environment.

The limits that should be achieved through application of the BATs are provided in Table 7.23. The particulate limit applicable to Munmorah Power Station is 50 mg/Nm³ equivalent to the NSW

DECCW Group 6 emission standards (Table 7.1). Malfroy (2007) reported the levels recorded over the 2004-2006 period were well within this guideline limit (Unit 3 was ~8 mg/m³ and Unit 4 ~29 mg/m³).

Further discussion with reference to future emissions of particulate matter (solid particles/dust) and fabric filter performance is provided in Section 7.8.

The emissions of persistent organic pollutants such as mercury, polychlorinated dibenzodioxin and dibenzofuran (PCDD/F) can be further controlled where emission levels are unacceptable. Additional control of organic compounds and heavy metals can be achieved through the adoption of sorbent injection techniques. However the significant economic costs of this type of infrastructure significantly outweighs any potential environmental benefits that arise from its application.

7.10 Mitigation Measures and Monitoring

The current operational practises and the proposed rehabilitation of Munmorah Power Station include a number of mitigation measures:

- Fabric filters were installed at Munmorah Power Station in the 1990s. Measured particulate emissions continue to comply with the 50 mg/m³ EPL limit and with the Directive 96/61/EC BAT emissions limits.
- Proposed installation of low NO_x burners will provide significant reductions and are likely to meet, or be very close to Group 6 limits (500 mg/Nm³).
- Sulfur emissions are directly related to the sulfur content in the coal therefore the proposed co-firing of gas will act as an SO₂ emissions control mechanism. In addition Delta Electricity proposes to reduce the limit of sulfur in coal from 1% (the current EPL limit) to 0.7%.
- Delta will continue to carry out continuous and manual in stack emissions monitoring, as it has done so historically, for all the relevant regulated pollutants stipulated within the PoEO (Clean Air) Act to monitor compliance with the regulated emission limits. This will provide confidence as to the extent of the improvements realised through the rehabilitation works proposed for this facility.

It is expected that the increased efficiency of the plant resulting from the rehabilitation will result in a reduction in the emissions to atmosphere per unit of electricity generation, particularly the emission of greenhouse gases

Air quality monitoring network

The current air quality monitoring network is able to adequately capture the worst case air quality impacts from Munmorah following the rehabilitation program, assuming the concurrent operation of Munmorah, Colongra gas turbine, Vales Point and other major industrial facilities and diffuse source air emissions.

7.11 Conclusion


Munmorah Power Station currently complies with Group 2 emission standards. The *Protection of the Environment Operations (POEO) (Clean Air) Regulation*. 2002 requires older plant operating in NSW to comply with Group 5 emission standards by 2012.

The proposed rehabilitation of Munmorah Power Station will require a variation of the Environment Protection Licence to change the designated Fee Based Activity Scale to ">4000 Gwh generated". A change in plant intensity such as the one proposed triggers a requirement to meet Group 6 emission limits.

Munmorah Power Station is currently compliant with all Group 6 emission standards, with the exception of NO_x. The rehabilitation program aims to address this issue.

Low NO_x burners are being proposed as part of the rehabilitation works. Comprehensive modelling of the emissions from the rehabilitated power station, with the installation of low NO_x burners, suggest that the Group 6 NO_x limits will be achieved under all operating conditions, with the possible exception of low load operations during start-up and shut-down or if the station is in standby mode (rare for a baseload power station).

The preceding air quality impact assessment for the proposed rehabilitation works for Munmorah Power Station incorporated a dispersion modelling study to understand local air quality impacts, a study of relevant peer reviewed and technical literature, rehabilitated air emissions profile and best available emission control techniques for a facility of this nature, and a review of the stack



emissions and ambient air monitoring measures that have been in place over the last 15 years.

Delta Electricity has been in discussion with the DECCW regarding improvements in stack sampling methods necessary to meet current stack emission sampling requirements. It is expected that the rehabilitation will include a requirement to upgrade sampling to include in-stack sampling to meet the updated requirements. This will improve the quality of data as well as confidence in the performance of the combustion and associated emissions control systems.

Local Impacts

The dispersion modelling program assessed the air quality impact on the local scale of emissions of oxides of nitrogen, sulfur dioxide, fine particulates and other pollutants (including heavy metals, volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs)).

This assessment was able to demonstrate that the air emissions from the plant would not contribute to any further exceedances in the guideline limits for all pollutants with the exception of SO₂.

A potential for occasional exceedance in guideline limits for sulfur dioxide was identified for the 10 min and hourly averaged parameters under modelled worst case conditions. However this finding is highly unlikely given the conservative nature of the methodology adopted in representing cumulative air quality impacts for this pollutant. This probability would reduce with increased levels of natural gas being co-fired through plant operation.

Regional air quality impact

The air quality impacts on the regional and interregional basis were assessed based on a literature review of air quality studies conducted by a range of specialists including the CSIRO (as referenced within the document). The primary conclusions of this literature review were that there is likely to be little to no discernible impacts upon regional air quality through this region in terms of peak ozone concentrations or NO₂ ground level concentrations. This conclusion is based on the evidence purporting that the regional atmosphere is limited of anthropogenic volatile organic compound sources, and the presence of surplus NO_x.

The emissions of other pollutants that have been classified as including but not limited to trace elements (including lead (Pb) and other heavy metals), CO, VOCs and subset groups including

PAHs, are already compliant with Group 6 emission standards and world's best practice Best Available Techniques (BATs). There is likely to be a largely negligible change in the air quality impact with respect to the emissions of these pollutants following the plant rehabilitation.

The report also assessed the adequacy of the current ambient air monitoring network and emissions monitoring plan to represent the plant's ongoing performance. The pollutant contours appended to this technical report were able to demonstrate that the LMPS air monitoring station will be able to capture the worst case pollutant concentrations. The assessment of pollutant contours developed as part of the Holmes Air Sciences study also found that the worst case impact of air emissions from the yet to be commissioned Colongra gas turbine development will be in the same region. The emissions monitoring program was also deemed to be adequately robust so as to capture emissions performance through all plant operating conditions.

Best Available Techniques (BATs)

The report has assessed the Munmorah plant rehabilitation program in terms of the best available emission control measures (BATs). Recognising that any change in the air quality impact with respect to the emissions of these pollutants following the plant rehabilitation is likely to be negligible, the assessment concludes that the plant is implementing as many of the BAT measures as is justifiable, on the basis of the marginal environmental benefit.