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PREPARED FOR

Tasman District Council

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Assessment of the impacts of regulatory measures targeting domestic home heating on annual average $PM_{2.5}$ in Richmond

Envirolink Report 1777-TSDC134

EXECUTIVE SUMMARY

The Ministry for the Environment is carrying out a review of how particulate matter is managed with particular focus being given to the value of setting rules for $PM_{2.5}$ and long term exposure. The review arises as a result of a Parliamentary Commission for the Environment Report (2015) report on the state of air quality in New Zealand.

Tasman District Council has an operative Air Plan which includes measures to reduce daily winter PM_{10} concentrations from wood burners. The objective of this report is to evaluate the potential implications of the introduction of a National Environmental Standard (NES) for annual average $PM_{2.5}$ with a focus on whether existing measures to reduce daily winter PM_{10} will be adequate to meet an annual average $PM_{2.5}$ limit.

The current World Health Organisation annual average guideline for $PM_{2.5}$ is 10 $\mu g/m^3$. A recent report by WHO recommends a review of the $PM_{2.5}$ guidelines because the science suggests a lower long term (annual) guideline may be required to protect health.

Tasman District Council have carried out monitoring of $PM_{2.5}$ in Richmond and data was available for the period from October 2015 to December 2016. The relationship between $PM_{2.5}$ and PM_{10} concentrations from that monitoring period was used to estimate annual average $PM_{2.5}$ concentrations in Richmond from 2006 - 2016. The assessment does not include an evaluation for worst case year in terms of meteorology.

The annual average concentration for Richmond for 2016 was around 10 $\mu g/m^3$. This is unlikely to represent worst case meteorological conditions. Of the last 5 years, 2012 was found to have the likely worst case annual average $PM_{2.5}$ concentrations at 12.6 $\mu g/m^3$. Based on this result a reduction in annual average $PM_{2.5}$ of 21% would be required to meet an annual average concentration of 10 $\mu g/m^3$.

Domestic heating, and natural sources are likely the main sources of annual average $PM_{2.5}$ contributing around 71% and 14% respectively.

The maximum estimated annual average concentration for $PM_{2.5}$ of 12.6 $\mu g/m^3$ (2012) may reduce to around 9.2 $\mu g/m^3$ (a 27%) reduction if 2012 domestic heating concentrations were reduced by 35%, as predicated by revised projections modelling. Confirmation that PM_{10} concentrations have been reducing since 2012 is required, however, as basic indicators of trends in concentrations between 2012 and 2016 are in conflict with the projections. Updating of an assessment of trends in PM_{10} concentrations after adjusting for the impact of meteorological conditions is recommended.

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1 INTRODUCTION

In 2004 the Ministry for the Environment established a National Environmental Standard (NES) for PM_{10} (particles in the air less than 10 microns in diameter) for a 24-hour averaging period. The limit was set at 50 µg/m^3 with one allowable exceedance per year. PM_{10} was selected as the indicator of health impacts associated with exposure to particulate matter in the air. In 2015, a review of air quality by the Parliamentary Commissioner for the Environment highlighted issues with the current NES for PM_{10} suggesting investigation into the adoption of $PM_{2.5}$ as the key indicator with priority given to an annual average standard to capture the significant chronic impacts of particulate exposure. The focus on $PM_{2.5}$ and annual average exposure is consistent with a recent WHO report (World Health Organization, 2013) which indicates that annual average $PM_{2.5}$ is the strongest indicator of health impacts.

The National Environmental Standards for Air Quality (NESAQ) (2004) did not include $PM_{2.5}$ as an indicator because it was proposed that management of PM_{10} would result in reductions in concentrations of $PM_{2.5}$ and because it was argued that the coarse fraction did result in health impacts. While the latter may be true, $PM_{2.5}$ is a stronger indicator and this management by proxy position is unlikely to be considered robust in terms of future reviews of New Zealand guidelines and standards given the increased evidence with respect to long term exposures and impacts of PM2.5.

It is likely that many urban areas in New Zealand would require more stringent management to reach a guideline of 25 µg/m^3 for $PM_{2.5}$ (as recommended in WHO (2006) than to reach a target of 50 µg/m^3 for PM_{10}. However, if an annual average $PM_{2.5}$ standard alone were adopted in the NES review it may influence the extent of focus required on solid fuel burning for domestic home heating.

In response to the likelihood of an annual average $PM_{2.5}$ standard Tasman District Council (TDC have been monitoring for $PM_{2.5}$ in conjunction with PM_{10} at their Richmond monitoring site. Understanding the relationship between sources of 24-hour average PM_{10} concentrations and annual average $PM_{2.5}$ concentrations will enable TDC to more effectively manage air quality in relation to the outcomes of the NES review.

The objective of this study are to advise TDC on:

- Likely annual average $PM_{2.5}$ concentrations for 2016 and the relationship between PM_{10} and $PM_{2.5}$ based on monitoring carried out during 2015 and 2016.
- Estimated annual average concentrations for the preceding five years based on the above determined relationship with PM_{10}.
- A comparison of data to the revised NES for particulate or WHO guideline if revised NES content is not available.
- The likely relative contribution of domestic heating to annual average $PM_{2.5}$ concentrations in Richmond.
- An evaluation of the likely attainment of the revised NES based on the current Air Plan projections for daily winter PM_{10}. This includes an assessment of reductions in daily winter PM_{10} emissions and likely ongoing reductions in daily winter PM_{10} and annual average $PM_{2.5}$.
- An assessment of any further reductions required to meet the revised NES (over and above what is likely to be achieved through the Air Plan)
- The spatial distribution of existing PM_{10} and $PM_{2.5}$ solid fuel burner emissions across Richmond in map form.

1.1 WHO guidelines and recommendations for PM_{10} and $PM_{2.5}$

The World Health Organisation (WHO) is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries and monitoring and assessing health trends (“World Health Organisation,” 2014).

The current WHO guidelines are:

- PM_{10} - 50 µg m^{-3} (24-hour average, three allowable exceedences) and 20 µg m^{-3} annual average.

- $PM_{2.5}$ - 25 µg m^{-3} (24-hour average, three allowable exceedences) and 10 µg m^{-3} (annual average) (World Health Organization, 2006).

Technical supporting documentation indicates that particulate is considered a no threshold contaminant (there is no safe threshold) and that there is insufficient evidence for policy differentiation based on composition.

In 2013 the WHO conducted a review of evidence for air quality guidelines. The review identified new health outcomes associated with exposure to particulate concentrations, additional support for other health outcomes and makes recommendations that WHO review both short and long term guidelines for $PM_{2.5}$ and potentially for PM_{10}.

1.2 Review of the NES for particulate

The NES for particulate is currently under review by the Ministry for the Environment. The specifics of the review were not publicly available at the time this work was carried out. However, scientific evidence strongly supports the use of an annual average $PM_{2.5}$ value as most protective for health. For the purposes of this work annual average $PM_{2.5}$ concentrations are compared with values of 10 µg/m^3 (WHO guideline).

2 PM_{10} AND $PM_{2.5}$ MONITORING AND TRENDS

Air quality monitoring of PM_{10} has been carried out in Richmond since the early 2000s. Concentrations of $PM_{2.5}$ have also been measured in Richmond from October 2015 to December 2016.

Figure 2.1 shows winter concentrations of PM_{10} have decreased in Richmond since monitoring commenced with the majority of the reductions occurring between the period 2000 and 2010 (Figure 2.1). Data indicate a reduction of around 45% over this earlier period and no significant difference in winter average or 75th percentile concentrations for 2010 and 2016.

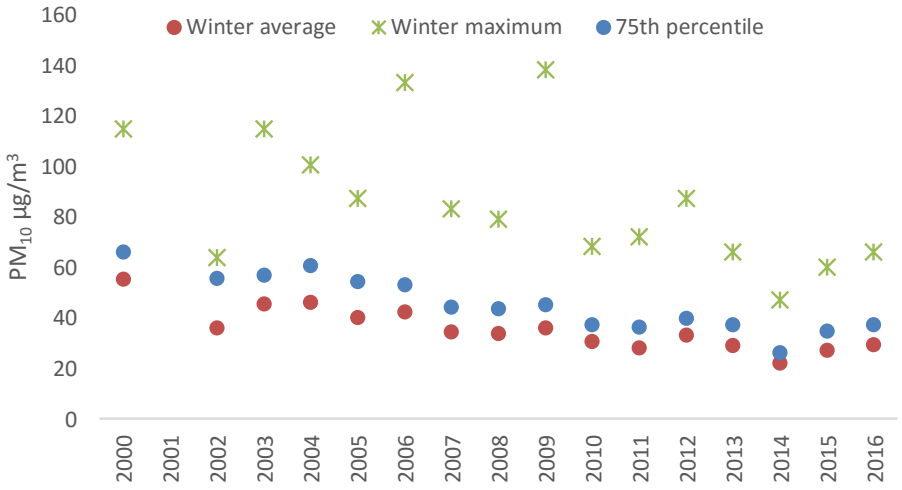

Figure 2-1: Trends in annual average and median and winter average PM_{10} concentrations from 2000 to 2016

Daily average $PM_{2.5}$ concentrations measured in Richmond during 2016 are shown in Figure 2.2. During the winter months the WHO guideline value for $PM_{2.5}$ of 25 µg/m^3 was regularly exceeded. Concentrations of $PM_{2.5}$ during the summer month were significantly lower, averaging around 5-6 µg/m^3.

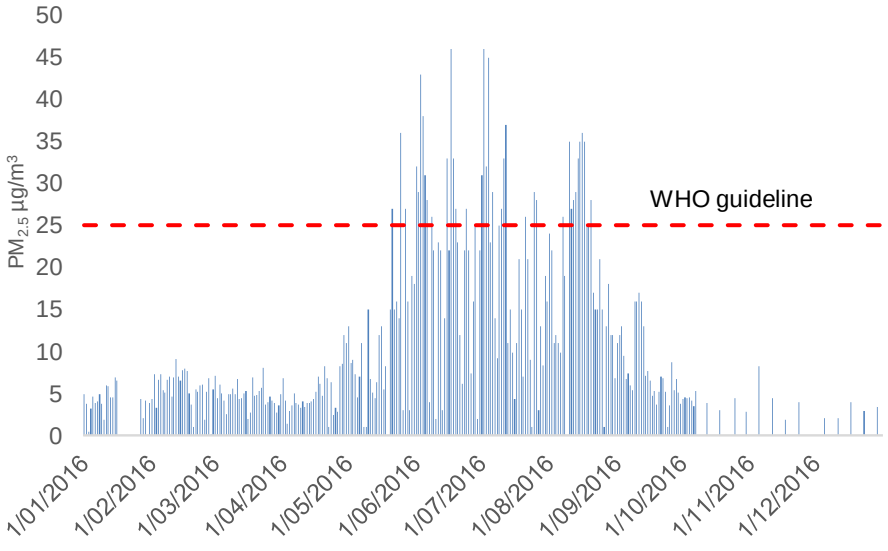

Figure 2-2: Daily average $PM_{2.5}$ concentrations measured in Richmond during 2016

Figure 2.3 shows daily average $PM_{2.5}$ concentrations for the period January to May 2017 compared with concentrations of PM_{10} measured at the same site using the same monitoring method. Data were analysed using reduced major axis regression (RMA). Results indicate the $PM_{2.5}$ concentrations are around 90% of the PM_{10} concentrations during the winter months and around 50% during the summer months.

The relationship between $PM_{2.5}$ and PM_{10} can be described using the following equations:

- Non-winter $PM_{2.5} = 0.54\ PM_{10} – 1.2$
- Winter $PM_{2.5} = 1.05\ PM_{10} – 7.5$

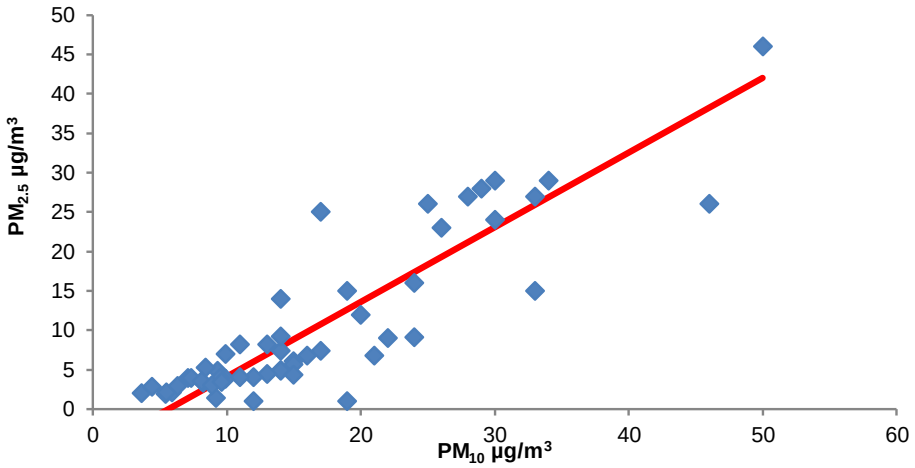

Figure 2-3: Comparison of PM_{10} and $PM_{2.5}$ concentrations measured in Richmond for 2016

A key factor influencing PM_{10} discharges is households using wood for domestic home heating. Figure 2.3 shows changes in the number of households using wood for home heating (from census data) along with changes in the number of dwellings in Richmond over time (Richmond East and West census area units). This shows a reduction in households using wood from just over 2000 in 2001 to around 1700 households in 2013. The total number of dwellings in these CAUs increased from just less than 4000 in 2001 to 4700 in 2013. (a 19% increase)

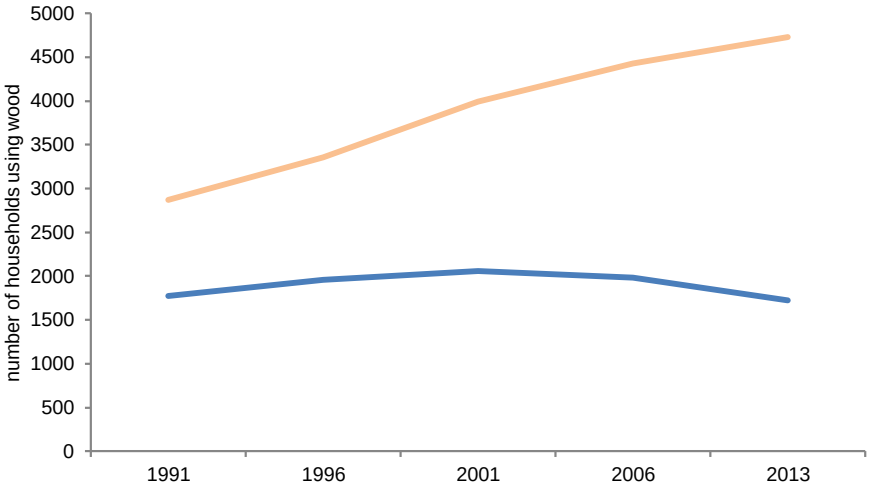

Figure 2-4: Total households and those using wood for heating from 1991 to 2013 (Statistics New Zealand 2013).

3 ANNUAL AVERAGE $PM_{2.5}$ CONCENTRATIONS

The annual average $PM_{2.5}$ concentrations for Richmond for 2016 was 10.0 µg/m^3. The winter average was 18 µg/m^3 and the average for the non-winter months was around 5.7 µg/m^3.

Concentrations of $PM_{2.5}$ were estimated for the years 2006 to 2015 using the relationship of $PM_{2.5}$ = 0.54 PM_{10} – 1.2 for non-winter months (September to April) and the relationship of 1.05 PM_{10} – 7.5 for the winter months. The relationships were derived using reduced major axis regression (RMA) on the partisol $PM_{2.5}$ and partisol PM_{10} concentrations measured at the Plunket Monitoring site during 2016.

Table 3.1 compares the annual average PM_{10} concentrations and $PM_{2.5}$ estimates for the years 2006-2016 and considers the reductions required for each indicator to meet either the 2004 NES (for PM_{10}) or the WHO guideline for annual average $PM_{2.5}$. Because reductions in PM_{10} are evident over the period 2006-2010 only data from 2011 onwards were considered with regards to further reductions required to meet guidelines or standards.

Annual average $PM_{2.5}$ were estimated in the range of 8.5-12.6 µg/m^3 for the years 2011 - 2016. Based on these estimates, concentrations of $PM_{2.5}$ would need to be reduced by up to 21% to meet an annual average concentration of 10 µg/m^3, should the revised NES include a standard of this magnitude. This assessment does not include an evaluation for the worst-case year in terms of meteorology.

It is also worth noting that there is a difference in the way year to year variability in meteorological conditions impacts on these two different exposure periods. For the 24-hour average the influencing factor is the extent of impact of meteorology on a given day. That is, how low the wind speeds are and how stable the lower atmosphere is whereas for the annual average the frequency of calm stable conditions is a key variable.

Data suggests the reduction required to meet an annual average $PM_{2.5}$ guideline (0-21%) is not greater than required to meet the current daily NES for PM_{10} (24-hour average of 50 µg/m^3) of around 29%, noting that measures targeting specific sources will have different effects because of different relative contributions to winter daily versus annual average concentrations. This is the opposite situation to that found for Nelson Airshed A which required a 14% reduction to meet the current NES for PM_{10} and a higher reduction to meet an annual average $PM_{2.5}$ (Wilton & Zawar-Reza, 2015). The extent to which a revised NES based on an annual average $PM_{2.5}$ is likely to represent a more stringent target than the current NES will vary with location.

Table 3.1: Summary PM_{10} and $PM_{2.5}$ (estimated) data for Richmond

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Annual average $PM_{2.5}$ (estimated based on ratios to PM_{10})	16.4	13.7	13.6	14.5	12.5	11.4	12.6	11.9	8.5	10.8	10.0
Annual average PM_{10}	23	21	21	22	20	18	19	19	14	18	19
Reduction to meet annual average $PM_{2.5}$ of 10 µg/m^3	39%	27%	26%	31%	20%	12%	21%	16%		7%	
Second highest PM_{10} (24-hour average)	105	79	56	76	67	69	70	59	43	52	60
Reduction to meet 24-hour average 50 µg/m^3	52%	37%	11%	34%	25%	28%	29%	15%		4%	17%

It is also worth noting that there is a difference in the way year to year variability in meteorological conditions

3.1 24-hour average $PM_{2.5}$ concentrations

The maximum daily $PM_{2.5}$ concentrations measured in Richmond during 2016 was 46 µg/m^3. This value is almost double the current WHO guideline for 24-hour average $PM_{2.5}$ of 25 µg/m^3. It is possible that this guideline will be integrated into the New Zealand guidelines or standards during the NES review. The WHO guideline allows for three exceedences per year of 25 µg/m^3. The fourth highest $PM_{2.5}$ concentrations measured at Richmond during 2016 was 43 µg/m^3 and was measured on 3 June 2016. The corresponding PM_{10} concentration was 57 µg/m^3.

4 DOMESTIC HEATING CONTRIBUTION

The domestic heating contribution to annual average PM_{10} and $PM_{2.5}$ concentrations has been estimated for Richmond using 2016 PM_{10} concentrations, data from the 2010 air emission inventory (Wilton & Baynes, 2010) and data from source apportionment studies (Ancelet & Davy, 2016).

The 2010 emission inventory includes estimates of PM_{10} and $PM_{2.5}$ including by month of the year. The relative contributions vary with season (e.g., domestic heating is greater during the winter). Meteorological conditions also vary with season (conditions inhibiting dispersion are more prevalent during the winter months). It is therefore necessary to assess concentrations from each source for each month of the year to estimate the relative contribution to annual average concentrations.

The contribution of natural sources to $PM_{2.5}$ and PM_{10} concentrations was assessed using the GNS 2013-2016 source apportionment receptor modelling work which quantified the contribution of natural sources to $PM_{2.5}$ and PM_{10}. This identified profiles for marine aerosol in the $PM_{2.5}$ and PM_{10} size fractions but did not include a dust profile in either size fraction. The contribution of natural sources to $PM_{2.5}$ and PM_{10} concentrations from this study was averaged by month of year to estimate the contributions to annual concentrations by season.

The relative contribution of sources to annual average PM_{10} and $PM_{2.5}$ concentrations is normally estimated by subtracting the monthly average natural sources contribution to concentrations from the monthly average concentration and then allocating the remaining concentration to anthropogenic sources based on the emission distribution from the inventory. However, in this instance the receptor modelling outputs (averaged for winter and non-winter months) for motor vehicles were also subtracted from the monthly average concentrations (and the emission inventory contributions (i.e., treated the same way as natural sources). This change made no substantive difference to the PM_{10} relative contributions but reduced the annual average $PM_{2.5}$ contribution for motor vehicles from 12% to 4%, which was more closely aligned to the receptor modelling result. It was noted that the inventory motor vehicle emission estimates (2010) were outdated as PM emission factors for 2016 would be significantly lower. The GNS receptor modelling data showed that $PM_{2.5}$ concentrations from motor vehicles were only a fraction (10%) of the PM_{10} concentrations. The prevalence of resuspended road dust in the PM_{10} profile for motor vehicles is a possible reason for this.

Figure 7.1 shows the estimated relative contribution of sources to annual average PM_{10} and $PM_{2.5}$ concentrations for Richmond. The output varies slightly relative to the receptor modelling contribution to annual averages in that the sources are identified differently and the source apportionment evaluates contributions at a specific location, whereas the estimate below will be more spatially averaged across the urban area. The receptor modelling for PM_{10} identifies 52% from biomass combustion and 17% from motor vehicles,16% marine aerosol with the remainder coming from other sources including secondary sulphate (potentially originating from natural marine sources or industrial coal) and an unidentified source of copper, chrome, arsenic (Ancelet & Davy, 2016).

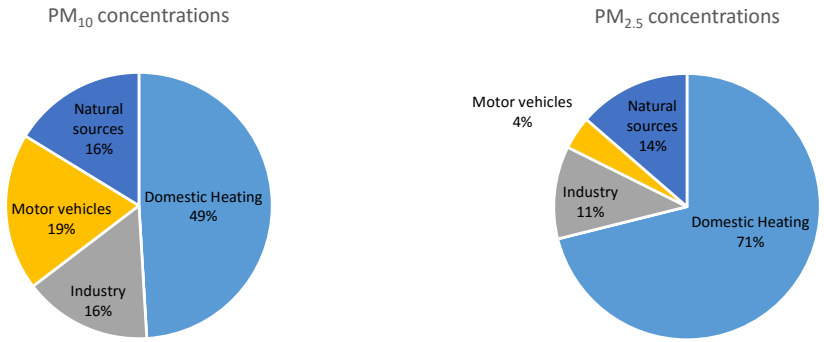

Figure 4-1: Estimated relative contribution of sources to annual average PM_{10} and $PM_{2.5}$ concentrations for Richmond.

5 IMPACT OF MANAGEMENT OPTIONS ON ANNUAL AVERAGE $PM_{2.5}$

Tasman District Council has an operative air plan which includes measures targeting outdoor burning and domestic home heating to reduce wintertime peak concentrations of PM_{10}. Measures included:

- Phase out of solid fuel burners at the time a house is sold (replacement with NES burners is allowed).
- No outdoor rubbish burning.
- No installation of burners not meeting an emission criteria of 1.5 g/kg after 2007.
- A reduction in industrial emissions of 10%.
- No wood burners in new dwellings or existing dwellings where there is no solid fuel option currently in place from 2007. Low emission pellet fires were allowed to be installed in these dwellings.

Assessments of the effectiveness of management options (Wilton, 2003, 2005) included measures such as a ban on open fires that were subsequently not adopted by Council. They also note the absence of dispersion modelling data to determine the impact of Nelson Pine Industries on the Richmond Airshed and do not include information, now available, on the contribution of natural sources (e.g., marine aerosol) to PM_{10} concentrations in Richmond. An updated analysis of the effectiveness of the air plan was made in 2010 (Figure 5.1) using the measures adopted by Council (Wilton, Cavanagh, & Baynes, 2010). While this likely overestimates the impact of management measures because it excludes natural source contributions and potential NPI impacts, it is noted that in 2010 the projections assumed a greater number of households with wood burners than indicated by the inventory, i.e., concentrations may have been lower than predicted.

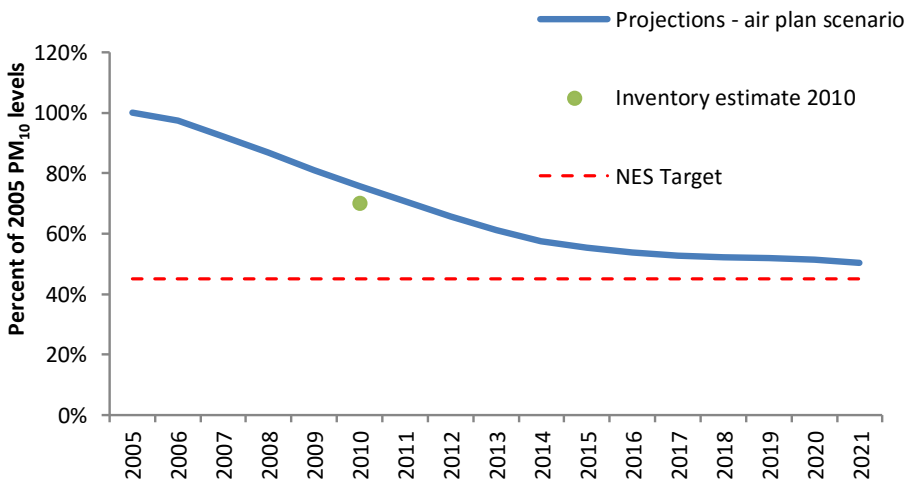

Figure 5-1: Estimated relative contribution of sources to annual average PM_{10} and $PM_{2.5}$ concentrations for Richmond.

The highest concentrations (annual average and peak) for Richmond since 2011, when reductions in concentrations appeared to taper, is for 2012. Table 3.1 shows reductions in 2012 peak concentrations of 29% in total daily winter PM_{10} concentrations would be required to meet the current NES compared with reductions of around 21% to meet an annual average concentration of 10 $\mu g/m^3$ for $PM_{2.5}$.

From Figure 5.1, 2012 concentrations are predicted to reduce by a further 24% (relative to 2012) through the air plan measures. However, the impact of updated emission factors, wood burner numbers and the absence of natural sources in the assessment create significant uncertainty in the reliability of the further reductions estimated. To address this, the projection was remodelled to include natural sources, the 2010 burner numbers and updated

for most current understanding of emission factors. No allowance was made for NPI or new pellet burners as these were not integrated into the projections model and remodelling was beyond the scope of this report.

The reduction predicted from 2012 to 2021 using a 6% natural sources contribution (monthly winter average from GNS studies (Ancelet & Davy, 2016)) is around 30% in winter peak PM_{10}. In the projections model this is achieved primarily through a reduction in domestic heating PM_{10} emissions (of 35%). Reducing 2012 domestic heating PM_{10} by 35% gives a reduction in annual average $PM_{2.5}$ concentrations of around 27%. The resulting annual average concentration of 9.2 µg/m^3 is less than the 10 µg/m^3 WHO guideline. Management measures would therefore be sufficient to meet annual average guideline or standard for $PM_{2.5}$ of 10 µg/m^3 if meteorological conditions more conducive to annual concentrations than 2012 did not occur.

Similarly, if 2012 peak PM_{10} concentrations are reduced by 30%, as predicted by the revised projection model the resulting peak concentration would be around 49 µg/m^3. This would be sufficient to meet the current NES for PM_{10} if meteorological conditions more conducive to peak concentrations than 2012 did not occur.

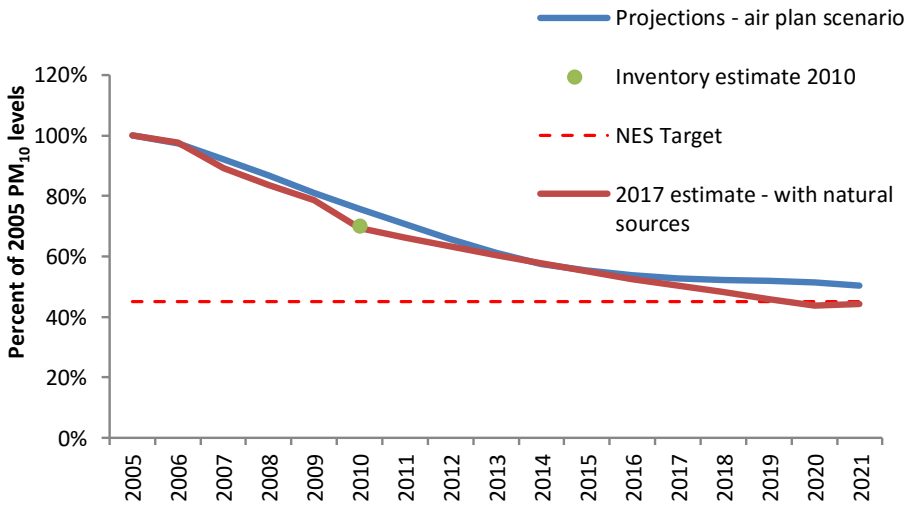

Figure 5-2: Projections of PM_{10} in Richmond updated for emission factors, 2010 inventory data and natural sources contribution.

While results suggest current Air Plan management measures may be adequate to meet both the peak 24-hour average PM_{10} concentration limits (current NES of 50 µg/m^3, one allowable exceedance) and potential annual average $PM_{2.5}$ it does depend on whether the projected 30% reduction in PM_{10} (2012-2021) occurs. It is noted that over half of this reduction (17%) was estimated to have occurred from 2012-2016 and there is no obvious downward trend in winter average or 75th percentile PM_{10} concentrations since around 2010 (Figure 2.1). It is possible that year to year variability in meteorological conditions is masking trends in these data as other indicators, e.g., number of exceedances of 50 µg/m^3 per year, are potentially indicative of reductions. Updating of meteorology adjusted PM_{10} concentrations either through updating of existing normalising spreadsheets or re-evaluation of meteorological conditions associated with elevated pollution (trends analysis) could be carried out to provide an indication of likely trends with meteorological impacts minimised. An update could evaluate whether using current meteorological monitoring sites rather than the Nelson Airport site used previously was feasible.

It has also been noted in TDC reports that there is the potential that exceedences during 2016 were affected by outdoor burning on the Waimea plains. The potential contribution could be evaluated through examination of time of day profiles for pollution events, trends in these profiles over time and potentially through an updated trends analysis, if the latter were to capture elevated PM_{10} concentrations occurring when meteorological conditions differed to normal pollution events i.e., it may determine a separate set of meteorological conditions which included PM_{10} concentrations from outdoor burning events.

6 SPATIAL DISTRIBUTION IN ANNUAL AVERAGE $PM_{2.5}$ EMISSIONS

Spatial distribution in annual average $PM_{2.5}$ was estimated for Richmond at a meshblock level based on the CAU estimates for home heating for 2010. The basis for the emission estimates were the 2012 emission inventory daily winter PM_{10} data adjusted for increase in dwellings as indicated by the 2013 census and for the proportion in the $PM_{2.5}$ size fraction. Data were distributed to meshblocks based on 2013 data of the proportion of total households using wood for heating from the 2013 census that fell within each meshblock.

Figure 6.1 shows the emission estimates in tonnes/annum for $PM_{2.5}$ across Richmond and Figure 6.2 provides an indication of the emission density by dividing the emission estimate for the meshblock by the size of the meshblock. This suggests potential hotspots on the western fringe of the town as well as a number of small pockets in the east and northern ends of town. Figures 6.3 and 6.4 show similar data for PM_{10} with similar hotspots.

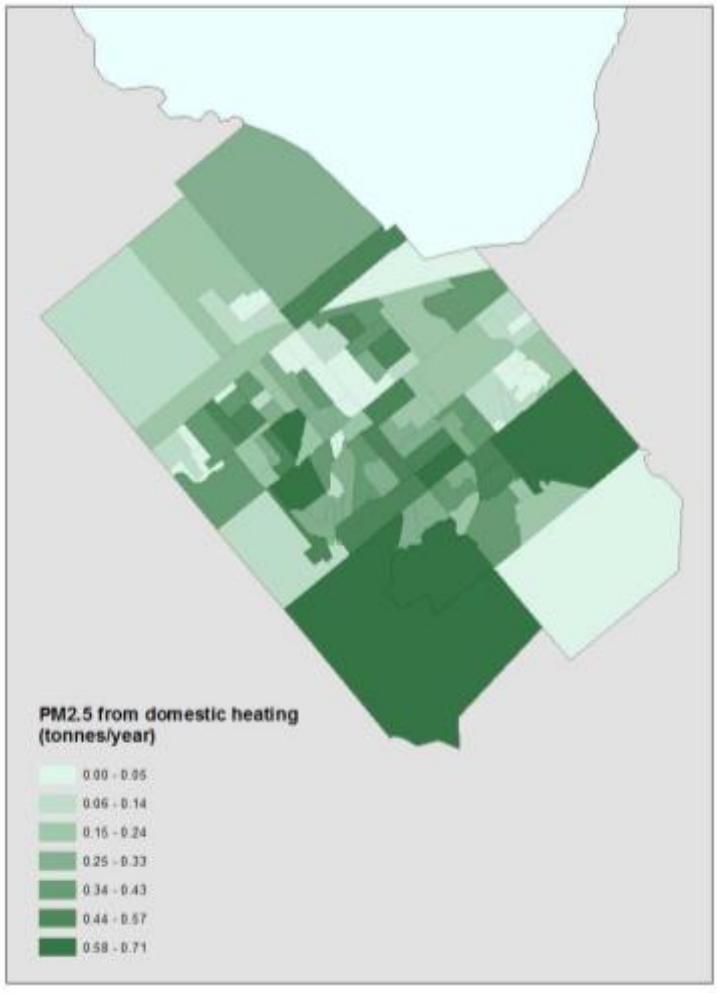

Figure 6-1: Annual average $PM_{2.5}$ emissions (tonnes/ annum) for Richmond

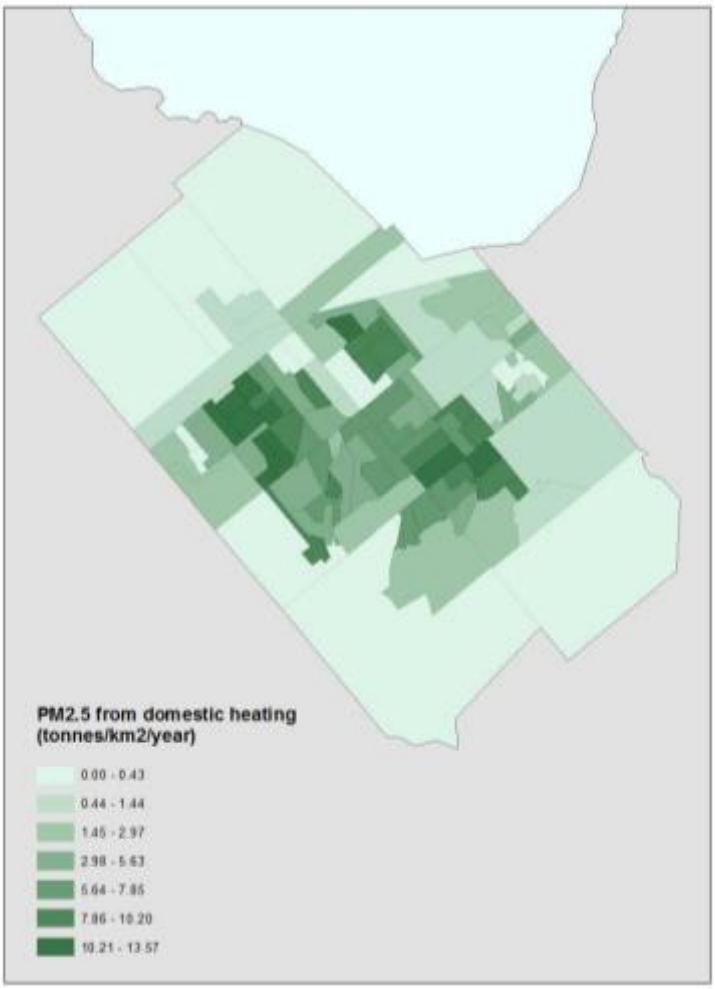

Figure 6-2: $PM_{2.5}$ emission density (tonnes/ km^2/ annum) for Richmond

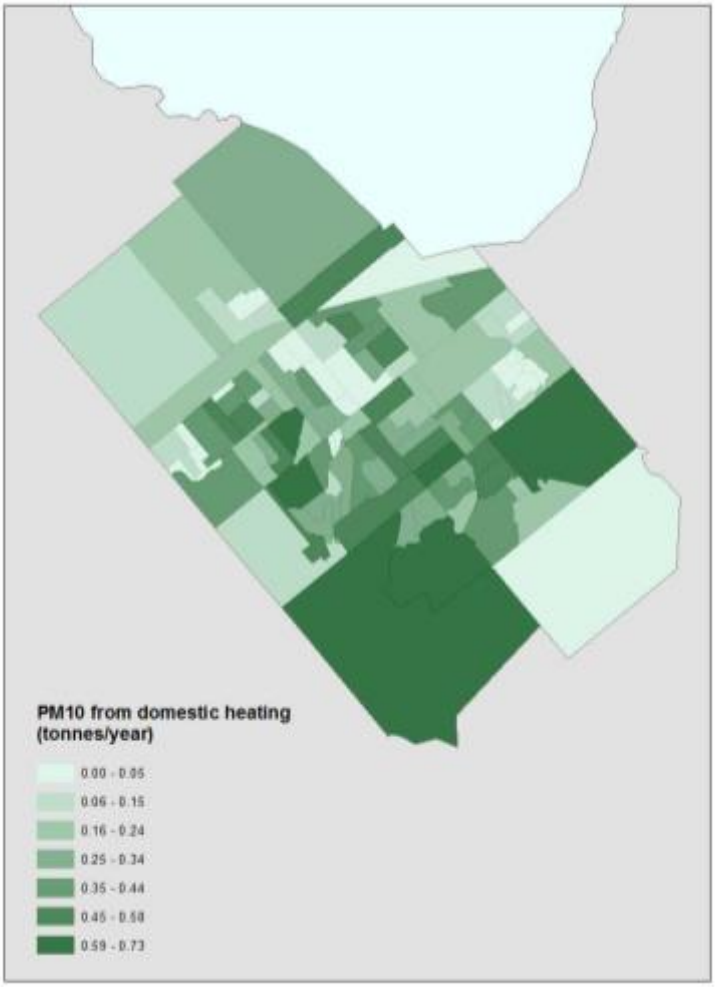

Figure 6-3: Annual average PM_{10} emissions (tonnes/ annum) for Richmond

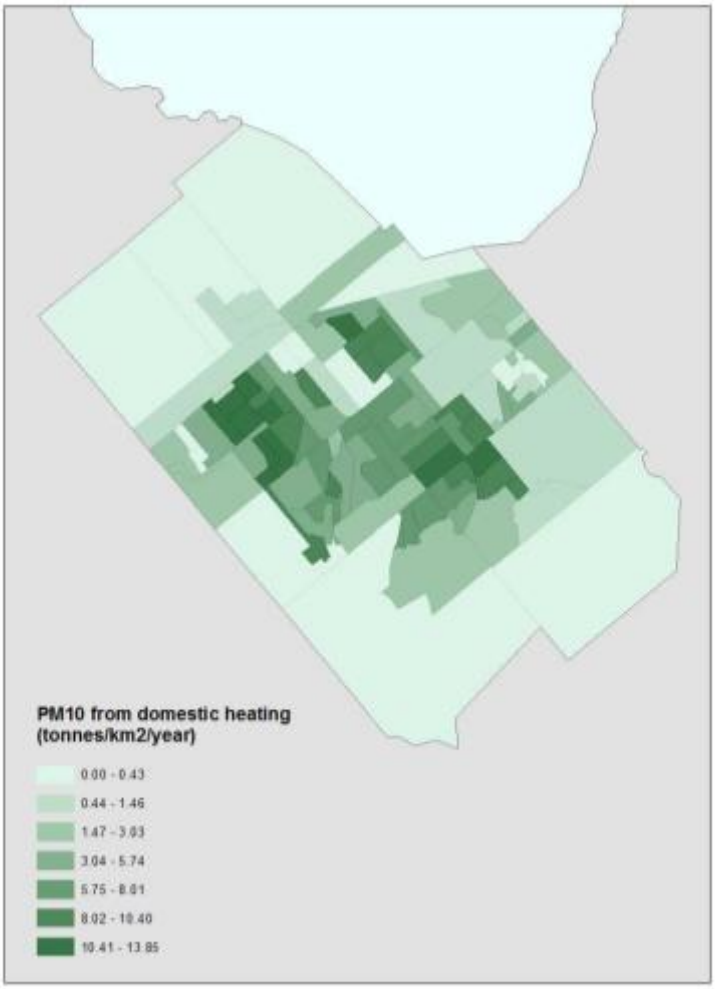

Figure 6-4: PM_{10} emission density (tonnes/ km^2/ annum) for Richmond

7 SUMMARY

The purpose of this report was to advise Tasman District Council on:

- Annual average $PM_{2.5}$ concentrations for 2016 and the relationship between PM_{10} and $PM_{2.5}$ based on monitoring carried out during 2015 and 2016.
- Estimated annual average concentrations for the preceding five years based on the above determined relationship with PM_{10}.
- A comparison of data to the WHO guideline for annual average $PM_{2.5}$.
- The likely relative contribution of domestic heating to annual average $PM_{2.5}$ concentrations in Richmond.
- An evaluation of the likely attainment of the revised NES based on the current Air Plan projections for daily winter PM_{10}. This includes an assessment of reductions in daily winter PM_{10} emissions and likely ongoing reductions in daily winter PM_{10} and annual average $PM_{2.5}$.
- An assessment of any further reductions required to meet the revised NES (over and above what is likely to be achieved through the Air Plan)
- The spatial distribution of existing PM_{10} and $PM_{2.5}$ solid fuel burner emissions across Richmond in map form.

The annual average $PM_{2.5}$ concentration for 2016 for Richmond was 10 µg/m^3. The relationship between $PM_{2.5}$ and PM_{10} was assessed for the winter and non-winter months and can be described using the following equations:

- Non-winter $PM_{2.5} = 0.54\ PM_{10} – 1.2$
- Winter $PM_{2.5} = 1.05\ PM_{10} – 7.5$

Estimated annual average $PM_{2.5}$ concentrations for the years 2011- 2015 were estimated using the above equations and gave averages ranging from 8.5 - 12.6 µg/m^3, depending on the year. These compare with a WHO guideline for annual average $PM_{2.5}$ of 10 µg/m^3. Based on these estimates the reductions in annual average $PM_{2.5}$ concentrations ranges from 0-21%.

A revised air plan projection estimates a 30% reduction in daily winter PM_{10} concentrations from 2012 – 2021 may occur as a result of a 35% reduction in PM_{10} emissions from domestic heating. The maximum annual average concentrations $PM_{2.5}$ of 12.6 µg/m^3 (2012) for recent years may reduce to around 9.2 µg/m^3 (a 27%) reduction if 2012 domestic heating concentrations were reduced by 35%, as predicated by projections modelling. The 2012 value is used because it is unlikely that 2016 represents worst case meteorological conditions for either peak or annual average PM_{10} or $PM_{2.5}$.

Spatial distribution of annual average $PM_{2.5}$ concentrations indicates hotspots typically in the outskirts of Richmond on the western, eastern and northern fringes.

Domestic heating is the main source of annual average $PM_{2.5}$ contributing around 74% of concentrations. Marine aerosol is the next largest contributor at around 13%.

Results indicate that current Air Plan measures may be sufficient to meet an annual average $PM_{2.5}$ limit of 10 µg/m^3 should this be the value and indicator selected in a revised NES. However, the analysis has identified a number of areas of uncertainty:

- The analysis is dependent on a 30% reduction in PM_{10} concentrations from 2012 – 2021 with over half this being estimated to occur from 2012-2016. Lack of a reduction in winter average PM_{10} concentrations from 2012 to 2016 is of concern and requires further investigation.
- Revised projections have been carried out to include natural sources and updated emission factors but have not included the potential contribution of NPI or pellet fires in new dwellings. The latter is

unlikely to have significant impact on the analysis but it is recommended that dispersion modelling results for NPI be made available and projections updated accordingly.

- It is unclear whether 2012 represents the likely worst case year for meteorological conditions in terms of peak PM_{10} concentrations or annual average $PM_{2.5}$ concentrations. Further evaluation of this would be of value.

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