

# Rotorua Air Emissions Inventory 2005

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E mahi ngatahi e pai ake ai te taiao*



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Cover Photo: Source – RDAM 2003 plus LIDAR elevation layer



## Table of Abbreviations

|                        |  |
|------------------------|--|
| AP42.....              | Document of emission factors published by the USEPA's Emission Factor and Inventory Group. |
| CAU .....              | Census Area Unit.  |
| CO .....               | Carbon monoxide.   |
| GNS.....               | GNS Science Limited (New Zealand Crown Research Institute).                                |
| HCV .....              | Heavy commercial vehicle.  |
| LAMA .....             | Local Air Management Area.   |
| LIDAR.....             | Light Detection and Ranging.   |
| LCV.....               | Light commercial vehicle.  |
| LTO.....               | Landing and takeoff (of aircraft).   |
| MfE .....              | Ministry for the Environment.  |
| NERMN.....             | Natural Environment Regional Monitoring Network.   |
| NIWA .....             | National Institute of Water and Atmospheric Research, New Zealand.                         |
| NO <sub>x</sub> .....  | Oxides of nitrogen.  |
| NPI EET.....           | Australian National Pollution Inventory Emission Estimation Technique.                     |
| NZTER.....             | New Zealand Transport Emission Rate database.  |
| PM .....               | Particulate matter.  |
| PM <sub>10</sub> ..... | Particulate matter less than 10 microns.   |
| RAMM.....              | Road Asset Management Model (Land Transport New Zealand).                                  |
| RDAM .....             | Regional Digital Aerial Mosaic.  |
| SO <sub>2</sub> .....  | Sulphur dioxide.   |
| USEPA.....             | United States Environmental Protection Agency.   |
| VKT.....               | Vehicle kilometres travelled.  |
| VOC .....              | Volatile organic compounds.  |



## Executive Summary

The Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004 has set a limit for PM<sub>10</sub> in air. In areas of our region where the limit for PM<sub>10</sub> is already being exceeded Environment Bay of Plenty is required to take action to ensure the limit can be complied with by 1 September 2013.

At this time the only area identified as exceeding the PM<sub>10</sub> limit is urban Rotorua. It is now the responsibility of Environment Bay of Plenty to progress matters to ensure PM<sub>10</sub> levels are reduced over the next seven years. For the Rotorua situation, this will mean establishing an Action Plan to achieve the required particulate levels.

This report describes an air emission inventory with a specific focus on the Rotorua Local Air Management Area (LAMA). An air emissions inventory is used to determine the contribution of PM<sub>10</sub> emissions (and other contaminants) from specific sources or groups of sources.

Ambient air quality monitoring within the LAMA shows that during the winter period exceedences of the National Environmental Standard for PM<sub>10</sub> has been recorded (on 25 occasions for 2006). Hence PM<sub>10</sub> has been the primary focus of this emission inventory. Ambient monitoring of the other contaminants (CO, SO<sub>2</sub>, NO<sub>x</sub> and VOC's) shows no exceedence of their respective standards.

The results from the inventory show that during the critical (in relation to the number of measured PM<sub>10</sub> exceedences) time of the year, domestic sources are the leading producer of PM<sub>10</sub> emissions (63%) for the LAMA.

Spatial distribution patterns for domestic emissions show higher concentrations are estimated in the Western Heights, Selwyn Heights, Koutu, Pukehangi North, Pukehangi South, Mangakakihi, Fordlands, Utuhina, Victoria and Glenholme West census area units in the western section of the LAMA. In the eastern area the trend is not as strong with only smaller pockets exhibiting elevated PM<sub>10</sub> results (Lynmore, Owhata and Holdens Bay). These are primarily densely developed residential suburbs with a reliance on older style wood burner technology for heating.

Industry is the second major contributor to PM<sub>10</sub> emissions within the LAMA (24% of the estimated emissions during the critical time of the year). Their impact on areas where PM<sub>10</sub> exceedences have been recorded is likely to be minimal.

Transport sources are only a moderate contributor to the PM<sub>10</sub> profile. During winter time their contribution is estimated at 12%.

How PM<sub>10</sub> behaves once emitted from the sources of interest is beyond the scope of this report and will be addressed in the third stage (airshed dispersion modelling) of this LAMA investigation.



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## Chapter 1: Introduction

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### 1.1 Purpose

The Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004 has set a limit for PM<sub>10</sub> in air. In areas of our region where the limit for PM<sub>10</sub> is already being exceeded Environment Bay of Plenty is required to take action to ensure the limit can be complied with by 1 September 2013.

At this time the only area identified as exceeding the PM<sub>10</sub> limit is urban Rotorua. An airshed has been determined for Rotorua. It is now the responsibility of Environment Bay of Plenty to progress matters to ensure PM<sub>10</sub> levels are reduced over the next seven years. For the Rotorua situation this will mean establishing an Action Plan to achieve the required particulate levels.

This report describes an air emission inventory with a specific focus on the Rotorua Local Air Management Area (LAMA) (Figure 1). An air emissions inventory is used to determine the contribution of PM<sub>10</sub> emissions (and other contaminants) from specific sources or groups of sources. This inventory also provides several key inputs required for an airshed modelling study, which is currently being undertaken by Endpoint Ltd.

This inventory builds on previous region wide inventories undertaken by Opus International Consultants (1997) and Sinclair Knight Merz (2003).

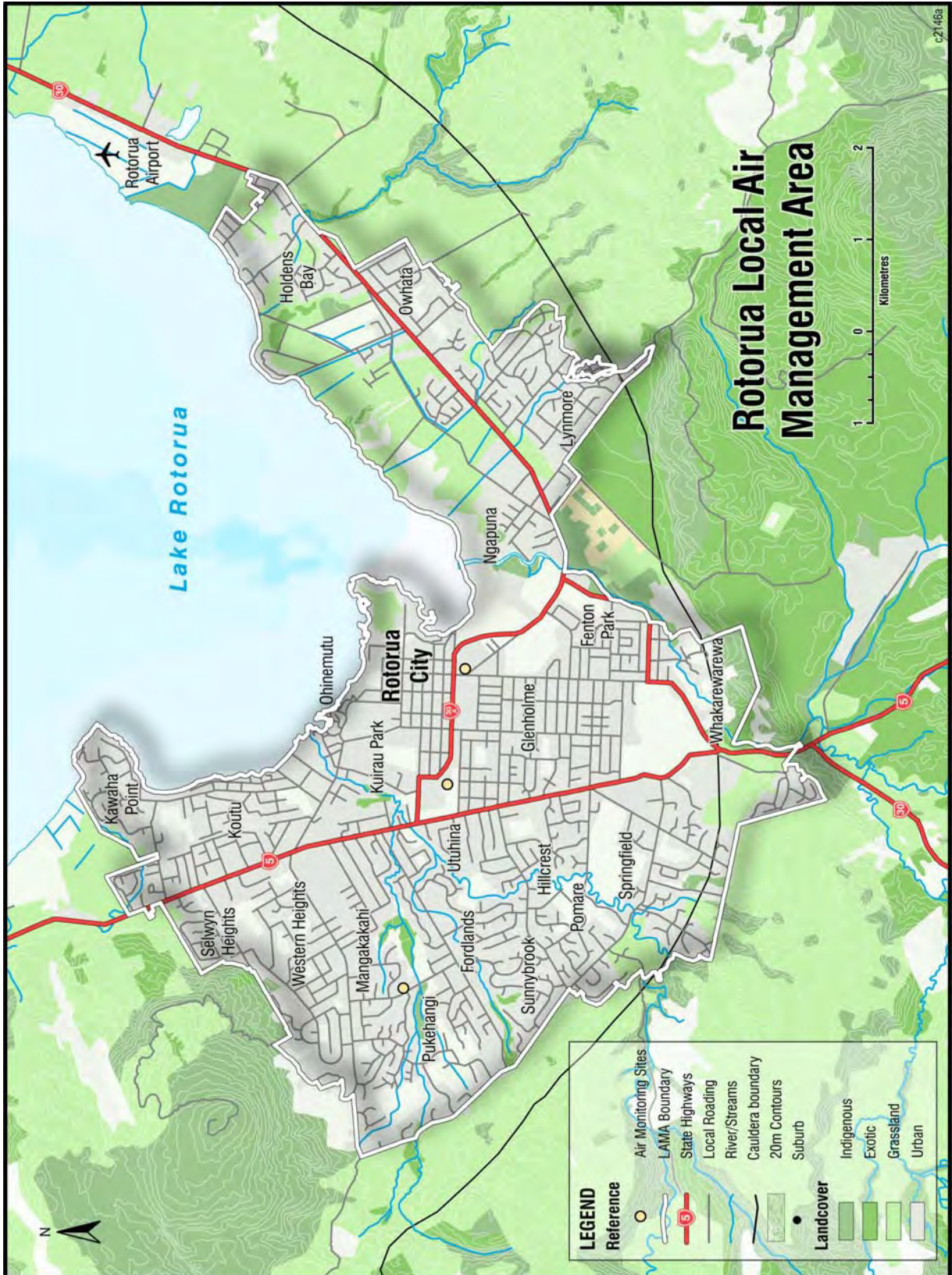


Figure 1 Rotorua Local Air Management Area (New Zealand Gazette, 2005)

## 1.1 Scope

The reference year for this inventory is 2005. When this information is not available the nearest information to 2005 has been used and referenced accordingly.

This inventory has been compiled by source type and the spatial distribution is presented on the basis LAMA.

This inventory assesses the contaminants shown in Table 1. PM<sub>10</sub> is of greatest interest due to already measured exceedences of the standard. Where possible, calculations are undertaken for the remaining contaminants.

Table 1 Contaminants for the Rotorua LAMA inventory 2005

| Contaminant type                          |
|---|
| Particulate matter (PM <sub>10</sub> )    |
| Carbon monoxide (CO)                      |
| Sulphur dioxide (SO <sub>2</sub> )        |
| Oxides of nitrogen (NO <sub>x</sub> )     |
| Selected volatile organic compounds (VOC) |

Software developments and the improvement in the detail of activity data has meant that this inventory has used different estimation methodologies and included some different sources when compared with the last regional inventory undertaken for 2001.

## 1.2 Characteristics of the Rotorua Area

In order to better understand the geographical situation and meteorological factors affecting the LAMA and ultimately the distribution of contaminants, the following section has been included. Further investigation of these important interactions will be undertaken in more detail in the accompanying airshed modelling investigation undertaken by Endpoint Limited.

### 1.2.1 Geophysical

The Rotorua LAMA is located in the southern area of the Rotorua Basin (Figure 2). The basin was formed from the caldera generated by ground collapse following the eruption of the Mamaku Ignimbrite formation, centred on the present day Ngongotaha. The dimensions of the basin are approximately 12 km wide (east/west) and 17 km long (north/south). The elevation of the LAMA can be described as a tilting plane with the western margin located at the base of Mt Ngongotaha with an elevation of 350 m (Moturiki Datum) sloping in a NE direction to the lake edge with an elevation of 280 m. The south east boundary is at 320 m.

A unique ground temperature situation exists within the LAMA which ultimately affects boundary layer meteorology. The influence of geothermal activity causes elevated ground temperature within central parts of the LAMA. This pattern is highlighted in Figure 3, which is based on a 1967 survey (pers. comms. Brad Scott) and a second map based on data collected by Finlayson in 1990 (Finlayson, 1992).

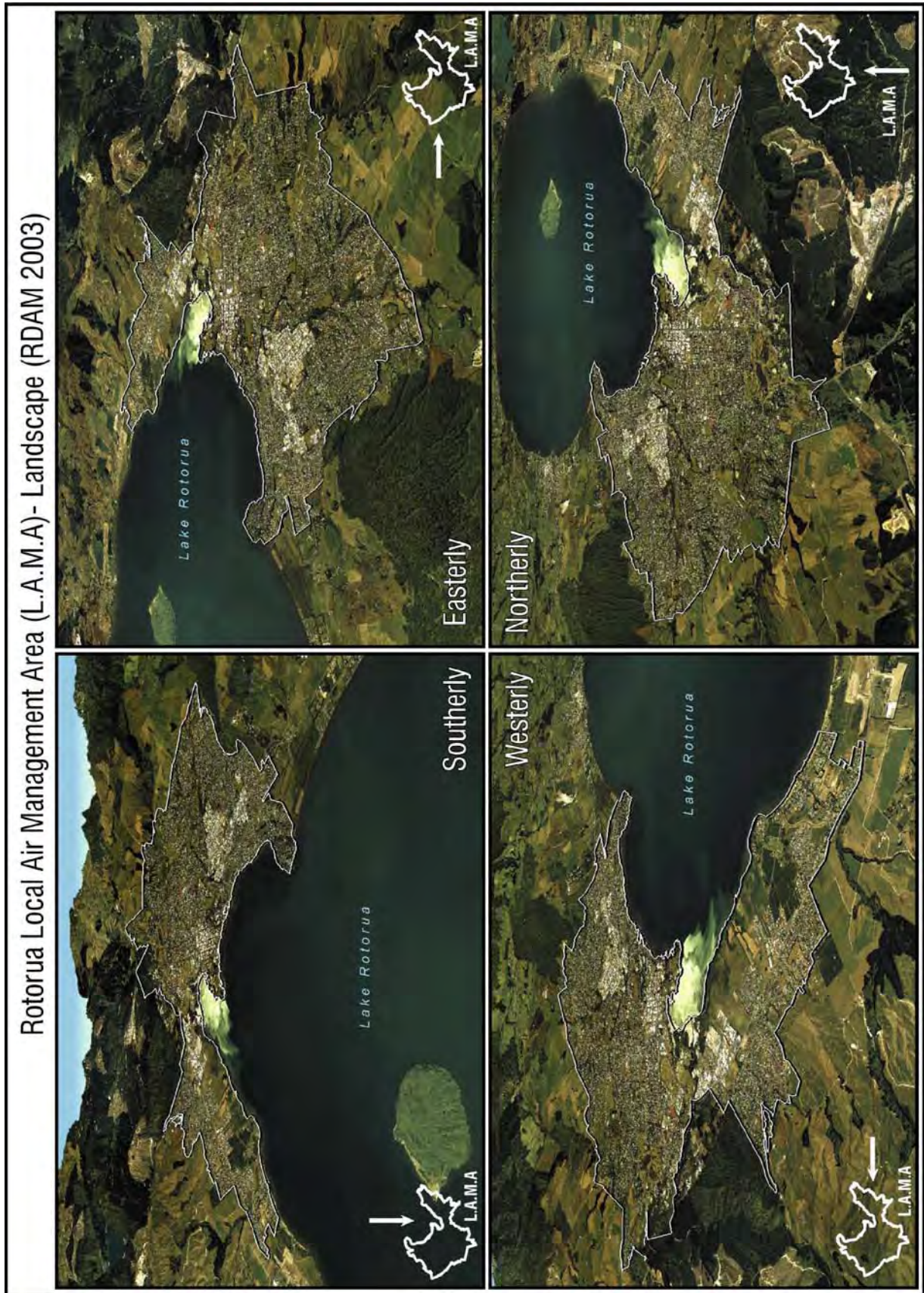


Figure 2 Rotorua Landscape (RDAM plus LIDAR)

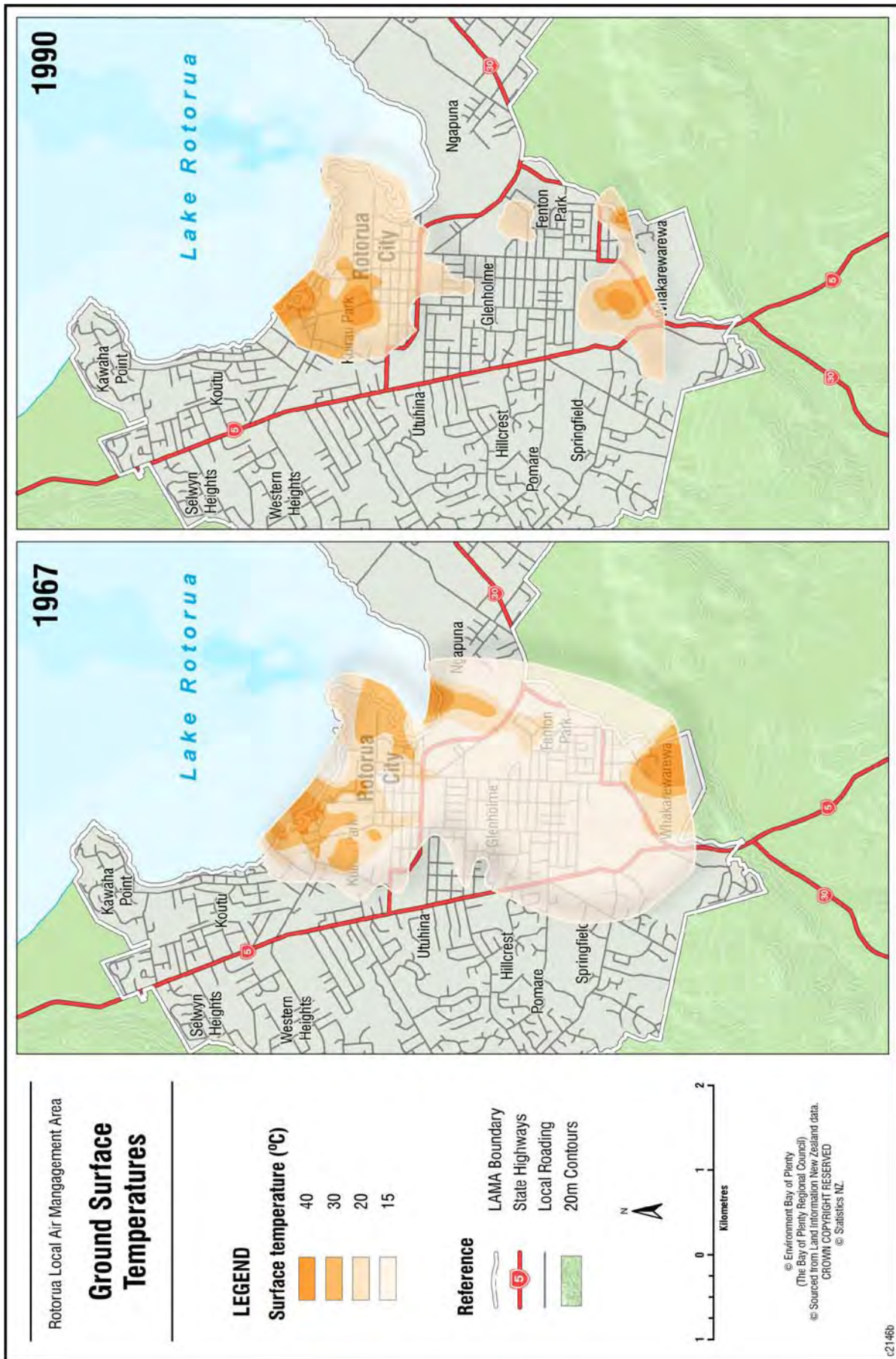


Figure 3 Ground surface temperatures



Lake Rotorua also affects the local meteorology. The lake is relatively flat bottomed with its deepest contour at around 26 metres, west of Mokoia Island. At around 80 km<sup>2</sup>, Lake Rotorua has the largest surface area of all the Rotorua Lakes and it also has the largest catchment area at around 508 km<sup>2</sup>. Surface water temperature variation is shown in Figure 4. The lake/land temperature relationship has the effect of causing elevated temperature inversions due to the advection of warmer lake air (during light northerly winds) across the shoreline to a cooler land area (showing a structure similar to a warm front weather system) (modified from Oke, 1987).

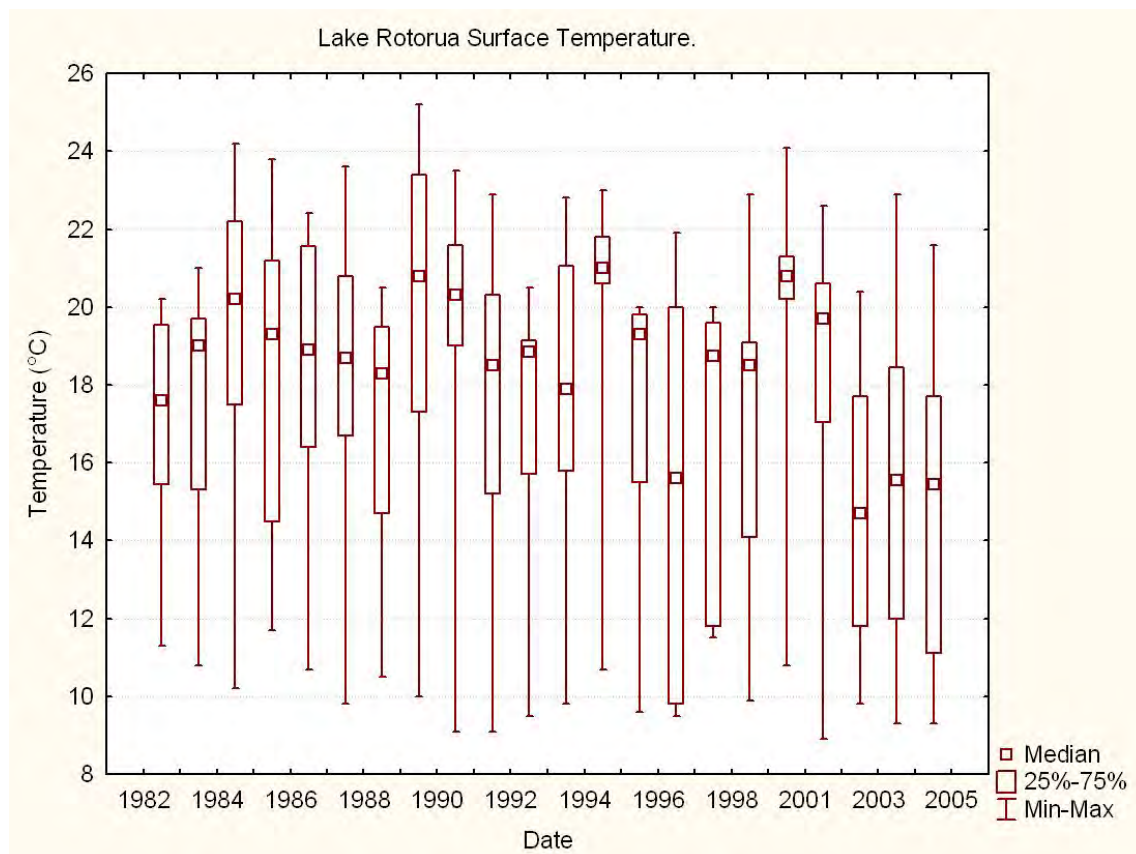


Figure 4 Lake Rotorua surface temperatures (Source Environment Bay of Plenty database)

### 1.2.2 Meteorology

The Rotorua LAMA is sheltered by high country to the south and the immediate caldera basin; it has less wind than many other parts of New Zealand (NIWA, 2006). Being inland, a wide range of temperature is experienced (Figure 5). Warm, dry and settled weather predominates during summer. Typical summer daytime maximum air temperatures range from 21°C to 26°C, rarely exceeding 30°C. Winters are cool and this is normally the most unsettled time of the year. Typical winter daytime maximum air temperatures range from 10°C to 14°C (Figure 6). Frosts occur in clear, calm conditions in winter along with the frequent development of temperature inversions<sup>1</sup>, forming within the basin. Sunshine hours average 2100. Southwesterlies prevail. Lake breezes often occur in Rotorua on warm summer days.

<sup>1</sup> Under certain conditions, the normal vertical temperature gradient is inverted such that the air is colder near the ground surface. This can occur when, for example, a warmer, less dense air mass moves over a cooler, more dense air mass.

### Climate Summary 1971 - 2000

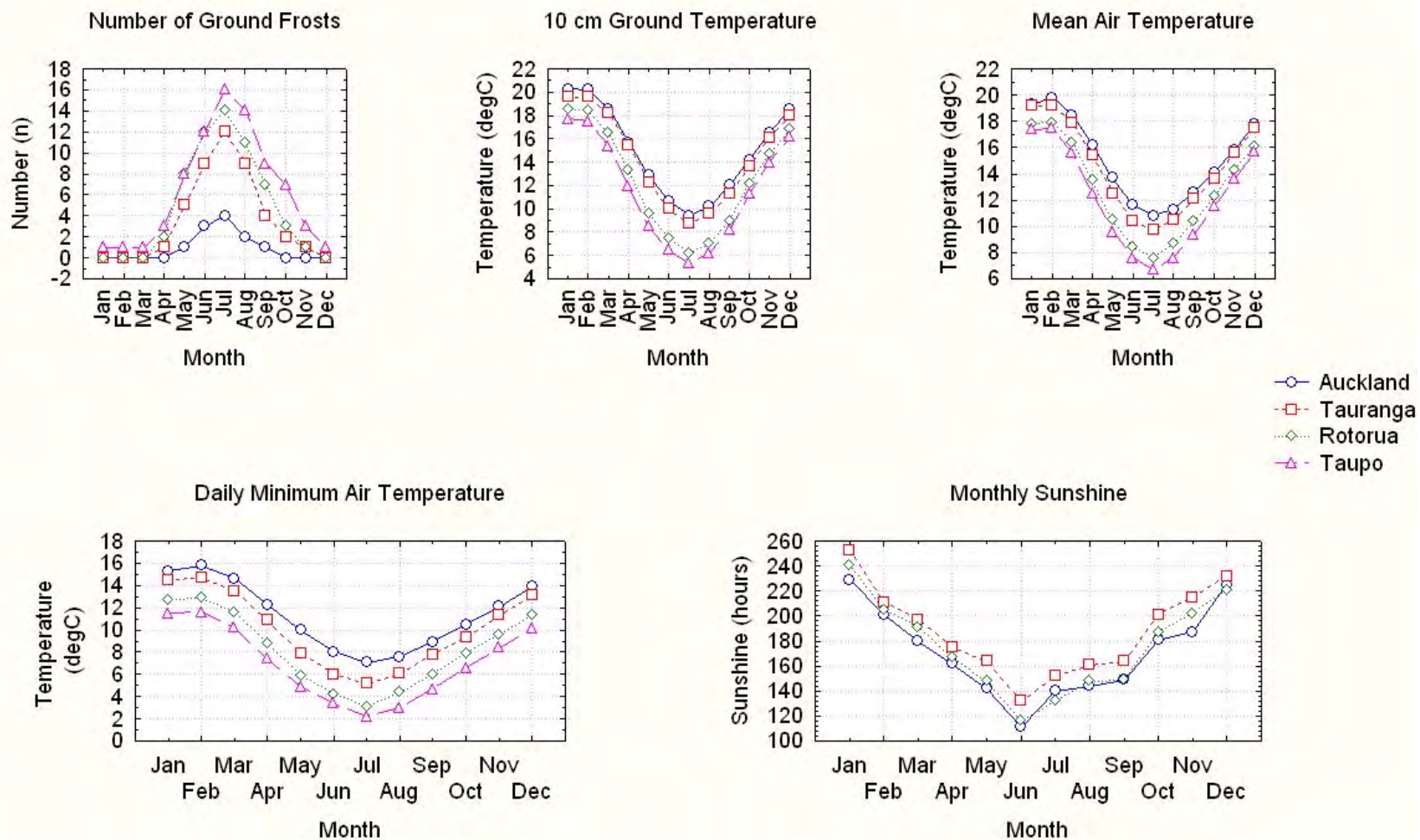


Figure 5 Climate summary for Rotorua Aero (and comparison sites) – 1971-2000 (Source NIWA CLIDB)

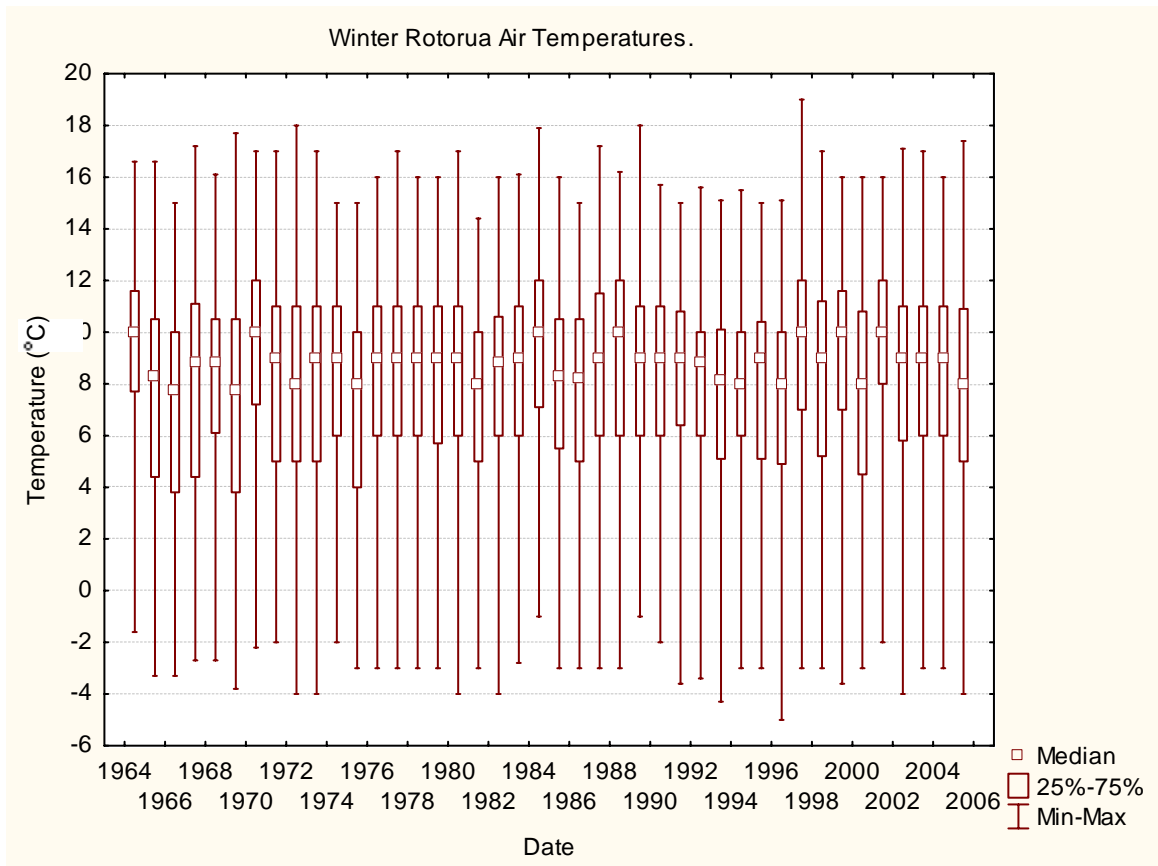
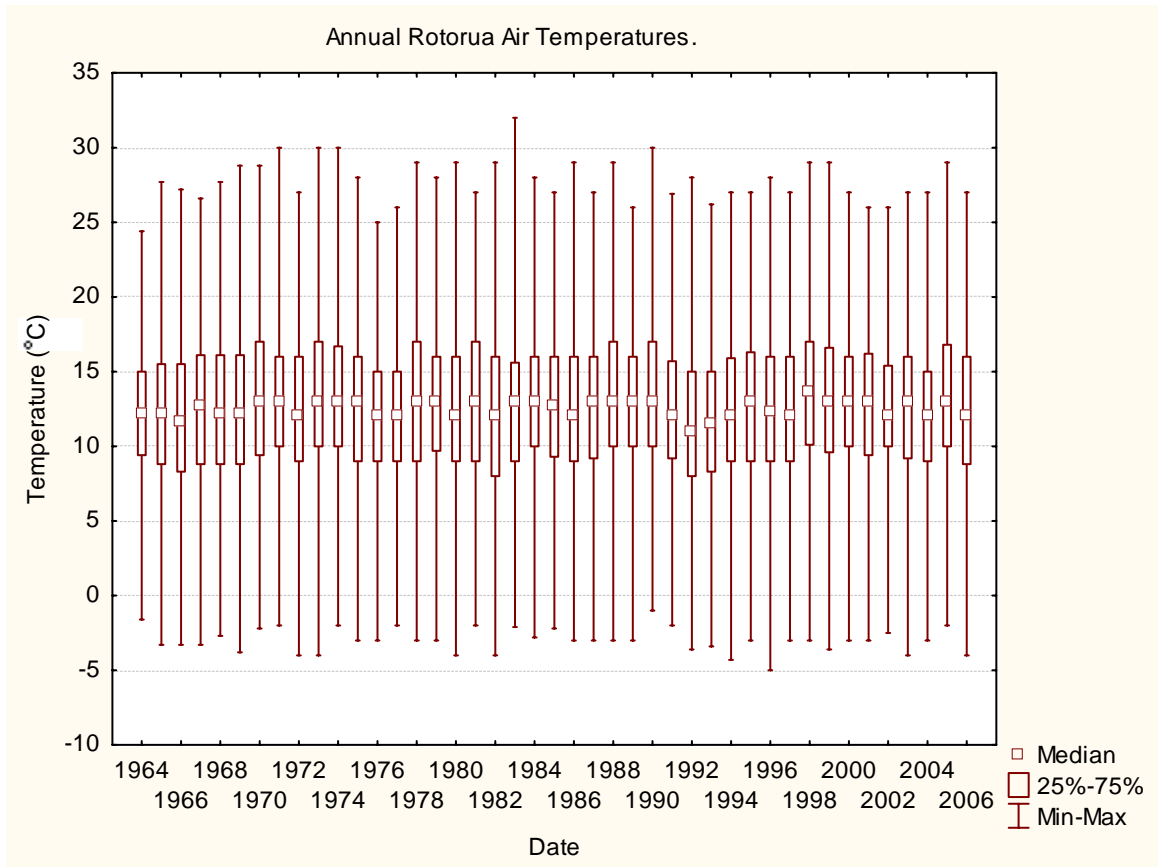


Figure 6 Air temperature summaries recorded at Rotorua Aero (source: NIWA Climate Database)

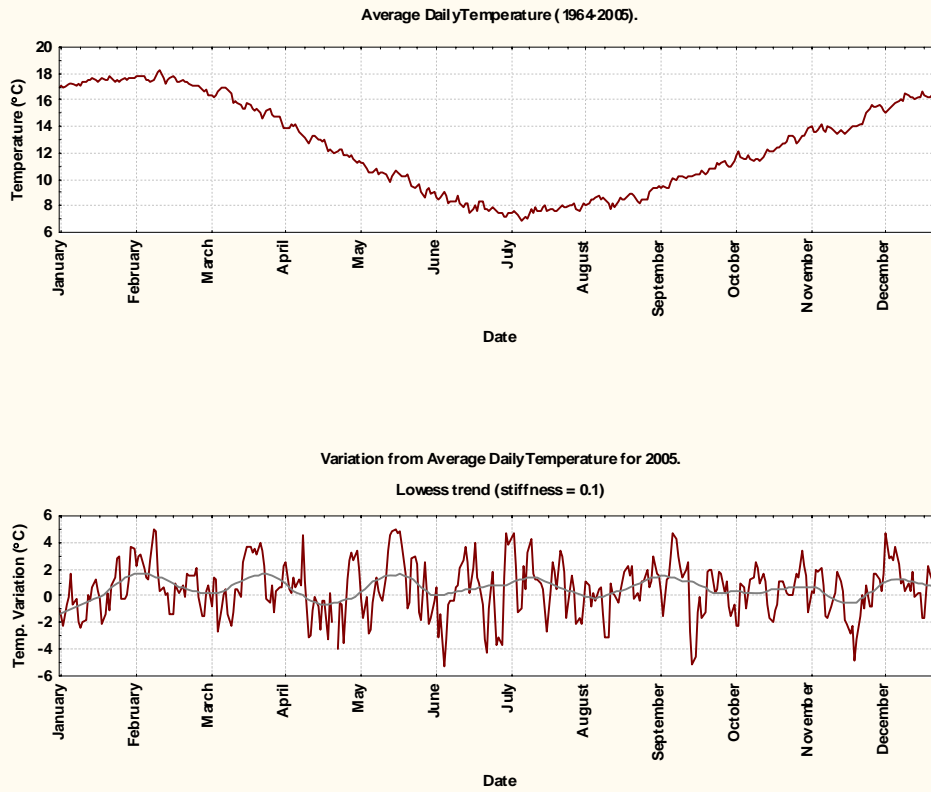
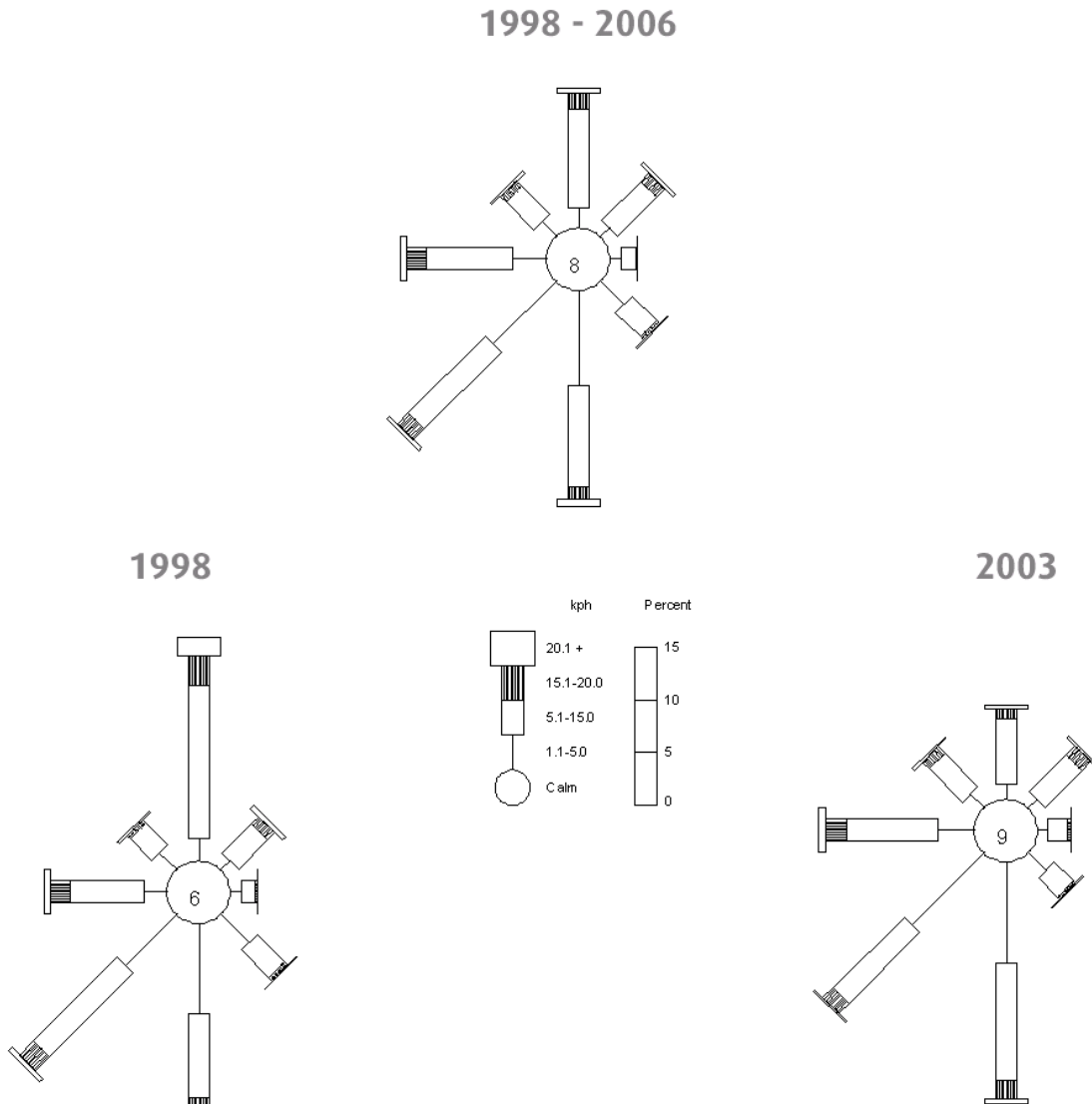


Figure 7 Annual air temperature time series for 2005 and the variation from the long term mean (1971-2000) – (Source NIWA CLIDB)

Figure 7 shows the temperature profile for the Rotorua basin for 2005 along with the variation of this time series from the long term mean. Trend analysis shows the average daily temperature to be above average for nearly the entirety of 2005. A closer investigation of June shows several strongly negative periods (up to -5°C variation) which would probably result in periods of increased domestic emissions.



**Figure 8** Wind record from the Pererika Street meteorological site (1998 was deemed a La Nina year and 2003 an El Nino period) – (Source Environment Bay of Plenty database)

The wind climate is also important when discussing air quality. Detailed analysis will be undertaken in the accompanying modelling investigation, but quick analysis of a period of record from the Pererika Street meteorological site shows the effect of medium term climatic patterns (i.e. Southern Oscillation Index) (Figure 8). The La Nina period shows expected significant northerly contributions to the measured wind field. This will change the natural  $PM_{10}$  composition (increase in sea borne particulate) impacting on the LAMA. Calm conditions contribute less than 10% at this site. The shorter period of record from the new Edmund Road site (located in the Mangakakahi suburb within the LAMA) shows the period of calm to be several times higher than the more exposed Pererika site. The higher calm period at this new site highlights reduced natural dispersion capabilities and the dominating effect of local topography.

### 1.3.3 Population and Dwellings

Population figures from the last three censuses are reported in Table 2. For the last five years there has been a population increase of 2.7% for the Rotorua LAMA.

*Table 2 Census night resident population counts (source: Statistics New Zealand)*

| Area Unit                        | 1996 Census Night Population Count | 2001 Census Night Population Count | 2006 Census Night Population Count (Provisional) |
|----------------------------------|------------------------------------|------------------------------------|--|
| 538601 Ngongotaha North          | 2,934                              | 2,934                              | 2,870  |
| 538602 Ngongotaha South          | 1,095                              | 1,140                              | 1,140  |
| 538721 Poets Corner              | 273                                | 255                                | 270  |
| 538722 Ngapuna                   | 672                                | 588                                | 540  |
| 538731 Owhata South              | 480                                | 504                                | 580  |
| 538732 Lynmore                   | 2,733                              | 2,991                              | 3,120  |
| 538741 Owhata West               | 3,249                              | 3,207                              | 3,750  |
| 538742 Owhata East               | 2,079                              | 2,097                              | 2,130  |
| 539000 Selwyn Heights            | 1,170                              | 1,176                              | 1,100  |
| 539100 Western Heights           | 3,759                              | 3,576                              | 3,730  |
| 539200 Fairy Springs             | 2,067                              | 2,022                              | 2,000  |
| 539310 Pukehangi North           | 2,244                              | 2,019                              | 2,180  |
| 539320 Pukehangi South           | 1,911                              | 2,457                              | 2,770  |
| 539400 Mangakakahi               | 2,427                              | 2,325                              | 2,480  |
| 539500 Sunnybrook                | 1,905                              | 1,824                              | 1,910  |
| 539600 Fordlands                 | 2,031                              | 1,959                              | 1,890  |
| 539700 Utuhina                   | 1,377                              | 1,365                              | 1,430  |
| 539800 Pomare                    | 1,398                              | 1,416                              | 1,460  |
| 539900 Hillcrest                 | 1,701                              | 1,563                              | 1,580  |
| 540000 Springfield               | 4,188                              | 4,389                              | 4,340  |
| 540100 Kawaha Point              | 1,440                              | 1,617                              | 1,630  |
| 540200 Koutu                     | 2,370                              | 2,118                              | 2,110  |
| 540300 Ohinemutu                 | 306                                | 291                                | 310  |
| 540410 Kuirau                    | 3,168                              | 3,030                              | 2,850  |
| 540420 Victoria                  | 2,427                              | 2,112                              | 2,010  |
| 540510 Glenholme East            | 2,583                              | 2,490                              | 2,490  |
| 540520 Glenholme West            | 2,247                              | 2,217                              | 2,250  |
| 540600 Fenton                    | 2,103                              | 2,061                              | 2,230  |
| 540700 Whaka                     | 591                                | 561                                | 690  |
| <b>LAMA Total</b>                | <b>56,928</b>                      | <b>56,304</b>                      | <b>57,840</b>                                    |
| <b>LAMA Population Gain/Loss</b> |                                    | <b>-624</b>                        | <b>1,536</b>                                     |
| <b>LAMA Percentage change</b>    |                                    | <b>-1.10%</b>                      | <b>2.73%</b>                                     |

The number of dwellings has increased by 4.4% from 2001 to 2006 (Statistics New Zealand, 2007).

By 2013 the resident population of the Rotorua District is projected to increase modestly by 5.8% (Environment Bay of Plenty, 2002).

Increases in population are theoretically positively correlated with an increase in emissions (e.g. greater traffic volumes, greater domestic heating demands), however the significance of the increase can be offset by improvements in technology, although due to financial constraints the new technology usage may not be as dominant as the population effect.

### 1.3.4 Deprivation Index

The prosperity of the population can also be linked with emissions. Anecdotal evidence suggests lower socio-economic groups favour wood burning as a means of heating as the fuel can often be sourced more cheaply than other heating methods.

This section is based on the index of deprivation, NZDep01, which is an academically rigorous integration of nine variables from the 2001 census, reflecting eight dimensions of deprivation. The index was developed by researchers at the Health Services Research Centre, a joint venture between the Wellington School of Medicine, University of Otago, and the Institute of Political Studies, Victoria University of Wellington.

While this index (NZDep01) was developed from a health sector perspective for three main purposes — resource allocation, research and advocacy — it has application in other sectors. For example, it can be used as a basis for development of funding formulae and community advocacy. In environmental resource management, the index can assist the assessment of the social and economic well-being of people and communities, an element of sustainable management under the Resource Management Act 1991.

The index of deprivation is listed as 1 being least deprived and 10 being most deprived. The index is calculated from income, employment, communication, transport, support, qualifications, home ownership and living space parameters.

The Rotorua LAMA has a highly polarised population with proportionally more people at the outer Index of Deprivation levels 1, 8, 9 and 10 and fewer people in the middle levels 3, 4, 5 and 6 than the New Zealand average (Figure 9).

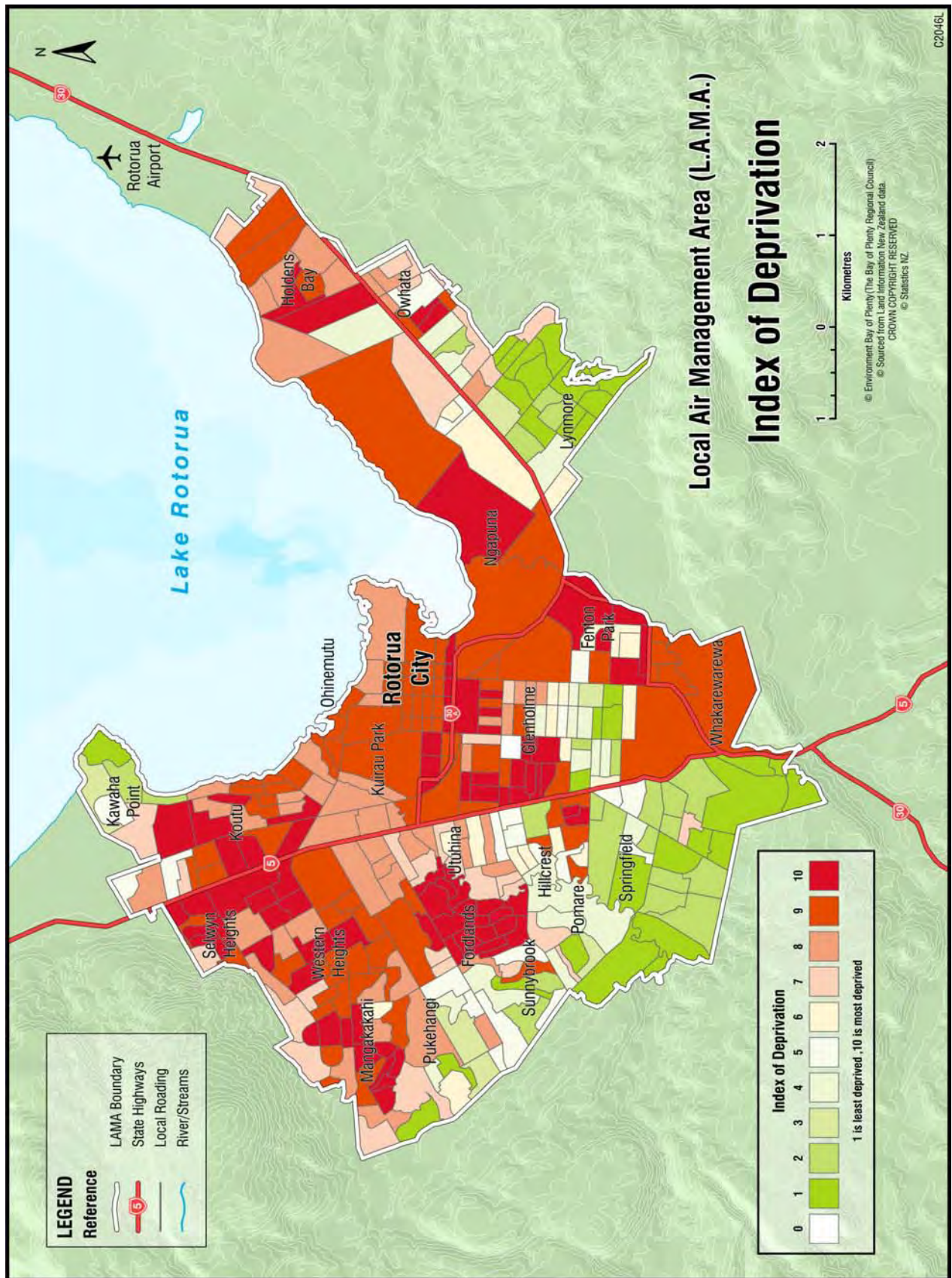


Figure 9 Index of Deprivation for the Rotorua LAMA (Source Statistics New Zealand)





## Chapter 2: Air Contaminants Sources and Effects

The contaminants (Table 3) included in this emission inventory are particulate matter, carbon monoxide, sulphur dioxide, the oxides of nitrogen, and VOC's. These are commonly referred to as the primary or indicator air pollutants, and are produced by a variety of sources throughout the LAMA.

Table 3 Contaminants determined in this report

| Contaminant                           | Comment  |
|---------------------------------------|--|
| Particulate matter (PM)               | PM includes dust, smoke, aerosols, haze and fallout. Airborne PM arises from many sources including combustion processes (especially coal and wood burning), motor vehicle emissions, vehicle movements on sealed and unsealed roads, road and building construction, as well as numerous industrial operations. Natural sources of PM include volcanoes, sea spray, plant and animal matter (e.g. pollens and fungal spores) and wind blown dust and dirt. PM can cause nuisance effects when it settles on surfaces such as cars, window ledges, washing, etc. |
| PM <sub>10</sub>                      | Particles below 10 microns or PM <sub>10</sub> can affect visual air quality and can have respiratory effects because they are small enough to be inhaled. PM <sub>10</sub> has been of increasing concern with no threshold level for effects known because it has been shown to endanger human health. PM <sub>10</sub> can be estimated relatively easily with emission factors and particle size distribution data.  |
| Carbon Monoxide (CO)                  | CO is formed as a product of incomplete combustion in burning fossil fuels. The main source in Rotorua is motor vehicle emissions, and elevated levels are mainly found in areas of significant traffic congestion. Other sources can include domestic fires, and industrial combustion. CO is a poisonous gas, which acts by displacing oxygen from the blood. Prolonged exposure at moderate levels can lead to symptoms such as headaches and dizziness. Chronic exposure at lower levels has been linked to an increased incidence of heart disease.         |
| Sulphur dioxide<br>(SO <sub>2</sub> ) | SO <sub>2</sub> is mainly produced by the burning of fossil fuels. The primary sources are coal (<0.5 – 3.0% sulphur), fuel oil (0.5 - 3.5% sulphur) and diesel (0.3% sulphur). There is no significant sulphur in natural gas, petrol, or in wood. A number of industrial processes also emit sulphur dioxide, while volcanoes are a major natural source. The primary effect of SO <sub>2</sub> is as a respiratory irritant, although on a global scale it is also of concern in the production of acid rain and acidification of soils.                      |

| Contaminant                           | Comment  |
|---------------------------------------|--|
| Oxides of Nitrogen (NO <sub>x</sub> ) | NO <sub>x</sub> describes nitric oxide (NO) and nitrogen dioxide (NO <sub>2</sub> ) which are formed in combustion processes by oxidation of the nitrogen present in combustion air. Nitric oxide is the primary product, which is then oxidised to NO <sub>2</sub> in ambient air. Motor vehicles are the major source of NO <sub>x</sub> in most parts of New Zealand. Large combustion sources may be significant localised sources. The main health effects are due to NO <sub>2</sub> , which is a respiratory irritant. In major urban areas (e.g. Los Angeles) both gases are a concern as precursors for photochemical smog, produced from NO <sub>x</sub> reacting with hydrocarbons under the influence of sunlight. |
| Volatile Organic Compounds (VOC's)    | Priority hazardous air contaminants have been selected for airshed management in the updated New Zealand Ambient Air Quality Guidelines (MfE, 2002). Emission factors are currently being developed for these contaminants, in particular, for vehicles by the Ministry of Transport. Some emission factors for these pollutants are available from Australia and USA.   |

## Chapter 3: Methodology and Data Sources

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### 3.1 Data Collection Criteria

The various sources selected for the inventory represent the most significant sources in the LAMA, encompassing: transport, industrial, residential and commercial.

### 3.2 Data Sources

#### 3.2.1 Industrial

Assessing emissions from industry (Figure 10) involves the collection of data relating to the process, referred to as activity data, and the application of emission factors to these data. The activity data required for industry depends on the type of discharge. The types of activity data required for different industrial discharges are contained in Appendix 1.

Industrial emissions sources include wood, diesel, coal, and gas combustion.

A combination approach has been used for this inventory, for PM<sub>10</sub>, hours of operation multiplied by consent discharge limit has been used. For other contaminants fuel consumed multiplied by the appropriate emission factor was used.

One limitation with using data from resource consent files is that in some instances data is limited to the maximum allowable fuel or material used. If this data is to be used, assumptions are required as to what proportion of the maximum allowed is actually used. For this inventory the maximum consented discharge limit has been used because our main interest is in the worst-case scenario.

(NB. For convenience, school boilers are also shown in Figure 10, although these emissions are treated as a sub-group of domestic heating sources in the discussion of results).



Figure 10 Industrial and school discharges (Source Environment Bay of Plenty database)

### 3.2.2 Transport

Calculations for PM, CO, NO<sub>x</sub> and VOC's are included for this source. SO<sub>2</sub> has been omitted as the appropriate emission factors were not available for use at a neighbourhood level. A simplistic description of the emission process for this pollutant is – sulphur in equals sulphur out. This calculation is much easier to determine on a regional scale on the basis of total fuel consumption. On the neighbourhood scale which is being used in this report, an unnecessary level of complexity would need to be added. Central government initiatives are resulting in a reduction of sulphur levels in fuel, which will see a corresponding reduction in SO<sub>2</sub>. NERMN monitoring for SO<sub>2</sub> elsewhere in the region shows that levels are only elevated in areas in proximity to specific industrial processes.

#### (a) Urban Roads

Motor vehicle emission factors were derived from the Ministry of Transport (MoT) vehicle model for 2001 (NZTER version 1).

For the 2001 inventory, a default vehicle fleet profile was used, as recommended by the Ministry of Transport because it was considered that data from regional vehicle registrations would not necessarily be reflective of the local fleet. This differs from the approach used in 1996, and may under-estimate the contribution from diesel vehicles, which are expected to be higher than average due to the region's forestry and port activities.

For this inventory, local traffic count data and vehicle registration information was used to define the fleet profile for the Rotorua LAMA.

Various options for this fleet composition are shown in Table 4. The source of the data in each column is as follows:

- the default national profile for 2004 is taken from MoT;
- the vehicle registration data for Rotorua is from an analysis of registrations for 2005, and has also been presented in an aggregated form in column four;
- the final two columns give an analysis of vehicle count data for a sample of roads around Rotorua (Figure 11). Count data was analysed for about 70 locations, or just under 10% of the approximately 770 locations in the MoT RAMM traffic database for the whole city.

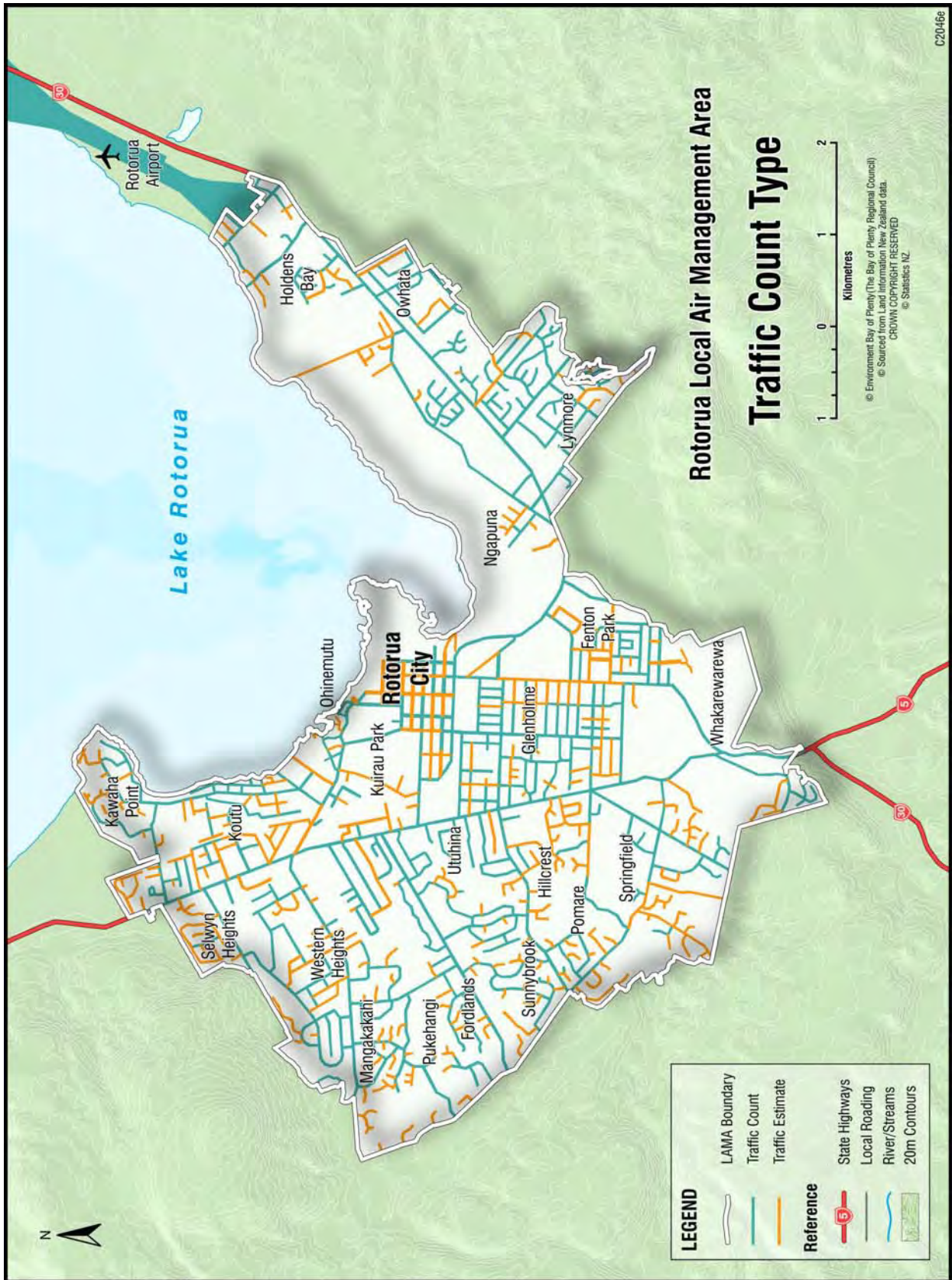


Figure 11 Traffic count data type (Source RAMM)

Table 4 Fleet composition for LAMA urban road network

| Type         | National fleet | Rotorua registrations | Registrations aggregated | RDC Main Rds | RDC Minor Rds |
|--------------|----------------|-----------------------|--------------------------|--------------|---------------|
| Motorcycles  | 0.3%           | 1.89%                 | 97.2                     | 97.5         | 96.9          |
| Cars, petrol | 72.0%          | 70.55%                |                          |              |               |
| Cars, diesel | 5.6%           | 8.26%                 |                          |              |               |
| LCV, petrol  | 6.6%           | 5.21%                 |                          |              |               |
| LCV, diesel  | 7.2%           | 11.25%                |                          |              |               |
| HCV, sm, p   | 0.2%           | 0.05%                 | 2.8                      | 2.4          | 3.0           |
| HCV, sm, d   | 3.0%           | 1.65%                 |                          |              |               |
| HCV, med, p  | 0.2%           | 0.00%                 |                          |              |               |
| HCV, med, d  | 1.0%           | 0.34%                 |                          |              |               |
| HCV, lge, p  | 0.1%           | 0.00%                 | 0.0                      | 0.1          | 0.1           |
| HCV, lge, d  | 3.1%           | 0.00%                 |                          |              |               |
| Buses, med   | 0.2%           | 0.80%                 | part of HCV              | part of HCV  | part of HCV   |
| Buses, large | 0.3%           |                       |                          |              |               |

Clearly, it would not be appropriate to use the national default fleet profile for Rotorua urban roads. In fact, the traffic count data for these roads very closely matches the registration data distribution, by broad categories. From Table 4 the following profile was chosen for Rotorua (Table 5).

Table 5 Fleet profile determined for the LAMA urban road network

|                    | MC/MP  | Cars |      | LCVs |      | HCV, small |      | HCV, med |      | HCV, lge |      | Buses |      |
|--------------------|--------|------|------|------|------|------------|------|----------|------|----------|------|-------|------|
|                    | Petrol | Pet. | Dsl. | Pet. | Dsl. | Pet.       | Dsl. | Pet.     | Dsl. | Pet.     | Dsl. | Pet.  | Dsl. |
| <b>Profile (%)</b> | 1.9    | 70.6 | 8.3  | 5.2  | 11.3 | 0.1        | 1.5  | 0.0      | 0.3  | 0.0      | 0.1  | 0.0   | 0.7  |

The following corridor flow options from NZTER were determined to be representative for the Rotorua LAMA. Table 6 gives the emission factors for these chosen options, in g/VKT (grams/vehicle-kilometres travelled).

Table 6 Emission factors for LAMA urban road network

|                       | CO     | NOx   | PM    | VOC   |
|-----------------------|--------|-------|-------|-------|
| <b>2005</b>           |        |       |       |       |
| Suburban, cold start  | 29.245 | 1.373 | 0.177 | 4.866 |
| Suburban, free flow   | 5.495  | 1.042 | 0.073 | 0.841 |
| Suburban, interrupted | 8.373  | 1.157 | 0.092 | 0.989 |
| <b>2009</b>           |        |       |       |       |
| Suburban, cold start  | 23.208 | 1.264 | 0.139 | 4.266 |
| Suburban, free flow   | 3.799  | 0.842 | 0.056 | 0.566 |
| Suburban, interrupted | 5.610  | 0.937 | 0.072 | 0.687 |
| <b>2013</b>           |        |       |       |       |
| Suburban, cold start  | 18.909 | 1.176 | 0.112 | 3.975 |
| Suburban, free flow   | 2.637  | 0.715 | 0.044 | 0.393 |
| Suburban, interrupted | 3.733  | 0.796 | 0.056 | 0.497 |
| <b>2017</b>           |        |       |       |       |
| Suburban, cold start  | 16.400 | 1.125 | 0.090 | 3.881 |
| Suburban, free flow   | 1.916  | 0.640 | 0.034 | 0.292 |
| Suburban, interrupted | 2.564  | 0.712 | 0.044 | 0.386 |

Hourly variations in traffic flow information are also taken from the analysis of traffic count data for approximately 70 sites. As expected the distribution varies between different roads but some of this will be due simply to the counts being made on different days of the week.



Also, many of the roads showing the greatest variations have quite small traffic volumes, and hence the percentage data is more susceptible to small variations. The distribution shown below (Table 7) is based on an average across all of the sites analysed, regardless of road type, this distribution has been applied universally across all roads in the study area.

*Table 7 Hourly flow variations for the LAMA*

| <b>Time</b> | <b>Traffic distribution</b> |
|-------------|-----------------------------|
| 0000-0100   | 0.6%                        |
| -0200       | 0.4%                        |
| -0300       | 0.3%                        |
| -0400       | 0.3%                        |
| -0500       | 0.4%                        |
| -0600       | 0.7%                        |
| -0700       | 1.4%                        |
| -0800       | 3.4%                        |
| -0900       | 6.3%                        |
| -1000       | 5.9%                        |
| -1100       | 6.5%                        |
| -1200       | 7.0%                        |
| -1300       | 7.6%                        |
| -1400       | 7.5%                        |
| -1500       | 7.2%                        |
| -1600       | 8.2%                        |
| -1700       | 8.3%                        |
| -1800       | 8.4%                        |
| -1900       | 6.2%                        |
| -2000       | 4.7%                        |
| -2100       | 3.4%                        |
| -2200       | 2.6%                        |
| -2300       | 1.7%                        |
| -2400       | 1.1%                        |

(b) State Highways

Figure 12 shows the vehicle type composition at each of the State Highway count sites within and adjacent to the LAMA. Table 8 shows the combination of data from Figure 12 and a percentage breakdown based on type for the State Highways bisecting the LAMA.

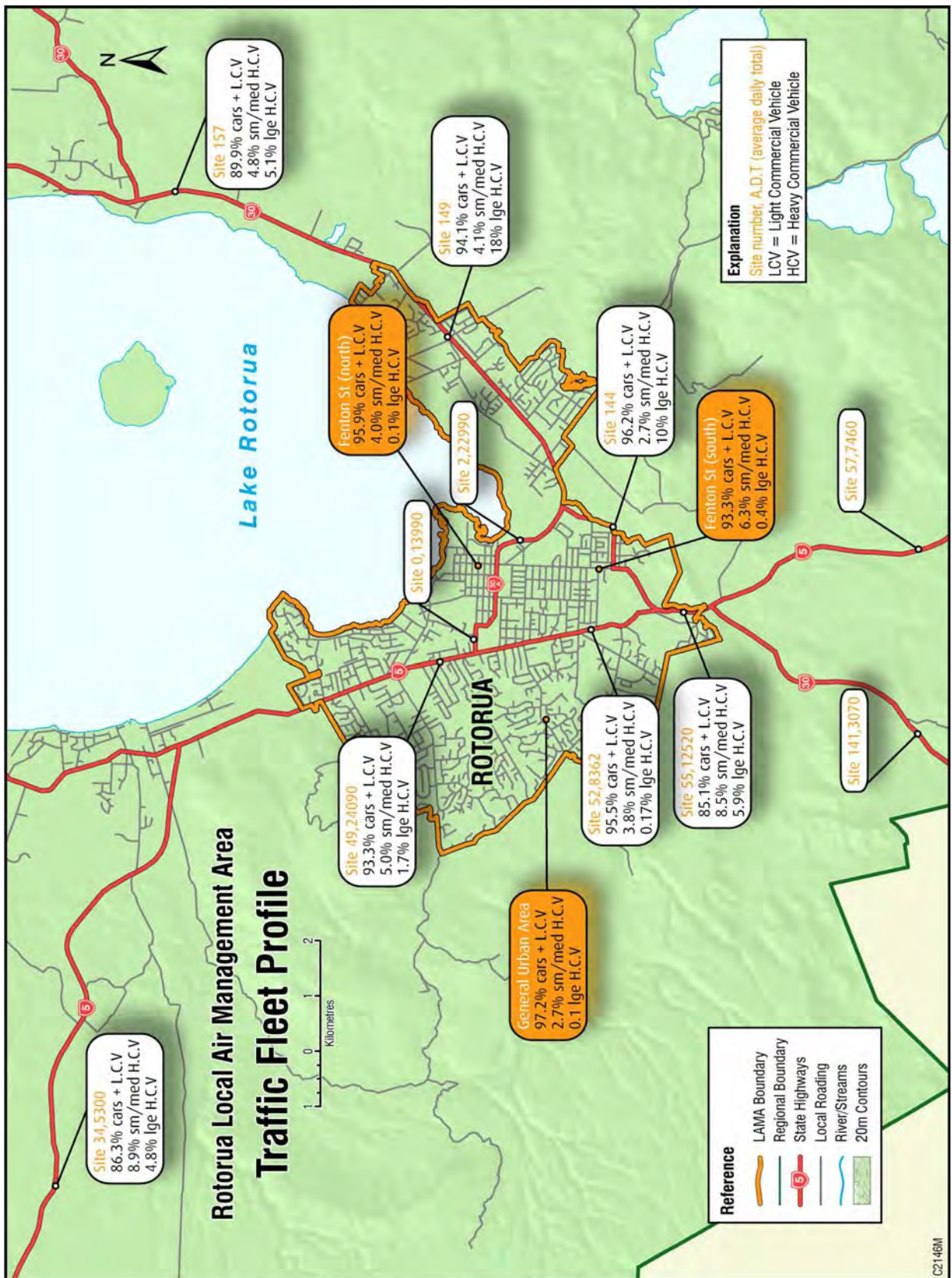


Figure 12 State Highway traffic count sites and summarised information (Source Graham, 2006a)

Table 8 Fleet composition for LAMA State Highway road network

| Type         | National Fleet | Rotorua Registrations | Registrations aggregated | RDC-State H'ways | SH breakdown |
|--------------|----------------|-----------------------|--------------------------|------------------|--------------|
| Motorcycles  | 0.3%           | 1.89%                 | 97.2                     | 94.8             | 1.84         |
| Cars, petrol | 72.0%          | 70.55%                |                          |                  | 68.84        |
| Cars, diesel | 5.6%           | 8.26%                 |                          |                  | 8.06         |
| LCV, petrol  | 6.6%           | 5.21%                 |                          |                  | 5.08         |
| LCV, diesel  | 7.2%           | 11.25%                |                          |                  | 10.98        |
| HCV, sm, p   | 0.2%           | 0.05%                 | 2.8                      | 3.9              | 0.10         |
| HCV, sm, d   | 3.0%           | 1.65%                 |                          |                  | 3.15         |
| HCV, med, p  | 0.2%           | 0.00%                 |                          |                  |              |
| HCV, med, d  | 1.0%           | 0.34%                 |                          |                  | 0.65         |
| HCV, lge, p  | 0.1%           | 0.00%                 | 0.0                      | 1.3              |              |
| HCV, lge, d  | 3.1%           | 0.00%                 |                          |                  | 0.5          |
| Buses, med   | 0.2%           | 0.80%                 | part of HCV              | part of HCV      | 0.8          |
| Buses, large | 0.3%           |                       |                          |                  |              |

The chosen profile for the State Highways is shown in Table 9.

Table 9 Fleet profile determined for the LAMA State Highway road network

|                    | MC/MP  | Cars  |      | LCVs |       | HCV, small |      | HCV, med |      | HCV, lge |      | Buses |      |
|--------------------|--------|-------|------|------|-------|------------|------|----------|------|----------|------|-------|------|
|                    | Petrol | Pet.  | Dsl. | Pet. | Dsl.  | Pet.       | Dsl. | Pet.     | Dsl. | Pet.     | Dsl. | Pet.  | Dsl. |
| <b>Profile (%)</b> | 1.84   | 68.84 | 8.06 | 5.08 | 10.98 | 0.1        | 3.15 | 0.0      | 0.65 | 0.0      | 0.5  | 0.0   | 0.8  |

The corridor flow option of NZTER gives the following emission factors (Table 10), in g/VKT. Particulate matter factors are higher than those used for the urban road network (Table 6) as there is a greater proportion of large diesel vehicles present on the State Highway network.

Table 10 Emission factors for LAMA State Highway road network

|                       | CO     | NOx   | PM    | VOC   |
|-----------------------|--------|-------|-------|-------|
| <b>2005</b>           |        |       |       |       |
| Suburban, cold start  | 28.787 | 1.659 | 0.192 | 4.813 |
| Suburban, free flow   | 5.432  | 1.255 | 0.084 | 0.843 |
| Suburban, interrupted | 8.269  | 1.404 | 0.106 | 0.995 |
| <b>2009</b>           |        |       |       |       |
| Suburban, cold start  | 22.827 | 1.525 | 0.149 | 4.215 |
| Suburban, free flow   | 3.754  | 1.040 | 0.064 | 0.569 |
| Suburban, interrupted | 5.538  | 1.166 | 0.081 | 0.692 |
| <b>2013</b>           |        |       |       |       |
| Suburban, cold start  | 18.580 | 1.401 | 0.117 | 3.922 |
| Suburban, free flow   | 2.604  | 0.888 | 0.049 | 0.395 |
| Suburban, interrupted | 3.684  | 0.996 | 0.062 | 0.501 |
| <b>2017</b>           |        |       |       |       |
| Suburban, cold start  | 16.100 | 1.313 | 0.092 | 3.825 |
| Suburban, free flow   | 1.890  | 0.787 | 0.036 | 0.293 |
| Suburban, interrupted | 2.529  | 0.883 | 0.046 | 0.389 |

(c) Aircraft

Airport activity data for the number of takeoffs and landings was obtained from Rotorua Regional Airport Limited (pers. comms, Matt Clarke). Landing and take offs (LTO's) are summarised in Figure 13. For scheduled aviation (commercial passenger services), 4,486 LTO's were recorded, for general aviation (training flights, charters, private etc), 5,018 LTO's were recorded.

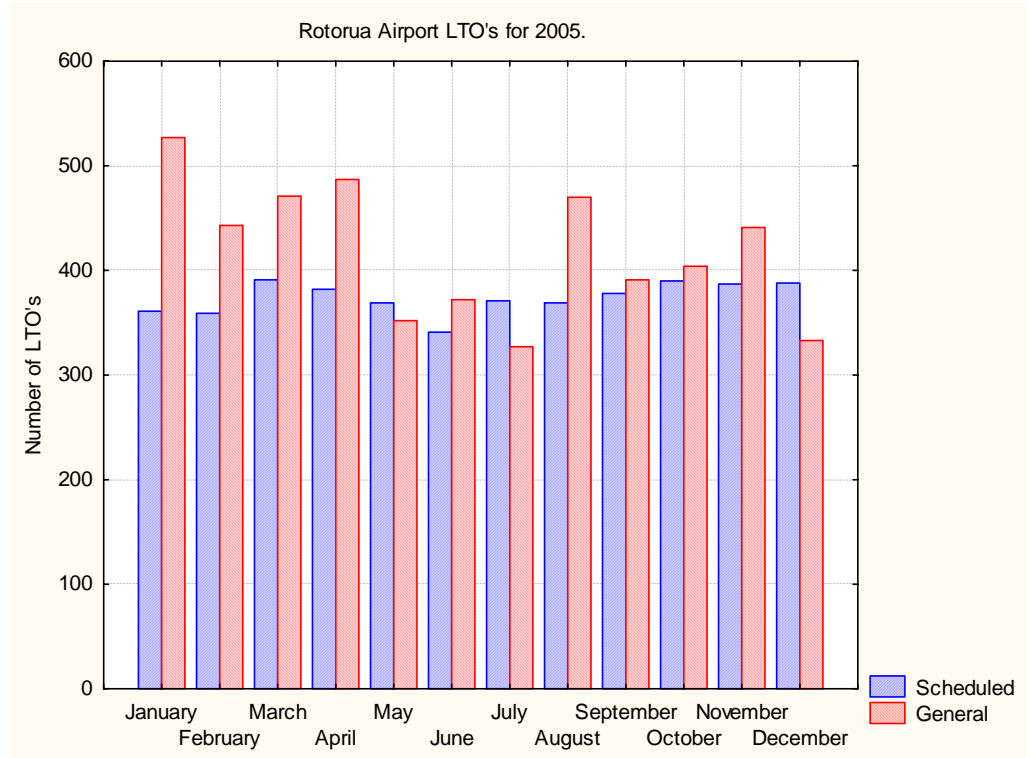


Figure 13 Rotorua airport LTO's for 2005 (Source – Rotorua Regional Airport Limited)

Emission factors applicable to regional aircraft and general aviation were used from the Australian NPI EET (Environment Australia, 2003). Regional airlines are defined as those that provide regular scheduled public transport services linking smaller rural centres with the main cities. The general aviation sector includes private, business, training and agricultural aerial movements. Default time-in-mode data is used in the emission factors from the EET.

For general aviation (piston engine) the emission factors (Table 11) were used.

Table 11 General aviation emission factors

| General Aviation Emission Factors |      |        |        |                      |                 |
|-----------------------------------|------|--------|--------|----------------------|-----------------|
| Approach, kg/LTO                  |      |        |        |                      |                 |
|                                   | CO   | HC     | NOx    | TSP/PM <sub>10</sub> | SO <sub>2</sub> |
| general/piston                    | 2.89 | 0.043  | 0.0039 | 0.33                 | 0.0005          |
| Taxi / Idle, kg/LTO               |      |        |        |                      |                 |
| general/piston                    | 1.29 | 0.0767 | 0.0011 | 0.88                 | 0.00026         |
| Takeoff, kg/LTO                   |      |        |        |                      |                 |
| general/piston                    | 0.26 | 0.0027 | 0.0006 | 0.0165               | 0.00005         |
| Climbout, kg/LTO                  |      |        |        |                      |                 |
| general/piston                    | 2.97 | 0.0352 | 0.0123 | 0.275                | 0.0006          |

For scheduled aviation the emission factors below were used (Table 12) (Boeing 733 using CFM56-3C-1 jet engines and Saab SF34 using GE CT7-5 turboprop engines). No factors were available for AT72 or B190 so Saab values were used as these are both turboprops.

Table 12 Scheduled aviation emission factors

| Scheduled Aviation Emission Factors |        |        |                 |                      |                 |
|-------------------------------------|--------|--------|-----------------|----------------------|-----------------|
| Approach, kg/LTO                    |        |        |                 |                      |                 |
|                                     | CO     | HC     | NO <sub>x</sub> | TSP/PM <sub>10</sub> | SO <sub>2</sub> |
| jet                                 | 0.5375 | 0.0061 | 0.7883          | 0.0950               | 0.1570          |
| turbo                               | 0.1289 | 0.0162 | 0.0839          | 0.0720               | 0.0023          |
| wt. avg.                            | 0.1800 | 0.0149 | 0.1720          | 0.0682               | 0.0217          |
| Taxi/Idle, kg/LTO                   |        |        |                 |                      |                 |
| jet                                 | 7.2000 | 0.3804 | 1.1400          | 0.1160               | 0.2500          |
| turbo                               | 1.6571 | 0.2106 | 0.1031          | 0.2110               | 0.0060          |
| wt. avg.                            | 2.3509 | 0.2319 | 0.2329          | 0.1802               | 0.0365          |
| Takeoff, kg/LTO                     |        |        |                 |                      |                 |
| jet                                 | 0.1060 | 0.0034 | 2.4367          | 0.0430               | 0.1060          |
| turbo                               | 0.0152 | 0.0061 | 0.0837          | 0.0340               | 0.0005          |
| wt. avg.                            | 0.0265 | 0.0057 | 0.3782          | 0.0320               | 0.0137          |
| Climbout, kg/LTO                    |        |        |                 |                      |                 |
| jet                                 | 0.1339 | 0.0059 | 2.6477          | 0.0470               | 0.1340          |
| turbo                               | 0.0762 | 0.0282 | 0.3725          | 0.0590               | 0.0022          |
| wt. avg.                            | 0.0834 | 0.0254 | 0.6573          | 0.0522               | 0.0187          |

### 3.2.3 Domestic Sources

Iremonger & Graham (2006) gives a summary of the key results from the survey of home heating methods, frequency, fuel use and back yard rubbish burning in Rotorua.

The survey was based on telephone interviews of 800 households in the Rotorua urban area. There are about 17,000 households altogether in Rotorua and the survey sample size was designed to give a margin of error of  $\pm 3.5\%$ , at the 95% confidence level. The households were selected on the basis of the twenty five census area units (CAU's) in the urban area, and the distribution was designed to ensure a proportional representation across all of these CAU's.

The distribution of heating methods used by each household for heating their main living area was as follows (Table 13).

Table 13 Heating methods from 2005 heating survey

| Source            | Percentage |
|-------------------|------------|
| Open Fire         | 5%         |
| Wood (log) burner | 43%        |
| Multi-fuel burner | 2%         |
| Gas (reticulated) | 19%        |
| Gas (bottled)     | 25%        |
| Oil-fired         | 0%         |
| Geothermal        | 5%         |
| Electricity       | 33%        |

The results for households using wood for heating compare well with the figure of 45% reported for Rotorua in the 2001 census. Similarly, the census figures for gas usage were 15% reticulated and 28% bottled.

Geothermal heating was a low percentage of the total across the whole city, but in those areas where it is available the proportion of users was more typically 30 to 50%.

A heating model (Appendix 2) was derived by Graham (2006b) based on the results from the heating survey and has been used for determining emission rates from this particular source.

Schools have also been included as a sub-group of this source category. The schools shown previously in Figure 10, for 2005, use the combustion of coal as a form of energy for heating. It should be noted that since 2005, Selwyn Primary School and Rotorua Girls High School have converted to a cleaner burning, wood pellet fired boiler process.

The heating profile for the school boilers will differ from that determined for the domestic heating as no operation is required on Saturday and Sunday and during the evenings. The calculation for this particular source was based on coal supply figures for the 2005 year and emission factors for overfeed stoker boilers taken from USEPA AP42 and Coal Research Ltd (the same factors were used in SKM, 2001).

### 3.2.4 **Small Industrial/Commercial Sources of PM<sub>10</sub>**

Most emission inventories ignore the releases from small industrial and commercial sources because they are considered to be relatively insignificant at a regional or national scale. However, the Rotorua emissions inventory is being done at a much finer and more detailed scale than most others. Therefore it was considered important that these small sources should be included, at least to the extent of allowing their significance to be assessed.

There are no well-established guidelines on the inventory methodology that should be used for these small sources and, in particular, a complete lack of published emission factors. These factors were therefore developed from 'scratch', using the approach described below.

#### (a) Facility Types

The types of facilities considered for the inventory are listed in Table 14. These were derived from a database of 'waste producers' obtained from the Rotorua District Council, which was linked to property information in a GIS.

Table 14 Facility types assessed for particulate matter contributions

| Facility types  |
|---|
| Light metal fabrication (e.g. trailers, pool gates and fences, clotheslines, etc) |
| Heavy engineering/plant and equipment maintenance                                 |
| Panel beaters (including spray painting)  |
| Light vehicle workshops (motorbikes, cars, vans)                                  |
| Heavy vehicle workshops (trucks, etc)   |
| Metal finishers - powder coating  |
| Metal finishers - electroplating  |
| Joinery factories (furniture manufacture, etc)                                    |
| Bakeries  |
| Printing works (small commercial)   |
| Packaging manufacture   |
| Tanneries (small-specialty products)  |
| Wreckers (vehicle dismantlers)  |
| Scrap metal dealers   |
| Waste management (recycling, bins) depots   |
| Appliance repairs   |
| Timber milling/processing (small)   |
| Paint and other solvents/chemicals (mixing, packaging)                            |
| Photographic developing/printing  |
| Abattoirs   |
| Stone/bone/wood grinding, carving, etc (jewellery, sculpture)                     |

## (b) Point Source Emission Data

Most, but not all, of the above sources will have some point sources emissions, mainly from building ventilation fans or from dust control equipment fitted to specific items of equipment. An indication of the possible magnitude of these emissions was obtained from a summary of test data provided by a company that specialises in stack testing. These results are summarised in Table 15, which indicates emissions varying from almost zero (ca. <0.02 kg/hr) up to relatively high rates of 1 to 4 kg/hr. However, it should be noted that these higher emission rates (ca. > 1 kg/hr) are considered to be typical. Sources with this level of emissions would almost certainly give rise to complaints to the Regional Council, and subsequent action to ensure that the emissions are better controlled.

Table 15 Point Source Emissions from Selected Industries (Graham, 2006c)

| Industry type                  | kg/hr                  |
|--------------------------------|------------------------|
| timber & joinery, good control | 0.07, 0.07             |
| timber & joinery, poor control | 1.8, 3.6               |
| spray painting                 | 0.14, 0.03             |
| abrasive blasting              | 0.05, 0.04             |
| metal fabrication, etc         | 0.04, 0.07, 0.14, 0.01 |
| printing                       | 0.05                   |
| packaging                      | 0.36, 0.72             |
| coffee roasting                | 0.11                   |
| coffee drying                  | 1.37                   |
| bakeries                       | 0.04                   |
| tyre retreads                  | 0.01                   |
| sand dryer                     | 1.08                   |
| concrete plant                 | 0.11                   |
| roofing tiles                  | 0.02                   |
| coal-fired boiler              | 2.16                   |

On the basis of the data shown in the above table, it was decided to allocate source emission rates as follows (Table 16), using a subjective classification of the different sources.

Table 16 Particulate matter contribution classification (Graham, 2006c)

|  |                                     |                               |
|--|-------------------------------------|-------------------------------|
| <b>Facilities with the highest potential for PM emissions:</b> |                                     | assigned a rate of 0.1 kg/hr  |
| Heavy engineering/maintenance                                  | Metal finishers – powder coating    |                               |
| Joinery factories  | Bakeries                            |                               |
| Panel beaters  | Stone/bone/wood grinding or carving |                               |
| Light metal fabrication  |                                     |                               |
| <b>Facilities with lower potential for PM emissions:</b>       |                                     | assigned a rate of 0.02 kg/hr |
| Light vehicle workshops  | Paint and other solvents            |                               |
| Printing works   | Metal finishers – electroplating    |                               |
| Packaging manufacturers  | Appliance repairs                   |                               |
| Tanneries (small specialty products)                           |                                     |                               |
| <b>Facilities with very little potential for PM emissions:</b> |                                     | assigned a rate of 0.0 kg/hr  |
| Abattoirs  | Photographic developing/printing    |                               |
| <b>Facilities with the potential for ‘yard’ emissions:</b>     |                                     | assigned a rate of 0.1 kg/hr  |
| Wreckers   | Waste management                    |                               |
| Scrap metal dealers  | Timber yards                        |                               |

The above factors allow for an initial estimate of the controlled and uncontrolled emissions from the different groups of sources. The figures used are totally subjective and should simply be seen as providing ball-park estimates of the possible emissions. The main purpose of the calculations is to determine whether or not the emissions from these small sources are a significant contributor to the Rotorua inventory. Further work may be required if this is found to be the case.

### 3.3 Uncertainty

Uncertainties are inherent in any emission inventory. Uncertainty arises from:

- The use of average emission figures.
- Applying emission factors from other regions or countries.
- Activity levels that cannot readily be captured.

The uncertainty in emission factors as a result of averaging is usually reported in the emission factor reference. A LAMA specific model containing New Zealand specific factors has been used for transport sources and New Zealand developed factors have been used for domestic heating.

USEPA derived factors have been used for industrial sources, this is typical practice because it is generally the only comprehensive data set, but they may not be entirely relevant to New Zealand operating conditions. For PM<sub>10</sub> calculations the hours of operation and the consent limit has been used.

The emission factors used in the inventory were the best available at the time. Uncertainty in the activity statistics for each source is summarised in Table 17.



Table 17 *Uncertainties associated with inventory calculations*

| Source                    |                | Comment   |
|---------------------------|----------------|---|
| Transport                 | Motor vehicles | Good certainty in VKT data given the road length data from RAMM data base. Limitations are in whether measurements have been taken at enough points on a road to be truly representative. Vehicle counts are likely to vary seasonally particularly, due to tourism over summer, but the VKT data is expected to be reasonably representative of an annual average. |
|                           | Aircraft       | Strong certainty in the data for landing and take offs obtained from the Rotorua Airport Limited, but moderate certainty for the time in mode data that is assumed in the factors used for Australian regional airports and general aviation. Some grouping of the engine types was required due to limited documented emission factors for each engine.            |
| Domestic                  |                | All domestic source activity data is reasonably certain because it has been built on the results from a detailed LAMA specific domestic heating survey. School boiler coal consumption, also reasonably certain.  |
| Light industry/commercial |                | Low certainty for the result from this category. Good knowledge of types of activity from the RDC database, but limited knowledge of discharges for these point sources. The methodology acknowledges this screening approach to determine if more detailed investigations are necessary.   |
| Industrial                |                | There is reasonable certainty in the activity data for industrial sources, the majority of which was obtained by direct contact with industry. For PM hours of operation are used (for which there is good certainty) in conjunction with consented discharge limits (actual discharge should be lower than this figure).   |

Inventories are useful tools for assessing the sources contributing to pollution but the results need to be interpreted and used bearing in mind that the inventory is not the result of an exact science.

Certain policy decisions may require a more refined and/or localised information base and further investigations may be needed in such cases.

## Chapter 4: Data Summary and Analysis

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The data summary information is presented in two forms firstly by emission source type in a tabular format and secondly by contaminant type in a spatial format. This approach gives a numerical value for each dominant source and also an indication of distribution of each contaminant.

### 4.1 By Emission Source

This section presents the estimated emissions for the various sources based on the best information available for activity data and emission factors to represent the 2005 year. The data is presented for two timescales: i) annual and ii) 'winter time' (which is deemed to be approximately 180 days based on the determined domestic heating season from Iremonger and Graham, (2006)).

This wintertime check is important as it is during this time that exceedences of the PM<sub>10</sub> standard are being recorded within the LAMA.

#### 4.1.1 Discussion

On an annual basis domestic heating contributes 46% of the estimated particulate matter in the LAMA. When determined for the 2005 winter heating season this increases to 63% of the estimated particulate matter. Industry is the second main contributor with 35 and 24% for annual and winter time figures respectively. Calculations for transport show a lesser contribution with 17 and 12% respectively for annual and winter periods.

Contributions from schools, back yard burning, commercial (light industry) and aviation are deemed less significant.

Table 18 Annual emission totals

|                   | Tonnes/year 2005 |             |                 |                 |            |
|-------------------|------------------|-------------|-----------------|-----------------|------------|
|                   | PM <sub>10</sub> | CO          | NO <sub>x</sub> | SO <sub>2</sub> | VOC        |
| <b>Industry</b>   | <b>77</b>        | <b>260</b>  | <b>40</b>       | <b>30</b>       | <b>5</b>   |
| <b>Transport</b>  | <b>38</b>        | <b>2670</b> | <b>384</b>      | <b>-</b>        | <b>335</b> |
| Aviation          | 8                | 49          | 7               | <1              | 2          |
| Vehicles          | 30               | 2621        | 377             | n/d             | 332        |
| <b>Domestic</b>   | <b>102</b>       | <b>937</b>  | <b>7</b>        | <b>3</b>        | <b>261</b> |
| Domestic heating  | 97               | 920         | 6               | 3               | 259        |
| Schools           | <1               | <1          | <1              | <1              | <1         |
| Backyard burning  | 5                | 17          | 1               | <1              | 2          |
| <b>Commercial</b> | <b>11</b>        | <b>n/d</b>  | <b>n/d</b>      | <b>n/d</b>      | <b>n/d</b> |

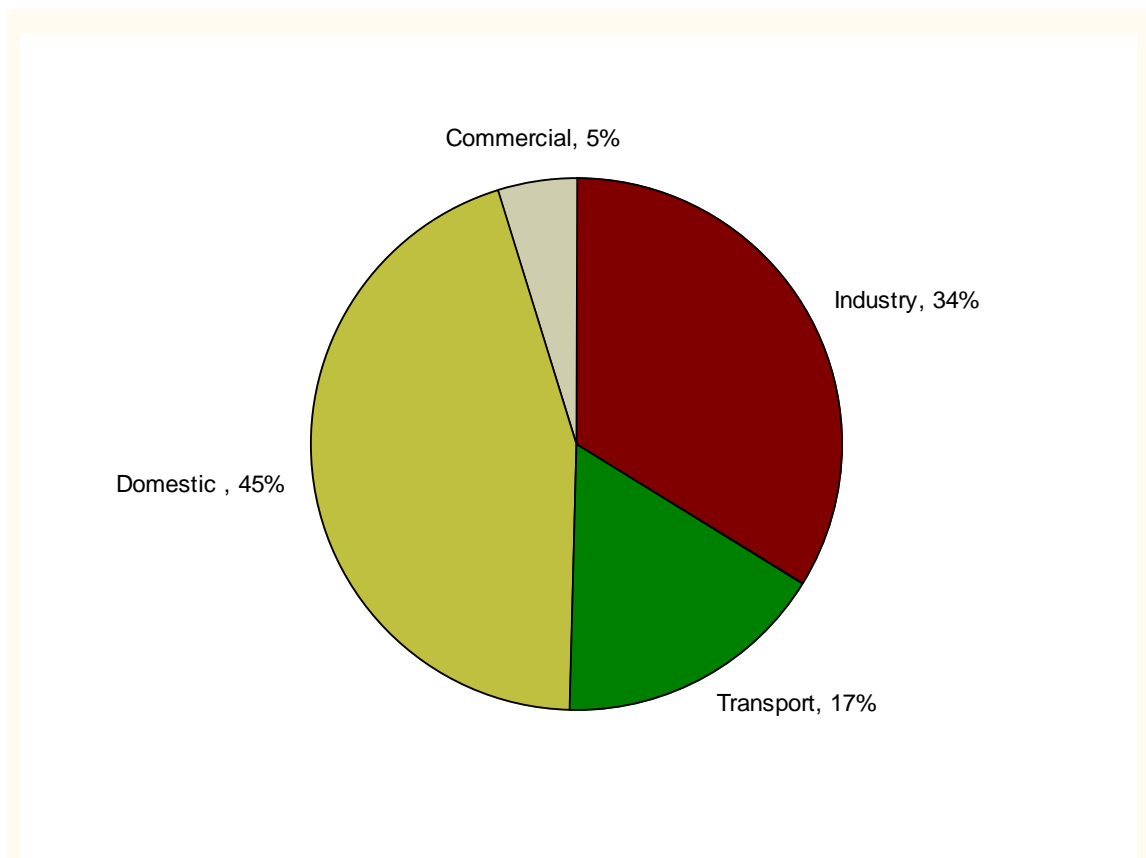
Figure 14 PM<sub>10</sub> percentage by source

Table 19 Winter time emission totals

|                   | Tonnes/winter 2005 |      |                 |                 |     |
|-------------------|--------------------|------|-----------------|-----------------|-----|
|                   | PM <sub>10</sub>   | CO   | NO <sub>x</sub> | SO <sub>2</sub> | VOC |
| <b>Industry</b>   | 39                 | 130  | 20              | 15              | 3   |
| <b>Transport</b>  | 19                 | 1335 | 192             | n/d             | 168 |
| <b>Domestic</b>   | 100                | 929  | 6               | 2               | 255 |
| <b>Commercial</b> | 6                  | n/d  | n/d             | n/d             | n/d |

(n/d = not determined)

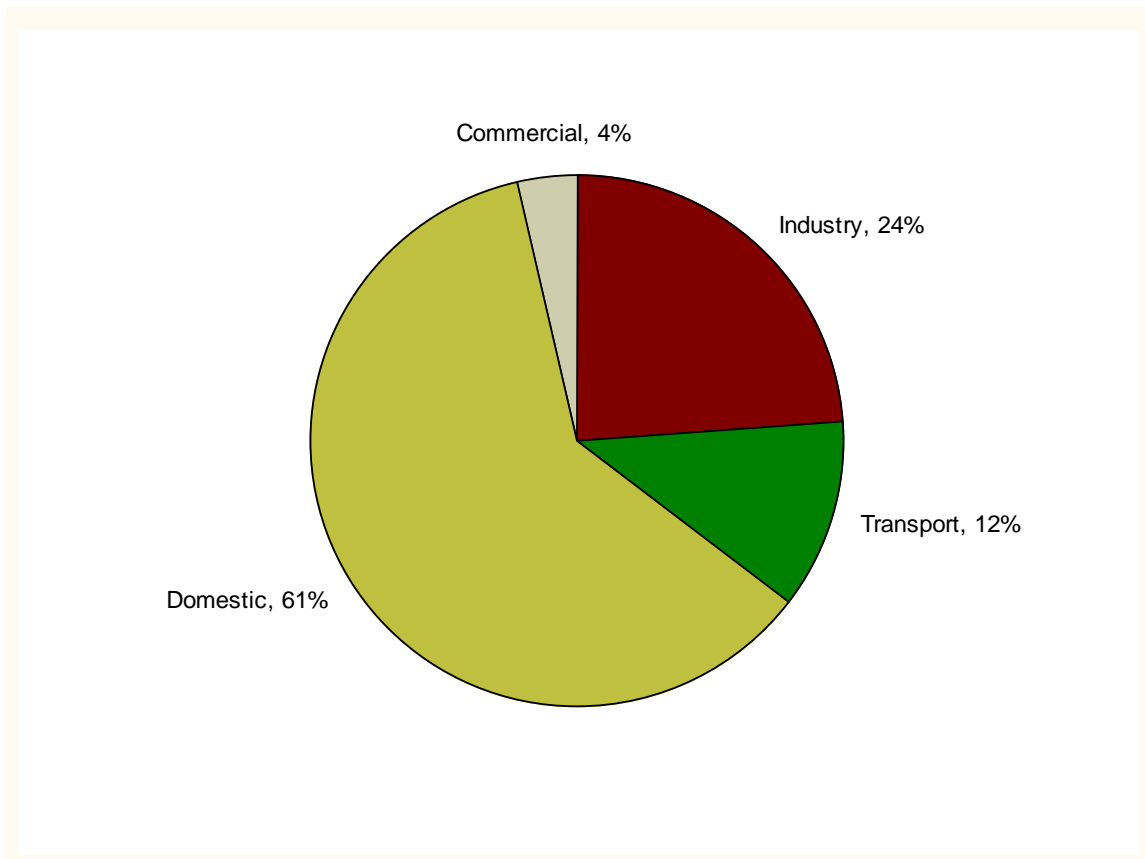


Figure 15 PM<sub>10</sub> winter percentage by source

## 4.2 By Contaminant

The mapping in this section is by 250m x 250m grid. Emissions are calculated on an area basis for each grid.

### 4.2.1 Discussion

The figures for the previous section are for the LAMA as a whole. Contributions from various sources will differ throughout the LAMA based on intensity of activity. This section of the inventory will look at this emission distribution within the LAMA in more depth. Bearing in mind that how the contaminant behaves once emitted from the sources of interest, is beyond the scope of this report and will be addressed in the accompanying airshed model investigation.

Several maps (Figures 17 – 19) have been produced to show the distribution of sources for each contaminant and the quantity of each contaminant emitted from these sources.

Figure 17 shows the spatial patterns associated with particulate matter emissions. For domestic emissions higher concentrations are estimated in the Western Heights, Selwyn Heights, Koutu, Pukehangi North, Pukehangi South, Mangakakahi, Fordlands, Utuhina, Victoria and Glenholme West census area units in the western section of the LAMA. In the eastern area the trend is not as strong with only smaller pockets exhibiting elevated  $PM_{10}$  results (Lynmore, Owhata and Holdens Bay). These are primarily densely developed residential suburbs with a reliance on older style wood burner technology (Figure 16) for heating (data from Iremonger & Graham, 2006).

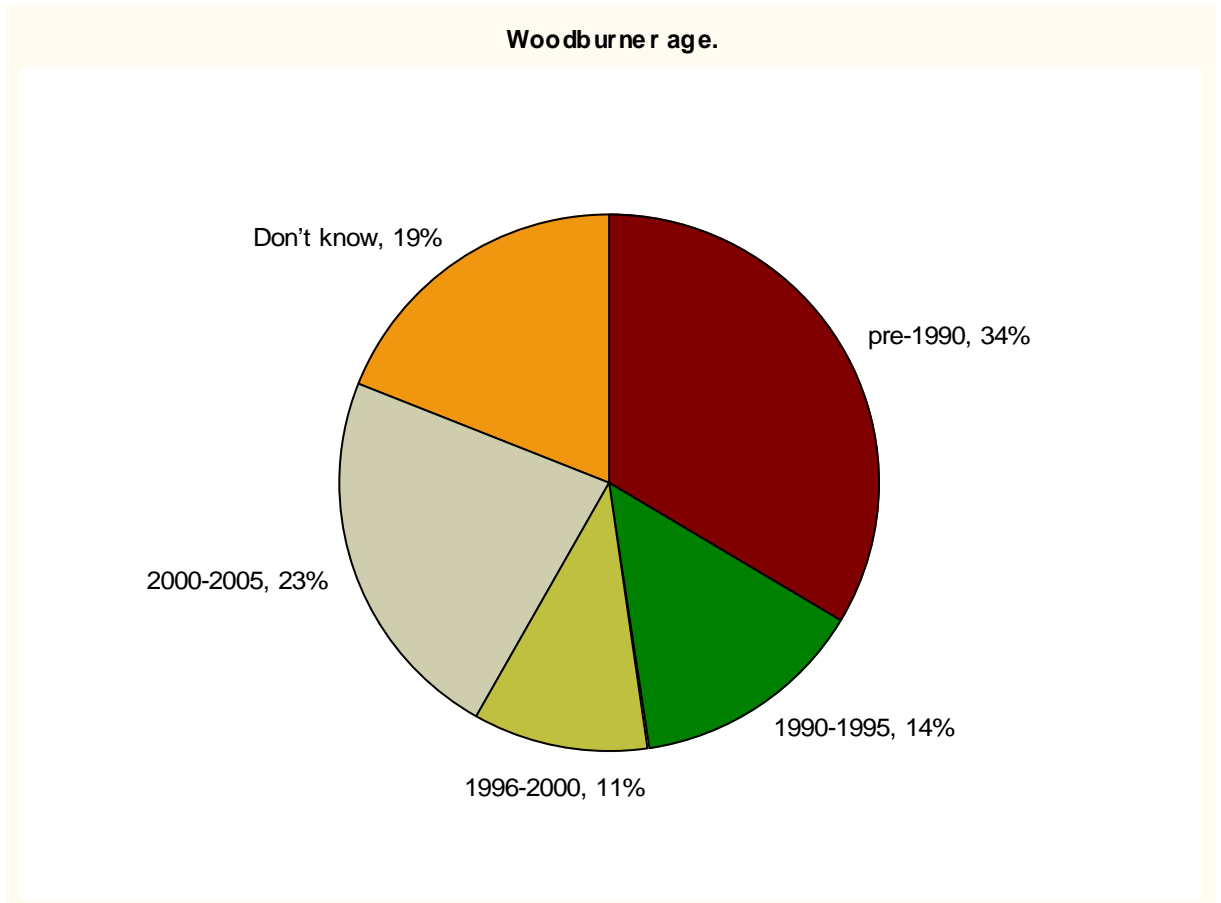


Figure 16 Wood burner age for the Rotorua LAMA (Source Iremonger and Graham, 2006)

For transport sources emissions are dominated by the roading network (aviation activity is only a minor contributor), in particular the State Highways and intersections associated with the busier urban road network.

Light and heavy industry are primarily restricted to two areas within the LAMA (the area bounded by Vaughan and Te Ngae Roads in the east and the area in the north eastern end of the Mangakakahi CAU). The main contributors are those timber processing industries that operate wood fired boilers.

The other contaminants (Figure 18 and 19) investigated mimic the distribution patterns exhibited by the  $PM_{10}$  analysis. This is not unexpected due to the activity data being the dominant component in the emission calculation when reviewing the data spatially.

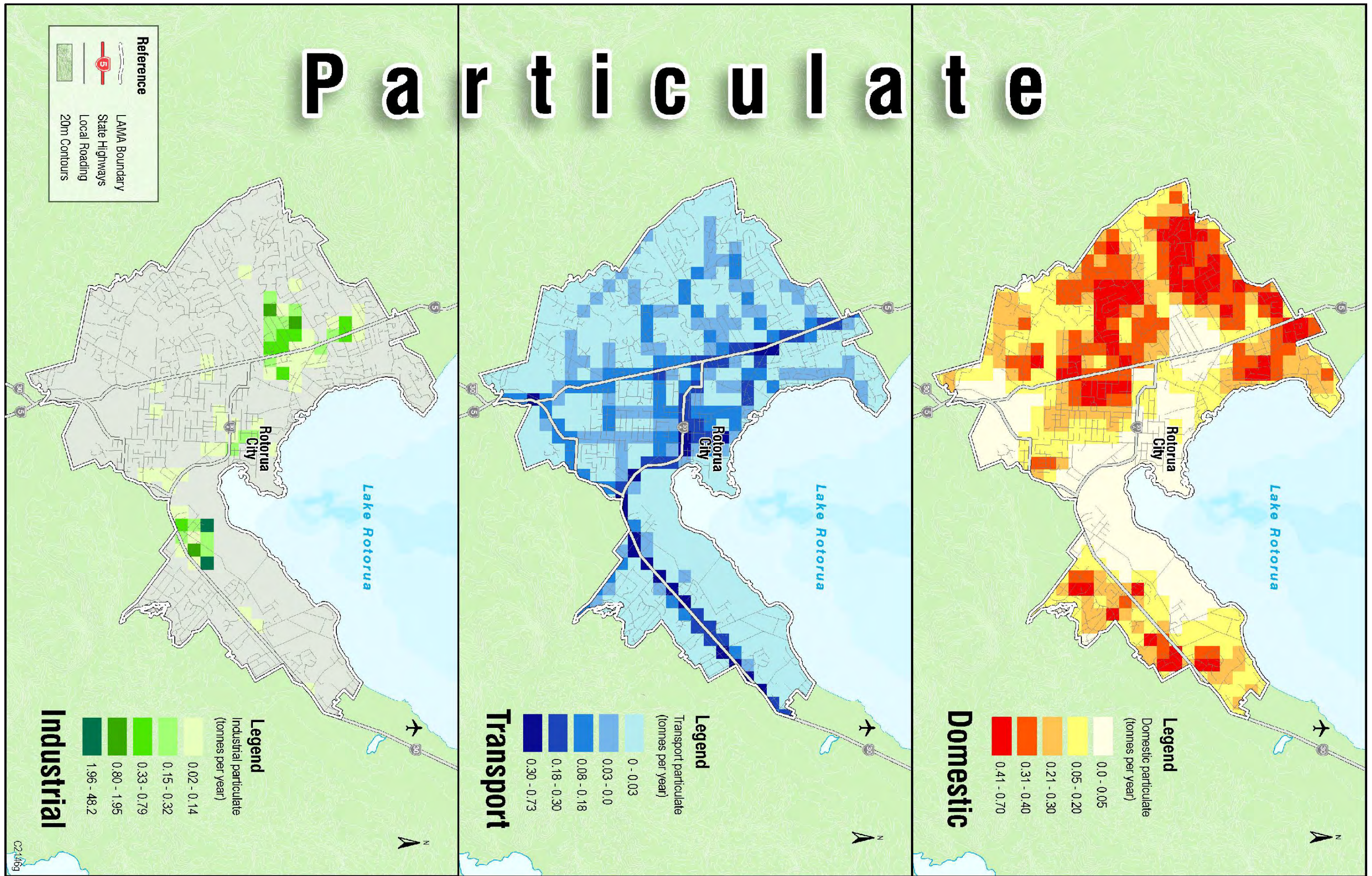


Figure 17 Particulate matter estimated emissions



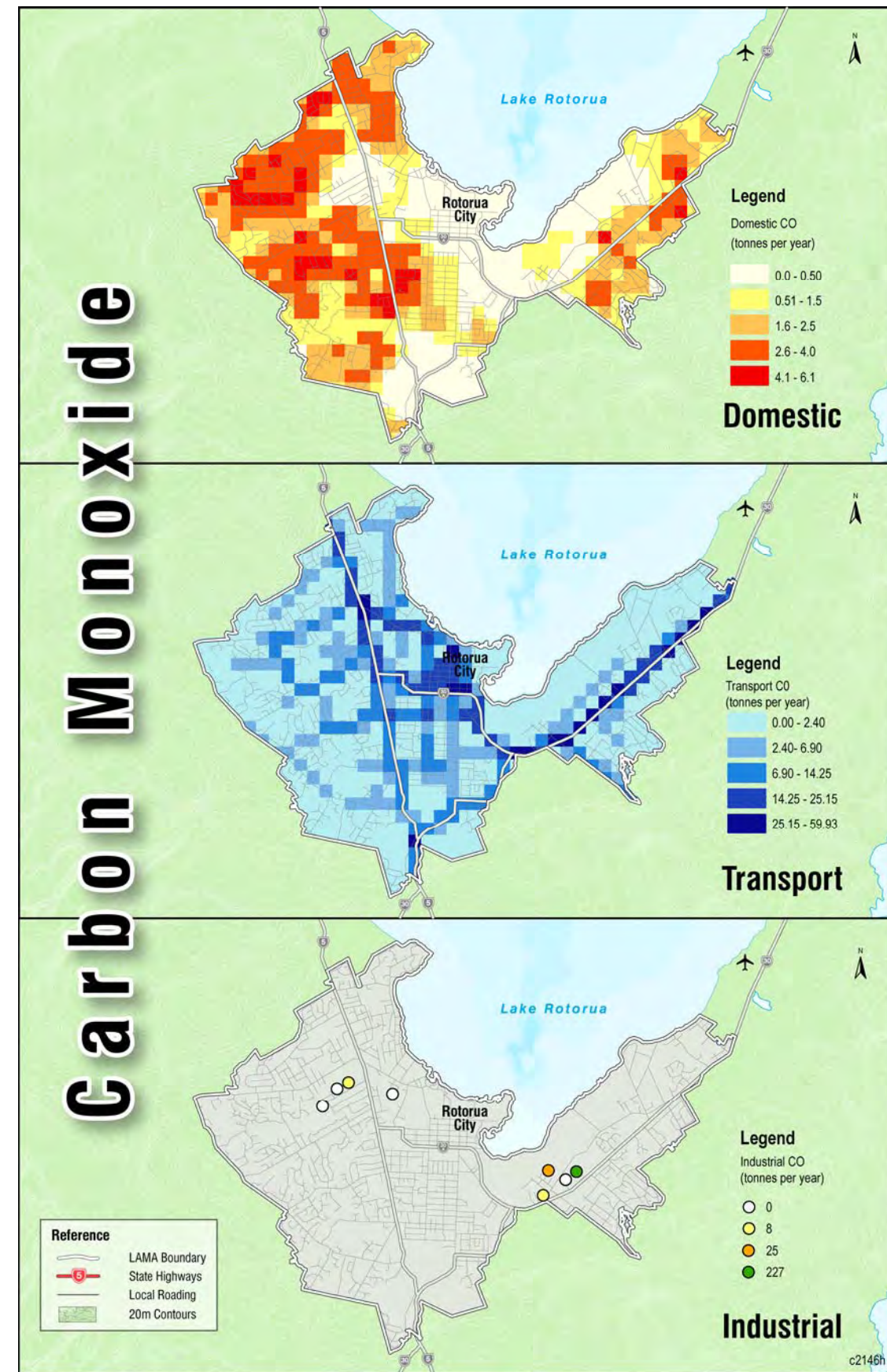
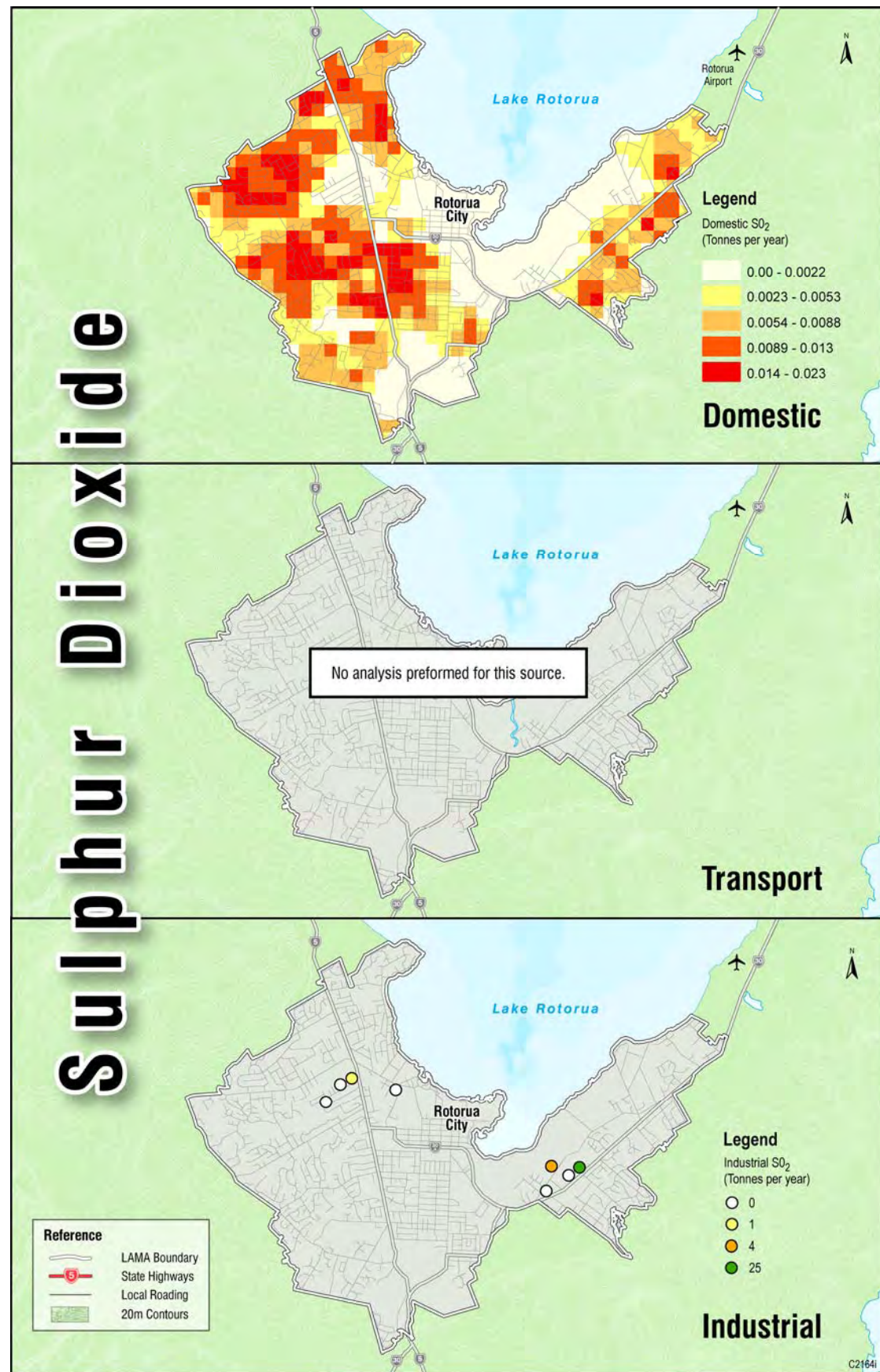


Figure 18 Other estimated emissions





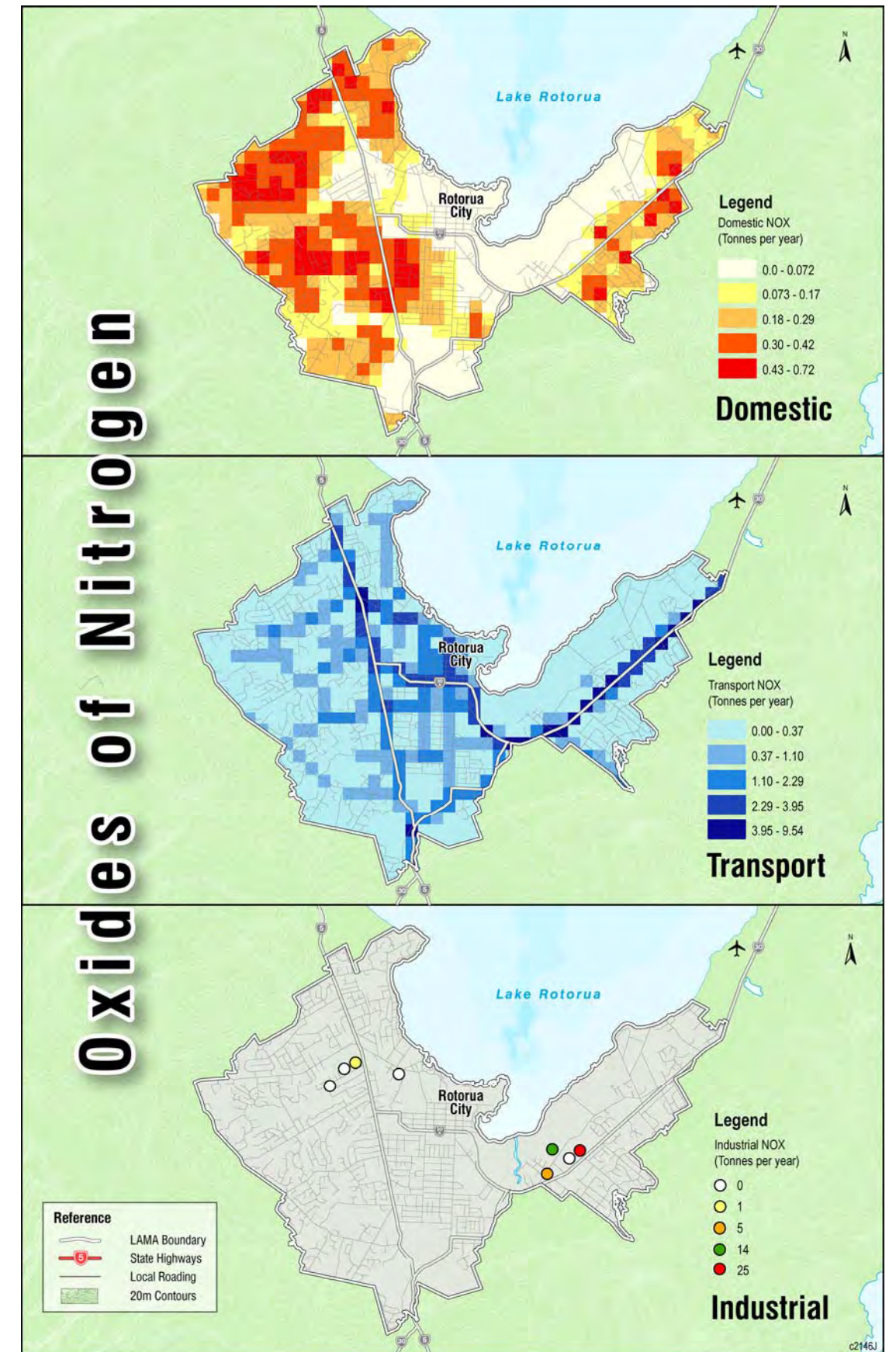
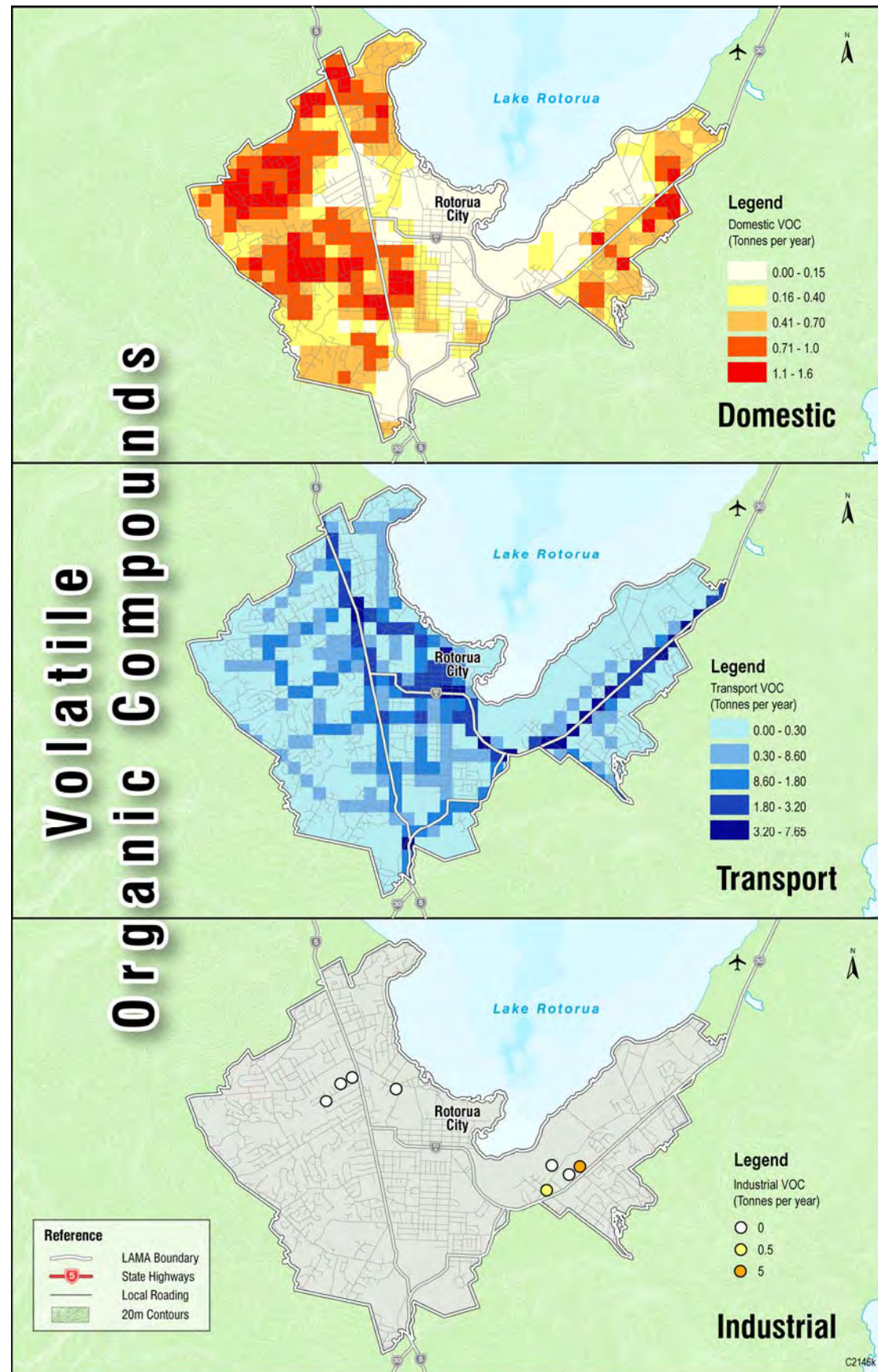


Figure 19 Other estimated emissions



## Chapter 5: Conclusion

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Ambient air quality monitoring within the LAMA shows that during the winter period exceedences of the National Environmental Standard for PM<sub>10</sub> has been recorded (on 25 occasions for 2006). Hence PM<sub>10</sub> have been the primary focus of this emission inventory. Ambient monitoring of the other contaminants (CO, SO<sub>2</sub>, NO<sub>x</sub> and VOC's) shows no exceedence of their respective standards.

The results from the inventory show that during the critical (in relation to the number of measured PM<sub>10</sub> exceedences) time of the year, domestic sources are the leading producer of PM<sub>10</sub> emissions (63%) for the LAMA. The major sub category in this section is domestic heating which could be the primary focus of any Action Plan initiatives. However the other sub categories (back yard burning and school boiler emissions) should not be ignored. Schools could be encouraged to look at cleaner and more efficient processes bearing in mind the financial constraints (Selwyn Primary and Rotorua Girls High School have recently adopted improved heating processes). The prohibition of back yard burning in the urban area as proposed in the draft Proposed Plan Change No.1 Bay of Plenty Regional Air Plan (Environment Bay of Plenty, 2006) would be beneficial in removing particulate emissions from the LAMA.

Industry is the second major contributor to PM<sub>10</sub> emissions within the LAMA (24% of the estimated emissions during the critical time of the year). Their impact on areas where exceedences have been recorded is likely to be minimal. However their operations should be regularly audited as required by the relevant consent conditions to ensure emissions are maintained below the stipulated discharge limits for particulate matter.

Transport sources are only a moderate contributor to the PM<sub>10</sub> profile. During winter time their contribution is estimated at 12%. Emissions from these sources are controlled primarily at the central government level through import regulations, WOF requirements, and fuel specifications. However roading network development at the design stage (at the district council level) should be addressing factors which impact on the quantity of emissions to the LAMA and ultimately the ambient air quality.

The spatial distribution of emissions (particularly PM<sub>10</sub>) as highlighted in Section 4.2 should be used as an initial guide as to where Action Plan initiatives could be focussed. Factors such as deprivation index (Section 1.3.4) should also be considered when determining these initiatives.

Population growth is a strong driver for emission production. Projected increases of 5.8% (Section 1.3.3) for the resident population for the Rotorua District will have a potentially negative effect of increasing emissions, unless offset by other means (e.g. economically viable technology advances, restrictions on certain activities/practices).

Topography and meteorology are also strong drivers when looking at what happens to the emissions once they enter the LAMA. These complex interactions have been flagged in Section 1.3 and will be investigated in more detail in the dispersion modelling component of this project.



## Chapter 6: References

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## Appendices

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|                          |   |
|--------------------------|---|
| <i>Appendix I</i> .....  | <i>Industrial data</i>                                |
| <i>Appendix II</i> ..... | <i>Model of Domestic Wood Burning (Graham, 2006b)</i> |





## Appendix I – Industrial Data

| Type              | consent # | Site                                | NZMG    |         | Process                   | Rating (2005)  |
|-------------------|-----------|-------------------------------------|---------|---------|---------------------------|----------------|
| Gas               | 30123     | Claymark Industries Ltd             | 2796971 | 6334262 | boiler, kilns             | 200 GJ/day     |
| Abrasive blasting | 30052     | Patchell Industries                 | 2792600 | 6336037 | Nelson inventory figures. | 0.3kg/day/site |
|                   | 62197     | TPC Group Ltd                       | 2797400 | 6334600 |                           |                |
|                   | 62211     | Lakeland steel products ltd         | 2792910 | 6336380 |                           |                |
|                   | 63494     | Roadmaster Trailers Ltd             | 2793994 | 6336274 |                           |                |
| Wood boiler       | 60842     | Stewart Logging Limited             | 2793000 | 6336400 | boiler, kilns             | 1 MW           |
|                   | 62444     | Tachikawa                           | 2797610 | 6334730 | boiler, kilns             | 4 MW           |
|                   | 61497     | McAlpines (Rotorua) Ltd (wood+coal) | 2797060 | 6334750 | boiler, kilns             | 8MW            |



## Appendix II – Model of Domestic Wood Burning (Graham, 2006b)

### Model of Domestic Wood Burning

(revised, 2 August, 2006)

#### 1. cross-checks on average rates from the Main worksheet

average daily wood use for log burners = 6.5 kg/day  
annual heating season (May to Sep plus a bit more) = 153 to 180 days

**total annual wood use = 995 to 1170 kg/yr**

This range compares well with the Building Research Association estimate of 1086 kg/yr (HEEP project report, 2006)

#### 2. home energy requirements

The HEEP study indicates typical heat outputs from wood burners in the range of 0.5 to 4 kWh, with most heaters never going above 6 kWh. They also indicate that a typical house would require 6.5 kW heat output to maintain comfortable room temperatures in mid-Winter. Part of this is supplied by body heat, lighting, etc, so wood burning only supplies about 5 kW. But also, many houses are likely to only require 1 to 3 kW, due to better insulation, design and construction. The thermal efficiency of most wood burners is around 60%. Hence, 3 kWh heat output requires an energy consumption of 5 kWh, and 5 kWh output requires 8.3 kWh. The typical energy content of firewood is 3.5 kWh/kg (75/25% seasoned/wet mix). Hence 5kWh will be generated from 1.4 kg of wood, and 8.3 kWh from 2.4 kg.

#### 2. maximum theoretical wood use

assume 5 kWh maximum demand, 3 kWh normal and 0.25 kWh low

|               | Wood Use, kg per period |           |           |           |           |           | Total       | Days/year | Total         |
|---------------|-------------------------|-----------|-----------|-----------|-----------|-----------|-------------|-----------|---------------|
|               | 0000-0600               | 0600-0900 | 0900-1500 | 1500-1800 | 1800-2200 | 2200-2400 |             |           |               |
| very cold day | 1.68                    | 7.2       | 8.4       | 4.2       | 9.6       | 0.56      | <b>31.6</b> | 20        | 632.8         |
| cold day      | 0.42                    | 5.7       | 6.6       | 4.2       | 7.6       | 0.28      | <b>24.8</b> | 60        | 1488.0        |
| moderate day  | 0                       | 4.2       | 4.2       | 2.1       | 5.6       | 0.14      | <b>16.2</b> | 60        | 974.4         |
| mild day      | 0                       | 0         | 0         | 0         | 5.6       | 0         | <b>5.6</b>  | 40        | 224.0         |
|               |                         |           |           |           |           |           |             | 180       | <b>3319.2</b> |

NB the estimated total usage, 3.3 tonnes, is approx equal to 4 truck loads. A few people quoted this sort of figure as total winter use, but for most it was more like 1 to 2 truckloads. So 3.3 tonnes/yr could be taken as representing a typical maximum, for the highest users.

#### 2. average theoretical wood use

Many users would be in the group that have no daytime heating during week days, as calculated below

|                    | Wood Use, kg per period |           |           |           |           |           | Total       | Days/year | Total          |
|--------------------|-------------------------|-----------|-----------|-----------|-----------|-----------|-------------|-----------|----------------|
|                    | 0000-0600               | 0600-0900 | 0900-1500 | 1500-1800 | 1800-2200 | 2200-2400 |             |           |                |
| very cold week day | 1.68                    | 3.6       | 0         | 0         | 9.6       | 0.56      | <b>15.4</b> | 16        | 247.0          |
| very cold weekend  | 1.68                    | 7.2       | 8.4       | 4.2       | 9.6       | 0.56      | <b>31.6</b> | 4         | 126.6          |
| cold week day      | 0                       | 0         | 0         | 0         | 7.6       | 0.14      | <b>7.7</b>  | 48        | 371.5          |
| cold weekend       | 0.42                    | 3.6       | 6.6       | 4.2       | 7.6       | 0.28      | <b>22.7</b> | 12        | 272.4          |
| moderate week day  | 0                       | 0         | 0         | 0         | 5.6       | 0.14      | <b>5.7</b>  | 48        | 275.5          |
| moderate weekend   | 0                       | 0         | 0         | 0         | 5.6       | 0.14      | <b>5.7</b>  | 12        | 68.9           |
| mild day           | 0                       | 0         | 0         | 0         | 0         | 0         | <b>0.0</b>  | 40        | 0.0            |
|                    |                         |           |           |           |           |           |             | 180       | <b>1361.92</b> |

#### 3. Proposed maximum usage rate per household, in kg/hr

(based on a 3: 1 combination of the above two scenarios)

|            | Wood Use, kg per period |             |             |             |              |             | Total daily, kg | avge daily, kg/hr |
|------------|-------------------------|-------------|-------------|-------------|--------------|-------------|-----------------|-------------------|
|            | 0000-0600               | 0600-0900   | 0900-1500   | 1500-1800   | 1800-2200    | 2200-2400   |                 |                   |
| weekend    | <b>0.3</b>              | <b>2.4</b>  | <b>1.4</b>  | <b>1.4</b>  | <b>2.4</b>   | <b>0.3</b>  | 31.6            | 1.3               |
| week day   | <b>0.3</b>              | <b>1.5</b>  | <b>0.4</b>  | <b>0.4</b>  | <b>2.4</b>   | <b>0.3</b>  | 19.5            | 0.8               |
| as % daily |                         |             |             |             |              |             |                 |                   |
| weekend    | <b>0.9%</b>             | <b>7.6%</b> | <b>4.4%</b> | <b>4.4%</b> | <b>7.6%</b>  | <b>0.9%</b> | <b>100.0%</b>   |                   |
| week day   | <b>1.4%</b>             | <b>7.7%</b> | <b>1.8%</b> | <b>1.8%</b> | <b>12.3%</b> | <b>1.4%</b> | <b>100.0%</b>   |                   |