Ministry for the
Environment
Manatū Mō Te Taiao

GEMS/AMIS Air Quality Monitoring Programme Annual Report 2006

Prepared for the Ministry for the Environment by:

Watercare Services Ltd
52 Aintree Avenue
Airport Oaks
PO Box 107 028
Auckland
Ph 09 539 7600
Fax 09 539 7601

Kath McLeod, Author
Lauren Jones, Peer Reviewer

Published in July 2007 by the
Ministry for the Environment
Manatū Mō Te Taiao
PO Box 10362, Wellington, New Zealand

ISBN: 978-0-478-30161-8
Publication number: ME 825

This document is available on the Ministry for the Environment's website:
www.mfe.govt.nz

Ministry for the Environment
Manatū Mō Te Taiao

Contents

Tables

Figures

1 Summary

This report contains the 2006 annual ambient air quality dataset, measured from two sites in Auckland and one site in Christchurch. These sites form New Zealand's contribution to the Global Environmental Monitoring System (GEMS).

The GEMS monitoring sites were established to measure key air pollutants associated with adverse effects on people's health and wellbeing. The GEMS sites include some of the longest running air quality monitoring sites in New Zealand. For example, various air quality monitoring has been undertaken at the Gavin Street, Penrose site in Auckland since 1964. These sites were established to determine the effects of policies for air quality management and are important for recording trends in pollution levels in New Zealand. The GEMS sites have provided long term continuity in monitoring data for Auckland and Christchurch, and provide an important snapshot of air quality for two of New Zealand's largest cities.

The two Auckland monitoring sites include a site dominated by residential and vehicle emissions (Kowhai Intermediate School, Kingsland) and a site representative of vehicle and industrial emissions (Gavin Street, Penrose). The Greers Road, Burnside site in Christchurch is located within a residential area and represents emissions from domestic properties.

Air pollutants arise from a number of different sources. Particulate matter (PM_{10}) arises principally from domestic heating, industrial processes and vehicle emissions (as well as natural processes such as soil erosion and sea salt). Sulphur dioxide is produced from the burning of fossil fuels, particularly coal and oil. Carbon monoxide is a product of incomplete combustion of carbon containing fuels, especially from motor vehicles. Volatile organic compounds (VOCs) are organic chemicals, such as hydrocarbons, that are closely tied to vehicle emissions and many industrial processes. Historically, lead was a petrol additive but since the significant reduction of lead in petrol from 1996, levels have declined in New Zealand.

Five ambient air quality standards for carbon monoxide, nitrogen dioxide, ozone, PM_{10} and sulphur dioxide were promulgated in October 2004. These standards are the minimum requirements that outdoor air quality must meet to guarantee a set level of protection for human health and the environment. The ambient standards are based on existing ambient air quality guidelines. Guideline levels for pollutants (and averaging periods) not covered by the standards still apply.

For most of the time, air pollutants at all sites during 2006 were below these standards. However, there were times when these standards were exceeded. There was one exceedance of the carbon monoxide eight-hour standard at Greers Road, Burnside. The ambient air quality standard for CO makes allowance for one eight-hour exceedance per year before the standard is breached. Also at Greers Road, Burnside, there were 21 exceedances of the 24-hour standard for PM_{10}, mainly during the colder months from May to July 2006. These exceedances were most likely caused by home heating emissions. The standard allows for one exceedance of the PM_{10} 24-hour threshold per year.

2 Introduction

This report presents the 2006 ambient air quality data set for Auckland and Christchurch, New Zealand. The monitoring is conducted by Watercare Services Ltd, on behalf of the Ministry for the Environment (MfE).

The MfE has a Memorandum of Understanding with the New Zealand Ministry of Health (MoH) to collect and supply air quality monitoring data to the World Health Organisation (WHO) from three sites – two in Auckland and one in Christchurch.

This data has historically formed New Zealand's contribution to the WHO's Global Environmental Monitoring System/Air Pollution Programme (GEMS/AIR) which began in 1973.[1]

In 1996 the WHO developed the Air Management Information System (AMIS) the successor to GEMS/AIR. The objective of AMIS is to transfer information on air pollutant concentrations and air quality management between countries and to support and help maintain air quality in parts of New Zealand that enjoy clean air, and to improve air quality in places where it has deteriorated.

As a result, monitoring from the AMIS programme is used by the MfE to support and enhance ambient air quality monitoring and management in Auckland and Christchurch. In fact the GEMS/AMIS ambient air quality sites are the longest running sites in New Zealand, and as such are very important in identifying local long term trends of air pollution.

The Auckland sites are located in the industrial area of Penrose to the southeast of the city centre and in Mt Eden and Kingsland, both of which are older residential areas just south of the city centre. Air quality monitoring has been performed in Penrose since 1964 and at Mt Eden between 1982 and 2004. In October 2004 the Mt Eden site was decommissioned pending redevelopment of the site and replaced by the Kingsland site at Kowhai Intermediate.

Between 1989 and 2002 monitoring was undertaken in Christchurch at a site located in the older residential area of St Albans which is just north of the city centre. Due to impending redevelopment of this site the monitoring station was relocated in November 2002 to a site in Burnside/Bishopdale which is a newer residential area to the north-west of the city centre.

Environment Canterbury provided sampling services for gravimetric and passive monitoring methods at Christchurch sites (Coles Place, St Albans and Greers Road Burnside).

This report includes graphical and statistical presentations of the data as well as any data collection issues that may have arisen during the monitoring period.

All data in this report has been completely validated. Quality assurance checks have been carried out to ensure invalid and calibration data is not reported.

---

[1] Schwela DH. 1999. Public health and the air management information system (AMIS). *Epidemiology* 10(5): 647–55.

3 Air Pollutants Monitored

3.1 Particulate matter

Particulate matter can be a significant air pollutant that is associated with a variety of health and environmental effects.

Sources of particulates vary widely from location to location reflecting the wide range of emission sources that contribute to particulate concentrations in New Zealand. Typical sources can include:

- fine particulates emitted as a result of fuel combustion such as those associated with road vehicles, power generation, industrial processes, domestic heating appliances and particulates formed by chemical reactions in the atmosphere (comprised largely of sulphates and nitrates)
- coarse particulates that arise from a wide range of sources, including resuspended dusts from road, vehicles, construction works, mineral extraction processes, wind-blown dusts and soils, sea salt, and biological particles such as pollen.

A variety of measurements can be used to determine the different health and environmental effects of particulate matter. As part of the GEMS/AMIS programme two particle size fractions are monitored:

- fine particulates (PM_{10})
- total suspended particulates (TSP).

3.1.1 Fine particulates (PM_{10})

As described above, particles with a diameter of 10 µm or less can be inhaled into the respiratory system. The main effect is on human health. The coarser fractions of airborne particles (2.5 µm to 10 µm) are deposited in the trachea bronchial region, where asthma attacks are triggered.

Particulate matter refers to numerous substances that exist in the atmosphere. It is a somewhat complex pollutant, encompassing a wide range of chemically and physically diverse substances. Particulate matter includes all solids and aerosols that exist in ambient conditions.

3.1.2 Total suspended particulate (TSP)

TSP consists of all particles which range in size up to 50 µm in diameter. TSP is sufficiently small enough to be inhaled; however, the larger particles (10–50 µm) are readily filtered out in the nasal cavity. Particles 10 µm and less can be drawn into the respiratory system. TSP has an effect on both the aesthetic and health quality of the ambient air.

3.2 Lead

Lead is a toxic metal emitted into the air both from motor vehicles that use leaded fuel and some industry. Since lead was removed from fuel in 1996 concentrations of lead in air have dropped markedly. In October 2000 monitoring of lead was reduced from monthly samples to samples taken over a three-month period during the winter period (June–August) only.

3.3 Sulphur dioxide

Sulphur dioxide is an acidic gas with a pungent odour, which is mainly produced by the burning of fossil fuels. The gas is quite corrosive and can cause damage to buildings and other materials.

It can also have significant effects on the human respiratory system. Inhalation of high ambient concentrations of sulphur dioxide can cause stimulation of the nerves in the air passages, resulting in a reflex cough, irritation and chest tightness.

In addition, sulphur dioxide can also cause narrowing of the air passages, particularly in people suffering from asthma and chronic lung disease. These people frequently have narrowed airways, and any further restriction will have a disproportionately large effect, compared to people with uncompromised respiratory systems.

3.4 Carbon monoxide

This colourless, odourless, toxic gas is formed as a product of incomplete combustion in the burning of fossil fuels. The main sources in most parts of New Zealand are motor vehicle exhaust emissions, and as such elevated levels are mainly found in areas of significant traffic congestion, particularly at busy intersections on inner-city streets.

Carbon monoxide acts on humans by displacing oxygen from the blood. Prolonged exposure at moderate levels can lead to symptoms such as headaches and dizziness, while at high levels it can lead to loss of consciousness and even death. At the lower levels typically encountered in urban areas, carbon monoxide measurements can serve as a useful indicator for objectionable levels of vehicle exhaust fumes.

3.5 Nitrogen oxides

Nitrogen oxides incorporate several species that exist in the atmosphere, which are collectively referred to as NO_x. The two main oxides are nitrogen dioxide (NO_2), which is of concern due to its potential to cause adverse health effects, and nitric oxide (NO), which is less toxic but may oxidise to NO_2 in the atmosphere.

Nitrogen oxides are formed in most combustion processes by oxidation of the nitrogen present in the atmosphere. Nitric oxide is the predominant primary product but, as indicated, this can then be oxidised to nitrogen dioxide in ambient air. Emissions from motor vehicles are the major source of the NO_x in most parts of the country, although power stations and other large combustion units may be significant localised sources as well.

The main adverse health effects of the oxides of nitrogen are due to NO_2, which is a respiratory irritant. Nitric oxide is believed to be quite harmless at the levels normally encountered in urban air.

NO_x is also an important air pollutant because of its role in photochemical smog. NO_2 is a reddish brown gas, and has synergistic effects with other pollutants such as SO_2 and particulate.

3.6 Volatile organic compounds

Volatile organic compounds are chemicals that easily evaporate at room temperature. The term 'organic' indicates that the compounds contain carbon.

To rationalise air quality guidelines, the Ministry for the Environment has compiled a list of priority contaminants, based on a review of international literature. The priority list includes the volatile organic compounds (VOC) benzene and 1,3-butadiene and provides ambient air quality guidelines for these contaminants (MfE 2002).

4 Ambient Air Quality Guidelines and Standards

In October 2004 the Ministry for the Environment introduced the National Environmental Standards (NES) for air quality. The NES includes five standards for ambient (outdoor) air quality. These and other New Zealand guidelines are described in Table 1 below.

The criteria applied to TSP, 60 µg/m^3 (seven-day average), was previously applied by the Ministry of Health. This has been superseded by the Ministry's Ambient Air Quality Guidelines but is useful for analysing the results of the monitoring data.

Table 1: National environmental standards, guidelines and regional targets[2]

Air pollutant	National environmental standards 2004	Ministry for the Environment Ambient Air Quality Guidelines 2002 and Other	Averaging period	National environmental standards permissible excess
Carbon monoxide	10 mg/m^3		8-hour average	One 8-hour period in a 12-month period
		30 mg/m^3	1-hour average	
Nitrogen dioxide		100 µg/m^3	24-hour average	
	200 µg/m^3		1-hour average	9 hours in a 12-month period
Sulphur dioxide		120 µg/m^3	24-hour average	
	350 µg/m^3		1-hour average	9 hours in a 12-month period
	570 µg/m^3		1-hour average	Not to be exceeded at any time
Benzene				
– Year 2000		10 µg/m^3	Annual average	
– Year 2010		3.6 µg/m^3	Annual average	
1,3-butadiene		2.4 µg/m^3	Annual average	
Fine particulate (PM_{10})		20 µg/m^3	Annual average	
	50 µg/m^3	50 µg/m^3 (Auckland Regional Council and Environment Canterbury)	24-hour average	One 24-hour period in a 12-month period
Total suspended particulate (TSP)		60 µg/m^3 (Ministry of Health[2]	7-day average	
Lead		0.2 µg/m^3	3-month average	

2 See http://www.mfe.govt.nz/laws/standards/air-quality-standards.html

5 Monitoring Sites

5.1 Site descriptions

A brief description of all the monitoring sites in the GEMS/AMIS air quality monitoring programme is given below. This includes the two Auckland sites at Gavin Street in Penrose and Kowhai Intermediate School in Kingsland, and two sites in Christchurch at Greers Road, in Burnside and Coles Place, in St Albans (note at Coles Place, only TSP and lead are monitored by the Ministry for the Environment).

5.1.1 MfE Kowhai, Auckland – site AKL073

<table>
<tr><td>Site name</td><td colspan="2">MfE Kowhai, Kingsland</td><td>Site ID</td><td>AKL073</td></tr>
<tr><td>Address</td><td colspan="2">Kowhai Intermediate School, Sandringham Road, Auckland</td><td>Site class</td><td>Residential – Peak</td></tr>
<tr><td colspan="5">Description
This site is located within the grounds of Kowhai Intermediate School. It is surrounded by residential properties on three sides as well as the school buildings which lie about 100 metres to the east. The busy New North Road is approximately 100 metres to the north of the site whilst Sandringham Road runs northwest to southeast past the site and Eden Park rugby ground which is within 300 metres to the southeast of the site. It is representative of emissions arising from road, vehicles as well as domestic properties in the older inner-city area of Kingsland which lies to the south of Auckland city centre. This is a new site commissioned in 2004, designed to replace the neighbouring Kelly Street site in Mt Eden which is due to be redeveloped. The new Kowhai site lies about 500 metres to the west of Kelly Street and both sites have the same ‘Residential – Peak’ classification. During 2004 a period of parallel monitoring between the two sites was undertaken before all monitoring was re-located to the new Kowhai site in October 2004.</td></tr>
<tr><td rowspan="2">Pollutants monitored</td><td>CO
N</td><td>NO_2
Y</td><td>SO_2
N</td><td>VOCs
Y</td></tr>
<tr><td>PM_{10}
Y</td><td>TSP
Y</td><td>Lead
Y</td><td rowspan="3"></td></tr>
<tr><td rowspan="2">Meteorological parameters monitored</td><td>Wind speed
Y</td><td>Wind direction
Y</td><td>Relative humidity
Y</td></tr>
<tr><td>Temperature (6 m)
Y</td><td>Temperature (10 m)
N</td><td>Temperature (2 m)
N</td></tr>
</table>

Location map	Photograph
	

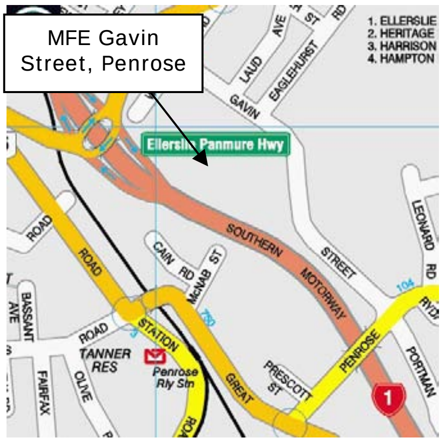
5.1.2 MfE Gavin Street, Penrose, Auckland – site AKL009

Site name	MfE Gavin Street, Penrose	**Site ID**	AKL009	
Address	Transpower, Gavin Street, Penrose, Auckland	**Site class**	Industrial – dense / traffic – peak	

Description

This site is located within the grounds of the Transpower New Zealand Limited electrical substation on Gavin Street. It is representative of road, vehicle and industrial emissions in the Penrose area which lies to the southeast of Auckland city centre and is also approximately 50 metres northeast of the Southern Motorway. There are residential properties immediately to the northeast of the site. During 2003 parallel monitoring was undertaken between this site and the neighbouring ACI site on Great South Road, in Penrose, with a view to consolidating all monitoring at the Gavin Street site early in 2004.

Pollutants monitored	**CO** N	**NO_2** Y	**SO_2** Y	**VOCs** Y
	PM_{10} Y	**TSP** Y	**Lead** Y	
Meteorological parameters monitored	**Wind speed** Y	**Wind direction** Y	**Relative humidity** Y	
	Temperature (6 m) Y	**Temperature (10 m)** N	**Temperature (2 m)** N	

Location map	Photograph
	

5.1.3 MfE Greers Road, Burnside, Christchurch – site CAN002

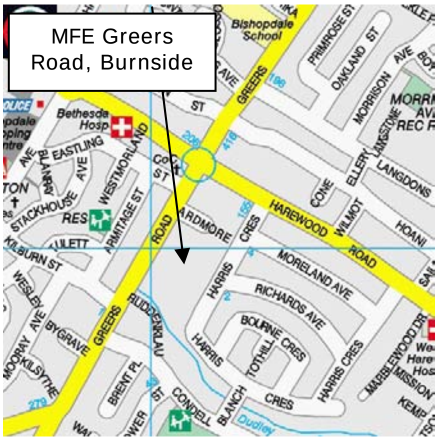
Site name	MfE Greers Road, Burnside	**Site ID**	CAN002
Address	Transpower, Greers Road, Burnside, Christchurch	**Site class**	Residential – Neighbourhood

Description

This site is located in a paddock to the rear of the Transpower New Zealand Limited electrical substation on Greers Road, and is surrounded by residential properties on four sides. It is representative of emissions arising from domestic properties in the newer suburban areas of Burnside and Bishopdale which lie to the northwest of Christchurch city centre.

Pollutants monitored	**CO** Y	**NO_2** Y	**SO_2** Y	**VOCs** Y
	PM_{10} Y	**TSP** N	**Lead** N	
Meteorological parameters monitored	**Wind speed** Y	**Wind direction** Y	**Relative humidity** Y	
	Temperature (6 m) N	**Temperature (10 m)** Y	**Temperature (2 m)** Y	

Location map



Photograph

5.1.4 MfE Coles Place, St Albans, Christchurch – site CAN003

Site name	MfE Coles Place,St Albans	**Site ID**	CAN003	
Address	Coles Place, St Albans, Christchurch	**Site class**	Residential – Neighbourhood	
Description This site is operated by Environment Canterbury and is located on an area of public open space at the end of Coles Place. It is surrounded by residential properties on four sides. It is representative of emissions arising from domestic properties in the older suburban area of St Albans which lies to the north of Christchurch city centre.				
Pollutants monitored	**CO** N	**NO_2** N	**SO_2** N	**VOCs** Y
	PM_{10} N	**TSP** Y	**Lead** Y	
Meteorological parameters monitored	**Wind speed** N	**Wind direction** N	**Relative humidity** N	
	Temperature (5 m) N	**Temperature (10 m)** N	**Temperature (2 m)** N	

Location map

Photograph

5.2 Air pollutants monitored at GEMS/AMIS sites

An overview of the air pollutants monitored at each site, as part of the GEMS/AMIS programme, is given in Table 2 below.

Table 2: Air pollutants monitored at GEMS/AMIS sites

Site	CO	NO_2	SO_2	VOC	PM_{10}	TSP	Lead*
Kowhai Intermediate, Kingsland AKL073		✓		✓	✓	✓	✓
Transpower, Gavin Street, Penrose, Auckland AKL009		✓	✓	✓	✓	✓	✓
Greers Road, Burnside, Christchurch CAN002	✓	✓	✓	✓	✓		
Coles Place, St Albans, Christchurch CAN003				✓		✓	✓

Note:

* Lead is monitored in the months of June, July and August only.

6 Methods

6.1 Quality assurance

All monitoring services are undertaken by Watercare Services Ltd in accordance with the Ministry for Environment's 'Good-practice Guide for Air Quality Monitoring and Data Management' and wherever applicable the appropriate Australian/New Zealand and US EPA monitoring methods.

Watercare Laboratory Services is accredited by IANZ (International Accreditation New Zealand) and since October 2003 has held accreditation for the following methods:

- Australian Standard AS 3580.7.1 – 1992 'Method 7.1: Determination of carbon monoxide – direct-reading instrumental method'
- Australian Standard AS 3580.5.1 – 1993 'Method 5.1: Determination of oxides of nitrogen – chemiluminescence method'
- Australian Standard AS 3580.4.1 – 1990 'Method 4.1: Determination of sulphur dioxide – direct reading instrumental method'
- US EPA Method 40, Part 50, Appendix J 'Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere'.

As part of the GEMS/AMIS programme, Watercare Laboratory Services provides the following monitoring services:

- Instrument operation, calibration and maintenance. This includes the use of automatic daily calibration systems for all continuous ambient gas monitors ensuring the requirements of the relevant Australian Standards for weekly calibration of continuous analysers are considered.
- Site maintenance as well as, when necessary, commissioning new sites and decommissioning old sites.
- Data logging, polling, checking, re-scaling, validation, ratification and reporting. This encompasses the entire data quality assurance process ensuring that the final dataset reported is fit for the purpose of the GEMS/AMIS programme.

6.2 Analytical methods

6.2.1 Carbon monoxide

Measurements are made in accordance with AS 3580.7.1 – 1992 'Determination of Carbon Monoxide – Direct Reading Instrumental Method'. The performance of the instrument is checked using an automatic calibration system ensuring compliance with the method which requires instrumentation to be calibrated on a weekly basis.

The instruments themselves are infra red absorption gas analysers which continuously measure carbon monoxide. This allows data to be analysed and reported over a variety of average periods, including 10 minutes, 24 hours and one year.

6.2.2 Nitrogen oxides

Measurements are made in accordance with AS 3580.5.1 – 1993 'Determination of Oxides of Nitrogen – Chemiluminescence Method'. The performance of the instruments is checked using an automatic calibration system ensuring compliance with the method which requires instrumentation to be calibrated on a weekly basis.

The instruments themselves are chemiluminescence gas analysers which continuously measure nitrogen oxides. This allows data to be analysed and reported over a variety of average periods, including 10 minutes, 24 hours and one year.

6.2.3 Sulphur dioxide

Measurements are made in accordance with AS 3580.4.1 – 1990 'Determination of Sulphur Dioxide – Direct Reading Instrumental Method'. The performance of the instruments is checked using an automatic calibration system ensuring compliance with the method which requires instrumentation to be calibrated on a weekly basis.

The instruments themselves are UV fluorescence gas analysers which continuously measure sulphur dioxide. This allows data to be analysed and reported over a variety of average periods, including 10 minutes, 24 hours and one year.

6.2.4 Volatile organic compounds

VOCs are measured each quarter (January–March, April–June, July–September and October–December) in accordance with the manufacturer's instructions (3M Technical Data Bulletin 1028).

VOC samples are taken using passive (3M) sampling badges, which are exposed for a three-month period. The VOCs diffuse on to the badges, which are coated with activated carbon. Following exposure the samples are forwarded to AgriQuality who extract the VOCs using carbon disulphide and analyse them using Gas Chromatography – Mass Spectrometry.

Note: Investigations have determined that samples of 1,3-butadiene are unstable when held above -4.41°C (BP) with significant reverse desorption occurring. Due to the potential for error over a three-month exposure period, 1,3-butadiene has not been analysed and reported. Alternative methods of measuring 1,3-butadiene are Occupational Safety and Health Administration Method 56 and National Institute of Occupational Safety and Health Method 1024. Both methods involve the use of solid sorbent coconut charcoal tubes.

6.2.5 Particulate matter (PM_{10})

Measurements are made in accordance with the US EPA equivalent method for measuring PM_{10} EQPM-1102-150 'Thermo Andersen Series FH62-C14 Continuous PM_{10} Ambient Particulate Monitor'. This method was designated as an Equivalent Method by the US EPA in accordance with 40 CFR Part 53 on 11 December 2002.

The Thermo Andersen FH62-C14 is fitted with a size-selective PM_{10} head and measures particle mass as it accumulates during sampling. As a result the instrument is able to record and output real-time measurements of PM_{10} data which allows measurements to be reported over a variety of average periods, including 10 minutes, 24 hours and one year. The inlet temperature of all beta-gauges operated by the Ministry for the Environment is 40°C.

6.2.6 Particulate matter (TSP)

Measurements of TSP are made in accordance with Watercare's Air Quality Group Test Method T101. It is a gravimetric method of measuring particulates and is modelled upon the High Volume sampler method. The technique has been used to provide TSP data at existing GEM/ AMIS sites since 1964.

The equipment used to measure TSP is quite basic and involves ambient air being pulled through a glass fibre filter by a pump with a gas meter being used to measure the air volume drawn through the filter. The filter is weighed before and after sampling. The TSP concentration is determined from the weight of particulates collected and the air volume sampled.

6.2.7 Lead

Lead is sampled during the winter months, June–August, using the same instrumentation used to measure TSP according to Watercare's Air Quality Group Test Method T101. This is a gravimetric technique used to measure particulates and is modelled upon the high volume sampler method. The technique has been used to provide TSP data at existing GEMS sites since 1964.

Analysis of lead is performed by Watercare Laboratory Services according to US EPA Methods 3051 and 200.7. This involves analysing each individual TSP filter exposed during the winter period using mixed acid digestion. This sample is then analysed for lead using the technique of Inductively Coupled Plasma – Optical Emission Spectrometry. The concentration of lead is then determined from the amount of lead detected and the total volume of air sampled during that sample period. Concentrations are then averaged for the three-month monitoring period.

7 Results and Discussion

7.1 Site performance and quality assurance

Valid data and data capture rates for NO_2, SO_2, CO, and PM_{10} from the Greers Road, Burnside site were below 90% for the month of May due to air conditioning problems. During November and December valid NO_2, SO_2, and CO data were also below 90% as the sampling lines fell inside the PVC housing. Annual valid NO_2, SO_2, and CO data were also less than 90% for 2006.

At Gavin Street, Penrose valid NO_2, and SO_2 data were below 90% for the month of June due to analyser faults and a power outage. Low valid SO_2 data was also recorded in July and August due to motor problems and communication faults. However, annual valid data for these pollutants were greater than 90% for 2006.

Continuously monitored pollutant's instrument performance during 2006 was generally very good, with all sites having annual data capture rates well over 90%. However, valid data and data capture rates for TSP at the St Albans site were less than 90% due to a faulty pump that was replaced in June 2006. Overall site performance is shown in Table 3 below, based on 10-minute averages for continuously monitored data. Percent data capture is the per cent of total instrument availability. Per cent valid data is defined as the per cent valid data following quality assurance adjustments.

Table 3: Percentage valid and capture data 2006

Analyte	Site	Percentage valid data (V) and Percentage data capture (C)																									
		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Annual	
		V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C
CO	Burnside	98.3	100	97.9	100	97.4	100	98.4	100	70.8	77.8	98.4	99.9	98.4	100	98.5	100	98.5	100	96.7	100	89.9	99.7	0.0	99.9	86.7	98.1
NO_2	Penrose	97.4	100	93.0	94.8	98.1	100	97.2	99.3	96.9	100	79.4	96.4	98.1	99.9	96.4	99.3	97.7	99.7	97.8	99.8	91.3	99.9	94.8	100	93.5	98.9
NO_2	Burnside	97.8	100	98.2	100	98.2	100	98.5	100	71.5	77.8	98.1	99.9	98.6	100	98.3	100	98.5	100	97.8	100	89.3	99.7	0.0	99.9	86.9	98.1
NO_2	Kowhai	98.7	100	97.7	100	94.8	96.3	98.3	99.9	98.4	100	93.9	95.5	95.8	97.6	94.7	96.4	91.5	100	97.5	100	98.1	100	98.1	100	96.5	98.8
SO_2	Penrose	97.6	100	92.1	94.8	97.1	100	96.1	99.3	97.1	100	83.4	96.4	81.5	99.9	84.9	99.3	96.6	99.7	96.7	99.8	96.8	99.9	97.0	100	92.9	98.9
SO_2	Burnside	98.5	100	98.0	100	97.4	100	97.7	100	71.0	77.8	97.0	99.9	97.7	100	97.1	100	97.8	100	97.7	100	88.8	99.7	0.0	99.9	86.4	98.1
PM_{10}	Burnside	98.4	100	99.1	100	99.1	100	99.1	100	60.7	77.8	98.1	99.9	98.4	100	98.9	100	99.1	100	98.8	100	97.7	99.7	97.5	99.9	95.4	98.1
PM_{10}	Kowhai	98.0	100	98.4	100	95.3	96.3	98.6	99.9	99.2	100	94.5	95.5	96.2	97.6	95.5	96.4	99.1	100	99.0	100	99.1	100	98.9	100	97.6	98.8
PM_{10}	Penrose	99.1	100	93.6	94.8	99.1	100	98.1	99.3	98.7	100	95.2	96.4	98.7	99.9	98.1	99.3	98.7	99.7	98.8	99.8	98.6	99.9	98.5	100	97.8	98.9
VOC	Penrose	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
VOC	Burnside	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
VOC	St Albans	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
TSP	St Albans	100	100	75	100	40	100	100	100	75	75	0	0	0	0	80	80	100	100	75	75	100	100	50	50	65.4	73.1
TSP	Penrose	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	50	100	100	100	100	100	94.2	100
TSP	Kowhai	100	100	100	100	100	100	100	100	80	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98.1	98.1
Lead	St Albans	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	80	80	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	80	80
Lead	Penrose	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	80	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	92.3	100
Lead	Kowhai	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	80	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	92.3	100

V = valid data

C = percent total captured data (includes calibration and invalid data)

7.2 Carbon monoxide (CO) 2006

CO was monitored at Greers Road, Burnside. One-hour and eight-hour averages have been calculated from 10-minute averages recorded by the instruments.

The maximum results and their dates are described below.

Site	1-hour maximum (mg/m^3)	99.9 percentile 1-hour (mg/m^3)	8-hour maximum (mg/m^3)	99.9 percentile 8-hour (mg/m^3)
Greers Road, Burnside	14.4 (9 June 22:00)	10.0	10.3 (10 June 02:00)	8.2

Results are given in Figures 6 to 9.

At Greers Road, Burnside during the 12-month period there were no exceedances of the ambient air quality one-hour guideline (30 mg/m^3). However, there was one exceedance of the eight-hour National Environmental Standard (10 mg/m^3) on 10 June 2006. Charts analysing this exceedance are described in Section 7.9. The NES allow for one CO eight-hour exceedance in a 12-month period.

7.3 Nitrogen oxides (NO_2 and NO) 2006

Oxides of nitrogen were monitored at Gavin Street, Penrose; Kowhai Intermediate, Kingsland; and Greers Road, Burnside. One-hour and 24-hour averages have been calculated from 10-minute averages recorded by the instruments.

The maximums for NO_2 and their dates for each site are described below.

Site	1-hour maximum ($\mu g/m^3$)	99.9 percentile 1-hour ($\mu g/m^3$)	24-hour maximum ($\mu g/m^3$)	99.5 percentile 24-hour ($\mu g/m^3$)
Gavin Street, Penrose	101.1 (8 June 11:00)	89.4	64.3 (7 June)	54.9
Kowhai Intermediate School, Kingsland	89.3 (3 July 13:00)	65.1	42.2 (5 July)	38.1
Greers Road, Burnside	83.7 (9 June 22:00)	69.4	44.9 (10 July)	38.8

Nitrogen dioxide results are in Figures 10 to 15 (Kowhai), 16 to 21 (Gavin Street), and 22 to 27 (Burnside).

There were no exceedances of the NO_2 ambient air quality one-hour standard (200 $\mu g/m^3$) or the 24-hour guideline (100 $\mu g/m^3$) during 2006 at any site in Auckland or Christchurch.

7.4 Sulphur dioxide (SO_2) 2006

Sulphur dioxide was monitored at Gavin Street, Penrose and Greers Road, Burnside. One-hour and 24-hour averages have been calculated from 10-minute averages recorded by the instruments.

The maximums for SO_2 and their dates for each site are described below.

Site	1-hour maximum (μg/m^3)	99.9 percentile 1-hour (μg/m^3)	24-hour maximum (μg/m^3)	99.5 percentile 8-hour (μg/m^3)
Gavin Street, Penrose	35.2 (20 June 13:00)	30.0	15.8 (23 June)	12.8
Greers Road, Burnside	58.7 (9 June 22:00)	38.5	26.7 (9 June)	13.8

Results for Gavin Street, Penrose are shown in Figures 28 and 29 and Greers Road, Burnside is shown in Figures 30 and 31. There were no exceedances of the SO_2 ambient air quality one-hour standard (350 μg/m^3) or the 24-hour guideline (120 μg/m^3) during 2006 at any site.

7.5 Volatile organic compounds (VOC) January–December 2006

Monitoring of VOCs was conducted at four sites, Kowhai Intermediate School, Kingsland; Gavin Street, Penrose; Greers Road, Burnside; and Coles Place, St Albans. VOC monitoring utilises passive sampling badges, exposed over a three-month period. A set of results for each 2006 quarter are shown in Tables 4 to 7. See monitoring method in section 4.

The benzene guideline is 10 μg/m^3 as an annual average, with an average value of 3.6 μg/m^3 to be achieved by 2010. The 2006 six-month and 12-month averages are described below.

Site	Six-month average (January–June 2006) Benzene (μg/m^3)	2006 annual average Benzene (μg/m^3)
Coles Place, St Albans	2.5	1.8
Greers Road, Burnside	2.2	1.6
Gavin Street, Penrose	1.3	1.1
Kowhai Intermediate School, Kingsland	1.5	1.3

Table 4: VOC results (January–March 2006)

January–February–March 2006 Analyte	Limit of detection (μg/m³)	Results (μg/m³)			
		Coles Place	Burnside	Gavin Street	Kowhai
Target VOCs					
Ethanol	ND				
Isopropyl alcohol	ND				
Acetone	ND				
Pentane	ND				
Dichloromethane	ND				
Butan-2-one	ND				
Hexane	0.5		1.0	1.0	1.0
Ethyl acetate	0.5			0.6	
Trichloromethane	ND				
1,1,1-trichloroethane	ND				
N-butanol	ND				
Benzene	0.3	0.6	0.5	0.8	0.9
2-methylhexane	ND				
2,3-dimethylpentane	ND				
3-methylhexane	ND				
Heptane	ND				
Trichloroethene	ND				
Propyl acetate	ND				
Methylcyclohexane	ND				
4-methylpentan-2-one	ND				
Toluene	0.3	3.4	2.9	6.0	5.8
Octane	ND				
Tetrachloroethene	ND				
Butyl acetate	ND				
Ethylbenzene	0.3	0.5	0.4	1.0	0.9
M+p-xylene	0.3	1.6	1.4	3.3	3.0
Styrene	ND				
O-xylene	0.3	0.6	0.5	1.1	1.0
Nonane	ND				
Alpha pinene	ND				
Propylbenzene	ND				
1,3,5-trimethylbenzene	ND				
Beta pinene	ND				
Decane	0.7			0.7	
1,2,4-trimethylbenzene	0.7	0.8		1.2	1.0
Limonene	ND				
Undecane	0.8			1.4	
Dodecane	ND				
Tetradecane	ND				

Note: ND = not detected

Table 5: VOC results (April–June 2006)

April–May–June 2006 Analyte	Limit of detection (µg/m³)	Results (µg/m³)			
		Coles Place	Burnside	Gavin Street	Kowhai
Target VOCs					
Ethanol	ND				
Isopropyl alcohol	ND				
Acetone	ND				
Pentane	2.2	2.5	2.6	3.1	2.6
Dichloromethane	ND				
Butan-2-one	ND				
Hexane	0.5	1.5	1.4	1.6	1.6
Ethyl acetate	0.5			0.9	
Trichloromethane	ND				
1,1,1-trichloroethane	ND				
N-butanol	ND				
Benzene	0.2	4.4	3.9	1.8	2.0
2-methylhexane	0.5	0.9	0.7	0.7	0.6
2,3-dimethylpentane	ND				
3-methylhexane	0.5	1.1	0.9	0.9	0.7
Heptane	0.5	0.9	0.7	0.9	0.6
Trichloroethene	0.5	0.5		0.5	0.6
Propyl acetate	0.5		0.5	0.6	
Methylcyclohexane	0.5			0.6	
4-methylpentan-2-one	ND				
Toluene	0.2	10.9	9.0	12.2	10.3
Octane	ND				
Tetrachloroethene	ND				
Butyl acetate	0.5			0.9	
Ethylbenzene	0.3	3.0	2.3	1.9	1.6
M+p-xylene	0.3	7.2	5.6	6.7	5.5
Styrene	ND				
O-xylene	0.3	2.6	2.1	2.3	1.9
Nonane	0.6			0.6	
Alpha pinene	0.7	0.8	0.9	0.8	
Propylbenzene	ND				
1,3,5-trimethylbenzene	0.6	0.8	0.6	0.8	0.7
Beta pinene	0.7	0.9	1.3	0.9	
Decane	0.6			1.0	
1,2,4-trimethylbenzene	0.6	2.6	2.1	2.2	2.1
Limonene	ND				
Undecane	0.7			1.7	
Dodecane	ND				
Tetradecane	ND				

Note: ND = not detected

Table 6: VOC results (July–September 2006)

July–August–September 2006 Analyte	Limit of detection (μg/m^3)	Results (μg/m^3)			
		Coles Place	Burnside	Gavin Street	Kowhai
Target VOCs					
Ethanol	ND				
Isopropyl alcohol	ND				
Acetone	ND				
Pentane	2.3			2.6	
Dichloromethane	ND				
Butan-2-one	ND				
Hexane	0.5	1.2	1.1	1.3	1.5
Ethyl acetate	0.5			0.7	0.5
Trichloromethane	ND				
1,1,1-trichloroethane	ND				
N-butanol	ND				
Benzene	0.2	1.9	1.4	1.4	1.6
2-methylhexane	ND				
2,3-dimethylpentane	ND				
3-methylhexane	0.5	0.5			
Heptane	0.5	0.5			
Trichloroethene	0.5			0.5	0.8
Propyl acetate	ND				
Methylcyclohexane	ND				
4-methylpentan-2-one	ND				
Toluene	0.3	6.6	4.8	9.1	9.6
Octane	ND				
Tetrachloroethene	ND				
Butyl acetate	0.5			0.7	
Ethylbenzene	0.3	1.1	0.7	1.3	1.2
M+p-xylene	0.3	4.2	2.9	5.8	5.9
Styrene	ND				
O-xylene	0.3	1.1	0.8	1.6	1.6
Nonane	ND				
Alpha pinene	ND				
Propylbenzene	ND				
1,3,5-trimethylbenzene	0.6				0.6
Beta pinene	ND				
Decane	0.7			0.7	
1,2,4-trimethylbenzene	0.6	1.3	0.9	1.7	1.7
Limonene	ND				
Undecane	0.7			1.2	
Dodecane	ND				
Tetradecane	ND				

Note: ND = not detected

Table 7: VOC results (October–December 2006)

October–November–December 2006 Analyte	Limit of detection (µg/m³)	Results (µg/m³)			
		Coles Place	Burnside	Gavin Street	Kowhai
Target VOCs					
Ethanol	ND				
Isopropyl alcohol	ND				
Acetone	ND				
Pentane	ND				
Dichloromethane	ND				
Butan-2-one	ND				
Hexane	0.4		0.5	0.5	0.5
Ethyl acetate	ND				
Trichloromethane	ND				
1,1,1-trichloroethane	ND				
N-butanol	ND				
Benzene	0.2	0.5	0.4	0.5	0.5
2-methylhexane	ND				
2,3-dimethylpentane	ND				
3-methylhexane	ND				
Heptane	ND				
Trichloroethene	ND				
Propyl acetate	ND				
Methylcyclohexane	ND				
4-methylpentan-2-one	ND				
Toluene	0.2	2.2	2.1	3.3	3.3
Octane	ND				
Tetrachloroethene	ND				
Butyl acetate	ND				
Ethylbenzene	0.3	0.4	0.3	0.5	0.5
M+p-xylene	0.3	1.2	1.1	1.8	1.7
Styrene	ND				
O-xylene	0.3	0.4	0.4	0.6	0.5
Nonane	ND				
Alpha pinene	ND				
Propylbenzene	ND				
1,3,5-trimethylbenzene	ND				
Beta pinene	ND				
Decane	ND				
1,2,4-trimethylbenzene	0.6			0.7	
Limonene	ND				
Undecane	0.7			1.3	
Dodecane	ND				
Tetradecane	ND				

Note: ND = not detected

7.6 PM_{10} 2006

PM_{10} is monitored at Greers Road, Burnside; Gavin Street, Penrose; and Kowhai Intermediate, Kingsland sites, using Thermo FH62-C14 Beta Gauges, and are included in this report. Twenty-four-hour averages have been calculated from 10-minute averages recorded by the instruments. All PM_{10} data is reported at standard temperature and pressure (0°C and 101.3 kPa).

The maximums for PM_{10} and their dates for each site are described below.

Site	24-hour maximum ($\mu g/m^3$)	99.5 percentile 24-hour ($\mu g/m^3$)
Gavin Street, Penrose	44.5 (7 June)	36.5
Kowhai Intermediate, Kingsland	40.0 (7 June)	35.5
Greers Road, Burnside	117.3 (14 June)	115.9

There were no exceedances of the ambient air quality standard (50 $\mu g/m^3$) at Gavin Street, Penrose or Kowhai Intermediate, Kingsland during the 12-month period.

At Greers Road, Burnside, there were 21 exceedances of the 24-hour standard. Each exceedance and the date are listed in Table 8 below. Charts describing 24-hour averaged data for 2006 for each site are shown in Figures 32 to 33 (Kowhai), 34 to 35 (Gavin Street), and 36 and 37 (Burnside). As there were exceedances at the Christchurch site, more data analysis was carried out in Section 7.9. All exceedances occurred over the winter period, a time when wood burning is widely used to heat homes. Cold winter conditions strongly influence air pollution in the region especially in calm conditions. All 21 exceedances occurred in cooler months between mid-May and July 2006.

Table 8: Greers Road, Burnside PM_{10} exceedances of the daily NES 2006

Date	Burnside PM_{10} ($\mu g/m^3$)
16/05/2006	66.3
17/05/2006	78.9
18/05/2006	68.5
6/06/2006	115.9
7/06/2006	86.1
8/06/2006	52.8
9/06/2006	93.7
10/06/2006	114.4
14/06/2006	117.3
15/06/2006	55.3
17/06/2006	51.3
20/06/2006	74.7
28/06/2006	54.9
9/07/2006	56.9
10/07/2006	116.3
11/07/2006	86.6
22/07/2006	82.3
23/07/2006	59.8
25/07/2006	59.3
26/07/2006	50.2
29/07/2006	62.3

Note: National Environmental Standard for PM_{10} = 50 $\mu g/m^3$

7.7 Total suspended particulates (TSP) 2006

TSP is measured as a seven-day average from, Gavin Street, Penrose; Kowhai Intermediate, Kingsland; and Coles Place, St Albans. Maximum results are shown in the table below.

Site	Maximum seven-day average ($\mu g/m^3$)
Gavin Street, Penrose	37 (5 July)
Kowhai Intermediate, Kingsland	48 (5 July)
Coles Place, St Albans	34 (3 August)

There were no exceedances of the Ministry of Health guideline of 60 $\mu g/m^3$ at any site. The data from each site is described in Figures 1 and 2 below.

Missing data information for 2006 at Coles Place, St Albans is as follows:

- earlier in the year (February to March), samples ran over seven days and were invalid
- mid-2006, the pump broke down in May and was replaced in July
- at the end of the year samples were missed over the Christmas period
- the other three data gaps were caused by technician error.

Figure 1: Auckland TSP seven-day average 2006

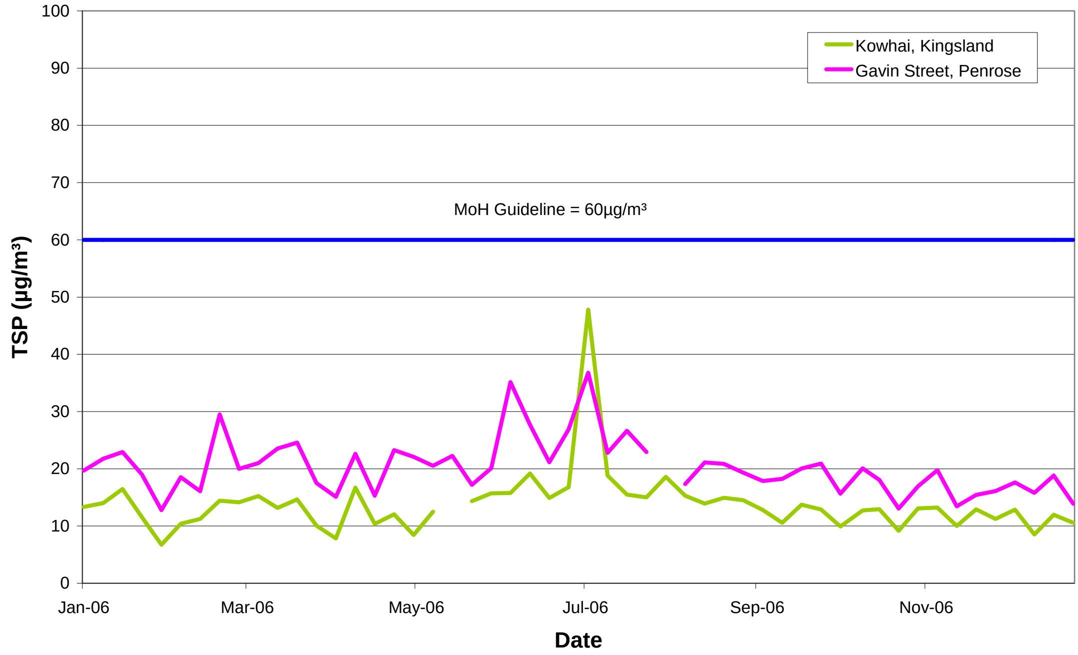


Figure 2: Auckland TSP seven-day average 1994–2006

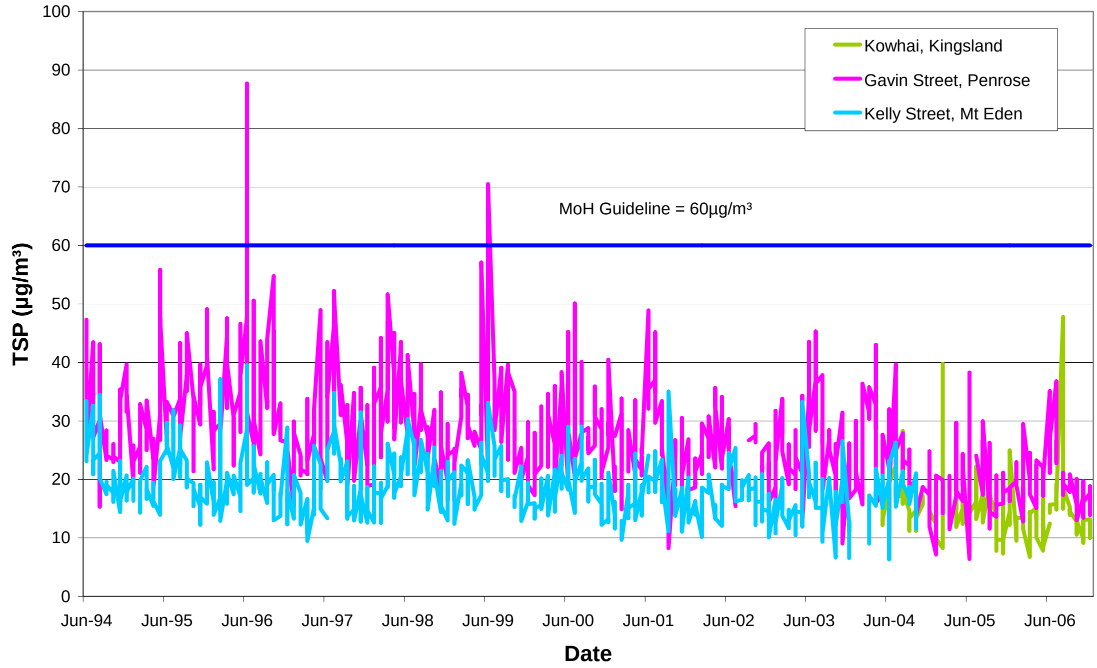


Figure 3: Christchurch TSP seven-day average 2006

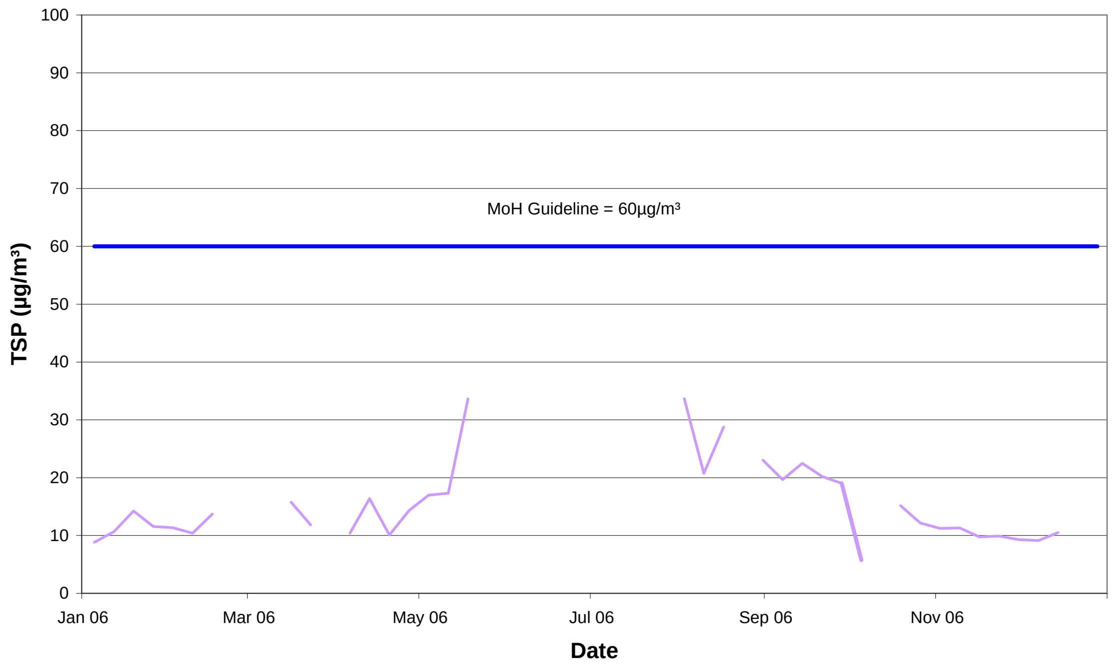
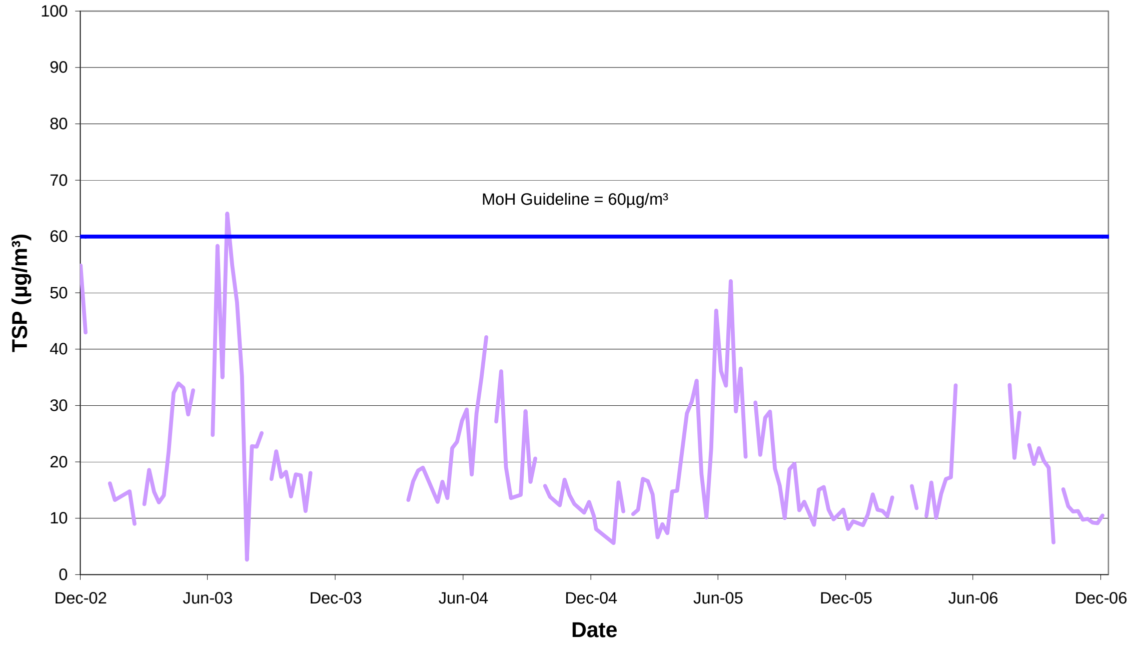


Figure 4: Christchurch TSP seven-day average 2002–2006



7.8 Lead (Pb) June–August 2006

Lead is measured from seven-day averaged TSP samples to derive a three-month average. The results are described in the Table below. Figure 5 provides moving three-month averaged lead data between January 1996 and September 2000 when lead monitoring was performed on a monthly basis. From this point lead continued to be monitored over a three-month period (June to August) annually.

Site	June 2006 average (µg/m³)	July 2006 average (µg/m³)	August 2006 average (µg/m³)	Winter 2006 average (µg/m³)
Kowhai Intermediate, Kingsland	0.023	0.019	0.012	0.018
Gavin Street, Penrose	0.018	0.015	0.008	0.014
Coles Place, St Albans	-	-	0.020	0.020

No site exceeded the three-month average guideline for lead (0.2 µg/m³).

Figure 5: MFE lead three-month average results 1996–2006

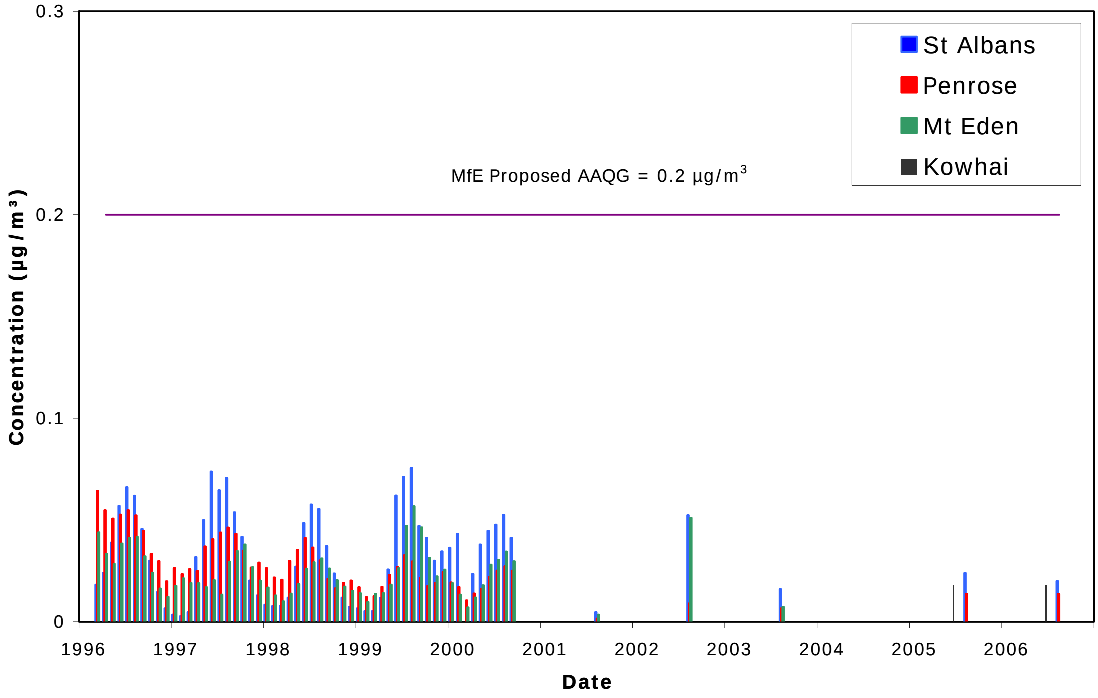


Figure 6: MFE Burnside CO one-hour fixed average January–December 2006

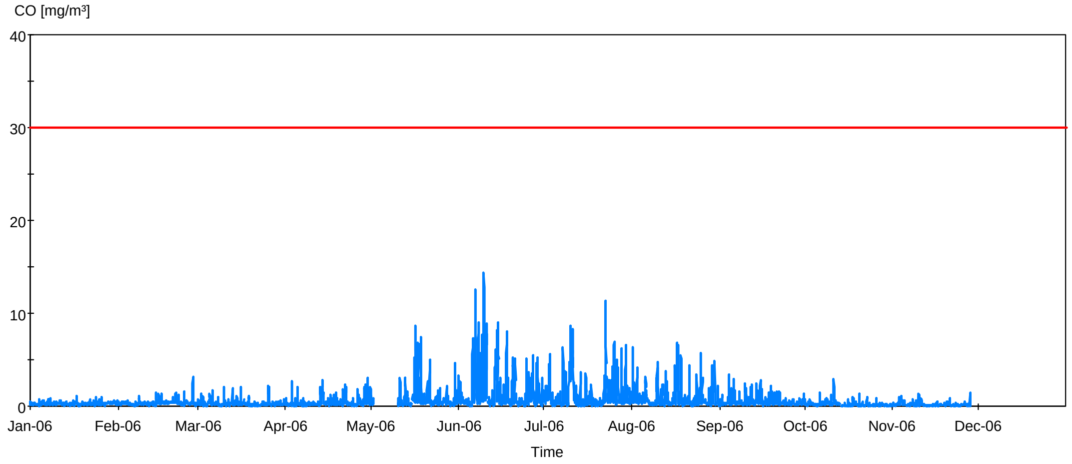


Figure 7: MFE Burnside CO one-hour fixed average 1 January 2003–31 December 2006

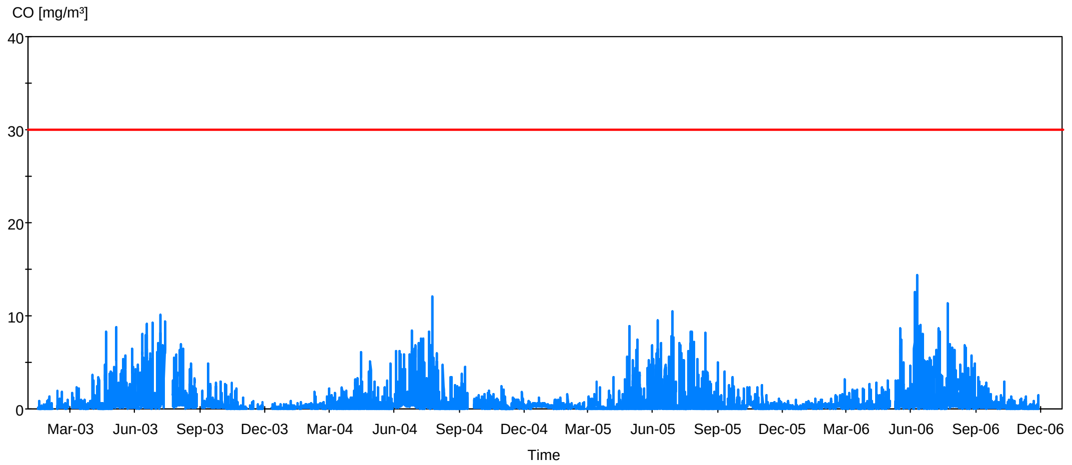


Figure 8: MFE Burnside CO eight-hour rolling average January–December 2006

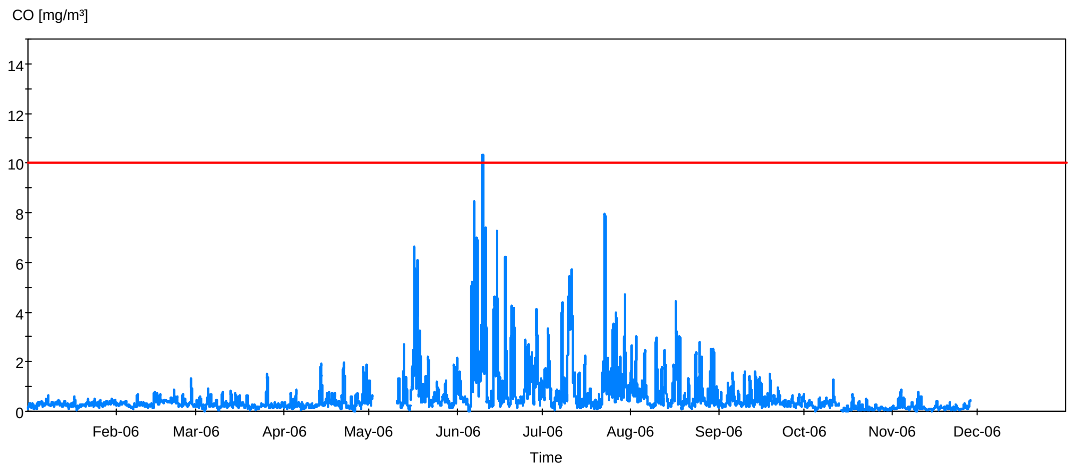


Figure 9: MFE Burnside CO eight-hour rolling average 1 January 2003–31 December 2006

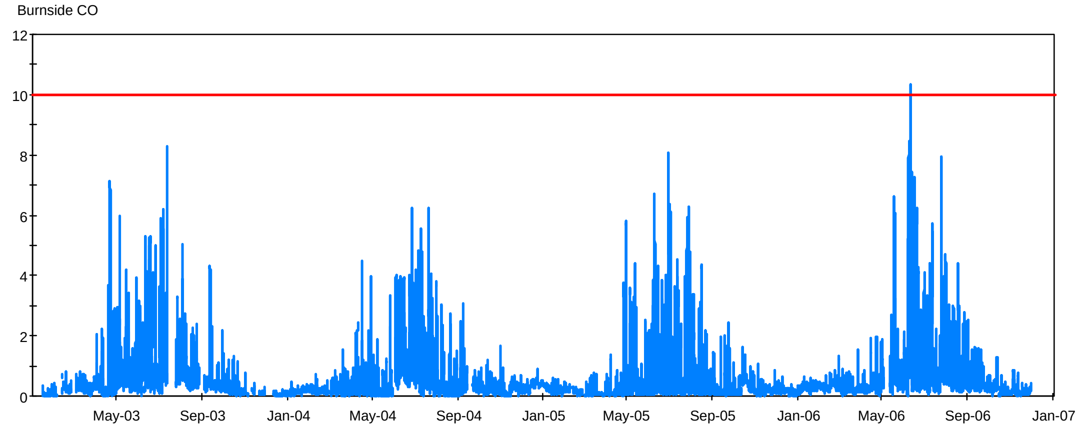


Figure 10: MFE Kowhai NO_2 one-hour fixed average January–December 2006

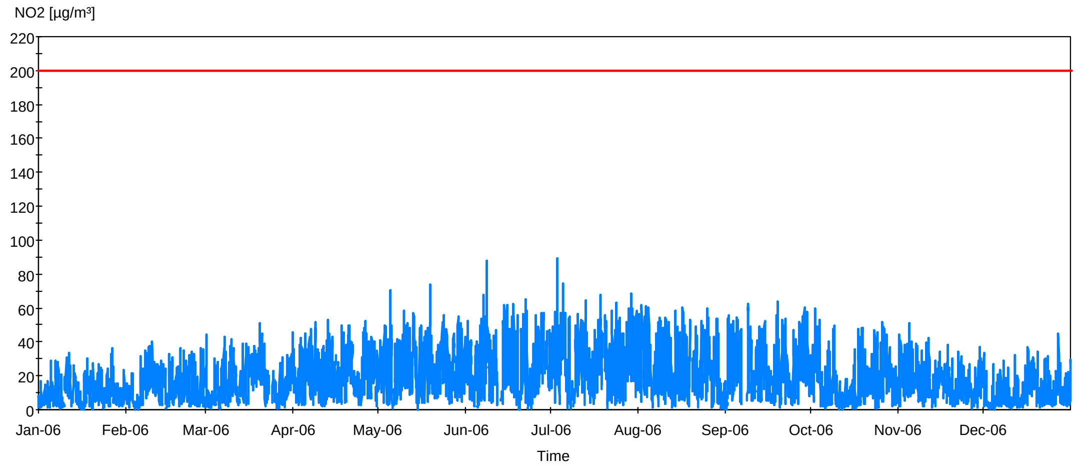


Figure 11: MFE Kowhai NO_2 one-hour fixed average 1 January 2004–31 December 2006

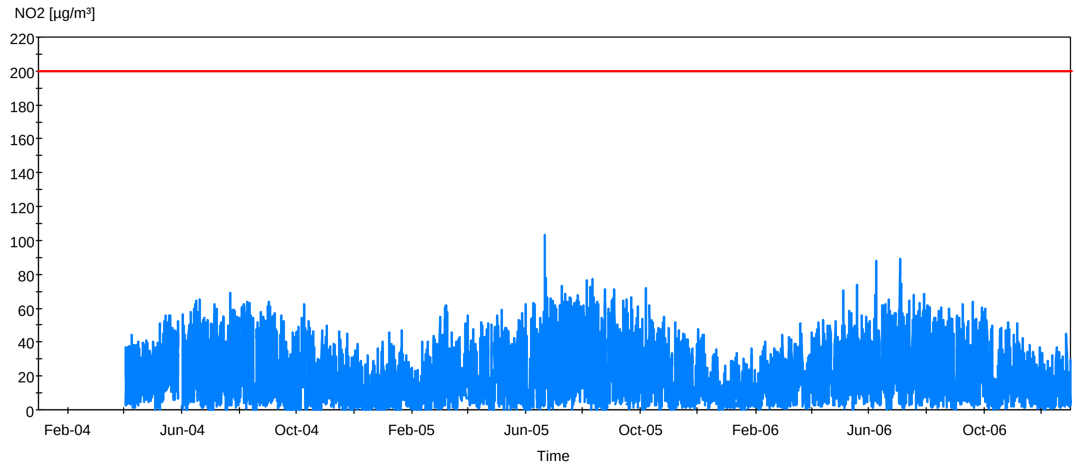


Figure 12: MFE Kowhai NO_2 24-hour fixed average January–December 2006

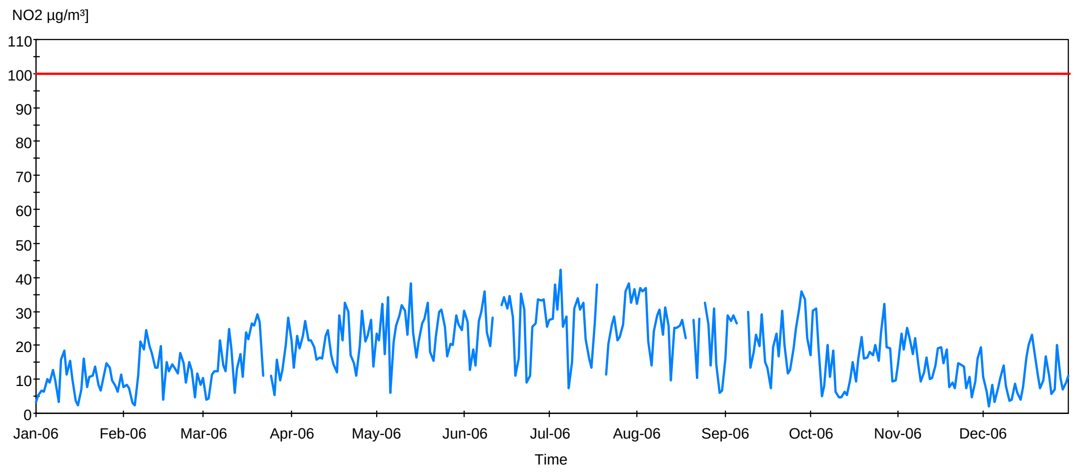


Figure 13: MFE Kowhai NO_2 24-hour fixed average 1 January 2004–31 December 2006

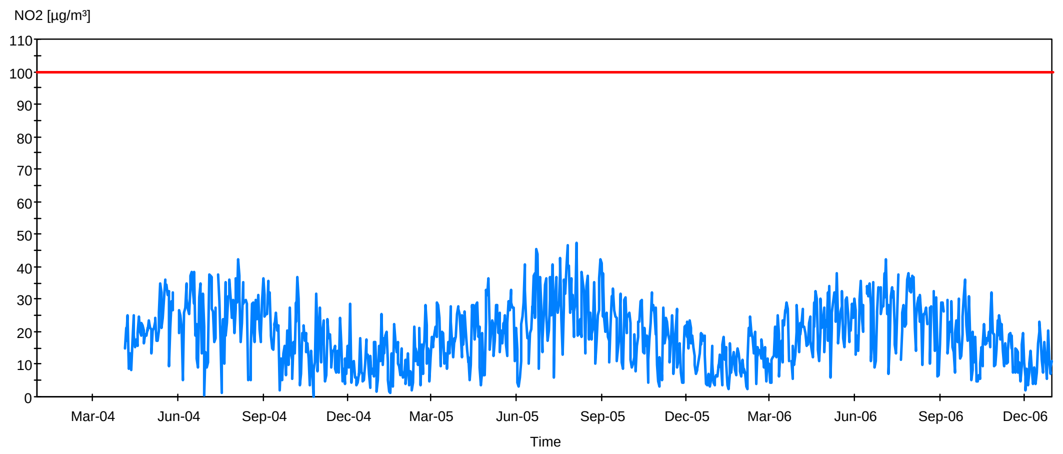


Figure 14: MFE Kowhai NO_2 and NO one-hour fixed average January–December 2006

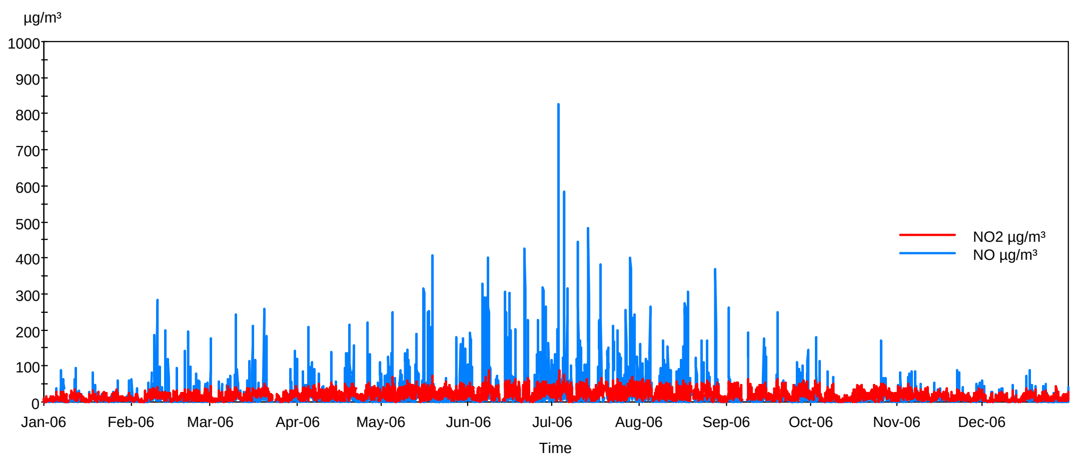


Figure 15: MFE Kowhai NO_2 and NO 24-hour fixed average January–December 2006

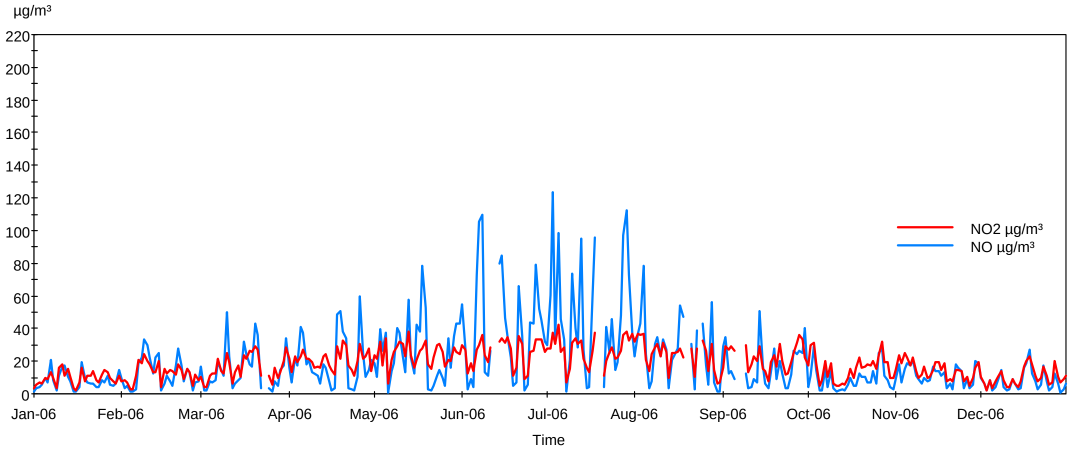


Figure 16: MFE Gavin Street NO_2 one-hour fixed average January–December 2006

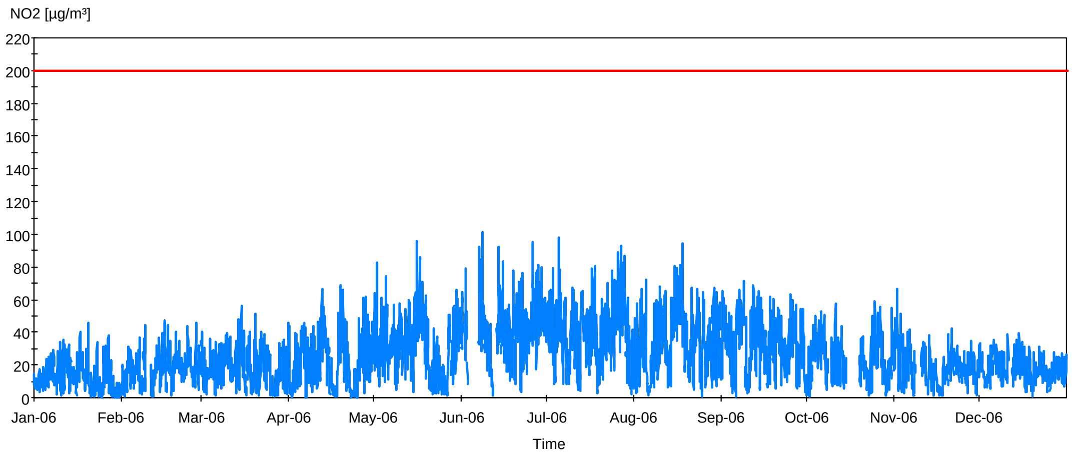


Figure 17: MFE Gavin Street NO_2 one-hour fixed average 1 January 1997–31 December 2006

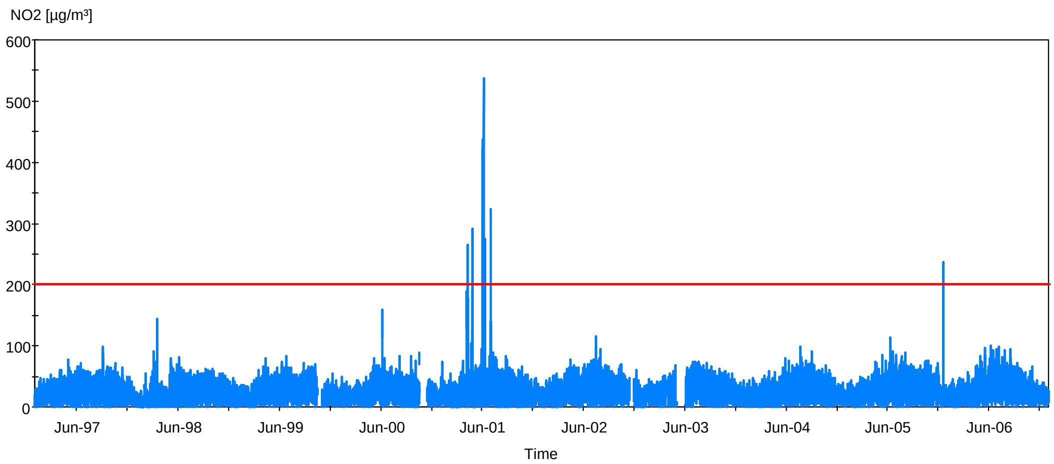


Figure 18: MFE Gavin Street NO_2 24-hour fixed average January–December 2006

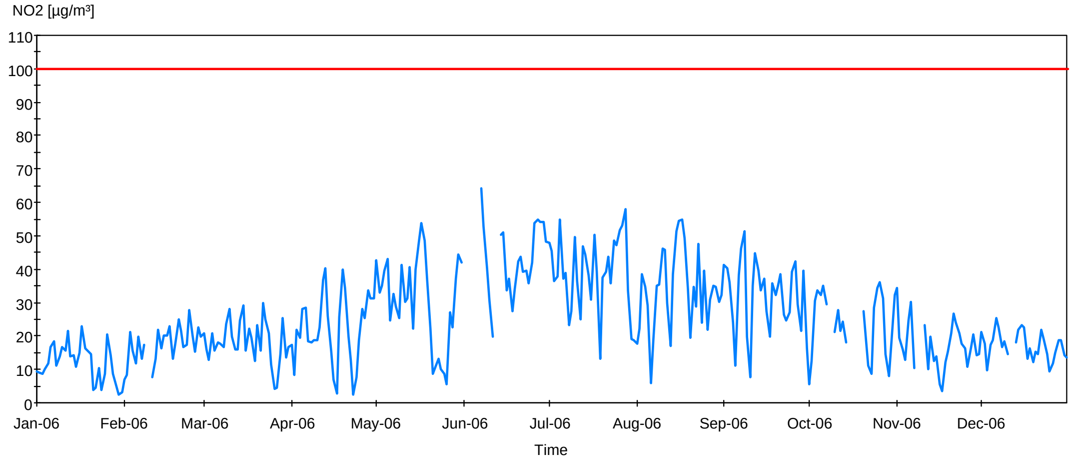


Figure 19: MFE Gavin Street NO_2 24-hour fixed average 1 January 1997–31 December 2006

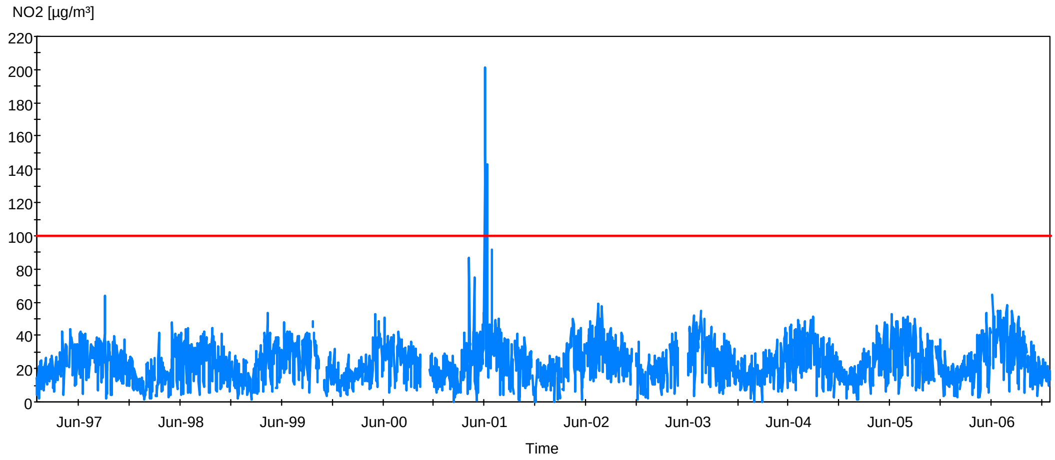


Figure 20: MFE Gavin Street NO_2 and NO one-hour fixed average January–December 2006

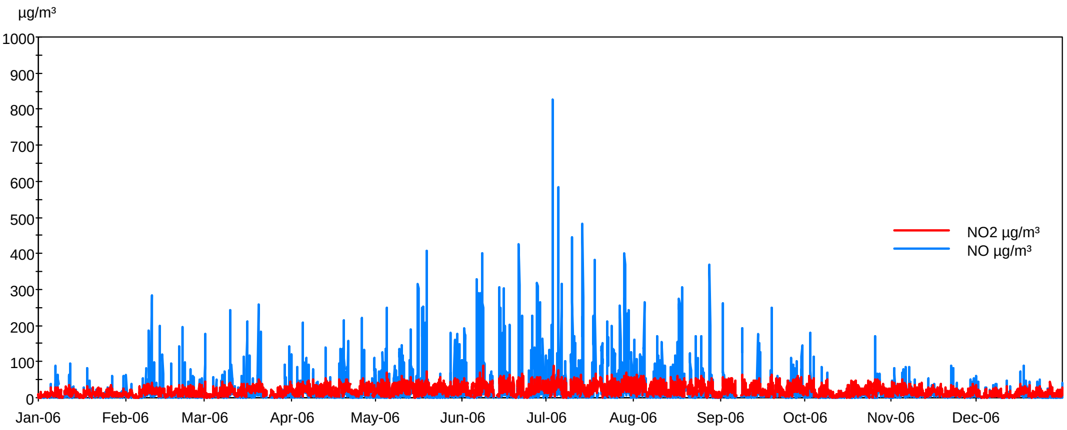


Figure 21: MFE Gavin Street NO_2 and NO 24-hour fixed average January–December 2006

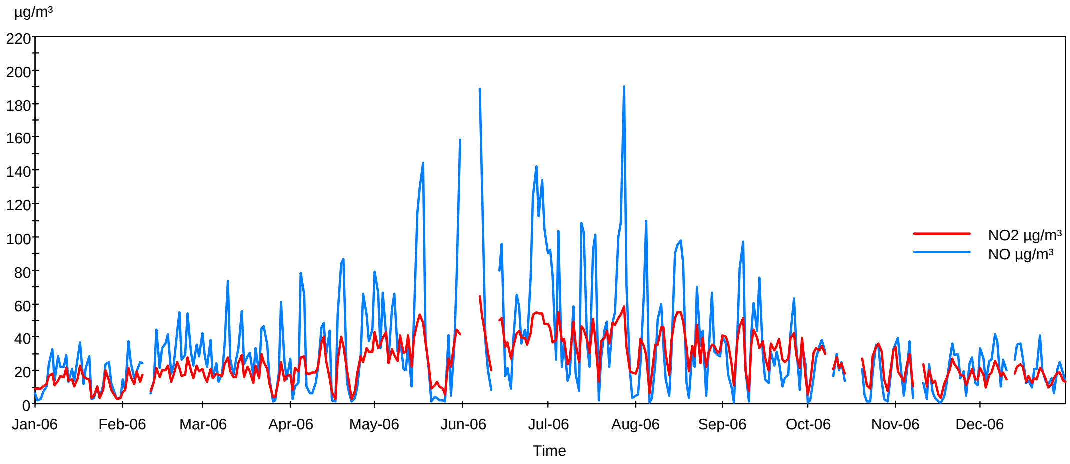


Figure 22: MFE Burnside NO_2 one-hour fixed average January–December 2006

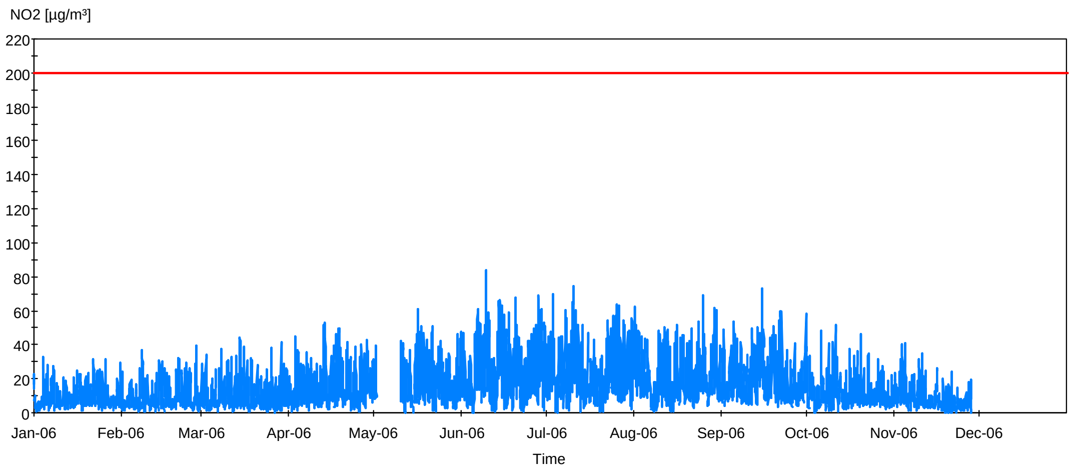


Figure 23: MFE Burnside NO_2 one-hour fixed average 1 January 2003–31 December 2006

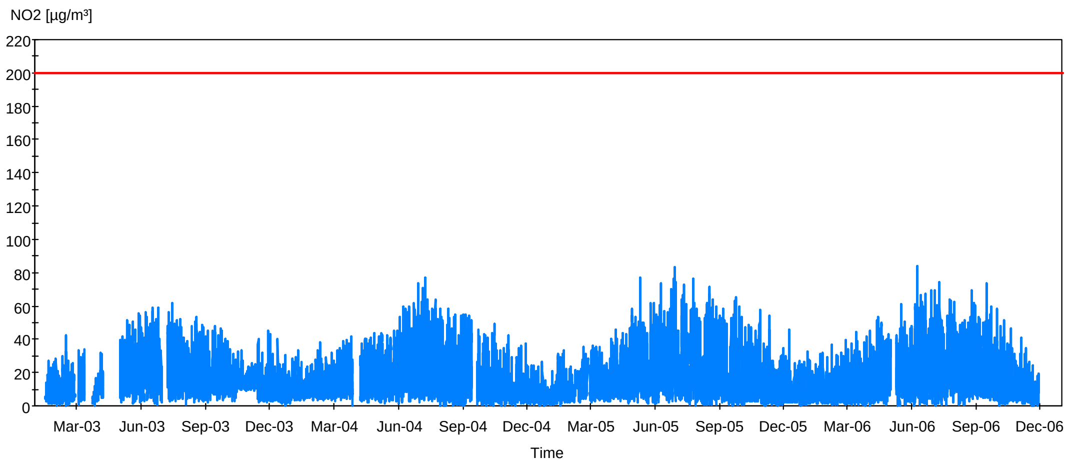


Figure 24: MFE Burnside NO_2 24-hour fixed average January–December 2006

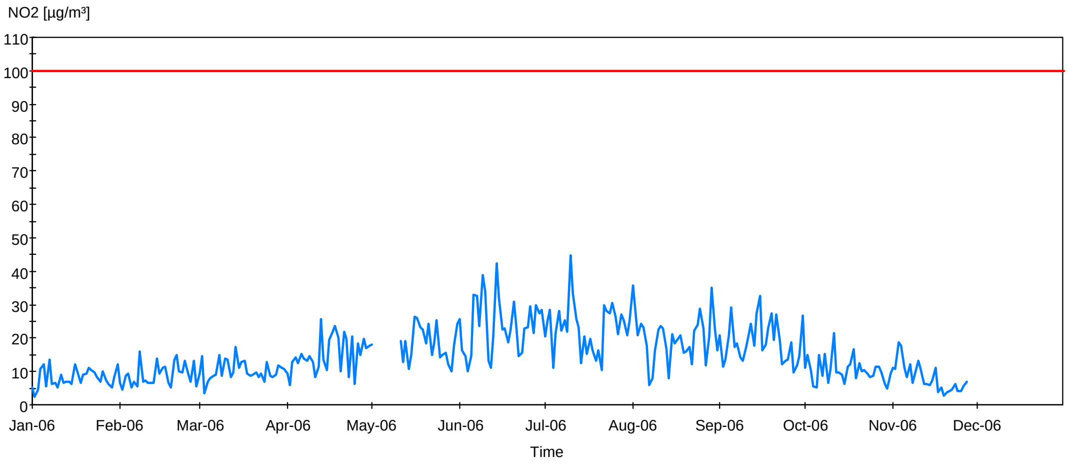


Figure 25: MFE Burnside NO_2 24-hour fixed average 1 January 2003–31 December 2006

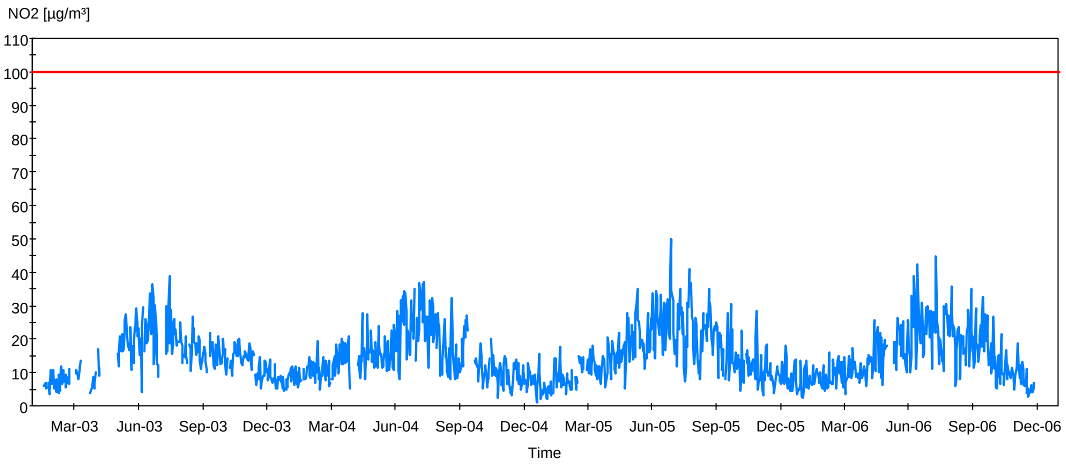


Figure 26: MFE Burnside NO_2 and NO one-hour fixed average January–December 2006

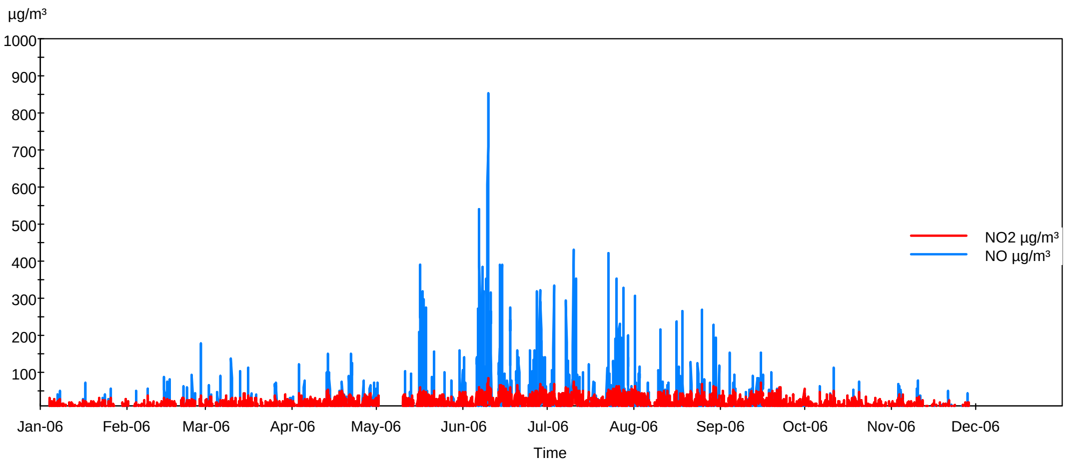


Figure 27: MFE Burnside NO_2 and NO 24-hour fixed average January–December 2006

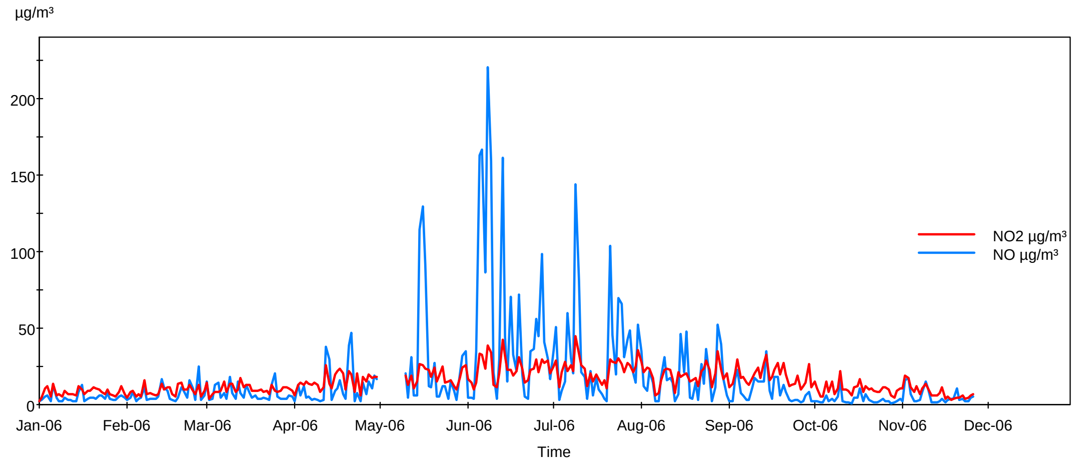


Figure 28: MFE Gavin Street SO_2 one-hour fixed average January–December 2006

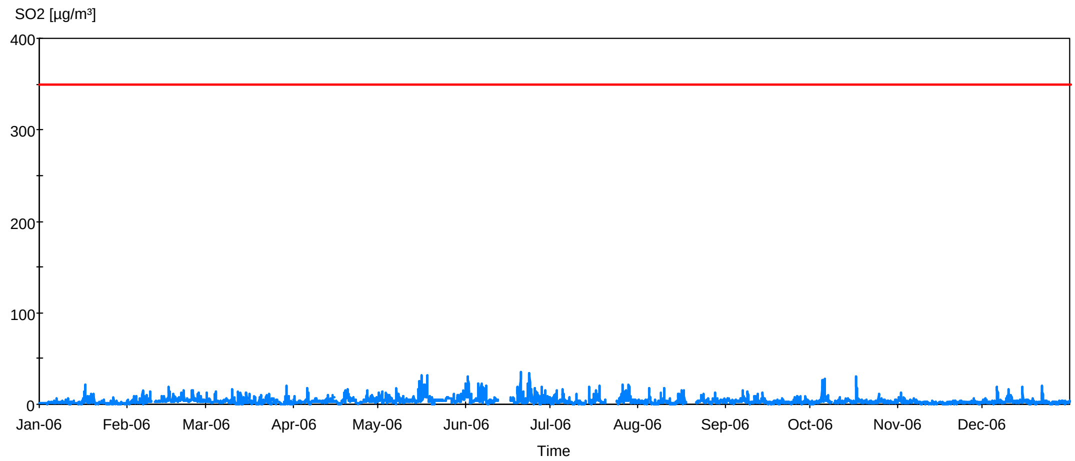


Figure 29: MFE Gavin Street SO_2 24-hour fixed average January–December 2006

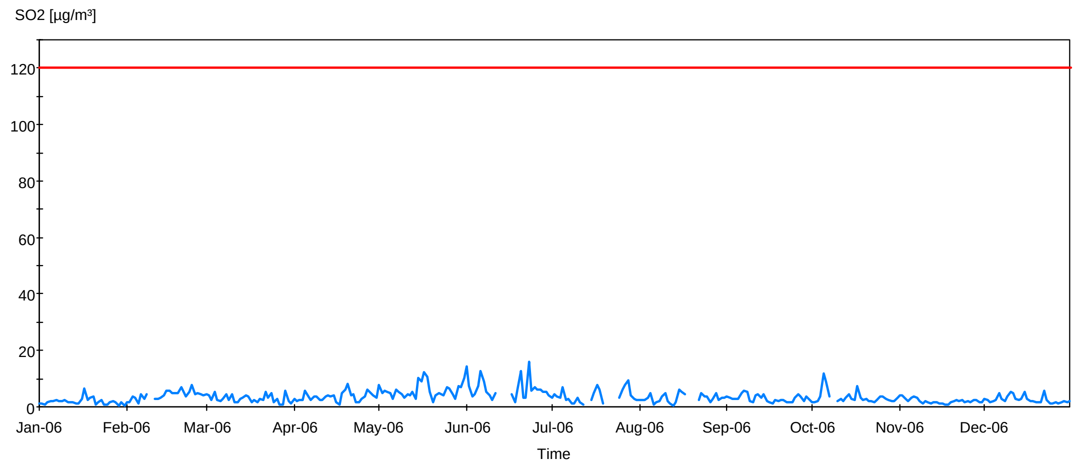


Figure 30: MFE Burnside SO_2 one-hour fixed average January–December 2006

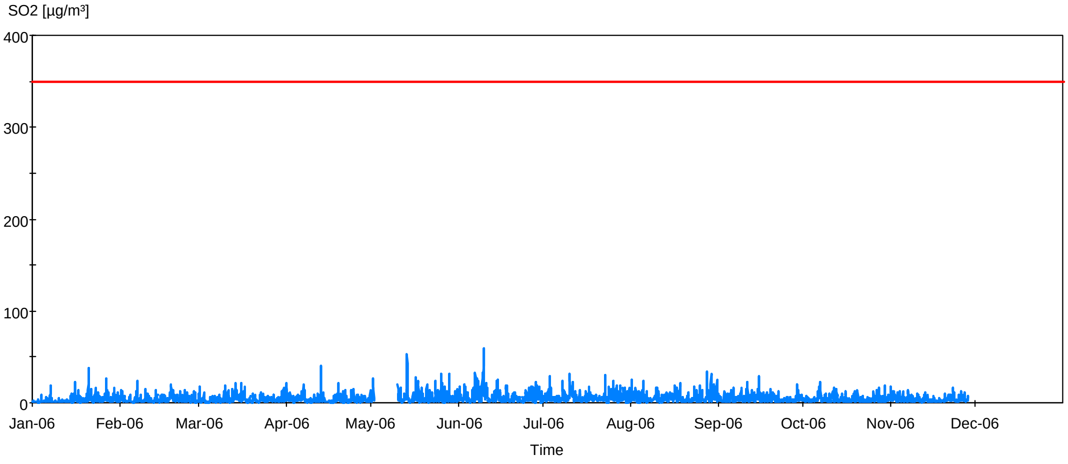


Figure 31: MFE Burnside SO_2 24-hour fixed average January–December 2006

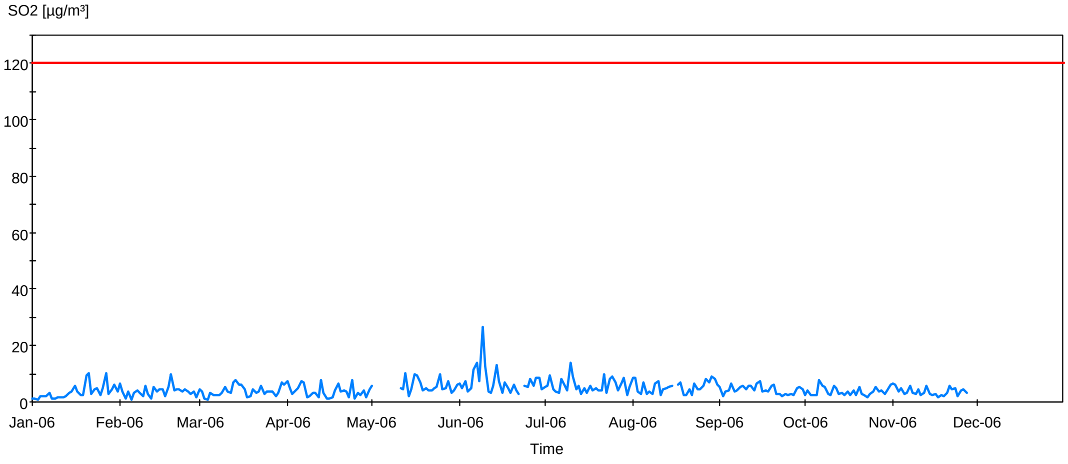


Figure 32: MFE Kowhai PM_{10} 24-hour fixed average January–December 2006

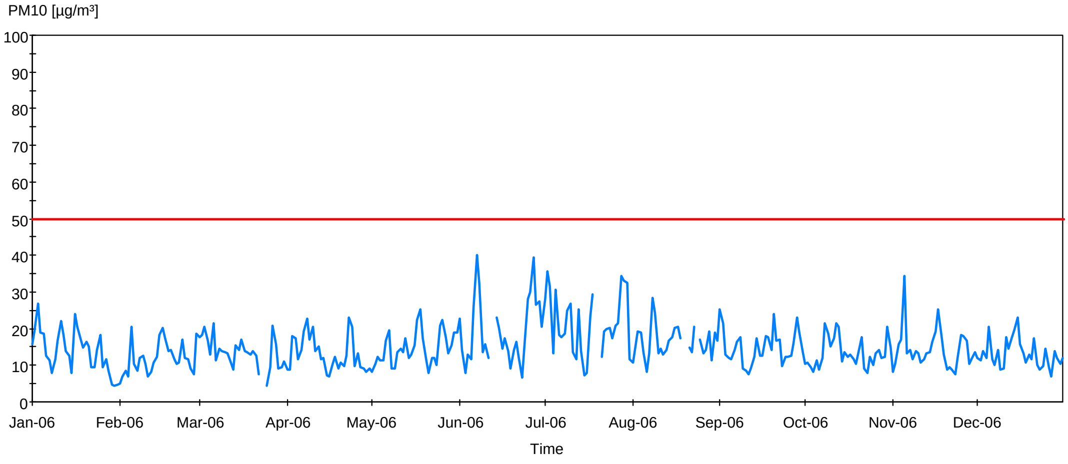


Figure 33: MFE Kowhai PM_{10} 24-hour fixed average 1 January 2004–31 December 2006

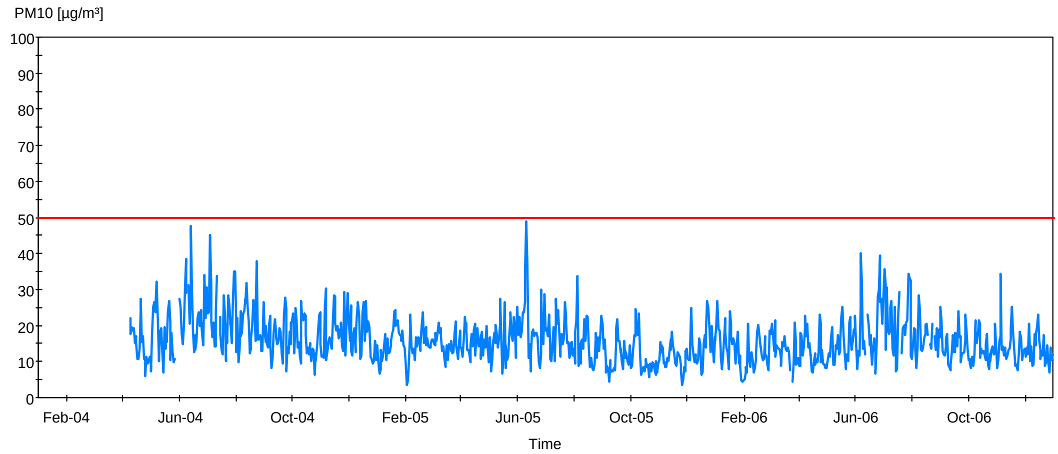


Figure 34: MFE Gavin Street PM_{10} 24-hour fixed average January–December 2006

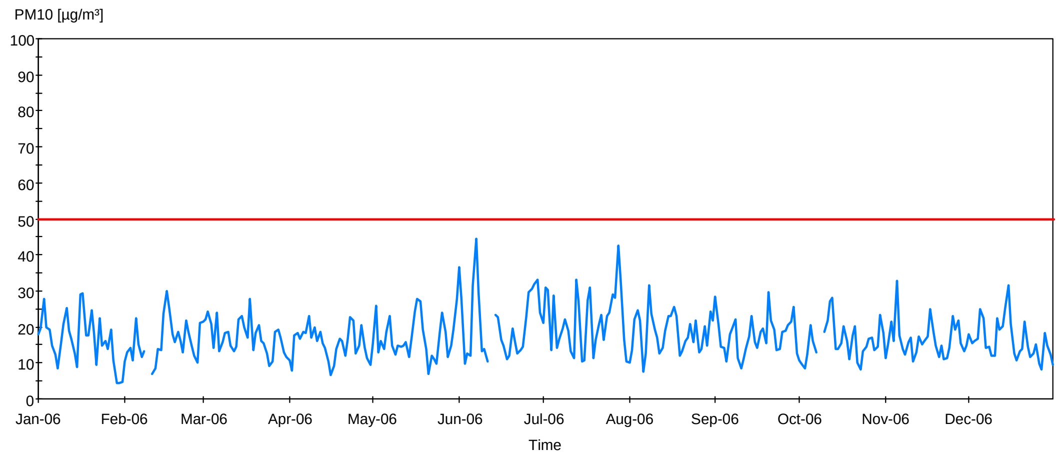


Figure 35: MFE Gavin Street PM_{10} 24-hour fixed average 1 January 2003–31 December 2006

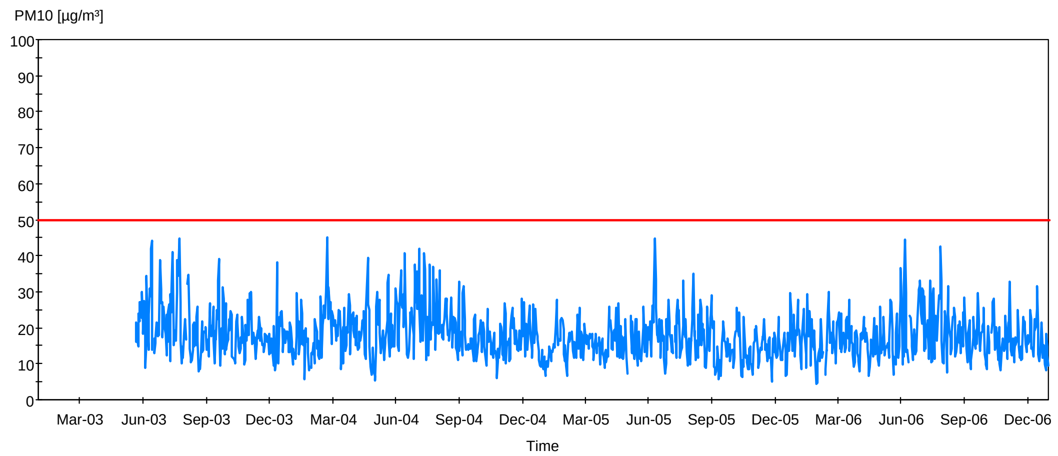


Figure 36: MFE Burnside PM_{10} 24-hour fixed average January–December 2006

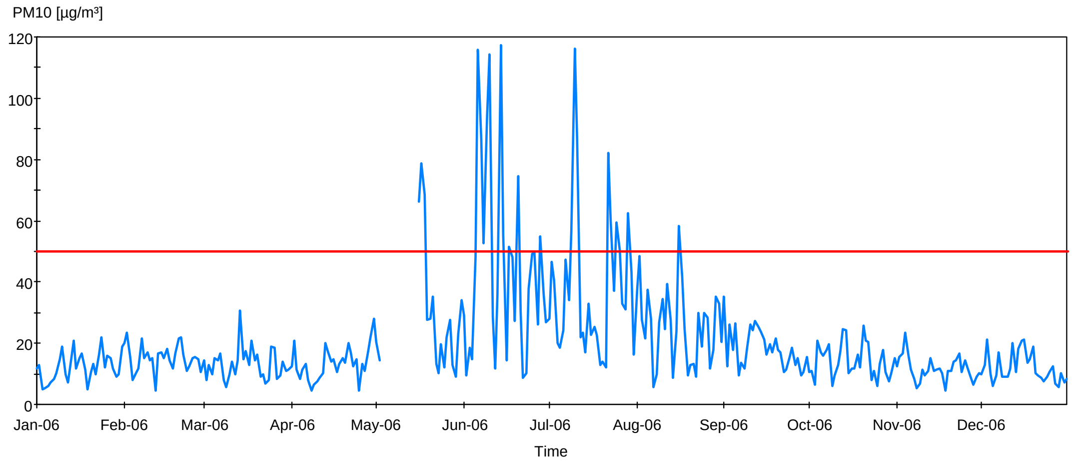
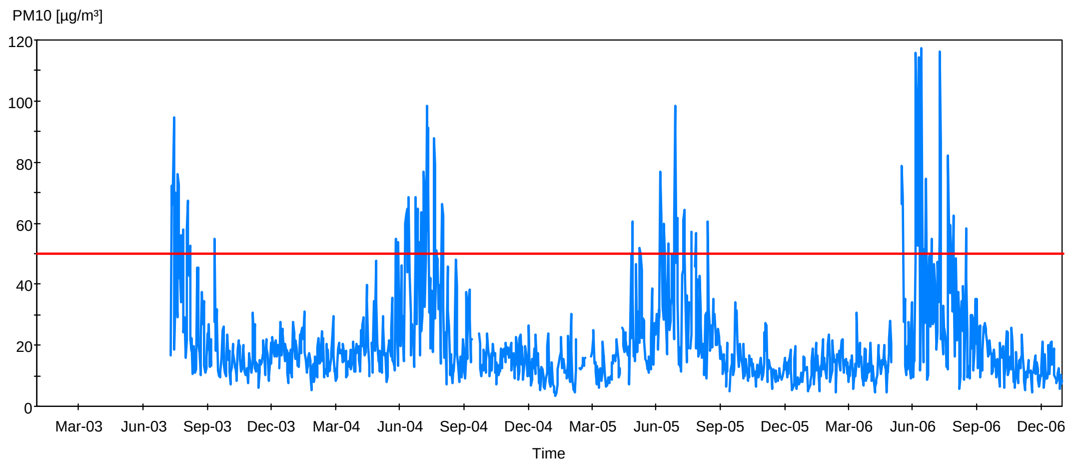


Figure 37: MFE Burnside PM_{10} 24-hour fixed average 1 January 2003–31 December 2006



7.9 Analysis of exceedances

7.9.1 Exceedances at Greers Road, Burnside

A 72-hour period, 9–11 June 2006, has been chosen as a typical example of winter diurnal trends coinciding with PM_{10} and CO exceedances, to describe the relationship between pollution levels and meteorological conditions. Figures 38 and 39 provide an example of the typical diurnal trend in PM_{10} and CO respectively during this period. Figures 40 to 42 present the meteorological conditions that influence the diurnal trend. It is apparent when comparing wind speed (Figure 40) with PM_{10} and CO concentrations that low wind speeds coincide with PM_{10} and CO peaks and conversely higher wind speeds coincide with low PM_{10} and CO concentrations. Reduced air mixing, caused by low wind speeds results in poor dispersion of pollution, while an unstable atmosphere caused by high wind speeds, is conducive to pollution dispersion. Wind rose analysis (Figure 42) shows the predominant wind was from a north north east direction with 32% calm.

Low temperatures, often coinciding with still atmospheric conditions, can cause temperature inversions. This can contribute to higher PM_{10} and CO concentrations being measured as pollution is trapped at ground level. A comparison of temperatures measured at 1.5 and 10m (Figure 44) does not indicate the presence or absence of a temperature inversion as the inversion height may be greater than 10m, however, a diurnal trend is apparent. As the temperature drops during the evening, Christchurch residents light their heating appliances causing PM_{10} and CO levels to peak just before midnight. As the fires die down and the atmosphere becomes more unstable toward morning, concentrations of PM_{10} and CO drop off.

A pollution rose for the same 72-hour period (Figures 43 and 44) describes the relationship between wind directions, wind speed and pollutant concentrations with 0% calm. Both pollution roses show no obvious patterns. This suggests that the incidents are related to meteorological conditions such as temperature inversions.

> Temperature inversions occur when the ground temperature falls below the surrounding air temperature. Air in contact with the ground is cooled to a lower temperature than the air layers above it. As an inversion continues, air becomes stagnant and pollution becomes trapped in the mixing layer close to the ground.

Figure 38: MFE Burnside PM_{10}, 10-minute fixed average 9–11 June 2006

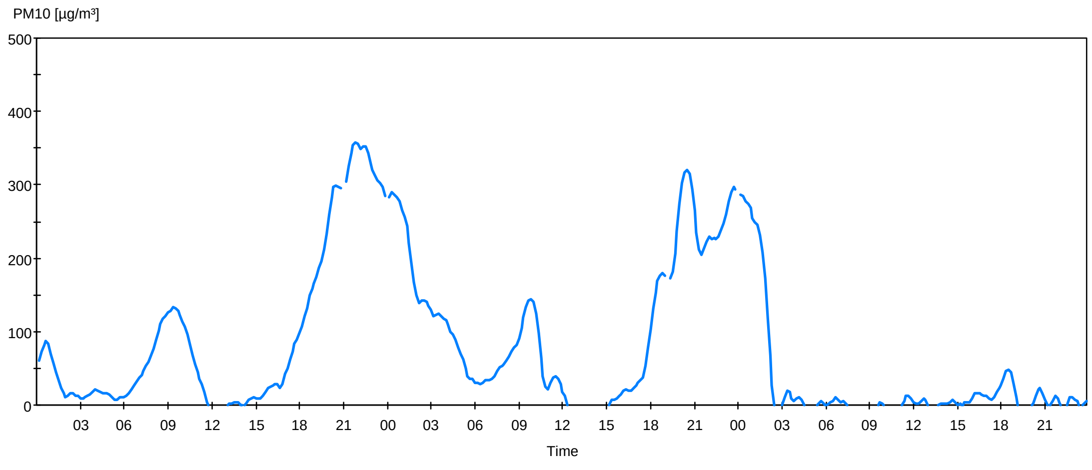


Figure 39: MFE Burnside CO, 10-minute fixed average 9–11 June 2006

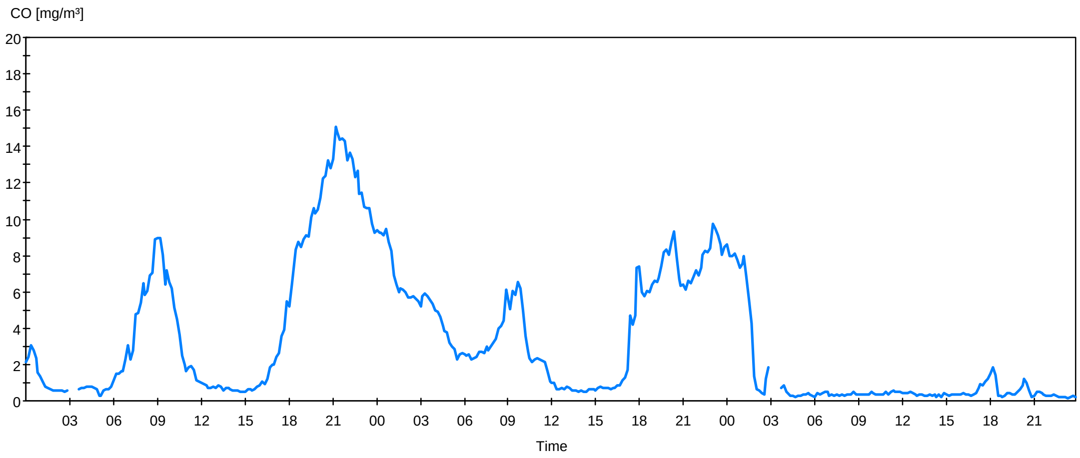


Figure 40: MFE Burnside wind speed, 10-minute fixed average 9–11 June 2006

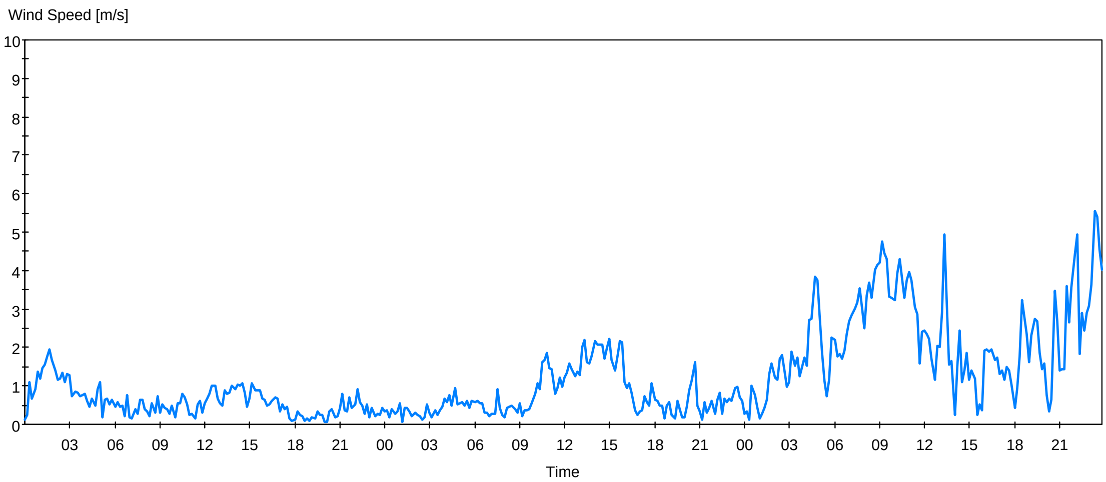


Figure 41: MFE Burnside ambient temperature, 10-minute fixed average 9–11 June 2006

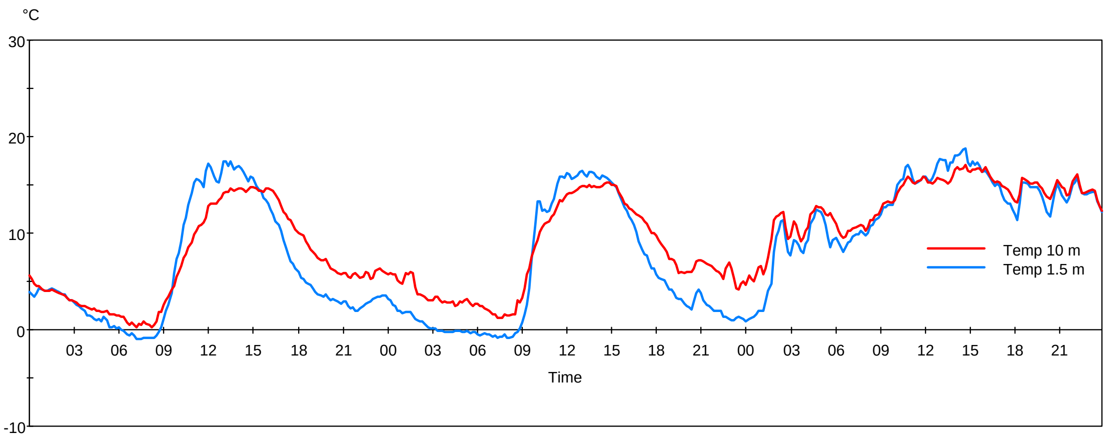


Figure 42: MFE Burnside pollution rose, wind speed 10-minute average 9–11 June 2006

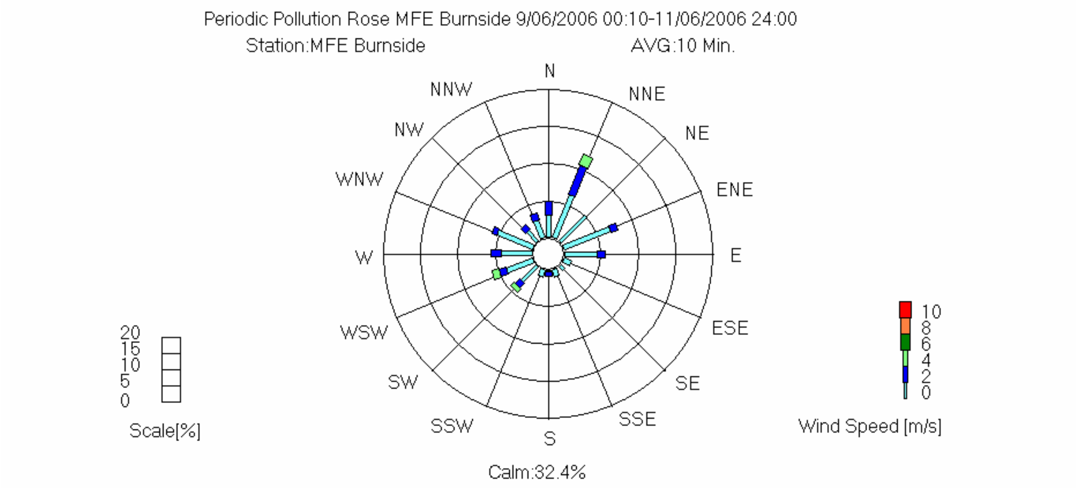


Figure 43: MFE Burnside pollution rose, PM_{10} 10-minute average 7–9 June 2006

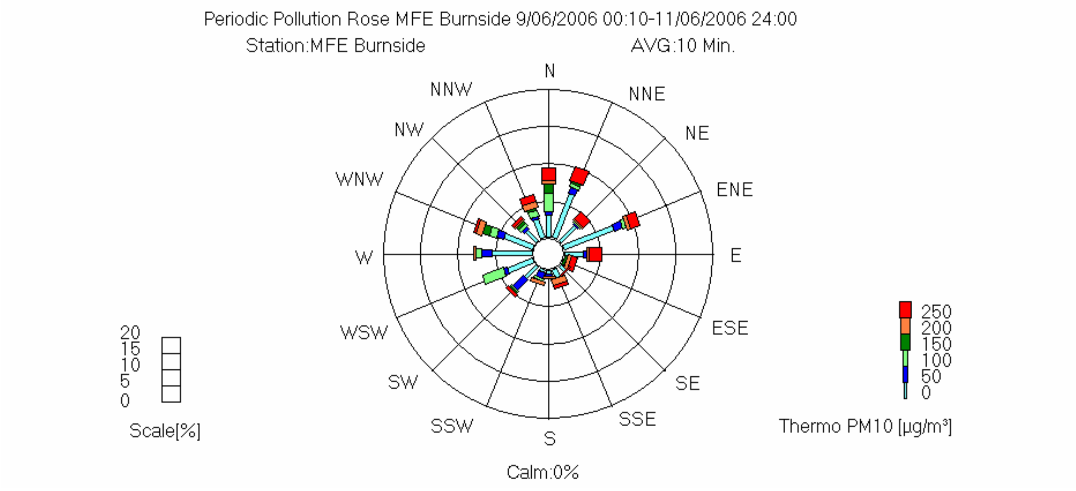


Figure 44: MFE Burnside pollution rose, CO 10-minute average 7–9 June 2006