APPENDIX D

MODELLING OF SULPHUR DIOXIDE LEVELS FROM COAL-BURNING INDUSTRIAL SOURCES USING A STOCHASTIC ESTIMATION TECHNIQUE

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Modelling of sulphur dioxide levels from coal-burning industrial sources using a stochastic estimation technique

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Abstract

The use of a stochastic (Monte Carlo) technique when modelling the potential impact of sulphur dioxide emissions from major industrial coal-burning sources has been investigated. The likelihood that the 1-hour average ground-level concentration of sulphur dioxide will exceed the NEPM(Air) standard of 570μg/m^3 as a result of emissions from a generic coal-fired power station, was predicted. The flexibility to use a different sulphur content distribution for each source allows for a more realistic estimation of the potential impacts of multiple coal-burning sources on the airshed which is important if local and regional airsheds are to be managed effectively.

Keywords: stochastic, Monte Carlo, air quality, sulphur, airshed management

1. Introduction

Analysis of coal samples reveals that the percentage of sulphur in coal, or sulphur content, is not uniform but instead varies depending on the location of the coal seam and within the seam as well. This variability implies that an air quality impact assessment based on dispersion modelling using a single value (typically the highest percentage sulphur content that is expected or allowed) may result in a conservative estimate of the impacts of a coal-burning pollutant source on air quality that is unrealistic.

The choice of representation of the sulphur content of coal becomes increasingly important when considering the impact of a source, either existing or proposed, on an airshed that may already contain a number of sulphur-emitting sources. The effective management of industrial areas that relies on model estimates of the impact of sulphur dioxide emissions on the local and regional airshed will only benefit from a tool that provides a more realistic yet still conservative approach to the estimation of the impact of sulphur dioxide emissions from coal-burning sources.

An additional complication is that each coal-burning source may be fuelled by different coal sources throughout the year. It will be important to model the variability in the sulphur content of coal as the amount of sulphur dioxide emitted from the stacks is directly related to the amount of sulphur present in the coal. In general, it is possible to combine data on the content of sulphur for all of the coal supplies to produce a single probability distribution for each coal-burning source for use with the dispersion modelling. Such a composite probability function may have multiple local maxima.

The random nature of the sulphur content of coal naturally suggests a stochastic approach to the modelling of sources that burn coal. The probability distribution of sulphur content is directly related to the frequency that a particular sulphur dioxide level is emitted from a source. A stochastic approach to the modelling that is able to take into account different coal sources, together with the variability of the sulphur content, both within and between the sources, coupled with an hour-by-hour analysis, will lead to a more realistic representation of the impacts of a source on air quality.

In order to determine the impact from the distribution of coal sulphur contents for various meteorological conditions, all possible combinations of the coal sulphur content will necessarily be considered in combination with these different meteorological conditions. A Monte Carlo simulation can be used to randomly select the coal sulphur content from the sulphur content distribution profiles for each source. When there may exist multiple coal burning sources within the study region, the predicted contribution made by each source can be scaled from the base emission rate used in the modelling. Contributions from each source may then be added together for each hour at each grid point.

2. Test cases

In order to highlight the importance of accurately representing of sulphur content of coal, two test cases were considered:

- Case A: A generic coal-fired power station with an emission rate of sulphur dioxide based on a 0.8% sulphur coal content.
- Case B: A coal-fired power station based on a 0.45% sulphur coal content.

For both cases, simulations were conducted based on either a fixed value for the sulphur content or a stochastic approach based on the Monte Carlo technique. For each of the stochastic simulations conducted, the Monte Carlo process was repeated 500,000 times for each hour for each grid point and the number of times the predicted ground-level concentration exceeded the criteria at each grid point was recorded. To ensure all possible combinations of varying coal sulphur contents and meteorological conditions were compared, the simulations were forced to run for an equivalent of (an arbitrary) 1000 years. Results were then scaled and results plotted to produce an estimate of the number of exceedences per year.

The predicted number of exceedences of the NEPM(Air) 1-hour average ground-level concentration of 570μg/m^3 for sulphur dioxide for the fixed sulphur content approach and the stochastic approach are presented. Results are presented over a subregion of the original domain that covers an area of 9 km by 8 km.

3. Results

3.1. Case A: A coal-fired power station based on an licensing limit of 0.8% sulphur.

The operating license typically specifies an allowable upper limit for the percent sulphur content within the coal consumed by the power station. For this scenario it is assumed that a licensing limit of 0.8% applies. The following scenarios were considered:

- The power station assumed to be consuming coal which consists of sulphur at the licensing maximum of 0.8%
- Stochastic method with the sulphur content distributed over a range of values between 0.2% and 0.8% as depicted in Figure 1.

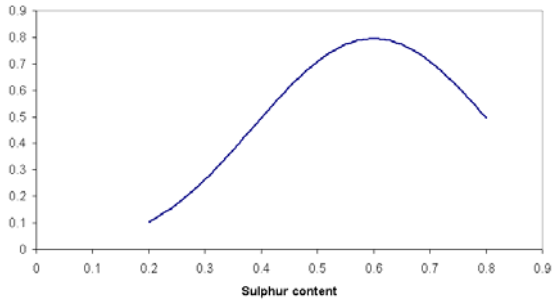

Figure 1. A theoretical sulphur content distribution profile with a maximum of 0.8%.

Presented in the upper panel of Figure 2 are the results for the predicted number of exceedences of the NEPM(Air) standard based on the assumption of a constant coal sulphur content. Presented in the lower panel of Figure 2 are the results using the stochastic method based on a variable sulphur content.

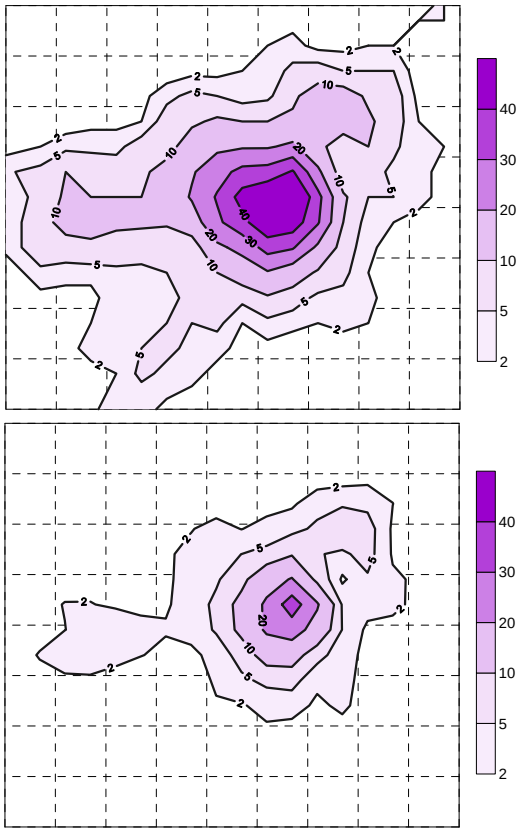

Figure 2.The predicted number of exceedences of sulphur dioxide based on a constant sulphur content of 0.8% (upper) and the stochastic technique (lower).

The difference in the number of predicted exceedences using the fixed sulphur content method minus the stochastic method is presented in Figure 3. Results indicate that for this example, the stochastic method using a distribution for the sulphur content of coal as depicted in Figure 1,

predicts significantly fewer exceedences than when the sulphur content is assumed to be fixed.

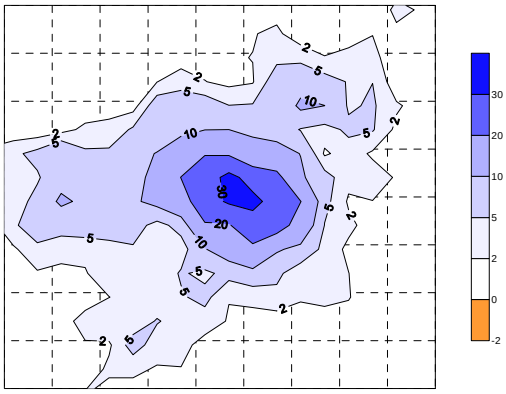

Figure 3. Difference in the number of predicted exceedences of sulphur dioxide based on the constant value approach minus the stochastic technique.

3.2. Case B: A coal-fired power station based on a sulphur content of 0.45%.

The previous example highlights that the prediction of exceedences based on a single value for the coal sulphur content may result in an unrealistically conservative estimate of the impact of a coal-burning source on the local airshed.

However, if a value of the sulphur content that represents the average is used, results using the fixed value approach may potentially underestimate the number of possible exceedences. To highlight this potential underestimation, two simulations were conducted assuming a distribution of coal sulphur content with a distribution centred around 0.45%:

- Fixed sulphur content approach assuming 0.45% sulphur; and
- Stochastic method with the sulphur content distributed over a range of values between 0.25% and 0.8% as depicted in Figure 4.

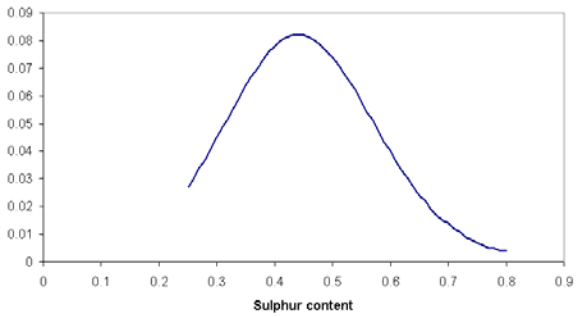

Figure 4. A theoretical sulphur content distribution profile with a local maximum at 0.45%.

Presented in the upper panel of Figure 5 are the results for the constant coal sulphur content scenario. Presented in the lower panel of Figure 5 are the results of the scenario for variable coal sulphur content.

The difference in the number of predicted exceedences using the fixed sulphur content method minus the stochastic method is presented in Figure 6.

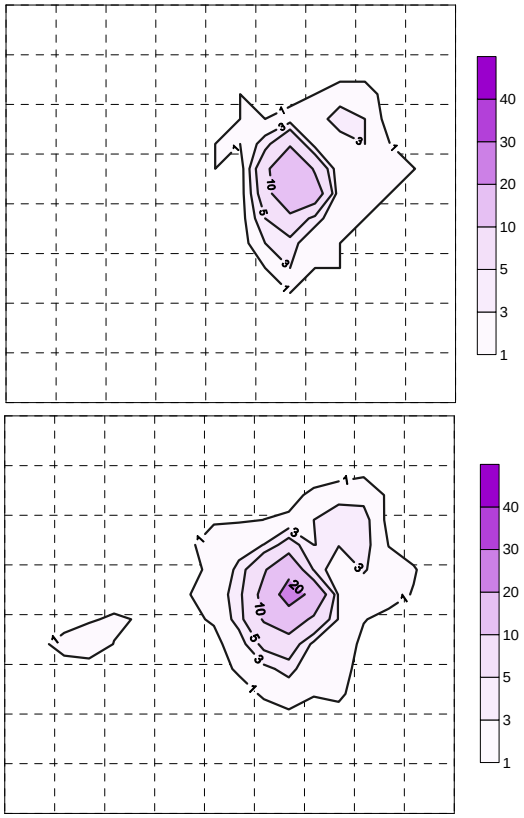

Figure 5. The predicted number of exceedences of sulphur dioxide based on a constant sulphur content of 0.45% (upper) and the stochastic technique (lower).

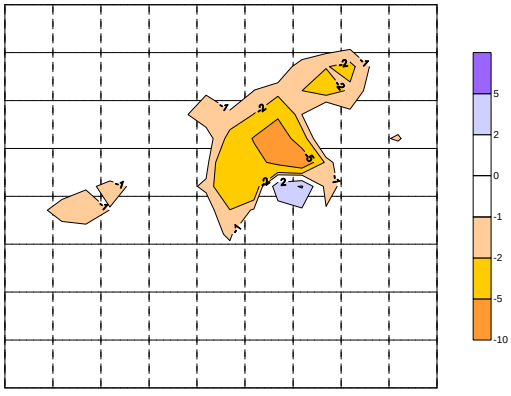

Figure 6. Difference in the number of predicted exceedences of sulphur dioxide based on the constant value approach minus the stochastic technique.

Results indicate that for this example, the stochastic method using the distribution for the sulphur content of coal of Figure 4, predicts slightly more exceedences than the fixed sulphur content approach as indicated by the negative values in the figure.

4. Implications for airshed management

Managing a complex airshed which may contain a wide variety of industrial sources and potentially variable emission rates is a challenge that faces a significant number of industrial cities within Australia and worldwide. The easy solution is to assume all industrial sources emit levels of pollution equal to their licence limits 100% of the time. This could result in unrealistic constraints on the potential future growth of industry.

The stochastic emissions technique allows a better representation of the potential range of emissions from each source. The technique is not limited to modelling the variability in sulphur content of coal, but can be applied to any variable emission so long as a probability function can be generated. Industrial facility licences are typically set at the maximum emission level for normal operations, and sometimes with a buffer to allow some flexibility for operations. The use of stochastic emissions modelling would allow better airshed management by the use of percentile emission licences.

During the environmental evaluation of new industrial facilities the potential impacts due to plant upset emissions should be considered. As the timing for upset emissions are not known it is common practice to model the upset emission rate for a full year of meteorological conditions to predict the worst potential impacts. By use of stochastic emission the frequency of impacts associated with unusual or upset emissions can be better quantified.

5. Discussion

The incorporation of a distributive representation of coal sulphur content combined with the application of a Monte Carlo stochastic method results in a conservative estimate of the impact of a coal-burning source on air quality. The results based on the stochastic approach are expected to be more realistic than estimates based on a single constant value for sulphur content that is typically based on the highest allowable and/or expected value.

The ability to incorporate a different sulphur distribution for each source result in a flexible and potentially more accurate approach to the estimation of exceedence probabilities than would otherwise be possible. The form of the sulphur content distribution is flexible, and may consist of multiple local maxima (for example).

The ability to more accurately represent the distribution of sulphur within coal using the stochastic technique makes this a very useful approach to modelling the potential impacts of coal-fired industries on the local and regional airshed.

References

National Environment Protection Council (NEPM). 1998, ‘National Environment Protection Measure for ambient air quality’.

Appendix E

Inter-Regional Transport Study of the Bayswater Power Station Expansion

Katestone Environmental

Inter-regional Transport Study of the Bayswater Power Station Expansion

Macquarie Generation

22 March 2006

Draft

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1. Introduction

Katestone Environmental has been commissioned by Macquarie Generation to determine the impact of emissions from the proposed expansion of Bayswater power station on air quality in the Sydney metropolitan area.

Macquarie Generation currently operates the Bayswater and Liddell power stations located in the Hunter Valley, New South Wales (NSW). An increase in demand for power has motivated the proposed expansion of the Bayswater power station to include two additional coal-fired power generating units which will be referred to as Bayswater B. There is currently two stack discharge configurations under consideration: a conventional two-flue, single stack arrangement, or two, Heller cooling towers. Both configurations are proposed to have a combined output capacity of either 2 x 750 MW or 2 x 1000 MW.

In order to determine the impact on air quality of any new development that introduces air-borne pollutants into the atmosphere, it is important to identify all geographical scales of importance. Depending on the size of the development, there may be potential to impact on air quality at various scales including the local, regional, and possibly inter-regional scale.

In December 2004, Katestone Environmental conducted a pre-feasibility air quality study of Bayswater B (Katestone, 2005). Based on conservative estimates, this study established that the local airshed was capable of accommodating the proposed expansion to the existing power station. The pre-feasibility study was subsequently extended (Katestone, 2006) to examine more realistic operating scenarios and was able to quantify the impact of emissions from Bayswater B on air quality in the nearby region.

This study considers the potential for emissions of oxides of nitrogen from Bayswater B to be transported into more populated regions and influence the formation of photochemical smog. Photochemical smog forms as a result of complex chemical reactions in the atmosphere between oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and carbon monoxide (CO). The major sources of NO_x, VOCs and CO are anthroprogenic and biogenic emissions. Ozone is the most important air pollutant formed in the photochemical reaction and is the key measure of the impact of the expansion of Bayswater Power Station in this study.

The Metropolitan Air Quality Study (MAQS) conducted by the NSW government in 1992, identified inter-regional transport of pollutants from industries within and outside the greater metropolitan region (GMR) as a potentially important mechanism by which pollutants emitted from distant sources may, under certain synoptic conditions, enter the GMR and impact on air quality in this region. According to the MAQS, the GMR includes the population centres of Sydney and the Central Coast, the Illawarra (Wollongong) and the lower Hunter (Newcastle) regions.

In 1998, the NSW Government introduced its 25-year air quality management plan Action for Air, in which is outlined seven key objectives for the control and reduction of regional air pollution in the GMR. With air quality issues becoming of increasing importance in the expanding, highly-urbanised GMR, quantification of the contribution of pollutant sources to air quality degradation within the region is of significant interest and the subject of some controversy.

In 2002, the CSIRO completed a study (IRTAPS) investigating the impact of the seven coal-fired power stations within and close to the GMR on air quality (Nelson et al., 2002a). These existing power stations are owned by Delta Electricity, Eraring Energy or Macquarie Generation and are located in either the Hunter Valley, Central Coast or Western Coalfields regions. From an initial 16 months of monitoring data covering the summer months of 1996-1997 and 1997-1998, IRTAPS identified a number of days in which inter-regional transport may have occurred. From all days identified, four case study periods were investigated in more detail: 20-22 January 1997; 6-8 February 1997; 25-27 October 1997; and 11-13 March 1998. For each of these periods synoptic conditions were analysed and model sensitivity to the biogenic emissions was conducted. Results are presented in Nelson et al. (2002a, 2002b). A subset of results is also presented in Malfroy (2002).

1.1 Scope of study

The current study of the inter-regional transport (IRT) of emissions from Bayswater B was conducted in conjunction with the CSIRO. Results from IRTAPS that relate to the present state of air quality associated with existing emission sources, forms the basis (or base case) for this study. The findings of IRTAPS are extended via the modification of the emissions inventory to include the Bayswater B expansion.

The main objective of the IRT study was to quantify the potential impact of two proposed configurations of the Bayswater B expansion on air quality on the major urban areas within the GMR, with a particular focus on Sydney's metropolitan region. In order to accomplish this goal, three scenarios have been modeled:

- Base Case (existing situation)
- 2 x 1000 MW twin-flue, single conventional stack
- 2 x 1000 MW Heller Cooling Towers

Scenarios 2 and 3 are expected to provide a reasonable estimate of the upper bound of the impact of Bayswater B on Sydney air quality for the case study days considered. Should Macquarie Generation choose to develop this project with 2 x 750 MW capacity, the corresponding approximately 25% reduction of emissions, is anticipated to result in an impact on air quality within the GMR which is less than that predicted for the 2 x 1000 MW scenarios.

Using CSIRO's TAPM-CTM model, both the conventional and Heller configurations were considered in detail for each of the four case study periods outlined in Section 1 and identified by CSIRO as being associated with IRT.

1.2 Limitations of study

The inter-regional transport study of emissions from Bayswater B is not only numerical-modelling based but relies heavily on the findings of a previous study and thus there are inherently a number of limitations associated with the current study.

- The current study builds on work and results presented in IRTAPS (Nelson 2002a) and does not attempt to validate either the choice of study periods, model performance (beyond ensuring correct implementation), nor model sensitivity.

- No further investigations were conducted into other possible IRT days.

- Privacy issues prevented Katestone from direct access to files containing emissions information on existing facilities and thus no validation of the base case emissions

was possible. Katestone did however append these files to include emissions from each of the two proposed Bayswater B configurations.

- All numerical models based on approximating a governing set of equations will inherently be associated with some degree of error. The more complex a physical scenario a numerical model is meant to represent, typically, the greater the number of physical processes which must necessarily be parameterized. This frequently results in a large number of tune-able parameters within the model. Carefully conducted and thorough sensitivity analyses, ensure that the choice of model parameters used for a given scenario produces reasonable and reliable results. The process of model validation and sensitivity testing can be time consuming and expensive. Therefore, model users must often rely on: default parameter values as recommended within the model user guides or input files; advice from model developers (if available); or published results available in the literature. There exists extensive in-house expertise in the use of TAPM and TAPM-CTM within Katestone and our modelers make use of close ties with CSIRO, developers of TAPM-CTM, to ensure that model results are of the highest possible quality.

2. Bayswater B stack and emission characteristics

A summary of stack and emission characteristics for both the conventional and Heller configurations is given in Table 1.

The emission rate of oxides of nitrogen from the expansion of the proposed Bayswater Power Station is based on the requirements of the Protection of the Environment Operations (Clean Air) Regulation 2002 that specifies a maximum discharge concentration of 500 mg/m^3 for new coal-fired boilers with capacities greater than 30 MW. This represents an upper bound on emissions of oxides of nitrogen.

For the Heller configuration a stack temperature of 48.2°C was applied to all hours. This value for the stack temperature was based on data provided by Macquarie Generation for an ambient temperature of 23.9°C.

Table 1: Stack and emission characteristics for each of the power station configurations.

Parameter	Conventional 2 x 1000 MW	Heller 2 x 1000 MW
Number of stacks	1	2
Number of flues per stack	2	1
Stack location	302895, 6412735	302790, 6412470 303000, 6413000
Stack height (m)	250	150
Stack diameter (m)	11.6	93
Stack temperature (°C)	145.8	48.2
Flow rate (Nm^3/s) per flue	1,722	41,570
Exit velocity (m/s)	25	7.2
Total emission rate of oxides of nitrogen (g/s)	905.4	905.4

3. Impact assessment criteria

The NSW Department of Environment and Conservation has published its requirements for air quality impact assessment in the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DEC, 2005). For ozone, the DEC specify impact assessment criteria based on the standards contained in the National Environment Protection (Ambient Air Quality) Measure (NEPC, 1998) for 1-hour and 4-hour averaging periods (Table 2).

Table 2: Impact assessment criteria for ozone.

Pollutant	Averaging Period	Criteria (ppb)
Ozone	1 hour	100
	4 hour	80

4. Modelling of Inter-Regional Transport using TAPM-CTM

4.1 Methodology

Previous modelling studies of the Bayswater power station expansion undertaken by Katestone Environmental were conducted using TAPM v2.8 (Katestone, 2005) and TAPM v3.0.5 (Katestone, 2006). Although both of these versions of TAPM have the ability to model air pollution chemistry, the photochemical component of the coupled TAPM-CTM model is considered to be superior in its ability to model complex chemical processes. In order to ensure as accurate a result as possible it was decided to use TAPM-CTM for the current study.

Results presented in IRTAPS were based on TAPM or DARLAM for the meteorological component and CIT for the chemical transport modelling. Katestone Environmental was able to obtain TAPM-CTM v1.4e output files from CSIRO for each of the four case study periods investigated in detail in IRTAPS. The current dispersion modelling was conducted using TAPM-CTM v1.5b. The use of different meteorological and chemical models will naturally lead to differences between results presented in IRTAPS, those of CSIRO using TAPM-CTM v1.4e, and those presented in this study (TAPM-CTM v1.5b). These differences may be attributed to a number of factors including:

- The use of different versions of TAPM (or the use of DARLAM instead of TAPM in the case of IRTAPS)
- The chemical models CIT and CTM use different vertical diffusion algorithms.
- CTM uses 3-D temperature and humidity chemistry calculations where CIT only uses near-surface.
- Updating of meteorological fields is more frequent in TAPM-CTM (300s) as opposed to TAPM-CIT, which is updated hourly.
- CIT used the original MAQS biogenic emissions algorithm whereas CTM uses the algorithms developed during the NSW Environment Trust Biogenics project (NSW EPA 1996).
- The anthropogenic inventory used for the TAPM-CTM modelling uses a slightly different motor vehicle emissions inventory. Additionally, VOC emissions from cut grass were included in the TAPM-CTM modelling.
- An error in the units of the vapour pressure term associated with the stomatal resistance calculation in an earlier version of TAPM-CTM v1.4e was corrected in TAPM-CTM v1.5b.

4.2 Study domain and model set up

The study domain used in the current study is the same as that used in IRTAPS and is given in Figure 1. It covers an area of 360 x 360 km, centred at latitude -33.56°, longitude 151.2°.

Results are presented from a 3 x 3 km resolution grid centred over the study region.

The TAPM-CTM configuration files for each of the case study periods were used as supplied by CSIRO and, except for the point source emission file, no modifications of the input files were required. Based on emission parameters as given in Table 1, an emission file was created for each of the Bayswater B configurations.

4.3 Case study periods

For each of the four case study periods, three numerical simulations were conducted using model parameters and default values as recommended by CSIRO. The first involved producing a baseline of modelled ozone resulting from current sources in the region (i.e. the base case). The second simulation incorporated the proposed Bayswater B conventional stack (2 x 1000 MW) emissions into the point source emissions inventory. The third incorporated the proposed Bayswater B Heller stack (2 x 1000 MW) emissions into the point source emissions inventory.

As noted in Section 1, the case study periods identified by IRTAPS as being associated with inter-regional transport were:

- 20-22 January 1997
- 6-8 February 1997
- 25-27 October 1997
- 11-13 March 1998

Each study period involves three days of model simulations. The first day is a model spin-up day and results from this day are not considered. Results from the second and third day of the study period are presented in the following section.

5. Results

5.1 Comparison of base case results with those of CSIRO

The model was validated by comparing results of the base case developed for this study with results obtained by CSIRO using TAPM-CTM v1.4e for the case study periods of IRTAPS. Changes to the TAPM-CTM model associated with the different versions of the code (as noted in Section 4.1), has lead to differences between the base case results for this study and those of CSIRO using TAPM-CTM v1.4e. In particular, the current version of the model, consistently predicts a value for the maximum 1-hour average concentration of ozone that is less than that predicted using the earlier version by 1.9 to 17.5 percent (or 2 to 15.1 ppb). The degree of difference can be entirely accounted for by the correction to the units for the vapour pressure (Martin Cope, CSIRO, personnel communication).

A summary of the peak predicted 1-hour average concentration of ozone for each of the case study days is presented in Table 3.

Table 3: Model validation. Maximum 1-hour average concentration of ozone for each of the case study days.

Study day	Base case		Percentage Difference
	TAPM v1.5b (ppb)	TAPM v1.4e (ppb)	
21 January 1997	85.9	101.0	17.5
22 January 1997	105.9	107.9	1.9
7 February 1997	107.4	116.6	7.8
8 February 1997	132.5	135.1	2.0
26 October 1997	76.6	88.9	16.0
27 October 1997	75.5	78.1	3.4
12 March 1998	84.4	95.5	13.3
13 March 1998	79.7	82.8	3.9

5.2 Impact of Bayswater B on air quality in the Greater Metropolitan Region

The results for each of the three modelling scenarios (base case, conventional configuration and Heller configuration) for all eight case study days are summarised in Tables 4 through 8. Included in the tables are the predicted maximum 1-hour and 4-hour average concentrations of ozone, and the maximum differences in the 1-hour and 4-hour concentrations of ozone calculated as the maximum values from the Bayswater B scenarios minus the base case. Results are also presented for 1-hour average concentrations of ozone for hours 9:00 and 15:00.

5.2.1 Contributions to the maximum 1-hour average concentration of ozone

The model predicts an exceedance of the 1-hour average ozone criterion of 100 ppb on three of the eight case study days, with a total of 10 hourly exceedences (Table 4). Neither the frequency nor magnitude of the exceedance varied with the inclusion of Bayswater B with differences between the peak maximum 1-hour average concentration of ozone for all three scenarios of less than 0.3%. Thus, for the case study periods investigated, no significant impact of Bayswater B on the peak value of the maximum 1-hour average concentration of ozone was predicted.

The results do suggest that over the entire domain there is an impact on the maximum 1-hour average concentration of ozone ranging from 3.6 to 10.8 ppb for the conventional configuration and 2.5 to 11.5 ppb for the Heller configuration. However, for all case days considered, the geographic location of the region that is affected by Bayswater B emissions (typically in northern portion of the study region in the Muswellbrook or Newcastle area) differs from the region containing the predicted maximum 1-hour average concentration of ozone (typically in the southern part of the domain to the south-west of Sydney and/or west of Wollongong). The regional distribution of the base case maximum 1-hour average concentration of ozone and the magnitude of the contribution from Bayswater B for 12 March 1998 are highlighted in Figure 2. Plots for other case study days are presented in Appendix 1.

Table 4: Predicted maximum 1-hour average concentration of ozone and maximum difference in 1-hour average concentration of ozone difference levels for each of the case study days.

Study Day	Base case	Conventional		Heller	
	Maximum (ppb)	Maximum (ppb)	Max-diff. (ppb)	Maximum (ppb)	Max-diff. (ppb)
21 January 1997	85.9	85.9	4.4	86.0	2.5
22 January 1997	105.9	106.0	4.3	105.9	5.1
7 February 1997	107.4	107.4	10.8	107.4	9.4
8 February 1997	132.5	132.5	3.6	132.6	7.0
26 October 1997	76.6	76.7	6.9	76.6	7.9
27 October 1997	75.5	75.9	4.7	75.5	5.7
12 March 1998	84.4	84.4	7.1	84.2	7.7
13 March 1998	79.7	79.8	5.3	79.8	11.3

Table 5: Hours for which exceedences of the criterion for 1-hour average concentration of ozone occurred for each of the three case study days.

Study Day	Number of exceedences	Exceedence Hour (Base case 1-hour average concentration of ozone (ppb)
22 January 1997	2	14:00 (106.9), 15:00 (100.0)
7 February 1997	3	15:00 (104.8), 16:00 (107.4), 17:00 (104.7)
8 February 1997	5	14:00 (116.5), 15:00 (132.5), 16:00 (131.6), 17:00 (124.1), 18:00 (105.5)

5.2.2 Hour 9:00 one-hour average concentration of ozone

In order to aid in the comparison of the current results with those presented in IRTAPS, the maximum 1-hour average concentrations of ozone at hour 9:00 are presented. Note that the 1-hour average concentration of ozone assigned to hour 9:00 is for the averaging period from 9:00 to 10:00.

Results are summarised in Table 6. Ozone concentrations are generally in the low to mid 40's and are consistent with typical background levels. Over all case days, results in general indicate a slight reduction in ozone levels due to Bayswater B emissions. Contributions ranged from -7.4 to 2.3 ppb for the conventional configuration and from -4.7 to 2.5 ppb for the Heller configuration.

Figure 3 includes contour plots of maximum 1-hour average concentrations of ozone for the base case as well as contribution plots for both of the Bayswater B configurations for hour 9:00, 12 March 1998. The area impacted by the power station at this particular time is very localised in a region to the west-southwest of Muswellbrook.

The scatter plots in Figure 3 highlight that the reduction in ozone level due to emissions from the Bayswater B expansion on ozone concentrations at 9:00 on 12 March 1998, occurred in regions that in the base case experienced ozone concentrations in the range from 20 to 35 ppb. The contribution of emissions from Bayswater B to the 1-hour average concentration of ozone ranged from - 7.4 to 0.8 ppb for the conventional configuration, and from - 4.7 to 0.5 ppb for the Heller configuration.

Results presented here are typical of all days studied although the region of localised impact varies. Plots for other case study days are presented in Appendix 2.

Table 6: Predicted base case maximum 1-hour average concentration of ozone and maximum/minimum differences in 1-hour average concentration of ozone at hour 9:00 for each of the case study days.

Study Day	Hour	Base case	Conventional		Heller	
		Maximum (ppb)	Min-diff. (ppb)	Max-diff. (ppb)	Min-diff. (ppb)	Max-diff. (ppb)
21 January 1997	9:00	38.6	-2.5	1.1	-0.7	0.3
22 January 1997	9:00	43.4	-3.1	0.7	-0.3	0.5
7 February 1997	9:00	40.4	-4.0	1.6	-2.4	0.9
8 February 1997	9:00	45.2	-2.1	1.3	-1.1	0.5
26 October 1997	9:00	47.5	-6.0	1.8	-2.9	0.8
27 October 1997	9:00	46.4	-3.4	2.3	-1.7	2.5
12 March 1998	9:00	40.0	-7.4	0.8	-4.7	0.5
13 March 1998	9:00	42.8	-1.7	1.2	-4.1	2.0

5.2.3 Hour 15:00 one-hour average concentration of ozone

Although the exact hour of the maximum predicted 1-hour average concentration of ozone varies between 14:00 and 16:00, to aid in the comparison of current results with those of IRTAPS, model predicted 1-hour average concentrations of ozone for hour 15:00 are presented. Note that the value for 1-hour average concentration of ozone assigned to hour 15:00 is for the averaging period from 15:00 to 16:00.

Results are summarised in Table 7. Consistent with those presented in Section 5.2.1, maximum 1-hour average concentrations of ozone at this time range from 70.1 to 132.5 ppb with exceedences of the 1-hour criterion for ozone of 100 ppb occurring on three of the eight days.

Results in general indicate that there are areas of limited size within the study region that experience a reduction or increase of ozone levels with contributions ranging from -10.0 to 10.7 ppb for the conventional configuration, and from - 5.7 to 9.1 ppb for the Heller configuration.

Figure 4 includes contour plots of maximum 1-hour average concentrations of ozone for the base case as well as contribution plots for the two Bayswater B configurations for hour 15:00 on 12 March 1998. The area impacted by the power station at this particular time is localised to a region to the west of Muswellbrook.

The scatter plots in Figure 4 highlight the negative and positive contribution of emissions from Bayswater B to the overall 1-hour average concentration of ozone. Deviations from the base case 1-hour average concentrations of ozone ranged from -10.0 to 7.1 ppb for the conventional configuration and from -4.0 to 7.7 ppb for the Heller configuration.

The scatter in Figure 4, when the base case indicates 1-hour average ozone concentration of less than 55 ppb, highlights that the impact of the emissions from Bayswater B is limited to areas which would otherwise experience background, or near background, levels of ozone at this time. In the region southwest of Wollongong where the base case 1-hour average concentration of ozone was greater than 70 ppb, Figure 4 indicates that for the Heller configuration, there was a slight contribution to 1-hour average concentrations of ozone of the order of $\pm$1 ppb.

Results presented here are typical of all days studied although the region of localised impact varies. Plots for other case study days are presented in Appendix 2.

Table 7: Predicted base case maximum 1-hour average concentration of ozone and maximum/minimum differences in 1-hour average concentration of ozone at hour 15:00 for each of the case study days.

Study Day	Hour	Base case	Conventional		Heller	
		Maximum (ppb)	Min-diff. (ppb)	Max-diff. (ppb)	Min-diff. (ppb)	Max-diff. (ppb)
21 January 1997	15:00	84.1	-4.9	3.4	-1.8	1.5
22 January 1997	15:00	100.0	-3.9	3.2	-1.4	4.2
7 February 1997	15:00	104.8	-2.7	10.7	-0.5	7.5
8 February 1997	15:00	132.5	-5.2	2.4	-1.2	7.0
26 October 1997	15:00	76.6	-13.1	6.9	-5.7	7.7
27 October 1997	15:00	70.1	-3.8	3.4	-0.4	5.3
12 March 1998	15:00	81.5	-10.0	7.1	-4.0	7.7
13 March 1998	15:00	79.7	-4.1	4.9	-1.4	9.1

5.2.4 Contributions to the maximum 4-hour average concentration of ozone

On these same three case study days for which exceedences of the 1-hour ozone criterion was predicted (i.e. 2 January 1997 and 7-8 February 1997) the model also predicts an exceedance of the 4-hour average ozone criterion of 80 ppb (Table 8). This suggests that the ozone events on these days were significant with elevated ozone levels sustained for several hours. Results for both the maximum and maximum-difference in the predicted 4–hour average concentration of ozone levels suggest that the inclusion of Bayswater B had no significant impact on the peak 4-hour average concentration of ozone during these case study periods with peak values varying by less than 0.2%.

Table 8: Predicted maximum 4-hour average concentration of ozone and maximum difference in 4-hour average concentration of ozone difference levels for each of the case study days.

Study Day	Base case	Conventional		Heller	
	Maximum (ppb)	Maximum (ppb)	Max-diff. (ppb)	Maximum (ppb)	Max-diff. (ppb)
21 January 1997	70.4	70.4	2.1	70.5	1.1
22 January 1997	85.1	85.0	2.8	85.2	2.4
7 February 1997	86.7	86.7	6.9	86.7	4.5
8 February 1997	108.5	108.6	2.0	108.6	4.4
26 October 1997	71.4	71.5	5.9	71.4	7.3
27 October 1997	68.9	69.1	3.2	69.0	4.5
12 March 1998	74.9	74.9	5.7	74.9	7.0
13 March 1998	70.1	70.1	2.7	70.1	7.5

6. Conclusions

Katestone Environmental has worked in conjunction with CSIRO to conduct an air quality assessment of the proposed expansion of Bayswater power station (Bayswater B) to quantify the impact of photochemical smog formation in the Sydney, Newcastle and Wollongong areas.

Four case study periods were studied in order to quantify the affect of the inter-regional transport of air emissions from Bayswater B on ozone levels. The case study periods correspond to those identified by CSIRO in IRTAPS.

Two proposed Bayswater B configurations were considered: a conventional, two-flue, single stack configuration and a configuration consisting of two Heller cooling towers. The combined output of either arrangement was modelled at 2 $\times$ 1000 MW.

The current study found that the maximum increase in the 1-hour average concentration of ozone within the study region, over the total eight days studied, did not exceed 10.8 ppb and 11.3 ppb for the conventional and Heller configurations respectively. Regions predicted to experience these variations in the 1-hour average concentration of ozone were found to be located outside the Sydney, Newcastle and Wollongong areas, primarily in the northern portion of the domain, to the west and south of Muswellbrook.

There was no significant change to the predicted peak 1-hour or 4-hour average concentration of ozone (with values differing by less than 0.3%). Based on current modelling results, the proposed expansion of Bayswater power station was not found to have a significant effect on ozone levels within the Sydney airshed during the case days investigated, and the inclusion of Bayswater B did not lead to additional exceedences of the 1-hour impact assessment criterion for ozone within the study region.

As the work conducted to date is based on Bayswater B having an output of 2 x 1000 MW, the results presented here are anticipated to provide a reasonable estimate of the upper bound on air quality impact for the case days considered. Results for the proposed 2 x 750 MW configurations are not expected to differ significantly from those presented here other than overall variations of ozone within the domain are anticipated to be less than quoted above as a result of the approximately 25% reduction in emissions.

There was no consistent trend found with respect to impact on ozone that could be attributed to fundamental stack design differences of the two configuration types. Further investigations would be required in order to quantify any possible significant trends in IRT as a result of differences in (for example) plume buoyancy associated with either the conventional configuration or Heller configuration. Thus, due to the limited number of study days investigated for the current study, results have not been able to highlight any differences between the conventional versus Heller stack discharge configurations that are of statistical significance.

7. References

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Figure 1: Study domain used by TAPM-CTM.

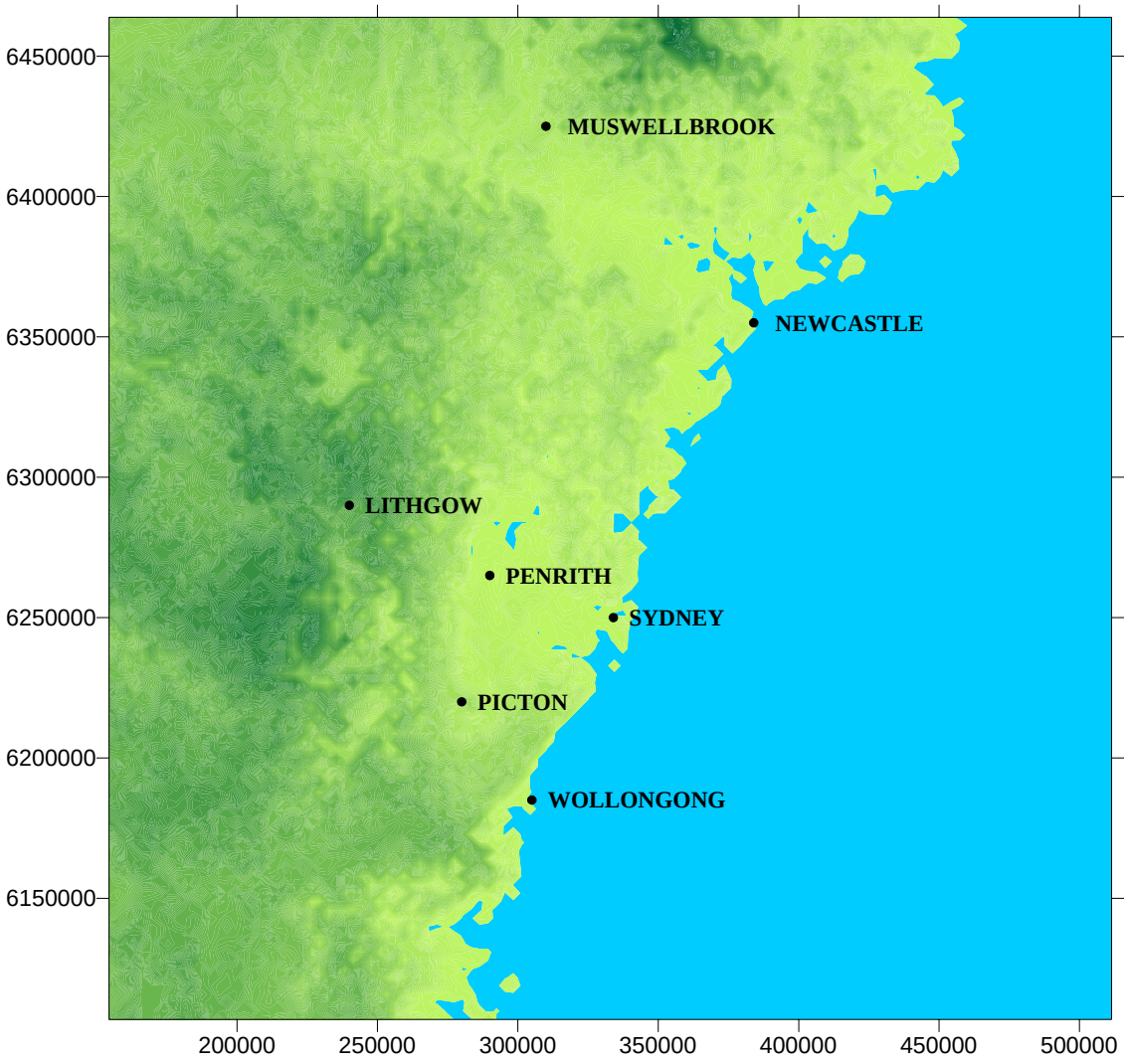
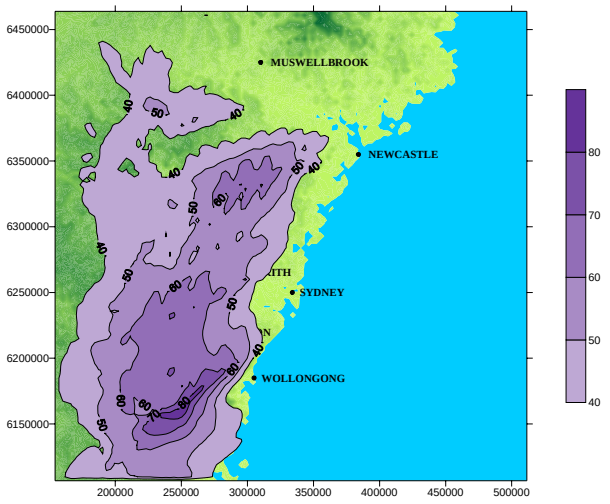
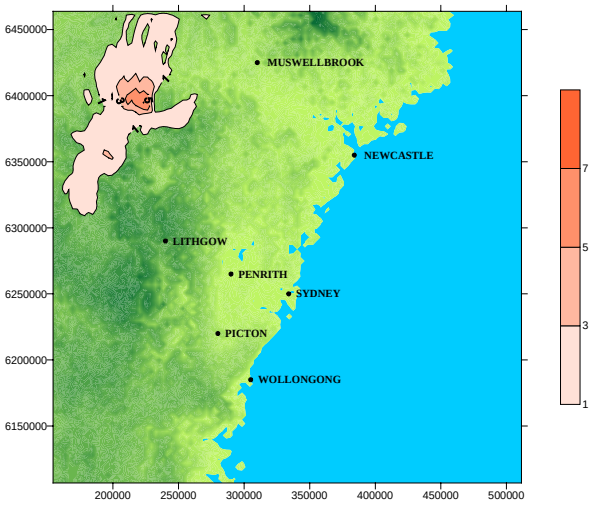


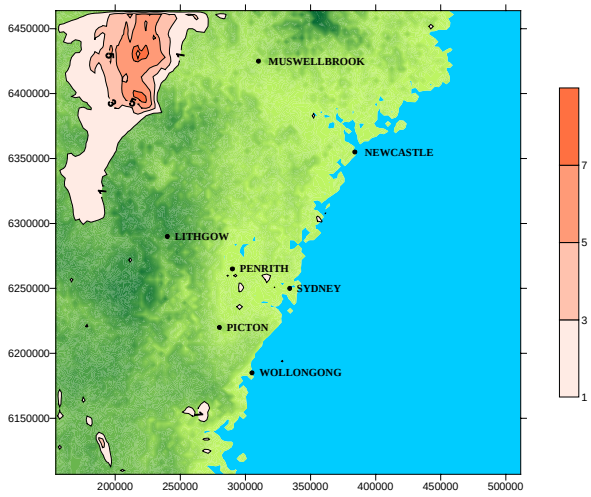
Figure 2: 12 March 1998. Plots of maximum 1-hour average concentration of ozone (base case) and the contribution of Bayswater B to the maximum 1-hour average concentration of ozone (conventional and Heller configurations).



Base Case (ppb)

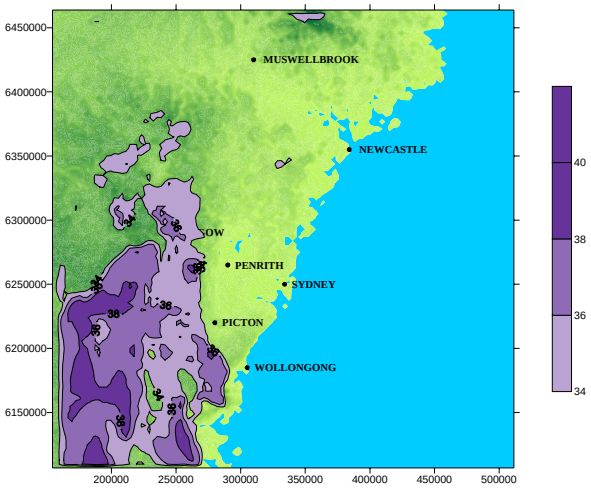


Contribution: Conventional Stack (ppb)



Contribution: Heller Stack (ppb)

Figure 3: 12 March 1998. Plots of hour 9:00, 1-hour average concentration of ozone (base case), the contribution of Bayswater B to the 1-hour average concentration of ozone (conventional and Heller configurations), and scatter plots.



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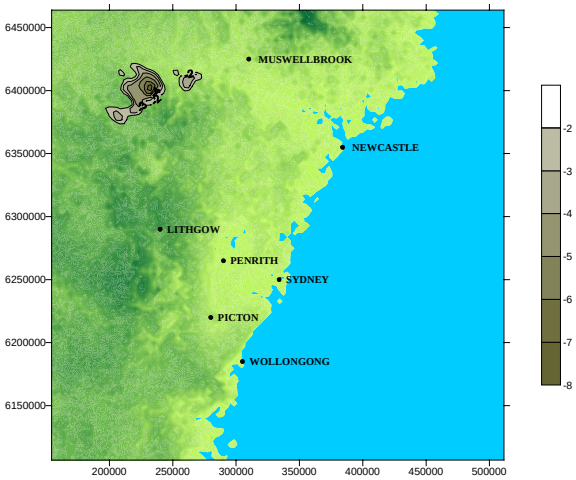

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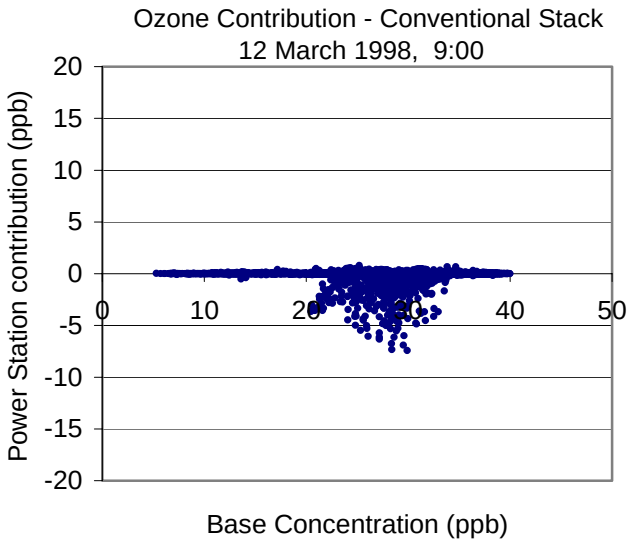

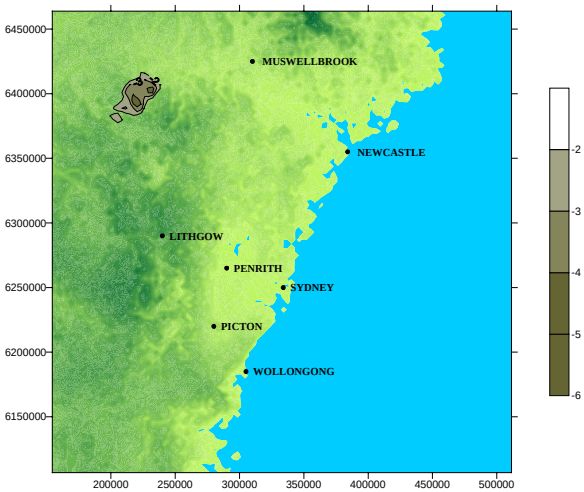

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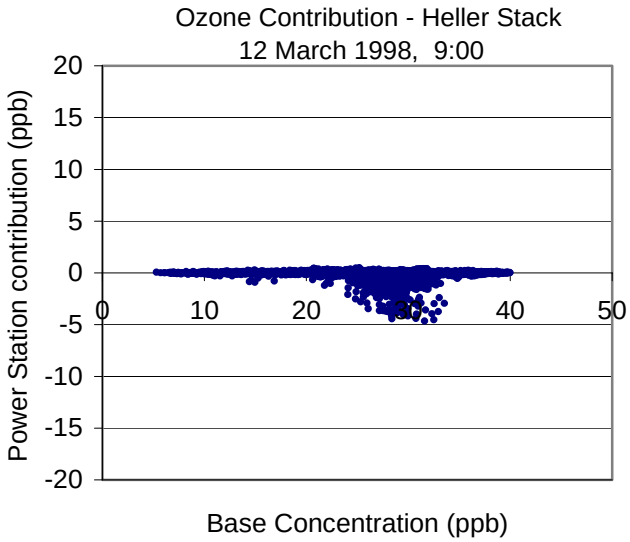
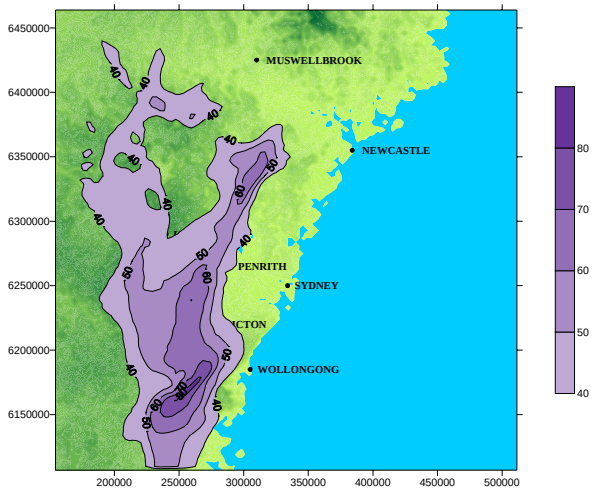
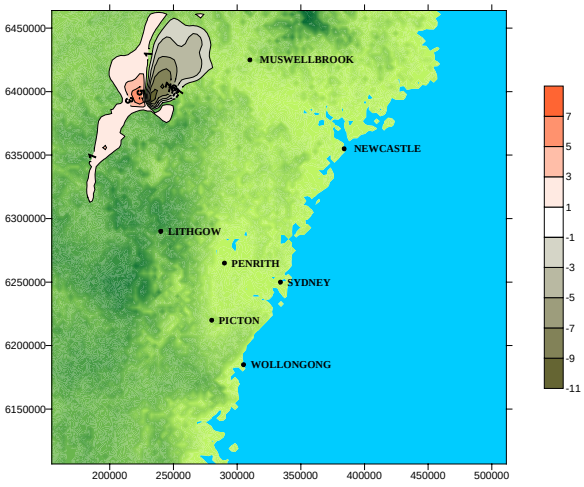


Figure 4: 12 March 1998. Plots of hour 15:00, 1-hour average concentration of ozone (base case), the contribution of Bayswater B to the 1-hour average concentration of ozone (conventional and Heller configurations), and scatter plots.



Base Case (ppb)



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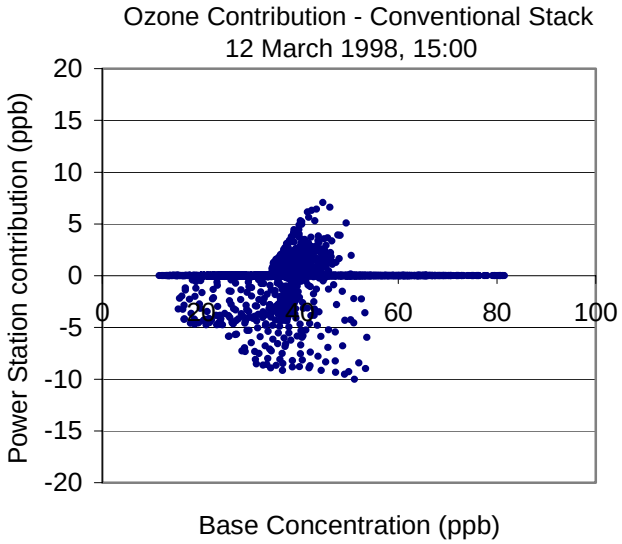
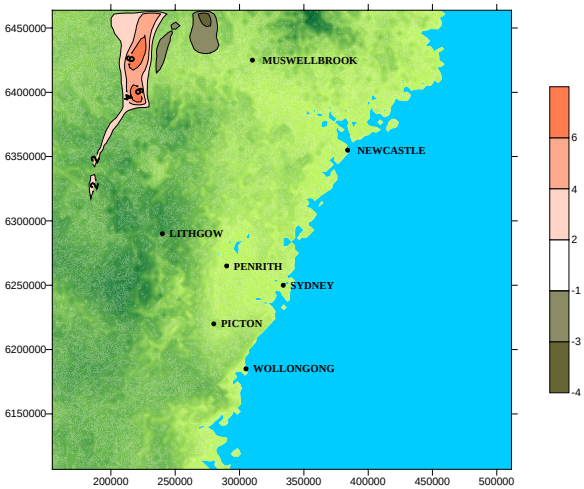
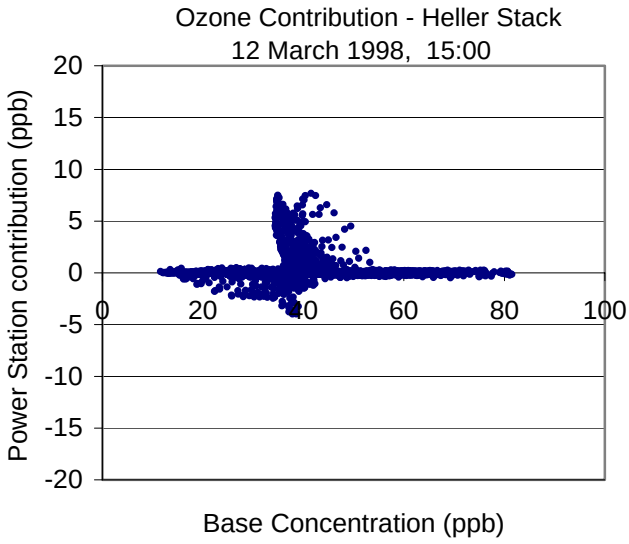


Base Concentration (ppb)



Contribution: Heller Stack (ppb)



Base Concentration (ppb)

View to existing Bayswater Power Station