Airshed modelling for PM_{10} concentrations – Marsden Point

Prepared for Northland Regional Council
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Executive Summary

Marsden Point is a gazetted airshed under the NESAQ and is the only airshed gazetted in New Zealand because of the presence of SO_2. Concentrations of PM_{10} in the airshed are largely unknown and Northland Regional Council is looking to address this through the establishment of a monitoring site for PM_{10}.

To determine the most appropriate location for PM_{10} monitoring airshed dispersion of emissions from domestic home heating, industry, motor vehicles and outdoor burning was carried out. Emissions from both inside and outside of the airshed were included to ensure any downwind impacts from Whangarei were captured.

The TAPM model was used to estimate PM_{10} concentrations within Marsden Point based on these emissions. The model predicted highest concentrations occurring as a result of the Whangarei plume dispersing between Ruakaka and Marsden Point. Concentrations were not predicted to exceed the NES. However, modelling did not include estimates of natural sources contributions and marine aerosol could be significant contributor in this location.

It is recommended that a monitoring site in Ruakaka be established for the purposes of measuring PM_{10} concentrations for compliance with the NES.

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1 Introduction

Marsden Point is located approximately 39 kilometres south of Whangarei on the west side of the Whangarei harbour. Historically the area was well known as the location of the Marsden Point Oil Refinery now known as the New Zealand Refining Company.

Air quality monitoring at Marsden Point has been limited to SO_2 because of the presence of the refinery. A 2008 inventory of industrial SO_2 sources found the New Zealand Refining Company was the third highest emitter of SO_2 in New Zealand (Wilton & Baynes, 2009). In 2005 Marsden Point was gazetted as an airshed under the National Environmental Standards (NES) because of SO_2 concentrations. The NES for SO_2 and other contaminants is shown in Table 1.1.

Table 1.1: National Environmental Standards for Ambient Air Quality (MfE, 2004)

Contaminant	NES values		
	Concentration	Averaging Period	Allowable exceedences / year
Carbon monoxide	10 mg m^{-3}	8-hour	1
Particles (PM_{10})	50 µg m^{-3}	24-hour	1
Nitrogen dioxide	200 µg m^{-3}	1-hour	9
Sulphur dioxide	350 µg m^{-3}	1-hour	9
Sulphur dioxide	570 µg m^{-3}	1-hour	0
Ozone	150 µg m^{-3}	1-hour	0

Monitoring of SO_2 in the Marsden Point airshed is carried out at a monitoring side in Ody Road. The location of this site is based on dispersion modelling of SO_2 emissions from the New Zealand Refining Company. During 2010 and 2011 concentrations of SO_2 at this site were fully compliant with the NES for SO_2 and with the 24-hour average guideline for SO_2 of 120 µg m^{-3} (Northland Regional Council, 2012).

The main contaminant of concern in other gazetted airsheds and many urban areas of New Zealand is PM_{10}, particles in the air less than 10 micron in diameter. Concentrations of PM_{10} have not been monitored in the Marsden Point airshed. The main source of PM_{10} emissions in most urban areas of New Zealand is solid fuel burning for domestic home heating. Northland Regional Council is looking to establish a monitoring site for PM_{10}. The NES requires that air quality monitoring take place at the location that has the highest concentrations of PM_{10} in an airshed. There is significant uncertainty around the most suitable location within the Marsden Point Airshed and an investigation is requried into where the highest PM_{10} concentrations might occur.

This report attempts to resolve the issue of an appropriate monitoring site for PM_{10} by modelling PM_{10} emission sources using The Air Pollution Model (TAPM). The outputs

will provide an indication of the locations where highest PM_{10} concentrations are likely as well as an indiacation of the likely magnitude of these concentrations.

The model is unable to include natural sources which may contribute to PM_{10} in the Mardsen Point airshed. In particular marine aerosol is likely to be a key contributor in this location and windblown dusts, e.g., from construction sites may also contribute. Source apportionment studies (e.g., Wilton et. al., 2010) show that marine aerosol can be a significant contributor to annual average PM_{10} concentrations but typically contribute less on days when PM_{10} concentrations are elevated as a result of meteorological conditions which restrict the dispersion of contaminants.

1.1 Marsden Point Airshed

The Marsden Point Airshed is shown in Figure 1.1. The area includes the census area units of Marsden Point-Ruakaka, most of Bream Head and part of Pataua-Whareora, Waiotira-Springfield, Parua Bay and Bream Bay.

Figure 1.1: Airshed boundary for Marsden Point

1.2 Whangarei Airshed

The Whangarei Airshed includes the following census area units: Tikipunga East, Tikipunga West, Kamo East, Otangarei, Whau Valley, Kensington, Western Hills, Regent, Mairtown, Riverside, Vinetown, Woodhill, Horahora, Maunu, Morningside, Raumaunga West, Raumaunga East, Port-Limeburners, Whangarei Central, Parahaki, Inlet-Port Whangarei and Onerahi. In addition, the areas of Kamo West, Sherwood Rise, Abbey Caves, Springs Flat, Three Mile bush and, Otaika-Portland are partially within the airshed (Figure 1.2).

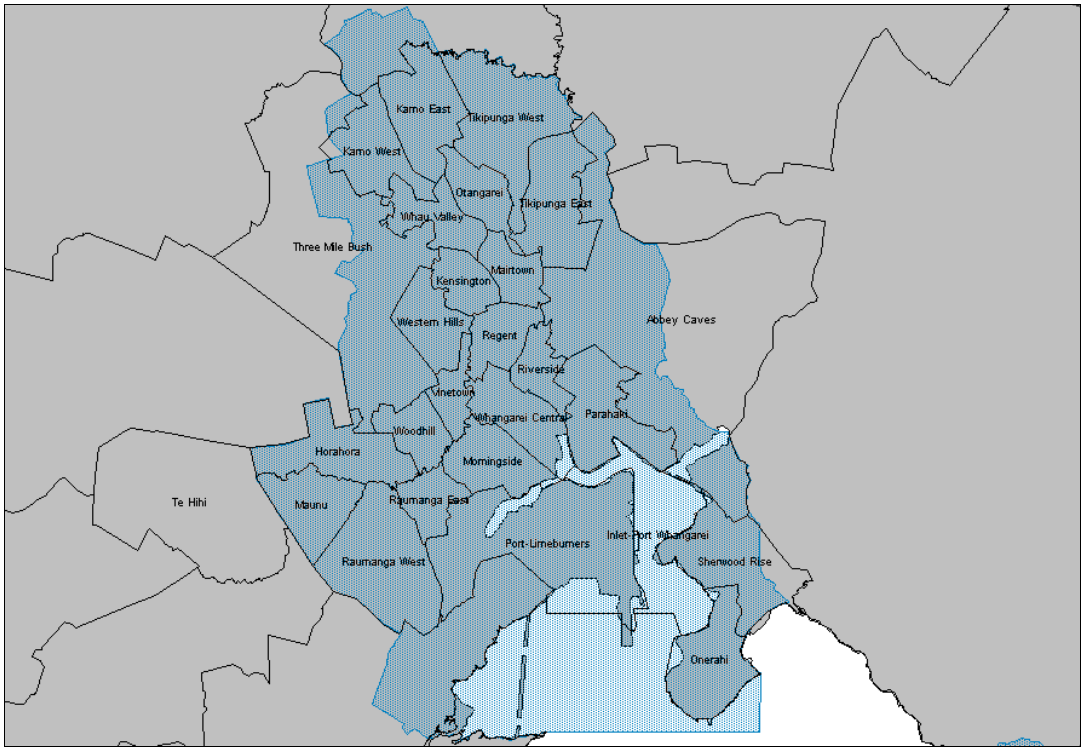

Figure 1.2: Airshed boundary for Whangarei (blue shading).

Figure 1.3: Location of Ody Road monitoring site at Taurikura

2 PM_{10} emissions estimates

2.1 Marsden Point and rural surrounds

2.1.1 Domestic heating

Solid fuel burning for domestic home heating is a key contributor to winter PM_{10} emissions in urban and rural areas of New Zealand. The main method for quantifying emissions from this source is an air emission inventory. In Northland an air emission inventory is available for the Whangarei airshed (Wilton, 2007) but no source quantification has been carried out beyond.

Emissions from domestic home heating were estimated for 2010 based on census data for 2006 which indicates the number of households in each CAU and meshblock[1] which use wood or coal burning to heat their home. Emissions factors and fuel use factors were applied to these numbers to estimate PM_{10} emissions (Table 2.1). The emission factors used were based on (Wilton, et. al., 2010) and the fuel use was the average daily household fuel use for wood and coal from the Whangarei inventory (Wilton, 2007).

Table 2.1: Emission Factors and Fuel Use Factors

Wood Fuel Use kg/day	Coal Fuel Use kg/day	Wood Emission Factor g/kg	Coal Emission Factor g/kg
17.7	10	7.5	28

The resulting daily domestic heating emissions were given a diurnal profile based on the results of real life emission testing of wood burners from a 2009 Christchurch study (Wilton & Bluett, 2011).

2.1.2 Motor vehicles

Motor vehicle emissions are a minor contributor to winter time PM_{10} in most urban areas of New Zealand. Emissions of PM_{10} from motor vehicles were estimated based on Ministry of Transport vehicle kilometre travelled (VKT) data for 2006 and the application of emission factors from VFEM. Estimates were made for each CAU and applied to meshblocks based on the assumption of an even distribution within each CAU.

2.1.3 Industry

The main source of industrial PM_{10} emissions in the Marsden Point Airshed is Carter Holt Harvey – Marsden. Combustion of wood at CHH – Marsden results in around 0.75 g/sec of PM_{10} which is discharged through an 18 metre high stack.

[1] Each CAU is broken up spatially into a number of smaller meshblock areas

Emissions of PM_{10} from the New Zealand Refining Company were also included in the model. Details of the discharge were obtained from the 1999 assessment of effects on the environment from the resource consent application.

2.1.4 Outdoor burning

Outdoor burning is a permitted activity in areas outside of the Whangarei airshed. Estimates of emissions from outdoor burning in the Marsden Point area and surrounding rural areas were made based on the following equation:

CAU PM_{10} (kg/day) = 0.0065 x number of households in CAU

This was derived based on emission estimates from 22 inventory studies throughout New Zealand. The relationship between number of households and estimated daily PM_{10} from these studies showed a good correlation (r^2 = 0.8). The inventories used to derive the relationship excluded Auckland.

2.2 Whangarei Area

Emissions of PM_{10} from the Whangarei airshed were based on the 2006 air emission inventory (Wilton, 2007). The inventory included emissions from domestic home heating, motor vehicles, outdoor burning and industry. Outdoor burning emissions from the Whangarei airshed were excluded from this evaluation as this activity is now regulated under the Air Plan.

The contribution of natural sources such as sea spray and soil were not included in the 2006 inventory as these sources cannot be identified in a robust manner using an inventory approach.

The PM_{10} domestic heating emission estimates from the inventory were allocated to CAUs and meshblocks based on the number of households using wood and coal in each area.

The combined Whangarei and Marsden Point emission density from domestic heating is shown in Figure 2.2. Lighter colours (typically blue and yellow) represent lower emission density and darker colours (typically orange and red) represent higher density emission areas.

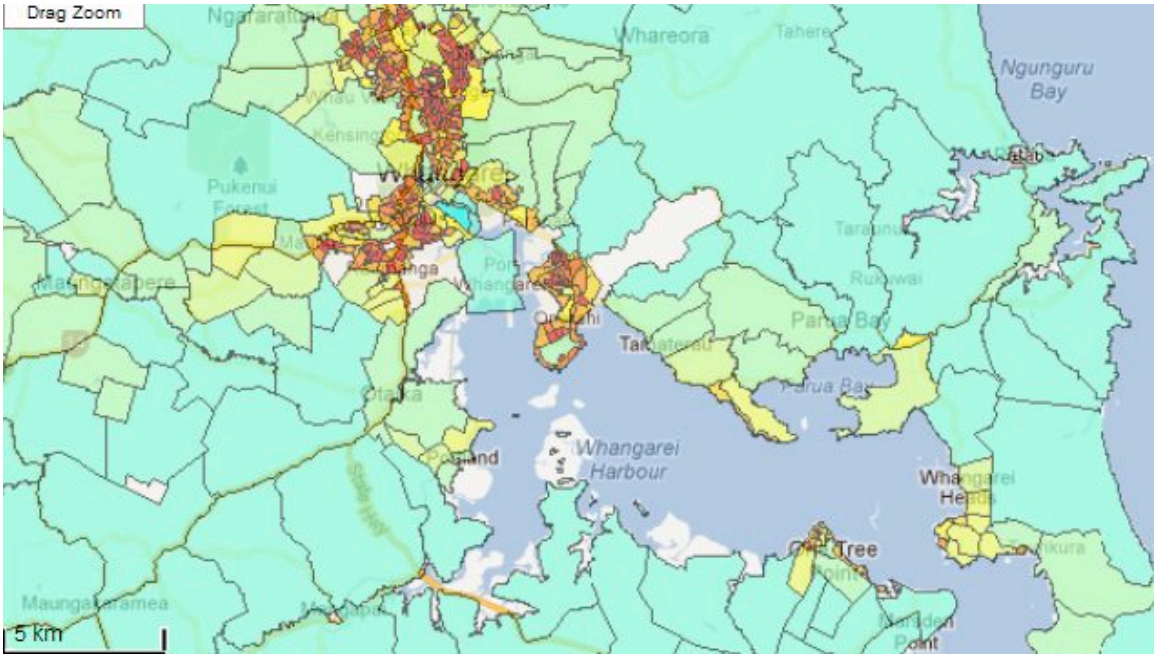

Figure 2.1: Spatial distribution of domestic PM_{10} emissions across Whangarei and Marsden Point airsheds.

3 Airshed modelling

3.1 Model setup and methodology

The Air Pollution Model (TAPM) version 4 was used to examine ground level concentration of PM_{10} for Whangarei and the environs. TAPM is a three-dimensional incompressible, non-hydrostatic, primitive equations model, which uses a terrain-following coordinate system (Hurley, 2002). The meteorological component of the model is supplied with a dataset derived from the Limited Area Prediction System (LAPS) analysis data from the Australian Bureau of Meteorology while the sea surface temperature is derived from Rand's global long term means at a resolution of 100 kilometres, although the prescribed values can be changed. The simulations presented here use four nested grids with a grid spacing of 27, 9, 3 and 1 kilometres, respectively. The meteorological model grid is configured with 50 zonal and meridional grid nodes; the pollution model of TAPM is designed with the same configuration. Default model options – such as soil temperature – were used since local information is scarce.

To predict PM_{10}, the air pollution module of TAPM was used in a tracer mode (with no chemistry). The domestic home heating component was allocated to tracer 1. Since most of the total emissions are from this source, only this one tracer was used to represent emissions. Emissions are configured to be released from an area source matching Whangarei's spatial dimension; emission profile was modified to hourly estimates for the purposes of this study. TAPM was integrated for a 4 month period as specified in Table 3.1. Other information on model setup is summarized in Table 3.1.

Table 3.1: Model Setup.

Meteorological Model Setup				
Simulation period	July and October 2009 January and April 2010			
	Grid-1	Grid-2	Grid-3	Grid-4
Grid spacing(metres)	27000	9000	3000	1000
Grid points	50	50	50	50
Vertical levels	25	25	25	25

The hourly emission rates over Whangarei are shown in Figure 3.1, these emission rates are released by the model for every hour, then using the meteorological module of TAPM, mixing in the atmosphere occurs and ground level concentrations are subsequently calculated. In addition, Carter Holt Harvey and NZ Refining Company's emissions are also represented in the model. Emissions characteristics are shown in table 3.2.

Table 3.2: Stack emission characteristics used for TAPM simulations.

Stack	**Exit Velocity (m/s)**	**Temp (K)**	**Radius (m)**	**Emission Rate (g/s)**
Carter Holt Harvey	13.3	355.5	0.71	0.75
NZRCA	28	473.5	1.3	0.02
NZRC B&C	21.7	484.0	2.05	0.38

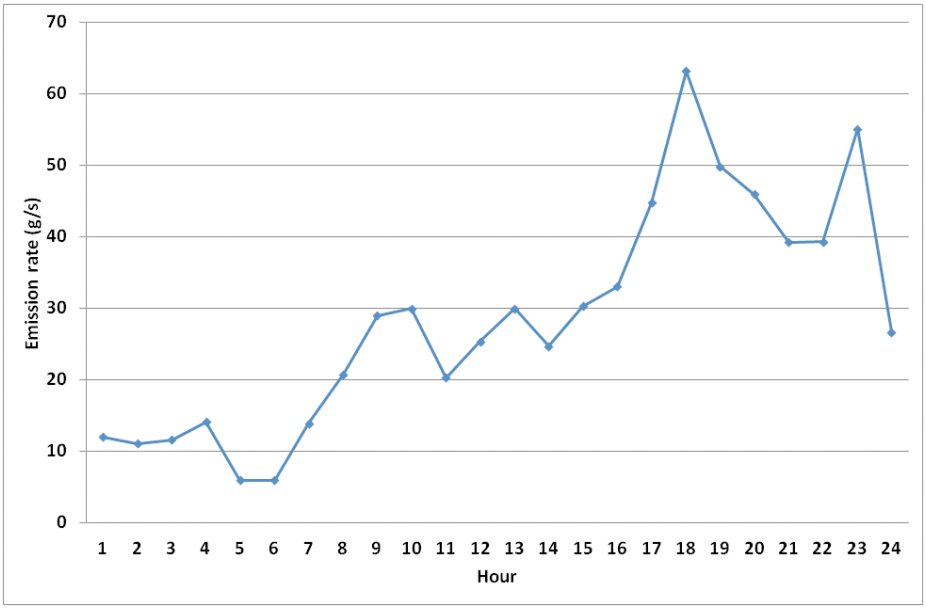

Figure 3.1: Hourly emission profiles used by TAPM for winter months.

3.2 Model Results and Discussion

Whangarei is located on North Island surrounded by relatively complex coastal and mountainous terrain; therefore it should possess highly variable meteorological conditions. Since monitoring data is not available, maps of average, maximum, and spatial statistics of ground level concentration are provided to elucidate the extent of the dispersive capabilities of the airshed. Figure 3.2 shows an example of night-time meteorology and particulate matter dispersion for a typical mid-night over the region. Over sloping terrain, nocturnal drainage flows or katabatic winds usually transport wind and pollutants from higher elevation to lower coastal zones. The figure shows concentration contour plots for particulate matter under such a situation with winds

carrying pollutants off-shore towards the refinery. The emissions from industry do seem to have an impact on the plum from the city increasing the ground level concentrations south of the refineries by 10 µg/m^3 (this is shown by the second peak in plume concentrations over the Marsden airshed (the yellow colour plume). This indicates that in some conditions the two airsheds – Marsden Point and Whangarei – can lead to localized deterioration in air quality in the Marsden Point airshed.

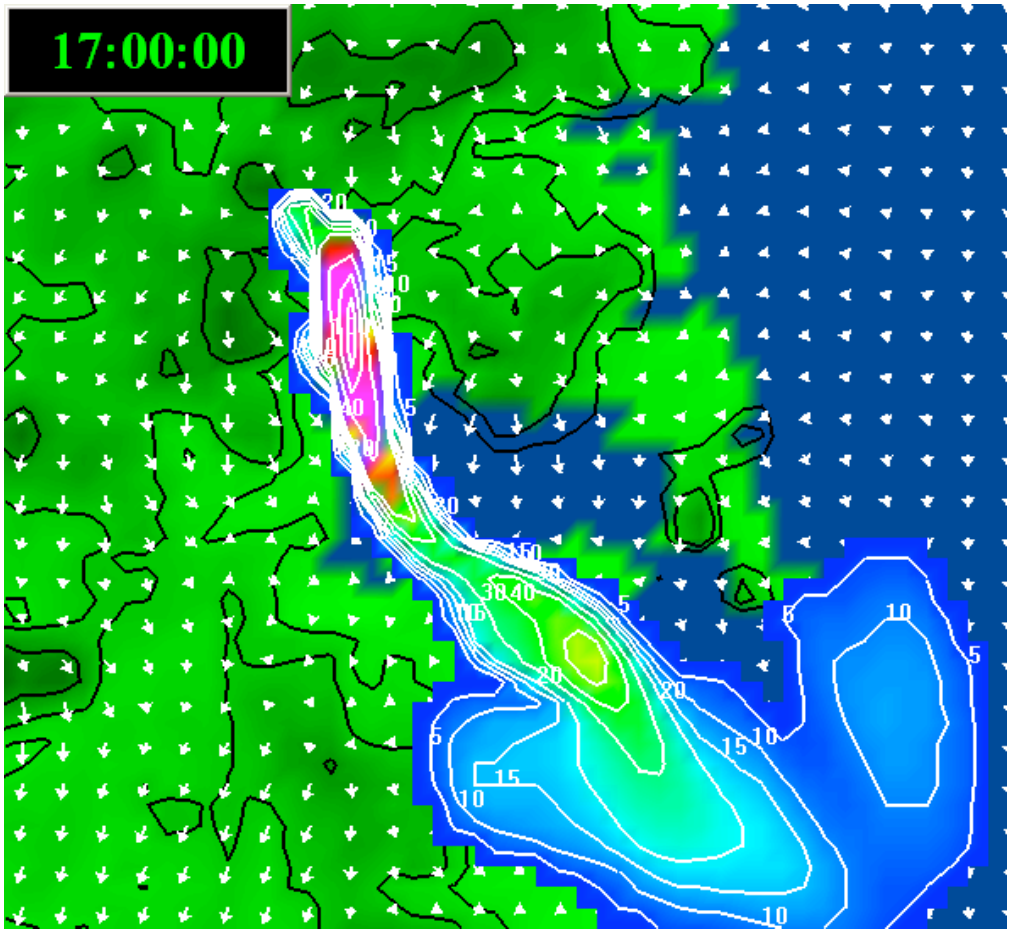

Figure 3.2: Wind vector fields at 10 meters above ground and ground level concentration of PM_{10} for a specific day at mid-night (units for the contour lines are in µg/m^3).

The model also provides estimates of the number of days the NES was exceeded for the specified periods. In April, the meteorology of the region and the emission profile did not cause severe problems for the city; there is only one day when the model predicted a portion of Whangarei would exceed the NES. For the month of July there is an increase in the predicted number of days by just one more day. Notably however, no NES breaches are estimated for areas outside of Whangarei. Moreover, no NES breaches were measured in Whangarei during the period modelled. It is therefore possible that the model provides a slight overestimate of PM_{10} concentrations in the Whangarei and Marsden Point airsheds.

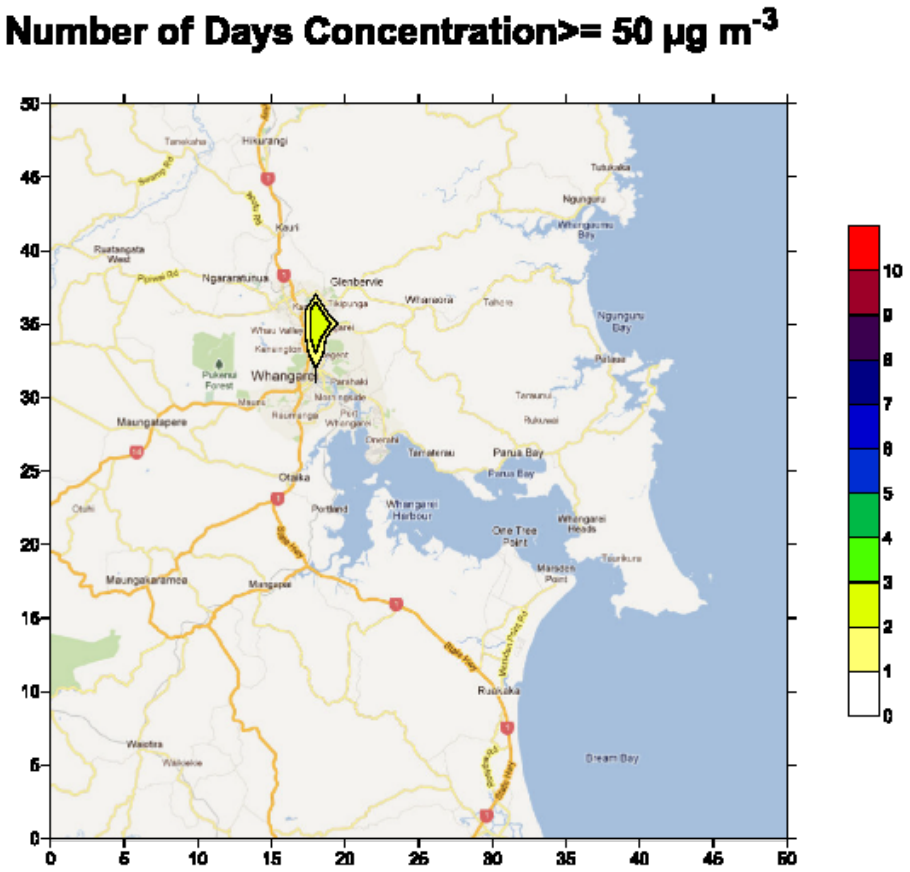

Figure 3.3: Contour plots of number of days the ground level concentrations exceeded NES for April 2010.

Figure 3.4 and 3.5 show contour lines of maximum hourly concentrations reached for the specified simulated periods and the average monthly values respectively. It is obvious that in July the air quality issue is exacerbated somewhat – similar to other urban airsheds in New Zealand where winter pollution is the most severe. The overall pattern is somewhat different for the two months reflecting the change in seasonal meteorology, but as mentioned above, the maximum concentrations are centred on the urban area.

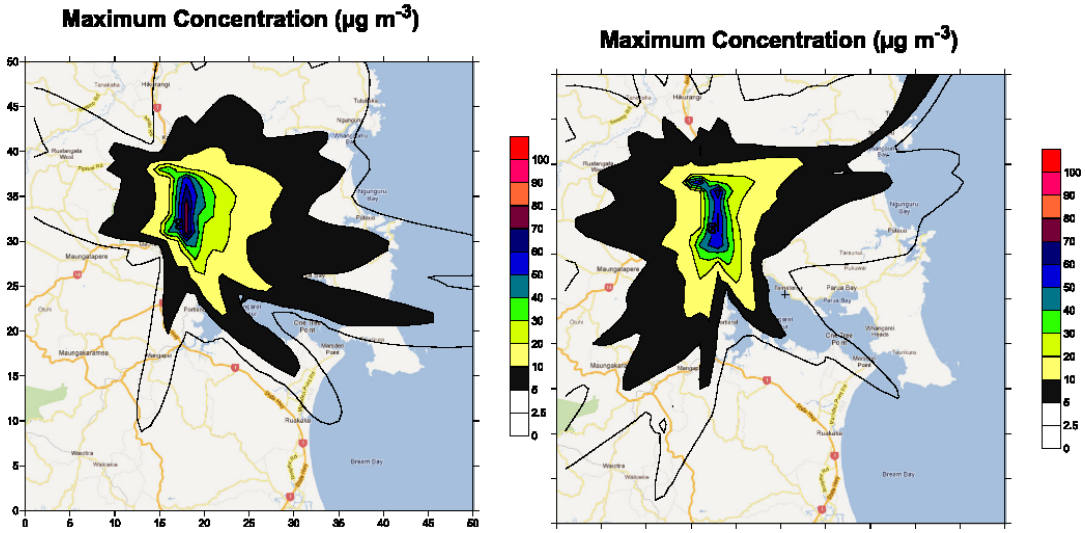

Figure 3.4: Maximum hourly simulated concentrations of PM10 for July 2009 (left panel), and April 2010 (right panel).

The average concentration contour lines show that as far as the average values are concerned, there is only substantial impact in the urban airshed and slightly to the seaward side of the city. This is because of the nocturnal katabatic winds which have the potential to carry particulate matter eastward in a very stable atmosphere. As can be seen from the emission profiles (above), most of the emissions occur at night or in the late evening. The monthly pattern for other months is very similar and is not shown.

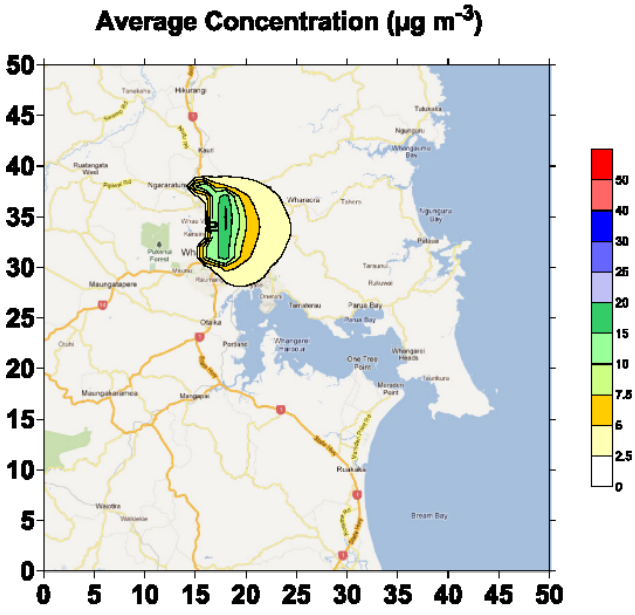

Figure 3.5: Monthly averaged concentrations of PM10 for July 2009.

4 Air quality monitoring site

Modelling suggests that the PM_{10} concentrations arising from anthropogenic sources will generally be low in the Marsden Point airshed but that elevated concentrations may occur on occasion as a result of the Whangarei urban plume and a smaller contribution from Marsden Point industries. The model predicts maximum PM_{10} concentrations of up to 40 µg m^{-3}. This excludes any potential contribution from marine aerosol.

The plume dispersion for the typical mid-night (Figure 3.2) occurs in the direction of Marsden Point with peak on-land concentrations predicted to occur between Ruakaka and Marsden Point Port area. Figure 4.1 indicates the general area where the highest concentrations are predicted. The area is largely rural.

Figure 4.1: Locations where modelling shows PM_{10} concentrations to be elevated

The NES for PM_{10} indicates that monitoring must be carried out where:

- people are exposed
- the ambient standards are most likely to be breached by the greatest margin or with the most frequency, whichever is more likely.

Taking into account both the location of the plume and the "exposure" requirement of the NES it would seem that Ruakaka would be more appropriate for the location of an air quality monitor. This area appears to fall within the plume contours, potentially around the 20 µg m^{-3} contour.

Figure 4.2 shows the area of Ruakaka including a number of open areas suitable for location of an air quality monitoring site.

Figure 4.2: Potential locations for an air quality monitoring site in Ruakaka (grassed areas away from residential dwellings)

It is recommended that the Council look to establish an air quality monitoring site for PM_{10} in Ruakaka. This site is recommended as the nearest residential area to where peak PM_{10} concentrations are estimated to occur as a result of the downwind plume from Whangarei combined with some localised industrial PM_{10}.

5 Conclusions

The purpose of this study was to identify areas within the Marsden Point airshed where PM_{10} concentrations were likely to be highest and to provide a recommendation on the siting of PM_{10} monitor to measure compliance with the NES.

The TAPM dispersion model was used to predict PM_{10} concentrations in Marsden Point and to identify the areas where concentrations were highest.

Air quality modelling of emissions from domestic home heating, motor vehicles, industry and outdoor burning from the Marsden Point airshed and from Whangarei suggests PM_{10} concentrations from anthropogenic sources are unlikely to exceed the NES in Marsden Point, although it is noted that marine aerosol was not included in the modelling and may be a significant contributor. The main influence on anthropogenic concentrations typically is the plume from the Whangarei airshed.

The NES for PM_{10} requires monitoring to be carried out in the location in an airshed where concentrations are likely to be highest and where people are exposed. In the case of Marsden Point the highest PM_{10} concentrations are predicted in the area to the north west of Ruakaka. Because of the rural nature of this area a monitoring site in Ruakaka is recommended to ensure monitoring is carried out in a location where people are exposed.

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