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Assessment of trends in PM_{10} concentrations in Airshed A and evaluation of airshed capacity.

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EXECUTIVE SUMMARY

Concentrations of PM_{10} in the Nelson South Airshed A area have decreased since monitoring began in 2001. Estimating the magnitude of the reduction is complicated by the impact of meteorology which varies from year to year. Methods to assess trends in concentrations while accounting for the impact of meteorological conditions were assessed in 2009 and the magnitude of the reduction from 2001 to 2008 in Nelson's Airshed A was estimated at around 56% (Bluett, Wilton, & Ponder Sutton, 2009).

Further reductions in PM_{10} concentrations have occurred since 2006. Previous tools developed to extrapolate changes in concentrations while adjusting for the impact of meteorology suggested a tapering in reductions from 2010 to 2012 with a further drop in concentrations from 2012 to 2013. Evaluation of unadjusted data suggested a tapering at 2010 and no further reduction. The plausibility of the 2013 reduction when considered in conjunction with Air Plan rules is uncertain. No rules were implemented that would have led to a significant reduction between 2012 and 2013, although increased compliance checks were implemented in recent years may have resulted in improvements in concentrations. A comprehensive understanding of trends is required for determining any further reductions in PM_{10} concentrations to meet the NES and as a result trends analysis was undertaken.

An assessment of the relationship between PM_{10} concentrations and meteorological conditions was carried out for the period 2006 to 2014 and trends in PM_{10} concentrations were assessed for the period 2001 to 2014. The meteorological conditions most conducive to elevated PM_{10} concentrations were more than eight hours when the temperature was less than five degrees and 24 hours when the hourly average wind speed was less than 2 ms^{-1}. An assessment of PM_{10} concentrations on days when these conditions occurred suggests a decrease in PM_{10} of around 66-69% since 2001. This is close to the 70% reduction required estimated for the original air plan based on worst case 2001 concentrations.

An evaluation of the worst case meteorological conditions for the second highest PM_{10} concentration days found that 2003 likely represented the worst case scenario for assessing the reduction required for NES compliance. An estimate of 2014 equivalent concentrations indicates a reduction in PM_{10} concentrations of around 14% is still required. Note however, that this is 14% of 2014 concentrations which represents only 5% relative to 2001 concentrations.

An evaluation of trends by time of day was also undertaken to investigate the possibility of additional air quality management issues relating to solid fuel burner use during the overnight period. Environment Canterbury staff found reductions in PM_{10} concentrations during the overnight period were less than during the evening period despite domestic heating being the main source at both times. To evaluate if the same issue was occurring in Nelson, the reduction in PM_{10} concentrations over the evening (6pm to midnight) period was compared to the reduction in PM_{10} concentrations during the overnight (midnight to 6am) period. The estimated reduction in PM_{10} concentrations during the evening period from 2006 to 2013 (46-50%) was similar to the overnight period (42-48%).

1 INTRODUCTION

1.1 Air quality monitoring in Nelson

Nelson City Council commenced monitoring of black smoke at three sites in Nelson during the 1980's. The sites were located in the central city, Victory Square and in Tahunanui. Black smoke concentrations at the Victory Square site were considerably higher than the other sites. During the 1990s the method of monitoring changed from measuring smoke to the measurement of suspended particulate (PM_{10}). The Council established its first permanent PM_{10} monitoring site in 2001 at a rear commercial site off St Vincent St in the Victory Square area (Figures 1.1).

Figure 1-1 St Vincent Street PM_{10} monitoring site

The monitoring method was initially a Partisol 2000 gravimetric PM_{10} monitor with a satellite unit to enable 24 hour PM_{10} to be measured every day. Filters were analysed by the Cawthron Institute and field and laboratory blanks were included in each filter set. The station was equipped with a 10 metre meteorological mast measuring wind speed and direction along with temperature and relative humidity.

In 2006 a Thermo FH62-c14 Beta Attenuation Monitor (BAM) replaced the Partisol sampler as the main monitoring method but was run at a reduced frequency measuring PM_{10} to check for differences between the two monitoring methods. Unlike the Partisol sampler, which only provides a 24-hour average, the BAM can provide hourly or half hourly average PM_{10} concentrations.

A decrease in PM_{10} concentrations in Nelsons Airshed A has occurred since monitoring began in 2001 as a result of measures introduced by Nelson City Council to reduce PM_{10} emissions from domestic home heating and outdoor rubbish burning. Quantifying the magnitude of the reduction is complicated by the impact of meteorology which varies from year to year.

In 2009 Bluett et al., undertook an analysis of trends in PM_{10} concentrations from 2001 to 2008 using a boosted regression tree (BRT) model to identify meteorological conditions conducive to elevated PM_{10} concentrations. This allowed the grouping of days based on pollution potential. The group of days with the highest air pollution potential were then subjected to a trend analysis. The trend analysis of 24-hour average PM_{10} concentrations showed that the median value had decreased by approximately 56% over the period 2001 to 2008. This compares with a required reduction in 2001 PM_{10} concentrations to meet the NESAQ of around 70% (Wilton, 2002). Over the time interval considered, the likelihood of a high potential pollution day resulting in an exceedence of the NES PM_{10} concentration has decreased by between 20 and 30%.

It appears that further reductions in PM_{10} concentrations have occurred since 2008. Previous tools developed to extrapolate changes in concentrations while adjusting for the impact of meteorological suggested a tapering in reductions from 2010 to 2012 with a further drop in concentrations from 2012 to 2013. Evaluation of unadjusted data suggested a tapering at 2010 and no further reduction. The plausibility of the 2013 reduction when considered in conjunction with Air Plan rules is uncertain. No rules were implemented that would have led to a significant reduction between 2012 and 2013, although increased compliance checks were implemented in recent years may have resulted in improvements in concentrations.

Understanding the trends is important for assessing any further reductions in PM_{10} concentrations required to meet the NES. The reduction required based on the second highest 2013 PM_{10} concentration is 14%. However, unless meteorological conditions during 2013 are representative of worst case the reduction required in PM_{10} will be greater. Identification of worst case meteorological conditions and an estimation of the equivalent concentration based on 2014 emissions are required.

1.2 Objectives

The objectives of this report are to:

- Identify meteorological conditions most conducive to elevated PM_{10} concentrations for the period 2006 to 2014.
- Assess trends in PM_{10} concentrations since 2001 based on the meteorological grouping.
- Identify the year when worst case meteorological occurred (for the second highest PM_{10} day).
- Estimate PM_{10} concentrations for 2014 emissions based on the “worst case” meteorological conditions.
- Quantify any further reduction required in PM_{10} concentrations in Airshed A to meet the NESAQ for PM_{10}.

2 METHODOLOGY

2.1 Monitoring data

The monitoring data used in the regression tree evaluation were the beta attenuation monitor (BAM) data from 2006 to 2014. Data prior to this period were excluded from the initial statistical analysis for a number of reasons. Firstly the significant reduction in PM_{10} over this period will confound the results as meteorology will be best classified in terms of pollution potential based on a period of relatively stable concentrations. Secondly, this evaluation attempts to temporally refine the assessment by considering the relationship between PM_{10} and meteorological conditions based on four time of day periods. Prior to 2006 PM_{10} data were available for 24-hour periods only and no temporal refining is possible. Relationships established based on the 2006-2014 time period are applied to earlier data, however allowing for the assessment of long term trends in concentrations.

The data to be included in the study was limited to the months May to August for each year. This assists in the characterisation of meteorological conditions most conducive to elevated winter time PM_{10} concentrations and is more relevant in terms of breaches of the NES. Days where data were missing were excluded from the regression tree analysis but may have been evaluated in the subsequent analysis if sufficient data were available. A total of 1015 days were included in the regression tree and 1665 days in the subsequent analysis.

2.2 Meteorological data

Meteorological data for the period from 2006 to 2014 were collated from the St Vincent Street air quality monitoring site for the variables shown in Table 2.1. The range of averaging periods were included to determine which variables most significantly explained variations in PM_{10} concentrations and which were the greatest indicators of elevated PM_{10}. Meteorological data for the period 2001 to 2005 were also collated from the St Vincent Street air quality monitoring sites for the variables found to be best indicators of pollution potential.

Table 2.1: Meteorological classifications used for the analysis

	Period	PM_{10}	Wind speed (ms^{-1})	Temperature (^oC)	Wind direction (^oN)	Relative Humidity %
24-hour average	Midnight to midnight	✓	✓	✓		✓
7-hour average	5 pm to midnight		✓	✓		✓
4-hour average	8 pm to midnight		✓	✓		✓
6-hour average	6am to midday		✓			
6-hour average preceding day	6pm to midnight		✓			
Minimum 1-hour	Midnight to midnight		✓	✓		✓
Minimum following day 1-hour	Midnight to midnight			✓		
Minimum sample day less minimum day following 1-hour	Midnight to midnight			✓		

Maximum 1-hour	Midnight to midnight	✓	✓		✓
Hourly average	5 pm	✓	✓	✓	✓
Hourly average	2 am	✓	✓	✓	✓
Hourly average	8 am	✓	✓	✓	✓
Hourly average	10 pm	✓	✓	✓	✓
Number of hours	5 pm to midnight	<1ms-1 <2 ms-1 <3ms-1	<1 ºC <5 ºC <10 ºC		

2.3 Statistical Analysis

Regression tree analysis was used to investigate the meteorological conditions with the greatest potential to produce elevated concentrations of PM_{10}. Classification and Regression Trees (CART) describe a statistical procedure that was introduced by Breiman, Friedman, Ohlsen, & Stone, (1984). Classification and Regression Trees have been applied to a wide variety of environmental studies including air quality problems (e.g., Zheng, Chen, Han, Zhao, & Ma, 2009, Hendrikx, Owens, Carran, & Carran, 2005).

Based on a set of predictor variables, this statistical approach repeatedly splits the response into a set of classes (or nodes) with maximum possible class purity at each split stage and arranges the final splits into a decision tree diagram. Analysis was undertaken using the Classification and Regression Tree (CART) analysis in Systat, which is software environment for statistical computing and graphics.

3 TRENDS IN PM_{10} CONCENTRATIONS

3.1 Trends in PM_{10} data

Concentrations of PM_{10} from 2001 to 2013 unadjusted for variability in meteorological impacts with time of day breakdowns are shown in Figure 3.1. Data illustrated includes the average, median (middle ranked 24-hour average PM_{10} concentration) and 25th, 75th and 90th percentile concentrations for the months May to August for each year. Data suggests the most significant reduction in concentrations occurred between 2001 and 2010.

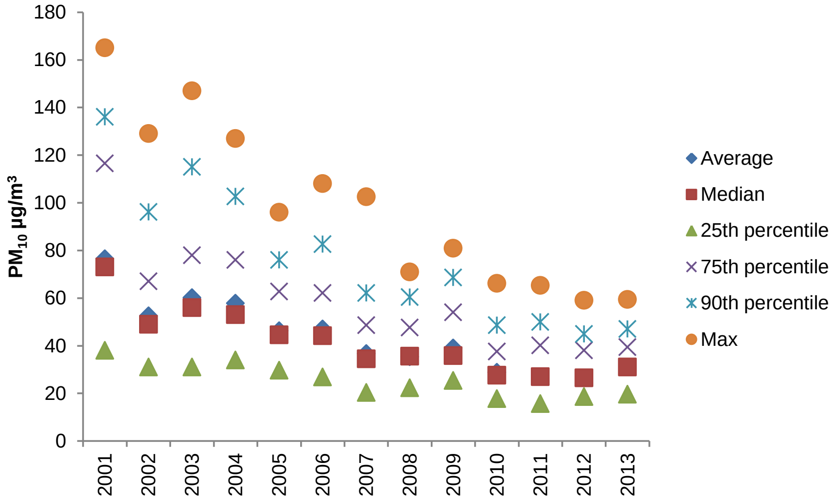

Figure 3.1: 24-hour average PM_{10} concentrations by year in Airshed A

Figure 3.2 illustrates the changes in PM_{10} concentrations by time of day grouping from 2006. Note hourly data is not available for concentrations measured prior to 2006. This time of day evaluation was carried out because recent analysis of trends data by Environment Canterbury suggested a discrepancy in the decrease in PM_{10} concentrations with the midnight to 6am period not decreasing to the extent that the evening to midnight period had. As wood burners are the main contributor at both times these time periods were expected to decrease proportionally. Results suggest a similar decrease across both the evening (6pm to midnight) and early morning (midnight to 6am) and a slightly smaller decrease in the morning (6am-midday) period. Only a slight decrease was observed in the afternoon PM_{10} concentrations, most probably as a result of the contribution of domestic home heating to PM_{10} concentrations from around 4pm to 6 pm.

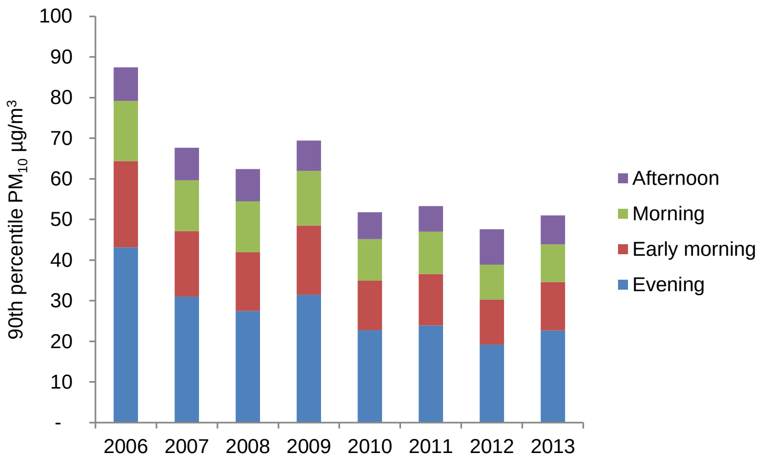

Figure 3.2: Trends in 90th percentile PM_{10} concentrations in Airshed A by time of day

3.2 Regression tree on PM_{10} data

The relationship between daily average PM_{10} data and meteorological conditions from 2006 to 2014 were analysed using a regression tree. The outputs using the meteorological input variables detailed in Table 2.1 are shown in Figure 3.3.

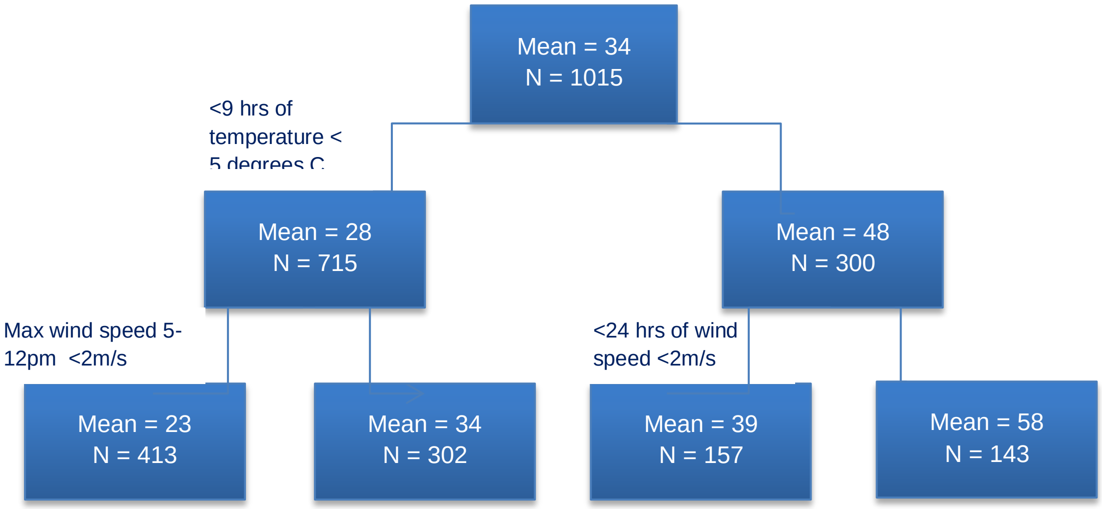

Figure 3.3: Regression tree output applied to data set for 24-hour average PM_{10} concentrations.

The meteorological variables found to have the greatest impact on 24-hour average PM_{10} concentrations were:

- The number of hours per day the temperature was less than five degrees Celsius.
- The number of hours per day the wind speed is less than 2 ms^{-1}.
- The maximum hourly average wind speed between 5pm and midnight.

The highest pollution dataset was characterised by more than eight hours of average temperature of less than five degrees Celsius and 24 hours (all day) of hourly average wind speeds less than 2 ms^{-1} (node 4 from Figure 3.3). There were 152 days when these meteorological conditions occurred from 2006 to 2014 (excluding August 2014) and 94 of them (62%) resulted in breaches of the NES. Notably however for the period 2001 to 2005 there were 95 days which met this criteria and breaches of 50 µg/m^3 occurred on 92 of them (98%). The average PM_{10} concentration for the period 2006 to 2014 on these days was 58 µg m^{-3} compared with 108 µg/m^3 for the 2001 to 2006 period.

The second highest pollution dataset was characterised by more than eight hours of average temperature of less than five degrees Celsius and less than 24 hours of hourly average wind speeds less than 2 ms^{-1} (node 3 from Figure 3.3). There were 173 days when these meteorological conditions occurred from 2006 to 2014 and 31 of them (18%) resulted in breaches of 50 µg/m^3. Prior to 2006 breaches occurred on 77% of the days when these meteorological conditions occurred.

Figure 3.4 shows summary statistics for PM_{10} concentrations from 2001 to 2014 on days when meteorological conditions were consistent with nodes 3 and 4. This suggests a reduction in PM_{10} concentrations of around 66% (mean concentrations) to 69% (90^{th} percentile concentrations) from 2001 to 2014 with the majority of this reduction occurring between 2001 and 2010.

Figure 3.4: Trends in PM_{10} concentrations for days when meteorological conditions met the high pollution potential criteria.

The proportion of days when these meteorological conditions were met that resulted in breaches of 50 µg/m³ are shown in Figure 3.5. This shows a decreasing trend in exceedences of 50 µg/m³ and is indicative of a significant reduction in PM_{10} emissions. Meteorological conditions that once would have resulted in exceedences of 50 µg/m³ on more than 90% of days now only result in exceedences less than 30% of the time. The number of days per year these conditions occurred (and resulted in breaches) is shown in Figure 3.6. This indicates that 2005, 2010 and 2014 all had fewer days when meteorological conditions were conducive to elevated PM_{10} concentrations (although 20014 data did not include August). In 2012 there was a high frequency of meteorological conditions conducive to elevated PM_{10} but only two exceedences. The year with the most number of days when meteorological conditions were conducive to elevated PM_{10} concentrations was 2001.

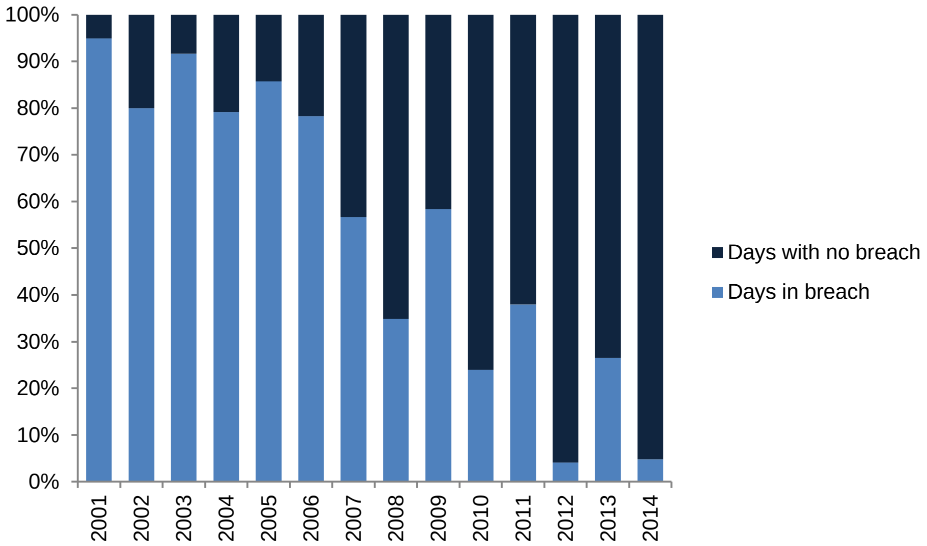

Figure 3.5: Trends in breaches of the NES on days when meteorological conditions met the high pollution potential criteria (nodes 3 and 4).

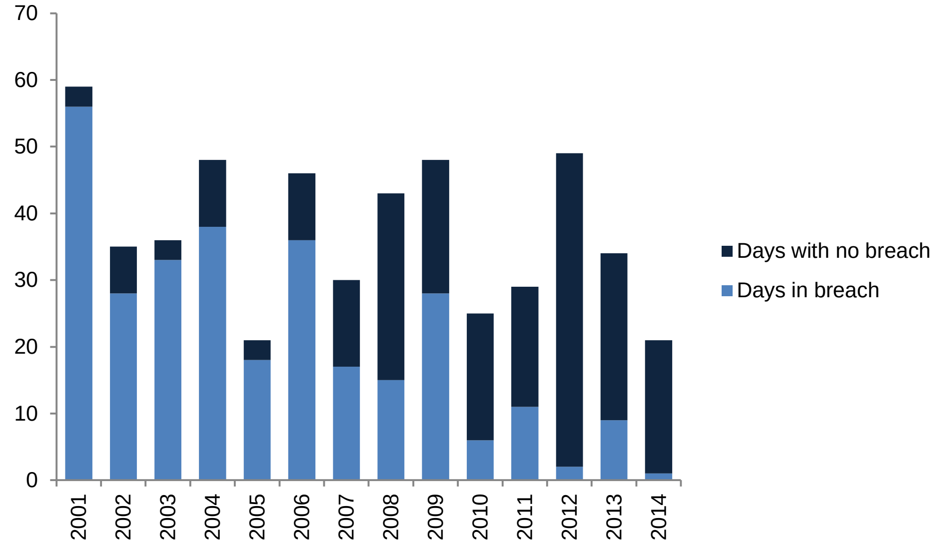

Figure 3.6: Trends in the frequency of meteorological conditions that meet the high pollution potential criteria (nodes 3 and 4) and the number of breaches on the NES on these days from 2001 to 2014 .

3.3 Regression tree on parts of day

The relationship between daily average PM_{10} data and meteorological conditions from 2006 to 2013 were evaluated using a regression tree for the time periods:

- 6am to midday (morning)
- Midday to 6 pm (afternoon)
- 6 pm to midnight (evening)
- Midnight to 6 am (overnight)

Meteorological conditions providing the best predictors of elevated PM_{10} concentrations were identified as:

- Morning - (temperature at 2am less than 2 degrees and temperature at 8am less than 5 degrees Celsius)
- Afternoon (24-hour average temperature less than 8 degrees Celsius)
- Evening (wind speed between 6pm and midnight of less than 2 ms^{-1} and temperature at 2am of less than 7 degrees)
- Overnight (temperature at 2am less than 2 degrees Celsius)

The time periods for which the relationship between meteorological conditions and PM_{10} explained the most variability were the evening, overnight and morning periods. No strong relationships between meteorological conditions and PM_{10} concentrations were found for the afternoon period.

3.4 Trend analysis on evening PM_{10} concentrations

An evaluation of PM_{10} concentrations by year for days when meteorological conditions met the high pollution criteria for the evening period was used to assess trends for this time of day whilst minimizing for some of the impact of meteorological conditions. This analysis was undertaken because Environment Canterbury staff had indicated reductions during the overnight period in Christchurch were small relative to the observed reduction during the evening. This was considered problematic because the main the source of PM_{10} during both periods was solid fuel burning for domestic home heating. Tampering of NES compliant burners to allow an overnight burn was proposed as a potential cause for this discrepancy (Tim Mallet, pers comm, 2014).

A total of 534 days when meteorological conditions met the criteria of six hour average wind speed between 6pm and midnight of less than 2 ms^{-1} and hourly average temperature at 2am of less than seven degrees were separated by year. Trends in 24-hour average PM_{10} concentrations within this dataset are displayed in Figure 3.4. A reduction in PM_{10} concentrations of around 46-50% is observed in evening PM_{10} concentrations from 2006 to 2013.

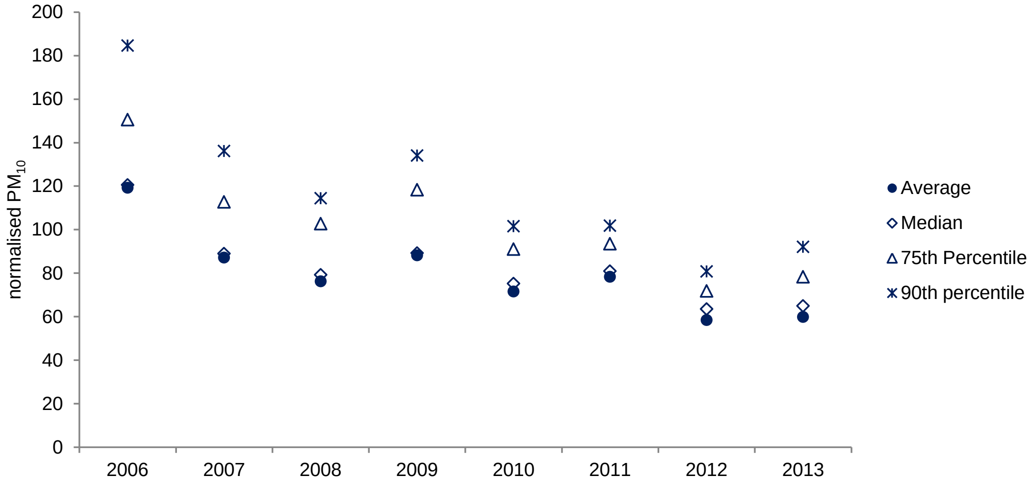

Figure 3.7: Summary statistics for evening (6pm to midnight) PM_{10} concentrations for the 534 days when meteorological conditions met the high pollution criteria.

3.5 Trend analysis on overnight PM_{10} concentrations

An evaluation of PM_{10} concentrations by year for days when meteorological conditions met the two highest pollution criteria for the overnight period was used to assess trends for this time of day whilst minimizing for some of the impact of meteorological conditions. The

A total of 522 days when meteorological conditions met the criteria hourly average temperature at 2am of less than seven degrees were separated by year. Trends in 24-hour average PM_{10} concentrations within this dataset are displayed in Figure 3.8. A reduction in PM_{10} concentrations of around 42-48% is observed in overnight PM_{10} concentrations from 2006 to 2013.

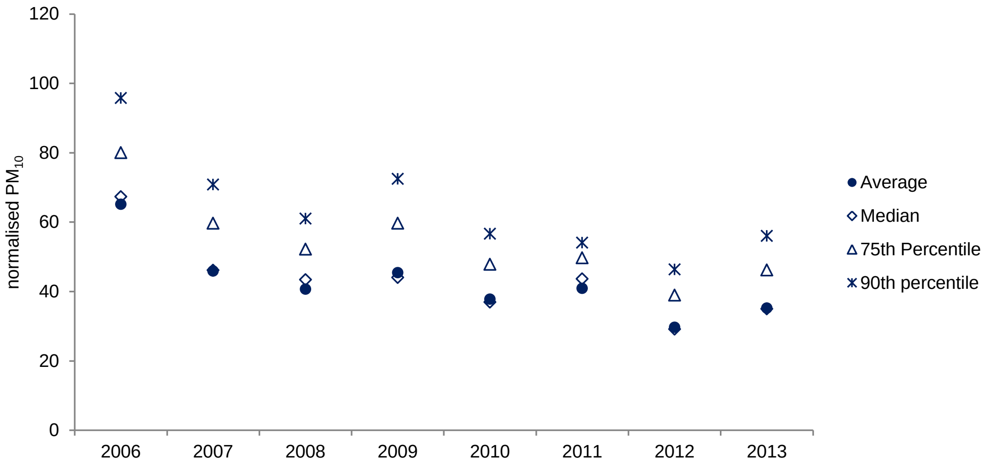

Figure 3.8: Summary statistics for overnight (midnight to 6am) PM_{10} concentrations for the 522 days when meteorological conditions met the high pollution criteria.

4 ESTIMATING THE REDUCTION REQUIRED IN 2014 PM_{10} CONCENTRATIONS

4.1 Identification of worst case meteorological conditions using meteorological categories

Identifying the year with the worst case meteorological conditions for the second highest PM_{10} day is problematic. A simple approach of the ratio of the second highest PM_{10} concentration to the winter mean PM_{10} concentration could provide a rough indication. However the limitation of this approach is that the mean PM_{10} concentration is influenced by the frequency of meteorological conditions conducive to elevated PM_{10} concentrations. As shown in Figure 3.6 this varies from year to year. An improvement on this method is therefore to take the mean PM_{10} concentrations on days when the meteorological conditions are conducive to elevated PM_{10} and compare this value to the second highest PM_{10} concentration. There are also limitations to this approach in that the distribution of PM_{10} concentrations within the high pollution potential days may vary from year to year because of meteorological conditions. Figure 4.1 compares the second highest PM_{10} concentrations each year to the mean PM_{10} concentrations (left) on days when the high pollution potential criteria was met and the smoothed mean concentration for these days (right).

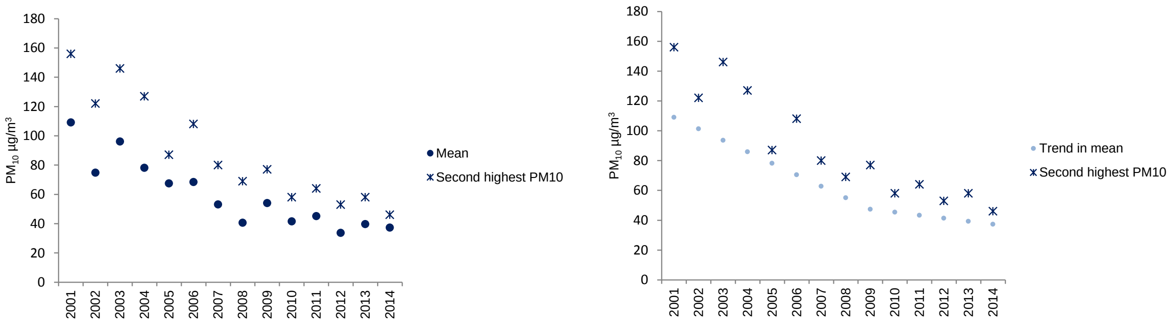

Figure 4.1: Comparison of yearly mean concentrations (left) and mean trend concentrations (right) to second highest PM_{10} concentrations

The largest peak to mean (trend) ratio was for the year 2003, although the years 2006 and 2009 also give high ratios. The meteorological conditions for 7 July 2003, 30 June 2006, and 19 June 2009 (second highest PM_{10} concentrations days for each year) were compared to identify which had worst case meteorological conditions in terms of pollution potential.

4.2 Characteristics of meteorological conditions for second worst day categories

The meterological conditions from the monitoring site highlight the antecedent conditions necessary for pollution build-up and poor air quality in the region. The wind speeds stay less than 1.5 m/s for the entire day for all three episodes with evening temperatures rapidly plummeting to less than 5 °C in the evenings. Nocturnal wind direction is dominated by south-easterly flow possibly due to local katabatic drainage flow from local topography; during the day the wind direction is lesss defined. There is a 20 $\mu g/m^{-3}$ difference is the morning peaks between the two days when hourly PM_{10} data is available, but the difference in evening peaks is over 100 $\mu g/m^{-3}$. Given that the meteorological conditions are rather similar for these cases, the difference in PM_{10} concentrations are most likely the result of significant changes in the evening emission profiles. Based on the available data, it is not possible to say which case has the worst conditions meteorologically, so we have to assume the meteorlogical conditions are similar. The only other way to determine which condition is worse is if we could calculate the static stability of the atmosphere by knowing what the temperature inversion strength is (i.e. by having temperature measurements at two different heights. We recommend that an additional temperature sensor at a height of 10 meters above the ground be installed to provide more analytic capability to study air pollution episodes, as this will allow calculation of temperature inversion strenghts which is also a key determinant of poor air quality.

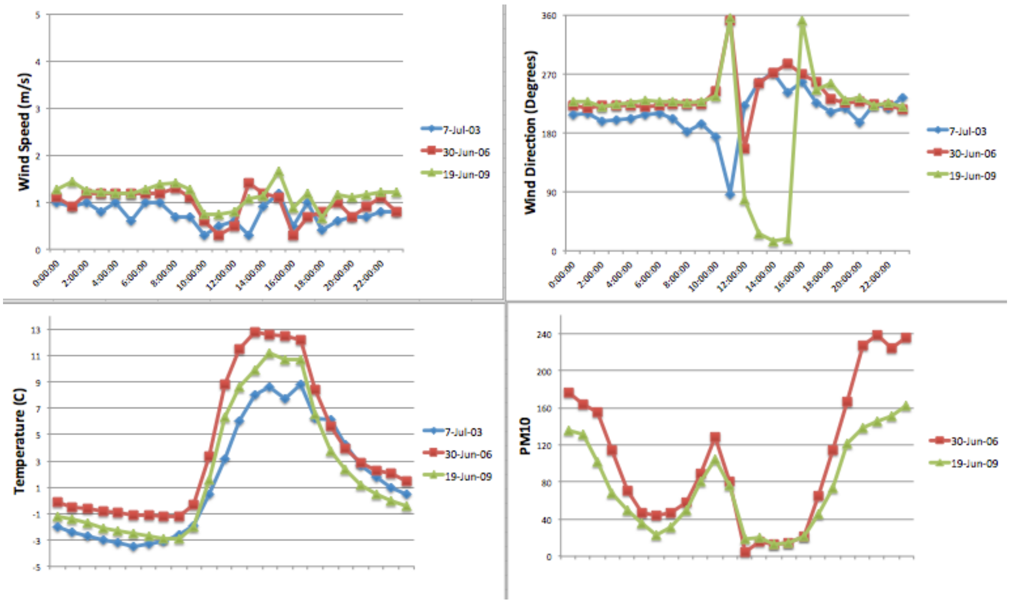

Figure 4.2: Time-series of wind speed, wind direction, temperature and PM_{10} for 7 July 2003 (blue line), 30 June 2006 (red line), and 19 June 2009 (Green line).

To relate local atmospheric conditions to synoptic scale influences, a classification of regularly reoccurring synoptic weather patterns developed by Kidson (2000) is typically used in New Zealand. On the basis of cluster analysis of 1000 hPa height fields derived from NCEP/NCAR reanalyses, Kidson (2000) identified 12 synoptic classes and related them to New Zealand weather regimes using temperature and precipitation observations. This classification has been used in several studies to assess the influence of synoptic weather patterns in a variety of applications including air pollution studies. It is available from 1958 to the present day and each day is classified into 1 of the 12 classes, this synoptic climatological classification is mainly of qualitative value. However, there may be applications in which the classes will be of quantitative use, as, for example, in the frequency analysis of extreme events. As local atmospheric conditions that lead to deterioration in air quality can be considered extreme in the sense that only a narrow range of local meteorological conditions will restrict dispersion sufficiently to permit the build-up of ambient pollutants, a quantitative investigation should therefore be possible, and is used is this report.

Figure 4.3 illustrates the Kidson types at synoptic scale for New Zealand, on all three days under consideration the country is under a high-pressure system with weak winds. Therefore the skies were most likely cloudless, allowing cold temperatures to develop in the evenings (Figure 4.2). These classifications support the observed data from Nelson’s monitoring station (i.e cold nightime temperatures, weak wind speeds, and potential for degradation in air quality).

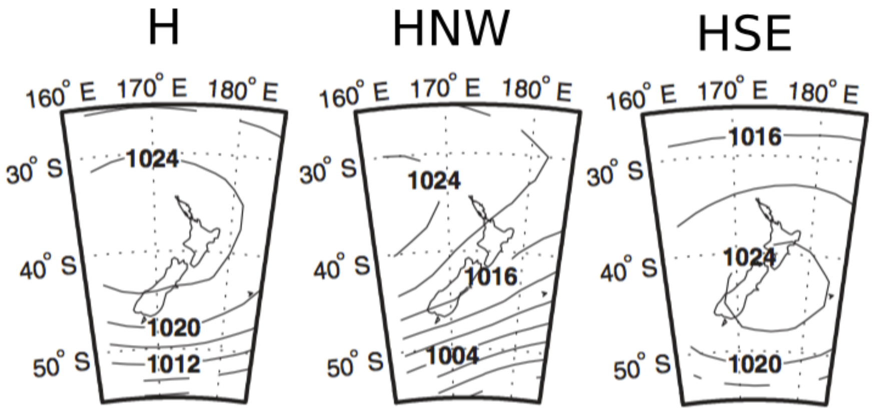

Figure 4.3: Kidson type for 7 July 2003 (HNW; High-pressure in north-west), 30 June 2006 (HSE; High-pressure in south-east), and 19 June 2009 (H; High-pressure).

4.3 Conclusion

The years 2003, 2006 and 2009 were identified as likely to be having worst case meteorological conditions based on measured concentrations (relationships of peaks to means). An evaluation of the meteorological conditions on these days was not able to differentiate between the years in terms of worst case meteorology and concluded that all years had meteorological conditions conducive to elevated PM_{10} concentrations. In the absence of meteorological parameters that could distinguish these days 2003 was estimated as the likely worst case year based on PM_{10} concentrations and the ration of the peak (second highest) to smoothed mean concentration. Applying the 2003 ratio (from section 4.1) to 2014 concentrations gives a second highest PM_{10} value of 58 µg/m^3. The reduction require to meet the NES based on this value is around 14%.

5 CONCLUSIONS

The objectives of this report were to:

- Identify meteorological conditions most conducive to elevated PM_{10} concentrations for the period 2006 to 2014.
- Assess trends in PM_{10} concentrations since 2001 based on the meteorological grouping.
- Identify the year when worst case meteorological occurred (for the second highest PM_{10} day).
- Estimate PM_{10} concentrations for 2014 emissions based on the "worst case" meteorological conditions.
- Quantify any further reduction required in PM_{10} concentrations in Airshed A to meet the NESAQ for PM_{10}.

The meteorological variables found to have the greatest impact on 24-hour average PM_{10} concentrations were:

- The number of hours per day the temperature was less than five degrees Celsius.
- The number of hours per day the wind speed is less than 2 ms^{-1}.
- The maximum hourly average wind speed between 5pm and midnight.

The highest pollution dataset was characterised by more than eight hours of average temperature of less than five degrees Celsius and 24 hours (all day) of hourly average wind speeds less than 2 ms^{-1}. There were 152 days when these meteorological conditions occurred from 2006 to 2014 and 94 of them (62%) resulted in breaches of the NES. Notably however for the period 2001 to 2005 there were 95 days which met this criteria and breaches of 50 $\mu g/m^3$ occurred on 92 of them (98%). The average PM_{10} concentration for the period 2006 to 2014 on these days was 58 $\mu g\ m^{-3}$ compared with 108 $\mu g/m^3$ for the 2001 to 2006 period.

The second highest pollution dataset was characterised by more than eight hours of average temperature of less than five degrees Celsius and less than 24 hours of hourly average wind speeds less than 2 ms^{-1}. There were 173 days when these meteorological conditions occurred from 2006 to 2014 and 31 of them (18%) resulted in breaches of 50 $\mu g/m^3$. Prior to 2006 breaches occurred on 77% of the days when these meteorological conditions occurred.

A trend evaluation on days which met both of these meteorological conditions showed a significant decrease in PM_{10} concentrations from 2001 to 2014 of around 66% (mean concentrations) to 69% (90^{th} percentile concentrations). Similarly an evaluation of the proportion of days when meteorological conditions conducive to elevated concentrations resulted in breaches of the NES shows that meteorological conditions that once would have resulted in consistent exceedences of 50 $\mu g/m^3$ now only result in exceedences less than 30% of the time.

An evaluation of the meteorological conditions on the day when the second highest PM_{10} concentrations were recorded for each year suggests that 2003 was the year with most conducive meteorological conditions for the purposes of calculating the reductions required in PM_{10} concentrations to meet the NES. This is the year with the worst case meteorological conditions on the day that the second highest PM_{10} concentration was recorded. Based on meteorological data for this day, the reduction required in 2014 PM_{10} concentrations to meet the NES is estimated at around 14%.

The year with the greatest frequency of meteorological conditions conducive to elevated PM_{10} concentrations was 2001.

An evaluation of trends by time of day was also undertaken to investigate the possibility of additional air quality management issues relating to solid fuel burner use during the overnight period. Environment Canterbury staff found reductions in PM_{10} concentrations during the overnight period were less than during the evening period despite domestic heating being the main source at both times. To evaluate if the same issue was occurring in Nelson, the reduction in PM_{10} concentrations over the evening (6pm to midnight) period was compared to the reduction in PM_{10} concentrations during the overnight (midnight to 6am) period. The estimated reduction in PM_{10} concentrations during the evening period from 2006 to 2013 (46-50%) was similar to the overnight period (42-48%).

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APPENDIX A: NORMALISING PM_{10} CONCENTRATIONS

One of the outputs of this work is to enable an assessment of trends in PM_{10} concentrations in future years. As all meteorology has some impact, one of the biggest issues in establishing a methodology for normalising data was determining what constitutes "no impact", that is, what concentrations should be normalised to. The method used aims to minimise the impact of varying meteorology for high pollution events and follows the same approach used in this report of tracking trends only on days with high pollution potential.

It should be noted that the following method provides only an indication of trends in high PM_{10} concentrations and results are not expected to give an indication of day to day variability in PM_{10} emissions but may provide some indication of annual trends in emissions. Results should be checked through a repeat of the methodology outlined in this report at least every five years. The following process relates to a spreadsheet tool that has been provided to Nelson City Council with this report.

Process:

1. Select all days during May to August and input into the spreadsheet in the date column
2. Input daily PM_{10} concentrations for each day into column C.
3. Input the number of hours per day the hourly average temperature was less than five degrees into column D.
4. Input the number of hours per day the daily wind speed was less than 2 ms^{-1} into column E.
5. Input the maximum hourly wind speed between 5pm and midnight into column F.
6. The average PM_{10} concentrations for the days with high pollution potential will automatically update as will the graph.