Assessing long-term trends in PM_{10} emissions and concentrations in Nelson

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Executive Summary

The objectives of this study are to advise Nelson City Council on:

(a) Real time methods for assessing trends in PM_{10} concentrations, in particular how to account for daily variations in meteorological conditions, their consequent impact on PM_{10} concentrations and compliance with the Straight Line Path (SLiP) and National Environmental Standard (NES).

(b) Methods (including appropriate emission rates) for assessing trends in PM_{10} emissions with time, in particular how to use information on changes in household heating methods and industry emission changes to track progress towards compliance with the NES.

The years considered for this study run from 2001 to 2008. A total of 2445 days of PM_{10} monitoring data was collected over this 8 year period. There is no obvious trend in the annual average PM_{10} concentrations. The method used to account for year-to-year variation in meteorology and to analyse the long term trend of PM_{10} concentrations was to use a boosted regression tree (BRT) model. The BRT identified and grouped days with similar meteorological variables together. 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 shows that the median value has decreased by approximately 56% over the period 2001 to 2008. Similarly, the upper quartile value has decreased by 54% from 2001 to 2008. Over the time 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%.

A trend analysis of PM_{10} emissions shows that the home heating and industry emissions are decreasing and tracking very closely with predicted air plan projections. Over the years 2001 to 2008, emissions are estimated to have decreased by 42%. It is interesting to compare this with the 54-56 % reduction in PM_{10} concentrations. The emission trend assessment is likely to underestimate actual emission reductions because the estimates only include changes in household emissions as a result of the Nelson City Council incentives programme and changes outside the programme where Nelson City Council knows about it because council permission is needed, e.g., a building consent for the installation of a replacement woodburner. Notwithstanding the difference between the trends in PM_{10} emissions and concentrations, it is concluded that actual emissions reduction is within Nelson City Council's Straight Line Path (SLiP) target.

A method has been developed to normalise (adjust up or down) PM_{10} data recorded in the year 2009 (and beyond) to the meteorological conditions which resulted in high pollution events over the years 2001 to 2008. The PM_{10} normalising process will allow the evaluation of the trends in PM_{10} data recorded in 2009 (and beyond) without having to repeat the BRT modelling exercise.

The results of the current study have been compared to an earlier investigation into the trends in PM_{10} concentrations for the years 2001 to 2005 undertaken by Sherman and Fisher (2006). The findings of the two studies are not inconsistent, with both showing decreases in PM_{10} concentrations during high pollution events of around 30% over the years 2001 to 2005.

The overall results of this study suggest that:

- the management options adopted by Nelson City Council have been effective in reducing PM_{10} emissions and concentrations in Nelson's airshed A
- Nelson City Council is currently on target to meet its Airshed A air quality goals as defined by the straight line path and the 2013 NES

1. Introduction

National Environmental Standards (NES) for air quality specify a 24-hour average standard for PM_{10} of 50 µgm^{-3}. The PM_{10} standard, which allows for one breach per year, must be met by 2013 or Councils are unable to grant resource consents for discharges to air in the airshed. In addition, if a straight line path (SliP) to compliance with the NES is not met, Councils are unable to grant consents for significant PM_{10} discharges. In Nelson PM_{10} concentrations in excess of 50 µgm^{-3} are measured regularly during the winter months.

An air plan for Nelson City Council (NCC) regulates domestic home heating and other sources of PM_{10} with an aim to achieving the NES by 2013. Incentives and education are also used to reduce PM_{10}. In the most polluted airshed in Nelson, a 70% reduction in PM_{10} emissions is required. Ongoing monitoring of PM_{10} concentrations is necessary to track compliance with the straight line path and to assess whether existing management measures are sufficient to meet the NES by 2013.

Tracking PM_{10} emissions and tracking PM_{10} concentrations are two methods of assessing compliance with the SLiP. However, both approaches contain uncertainties. Evaluating and comparing trends in both variables is necessary to provide a robust assessment of the impact of management measures on the wintertime air quality in Nelson.

Tracking trends in PM_{10} concentrations requires a method for adjusting measured values to account for variations in meteorological conditions. Emissions assessments quantify the amount of PM_{10} discharged to air. Variations in household heating options as a result of regulations, incentives or natural attrition and changes in industrial discharges result in changes in emissions of PM_{10}. Existing NCC systems for tracking changes in emissions require upgrading for more recent information on discharge rates and fuel consumption.

The objectives of this study are to advise Nelson City Council on:

(a) Real time methods for assessing trends in PM_{10} concentrations, in particular how to account for daily variations in meteorological conditions, their consequent impact on PM_{10} concentrations and compliance with the SLiP and NES.

(b) Methods (including appropriate emission rates) for assessing trends in PM_{10} emissions with time, in particular how to use information on changes in household heating methods and industry emission changes to track progress towards compliance with the NES.

It is anticipated that NCC will be able to manage PM_{10} concentrations in Nelson more effectively as a result of this work. In particular they will have more certainty in how to respond to resource consents for PM_{10} discharges and will be able to adjust incentives and education programmes based on the outcomes. Environmental benefits include increased certainty on whether or not PM_{10} concentrations will meet the NES by 2013. This arises from the ability to alter air quality management should trends assessments be inconsistent with projected improvements.

Because meteorological impacts are location specific, the outcomes of this report relate only to Nelson City Council. However, the methods described in this report could be applied by other Regional Councils in New Zealand who are currently evaluating the effectiveness of their management measures

2. Method

2.1. Trends in PM_{10} concentrations

2.1.1. Monitoring PM_{10} concentrations

Nelson City Council commenced monitoring of black smoke during the 1980s at three sites. One in the central city, one in Victory Square and one in Tahunanui. Black smoke concentrations at the Victory Square site were considerably higher than the other sites so when the Council established its first permanent PM_{10} monitoring site in 2001, a rear commercial site off St Vincent St in the Victory Square area was chosen.

The St Vincent St air quality monitoring site is located within a light industrial and commercial area. It lies at the bottom of a broad valley, which is surrounded by older residential housing, many of which rely on solid fuel heating. The valley is prone to temperature inversion conditions during winter where low wind speeds and little vertical mixing trap and concentrate air pollutants. The location of the St Vincent Street air quality monitoring site is shown in Figure 2-1. A photograph of the St Vincent Street site is shown in Figure 2-2.

In 2001 a Partisol 2000 gravimetric PM_{10} monitor and satellite unit were installed at the site. The use of a satellite unit in addition to the hub unit enabled 24 hour PM_{10} to be measured every day. Filters are analysed by the Cawthron Institute and field and laboratory blanks are included in each filter set. The station is equipped with a 10 metre meteorological mast measuring wind speed and direction along with temperature and relative humidity.

Figure 2-1: Aerial photograph of Nelson indicating location of the St Vincent Street PM_{10} monitoring site

Figure 2-2: Photograph of the St Vincent Street PM_{10} monitoring site

In 2006 the site was upgraded with the installation of a Thermo FH62-c14 Beta Attenuation Monitor (BAM) in an air conditioned enclosure measuring PM_{10} in 30 minute intervals. At that time the Partisol was reset to only measure once every 6 days to act as a cross check on the BAM measurements. Over the last year the Partisol Satellite intake has been fitted with a $PM_{2.5}$ intake which now measures $PM_{2.5}$ every 6th day while the Hub unit measures PM_{10} every 6th day.

The years considered for this study run from 2001 to 2008. A total of 2445 days of PM_{10} monitoring data was collected over this 8 year period. The PM_{10} data from 2001 to 2005 was monitored with the Partisol instrument. The PM_{10} data from 2006 to 2008 was monitored with the BAM. A cross-check of the Partisol and BAM PM_{10} data demonstrates a strong relationship between the two instruments. The correlation coefficient (R^2) for 2006 to 2008 (the three years that one day in six collocated data has been recorded) is greater than 0.96 for both average and high concentrations. The Partisol data is, on average, approximately 3-4% higher than the BAM data.

Given the strong relationship and small differences between the data from the two instruments it was concluded there would be little benefit gained from adjusting the BAM data to make it Partisol equivalent. Consequently, for the purposes of the trend analysis, no adjustment has been made to the BAM data. The non-adjustment of BAM data for this investigation is consistent with the approach taken by Nelson City Council in reporting PM_{10} concentrations to assess compliance with the NES.

2.1.2. Trend analysis of PM_{10} concentration data

The method used to analyse the long term trend of PM_{10} concentrations was to allow for statistical groupings of the relationship between PM_{10} and meteorological variables using a boosted regression tree analysis. Very briefly, the regression tree identifies which meteorological variables are correlated with the most variation in the PM_{10} concentrations. The tree model then clusters the PM_{10} data into groups with similar meteorological predictor variables. The PM_{10} data from a particular group (with similar meteorological predictor variables) is then broken down into year and subjected to trend analysis. The year-to-year differences in PM_{10} were tested for statistical significance using both the Kruskal-Wallis test and first year to last year differences using Chi-square test.

For this study the Boosted Regression Tree (BRT) algorithm was used. Basic regression trees give a stepwise model and this is probably their biggest disadvantage. Boosted regression trees are created by fitting many individual trees (with stepwise relationships) then combining them to make more smoothly varying relationships and to provide a more robust estimate of a modelled response. These combined predictions are used to partition observations into groups having similar values for the response variable, based on a series of splits constructed from the predictor variables (Hastie et al. 2001). BRT is stochastic in nature, with each run differing slightly (Elith et al. 2008).

Other advantages offered by BRT over basic regression trees include its ability to accommodate different types of predictor variables and missing values, its immunity to the effects of extreme outliers (thus avoiding biases) and the inclusion of irrelevant predictors, and its facility for fitting interactions between predictors (Friedman and Meulman 2003). The fitting of interaction effects is controlled by varying the size of the individual regression trees. Over-fitting can also be limited by identifying the optimal number of trees that maximise the ability of a model to make accurate predictions to new, independent sites while avoiding excessive model complexity; as well as by performing 10-fold cross validation, randomly partitioning the data ten separate times and comparing the models predictions to each partition (Leathwick et al. 2006).

2.2. Trends in PM_{10} emissions

Information on household heating changes occurring as a result of the Clean Heat Warm Homes programme or other mechanisms was provided in spreadsheet form by Nelson City Council. Details provided included:

- Date of replacement
- Household address
- Older heating method
- Replacement heating method
- Conversion type – e.g., clean heat warm homes or other
- Authorisation number
- Indicative capital value of home
- Airshed number

The number of different solid fuel burners removed each year in each airshed was determined from these data, as were the number of new gas, oil, pellet burners and NES compliant burners going into each airshed for each year.

These data were entered into existing NCC emissions tracking software, which was also upgraded based on the following revisions to input variables:

- Emission factor NES authorised wood burners – 3 g/kg based on results reported in Smith, et. al., 2008.
- Emission factors for industrial combustion as per Table 2.1.

- Additional industry categories added for control technologies.

Table 2.1: Emission factors for PM_{10} and TSP from Wilton et al. (2007)

Classification	PM_{10} (g/kg)	TSP (g/kg)	TSP (mg/m^3)
Chaingrate - multi cyclone	1.5	2.1	220
Light Fuel Oil	1.3	1.3	98
Vekos – standard with simple cyclone (coal)	3.8	6.2	650
Vekos – one multi cyclone (coal)	2.0	2.8	300
Coal boiler – two multi cyclones	1.7	2.4	250
Solid fuel boiler with bag filter	0.5	0.5	50
Low ram stoker with multi cyclone	2.0	2.8	300
All wood boilers	1.6	1.8	280
Underfeed stoker uncontrolled (coal)	2.0	2.8	300

Information on changes in industrial discharges since 2006 was sought from Nelson City Council. Emission tracking software was updated to include the information provided.

3. Trends in PM_{10} concentrations

3.1. Annual average PM_{10} concentrations

Figure 3-1 shows the distribution of 24-hour average PM_{10} concentration for each year as measured at the St Vincent Street monitoring site for 2445 days over the period 2001 to 2008.

Figure 3-1 shows that the median 24-hour average PM_{10} concentration has been reasonably consistent at approximately 20 µg m^{-3} over the period 2001 to 2008. However, Figure 3-1 suggests that the there may have been a general downward trend in the higher values (75th percentile and outliers) of PM_{10} concentrations over that same period. It is important to note that any year-to-year trends demonstrated in Figure 3-1 do not account for year-to-year variation in meteorology.

3.2. Identifying and grouping days with highest PM_{10} concentrations

The Nelson PM_{10} record contains 2445 days of data. This data set was subjected to a BRT analysis. The predictor variables and averaging periods used for the analysis are detailed in Table 3-1.

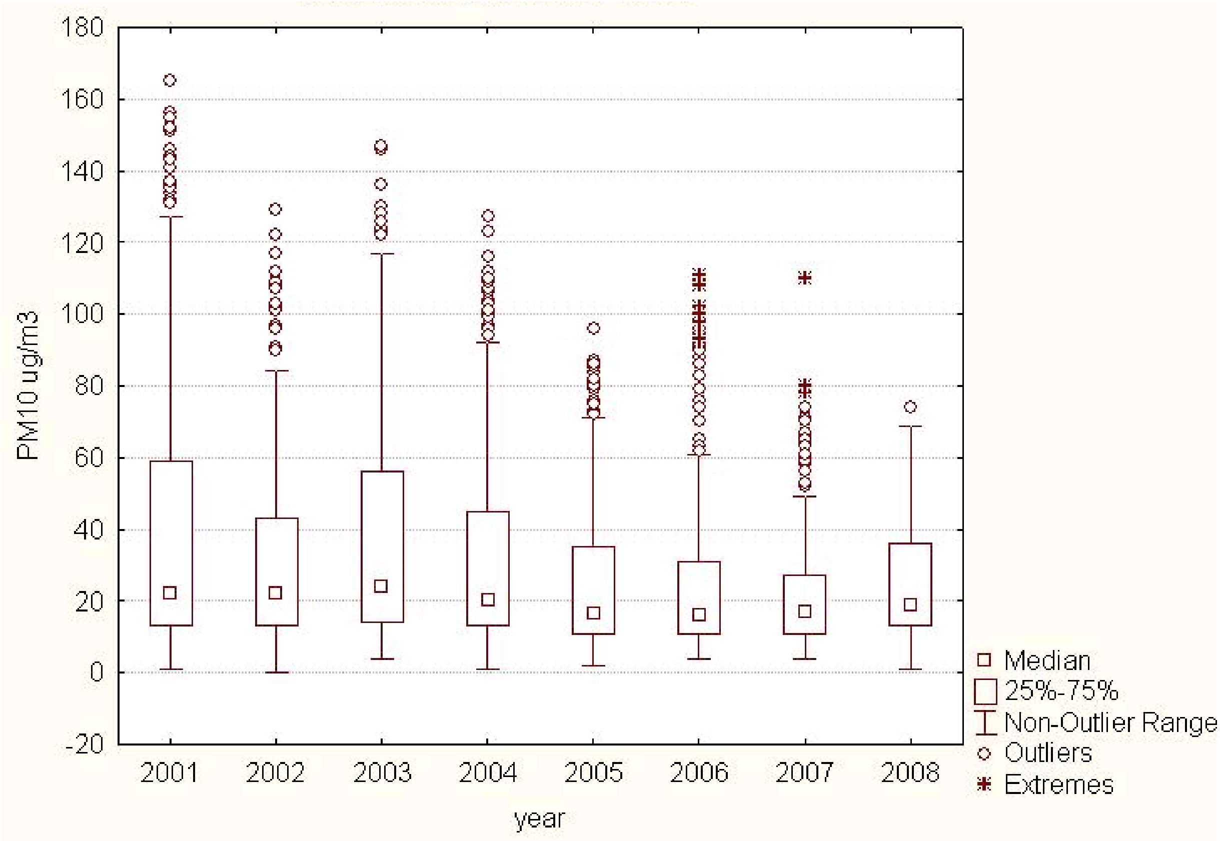

Figure 3-1: Distribution of 24-hour average PM_{10} concentrations in Nelson (St Vincent Street monitoring site) - 2001 to 2008

Table 3-1: Predictor variables and averaging periods used for the BRT analysis

	Wind speed (ms^{-1})	Temperature (^oC)	Relative humidity (%)	Wind direction (^oN)
24-hour average	✓	✓	✓	
8-hour average (1600 to 0000)	✓	✓	✓	
4-hour average (1600 to 2000)	✓	✓	✓	
Minimum 1-hour	✓	✓	✓	
Maximum 1-hour	✓	✓	✓	
5 pm	✓	✓	✓	✓
8 pm	✓	✓	✓	✓

The results of the BRT analysis are displayed in Figure 3-2. Note that: Mean = mean value of PM_{10} concentrations of the days within that particular group; STD = Standard deviation of the PM_{10} concentrations of the days within that particular group and N= number of days within that particular group.

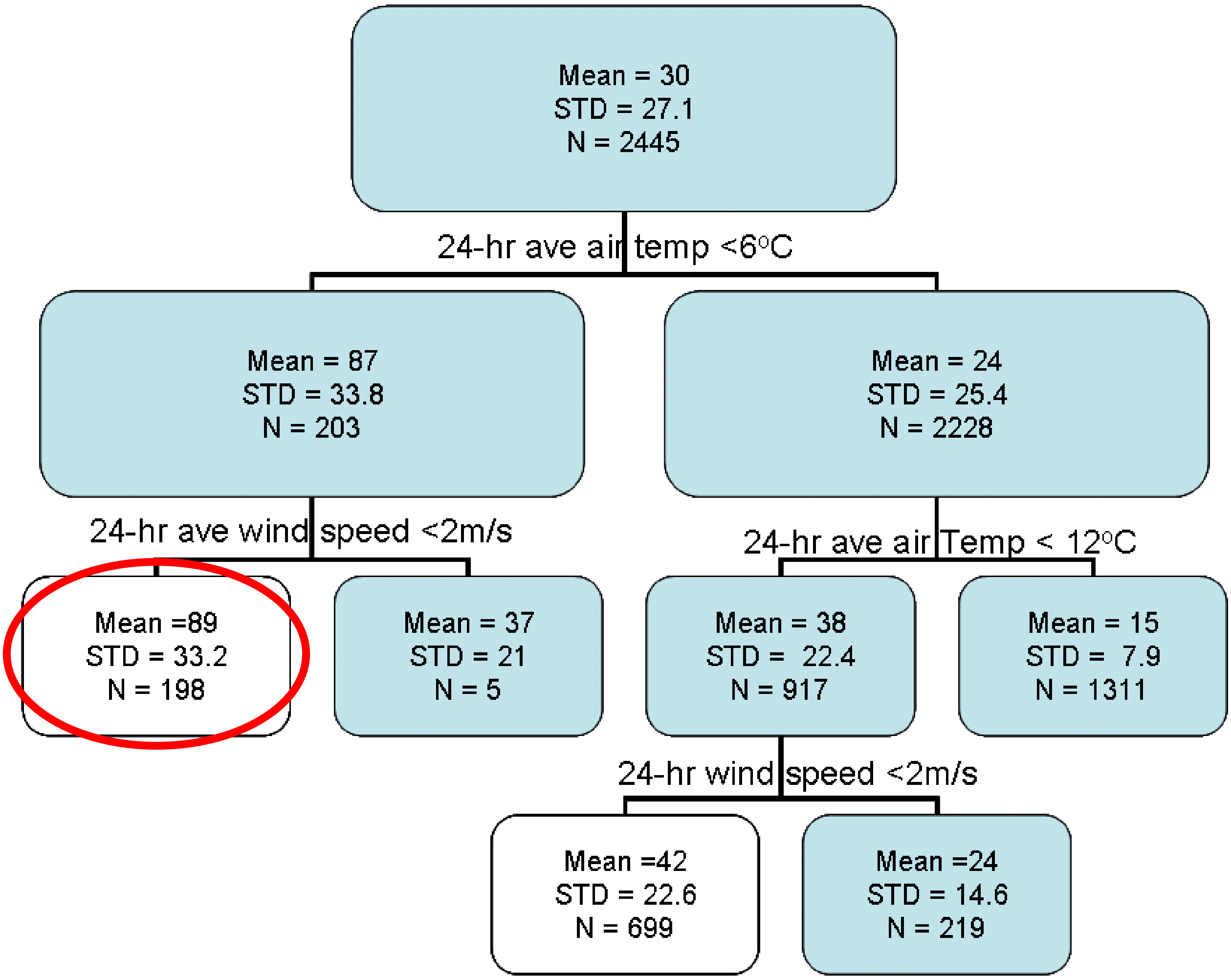

Figure 3-2: Boosted regression tree to fit full 24-hour average $PM1_{10}$ data set

Figure 3-2. shows that the main predictors used to categorise the 24-hour PM_{10} data were 24-hour average air temperature and wind speed. The BRT gave a coefficient of determination (r^2) of 0.52. This indicates that around 52% of the variation in PM_{10} concentrations could be explained by the relationships between the predictor variables and PM_{10} concentrations described by the BRT.

The tree grouped the data into five terminal nodes, one of which was designated as containing the days with the highest pollution potential. The days with the highest pollution potential are contained within the terminal node circled in read in Figure 3-2. A total of 198 days have been captured within this node (8% of the total days in the data set). The mean value of PM_{10} for days contained in this node is 89 μgm^{-3}. This high pollution node is defined by the following predictor variables: 24-hour average temperature less than 6^{o}C and 24-hour average wind-speeds less than 2 ms^{-1}. Of the 426 days when PM_{10} concentrations exceeded 50 μgm^{-3} from 2001 to 2008, 174 days (41%) were within the highest pollution category identified by the BRT. That is, they occurred on days when the 24-hour average wind speed was less than 2 ms^{-1} and the temperature less than 6 degrees.

Another 230 (54%) of the remaining high pollution days from 2001 to 2008 occurred when the wind speed was less than 2 ms^{-1} (24-hour average) and the 24-hour average temperature was between 6 and 12 degrees. This group of days populates the second highest pollution node and is shown in figure 3-2 as the white shaded pollution node which is not circled. Only 5% of high pollution days did not occur in the highest or second highest pollution nodes.

Of the 189 days with the highest pollution potential (days within node 1), 183 (92%) occurred in the winter months of June, July and August. Another 13 occurred during May and one each in September and October. The days with high pollution potential clearly occurred more frequently during the winter months.

The BRT has clustered the PM_{10} data into groups with similar meteorological predictor variables therefore enabling the analysis (to a helpful extent) to control for the year-to-year effects of varying meteorology. The PM_{10} data from the group identified as days with the highest pollution potential (which have similar meteorological predictor variables) is then subjected to time trend analysis.

3.3. Time trend analysis of high PM_{10} events

The 198 days identified as having high potential pollution data were disaggregated by year of monitoring. There were at least 20 high potential pollution days in all but two years; 2005 had only six days and 2007 had 17 days. The resulting year-to-year trend in 24-hour average PM_{10} concentrations is displayed in Figure 3-3.

Figure 3-3 shows that within the high potential pollution days, the highest PM_{10} concentrations (median and maximum values) were recorded early in the record (2001 and 2003). From 2003 to 2008 there has been a steady decline in the median values of PM_{10} occurring on the days with highest potential of poor air quality. Trends in the upper quartile concentrations are particularly relevant when assessing concentrations relative to the NES because it is the second highest PM_{10} value that needs to be reduced to below 50 μg m^{-3}. Figure 3-3 shows the upper quartile concentrations were highest in 2001 and have generally decreased in the years 2003 to 2008.

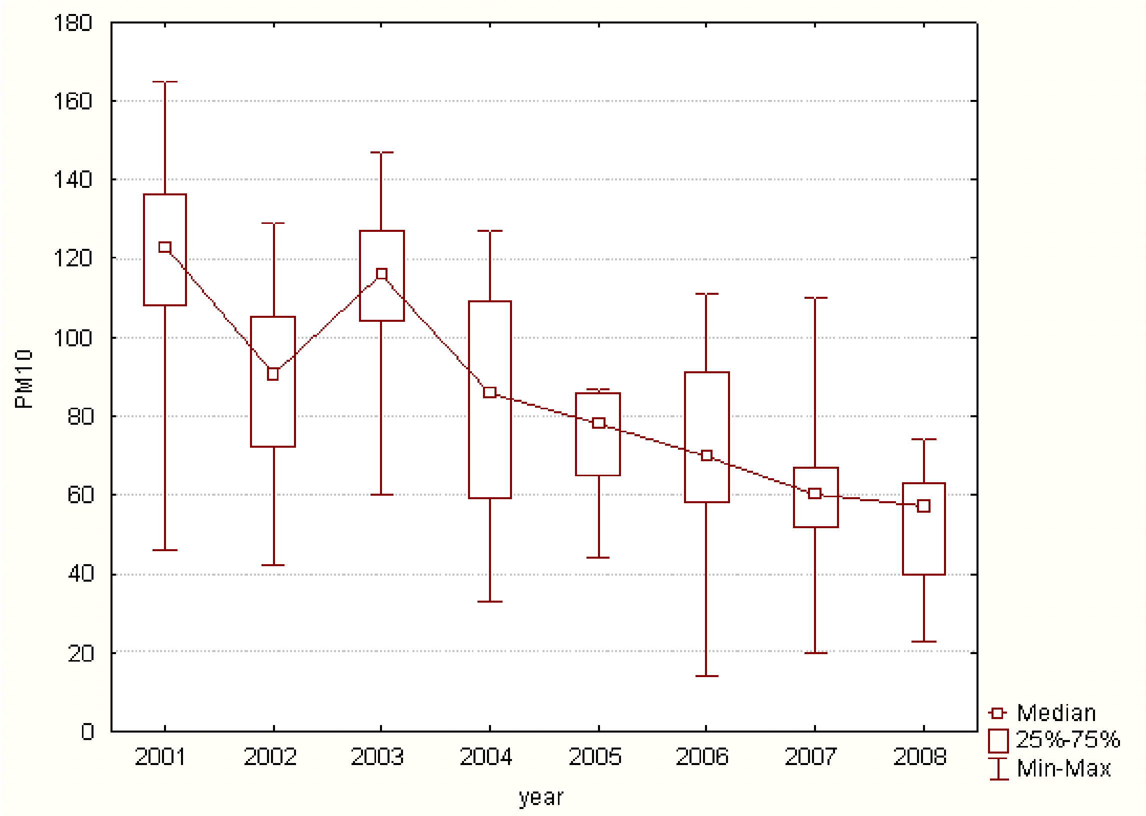

Figure 3-3: Year-to-year variation in 24-hour average PM_{10} concentration for the 198 days contained within the high potential pollution node

The trend of 24-hour average PM_{10} concentrations displayed in Figure 3-3 shows that the median value has decreased approximately 56% over the period 2001 to 2008. Similarly, the upper quartile value has decreased by 54% from 2001 to 2008. The year-to-year differences in PM_{10} were tested for statistical significance using both the Kruskal-Wallis and Chi-square tests. The results of these tests showed that the year-to-year difference in values of PM_{10} is statistically significant.

3.4. Trends in exceedences of the PM_{10} NES

Within the 198 high potential pollution days the PM_{10} NES concentration (50 μgm^{-3}, 24-hour average) was exceeded at total of 174 times. Figure 3-4 shows the year-to-year variation of the percentage of high pollution days with PM_{10} concentrations greater than 50 μgm^{-3} (24-hour average).

Figure 3-4 shows that the likelihood of a high potential pollution day resulting in an exceedence of the NES PM_{10} concentration was:

- between 90% and 100% in 2001 to 2003,

- between 80% and 90% in 2004 to 2006
- below 80% and below 70% for 2007 and 2008 respectively

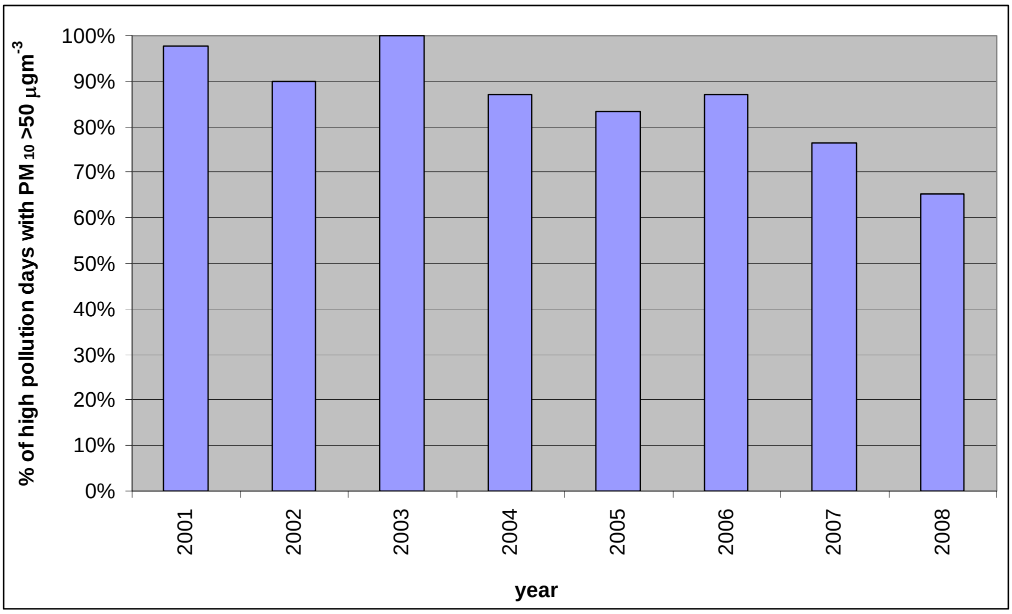

Figure 3-4: Year-to-year variation of the percentage of high potential pollution days with PM_{10} concentrations of greater than 50 μgm^{-3} (24-hour average).

Figure 3-4 suggests that 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%.

3.5. Meteorological conditions on NES exceedence days

The two highest PM_{10} nodes contain a total of 897 data points including 95% of the days when PM_{10} concentrations exceeded 50 µg m^{-3}. A BRT was conducted on this subset of PM_{10} data to further quantify the impact of meteorology on high pollution days. The results of the BRT analysis of the days captured within the two highest pollution nodes are displayed in Figure 3-5.

Figure 3-5 shows that critical predictor variables identified by this BRT are 24-hour average temperature (above or below 6°C) and 24-hour average wind speed (above or below 1 m/s). This BRT gave a coefficient of determination (r^2) of 0.62. This indicates that around 62% of the variation in PM_{10} concentrations could be explained by the relationships between the predictor variables and PM_{10} concentrations described by the BRT.

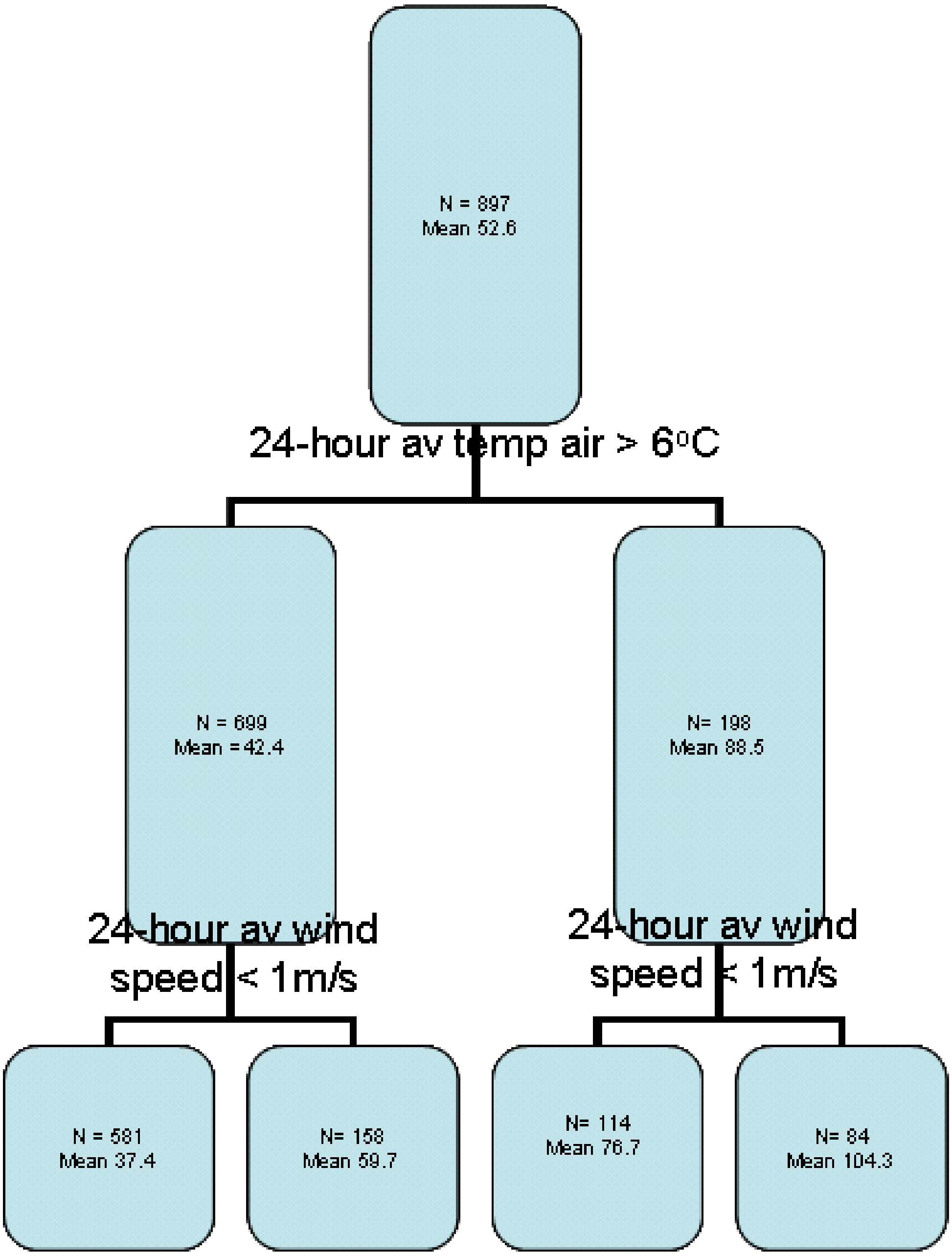

Figure 3-5: Boosted regression tree to fit the 987 days which were captured within the two highest PM_{10} nodes

The information generated by this BRT can be used to normalise (adjust up or down) PM_{10} data recorded in year 2009 (and beyond) to these particular meteorological conditions. When the 2009 data has been normalised for these particular meteorological conditions it can then be compared to data from previous years and used to evaluate the trends in PM_{10} concentrations for the years 2009 (and beyond). An example of how the 2009 data (and beyond) can be normalised is provided in Section 6: Normalising PM_{10} concentrations.

4. Trends in PM_{10} emissions

The impact of households changing heating methods each year on PM_{10} emissions for airshed A, is shown in Figure 4-1. The y axis depicts the percentage of 2001 PM_{10} emissions which combined with the x axis of years 2001 to 2021 demonstrates changes in PM_{10} emissions with time for the following:

- Projections of emissions based on air plan management measures
- Tracked changes in emissions based on actual conversions of burners

A dotted black line represents the reductions required in PM_{10} emissions to achieve the NES and is based on the assumption of a linear relationship between emissions and concentrations as discussed in Wilton (2002). In addition two SLiPs are shown. The red line is the 'official' NES SLiP. The steeper green one is an indicator used by Nelson City Council, as a precautionary approach to allow for the uncertainties in the emissions modelling. The need for this approach may reduce with time if trends in PM_{10} concentrations correspond well with projected emissions.

The "track changes" software is designed so the impacts of changes occurring during a full calendar year are observed during the subsequent year. For example the impact of changes occurring during 2008 will be observed in the difference between 2008 and 2009 emissions.

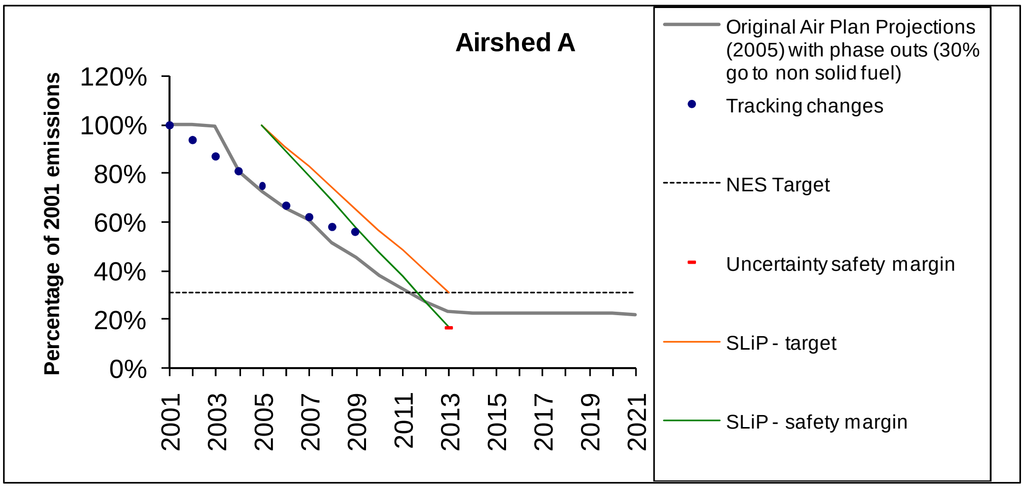

Figure 4-1: Tracked trends in PM_{10} emissions in Airshed A compared with Air Plan Projections and Straight Line Path

Figure 4-1 shows that PM_{10} emissions (blue dots) are tracking very closely with predicted air plan projections (grey line), with a slight variation in the tracked emissions trajectory around 2009. Overall concentrations are estimated to have decreased by 54% compared with 42 % for emissions. Note however, that the tracked emissions are likely to underestimate actual emission reductions because they do not include changes in households replacing solid fuel burners with electric or gas heating methods other than via the incentives programme. Notwithstanding this, results show current emissions are within both the SLiP and the precautionary SLiP.

Equivalent projections for Airsheds B1, B2 and C are shown in **Error! Reference source not found.**

5. Comparison of trends in emissions and concentration

A comparison of trends in PM_{10} concentrations and trends in emissions are shown in Figure 5-1. These are expressed as a percentage of 2001 emissions and concentrations respectively to allow comparison between these variables. The red crosses are the 75th percentile PM_{10} concentration for the highest pollution node of the BRT (Section 3.20) expressed as a percentage of the 2001 value.

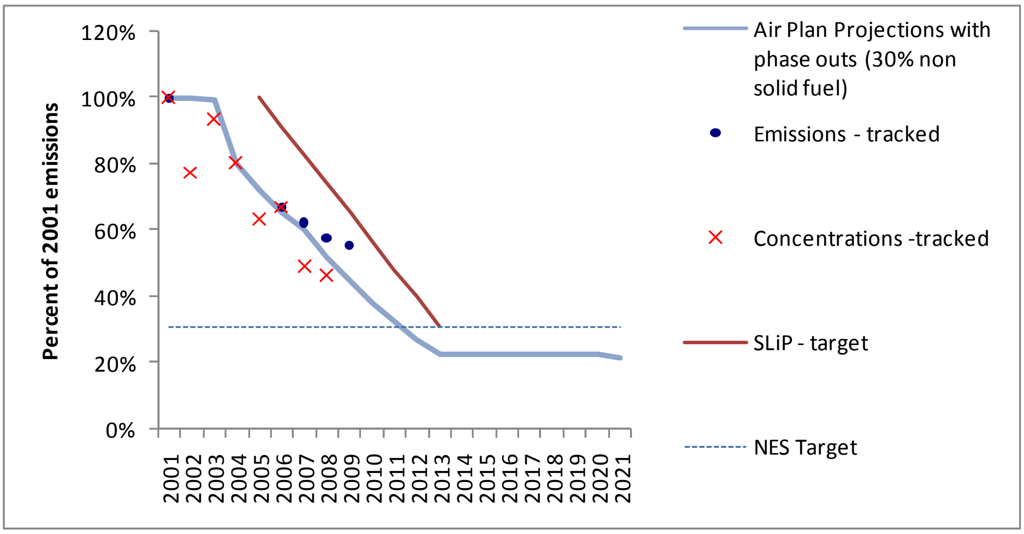

Figure 5-1: Tracked trends in PM_{10} emissions and concentration in Airshed A compared with Air Plan Projections and Straight Line Path

Figure 5-1 shows that the reduction in concentrations based on these data is around 54% from 2001 to 2008. It is important to note that a proportion of the 18% reduction in concentrations observed from 2006 to 2007 is likely to be associated with the change in monitoring method discussed in section 2.1.1. It is estimated that the change in monitoring method may be responsible for up to a quarter of the 18% reduction observed between 2006 and 2007.

A comparison of the emissions and concentrations reductions indicates that results are similar around 2006 and that there is a greater reduction in concentrations than emission from 2007 to 2008. As detailed previously emissions data are expected to underestimate reductions in PM_{10}. Overall results suggest that air plan measures are being effective in reducing PM_{10} and that the PM_{10} projections on which the measures are based are reliable.

6. Normalising PM_{10} concentrations

The results of the BRT described in Section 3.5 can be used to evaluate trends in PM_{10} data recorded in the years 2009 and beyond. Extending the trend analysis out to 2009 and beyond can be achieved by normalising PM_{10} data based on meteorological conditions associated with high pollution over the years 2001 to 2008. As all meteorology has some impact, one of the biggest issues in establishing a method for normalising data was determining what constitutes "no impact", that is, what concentrations should be normalised to.

The method used here aims to minimise the impact of varying meteorology for high pollution events. To include the majority of the days when 50 µg m^{-3} is exceeded the method for minimising the impact of meteorology on concentrations has been based on the two high pollution nodes from section 3.5. These include all days when the 24-hour average wind speed was less than 2 ms^{-1} and the temperature was less than 12 degrees Celsius.

The approach used is based on the assumption that Nelson City Council is most interested in tracking changes on high pollution days, not just the highest pollution subset. 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.

PM_{10} data to be adjusted includes all days when the 24-hour average wind speed is less than 2 ms^{-1} and temperatures are less than 12 degrees. It is proposed that this group alone is used to track changes with time. The following adjustments to data are recommended:

Select days that meet the meteorological criteria (wind speed <2 ms^{-1} and temperature <12 degrees).

- If daily average temperature is >6 °C and wind speed is > 1 ms^{-1} do not adjust data.

- If daily average temperature is >6 °C and wind speed is < $1ms^{-1}$ subtract 22.3 $\mu g\ m^{-3}$ from the 24-hour average PM_{10} concentration.

- If daily average temperature is <6 °C and wind speed is < $1ms^{-1}$ subtract 66.9 $\mu g\ m^{-3}$.

- If daily average temperature is <6 °C and wind speed is > $1ms^{-1}$ subtract 39.3 $\mu g\ m^{-3}$.

The PM_{10} normalising process has been coded into a spreadsheet tool which has be provided to NCC. This will allow council staff to evaluate trends in PM_{10} in future data (2009 and beyond) without having to repeat the BRT modelling exercise.

7. Comparison of PM_{10} trends from previous studies

At least one other study has been undertaken to assess the long term trends in PM_{10} concentrations monitored in Nelson. Sherman and Fisher (2006) determined the relationship between fine particulate pollution and weather variables using simple correlation analysis on PM_{10} data recorded at St Vincent Street from 2001 to 2005.

Sherman and Fisher identified ambient air temperature and the frequency of calms (winds speeds less than 0.5 ms^{-1} for greater than 50% of the hours during a particular day) to be the most important meteorological variables in defining which days have high air pollution potential. An example of this study's results show that for each year from 2001 to 2005 approximately 30 days had average temperatures between 6 and $9^{o}C$ and calm conditions persisted for more than 75% of the day. Using these criteria captured approximately 50% of the high pollution days that occurred in the winters of 2001 to 2005. The average PM_{10} concentrations for days that meet these meteorological criteria declined from approximately 95 $\mu g\ m^{-3}$ in 2001 to approximately 65 $\mu g\ m^{-3}$ in 2005. This result indicates a decrease of approximately 30% in average PM_{10} concentrations on high pollution days over the years 2001 to 2005.

A comparison of the findings of the current study with that of Sherman and Fisher show both studies found:

- A decrease in average PM_{10} concentrations on high pollution days over the period 2001 to 2005

- The rate of decrease in average PM_{10} concentrations on high pollution days was 30-33% over the period 2001 to 2005

A number of the conclusions drawn by Sherman and Fisher are relevant to the current study. These include:

- There is an overall trend towards lower winter peaks over the period from 2001 to 2005, but this is not necessarily a direct indicator of total emission reductions

- The findings of the study should be interpreted with caution, as the 5-year long record is relatively short given the nature of the variability of both emission and weather.

The current study has made some progress toward addressing the caution raised by Sherman and Fisher about the short data record by including an additional three years of data. It is interesting to note that the conclusions reached using the longer data record are consistent with those from the shorter data record. The current study demonstrates that the reduction in ambient PM_{10} concentrations is closely related to the reduction in emission in Airshed A and therefore helps fill a knowledge gap highlighted by Sherman and Fisher.

8. Conclusions

The objectives of this study are to advise Nelson City Council on:

(a) Real time methods for assessing trends in PM_{10} concentrations, in particular how to account for daily variations in meteorological conditions, their consequent impact on PM_{10} concentrations and compliance with the SLiP and NES.

(b) Methods (including appropriate emission rates) for assessing trends in PM_{10} emissions with time, in particular how to use information on changes in household heating methods and industry emission changes to track progress towards compliance with the NES.

The years considered for this study run from 2001 to 2008. A total of 2445 days of PM_{10} monitoring data was collected over this 8 year period. An evaluation of summary statistics for each year shows there is no obvious trend in the annual median but some indication of a downward trend in the higher 75th percentile concentrations. This was examined further in this study by attempting to minimise the impact of variability in meteorological conditions on high PM_{10} concentrations.

The method used to account for year-to-year variation in meteorology and to analyse the long term trend of PM_{10} concentrations was to use a boosted regression tree (BRT) model. The BRT identified and grouped days with similar meteorological variables together. 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 shows that the median value has decreased approximately 56% over the period 2001 to 2008. Similarly, the upper quartile value has decreased by 54% from 2001 to 2008. 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%.

A trend analysis of PM_{10} emissions shows that the home heating and industry emissions are decreasing and tracking very closely with predicted air plan projections. Over the years 2001 to 2008, emissions are estimated to have decreased by 42%. It is interesting to compare this with the 54-56 % reduction in PM_{10} concentrations. The emission trend assessment is likely to underestimate actual emission reductions because the estimates only include changes in household emissions as a result of the NCC incentives programme and changes outside the programme where Nelson City Council knows about it because a council permission is needed e.g. a building consent for the installation of a replacement woodburner. Notwithstanding the difference between the trends in PM_{10} emissions and concentrations, it is concluded that actual emissions reduction is within Nelson City Council's Straight Line Path (SLiP) target.

A method has been developed to normalise (adjust up or down) PM_{10} data recorded in the year 2009 (and beyond) to the meteorological conditions which resulted in high pollution events over the years 2001 to 2008. The PM_{10} normalising process will allow the evaluation of the trends in PM_{10} data recorded in 2009 (and beyond) without having to repeat the BRT modelling exercise.

The results of the current study have been compared to an earlier investigation into the trends in PM_{10} concentrations for the years 2001 to 2005 undertaken by Sherman and Fisher (2006). The findings of the two studies are not inconsistent, with both showing decreases in PM_{10} concentrations during high pollution events of around 30% over the years 2001 to 2005.

The overall results of this study suggest that:

- that the management options adopted by Nelson City Council have been effective in reducing PM_{10} emissions and concentrations in Nelson's airshed A
- Nelson City Council is currently on target to meet its Airshed A air quality goals as defined by the straight line path and the 2013 NES

9. References

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Appendix A; Emissions projections for airsheds B1, B2 and C.

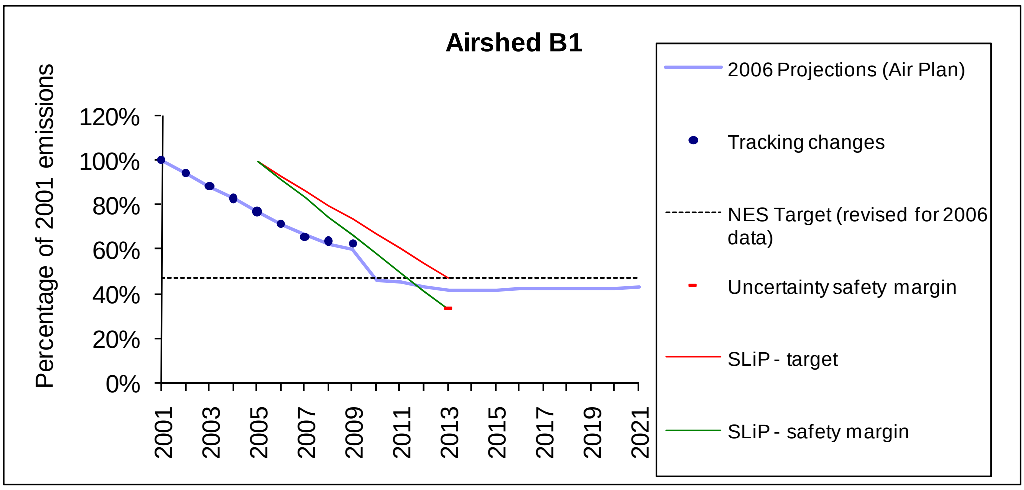

Figure A-1: Tracked trends in PM_{10} emissions in Airshed B1 compared with Air Plan Projections and Straight Line Path

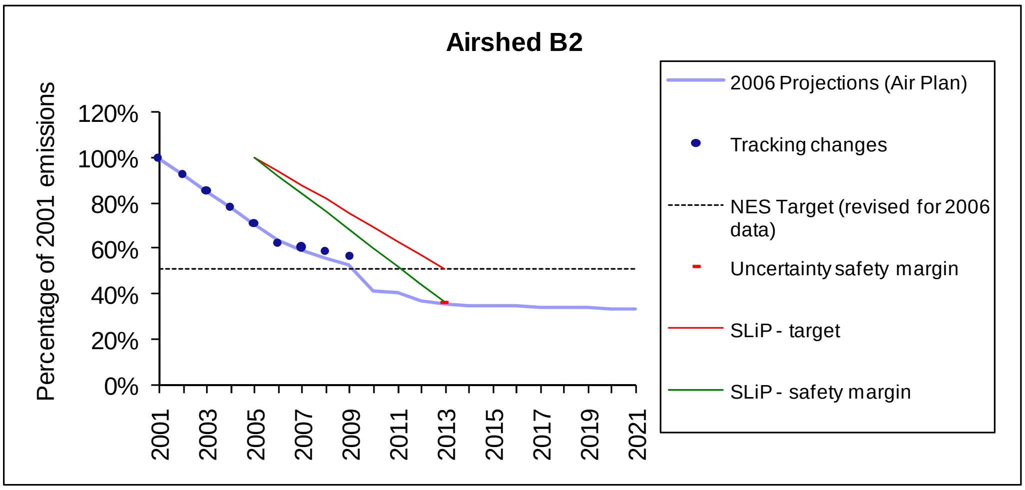

Figure A-2: Tracked trends in PM_{10} emissions in Airshed B2 compared with Air Plan Projections and Straight Line Path

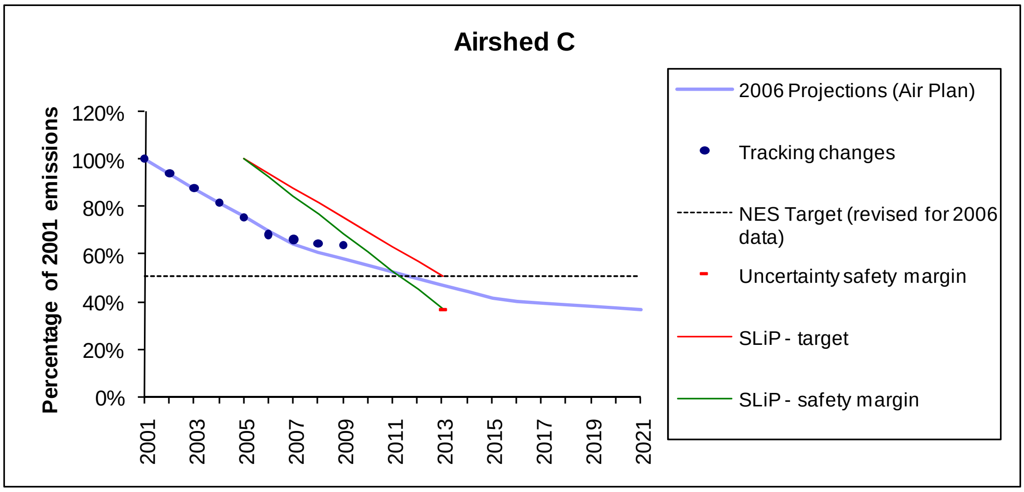

Figure A-3 : Tracked trends in PM_{10} emissions in Airshed C compared with Air Plan Projections and Straight Line Path