Consulting
Air pollution
Modelling &
Meteorology

Lane Cove Tunnel

Assessment of Air Quality Monitoring Data

Report to:

Thiess John Holland

Consulting Air pollution Modelling & Meteorology (CAMM)
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Graeme Ross & Associates Pty Ltd A.C.N. 063 931 420 A.B.N. 94 063 931 420
PO Box 292, Ashburton, Vic, Australia. 3147
Tel: (03) 9560 9555, Fax: (03) 9560 9554, Mobile: 0418 371 826, Email: graeme.ross@camm.net.au

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Client	**Parsons Brinckerhoff Australia Pty Ltd**			
Project No.	**14/06**	**Project manager**	**Graeme Ross**	
		QA/QC	**Stewart Allen**	
Report Authors	**Graeme Ross and Stewart Allen**			
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Graeme Ross & Associates Pty Ltd A.C.N. 063 931 420 A.B.N. 94 063 931 420
PO Box 292, Ashburton, Vic, Australia. 3147
Tel: (03) 9560 9555, Fax: (03) 9560 9554, Mobile: 0418 371 826, Email: graeme.ross@camm.net.au

EXECUTIVE SUMMARY

A technical review has been conducted of the monitoring data collected from the two (2) community-based monitoring stations (CBMSs) to assess if the data collected to date meets the ***intent*** of MCoA 165 in regards to providing adequate and representative:

- 'Base-line' information with which to assess any changes in ambient air quality following the operation of the tunnel.
- Input information to assist in demonstrating compliance with the requirement of MCoA 168, 170 and 173.

Concurrent data from the community-based station West (CBW) and East (CBE) for the 1-year period: June 2005 to May 2006 inclusive have been analysed in terms of:

- Comparison with ambient criteria for air pollution concentration.
- Correlation between CBMS Monitoring Stations
- Correlation between CBMS and 'Project Monitoring Station' Data
- Correlation between CBMS and DEC Monitoring Station Data

The key outcomes from this analysis of relevance to the two key elements of the assessment are as follows:

Adequacy of 'Base-line' Information

The assessment suggests that the 1-year dataset from CBW and CBE analysed in the report provides adequate and representative 'base-line' information with which to assess any changes in ambient air quality following the operation of the tunnel. The following outcomes and factors provide support for this conclusion:

- The good agreement between the CBMSs, and with the monitoring data from the other stations examined which reflect both spatial and temporal variations. Note that it could be argued that the good agreement between the CBMSs and the earlier 'Project Station' at Mowbray West Primary School implies that 2-years of site-representative data are in effect already available, albeit that the total dataset is spread over two different years and the earlier station was not a CBMS.
- The total 14-month dataset from the CBMSs already contains monitoring data from two (2) years for two of the months (May and June) during which the highest monthly background concentrations of nitrogen dioxide and carbon monoxide occur.
- The 14-month dataset will be progressively supplemented with more monitoring data for more 'duplicate months' prior to the opening of the tunnel.

Adequacy of Input Information re MCoA 168, 170 and 173

A key component in demonstrating compliance with the requirements of MCoA 168, 170 and 173 will be to provide: (i) monitoring data for direct use in assessing compliance with the conditions; and (ii) input data for any associated air impact assessment modelling.

The conclusions reached regarding the adequacy of the base-line information imply that the 1-year data set from CBE and CBW analysed will be adequate in regards to (i). In regards to (ii), the inputs to modelling will consist of meteorological data for representing transport and dispersion of the relevant emissions, and background concentrations of the pollutants of interest for input to both the emission estimates and as direct input to the modelling for representation of the background or 'other' sources.

DEC[1] (2005) requires a minimum of one year of site-representative meteorological and background air quality concentration data. The outcomes highlight that this requirement will be satisfied, albeit that the meteorological datasets will continue to be only one (essential) of the inputs to the construction of representative fully 3D meteorological fields.

It is also important to note that the modelling conducted in support of the design phase, CAMM (2004, 2006a, 2006b), indicates that the predicted incremental impacts resulting from the emissions to air from the two (2) tunnel vent stacks will be small. Indeed, the predicted magnitudes of these increments are such that they are significantly less than the normal variations (hour to hour, day to day, year to year, etc.) in monitoring data for each pollutant. As such, it is highly unlikely that a comparison of the monitoring data collected 'pre' and 'post' the opening of the tunnel will detect these increments. However, this form of comparison will provide the basis for assessing any changes in ambient air quality that arise from the estimated reduction in traffic from the network of surface roads when the tunnel opens.

[1] Department of Environment and Conservation (DEC), NSW.

CONTENTS

1. INTRODUCTION

The Road Traffic Authority (RTA) of NSW has appointed the Lane Cove Tunnel Company (LCTC) to construct the Lane Cove tunnel and associated road works, who has in turn subcontracted Thiess John Holland (TJH) to design and construct the Project.

The Director General's report for the Lane Cove Tunnel Project discussed the need for ambient air quality monitoring and this is reflected in a number of Ministers Conditions of Approval (MCoA 165, 168, 170 and 173).

As part of MCoA 165, Thiess John Holland (TJH) is required to collect at least two (2) years of ambient air quality data prior to the opening of the Lane Cove Tunnel Project:

"The Proponent shall establish one (1) community based monitoring station (CBMS) associated with each ventilation stack… at least two (2) years prior to the opening of the Project to traffic.".

TJH established and commenced monitoring at the CBMSs in May 2005, with 14 months of validated data to June 2006 inclusive currently available. Consequently, monitoring to May 2007 is required in order to obtain the specified minimum of two years of data. Note that TJH has also collected ambient air quality data for the Project at two ground based monitoring stations (GBMS) and two elevated receptor monitoring stations (ERMS), which have been operating since September 2005. Figure 1.1 illustrates the location of the various monitoring stations together with the location of the Lane Cove tunnel and the two vent stacks.

The possibility that the Project could open earlier than May 2007 has been recently identified so TJH have requested Consulting Air pollution Modelling & Meteorology (CAMM) to undertake a technical review to determine if the data that has, and will have been collected, is sufficient upon which the following can be assessed:

- There is sufficient and adequate data to meet the intent of MCoA 165 (as described in the Director Generals Report).
- The ambient data collected during the operational period can be compared to pre-operation and any improvements to the regional air shed could be determined.
- The ambient air quality data is suitable to enable compliance with the conditions of Approval, specifically MCoA 168, 170 and 173.

It is proposed that the technical review will form the basis of a supporting document to a Justification Report to be submitted by TJH to the Department of Planning to enable a modification to MCoA 165, and thus enable the Project to open early, if the technical review supports this outcome.

Note that CAMM has provided air quality modelling and advice in support of the Project Design Phase undertaken by Parsons Brinckerhoff Australia Pty Ltd (PB) for TJH. In particular, CAMM (2004, 2006a, 2006b) presented the outcomes of a regulatory assessment of emissions to air from the vent stacks associated with the Lane Cove tunnel. The results presented were for a range of design ventilation flow rates, including the "Optimum (Design) Case', with all cases shown to comply with the relevant ambient air quality criteria for both "normal" and "congested" traffic conditions.

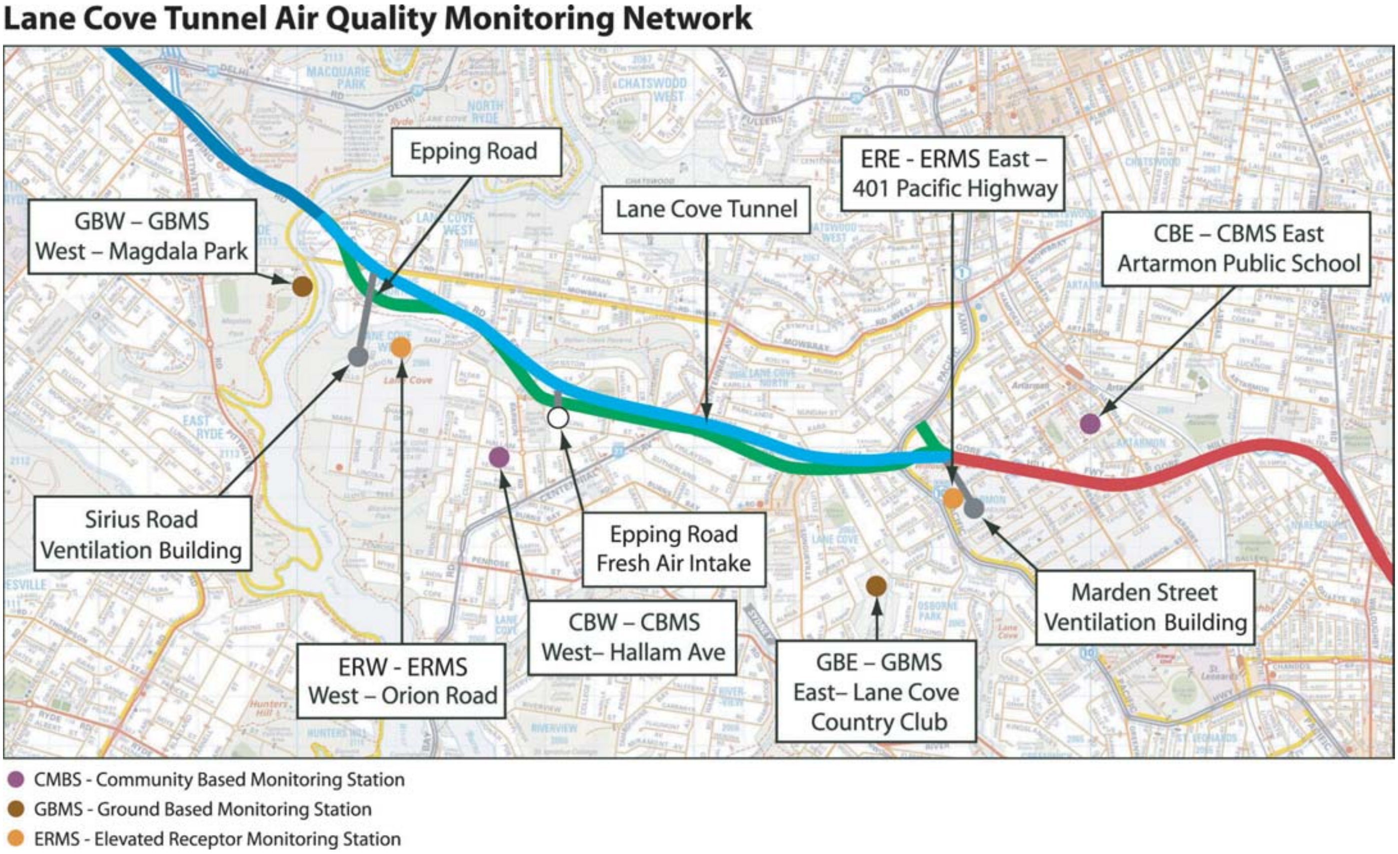


Figure 1.1: Lane Cove Tunnel Air Quality Monitoring Network

2. METHODOLOGY

2.1 Introduction

Concurrent data from the community-based station West (CBW) and East (CBE) for the 1-year period: June 2005 to May 2006 inclusive have been analysed in Section 3 in terms of:

- Comparison with ambient criteria for air pollution concentration.
- Correlation between CBMS Monitoring Stations
- Correlation between CBMS and 'Project Monitoring Station' Data
- Correlation between CBMS and 'DEC Monitoring Station' Data

The 'Project Monitoring Station' data selected covers the 1-year period 1st December 2000 to 30th November 2001, inclusive and corresponds to a sub-set of that collected from a project specific monitoring site at Mowbray West Primary School during the period 23rd October 2000 to 28th January 2002 (henceforth referred to as the 'Project monitoring station' or the Mowbray monitoring site)[2]. Data were also collected during this period from a second project specific monitoring site located at the intersection of Longueville and Epping Roads (henceforth referred to as the Epping Road monitoring site). Note that:

- Data from the Epping Road site are representative of near-road concentrations in one of the most heavily trafficked locations in the area, while Mowbray data are representative of the current concentration levels in the residential areas set back from the major arterial roads.[3]
- Data from both sites, for the 1-year sub-set period 1st December 2000 to 30th November 2001 were used in determining appropriate background concentration levels for the air impact assessment described in CAMM (2004, 2006a, 2006b). Table 2.1 contains the background concentrations used for the Level 1 Assessment for each indicator and averaging period, where the values illustrated are the maximum values measured at the Epping Road and Mowbray sites stations during the simulation period (see CAMM (2004) for further details).

Table 2.1: Summary of background concentrations for Level 1 Assessment (from CAMM, 2004)

Pollutant	Background Concentration: Areas on or close to busy roads (Epping Road site)	Background Concentration: Areas remote from busy roads (Mowbray site)
NO_2 – 1-Hour	8.2 pphm	5.8 pphm
NO_2 – Annual	1.9 pphm	1.3 pphm
CO – 1-Hour	8.3 ppm	3.3 ppm
CO – 8-Hour	5.3 ppm	2.7 ppm
PM_{10} – 24-Hour	48.1 $\mu g/m^3$	31.4 $\mu g/m^3$
PM_{10} – Annual	24.8 $\mu g/m^3$	14.1 $\mu g/m^3$

The 'EPA Monitoring Station' data selected corresponds to those collected at the NSW Environment Protection Authority (EPA)[4] Rozelle monitoring station for two 12 month periods, December 2000 – November 2001 (henceforth referred to as 'Rozelle 2001' and selected to

[2] Note that 24-hour averaged PM10 data from the Project Station was collected once every 6 days via a hi-vol sampler at the site. To make a compete year-long data set, these measurements were infilled using 24-hour averaged TEOM data collected at the nearby DEC Lindfield site. Full details of this process can be seen in CAMM (2004).
[3] Note that meteorological data concurrent with the concentration monitoring data were only collected at the Mowbray station.
[4] Department of Environment and Conservation (DEC), NSW.

correspond to the period covered by the 'Project Monitoring Station') and June 2005 – May 2006 (henceforth referred to as 'Rozelle 2005' and selected as broadly representative of the period covered by the CBMSs), respectively. PM_{10} data for Rozelle was not available for the period December 2000 – November 2001 and so cannot be analysed.

2.2 Comparison/Correlation Techniques Adopted

2.2.1 Analysis of Meteorological Data

- The local airshed surrounding the Lane Cove tunnel contains relatively complex topography and land-use characteristics. These complexities are in turn reflected in complexities in the local meteorology, with significant spatial variability as a result of complex interactions between synoptic scale influences and local scale influences due to topography and differential heating and cooling.
- The need to incorporate this complexity was recognised in the air impact assessments conducted in the original EIS[5] and in the 'Design Phase' (see CAMM 2004, 2006a, 2006b), with a combination of the prognostic model TAPM, the diagnostic model CALMET, together with the assimilation of wind observations from various meteorological monitoring stations, used to construct 3D meteorological fields with full spatial and temporal variability.
- As such, a detailed comparison between the available meteorological datasets, which are at different spatial locations, and in many cases are not for concurrent time periods, is unlikely to be of direct value in the context of the current analysis.
- Consequently, the comparison between the CBMS datasets, and with meteorological databases from other stations, has been limited to the following characteristics at each site, with the expectation that the analysis will merely provide further justification for the need to utilise 3D meteorology with full spatial and temporal variability:
  - Histograms of wind speed
  - Wind roses

2.2.2 Analysis of Air Pollution Concentration Data

Comparison with ambient criteria

The results presented in Section 3.2.1 provide time series plots of the pollutants/indicators of relevance and a comparison with the relevant ambient criteria. The plots are also presented in a form that allows a direct visual comparison between the CBMSs, and with equivalent data collected at the project specific sites at Epping Road and Mowbray West Primary School, which are illustrated in CAMM (2004).

Comparison/Correlation with other Datasets

The primary interest, and hence the comparison between the CBMS datasets, and with concentration databases from other stations, has focussed mainly on the 'upper end', or 'upper percentiles' of the measured concentrations, albeit that information on the full range of percentiles has also been presented. In this regard the results presented in Section 3 include:

- Tabulation of the following measures:

[5] RTA (2001).

    - Maximum
    - Mean
    - Mean of the top 10%
    - 90^{th} percentile
    - 50^{th} percentile (median)
    - 10^{th} percentile

- A scatterplot and correlation between datasets that have been ranked from highest to lowest. Note that the resulting ranked correlation and associated correlation coefficient provide a measure of the correlation between frequency distributions.
- Plots of monthly values for the Maximum, Mean and Mean of the top 10% of values for each month. These plots determine/display any clear seasonal variations.

3. RESULTS

3.1 Analysis of Meteorological Data

3.1.1 Wind Speed Analysis

Figures 3.1 and 3.2 show histograms of wind speed at the CBMSs, for hourly observations in the 12 months spanning June 2005 to May 2006, inclusive. These histograms show a predominance of light winds, with more the 50% of wind speed measurements being less than 2 m/s at each site. In general, it appears that wind speeds at the CBW monitoring station are typically less that at the CBE monitoring station. This is reflected in a higher percentage of "calm" winds (less than 0.5 m/s), smaller percentages in the higher wind speed classes, and an overall smaller average wind speed. Note that such differences are likely to be an indication of the complexity of the local wind fields as highlighted previously in Section 2.2.1.

Figure 3.3 shows an equivalent histogram of wind speed at the 'Project Monitoring Station' at Mowbray West Primary School, for the period December 2000 – November 2001. Comparing this to Figures 3.1 and 3.2, it is apparent that the distribution of wind speeds at the 'Project Monitoring Station' is similar to those at the CBMSs. In particular, there is a strong predominance of light winds, with well over 50% of wind speed measurements being less than 2.1 m/s. There is also a similar low incidence of high winds.

Figures 3.4 and 3.5 show histograms of wind speed at the NSW EPA[6] Rozelle monitoring station for two 12 month periods, December 2000 – November 2001 and June 2005 – May 2006, respectively. Note that this site is well removed from the CBMSs and the 'Project Monitoring Station', being some 6 to 7 km south of the LCT area. Despite this, the histograms for the Rozelle site show broadly similar characteristics to those of the CBMSs and 'Project Monitoring Station', i.e., a predominance of light winds. There are higher instances of larger wind speeds compared to the other sites, however, again over 50% of wind speed measurements are less than 2.1 m/s, and the average wind speed of each year at Rozelle is comparable to the CBMSs and 'Project Monitoring Station'.

[6] Department of Environment and Conservation (DEC), NSW

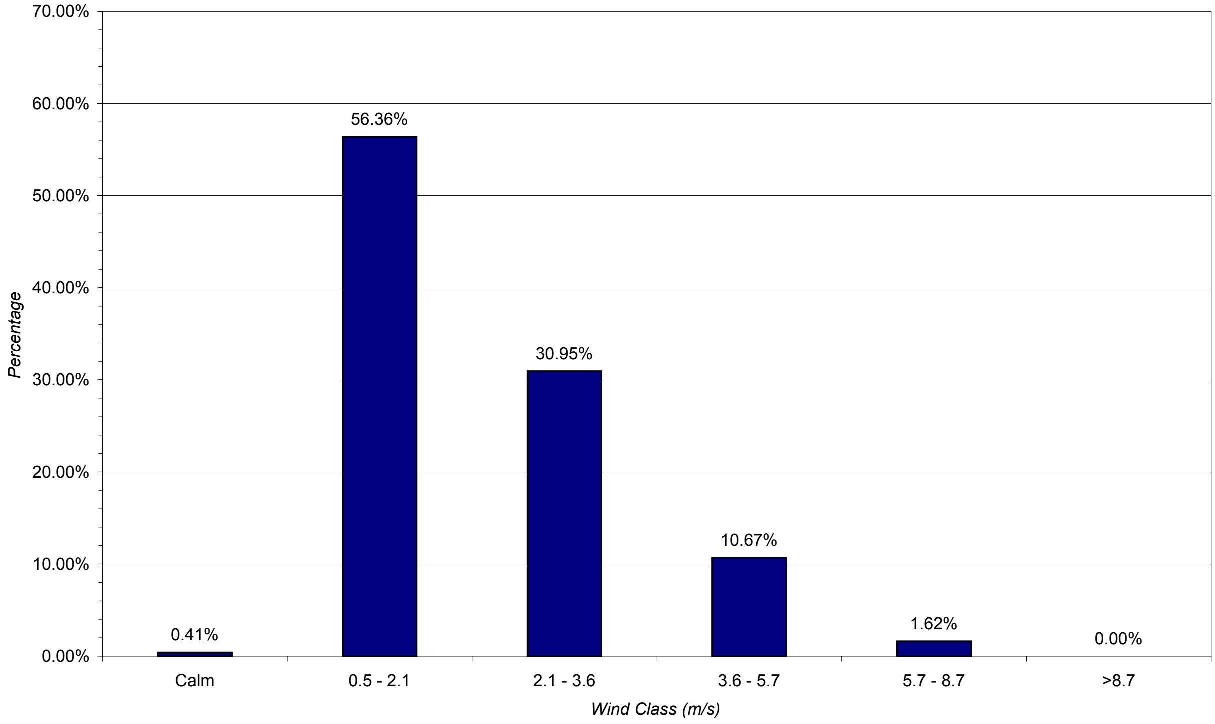


Figure 3.1: Histogram of Wind Speeds at CBE monitoring station, June 2005 – May 2006. Average wind speed is 2.16 m/s.

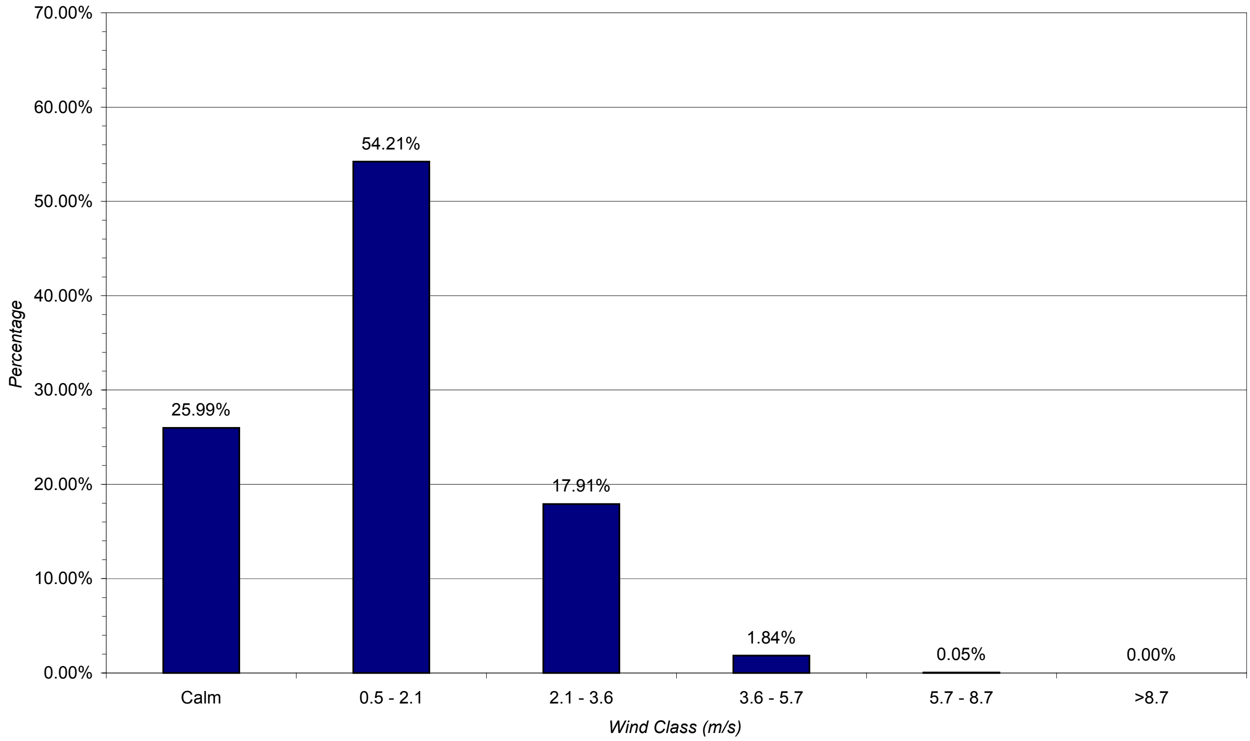


Figure 3.2: Histogram of Wind Speeds at CBW monitoring station, June 2005 – May 2006. Average wind speed is 1.19 m/s.

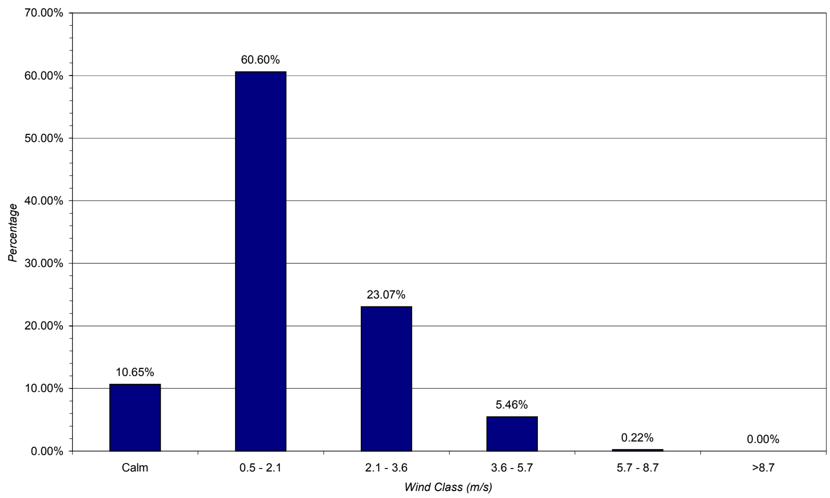


Figure 3.3: Histogram of Wind Speeds at 'Project Monitoring Station', December 2000 – November 2001. Average wind speed is 1.58 m/s.

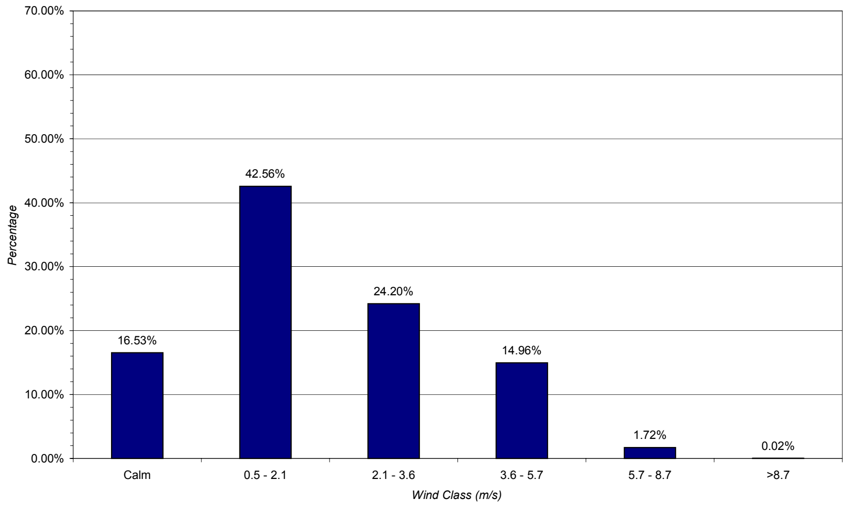


Figure 3.4: Histogram of Wind Speeds at NSW EPA Rozelle Monitoring Station', December 2000 – November 2001. Average wind speed is 1.96 m/s.

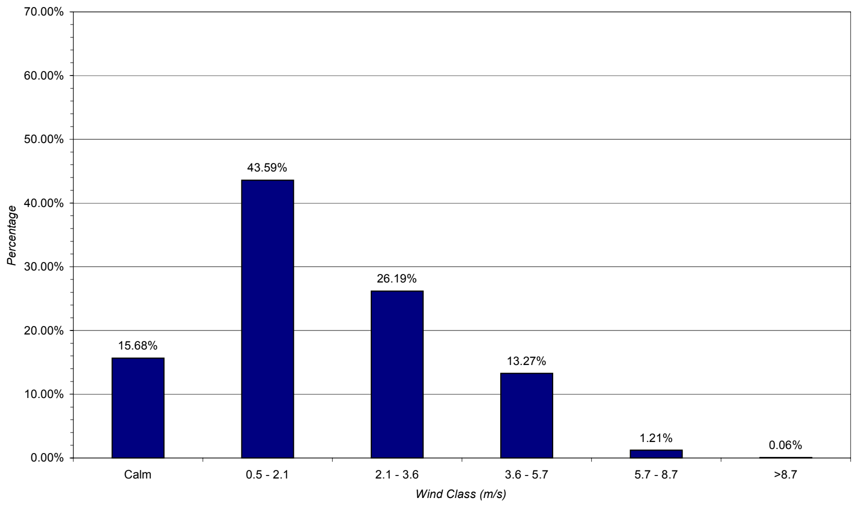


Figure 3.5: Histogram of Wind Speeds at NSW EPA Rozelle Monitoring Station, June 2005 – May 2006. Average wind speed is 1.92 m/s.

3.1.2 Wind Rose Analysis

Figures 3.6 and 3.7 show wind roses for the CBMSs, generated from hourly wind observations in the 12 months spanning June 2005 to May 2006, inclusive. The high instance of light winds, as noted in Section 3.2.1, is again readily apparent. It is also possible to see a predominance of winds blowing from the northeast and west at both sites. However, there are also notable differences, namely the larger fraction of 'calm' measurements at CBW, and the somewhat larger fraction of higher wind speeds from the northeast at CBE.

Figure 3.8 shows the wind rose for the 'Project Monitoring Station', for 12 months of hourly wind observations during December 2000 to November 2001, inclusive. Once again, the predominance of light winds, as noted in Section 3.2.1 is immediately clear. However, a comparison with Figures 3.6 and 3.7, shows that there are strong differences between this wind rose and those of the CBMSs. In particular, the magnitudes of the winds in Figure 3.8 are most similar to CBW, the nearest of the CBMSs to the 'Project Monitoring Station', although the distribution of wind directions appears to be quite different, with a more north-south orientation at the 'Project Monitoring Station'.

Figures 3.9 and 3.10 show wind roses for the NSW EPA[7] Rozelle monitoring station for two 12 month periods, December 2000 – November 2001 and June 2005 – May 2006, respectively. These wind roses also confirm the predominance of light winds. Importantly, there appears to be very good agreement between the two wind roses at this site, despite being from different years. However, they appear to be quite different from the wind roses for the CBMSs and the 'Project Monitoring Station'. This, along with the similarities in Figures 3.4 and 3.5, might suggest that the differences between the wind roses are due more to the difference in locations of the monitoring stations, rather than the different measurement periods. As a corollary to this, they suggest that there is little difference between given years at a specific location and that one year of data would be adequate by which to generate a 'base-line' data set.

Given the discussion in Section 3.1.1 on the predominance of light winds at these sites, a feature also evident in the wind roses, it is important to note that wind directions are generally variable for light wind speeds, possibly accounting for some of the differences between the wind roses. These differences, in addition to the apparently strong variations between sites due to their differing location, highlight the very complex nature of the meteorology in this airshed and demonstrate the need for modelling using advanced models such as TAPM or CALMET, as noted in the EIS (HAS, 2001) and the reports for modelling in the design phase (CAMM, 2004, 2006a, 2006b).

[7] Department of Environment and Conservation (DEC), NSW

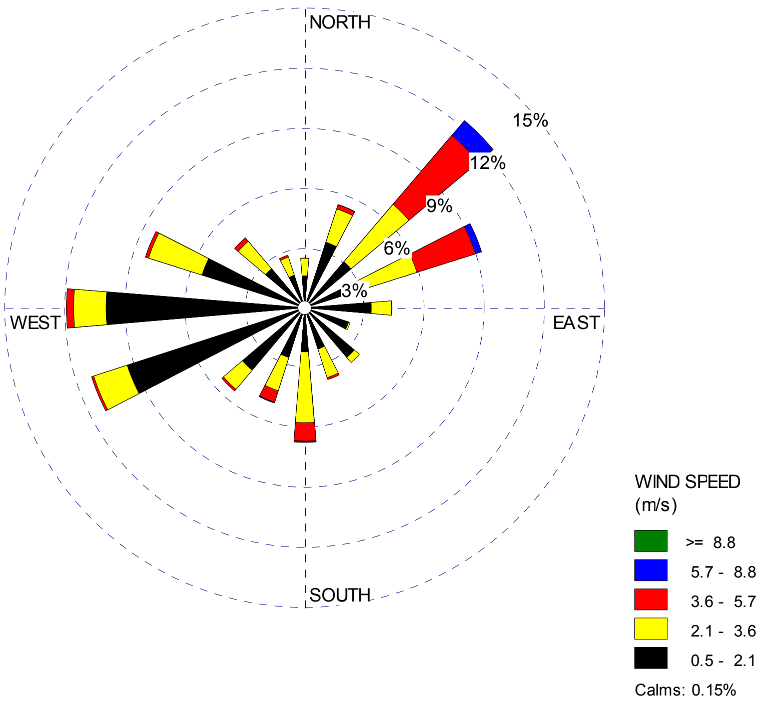


Figure 3.6: Annual Wind Rose for CBE, June 2005 – May 2006

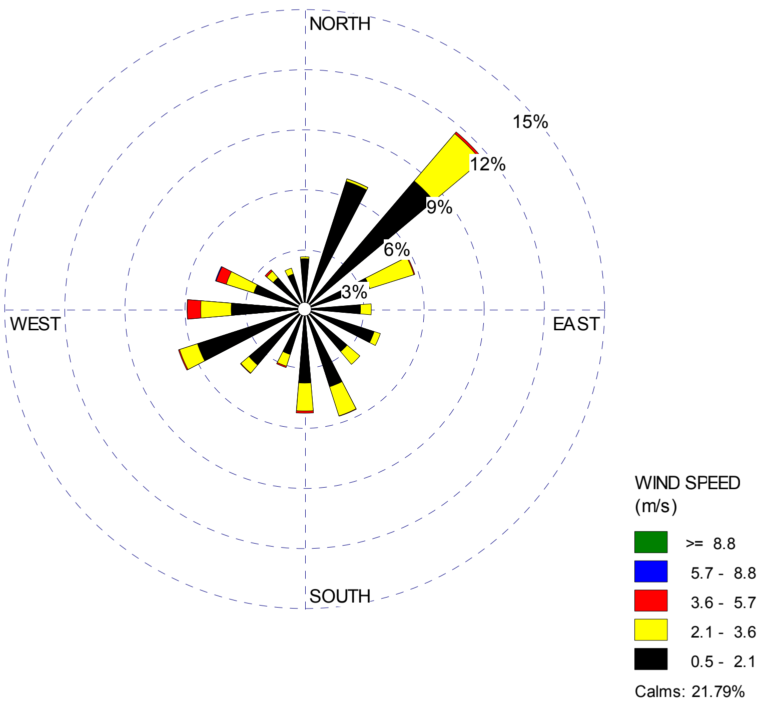


Figure 3.7: Annual Wind Rose for CBW, June 2005 – May 2006

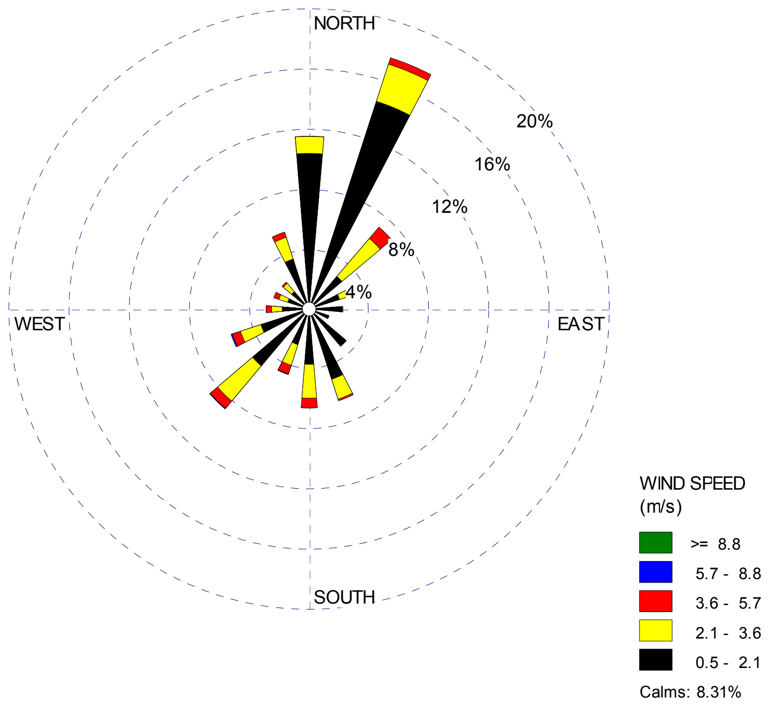


Figure 3.8: Annual Wind Rose for 'Project Monitoring Station', December 2000 – November 2001

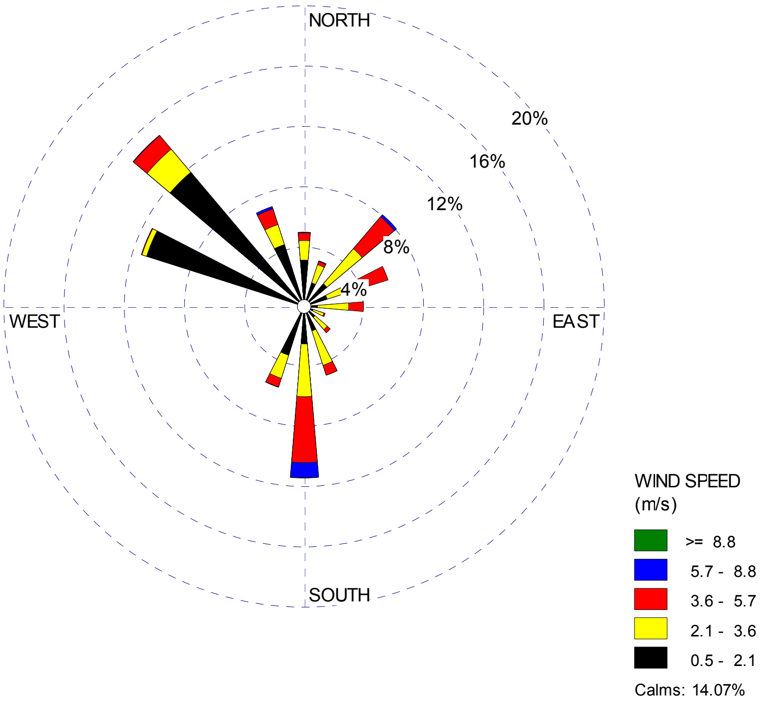


Figure 3.9: Annual Wind Rose for Rozelle Monitoring Station, December 2000 – November 2001

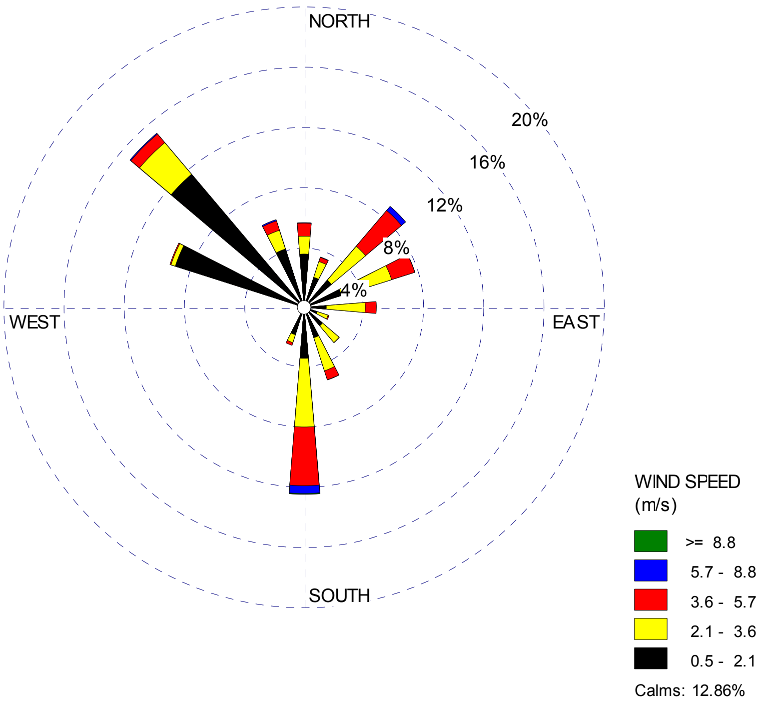


Figure 3.10: Annual Wind Rose for Rozelle Monitoring Station, June 2005 – May 2006

3.2 Analysis of Air Pollution Concentration Data

3.2.1 CBMS Monitoring Data – Comparison with Ambient Criteria

Two Community Based Monitoring Stations (CBMSs) were established by TJH and commenced monitoring in May 2005, with 14 months of validated data to June 2006 inclusive currently available. These stations are situated at each of the proposed LCT stacks, with the CBMS near the Sirius stack termed Community Based West (CBW) and the other near the Marden stack termed Community Based East (CBE).

Each of these monitors records continuous measurements of several air borne contaminants, specifically:

- Carbon Monoxide (CO)
- Nitric Oxide (NO)
- Nitrogen Dioxide (NO_2)
- Oxides of Nitrogen (NO_x)
- Particulate Matter with an aerodynamic diameter less than 10 microns (PM_{10})
- Particulate Matter with an aerodynamic diameter less than 2.5 microns ($PM_{2.5}$)

CAMM was provided with a subset of these contaminants specifically, NO_2, CO and PM_{10}. Furthermore, NO_2 was provided as a 1-hour average, CO was provided as an 8-hour rolling average and PM_{10} was provided as a 24-hour average[8].

The NSW EPA[9] has set assessment criteria for these contaminants, as specified in "Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales" (NSW EPA, 2001). For the species considered in this report, criteria are as described in MCoA 169:

- Nitrogen Dioxide: 0.12 ppm (12 pphm or 245 $\mu g/m^3$) for a 1-hour average.
- Carbon Monoxide: 9.0 ppm (10 mg/m^3) for an 8-hour rolling average
- PM_{10}: 50 $\mu g/m^3$ for a 24-hour average.

Figures 3.11 and 3.12 show time series of 1-hour averaged Nitrogen Dioxide at CBE and CBW, respectively. It is immediately clear that the criterion of 12 pphm is easily satisfied throughout the period examined. The maximum values recorded at each site throughout the period were 4.56 pphm and 5.51 pphm at CBE and CBW respectively. These equate to 38% and 46% of the criterion.

Figures 3.13 and 3.14 show time series of 8-hour rolling averaged Carbon Monoxide at CBE and CBW, respectively. It is immediately clear that the criterion of 9 ppm is easily satisfied throughout the period examined. The maximum values recorded at each site throughout the period were 1.42 ppm and 2.54 ppm at CBE and CBW respectively. These equate to 16% and 28% of the criterion.

Figures 3.15 and 3.16 show time series of 24-hour averaged PM_{10} at CBE and CBW, respectively. The criterion of 50 $\mu g/m^3$ is satisfied throughout the period examined, although the

[8] It should be noted that 1-hour averages of PM_{10} were also provided to CAMM. However 24-hour averages were chosen for analysis in order to make a direct comparison with similar data from the 'Project Monitoring Station' that was only available as 24-hour averages.

[9] Department of Environment and Conservation (DEC), NSW

maximum values recorded at each site throughout the period were 49.44 µg/m^3 and 46.94 µg/m^3 at CBE and CBW, respectively. These equate to 99% and 94% of the criterion

The analysis above shows that in the period from June 2005 to May 2006, there were no exceedences of the criteria by the pollutants of interest, although there were isolated instances of PM_{10} measuring values that were within 5% of their criteria. . It should be noted these PM_{10} maxima both occurred on the same day, 24 December 2005, on which a nearby bushfire occurred. In this case, it is possible to directly attribute these PM_{10} values to that specific event.

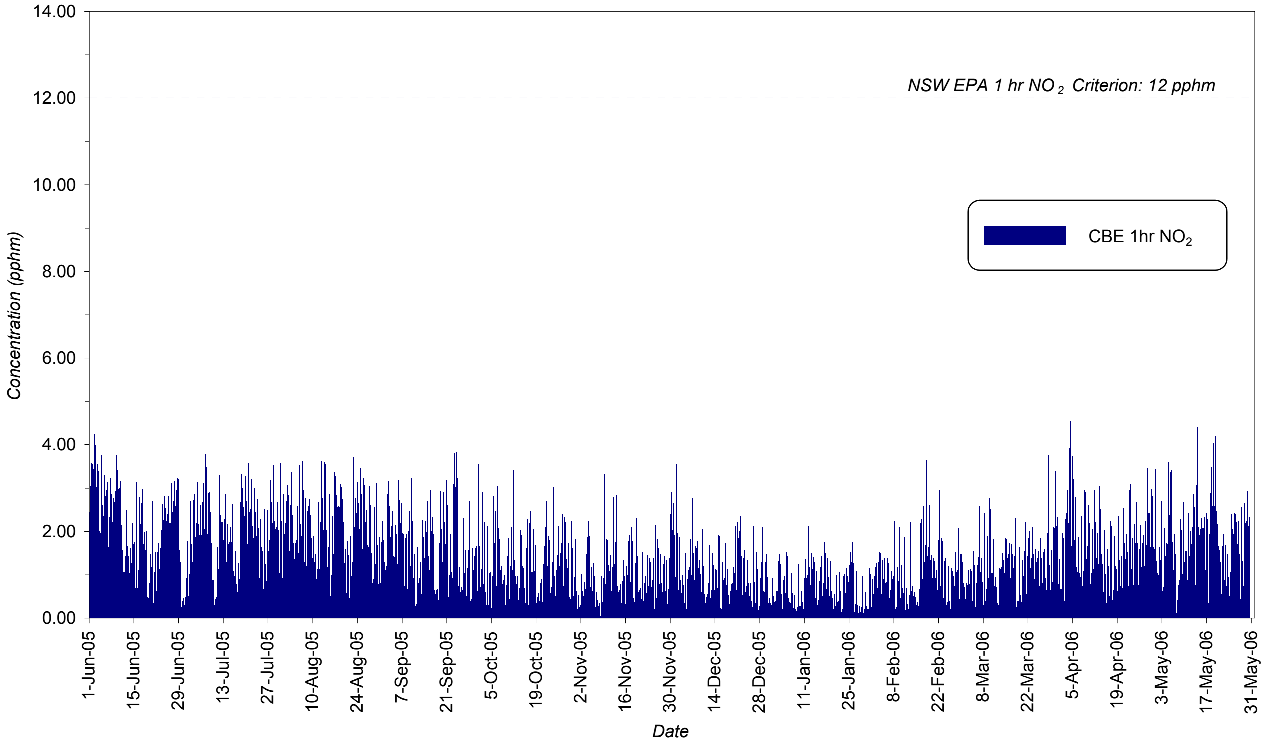


Figure 3.11: 1-Hour Average NO_2 – CBE Monitor

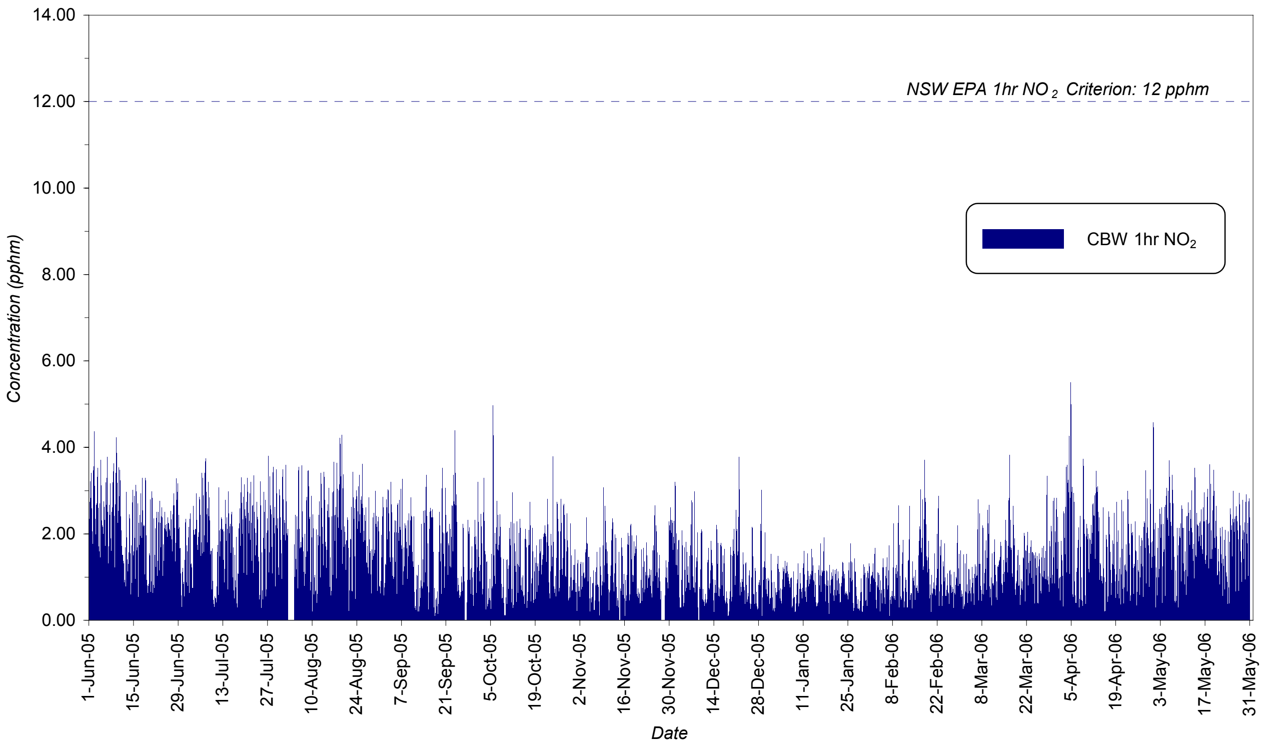


Figure 3.12: 1-Hour Average NO_2 – CBW Monitor

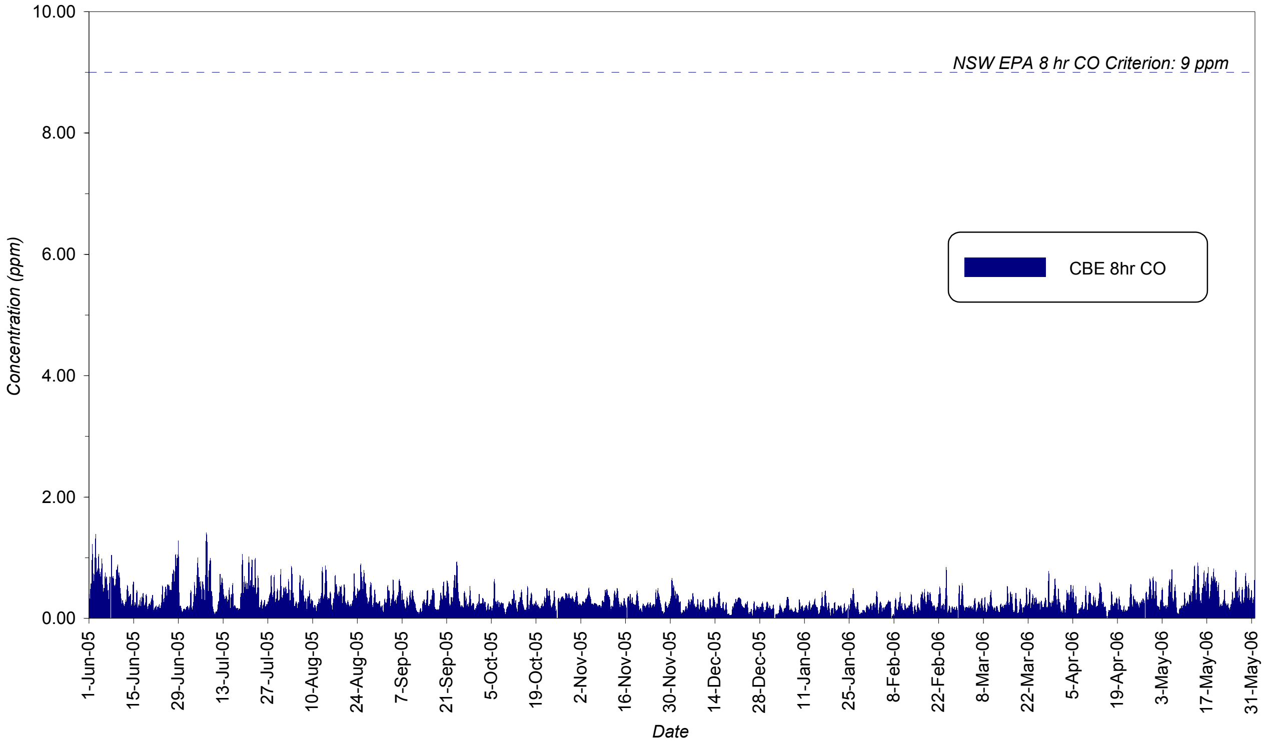


Figure 3.13: 8-Hour Rolling Average CO – CBE Monitor

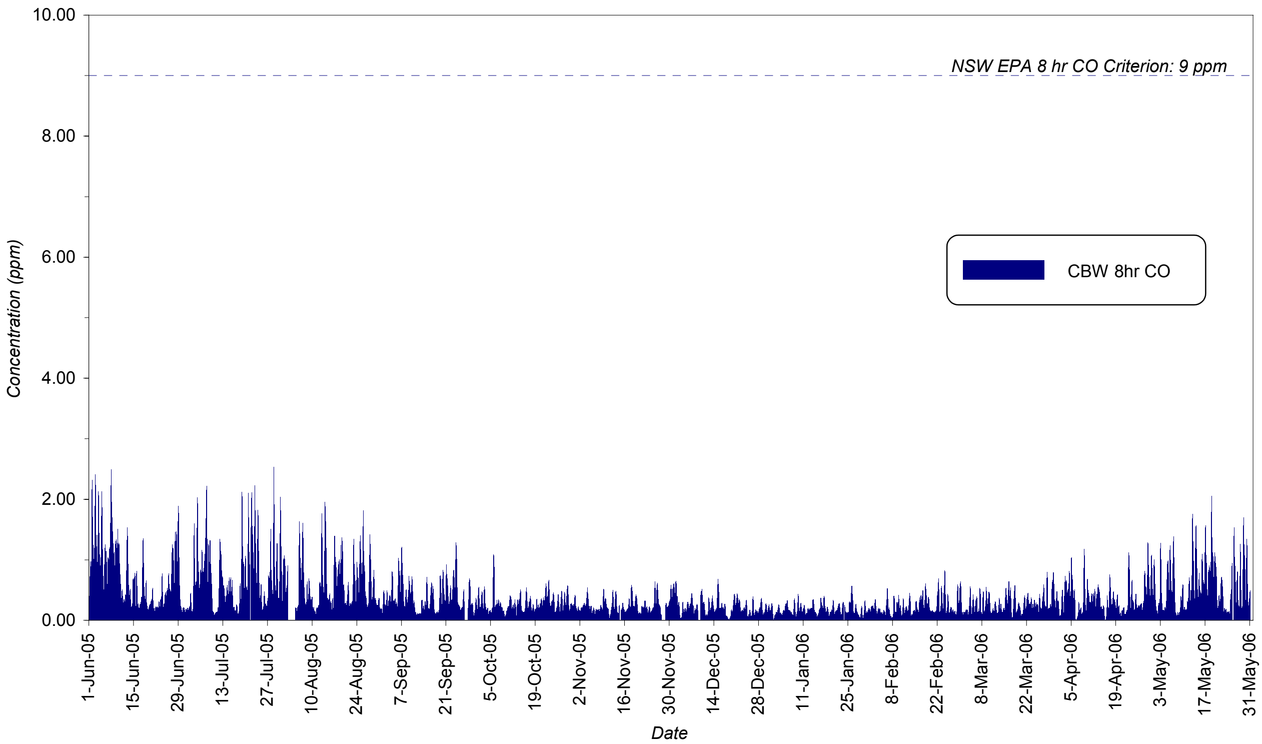


Figure 3.14: 8-Hour Rolling Average CO – CBW Monitor

PM_{10}

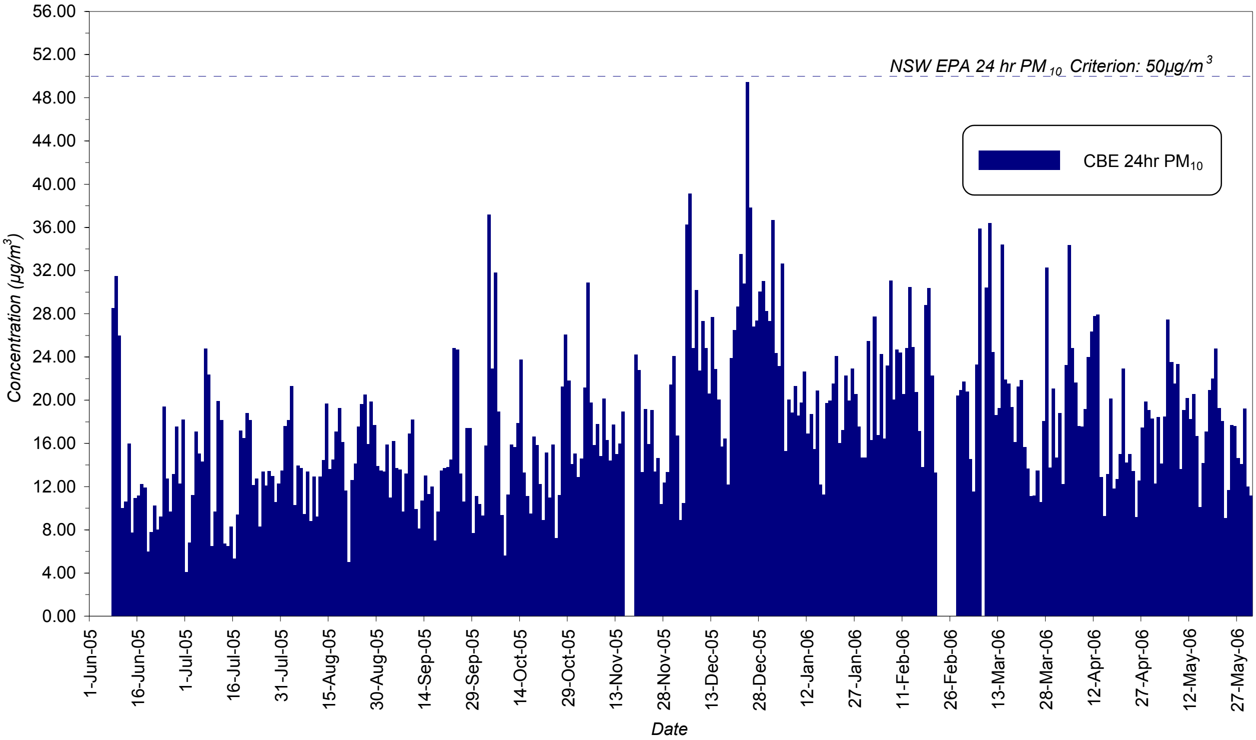


Figure 3.15: 24-Hour Average PM_{10} – CBE Monitor

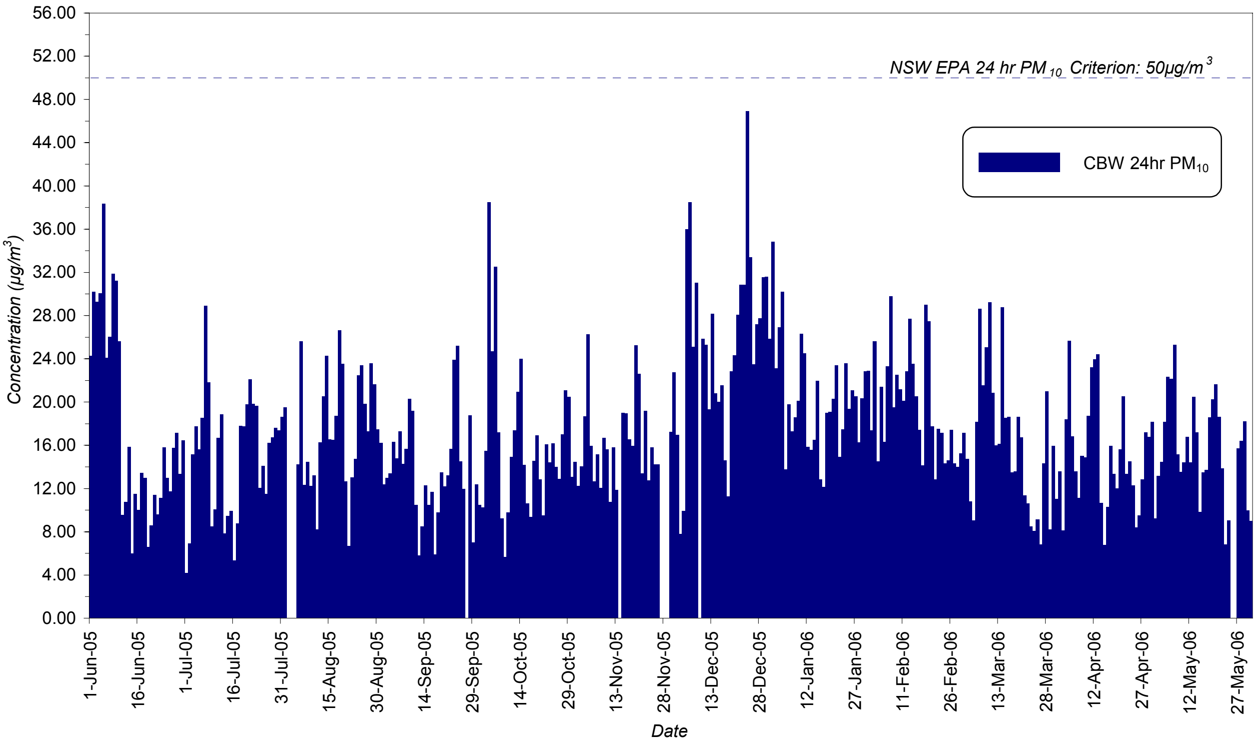


Figure 3.16: 24-Hour Average PM_{10} – CBW Monitor

3.2.2 Correlation between CBMS Monitoring Stations

This section considers how well the measurements taken at CBMSs of the various pollutants correlate with each other. Given that the two stations, CBE and CBW, have been operating concurrently, it is possible to analyse their correlations with their observations ordered in time. However, these measurements will be compared to non-concurrent observations taken at the 'Project Monitoring Station' and the Rozelle monitoring station in later sections of this report. Hence, the measurements at CBE and CBW will first be ranked by magnitude before being analysed for a correlation. This means that the highest concentrations at CBE and CBW will be paired with each other, along with the second highest concentrations, the third highest and so on, until no more can be paired.

Since each data set will have a small number of missing values, the number of pairs will equal the smaller number of observations at either site. Note that checking for ***ranked*** correlation between data sets is equivalent to checking for a good correlation between their frequency distributions. A measure of this correlation can be provided by "Spearman's Rho", with values close to +1 indicating a strong positive correlation of their distributions.

A direct correlation of ***concurrent*** observations taken at CBE and CBW is contained in Appendix 1.

Nitrogen Dioxide (NO_2)

Table 3.1 contains statistics of the NO_2 measurements taken at CBE and CBW for the period of interest. All the quantities show good agreement and each data set has a high degree of completeness. Figure 3.17 shows the ranked correlation of NO_2 at CBE against NO_2 at CBW displayed with a linear trend line fit using the least-squares method. It can be seen that there is a very close agreement between ranked pairs, with a correlation coefficient very near to 1. Moreover the pairs have a close 1:1 relationship, except for some of the highest concentrations, where the equivalent ranks are slightly higher at CBW than at CBE.

Figure 3.18 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plots show a high level of agreement, with the agreement between the two stations being strongest when considering the monthly means and weakest when considering the monthly maxima. Figures 3.18b and c also show that both stations display clear seasonal variations, with higher concentrations recorded in winter months. It should be noted, however, that the largest difference between any two given monthly maxima is less than 1 pphm.

Table 3.1: Statistics of NO_2 at CBMSs

NO_2	CBE	CBW
Count	8711	8678
% complete	99.44%	99.06%
Max	4.56	5.51
Mean of top 10%	2.96	2.86
Mean	1.23	1.22
90^{th} Percentile	2.49	2.37
50^{th} Percentile (median)	1.03	1.03
10th Percentile	0.31	0.32

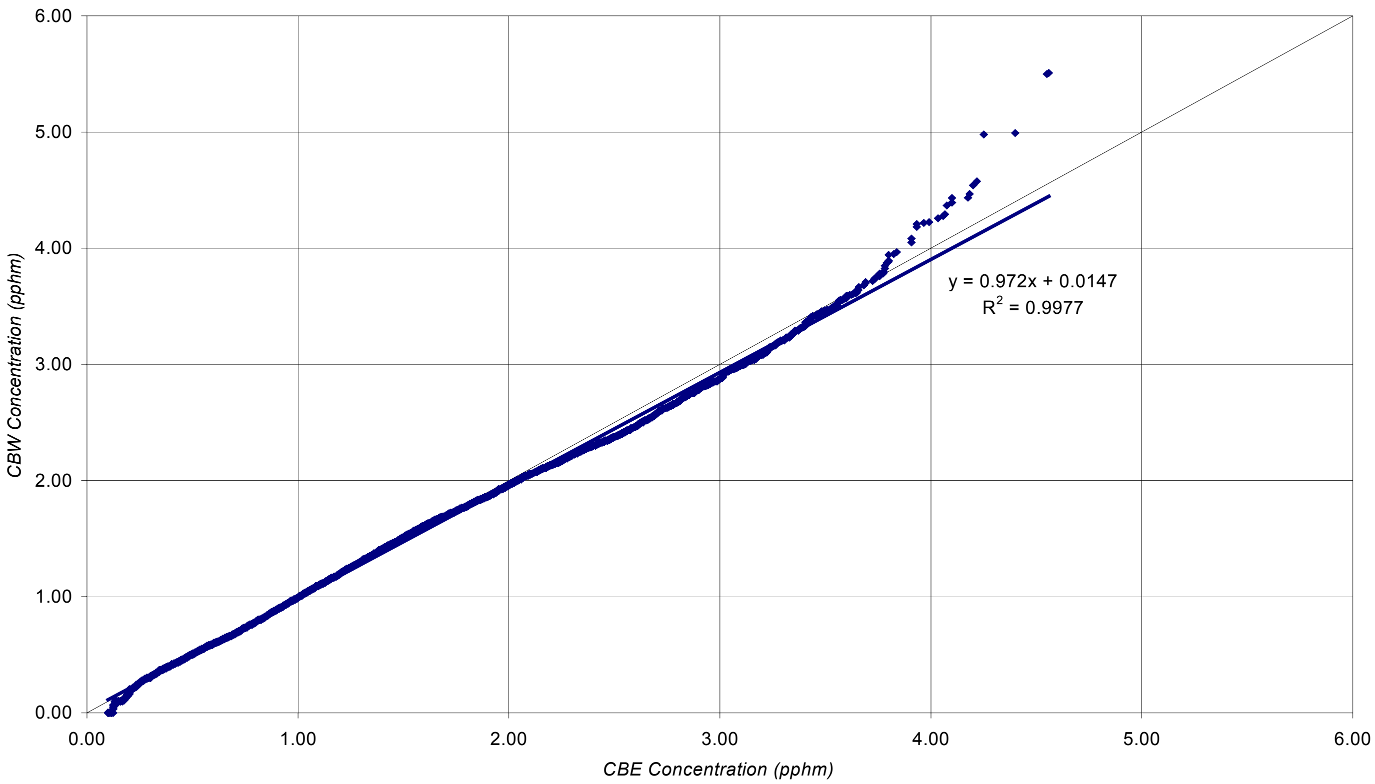
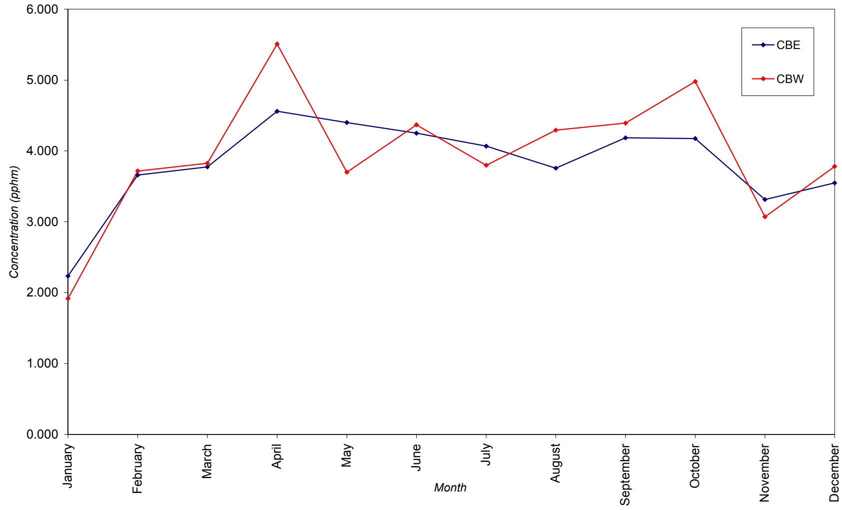
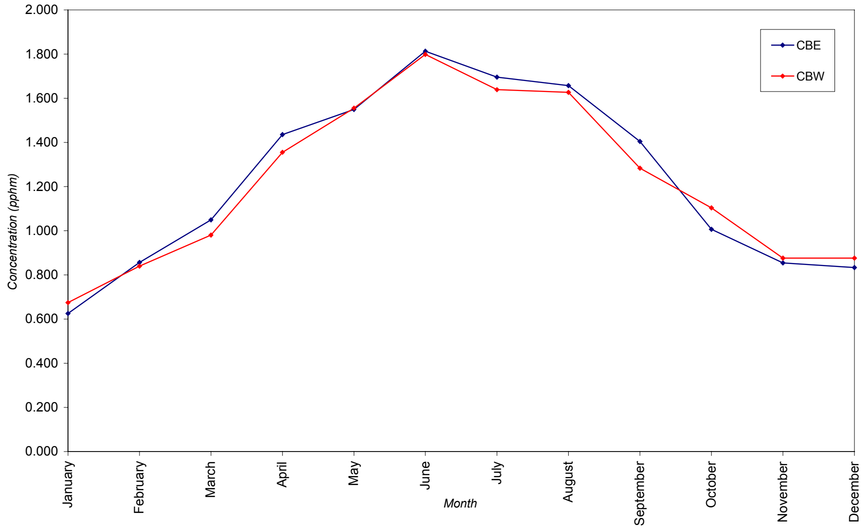


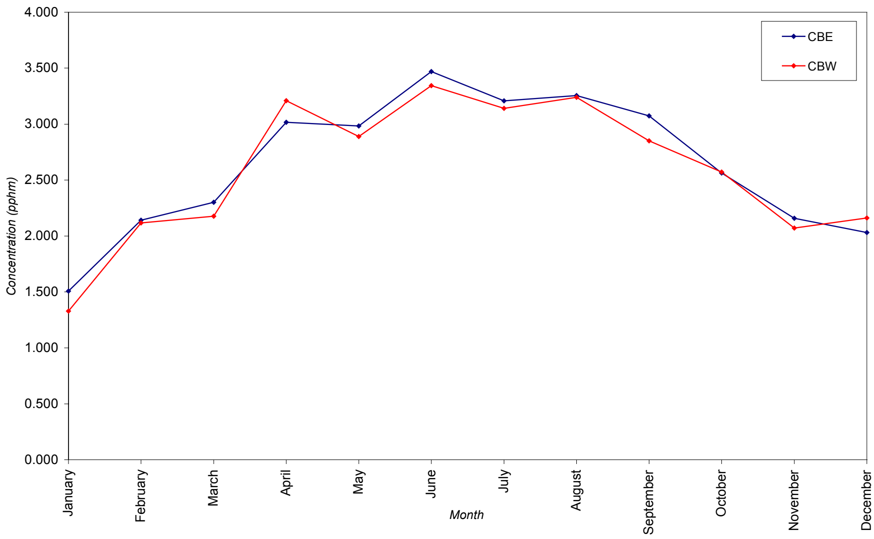
Figure 3.17: Ranked Scatterplot - CBE Vs. CBW – NO_2



(a)



(b)



(c)

Figure 3.18: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– NO_2

Carbon Monoxide (CO)

Table 3.2 contains statistics of the CO measurements taken at CBE and CBW for the period of interest. Each data set has a high degree of completeness and most of the quantities show good agreement. However, the maximum, mean of the top 10% and 90th percentile measures at CBE are roughly half of the equivalent values at CBW. Figure 3.19 shows the ranked correlation of CO at CBE against CBW, displayed with a linear trend line fit using the least-squares method. There is a very close agreement between ranked pairs, with a correlation coefficient very near to 1. However, the slope of the trend line also shows the CO measurements at CBE to be smaller than those at CBW by approximately a factor of 2. Although it is not possible to determine from Figure 3.19, the differences arise for approximately the top 50% of ranked measurements, a fact confirmed by the close agreement of the median values in Table 3.2

Figure 3.20 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plot shows that both stations display clear seasonal variations, with higher concentrations recorded in winter months. However, once again it is evident that CO measurements at CBE are approximately half those at CBW for concurrent months. The differences are now particularly apparent during winter months, but show good agreement during summer months.

Table 3.2: Statistics of CO at CBMSs

CO	CBE	CBW
Count	8707	8571
% complete	99.39%	97.84%
Max	1.42	2.54
Mean of top 10%	0.70	1.25
Mean	0.30	0.39
90th Percentile	0.53	0.87
50th Percentile (median)	0.25	0.26
10th Percentile	0.13	0.11

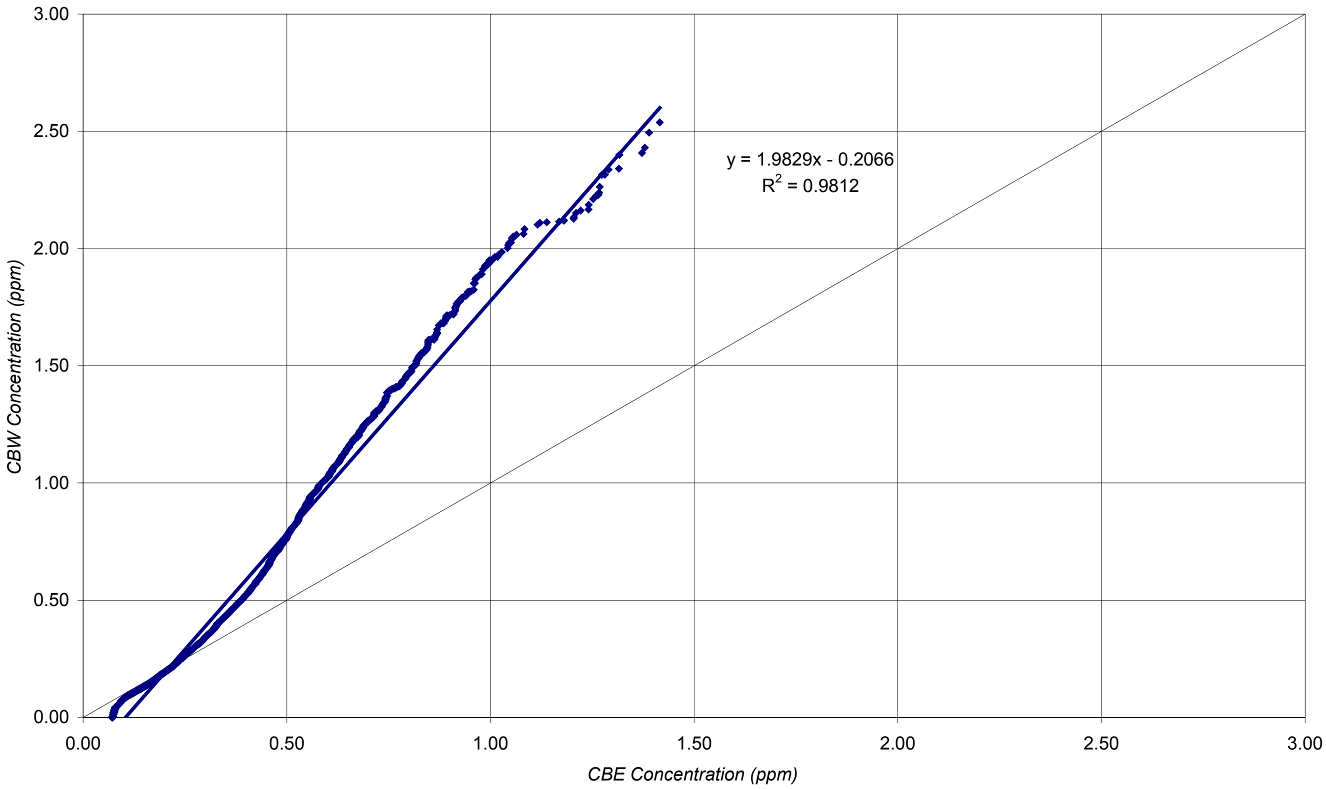
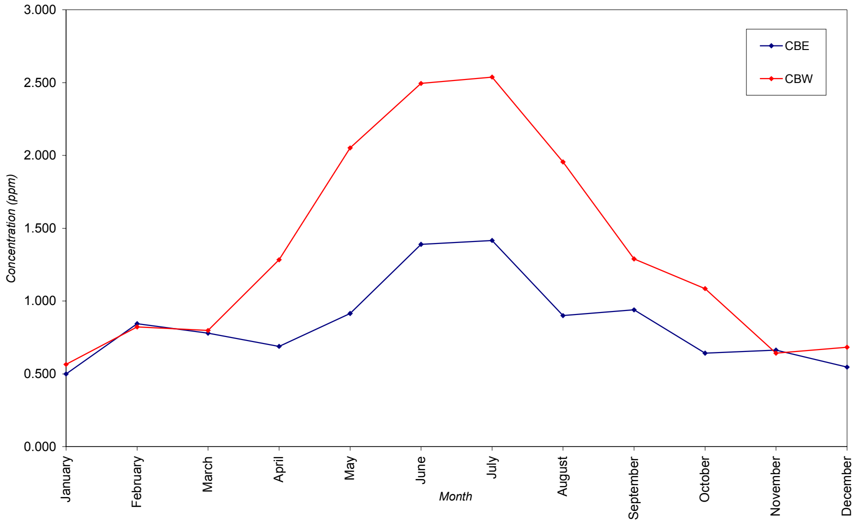
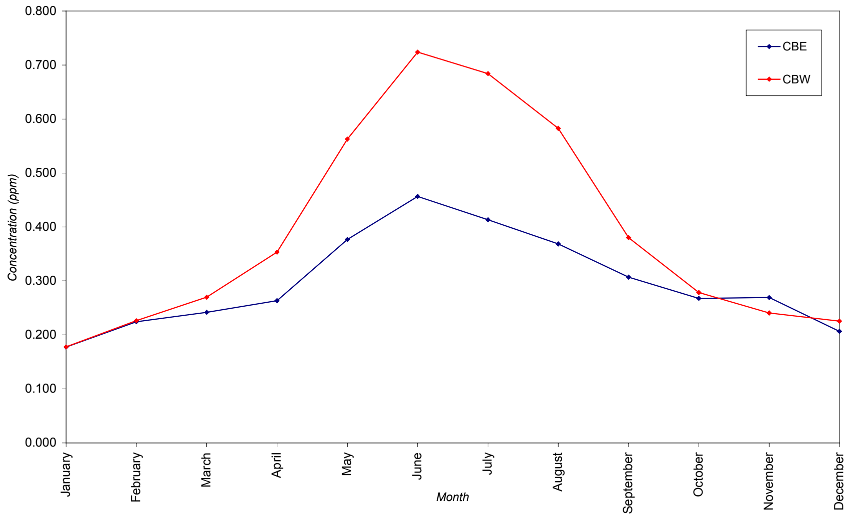


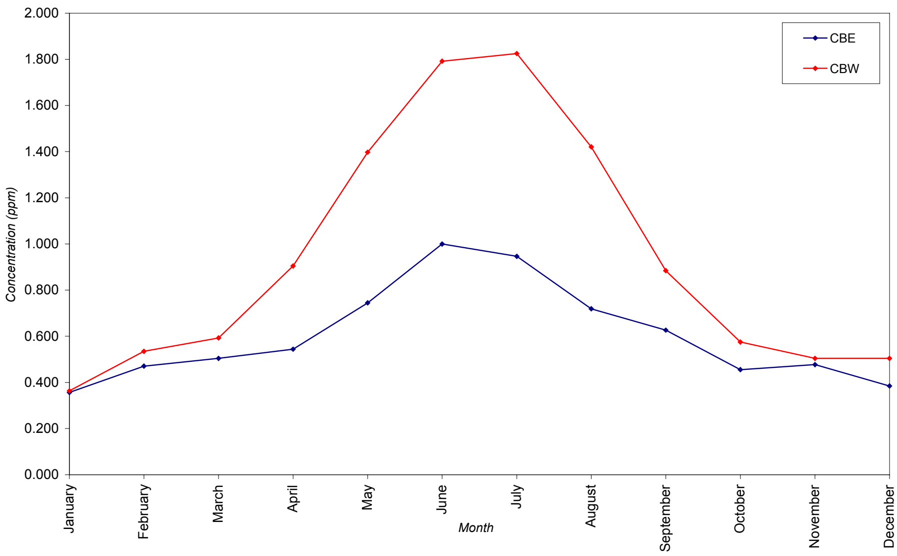
Figure 3.19: Ranked Scatterplot - CBE Vs. CBW –CO



(a)



(b)



(c)

Figure 3.20: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– CO

Particulates as PM_{10}

Table 3.3 contains statistics of the PM_{10} measurements taken at CBE and CBW for the period of interest. All the quantities show good agreement and each data set has a high degree of completeness. Figure 3.21 shows the ranked correlation of PM_{10} at CBE against CBW, displayed with a linear trend line fit using the least-squares method. It can be seen that there is a very close agreement between ranked pairs, with a correlation coefficient very near to 1. Moreover, the pairs have a close 1:1 relationship, except for some of the highest concentrations, where there is more scatter amongst the ranks without one station measuring consistently higher than the other.

Figure 3.22 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plot shows a good level of agreement, with the agreement between the two stations being generally consistent amongst all three measures. Seasonal variations, as seen for CO, are not apparent in the plots in Figure 3.22.

Table 3.3: Statistics of PM_{10} at CBMSs

PM_{10}	CBE	CBW
Count	358	365
% complete	98.08%	100.00%
Max	49.44	46.94
Mean of top 10%	31.80	30.72
Mean	17.23	16.88
90th Percentile	26.80	25.88
50th Percentile (median)	16.30	16.24
10th Percentile	8.90	9.02

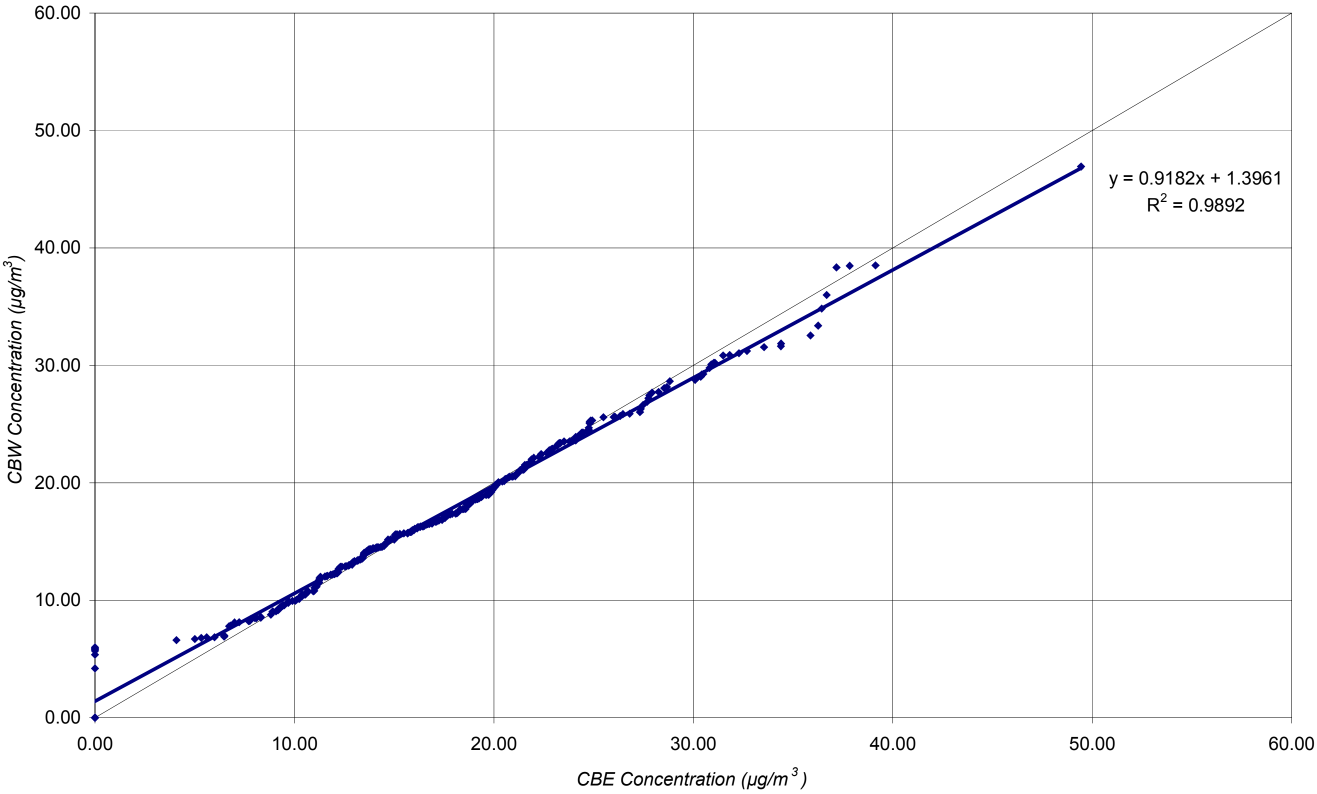
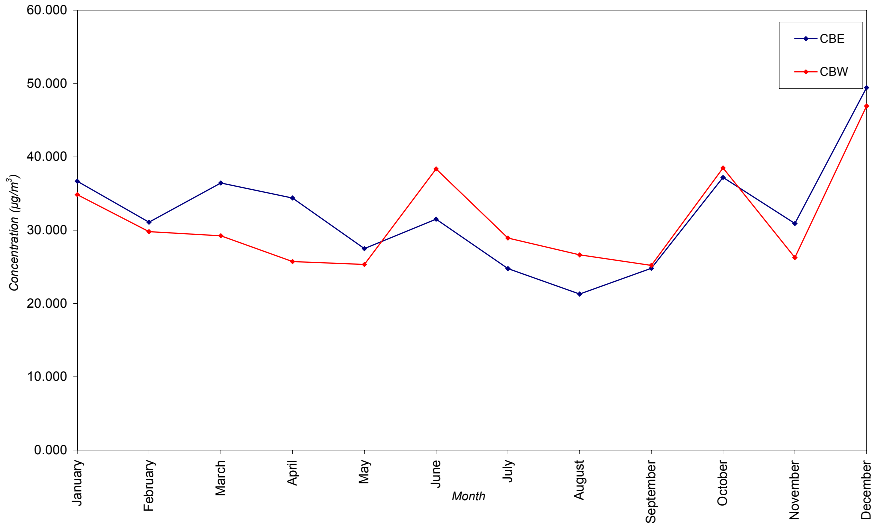
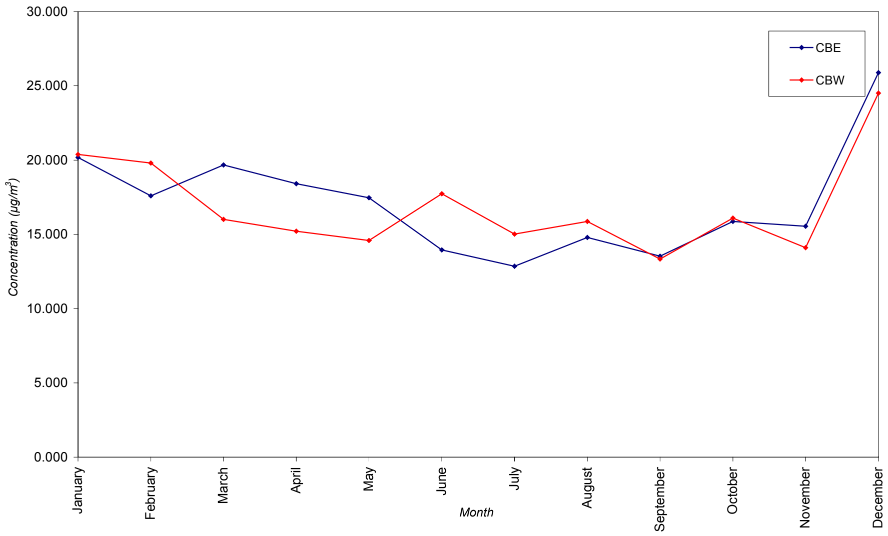


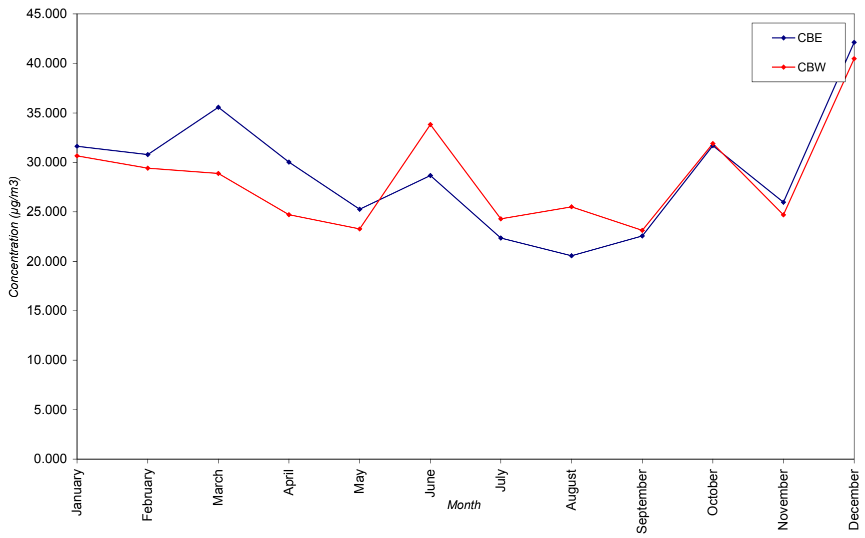
Figure 3.21: Ranked Scatterplot - CBE Vs. CBW – PM_{10}



(a)



(b)



(c)

Figure 3.22: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– PM_{10}

3.2.3 Correlation between CBMS and 'Project Monitoring Station' Data

Nitrogen Dioxide (NO_2)

Table 3.5 contains statistics of the NO_2 measurements taken at the Project Station for the period of interest and compares them against the same statistics for CBE and CBW. All the quantities show good agreement and each data set has a high degree of completeness, although there is a difference of approximately 1 pphm between the maxima at the Project Station and at CBE. Figure 3.23 shows the ranked correlation of NO_2 at the Project Station NO_2 against CBE and CBW, displayed with a linear trend line fit using the least-squares method. It can be seen that the there is a very close agreement between ranked pairs when comparing the Project Station against either of the CBMS data sets, with a correlation coefficient very near to 1. Moreover, the pairs have a close 1:1 relationship, except for some of the highest concentrations, where the equivalent ranks are slightly higher at the Project Station than at CBE and CBW.

Figure 3.24 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plots show a high level of agreement, with the agreement between the three stations being strongest when considering the monthly means and weakest when considering the month maxima. Figures 3.24b and c also show that the project station displays clear seasonal variations, as for the CBMSs, with higher concentrations recorded in winter months. There are some notable differences, particularly in Figure 3.24a, where the project station maximum for January is approximately 4pphm higher than the January maxima at CBE and CBW. It should be remembered, however, that these maxima are individual measurements and that large differences could be expected, especially given that the measurements for the project station were taken in a different year from that of the CBMS measurements.

Table 3.5: Statistics of NO_2 at 'Project Station' and CBMSs

NO_2	'Project Station'	CBE	CBW
Count	8196	8711	8678
% complete	93.56%	99.44%	99.06%
Maximum	5.80	4.56	5.51
Mean of top 10%	2.86	2.96	2.86
Mean	1.38	1.23	1.22
90th Percentile	2.38	2.49	2.37
50th Percentile (median)	1.20	1.03	1.03
10th Percentile	0.33	0.31	0.32

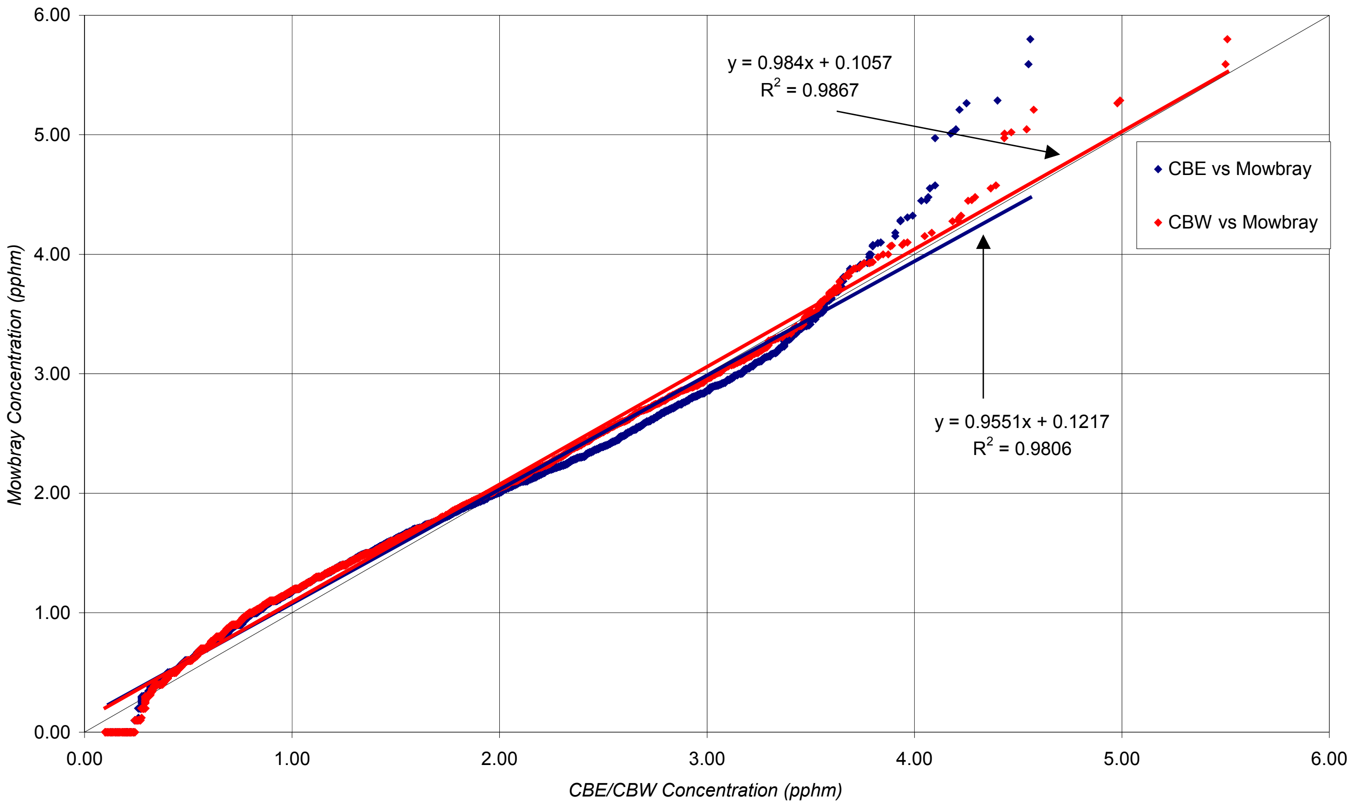
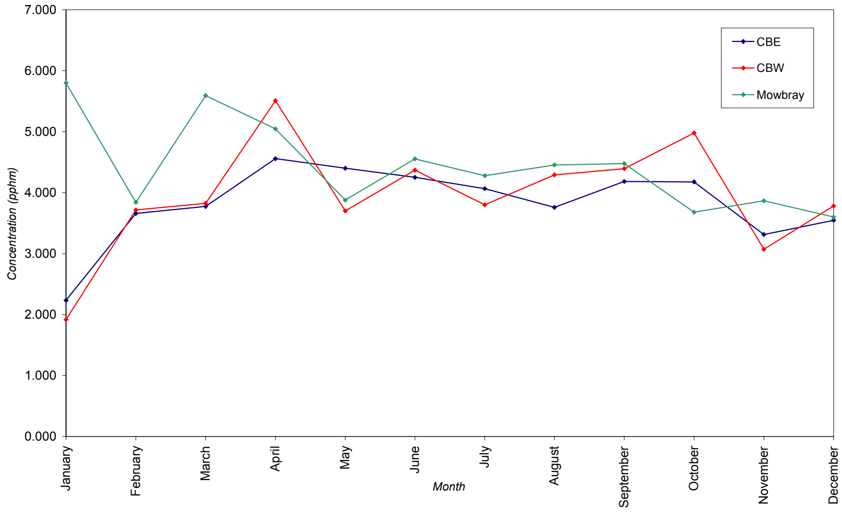
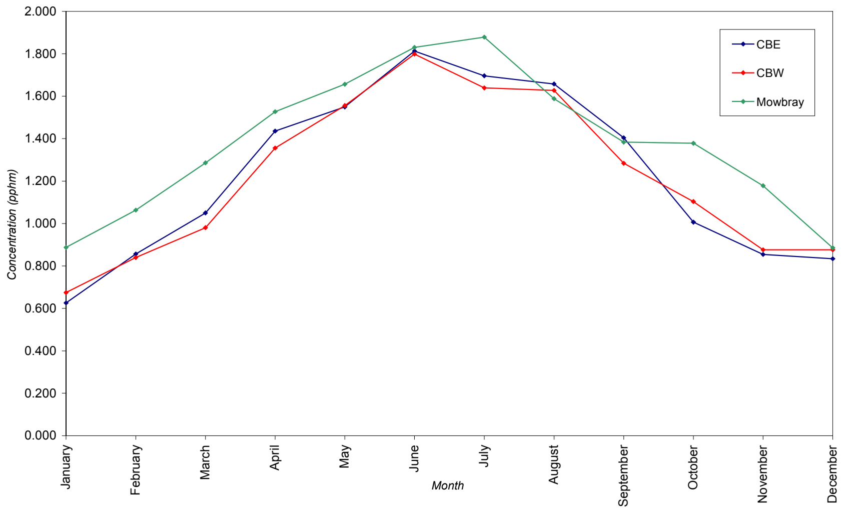


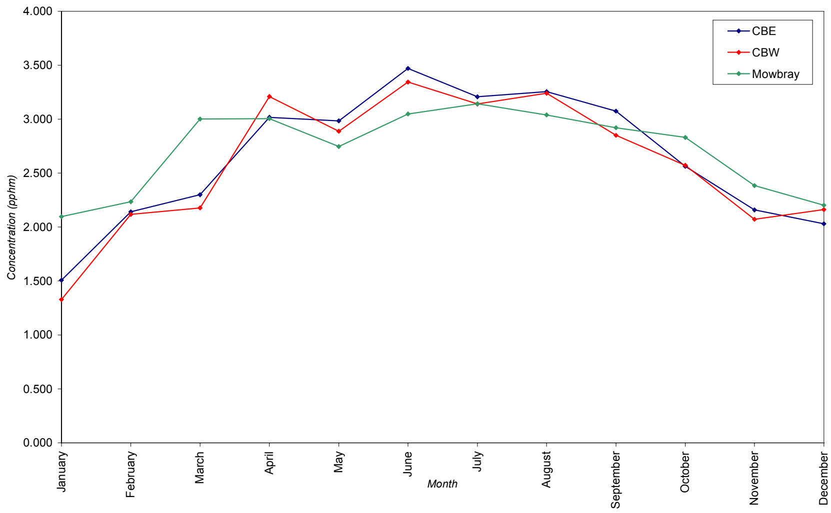
Figure 3.23: Ranked Scatterplot - CBE and CBW Vs. 'Project Station' – NO_2



(a)



(b)



(c)

Figure 3.24: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– NO_2

Carbon Monoxide

Table 3.6 contains statistics of the CO measurements taken at the Project Station for the period of interest and compares them against the same statistics for CBE and CBW. Each data set has a high degree of completeness and most of the quantities show good agreement. However, whilst the maximum, mean of the top 10% and 90th percentile measures at the project station show good agreement with the equivalent measure at CBW, they are roughly double the equivalent values at CBE. This is a similar observation as found when comparing only the CBMSs to each other. Moreoever, for low concentrations, such as seen when considering the median and 10 percentile measures in Table 3.6, it can be seen that the project station has lower values than at the CBMSs.

Figure 3.25 shows the ranked correlation of the Project Station CO against CBE and CBW, displayed with a linear trend line fit using the least-squares method. There is a very close agreement between ranked pairs, with a correlation coefficient very near to 1. However, the slope of the trend line also shows the CO measurements at the project station to be larger than those at CBE by approximately a factor of 2. Moreover, it appears that for lower ranked pairs, concentrations at the project station are typically lower than those at the CBMSs. These observations are in agreement with those made in Table 3.6

Figure 3.26 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plot shows that like the CBMSs, the project station displays the seasonal variations noted earlier, with higher concentrations recorded in winter months. However, once again it is evident that CO measurements at the project station, whilst showing similar magnitudes to those at CBW, are approximately double those at CBE for winter months. During summer months, there is good agreement between all three stations in all plots except figure 3.26b, where the project station is noticeable lower than the CBMSs. This is likely to be due to the differences between the project station and the CBMSs in measuring low concentrations, as noted above in the analysis of Figure 3.25.

Table 3.6: Statistics of CO at 'Project Station' and CBMSs

CO	'Project Station'	CBE	CBW
Count	8621	8707	8571
% complete	98.41%	99.39%	97.84%
Maximum	2.75	1.42	2.54
Mean of top 10%	1.28	0.70	1.25
Mean	0.28	0.30	0.39
90th Percentile	0.71	0.53	0.87
50th Percentile (median)	0.12	0.25	0.26
10th Percentile	0.01	0.13	0.11

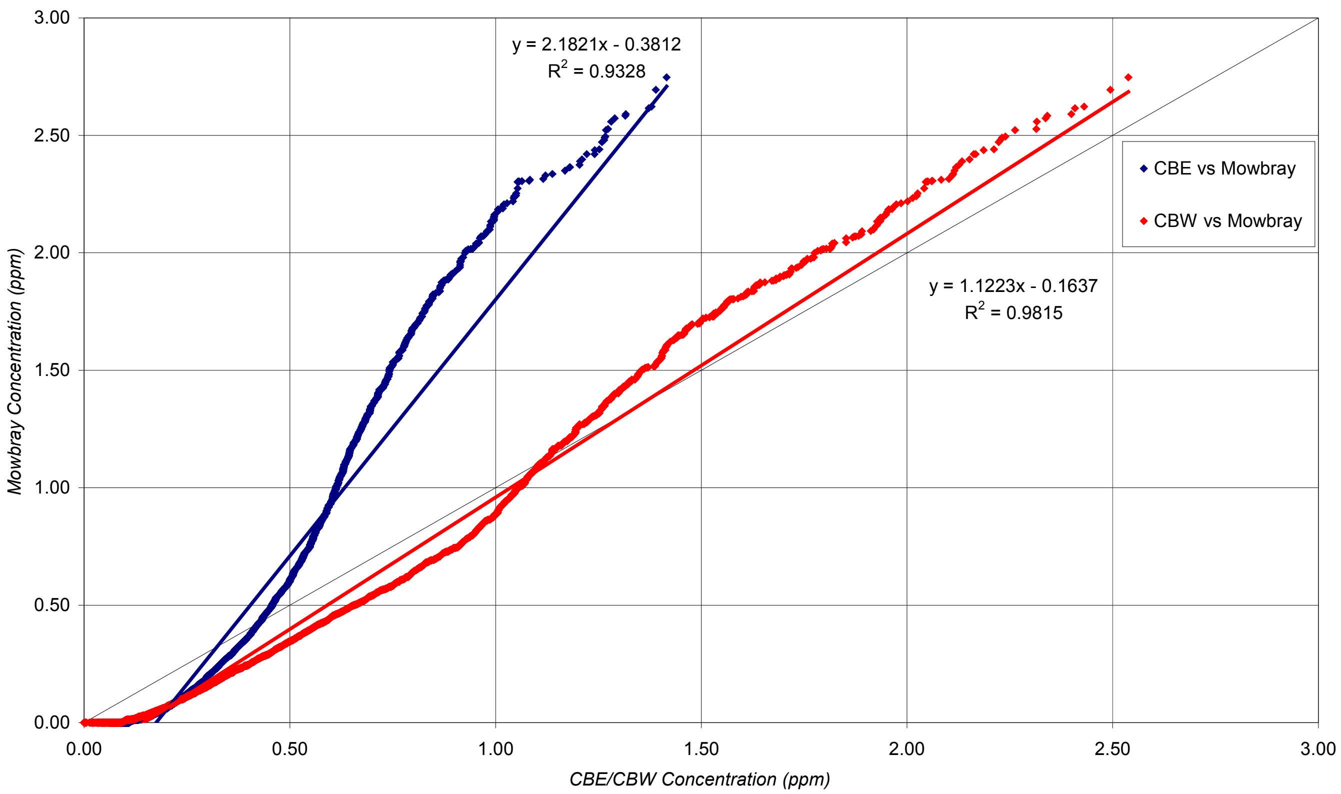
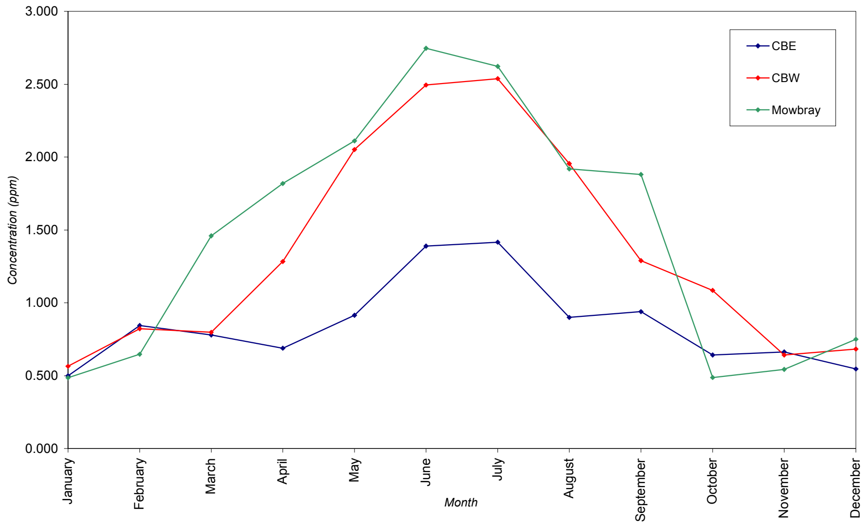
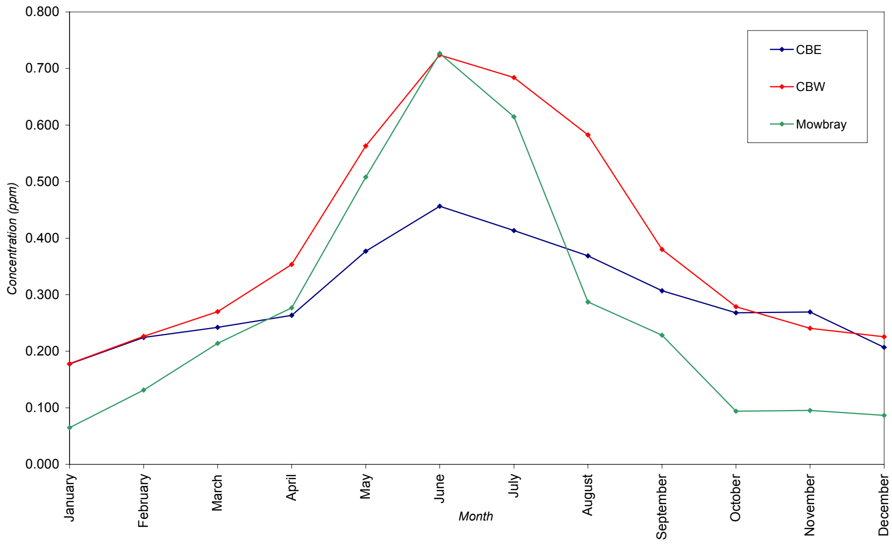


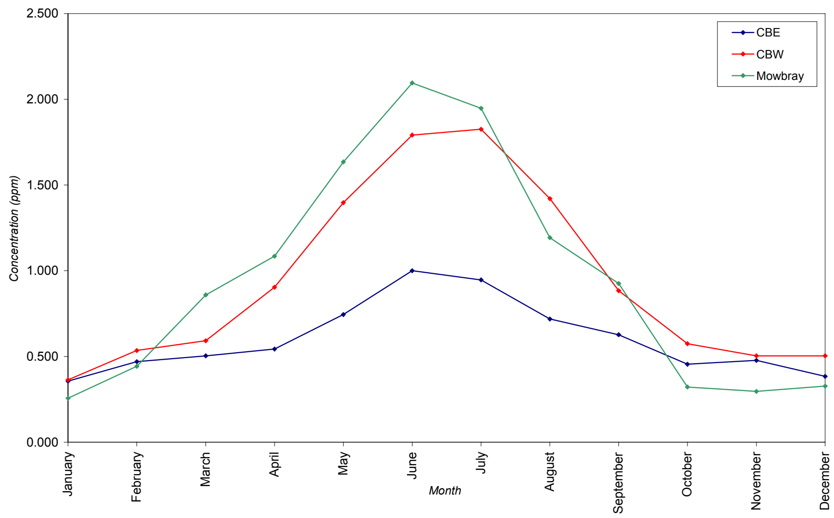
Figure 3.25: Ranked Scatterplot - CBE and CBW Vs. 'Project Station' – CO



(a)



(b)



(c)

Figure 3.26: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– CO

Particulates as PM_{10}

Table 3.7 contains statistics of the PM_{10} measurements taken at the Project Station for the period of interest and compares them against the same statistics for CBE and CBW, as shown in table 3.3. Most of the quantities show good agreement. However, the maximum, mean of the top 10% and 90^{th} percentile measures show some differences. Figure 3.27 shows the ranked correlation of the Project Station PM_{10} against CBE and CBW PM_{10}, displayed with a linear trend line fit using the least-squares method. It can be seen that the there is a very close agreement between ranked pairs, with a correlation coefficient very near to 1. The slope of the trend lines show that PM_{10} concentrations at the project station, particularly for higher ranked concentrations, are typically lower than those at the CBMSs.

Figure 3.28 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plot shows a good level of agreement, with the agreement between the two stations being generally consistent amongst all three measures. As above, the concentrations measured at the project station are typically less than those at the CBMSs, although these difference appear, overall, to be slight, with the possible exception of December. Seasonal variations, as seen for CO, are not apparent in the project station data, in agreement with the CBMS PM_{10} observations.

Table 3.7: Statistics of PM_{10} at 'Project Station' and CBMSs

PM_{10}	'Project Station'	CBE	CBW
Count	365	358	365
% complete	100.00%	98.08%	100.00%
Maximum	31.38	49.44	46.94
Mean of top 10%	25.10	31.80	30.72
Mean	14.07	17.23	16.88
90th Percentile	21.85	26.80	25.88
50th Percentile (median)	14.33	16.30	16.24
10th Percentile	8.58	8.90	9.02

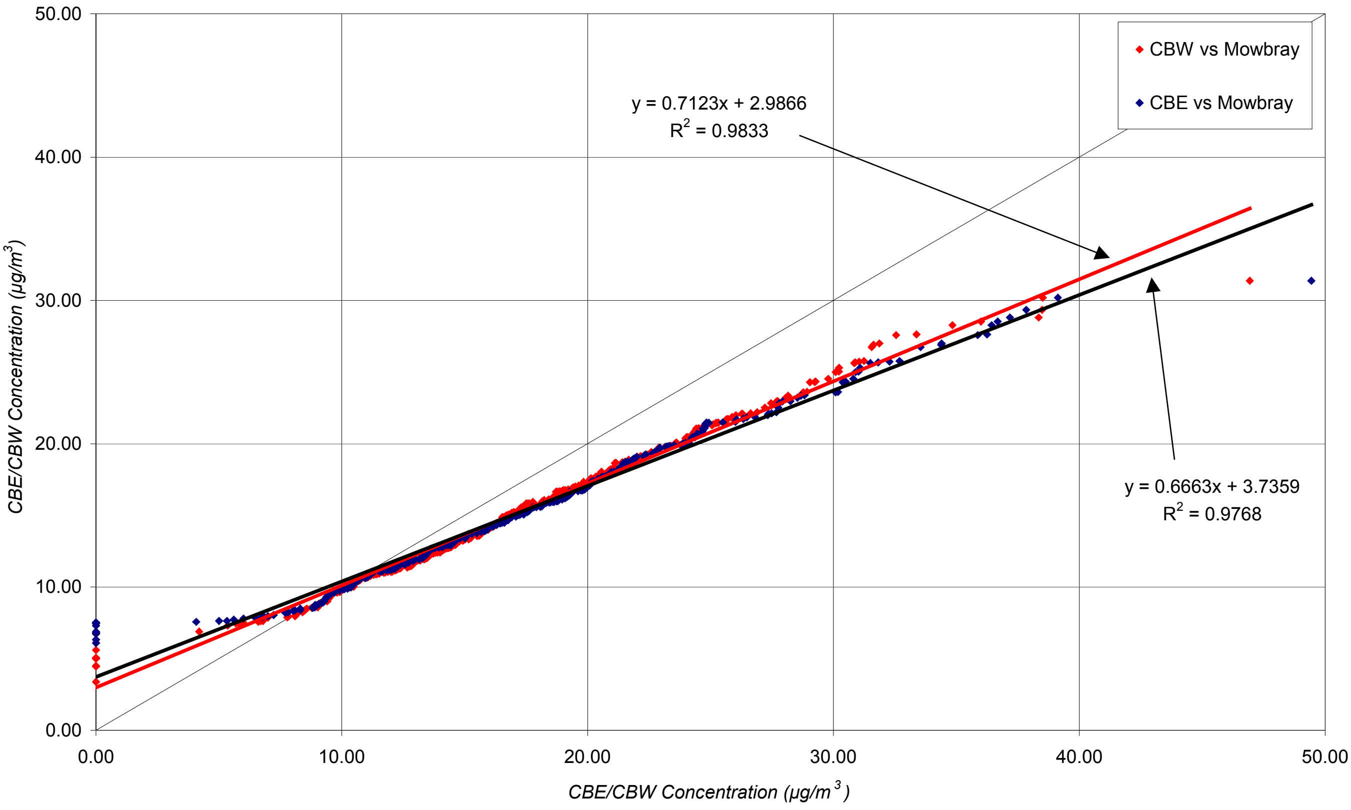
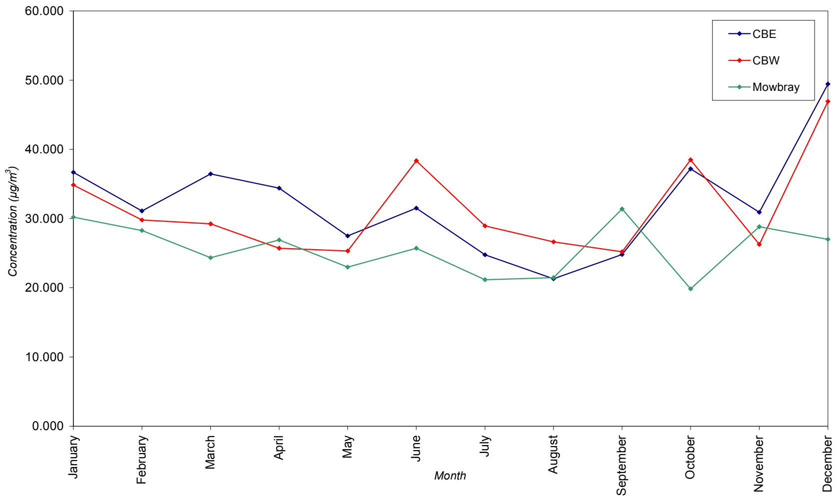
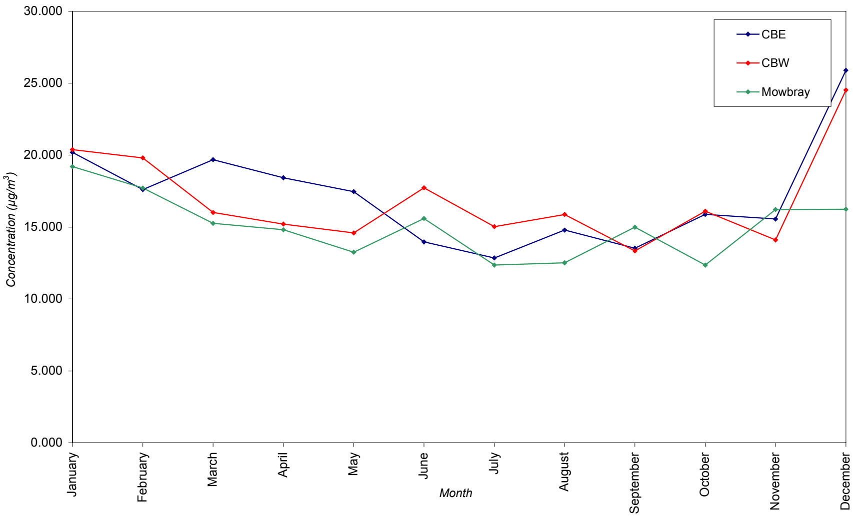


Figure 3.27: Ranked Scatterplot - CBE and CBW Vs. 'Project Station' – PM_{10}



(a)



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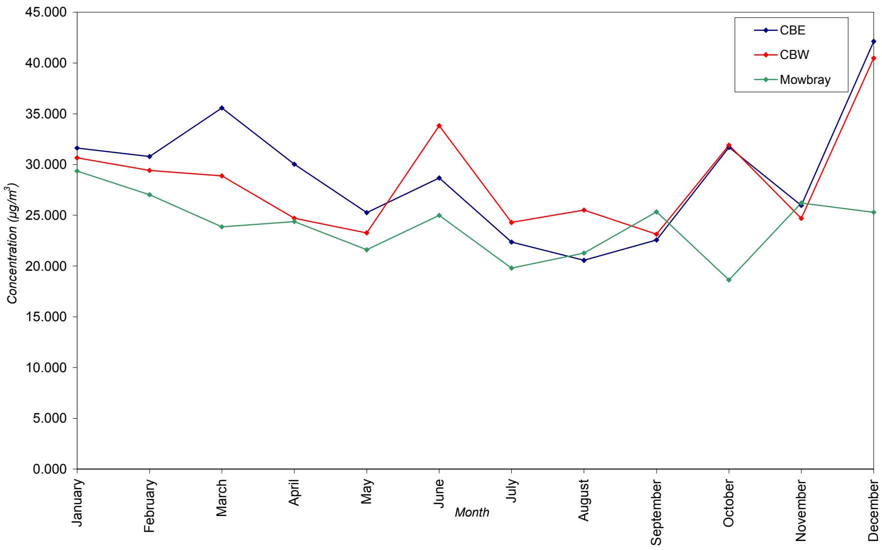


(c)

Figure 3.28: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– PM_{10}

3.2.4 Correlation between CBMS and DEC Monitoring Station Data.

Nitrogen Dioxide (NO_2)

Table 3.8 contains statistics of the NO_2 measurements taken at Rozelle for the period of interest and compares them against the same statistics for CBE and CBW. All the quantities show good agreement and each data set has a high degree of completeness. Figure 3.29 shows the ranked correlation of NO_2 at Rozelle against CBE and CBW, displayed with a linear trend line fit using the least-squares method. It can be seen that the there is a very close agreement between ranked pairs when comparing the Rozelle datasets against either of the CBMS data sets, with a correlation coefficient very near to 1. Moreover the pairs have a close 1 to 1 relationship, except for some of the highest concentrations, where the equivalent ranks are slightly higher at Rozelle than at CBE and CBW.

Figure 3.30 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plots show a high level of agreement, with the agreement between the three stations being strongest when considering the monthly means and weakest when considering the month maxima. Figures 3.30b and c also show that the project station displays clear seasonal variations, as for the CBMSs, with higher concentrations recorded in winter months. Typically, measurements from Rozelle in 2001 are larger than the other data sets and are notably higher in the earlier months in the year.

Table 3.8: Statistics of NO_2 at Rozelle (2001 and 2005) and CBMSs

NO_2	Rozelle 2001	Rozelle 2005	CBE	CBW
Count	8176	7942	8711	8678
% complete	93.33%	90.66%	99.44%	99.06%
Maximum	6.58	5.23	4.56	5.51
Mean of top 10%	3.18	3.02	2.96	2.86
Mean	1.44	1.29	1.23	1.22
90th Percentile	2.65	2.50	2.49	2.37
50th Percentile (median)	1.18	0.93	1.03	1.03
10th Percentile	0.29	0.14	0.31	0.32

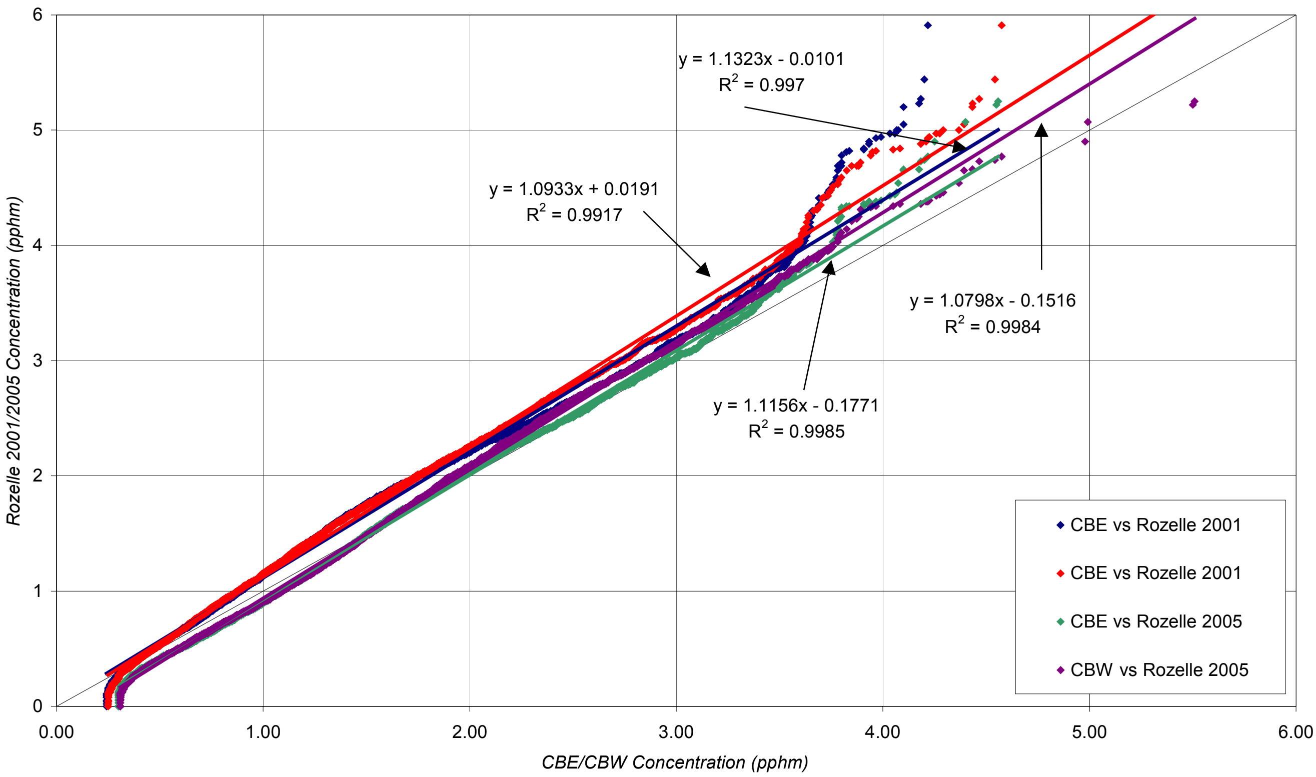
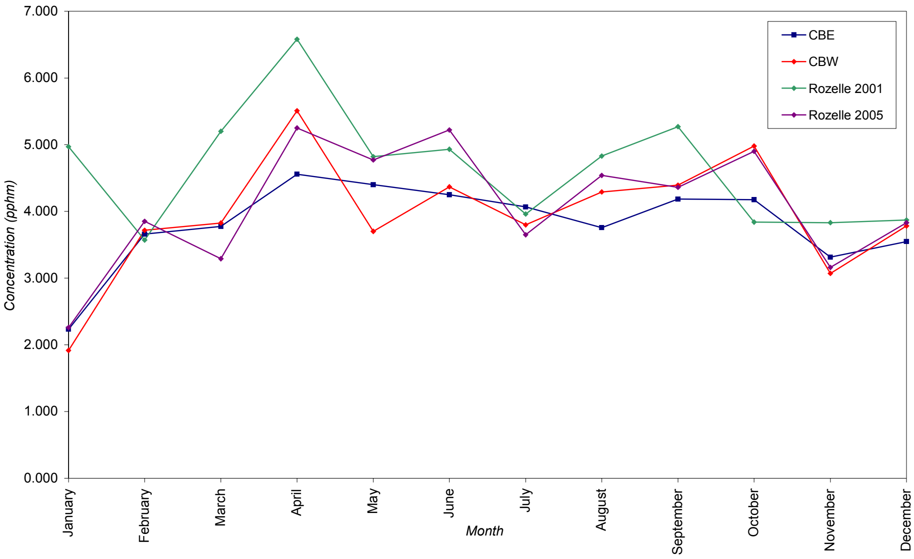
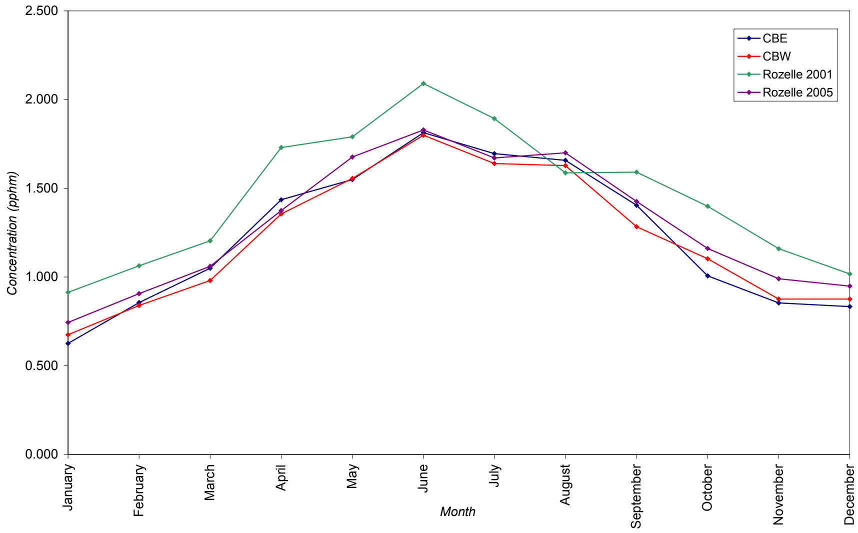


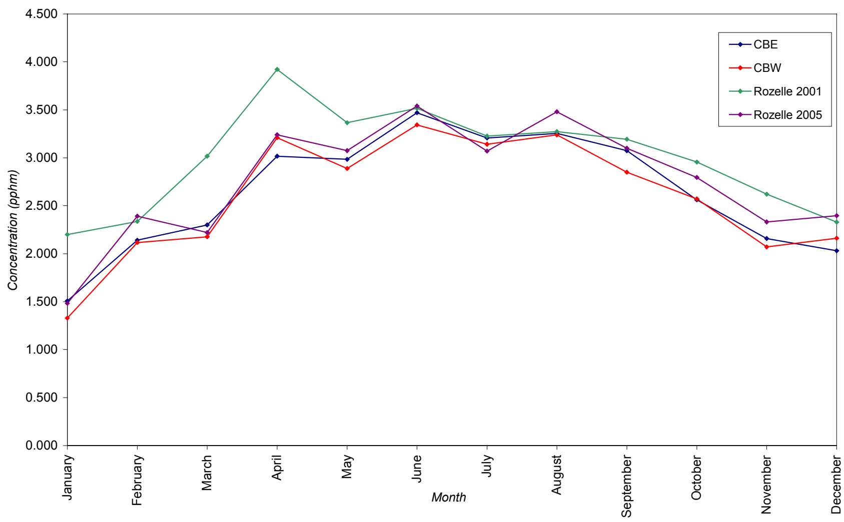
Figure 3.29: Ranked Scatterplot - CBE and CBW Vs. Rozelle 2001/2005 – NO_2



(a)



(b)



(c)

Figure 3.30: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– NO_2

Carbon Monoxide (CO)

Table 3.9 contains statistics of the CO measurements taken at Rozelle for the periods of interest and compares them against the same statistics for CBE and CBW. Each data set has a high degree of completeness and most of the quantities show reasonable agreement, with most values being close to either CBE or CBW. Whilst all values for each statistic may be similar, there is no clear ranking of the stations based on these measures.

Figure 3.31 shows the ranked correlation of CO at the Project Station against CBE and CBW, displayed with a linear trend line fit using the least-squares method. Whilst correlation coefficients are very near to 1, the agreement between ranked pairs is more variable than seen before. However the slope of the trend line suggest that concentrations for Rozelle 2001 are generally larger than those at either CBE or CBW and that concentrations for Rozelle 2005 are larger than those at CBE, but not CBW. It should be noted that whilst the correlations here may be weaker than others seen in this report, all correlation coefficients are still larger than 0.9, indicating a very good agreement between the data sets.

Figure 3.32 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plot shows that like the CBMSs, the Rozelle data sets display the seasonal variations noted earlier, with higher concentrations recorded in winter months. As stated above, it is difficult to see a clear ranking of the four data sets, but it appears that concentrations for Rozelle 2001 are generally higher, or at least comparable to CBW, whilst concentrations for Rozelle 2005 are less than CBW but comparable to CBE.

Table 3.9: Statistics of CO at Rozelle (2001 and 2005) and CBMSs

CO	Rozelle 2001	Rozelle 2005	CBE	CBW
Count	8402	8494	8707	8571
% complete	95.91%	96.96%	99.39%	97.84%
Maximum	3.19	2.13	1.42	2.54
Mean of top 10%	1.06	0.70	0.70	1.25
Mean	0.33	0.23	0.30	0.39
90th Percentile	0.60	0.44	0.53	0.87
50th Percentile (median)	0.23	0.17	0.25	0.26
10th Percentile	0.04	0.02	0.13	0.11

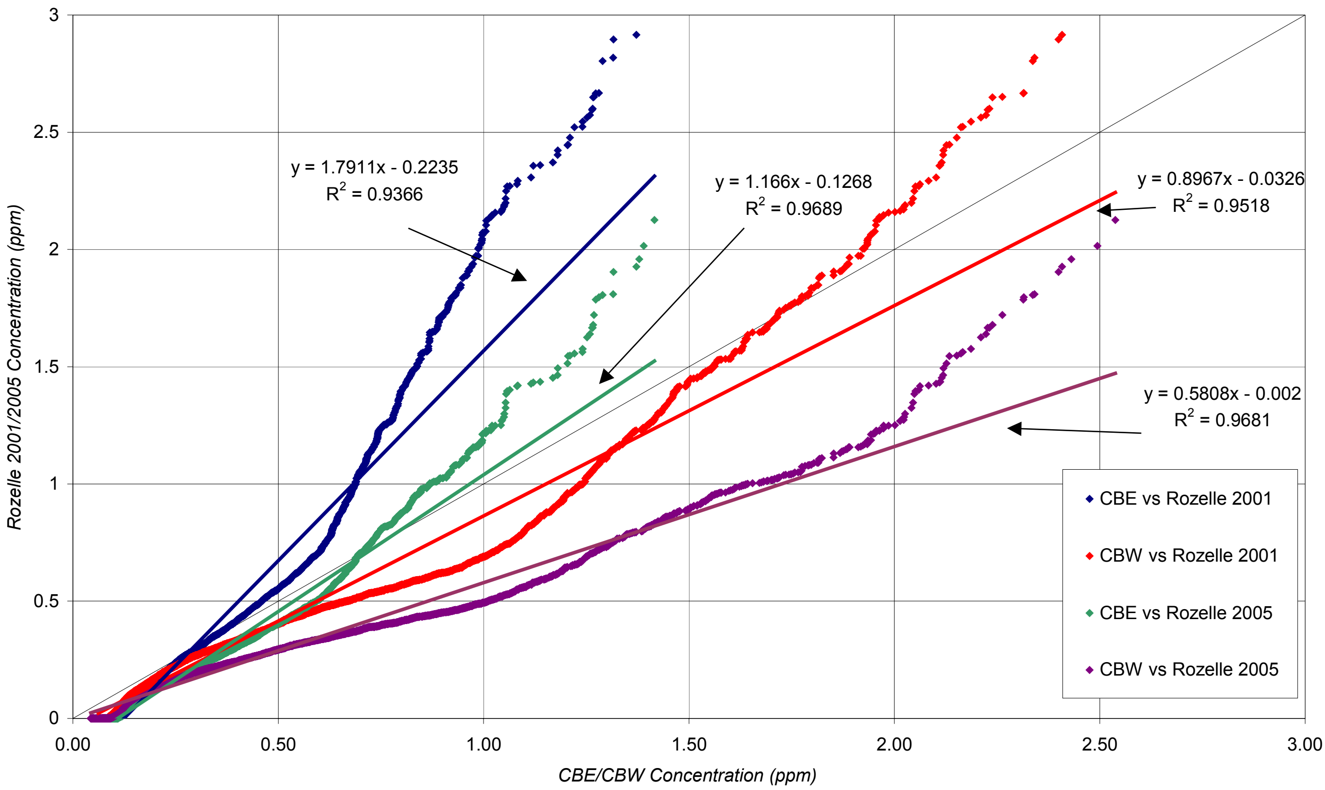
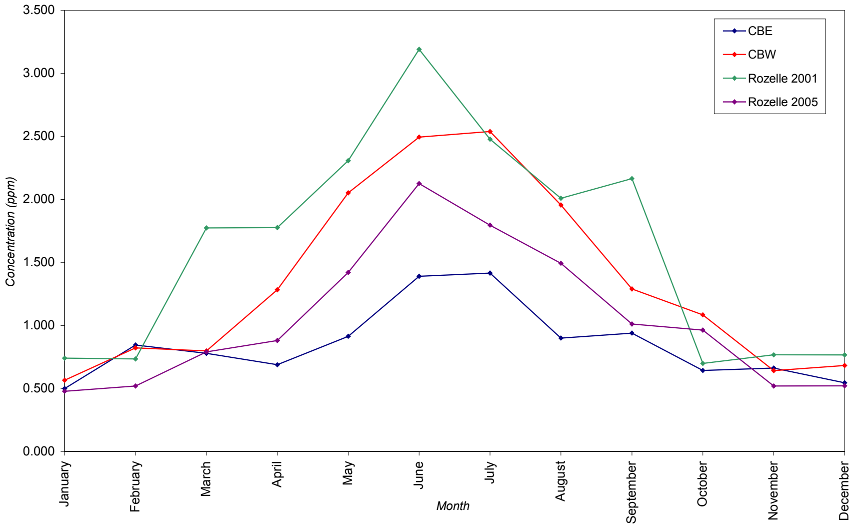
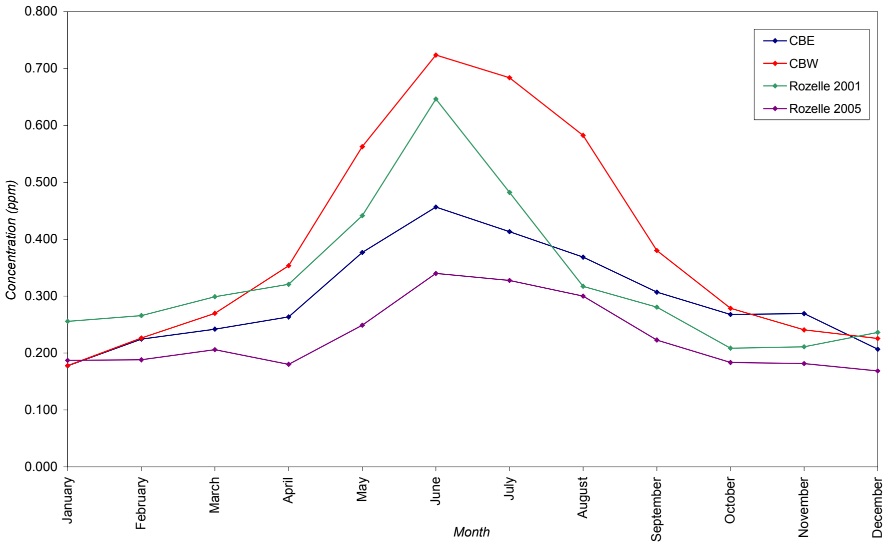


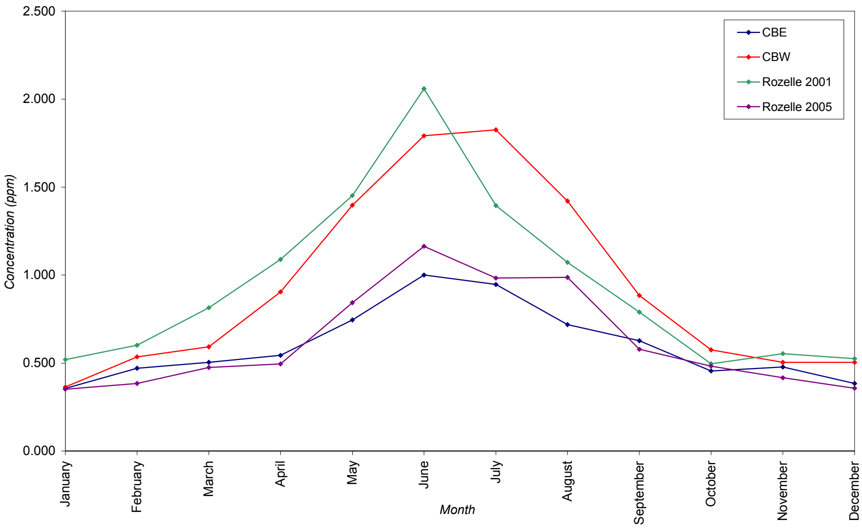
Figure 3.31: Ranked Scatterplot - CBE and CBW Vs. Rozelle 2001/2005 – CO



(a)



(b)



(c)

Figure 3.32: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– CO

Particulates as PM_{10}

Table 3.10 contains statistics of the PM_{10} measurements taken at the Project Station for the period of interest and compares them against the same statistics for CBE and CBW with all quantities showing good agreement. Figure 3.33 shows the ranked correlation of PM_{10} for Rozelle 2005 against CBE and CBW, displayed with a linear trend line fit using the least-squares method. It can be seen that there is a very close agreement between ranked pairs, with a correlation coefficient very near to 1. The slope and offset of the trend lines show that PM_{10} concentrations at Rozelle, are typically slightly higher than those at the CBMSs.

Figure 3.34 shows plots of monthly values for the maximum, mean and mean of the top 10% of values for each month. Each plot shows a good level of agreement, with the agreement between all stations being generally consistent amongst all three measures. As above, the concentrations measured at Rozelle are typically greater than those at the CBMSs. Seasonal variations are not apparent in any of the datasets.

Table 3.10: Statistics of PM_{10} at Rozelle (2005) and CBMSs

$PM_{2.5}$	Rozelle 2005	CBE	CBW
Count	357	358	365
% complete	97.81%	98.08%	100.00%
Maximum	49.52	49.44	46.94
Mean of top 10%	36.07	31.80	30.72
Mean	20.33	17.23	16.88
90^{th} Percentile	30.93	26.80	25.88
50^{th} Percentile (median)	18.82	16.30	16.24
10^{th} Percentile	357	358	365

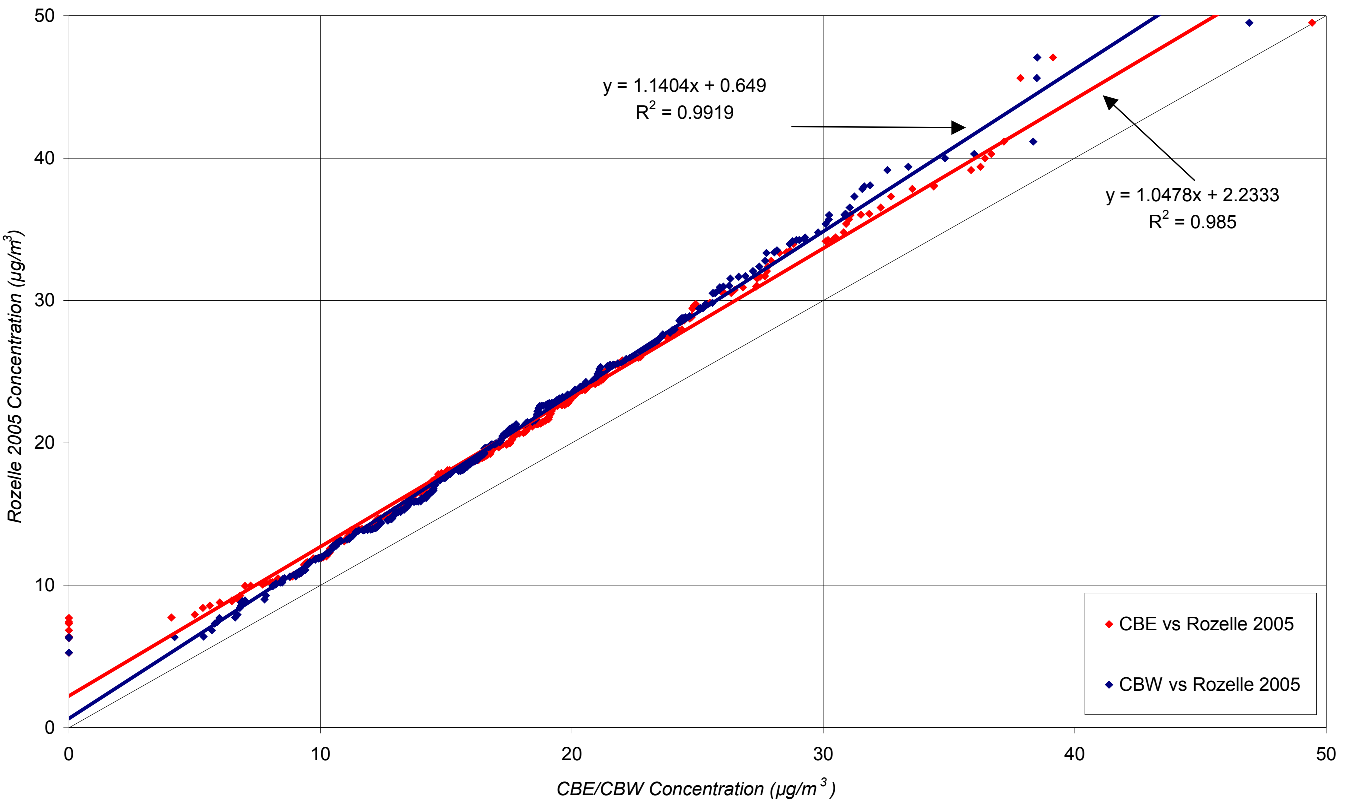
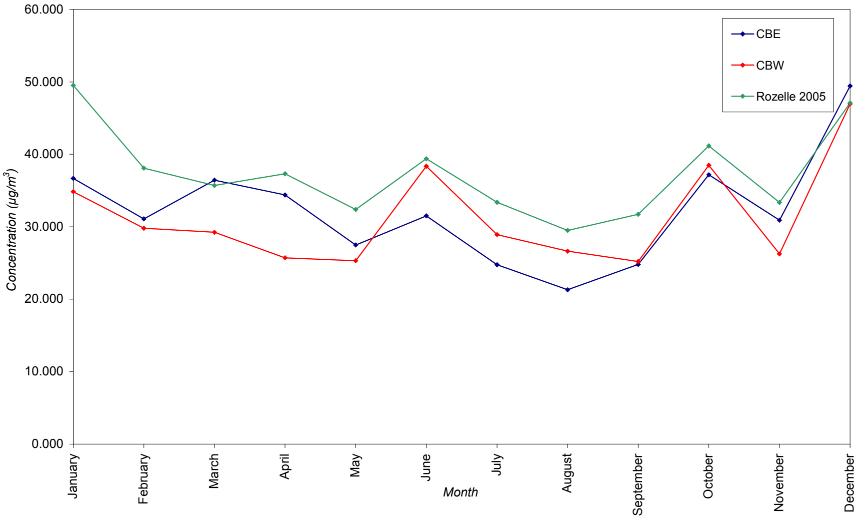
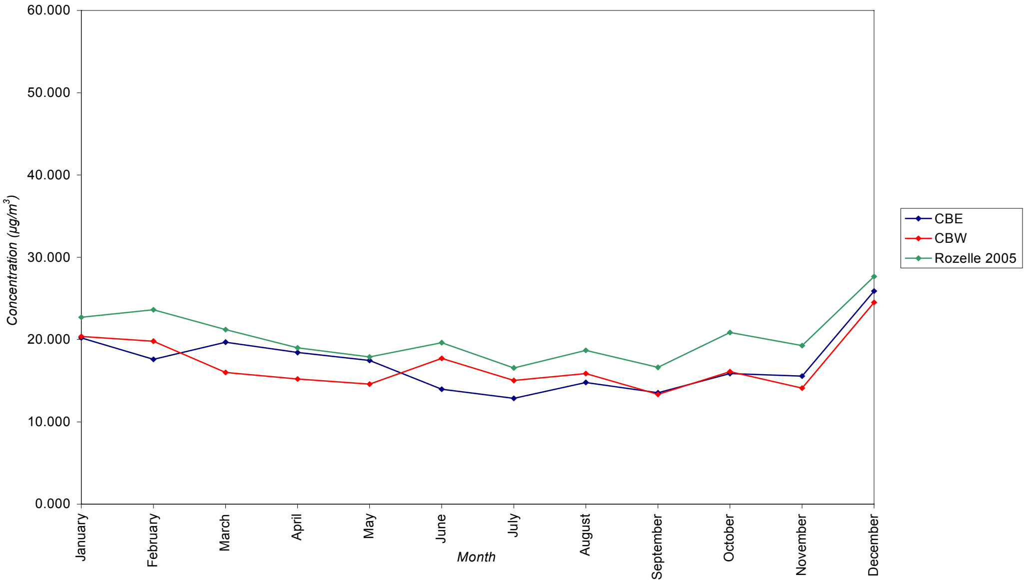


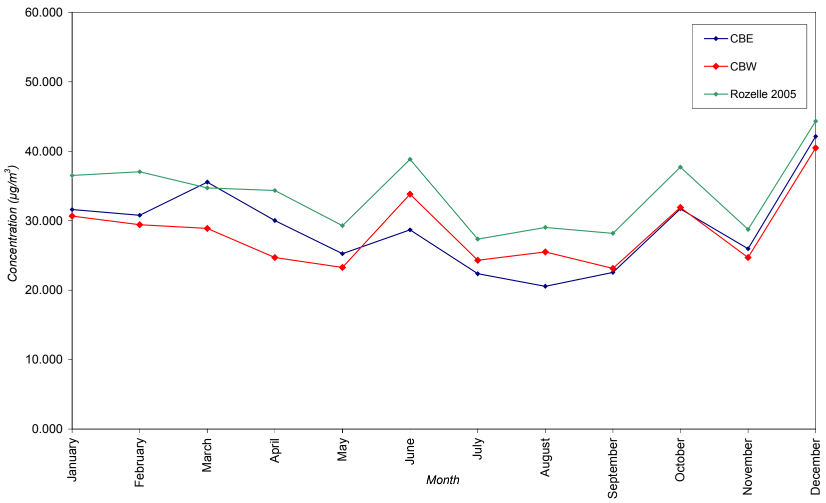
Figure 3.33: Ranked Scatterplot - CBE and CBW Vs. Rozelle 2005 – PM_{10}



(a)



(b)



(c)

Figure 3.34: Time Series of Monthly–(a) Maximum, (b) Mean, and (c) Mean of Top 10%– PM_{10}

4. DISCUSSION AND CONCLUSIONS

4.1 General

A technical review has been conducted of the monitoring data collected from the two (2) community-based monitoring stations (CBMSs) to assess if the data collected to date meets the ***intent*** of MCoA 165 in regards to providing adequate and representative:

- 'Base-line' information with which to assess any changes in ambient air quality following the operation of the tunnel.

- Input information to assist in demonstrating compliance with the requirement of MCoA 168, 170 and 173.

Concurrent data from the community-based station West (CBW) and East (CBE) for the 1-year period: June 2005 to May 2006 inclusive have been analysed in Section 3 in terms of:

- Comparison with ambient criteria for air pollution concentration.
- Correlation between CBMS Monitoring Stations
- Correlation between CBMS and 'Project Monitoring Station' Data
- Correlation between CBMS and EPA Monitoring Station Data

The key outcomes from this analysis that are of relevance to the two key elements of the assessment are discussed below under relevant section headings.

4.2 Adequacy of 'Base-line' Information

The collection of adequate and representative ambient air monitoring data to characterise 'base-line' information is an essential and important element of any 'environmental impact assessment' of a major project. Clearly, the more data collected (both spatially and temporally) the better, however, it is generally recognised that:

- The minimum temporal period is 1 year in order to capture the range of seasonal variations, etc. In this regard, it is relevant to note that the "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales" (DEC, 2005) require a minimum of one year of site-representative meteorological and background air quality concentration data, albeit that these data should be correlated against a longer-duration site-representative database.
- Data quality is a key factor.

The database from each of CBW and CBE is clearly of very high quality in terms of completeness and data quality assurance and has undergone independent auditing. In addition, the analysis conducted in Section 3 highlights that:

- There is a strong correlation between the data collected at the two stations for nitrogen dioxide and particles as PM_{10} and $PM_{2.5}$, particularly at higher percentiles, with any monthly and seasonal trends well represented and correlated. Carbon monoxide measurements at the two stations are also strongly correlated and contain the expected monthly and seasonal trends, however, the monitoring data from CBE are consistently less than those at CBW. An investigation of the reasons for this difference is beyond the scope of this report, but may be as a result of differences in the locations of the monitoring sites relative to roads in the context of the prevailing meteorology.

- There is a strong correlation between the data collected for nitrogen dioxide and particles as PM_{10} at the two CBMS stations with an equivalent 1-year dataset collected from the 'Project Station' at Mowbray West Primary School during Year 2001, particularly at higher percentiles, with monthly and seasonal trends also well represented and correlated. Note that no monitoring of $PM_{2.5}$ was conducted at the 'Project Station'. Carbon monoxide measurements at both stations are also strongly correlated with those at the 'Project Station and contain the expected monthly and seasonal trends, however, the monitoring data from CBE are consistently less than those at CBW and the 'Project Station'.
- There is a strong correlation between the data collected for nitrogen dioxide and particles as PM_{10} at the two CBMS stations with equivalent 1-year datasets collected from the EPA monitoring station at Rozelle for Years 2001 and 2005, particularly at higher percentiles, with monthly and seasonal trends also well represented and correlated. Note that no monitoring of $PM_{2.5}$ was available from Rozelle and PM_{10} data were only available for Year 2005. Carbon monoxide measurements at both stations are also strongly correlated with those at Rozelle for the two different years and contain the expected monthly and seasonal trends, albeit that the monitoring data from Rozelle for Year 2005 and from CBE are consistently less than those at CBW, the 'Project Station' for Year 2001, and Rozelle for Year 2001.

In summary, the assessment indicates that the 1-year datasets from CBW and CBE analysed in this report provide adequate and representative 'base-line' information with which to assess any changes in ambient air quality following the operation of the tunnel. The following outcomes and factors provide support for this conclusion:

- The good agreement between the CBMSs, and with the monitoring data from the other stations examined which reflect both spatial and temporal variations. Note that it could be argued that the good agreement between the CBMSs and the earlier 'Project Station' at Mowbray West Primary School imply that 2-years of site-representative data are already effectively available, albeit that the total dataset is spread over two different years and the earlier station was not a CBMS, and was not subjected to independent auditing.
- The total 14-month dataset from the CBMSs already contains monitoring data from two (2) years for two of the months (May and June) during which the highest monthly background concentrations of nitrogen dioxide and carbon monoxide occur.
- The 14-month dataset will be progressively supplemented with more monitoring data for 'duplicate months' prior to the opening of the tunnel.

4.3 Adequacy of Input Information re MCoA 168, 170 and 173

A key component in demonstrating compliance with the requirements of MCoA 168, 170 and 173 will be to provide: (i) monitoring data for direct use in assessing compliance with the conditions; and (ii) input data for any associated air impact assessment modelling.

The conclusions reached regarding the adequacy of the base-line information imply that the 1-year data set from CBE and CBW analysed will be adequate in regards to (i). In regards to (ii), the inputs to modelling will consist of meteorological data for representing transport and dispersion of relevant emissions, and background concentrations of the pollutants of interest for input to both the emission estimates and as direct input to the modelling for representation of the background or 'other' sources.

As highlighted previously, DEC (2005) requires a minimum of one year of site-representative meteorological and background air quality concentration data. The outcomes discussed in Section 4.2 highlight that this requirement will be satisfied for air quality concentration data. The analysis of meteorological data conducted in Section 3.1 confirms that the minimum DEC requirements are met in terms of available data from the CBMSs, albeit that these data will continue to be only one (essential) of the inputs to the construction of representative fully 3D meteorological fields. Note also that data from the other stations (GBMS and ERMS) will also assist in this regard

It is also important to note that the modelling conducted in support of the design phase, CAMM (2004, 2006a, 2006b), indicates that the predicted incremental impacts resulting from the emissions to air from the two (2) tunnel vent stacks will be small. Indeed, the predicted magnitudes of these increments are such that they are significantly less than the normal variations (hour to hours, day to day, year to year, etc.) in monitoring data for each pollutant. As such, it is highly unlikely that a comparison of the monitoring data collected before and after the opening of the tunnel will detect these increments. However, this form of comparison will provide the basis for assessing any changes in ambient air quality that arise from the estimated reduction in traffic from the network of surface roads when the tunnel opens. Note that the EIS demonstrated the improvements in air quality resulting from the tunnel and twin vent stacks. The EIS results were based on air dispersion modelling, so a 'before and after' comparison of the monitoring data will also assist in verifying the conclusions of that modelling.

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APPENDIX 1:
Correlation of Concurrent Data – CBMSs

It was noted in Section 3.2.2 that since data was collected concurrently for NO_2, CO and PM_{10} at the CBMSs, it is possible to see how well measurements taken at a particular time at each station correlate against each other. This appendix examines the data for such correlations, given that in the report, analysis was confined to examining correlations between ranked data.

Figures A1, A2 and A3 show the scatter plots of NO_2, CO and PM_{10}, respectively. All show relatively good correlations. Important features are the close 1:1 relationship for NO_2 and PM_{10} and that CO measurements at CBW are roughly double those at CBE, as given by the trend line.

The correlation is weakest for PM_{10}, which has an r^2 coefficient of 0.58. However, it can be seen in Figure A3 that there are a number of zero values for each site that lie on the axes of the plots. Figure A4 shows the scatter plot for PM_{10} again, but with those zero values removed (since it is likely they are erroneous). It can be seen that the correlation improves notably, with an r^2 coefficient of 0.81, and the slope of the trend line is closer to 1 than the trend line in Figure A3.

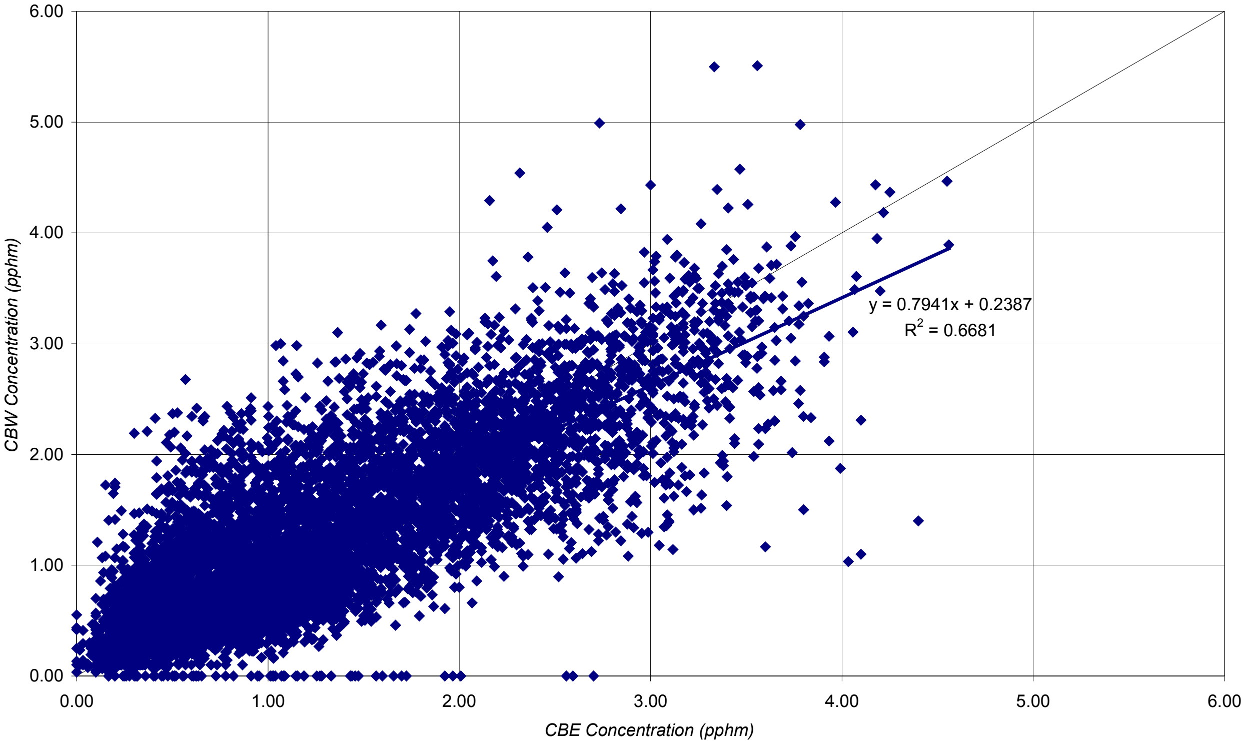

Figure A1: Scatterplot of Concurrent Observations- CBE Vs. CBW – NO_2

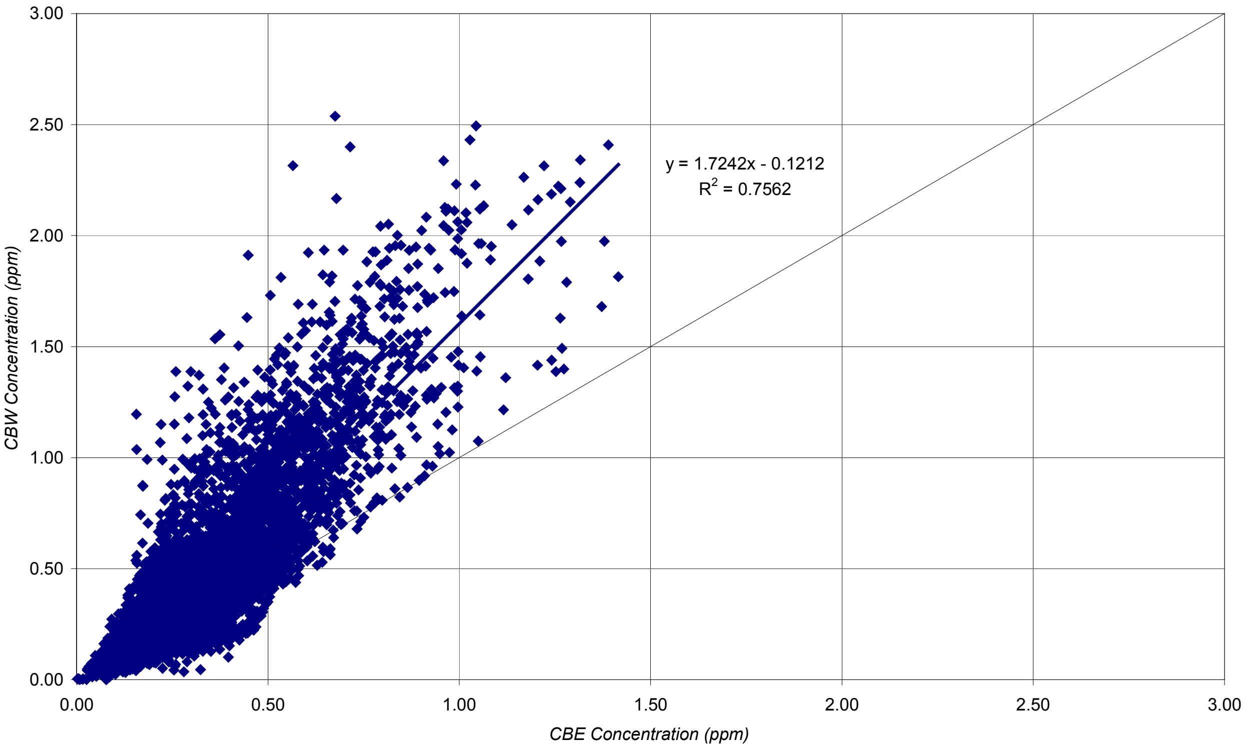

Figure A2: Scatterplot of Concurrent Observations - CBE Vs. CBW – CO

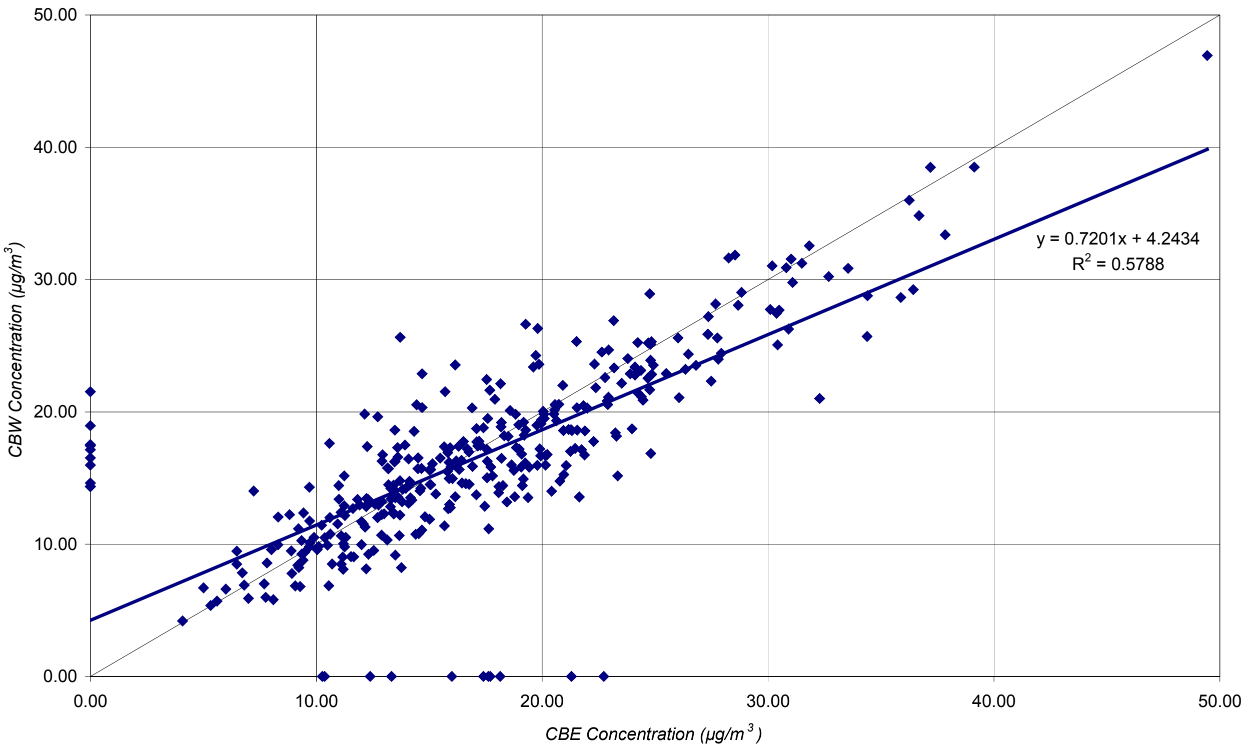

Figure A3: Scatterplot of Concurrent Observations - CBE Vs. CBW – PM_{10}

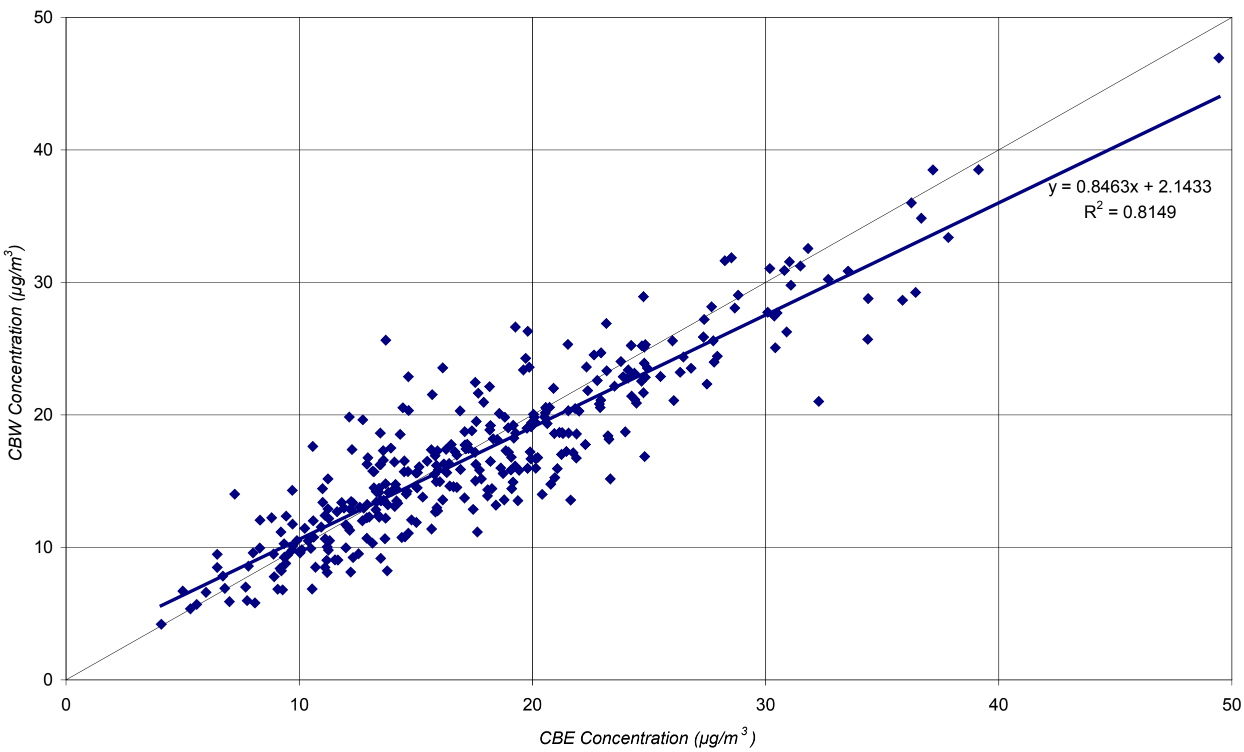

Figure A4: Scatterplot of Concurrent Observations - CBE Vs. CBW – PM_{10} – Zero values removed

Graeme Ross & Associates Pty Ltd A.C.N. 063 931 420 A.B.N. 94 063 931 420
PO Box 292, Ashburton, Vic, Australia. 3147
Tel: (03) 9560 9555, Fax: (03) 9560 9554, Mobile: 0418 371 826, Email: graeme.ross@camm.net.au