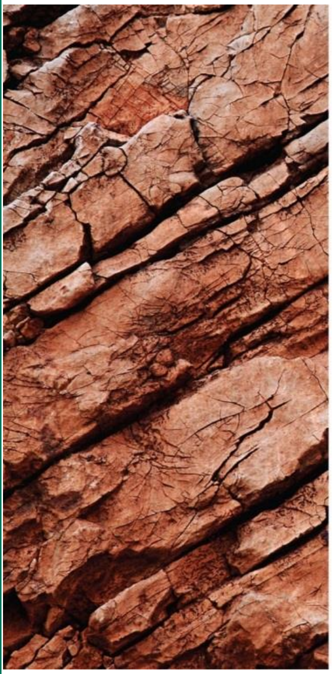
November 2015

URBAN AIRSHED MODELLING - DISPERSION OF PM10

Nelson Air Quality Plan - Air Quality Technical Assessment

REPORT

Submitted to:
Nelson City Council
110 Trafalgar Street
Nelson 7010



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1.0 INTRODUCTION

Nelson City Council (NCC) is carrying out a review of the Nelson Air Plan. This includes a plan change relating to the use of wood burners for home heating to be notified in January 2016, ahead of the wider Air Plan review which will take place later in 2016. This report provides an air quality technical assessment, the results of which will be used to guide NCC's decision-making process.

Golder Associates (NZ) Limited (Golder) completed a study in 2012 for NCC and the Tasman District Council (TDC), which developed an air quality model for the airsheds of Nelson and Richmond (Golder 2012). This was used to investigate dispersion of respirable particulate matter less than ten microns (PM_{10}) from all sources (domestic heating, motor vehicles, industry and natural emissions). The model was based on emissions inventories compiled in 2006 and 2005 for Nelson and Richmond respectively, and was used to study spatial patterns of ambient PM_{10}, and transport of PM_{10} between airsheds (Nelson A, B1, B2 and C, and Richmond). The model was also used to estimate the spatial extent of regions of exceedance of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NES) (the 24-hour PM_{10} standard), and compared these extents with the gazetted airshed boundaries.

NCC requires an update of the air quality model, incorporating new emissions inventories for Nelson and Richmond, to effectively inform management responses to air quality issues which are now current to NCC's air plan review. These include present-day cross-boundary transport between airsheds (which has implications for the effectiveness of policy measures if they are applied differently between airsheds), and the appropriateness of current airshed boundaries.

NCC requires a spatially more detailed approach, particularly with respect to transport of pollutants between Airsheds A and C, across Nelson City. Hence the terrain, meteorology and PM_{10} sources have been modelled at a higher resolution than previously, in order to capture more of this detail. Therefore, this project does not merely involve an update to new emissions data; the current approach is significantly different from the previous model, as described below.

The report is subject to the limitations listed in Appendix A.

2.0 MODELLING APPROACH

2.1 General

The dispersion modelling was carried out for this project using CALPUFF (Scire et al. 1999a; TRC 2011b, 2011a), supported by the meteorological models MM5 and CALMET (Scire et al. 1999). For a detailed discussion of how these models operate, see Golder (2012).

Previously, the meteorological model CALMET was run for the year 2008 at 500 m grid-cell resolution over an area containing Nelson, Richmond and much of the rest of the Tasman District. It was also run for the years 2008 and 2009 at 250 m resolution, and these higher resolution data sets were supplied to NCC and TDC for use by the air quality community to carry out smaller-scale assessments of industrial air quality impacts using CALPUFF. Airshed dispersion modelling was carried out by Golder in 2012 using CALPUFF and the 500 m meteorological data set.

Since the previous study, work has been carried out by Wilton and Zawar-Reza (2014) which identified 2009 as a worst-case air quality year from a meteorological perspective. Therefore the current airshed modelling is based on the meteorology of the winter of 2009, rather than 2008. In addition, the model has been run at 250 m resolution, rather than 500 m, for an improved representation of the terrain of the area and therefore the wind flows in the valley systems around Nelson City Centre. For a fuller description of the meteorological model configuration, see Appendix B.

2.2 Emissions of PM_{10} and Configuration of CALPUFF

Previously, emissions of PM_{10} from domestic heating and vehicles were specified as area sources in CALPUFF. Inventory data were supplied at a census meshblock level, but these were merged into larger sources to make the modelling computationally manageable, while still resolving the important areas of higher emissions. For a description of the emissions configuration used previously, see Appendix C of Golder (2012).

For this work, the latest inventory data were also supplied by Environet Ltd on a meshblock basis (the inventory for Nelson is reported on by Environet (2014); emissions data for Richmond were also supplied). To better capture the detailed spatial variability, the meshblock-based emissions were mapped onto a regular grid of cells, matching the meteorological grid at 250 m resolution. This does not capture all of the meshblock spatial variability, but is a significant improvement on the large-sized area sources used in the previous airshed modelling. The use of this gridded approach avoids the need to subjectively choose the important emission regions and represent them as four-sided polygons in the CALPUFF model, as was done in the previous airshed modelling. Although the cells are also specified as area sources in CALPUFF here, they are aligned with the CALMET grid, so that the whole area of each emission source grid cell is at the same terrain elevation as the corresponding meteorological grid cell. Some cells in urban areas contain several meshblocks; some meshblocks cover several cells and their emissions must be apportioned correctly. There are around 500 meshblocks in Nelson; the number of area sources used in the modelling here turns out to be around the same.

The dispersion modelling was carried out in several runs, each with a different set of sources, so that the contribution to the total PM_{10} from each set of sources could be calculated hour by hour. The source sets are summarized in Table 1.

Table 1: Modelled PM_{10} source regions.

Source name	Description
Airshed A	Nelson South home heating and motor vehicle emissions on a 250 m grid
Airshed B1	Tahunanui home heating and motor vehicle emissions on a 250 m grid
Airshed B2	Stoke home heating and motor vehicle emissions on a 250 m grid
Airshed C(1)	Home heating and motor vehicle emissions from all suburbs northeast of Nelson
Airshed C(2)	Home heating and motor vehicle emissions from Britannia CAU
Airshed C(3)	Home heating and motor vehicle emissions from CAUs Bronte and The Brook
Airshed C(4)	Home heating and motor vehicle emissions from Nelson East and Maitai Valley
Airshed C(5)	Home heating and motor vehicle emissions from Trafalgar CAU
Airshed C(6)	Home heating and motor vehicle emissions from The Wood CAU and Brooklands
Richmond West	Home heating and motor vehicle emissions from Richmond West CAU
Richmond East	Home heating and motor vehicle emissions from Richmond East CAU
Industry	Industrial emissions from Nelson, Richmond, and Nelson Pines Industries (NPI)

Note: Airsheds A, B1 and B2 are commonly used designations. The official Airshed C has been split into "sub-airsheds" here. Richmond West and East are the two census area units (CAUs) constituting the Richmond airshed.

The current boundary between Airshed A and Airshed C intersects CAUs Trafalgar and Bronte. Meshblock emissions from these CAUs have been assigned to the relevant Airshed, namely, A, C(3) or C(5).

The home heating and motor vehicles sources constitute sets of 250 m by 250 m grid cells. If the airshed boundary passes through a grid cell, contributions from the airsheds on either side are kept separate.

The industrial component of the emissions inventory contains emission rates, but not other parameters such as stack height and cross-sectional area, exit velocity and temperature, and location of nearby buildings. Most industry has been treated as low-level non-buoyant sources, with default stack heights of 10 m. Emissions from larger sources, including two sawmills in Nelson, and the NPI site located to the northwest of Richmond have been treated as point sources, with parameters taken from their respective air quality assessments. Modelled emissions are depicted in Figure 1. This shows shaded 250 m by 250 m cells of daily domestic heating and motor vehicle emissions combined, from the 2014 inventory (colour scale in kg/cell/day – note the colour changes for each doubling of emission rate). Cells which are included in the modelling are outlined in white – they account for at least 90 % of the total emission in each airshed. Airshed boundaries are marked as red lines, with airsheds and sub-airsheds labelled in red. Industrial sources are marked as blue circles. Axes are in metres, in the New Zealand Transverse Mercator system.

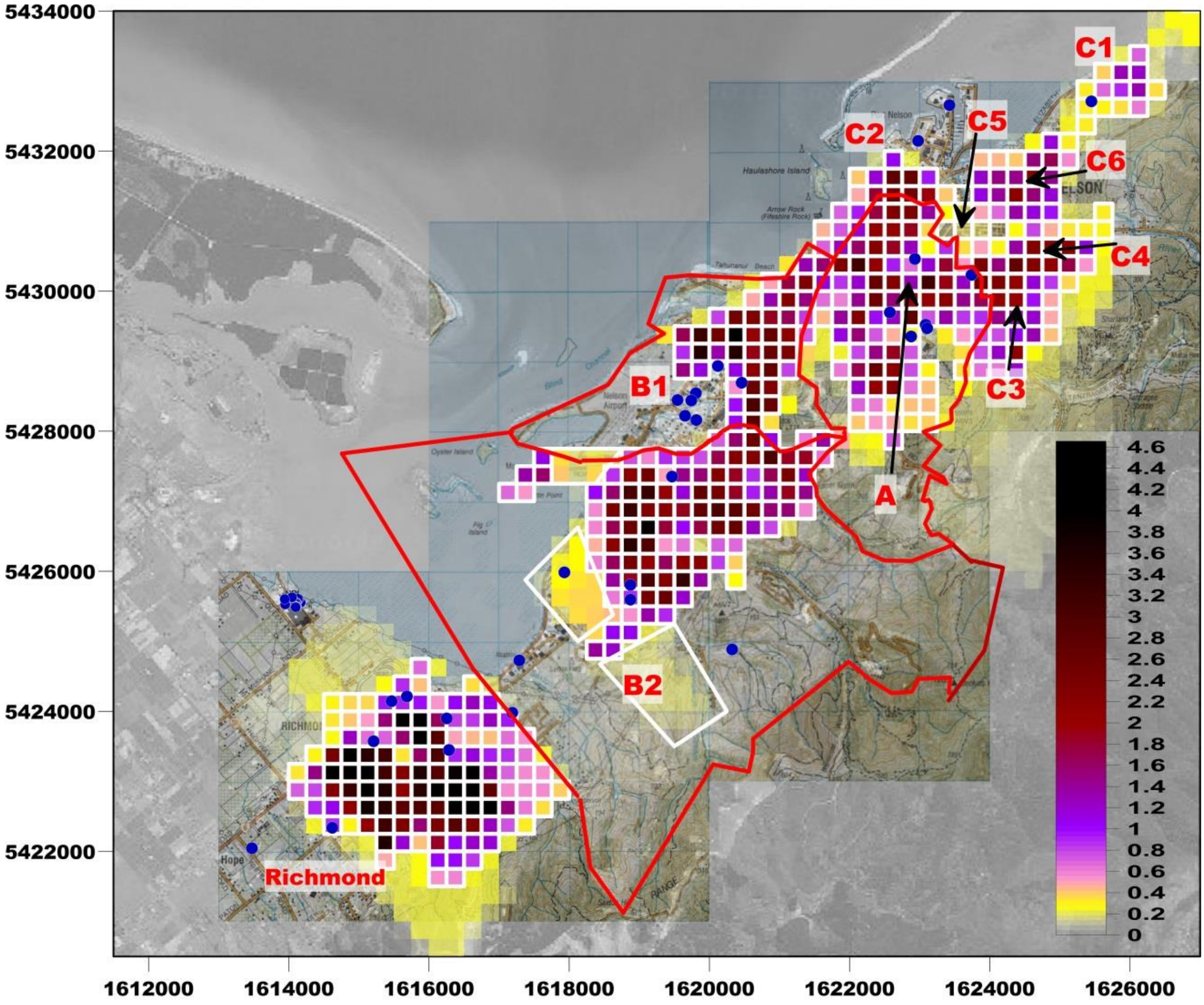


Figure 1: Emissions from domestic heating, motor vehicles and industry in Nelson and Richmond. Units are kg/cell/day.

Hourly profiles and monthly scaling factors for all sources were supplied by Environet Ltd. The model was run using the previously-generated meteorological outputs for the period May 2009 to August 2009 (inclusive), and emissions estimates for 2014. This is intended to provide an indication of the likely impacts of present-day PM_{10} emissions on a period of worst-case meteorology.

3.0 DISPERSION OF PM_{10} BETWEEN AIRSHEDS

3.1 Background

NCC requires an assessment of dispersion of PM_{10} between the currently-gazetted airsheds, using the latest emissions data. In particular, this includes an assessment of dispersion between various parts of Airshed C and Airshed A, with a view to evaluation by NCC of an appropriate boundary passing through the centre of Nelson. In addition, NCC has an interest in dispersion between Airsheds B1 and B2, and NCC and TDC both have an interest in dispersion between Airshed B2 and Richmond.

3.2 Method

Cross-boundary transport has been assessed using the following procedure:

1) A set of receptor locations has been specified, to represent the areas in question.
2) A time series of airshed model results for 24-hour average PM_{10} is extracted at each receptor location, apportioned according to contribution from the different source sets (airsheds, parts thereof, and industry) listed in Table 1.
3) The contribution to the PM_{10} at each receptor from the different sources is evaluated, for the winter-average PM_{10}, and the average of the ten highest PM_{10} concentrations at the receptor. In particular, the contribution from the airshed in which the receptor is located, and the nearest neighbours, is evaluated.
4) Individual worst-case 24-hour PM_{10} concentrations are further examined to determine the reasons for the cross-boundary transport in terms of the meteorology of those worst-case days.

The following sections examine the specific regions required by NCC.

3.3 Dispersion between Airsheds A and C

3.3.1 Introduction

Currently the boundary between Airsheds A and C passes through the central urban area of Nelson City. This is not a physical boundary to the low-level wind flow and the dispersion of pollution (as a hill ridge line can potentially be), and hence contributions to degraded air quality from either side of this boundary are to be expected.

The Trafalgar CAU occupies the central commercial area of Nelson and contains few domestic heating emissions. Given this, ambient PM_{10} experienced at this location will have a large component of PM_{10} originating in the surrounding areas. Also, the Britannia CAU (adjacent to the Tahuna Beach Road) is somewhat disconnected from the rest of Airshed C, and is likely to have a large component of PM_{10} originating in Airshed A.

As mentioned above, Airshed C extends southwards to the Grampians and northwards along State Highway 6, has been divided into six source regions, whose contributions to PM_{10} at any location can be determined. Receptors in each of these regions have been selected, in addition to receptors along the Airshed A / Airshed C boundary in the centre of Nelson. The receptors are shown in Figure 2. They are generally labelled according to the CAU in which they are located, except for Brook Street and St Vincent, which are at air quality monitoring sites.

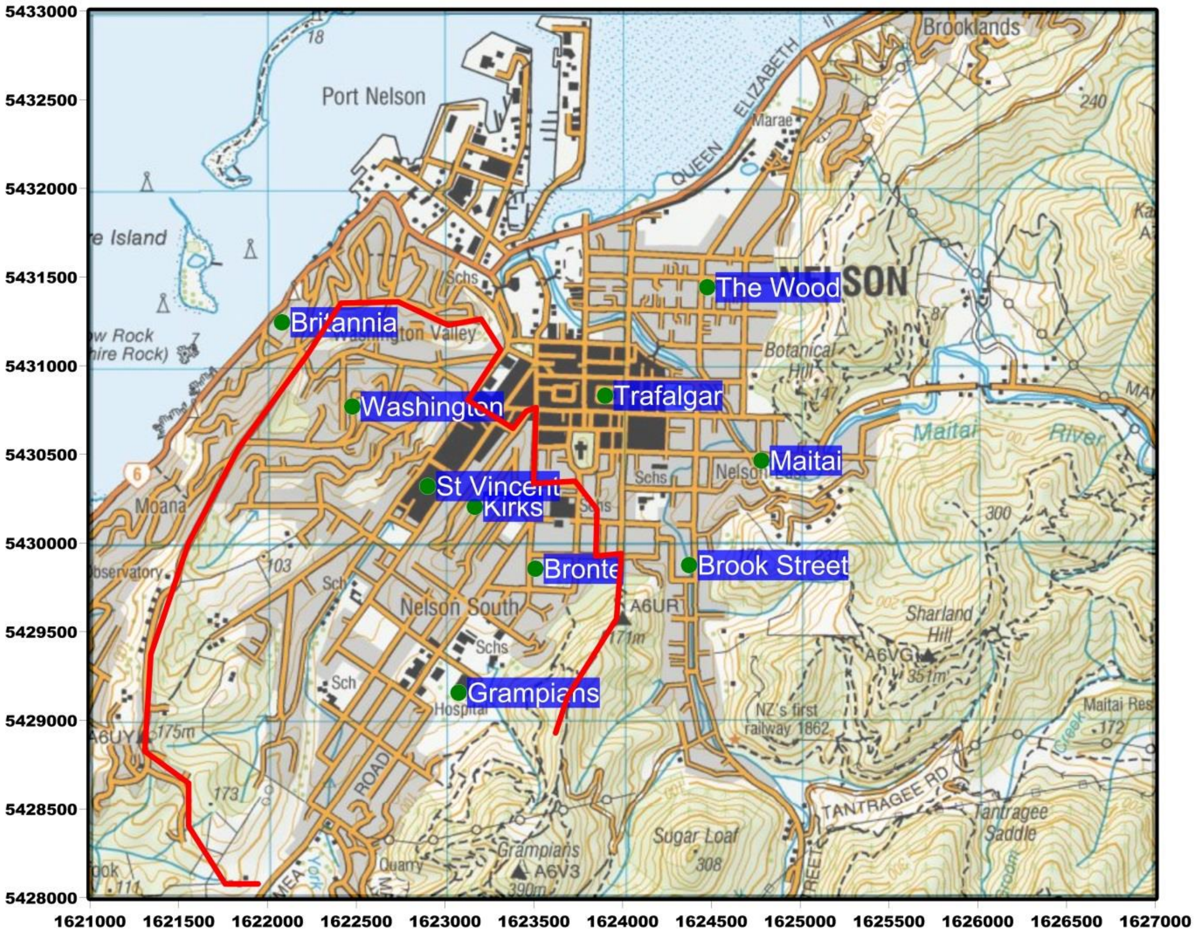


Figure 2: Receptor locations (green dots) for cross-boundary assessment - Airshed A to Airshed C. Part of the airshed boundary is indicated as a red line, which encloses Airshed A. Airshed C is to the north and east of this.

3.3.2 Cross-boundary transport

3.3.2.1 Receptors in Airshed C

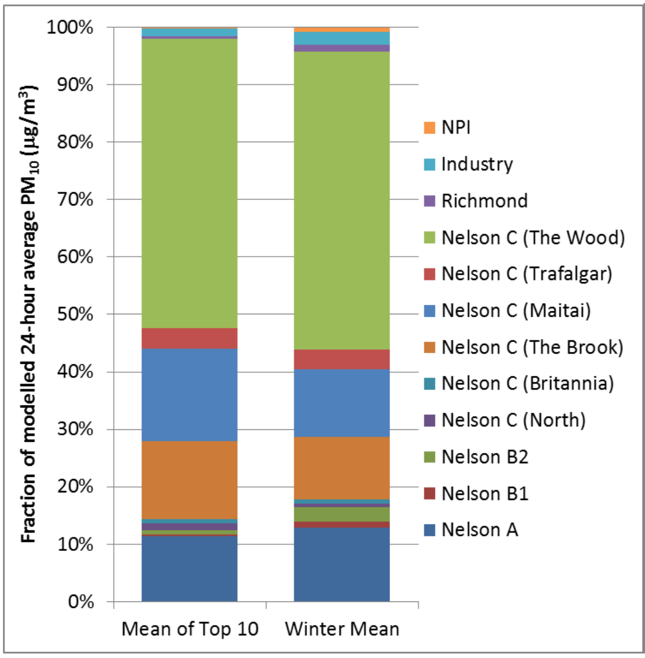
Figure 3 and Figure 4 show the proportions of peak PM_{10} concentrations arriving at selected receptors in Airshed C from each of the modelled source regions.

The Wood: According to the model, around 50 % of the anthropogenic PM_{10} at The Wood receptor on peak days was emitted from the CAU itself, with smaller contributions from The Brook and Nelson East, making around 85 % of the anthropogenic PM_{10} from all of Airshed C. Around 10 % of the PM_{10} at The Wood on peak days is emitted in Airshed A (see the top-left panel of Figure 3).

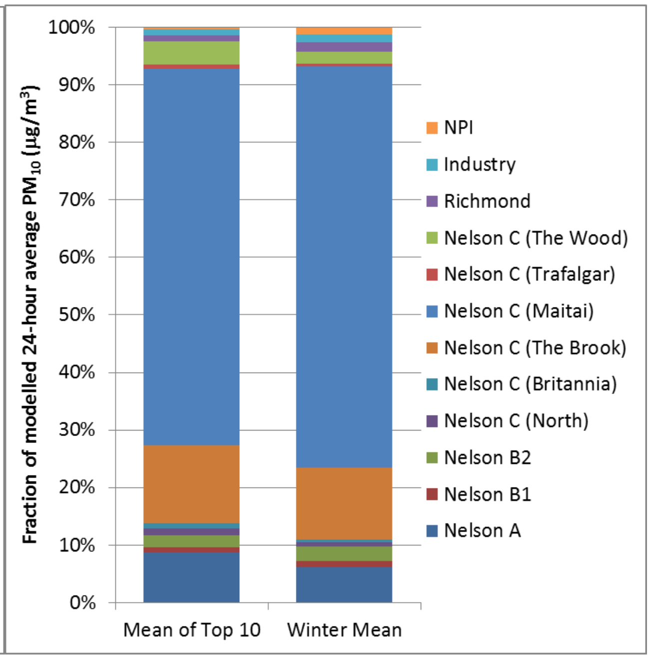
An examination of the meteorology on peak PM_{10} days shows evening drainage flows approaching The Wood area from the Maitai River Valley (Nelson East), the valley containing Brook Street, and Nelson South Valley (Airshed A). These flows can occur simultaneously, and converge on The Wood.

Maitai: This receptor is in Nelson East, the Maitai CAU. According to the model, around 65 % of the anthropogenic PM_{10} at the Maitai receptor on peak days was emitted from the CAU itself, with around 10 % from The Brook, making 85 % to 90 % from all of Airshed C. Around 10 % of the PM_{10} at the Maitai receptor on peak days is emitted in Airshed A (see the top-right panel of Figure 3).

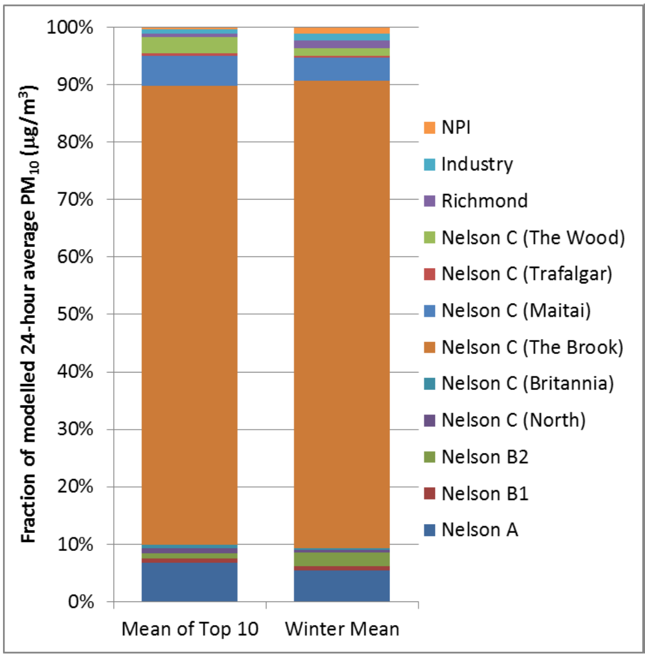
An examination of the meteorology on the days when the peak PM_{10} concentration occurs shows evening drainage flows along the Maitai River Valley (Nelson East) and the valley containing Brook Street, and Airshed A.



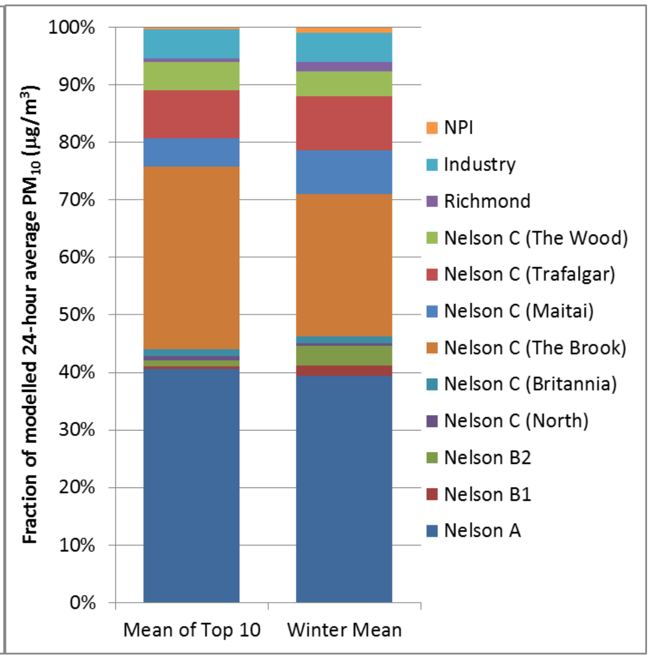
The Wood



Maitai



Brook Street



Trafalgar

Figure 3: Proportion of peak PM_{10} concentrations at selected receptors. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

Brook Street: This receptor is at 26 Brook Street, the ambient monitoring site, in The Brook CAU. According to the model, around 80 % of the anthropogenic PM_{10} at the Brook Street receptor on peak days was emitted from The Brook CAU itself, with contributions of less than 10 % from Maitai and Airshed A (see the bottom-left panel of Figure 3). The valley sides serve to act as a channel for the low-level wind flow, directing drainage flow northwards down the valley. There are few sources of PM_{10} upwind in this situation; hence the valley defines a physical airshed for Brook Street.

Trafalgar: Most of the Trafalgar CAU is located in Airshed C (one of its meshblocks is in Airshed A). This is not a residential area, hence most of the PM_{10} arriving here would have been emitted elsewhere. According to the model, less than 10 % of the anthropogenic PM_{10} at the Trafalgar receptor on peak days was emitted from the CAU itself. Around 40 % was emitted in Airshed A, and 50 % from the remainder of Airshed C (largest contribution around 20 % from The Brook) (see the bottom-right panel of Figure 3). This indicates that on peak PM_{10} nights, this receptor is located at the convergence of drainage flows, in air that originated from the south at The Brook, rather than air that originated from the east (the Maitai River Valley) (this may not be true of eastern parts of the Trafalgar CAU, but this has not been investigated).

Britannia: The Britannia CAU is a small suburban region which is part of Airshed C. According to the model, around 55 % of the PM_{10} experienced in Britannia originated in Airshed A, with around 20 % from Britannia itself, and 15 % from Airshed B to the southwest (see Figure 4). In this case, the ridge line dividing Airshed A and C does not appear to block flow over Britannia Heights from Airshed A to Airshed C (there are gaps in the ridge line), and southwesterly flows along the coast can transport PM_{10} from Airshed B.

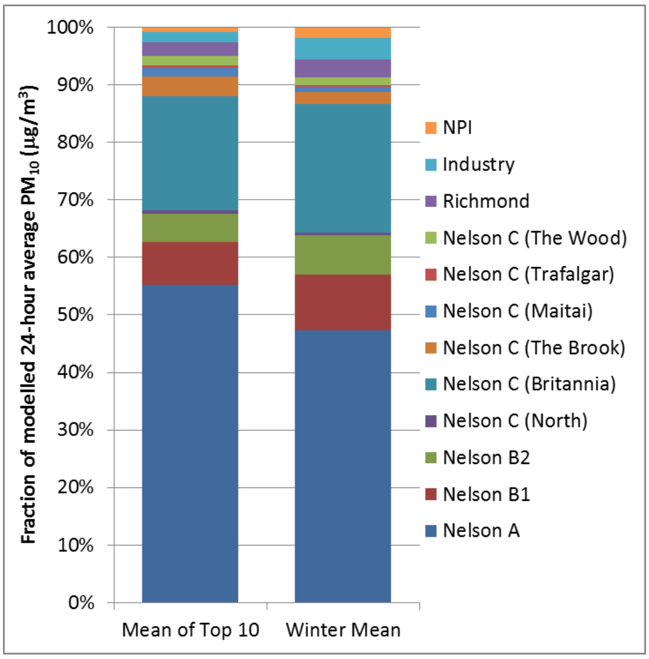
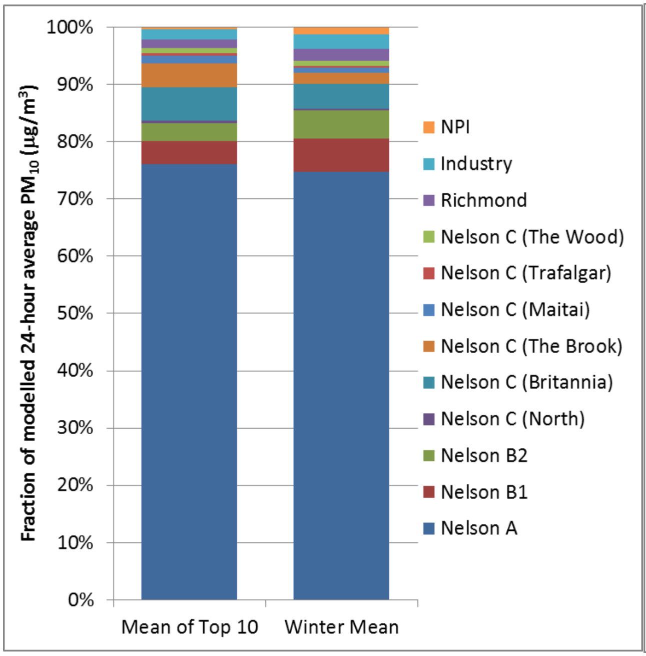


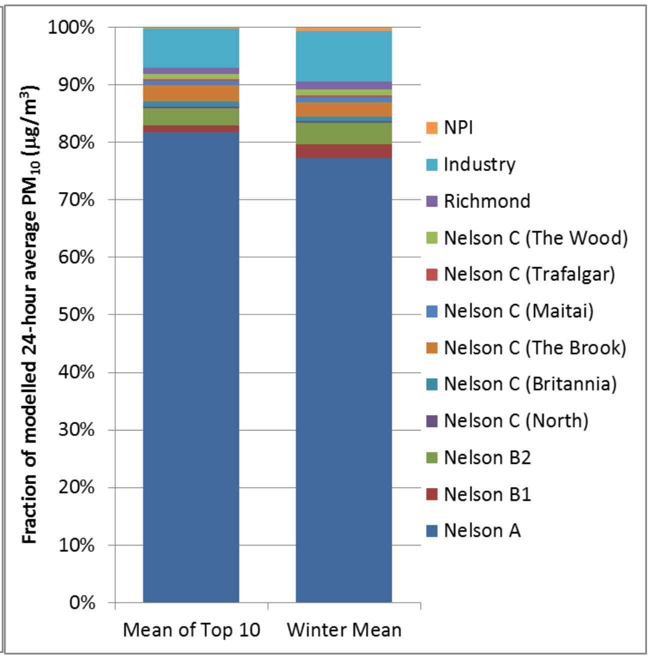
Figure 4: Proportion of peak PM_{10} concentrations at Britannia CAU. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

3.3.2.2 Receptors in Airshed A

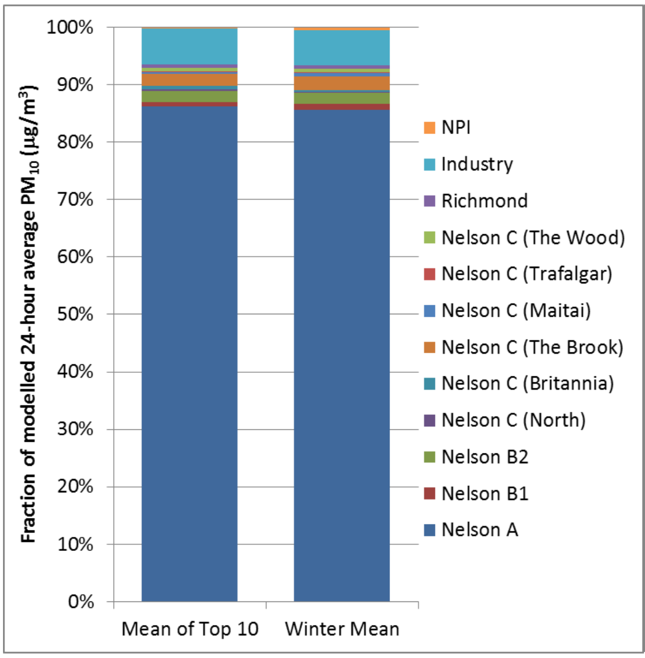
Figure 5 and Figure 6 show the proportions of peak PM_{10} concentrations arriving at selected receptors in Airshed A from each of the modelled source regions.



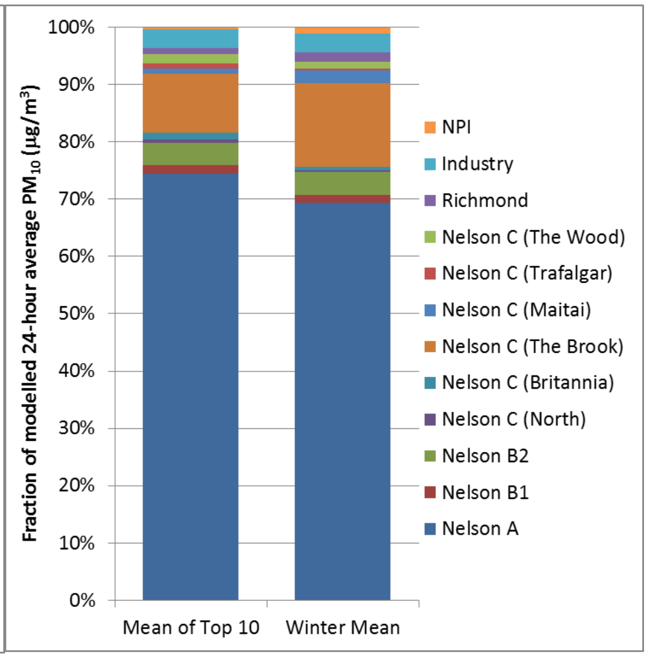
Washington



St Vincent



Kirks



Bronte

Figure 5: Proportion of peak PM_{10} concentrations at selected receptors. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

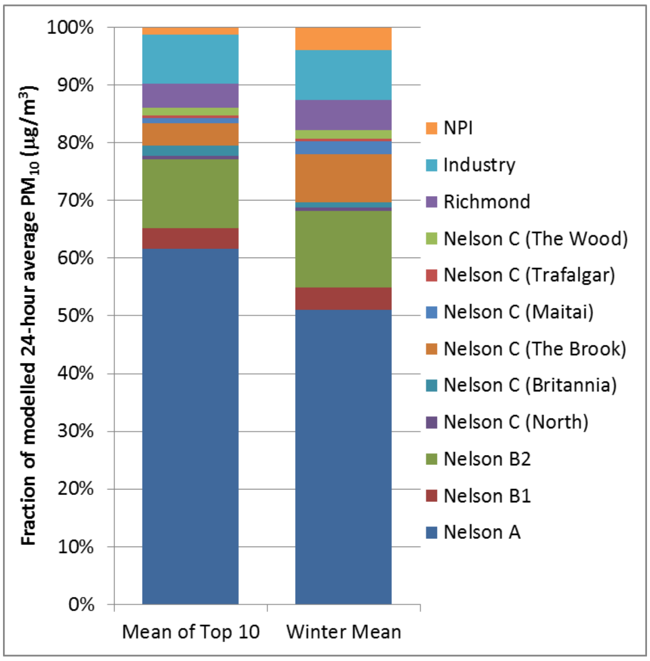


Figure 6: Proportion of peak PM_{10} concentrations at Nelson Hospital, in the Grampians CAU. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

Washington: This receptor is in the Washington CAU, in Airshed A, but is located quite close to the Britannia receptor in Airshed C. The model indicates that the proportions of PM_{10} from the various regions arriving at the Washington receptor on peak days are similar to those arriving at Britannia, with around 75 % from Airshed A, and small contributions from Airsheds B and C (see the top-left panel of Figure 5).

St Vincent: This receptor is the ambient air quality monitoring site at 117 St Vincent Street, in the Kirks CAU, Airshed A. The model indicates that 80 % of the PM_{10} arising on worst-case nights is from Airshed A itself, with 5 % from each of Airsheds B and C (see the top-right panel of Figure 5). There is an indication that 10 % is from industry. This may be an overestimate due to the use of default stack parameters for some industries.

Kirks: This receptor is in the residential part of Kirks CAU. The model indicates that PM_{10} levels are generally higher than at the St Vincent Street monitoring site, with proportions from Airshed A also higher, at nearly 90 % (see the bottom-left panel of Figure 5).

Bronte: This receptor is in Airshed A, although the northern portion of the Bronte CAU is across the boundary in Airshed C. According to the model, around 75 % of the PM_{10} experienced at this receptor on peak pollution nights was emitted from Airshed A itself, with just over 10 % from The Brook, in Airshed C (see the bottom-right panel of Figure 5). The days of the first- and 2nd-highest 24-hour modelled PM_{10} at this receptor have the highest contributions from The Brook. This is not surprising, as there are no terrain features separating this part of the Bronte CAU from the Brook, and air is free to flow between them.

Grampians: This receptor is in the urban part of the Grampians CAU, at Nelson Hospital. As it is just outside a residential area, PM_{10} levels are lower than in the centres of the residential CAUs, with the model indicating 60 % of PM_{10} on peak nights originating in Airshed A (see Figure 6).

3.3.3 Summary of results for Airsheds A and C

The airshed model has indicated that peak PM_{10} concentrations around the boundary between Airsheds A and C occur under conditions which are generally calm, or which include drainage wind flows down the valleys from the east (Nelson East, Maitai River Valley), the south (Brook Street), or southwest (Airshed A). These flows are independent of the large-scale flow and are driven by thermal contrasts in the complex terrain during the evening and night-time. The local flows do not depend on conditions that occurred during the day; neither do the 24-hour PM_{10} concentrations, as the majority of the PM_{10} is emitted during the evening.

The night-time drainage flows lead to a general drift of PM_{10} eventually northwards (depending on the valley direction). This means that PM_{10} levels in some parts of Airshed C are influenced by emissions from Airshed A. This does not appear to occur in the opposite direction, and only the areas of Airshed A close to the central urban area experience PM_{10} dispersed from closely neighbouring parts of Airshed C.

The dispersion of pollution from one suburb to another presents a challenge for airshed management, as there are no impermeable barriers to pollution dispersion, even at near-surface levels. Emissions from Airshed A impact air quality in Airshed C, and emission reduction measures applied to Airshed A will have a beneficial effect on Airshed C. It is beyond the scope of this project to provide recommendations on where the boundary should actually be for airshed management purposes. However, there appears to be no physically-based boundary which would divide the flat-terrain area of Nelson City into sub-regions and separate both the sources of PM_{10} and their impacts on ambient air quality.

3.4 Dispersion between Tahunanui and Stoke

3.4.1 Introduction

Currently the boundary between Airsheds B1 (Tahunanui) and B2 (Stoke) lies along Whakatu Drive and State Highway 6. As with the boundary between Airsheds A and C, this is not a physical boundary to the low-level flow and dispersion of pollution. However, it does separate the industrial area of Tahunanui from the residential areas of Stoke and Wakatu.

Receptors in each airshed have been selected for examination of cross-boundary pollution transport, as shown in Figure 7. They are generally labelled according to the CAU in which they are located, except for the Industrial receptor in the Nelson Airport CAU and the receptor labelled Wakatu, which is in the large Enner Glynn CAU.

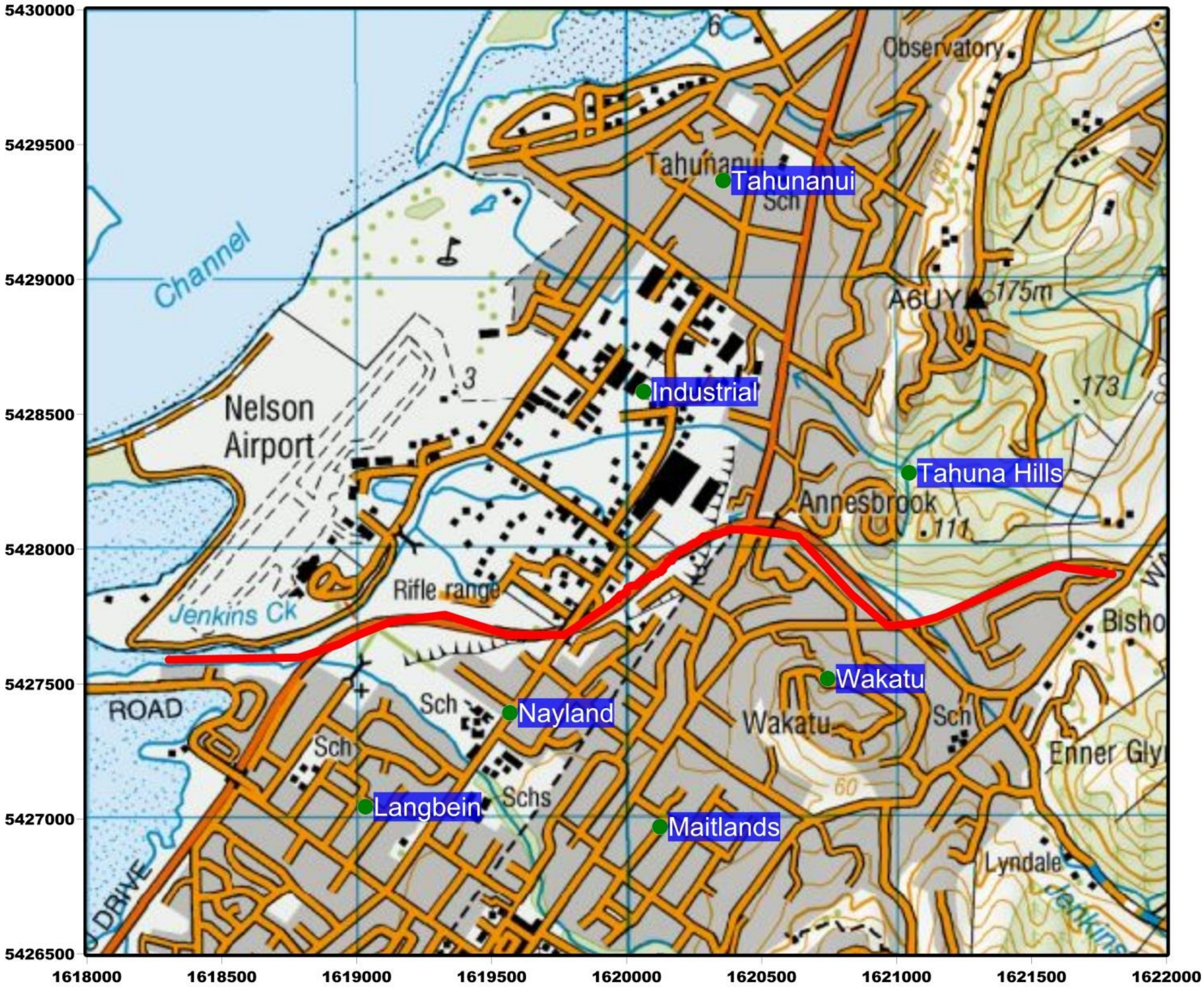


Figure 7: Receptor locations (green dots) for cross-boundary assessment - Airshed B1 to Airshed B2. The approximate airshed boundary is indicated as a red line. Airshed B1 is north of the line; Airshed B2 is to the south.

3.4.2 Cross-boundary transport

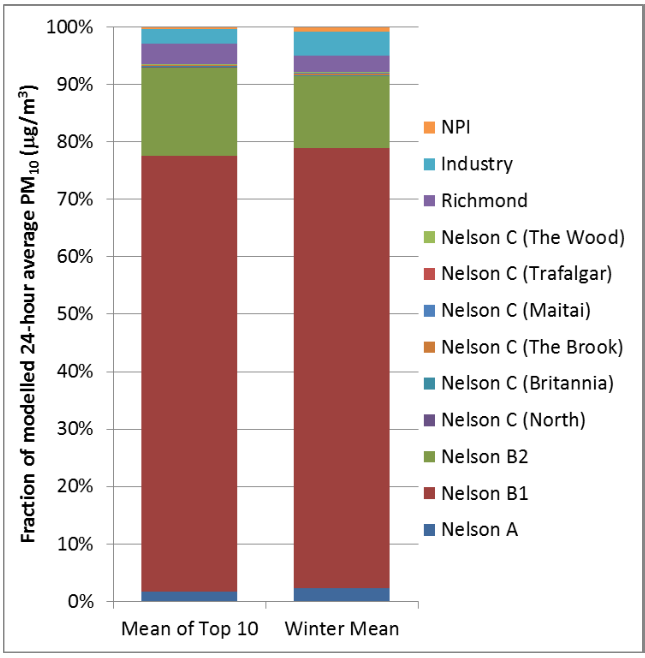
3.4.2.1 Receptors in Airshed B1

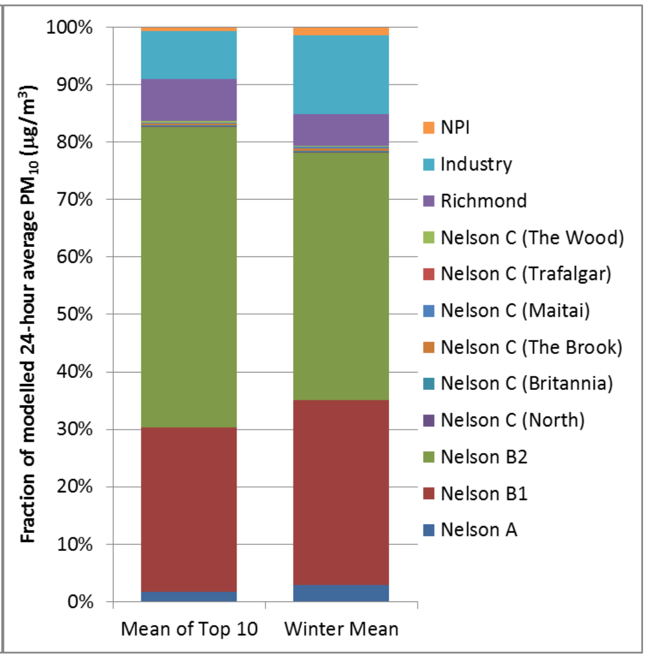
Figure 8 shows the proportions of peak PM_{10} concentrations arriving at selected receptors in Airshed B1 from each of the modelled source regions.

Tahunanui: This receptor is in a residential area in the north of the CAU. The model indicates that 75 % to 80 % of the 24-hour average PM_{10} on peak days originates in Airshed B1, with around 15 % from B2, and a negligible contribution from Airshed A. The highest peaks have the largest contributions from Airshed B2.

Industrial: This receptor is in the Nelson Airport CAU. As this is not a residential area, PM_{10} levels are lower than at the other receptors, and may originate elsewhere. In this case, the model indicates that 30 % of PM_{10} at this receptor on peak days originated in Airshed B1, with just over 50 % originating in B2.

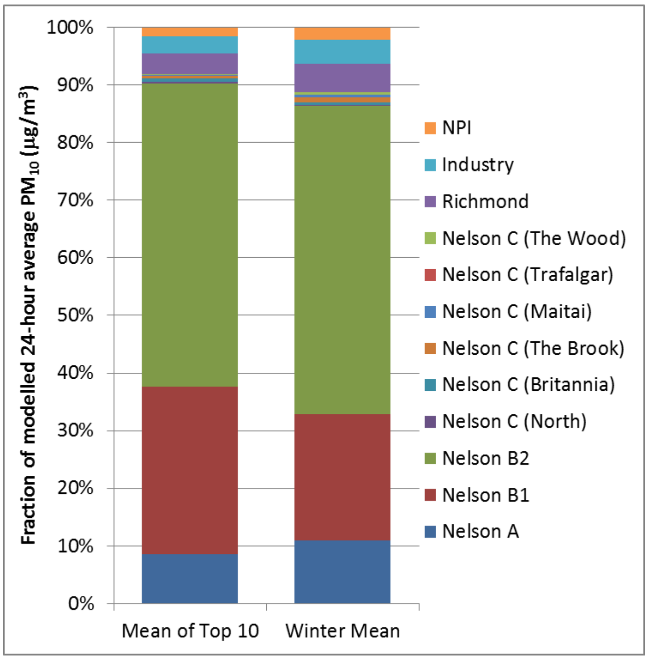
Tahuna Hills: This receptor is at the southern end of Airshed B1, near to the B1-B2 boundary, and fairly close to the southwestern part of Airshed A. The model indicates that nearly 30 % of PM_{10} at this receptor on peak days originated in Airshed B1, with 55 % originating in Airshed B2, and up to 10 % originating in Airshed A.





Tahunanui

Industrial

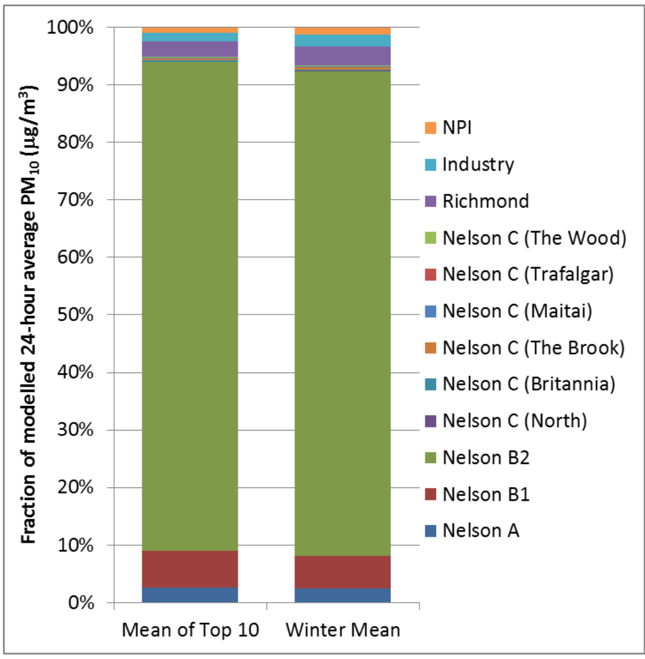


Tahuna Hills

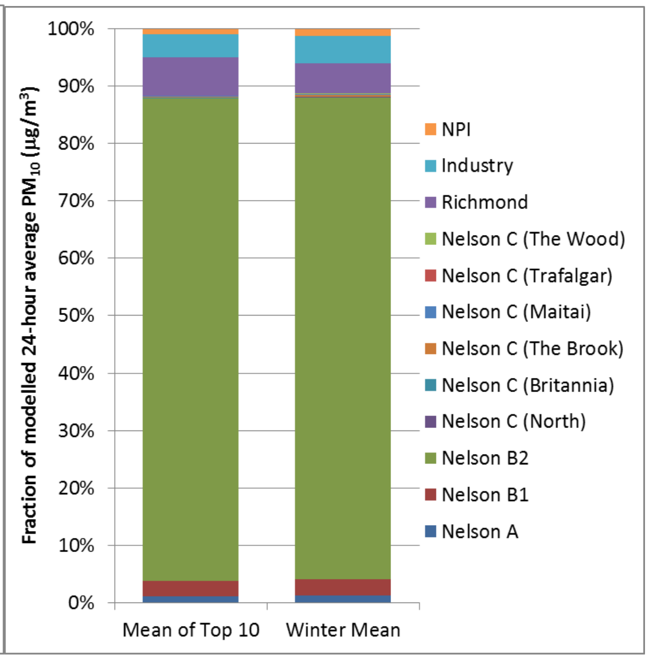
Figure 8: Proportion of peak PM_{10} concentrations at selected receptors. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

3.4.2.2 Receptors in Airshed B2

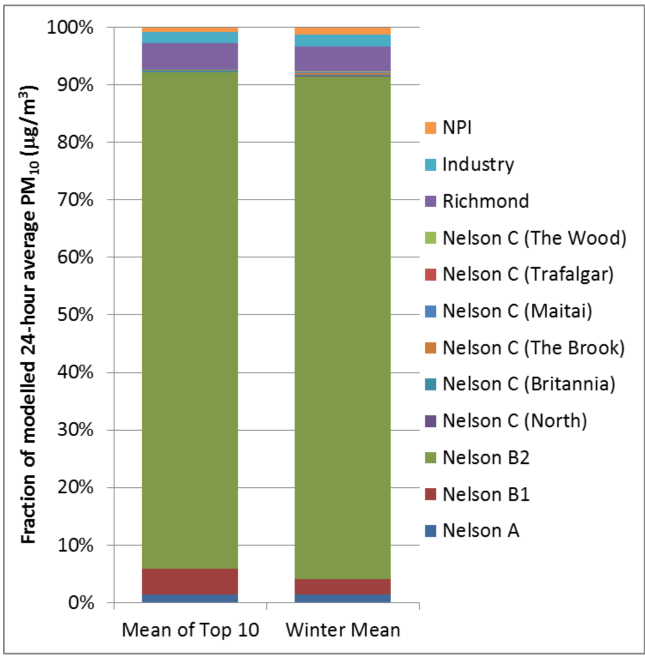
Figure 9 shows the proportions of peak PM_{10} concentrations arriving at selected receptors in Airshed B2 from each of the modelled source regions.



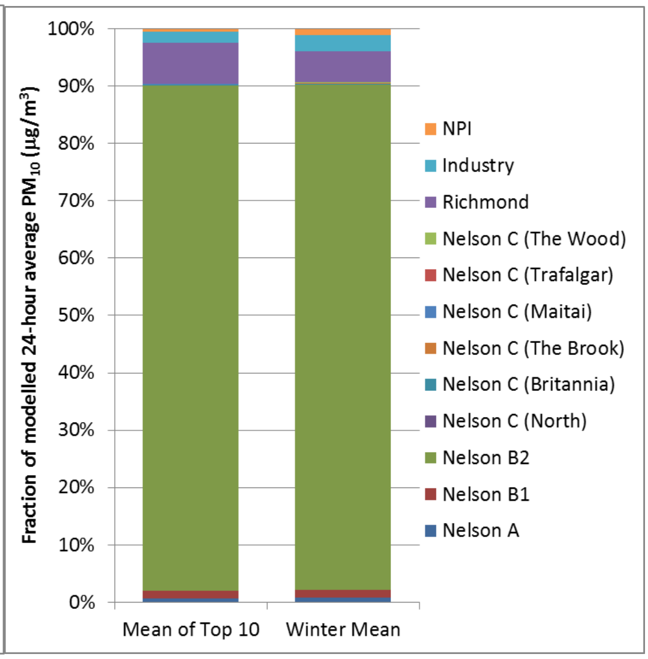
Wakatu



Nayland



Maitlands



Langbein

Figure 9: Proportion of peak PM_{10} concentrations at Britannia CAU. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

For each of these receptors in Airshed B2, south of the boundary with Airshed B1, at least 80 % of PM_{10} arriving on peak days originated in Airshed B2 itself.

3.4.3 Summary of results for the Airshed B1 / B2 boundary

The origins of PM_{10} arriving in Airshed B1 on peak pollution days are consistent with the meteorological situation outlined in Section **Error! Reference source not found.**, which indicates a drift from southwest to northeast, whereby receptors in Airshed B1 closer to the boundary with Airshed B2 have a larger proportion of PM_{10} originating in Airshed B2.

At receptors in Airshed B2, close to the boundary, contributions from Airsheds A and B1 are small. This is again consistent with wind direction experienced on worst-case pollution nights.

The boundary across Airshed B separates areas of distinctly different source types, but as mentioned above, is not a physical barrier to air pollution transport. The general direction of wind flow on peak days, from southwest to northeast leads to a contribution from emissions in Airshed B2 to air quality in Airshed B1. There is a small contribution from Richmond to PM_{10} at these receptors, as it is to the southwest. The small contribution is presumably due to the distance between the Richmond urban area and the Airshed B1 / B2 boundary. Cross-boundary transport of PM_{10} between Richmond and southern parts of Nelson Airshed B is examined in the next section.

3.5 Dispersion between Nelson and Richmond

3.5.1 Introduction

To assess cross-boundary pollution transport between Nelson and Richmond, several receptors have been chosen in the Richmond airshed, and the southern part of Nelson Airshed B2. The receptors are shown in Figure 10. The airshed boundary lies along Champion Road, which is aligned northwest to southeast; receptor labelled Richmond East lies on this road.

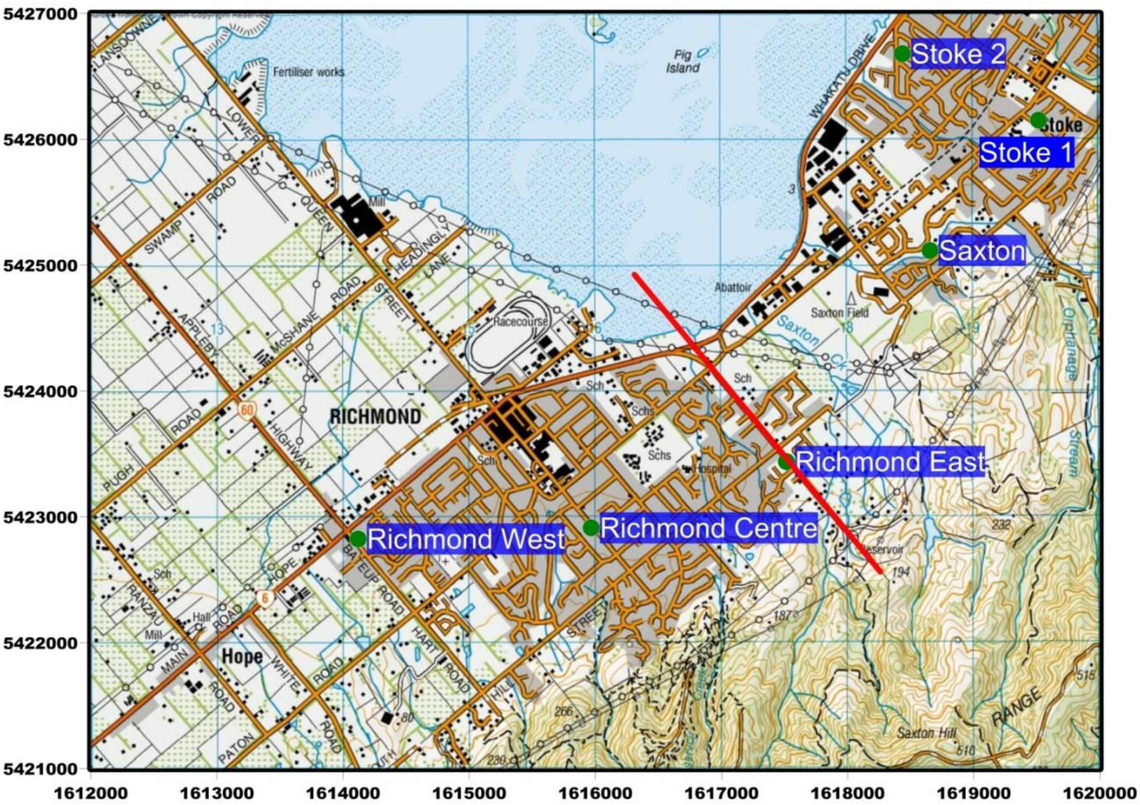
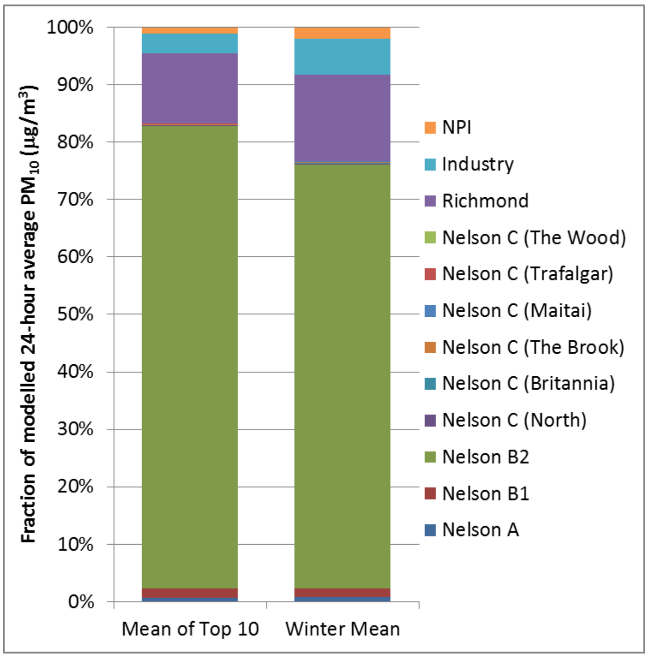


Figure 10: Receptor locations (green dots) for cross boundary assessment – Nelson Airshed B2 to Richmond. The approximate airshed boundary is indicated as a red line. Airshed B2 is to the north and east of this.

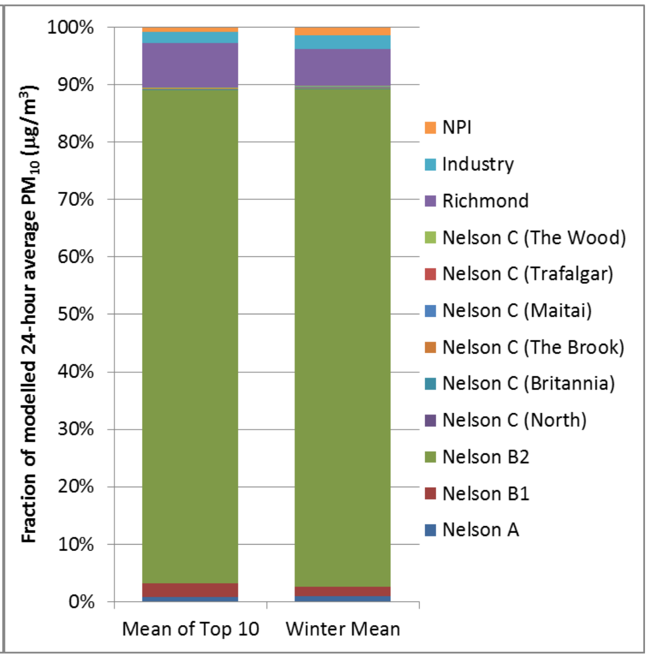
3.5.2 Cross-boundary transport

3.5.2.1 Receptors in Airshed B2

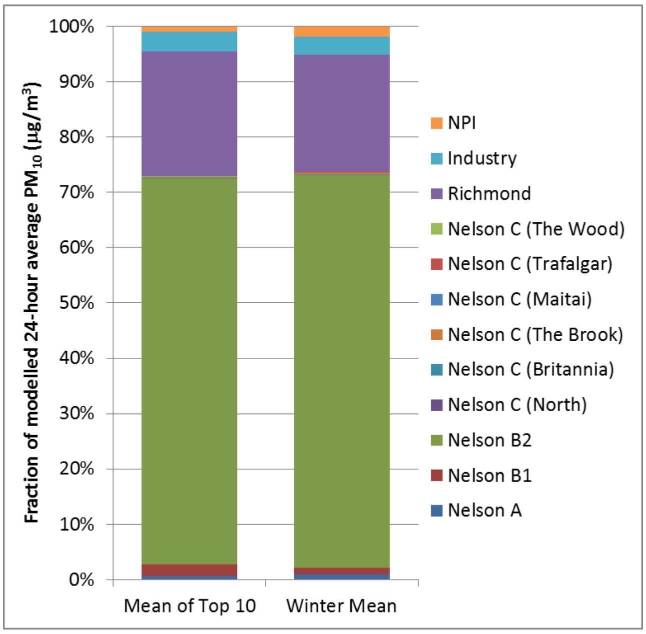
Figure 11 shows the proportions of peak PM_{10} concentrations arriving at selected receptors in Airshed B2 from each of the modelled source regions.



Stoke 2



Stoke 1



Saxton

Figure 11: Proportion of peak PM_{10} concentrations at selected receptors in Airshed B2. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

Stoke 2: This receptor is in the Saxton CAU. According to the dispersion model, the ten highest 24-hour average PM_{10} concentrations include around 80 % originating in Airshed B2, with 10 % to 15 % from Richmond averaged over winter.

Stoke 1: This receptor is in the Isel Park CAU. At this receptor, the ten highest modelled 24-hour average PM_{10} concentrations include 90 % originating in Airshed B2, with around 5 % from Richmond on average.

Saxton: This receptor is in the Ngawhatu CAU. Here, the ten highest modelled 24-hour average PM_{10} concentrations include 70 % originating in Airshed B2, with around 20 % from Richmond on average. However, the PM_{10} concentrations are lower here (there is a smaller area of Airshed B2 upwind of this location), and the magnitude of the concentration originating from Richmond is similar to that arriving at the Stoke receptors.

3.5.2.2 Receptors in Richmond

Figure 12 shows the proportions of peak PM_{10} concentrations arriving at selected receptors in Richmond from each of the modelled source regions.

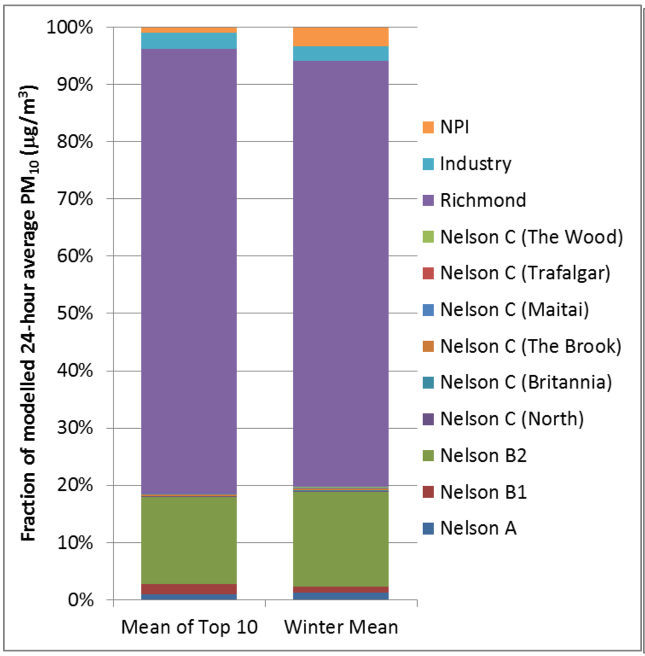
Richmond East: This receptor is on the border between the Nelson City and Tasman District. The model indicates that on worst-case PM_{10} days, 70 % of the PM_{10} experienced at this receptor originated in Richmond, with just under 20 % from Nelson (Airshed B2).

Richmond Centre: As this receptor is centrally located in an area of home heating emissions, the peak PM_{10} concentrations are dominated by local emissions. On worst-case days, the model indicates that 95 % of the PM_{10} in central Richmond originated in Richmond. About 2 % to 3 % of the PM_{10} arriving in Richmond on peak days originated in Nelson.

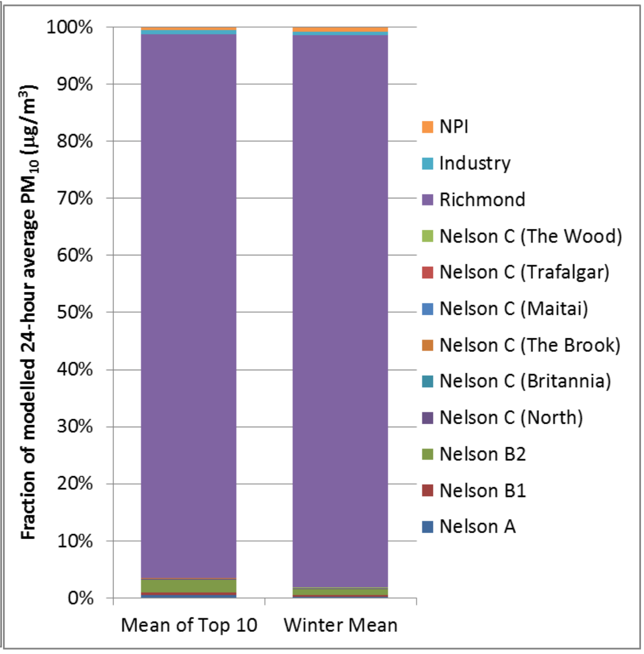
Richmond West: On worst-case days, model indicates 95 % of the PM_{10} at the western edge of the Richmond urban area originated in Richmond. However, the total PM_{10} is much smaller than in the town centre.

3.5.3 Summary of results for transport between Nelson and Richmond

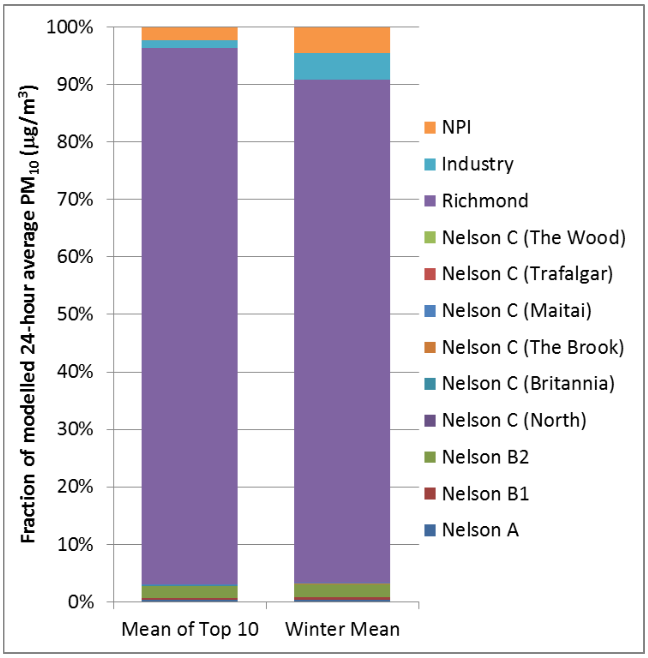
The meteorological model indicates that conditions on worst-case PM_{10} days include a period of southwesterly wind flow during the evening. This leads to some contribution to the total PM_{10} at each receptor from source regions to its southwest. However, in central parts of each source region, among high levels of home heating emissions, ambient PM_{10} is impacted much more by the local emissions than by incoming PM_{10} from the southwest. The high contribution from airshed B2 to PM_{10} at the two Stoke receptors and the Saxton receptor is thus due to their location in urban areas and their distance from Richmond. Similarly, the high contribution to PM_{10} at the Richmond receptors is due to their location relative to the urban area of Richmond, with low PM_{10} at the western receptor due to there being no significant emissions upwind in worst-case meteorological conditions.



Richmond East



Richmond Central



Richmond West

Figure 12: Proportion of peak PM_{10} concentrations in Richmond. Left column is the mean of the ten highest PM_{10} days; right column is the winter mean.

4.0 DISCUSSION

4.1 Model Performance

The dispersion model has been found to produce lower concentrations than those observed in recent years at the monitoring sites at St Vincent Street, Tahunanui and Brook Street. A number of possible reasons for the under-prediction are as follows:

- There are components of PM_{10} which have not been modelled, including natural sources (sea salt and soil dust) and secondary particulate pollutants. These may account for up to 20 % of the total PM_{10} (see Ancelet et al. 2013b).
- Peak PM_{10} concentrations in Airshed B are likely to be associated with motor vehicle movements and wind-blown dust in the industrial area (Ancelet et al. 2013a). These non-combustion components of PM_{10} are not represented in the modelling.
- The meteorological fields produced by CALMET are based on outputs from the weather forecasting and climate research model MM5, which were purchased by Golder from Lakes Environmental on behalf of NCC and TDC for the previous project. MM5 was not run in New Zealand, so no testing can be carried out or changes made. Golder has found since that time that the meteorological models used with 'default' settings may lead to an unreasonable amount of vertical diffusion and consequent diminishing of ground-level concentrations. This is not related to pollution transport around or over terrain features. An increase in the vertical resolution of the meteorological model can have a beneficial effect on the prediction of concentrations by providing a more realistic representation of the night-time meteorological boundary layer. This was found to be the case with TAPM (Golder 2015).

Despite the model's under-prediction of PM_{10} concentrations, Golder considers that the cross-boundary estimates, expressed in terms of percentages of total concentration, are reasonable. This depends on the transport of pollution in the modelled wind field. Golder has examined many of the modelled nights to ensure that flows around terrain features are realistic and found this be generally the case. Note that as the percentages have been presented as averages of the top-ten highest 24-hour PM_{10} concentrations, or as winter means, are not distorted by individual pollutant events in the model, and represent conditions that occur more generally.

4.2 Cross-Boundary Transport

The findings of the examination of cross-boundary transport of PM_{10} have been presented in Section 3.0 for each airshed boundary individually. The ability to carry out such an analysis is a strength of the model, due to the spatial detail in the terrain and meteorology. The meteorological parameters such as the low-level wind, temperature and boundary-layer properties can be examined hour-by-hour on any day, at a 250 m spatial resolution in this case.

The key flows affecting cross-boundary transport between Airsheds A and C have been found to be the down-valley winds in the Maitai River Valley, which flow towards Nelson East, the southerly valley winds from The Brook, and the Airshed A Valley. All of these affect the city centre and The Wood, before flowing out to sea.

At other locations in Nelson and Richmond, peak PM_{10} levels occur in southwesterly conditions, which prevail over the down-valley flows from the hills to the east. This means that there is some cross-boundary transport on high-pollution nights from Airshed B2 to Airshed B1, and from Richmond to Airshed B2, but not in the opposite direction.

5.0 CONCLUSION

This project provides a technical assessment of PM_{10} air quality in Nelson, using dispersion modelling techniques to examine emissions and dispersion of PM_{10} at high spatial resolution in a complex coastal environment. The project has focussed on the spatial distribution of peaks of PM_{10} and their compliance with the NES for PM_{10} within the currently designated airsheds of Nelson, and the dispersion of PM_{10} across the boundaries between airsheds.

The findings of this project will be used to guide NCC in its review of the Nelson Air Quality Plan. Changes in rules for the use of solid-fuel home heating will be influenced by current PM_{10} levels over Nelson, and may need to vary between different areas of the city. The modelling presented here allows a detailed examination of the dispersion of PM_{10} to determine how emissions from one area impact air quality in another.

6.0 REFERENCES

Ancelet T, Davy P & Trompetter WJ 2013a. Analysis of PM10 concentrations in Nelson Airshed B. GNS Science Consultancy Report 2013/47.

Ancelet T, Davy P & Trompetter WJ 2013b. Source apportionment of PM10 and PM2.5 in Nelson Airshed A. GNS Science Consultancy Report 2013/146.

Environet 2014. Nelson Air Emission Inventory - 2014. Report prepared for Nelson City Council, October 2014.

Golder 2015. Christchurch Airshed Modelling - Incorporation of Motor Vehicle Sources and Overnight Home Heating Emissions. Report 1521198-002 prepared by Golder Associates (NZ) Limited for the Canterbury Regional Council, July 2015.

Golder 2012. Development of an air quality model and meteorological data sets for the Nelson-Richmond urban area. Report prepared by Golder Associates (NZ) Limited for Nelson City Council and Tasman District Council, February 2012.

Scire J, Robe F, Fernau M & Yamartino R 1999. A User's Guide for the CALMET Meteorological Model (Version 5.0). Earth Tech, Concord, Massachusetts.

Scire JS, Strimaitis DG & Yamartino RJ 1999. A user's guide for the CALPUFF dispersion model (version 5.0). Earth Tech, Inc., Boston.

TRC 2011a. CALPUFF Modeling System - Version 6 User Instructions. Report prepared by Atmospheric Studies Group, TRC Companies, Inc., April 2011.

TRC 2011b. Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia'. Prepared for NSW Office of Environment and Heritage, Sydney, Australia, March 2011.

Wilton E & Zawar-Reza P 2014. Assessment of trends in PM10 concentrations in Airshed A and evaluation of airshed capacity. Report prepared for Nelson City Council, August 2014.

APPENDIX A

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APPENDIX B

Meteorological Model Configuration

1.0 BACKGROUND

Meteorological data sets for use with CALPUFF were produced by Golder (2012)[1] using the CALMET meteorological processor. They are described in detail in Appendix B of the Golder (2012) report, and the summary contained in this Appendix is derived from that report.

Three CALMET data sets were produced, for the following purposes:

1) Airshed modelling using 2008 meteorology (large domain, 75 x 76 km, resolution 500 m)

2) Industrial applications using 2008 meteorology (small domain, 26 x 26 km, resolution 250 m)

3) Industrial applications using 2009 meteorology (small domain, 26 x 26 km, resolution 250 m)

The main body of the current report is concerned with airshed modelling. However, data set (3) in the above list was used, for the following reasons:

- The 75 km by 76 km domain was not needed, but better resolution was required of the valley systems around the interface of Nelson airsheds A and C, Nelson City and Nelson South. Hence a 250 m resolution data set was chosen.
- Analysis of measured PM_{10} concentrations in Airshed A indicated that the meteorological conditions conducive to worst-case pollution episodes occurred more frequently in 2009 than 2008 (Wilton & Zawar-Reza 2014)[2], Therefore the modelling was carried out based on the 2009 meteorological data set, number (3) in the list.

Since 2012, minor updates to the CALMET model configuration have been implemented, in accordance with current modelling practices. Based on Appendix B of Golder (2012), only information relevant to data set (3), the 250 m resolution data set for 2009, is retained in this update.

The following sections describe the preparation of input data, including modelled meteorology from the numerical weather prediction model MM5, geographical information such as terrain heights derived from remote sensing (LIDAR, LIght Detection And Ranging), and data from meteorological monitoring stations. Section 2.0 discusses the input data in the order in which the information is used by CALMET to calculate hourly meteorological fields, followed by tabulations of CALMET's model configuration parameters.

2.0 CALMET PROCESSING

2.1 MM5 Data used as CALMET's 'Initial Guess'

The CALMET meteorological processor allows for the assimilation of outputs from MM5, and these are used to generate an initial estimate of each hour's meteorological fields in CALMET. This is known as the 'initial guess'.

Modelled hourly, three-dimensional fields of wind, temperature, relative humidity from MM5 were used in the initial-guess stage of the CALMET run for each hour. MM5 solves the equations of atmospheric motion mathematically to give a physically realistic wind field. Numerical outputs from MM5 were purchased from Lakes Environmental by Tasman District Council (TDC) and NCC. These were obtained for the year 2009, covering an area 50 km by 50 km at 4 km resolution, centred on Nelson (41.298 S, 173.327 E). Eighteen vertical levels were used, the lowest 15 m above ground level.

[1] Golder 2012. Development of an air quality model and meteorological data sets for the Nelson-Richmond urban area. Report prepared by Golder Associates (NZ) Limited for Nelson City Council and Tasman District Council, February 2012.

[2] Wilton E & Zawar-Reza P 2014. Assessment of trends in PM_{10} concentrations in Airshed A and evaluation of airshed capacity. Report prepared for Nelson City Council, August 2014.

The spatial resolution of CALMET is higher than that of MM5, with the MM5 fields interpolated onto the CALMET grid at the initial-guess stage.

2.2 Graphical Information for CALMET's 'Step 1' Fields

CALMET requires terrain and land-use data on a regular grid of points. This information enables the model to produce terrain-driven effects such as blocking and slope and valley flows, and to produce the variations in boundary-layer structure associated with changes in land use (particularly the contrast between land and sea). This is known as the 'Step 1' field.

To determine the detailed terrain elevation, aircraft flights have been carried out over Nelson and Richmond with on-board LIDAR remote sensing equipment. The resulting terrain height data, at 5 m contour resolution, were provided for the 2012 project by NCC and TDC. Gridded terrain information for the surrounding area has been derived using Golder's in-house GIS procedures. Land-use data were extracted from Golder's in house database and converted to the CALMET input format.

The meteorological model domain has dimensions 26 km x 26 km, consisting of 104 x 104 grid cells of size 250 m x 250 m. Maps of the terrain and land use data used in the CALMET run for airshed modelling are shown in Figure 1 and Figure 2, respectively. The colour-coding for land use categories is shown in Table 1.

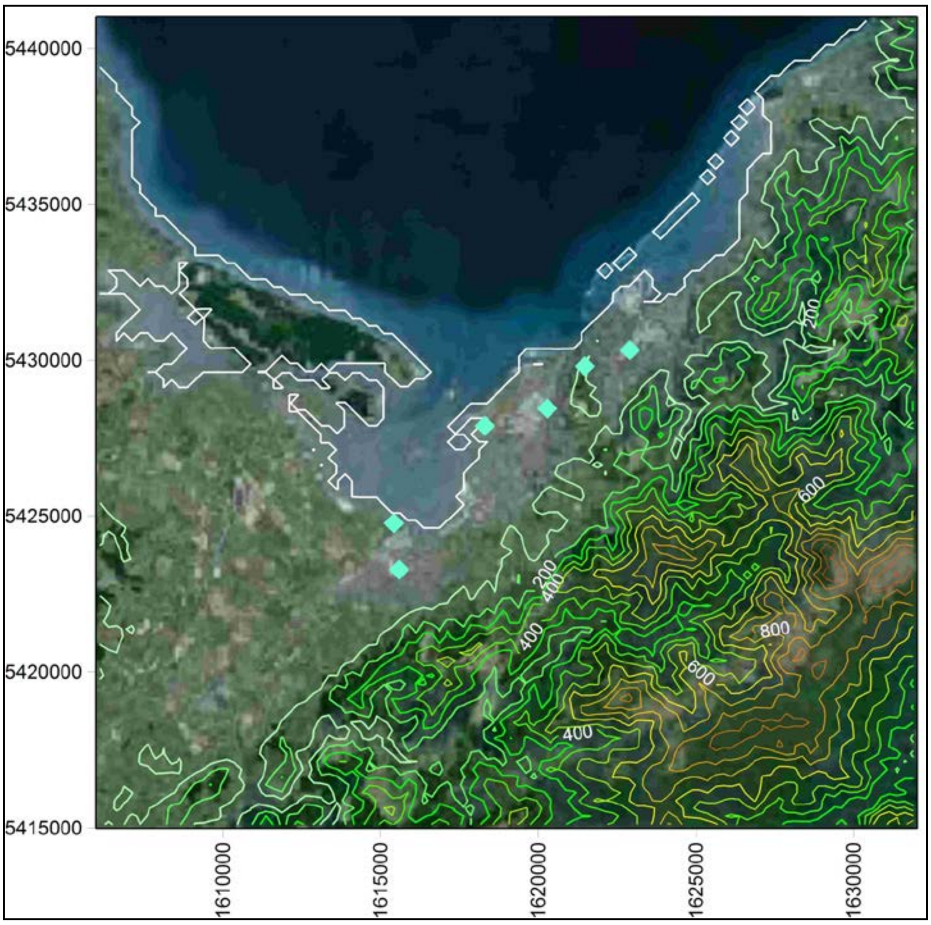

Figure 1: Contours of terrain height used for the CALMET modelling domain (contour interval 100 m, starting at zero). New Zealand Transverse Mercator coordinates are given in metres. Meteorological stations are indicated by blue diamonds.

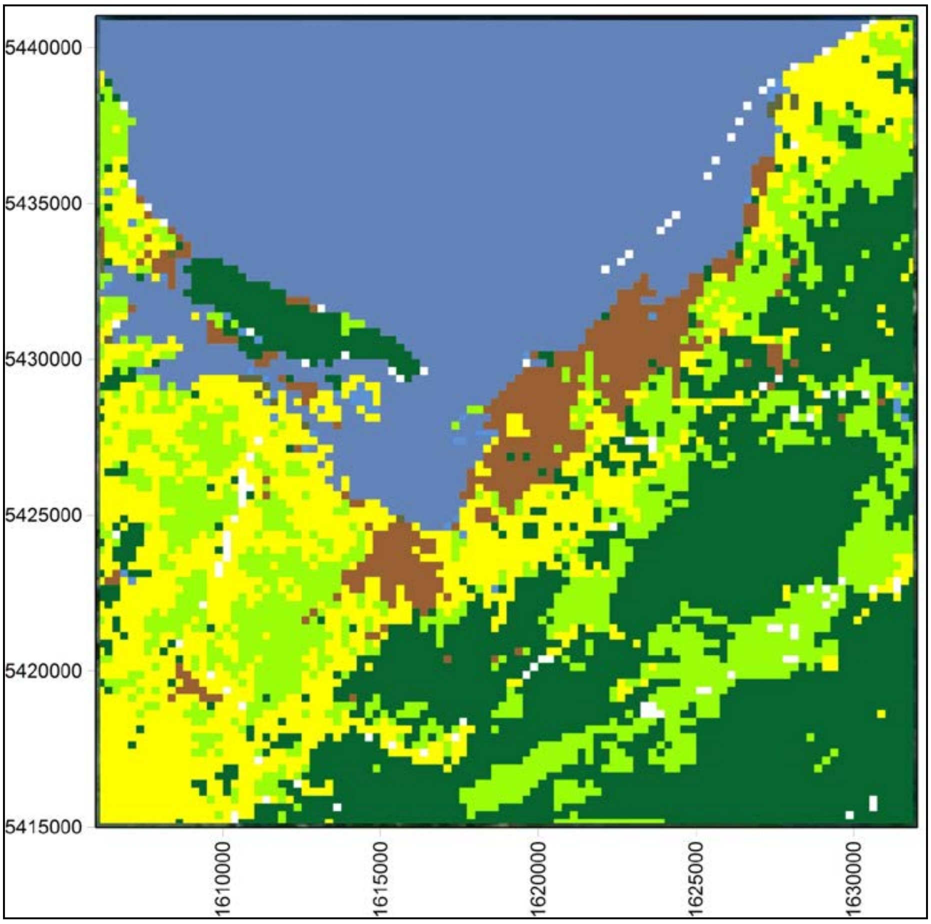

Figure 2: Land use map for the CALMET industrial source modelling domain. Colour coding as listed in Table 1.

Table 1: Land use categories used by CALMET.

Colour coding on Figure 2	Land use category
Brown	Urban or built-up land
Yellow	Agriculture
Light green	Rangeland (e.g., shrubs)
Dark green	Forest
Blue	Water
Olive green	Wetland
White	Barren land (e.g., beaches, sand spits, dry river beds)

Figure 3 shows a close-up of Figure 1 over Nelson City and Nelson South, to emphasize the system of valleys around the city.

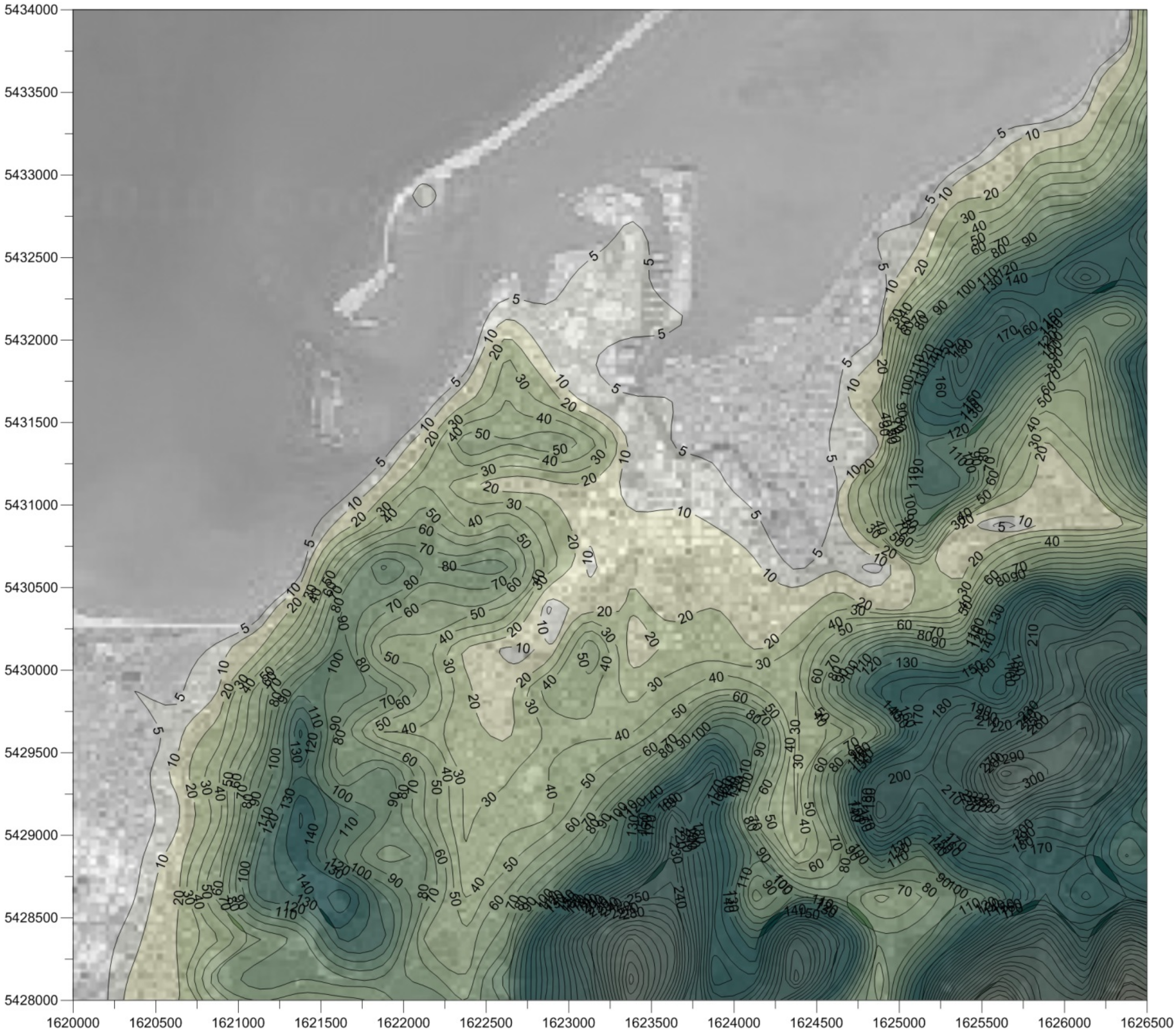

Figure 3: Detail of contours of terrain height used for the CALMET modelling domain, focusing on Nelson City and Nelson South. Contour intervals 5 m, 10 m, 20 m, then intervals of 10 m.

2.3 Meteorological Station Data for Objective Analysis

CALMET requires meteorological data from local weather stations. Local data are used to ensure that the modelled fields are consistent with observations. Incorporation of local observations leads to the final modelled meteorology, overriding the terrain-driven Step 1 field. Therefore, the observations are only used in the vicinity of monitoring sites, where the data are representative of the meteorology nearby. There are several monitoring sites in the Nelson/Richmond area operated by NCC and TDC. Data from these (and two others) have been used in the CALMET modelling, as described in this section.

Meteorological monitoring stations were commissioned by NCC and TDC, measuring surface wind, temperature, humidity, rainfall and wind gusts. These are located at Blackwood Street, St Vincent Street and Princess Drive in Nelson, the TDC office in Richmond and Richmond Park racecourse. The site data from NCC and TDC were supplemented by data from stations at Nelson Airport and Motueka (Riwaka), obtained from the National Climate Database (CLiDB).

A summary of the data availability from the meteorological stations is shown in Table 2. Wind speed and direction are available at all seven sites, temperature and relative humidity is measured at six of the seven sites, while rainfall is only available at two sites and pressure at one site. CALMET has been run with a time step of one hour. Wind roses for each of the stations are shown in Figures 4 to 10 of Appendix B of Golder (2012).

Table 2: Summary of surface meteorological station data used by CALMET. For National Climate Database (CliDB) stations the ID is the agent number.

Station name	Station ID	Location (km, NZTM)	Parameters
Nelson Aero AWS	4271	(1618.305, 5427.896)	Wind speed, wind direction, air temperature, relative humidity, pressure, rainfall
Motueka, Riwaka EWS	12429	(1597.621, 5450.361)	Wind speed, wind direction, rainfall
Nelson A&P showgrounds / Racecourse	1001	(1615.421, 5424.768)	Wind speed, wind direction, air temperature, relative humidity
Tasman District Council (TDC) building	1002	(1615.590, 5423.283)	Wind speed, wind direction, air temperature, relative humidity
Blackwood St reserve	1011	(1620.291, 5428.451)	Wind speed, wind direction, air temperature, relative humidity
Princess Dr	1012	(1621.478, 5429.803)	Wind speed, wind direction, air temperature, relative humidity
117 St Vincent St	1013	(1622.902, 5430.321	Wind speed, wind direction, air temperature, relative humidity

2.4 Other CALMET Configuration Parameters

Tables 3 to 7 provide details of user-specified parameters for generating hourly, three-dimensional meteorological data sets with CALMET. Parameters which vary between the three CALMET runs are indicated below. Parameters not mentioned here take default values, or they relate to a particular feature of the model that is not used. An evaluation of the performance of CALMET is provided in Appendix B of Golder (2012).

Table 3: Run control.

Parameter	Value
Start date / time	1 January 2009 00:00
Finish date / time	1 January 2010 00:00
Time zone	UTC+1200
Time step	3600 s

Table 4: Map projection.

Parameter	Value
Map projection	Tangential Transverse Mercator (TTM) assumed[3]
Datum region	WGS-84
Projection origin	41.298S, 173.237E
False origin (NZTM coordinates)	(1619.842, 5428.134) km

Table 5: Grid control.

Parameter	Value
SW corner of grid cell (1,1)	(1606.000, 5415.000) (km, NZTM)
Grid dimensions	104 x 104 grid cells of size 250 x 250 m
Vertical grid, number of layers	10
Cell-face heights for vertical grid (m)	0, 20, 40, 80, 120, 200, 400, 800, 1200, 2000, 3000

Table 6: Prognostic model options.

Parameter	Value
Use of MM5 for surface or upper-air information	NOOBS = 1; use MM5 for upper-air only
Use of MM5 for wind information	IPROG = 14; use MM5 as initial-guess wind field
Use of MM5 for temperature information	ITPROG = 1; use MM5 for upper-air only
Use of MM5 for relative humidity information	IRHPROG = 0; use surface observations
Use of MM5 for cloud information	ICLOUD = 3; diagnose cloud cover from MM5 relative humidity at 850mb
Use of MM5 for precipitation information	NPSTA = 0; precipitation included in the surface file

Table 7: Wind field options.

Parameter	Value
Extrapolation of surface wind observations	IEXTRP = -4; similarity theory used; only surface station data used in model layer 1 (not MM5 outputs)
Layer-dependent biases	-1, 9x0
Vertical extrapolation of surface winds (RMIN2)	-1.0; extrapolate all surface stations
Maximum radius of influence of meteorological data	RMAX1 = RMAX2 =10 km; RMAX3 = 30 km
Relative weighting of first-guess field and observations (that is, distance from site at which they are equally weighted)	R1 = R2 = 1.0 km
Radius of influence of terrain features	TERRAD = 2 km

[3] The coordinate system used in the modelling is not TTM, but NZ Transverse Mercator (NZTM). TTM is chosen in CALMET, as it allows any rectangular coordinate system to be used. The projection origin allows the rectangular coordinate system to be linked to a latitude/longitude system, in order to correctly obtain the sun angle and its influence on the meteorology.

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