greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Air quality State of the Environment monitoring programme

Annual data report, 2016

Tamsin Mitchell
Environmental Science Department

For more information, contact the Greater Wellington Regional Council:

Wellington
PO Box 11646

T 04 384 5708
F 04 385 6960
www.gw.govt.nz

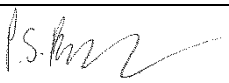
Masterton
PO Box 41

T 06 378 2484
F 06 378 2146
www.gw.govt.nz

GW/ESCI-T-17/50

June 2017

www.gw.govt.nz
info@gw.govt.nz

Report prepared by:	T Mitchell	Team Leader, Air Quality and Climate	
Report reviewed by:	P Fairbrother	Senior Science Coordinator	
Report approved for release by:	L Butcher	Manager, Environmental Science	 Date: 27/06/2017

The report may be cited as:

Mitchell T. 2017. *Air Quality State of the Environment monitoring programme: Annual data report, 2016.* Greater Wellington Regional Council, Publication No. GW/ESCI-T-17/50, Wellington.

Contents

1. Introduction

This report summarises the key results from the Air Quality State of Environment (AQSoE) monitoring programme for the period 1 January to 31 December 2016 inclusive. The programme is based on continuous monitoring of air quality indicators and selected meteorological variables at six sites across the Wellington Region.

2. Background

Air quality has been monitored in the Wellington Region since 1998, when a series of pilot investigations were carried out. The first long-term site was established in Upper Hutt in 2000. Other sites have been progressively added to the monitoring network, which now comprises five long-term sites (Wellington central, Lower Hutt, Wainuiomata, Upper Hutt and Masterton West). Shorter-term monitoring sites are occasionally established to assist with targeted investigations relating to specific air quality issues. For example, a second monitoring site was set up in Masterton East in 2012 to assist with understanding how air quality varies across the Masterton urban area.

2.1 Monitoring objectives

The objectives of Greater Wellington Regional Council's (GWRC) AQSoE monitoring programme are to:

1. Determine compliance with national guidelines and standards designed to protect human health and the environment;

2. Detect spatial and temporal trends in air quality;

3. Contribute to our understanding of air quality processes and impacts in the Wellington Region; and

4. Provide information required to determine the effectiveness of regional plans and policies.

2.2 Monitoring network

The Wellington Region has eight airsheds located in valleys between steep hills or mountains (Figure 2.1); Kapiti Coast, Porirua Basin, Wellington City, Karori, Lower Hutt Valley, Wainuiomata, Upper Hutt Valley and Masterton.

Each airshed has its own distinct microclimate, meteorological conditions and air quality pressures. Apart from the Masterton Urban airshed, these airsheds were formally gazetted in 2005 in accordance with the National Environmental Standards for Air Quality (NES-AQ)[1] (Davy, 2005). The Masterton Urban airshed replaced the former Wairarapa Valley airshed as of 1 September 2014. Not all airsheds are currently monitored as the NES-AQ only requires airsheds to be monitored where air quality standards are likely to be breached.

A new Wellington central site was established in 2015 on the corner of Willis Street and SH1. A mobile monitoring station was deployed at this site from January to early September 2015. It was replaced in January 2016 by a permanent monitoring station.

Site metadata are presented in Appendix 1.

[1] Resource Management (National Environmental Standards for Air Quality) Regulations 2004

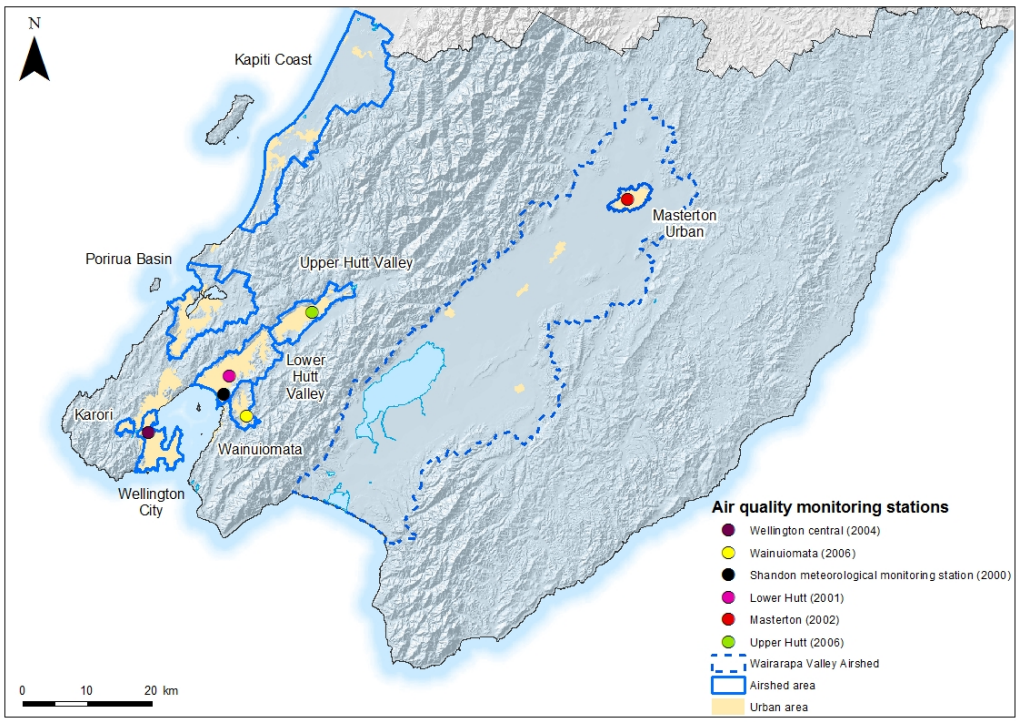


Figure 2.1: Airshed boundaries and location of GWRC air quality monitoring stations

2.3 Monitoring variables

The air quality indicators currently monitored in the Wellington Region are particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO) and nitrogen oxides (NOx) which include nitrogen dioxide (NO_2) and nitric oxide (NO). These contaminants can have adverse human health impacts when concentrations in air are elevated. The air quality indicators measured at each site are shown in Table 2.1.

The two other pollutants that are regulated by national standards, sulphur dioxide (SO_2) and ozone (O_3), are not presently monitored in the Wellington Region. Meteorological conditions in the region are not conducive to the formation of ozone and there are no known significant point source emissions of sulphur dioxide.

Meteorological instruments for recording variables such as wind speed, wind direction and temperature are co-located at each monitoring site to assist with the interpretation of air quality data.

Further information on air quality indicators monitored and measurement methods are provided in Appendix 2.

Table 2.1: Air quality monitoring sites and indicators monitored

Site	Station	Airshed	Indicators monitored	Data available from
Wellington central	Willis Street (intersection of Willis Street and SH1)	Wellington City	PM_{10}, $PM_{2.5}$, CO, NOx	2015
Lower Hutt	Birch Lane (Phil Evans Reserve)	Lower Hutt Valley	PM_{10}	2001
			CO, NOx	2001-2011
Wainuiomata	Wainuiomata Bowling Club (Moohan Street)	Wainuiomata	PM_{10}	2006
			$PM_{2.5}$	2012
Upper Hutt	Savage Park (Savage Crescent)	Upper Hutt Valley	PM_{10}, CO, NOx	2006
Masterton West (permanent site)	Wairarapa College (Pownall Street)	Masterton Urban	PM_{10}, CO	2002
			NOx	2003
			$PM_{2.5}$	2011
Masterton East (non-permanent site)	Herbert Street (Herbert Street)	Masterton Urban	PM_{10}	2012
			$PM_{2.5}$	2013
Shandon	Shandon golf course (Gear Island, Petone)	Lower Hutt Valley	Meteorological parameters	2000

2.4 Air quality assessment criteria and reporting

2.4.1 National environmental standards and guidelines for air quality

National ambient air quality guidelines (NAAQG) were established by the Ministry for the Environment (MfE) in 1994 and revised in 2002 (Ministry for the Environment, 2002). Some of these guideline values were adopted as part of the NES-AQ in 2004. The NES-AQ specifies minimum requirements for outdoor air quality to provide a nationally consistent level of protection for human health and the environment.

There are no national standards for $PM_{2.5}$, although a value of 25μg/m^3 (24-hour average) can be used for assessing monitoring results (Ministry for the Environment, 2002). In the absence of New Zealand standards, World Health Organization (WHO) guidelines are used for assessing the significance of $PM_{2.5}$ monitoring results (World Health Organization, 2006).

The relevant standards and guidelines for air quality indicators measured in the Wellington Region are shown in Table 2.2.

Table 2.2: Air quality standards and guidelines

Indicator	Standard or Guideline	Threshold concentration	Averaging period	Permissible exceedances per year
PM_{10}	NES-AQ	50 µg/m^3	24-hour	1
PM_{10}	NAAQG	20 µg/m^3	Annual	NA
$PM_{2.5}$	WHO Guideline	25 µg/m^3	24-hour	3
$PM_{2.5}$	WHO Guideline	10 µg/m^3	Annual	NA
Carbon monoxide	NES-AQ	10 mg/m^3	8-hour moving	6
Carbon monoxide	NAAQG	30 mg/m^3	1-hour	0
Nitrogen dioxide	NES-AQ	200 µg/m^3	1-hour	9
Nitrogen dioxide	NAAQG	100 µg/m^3	24-hour	0
Nitrogen dioxide	WHO Guideline	40 µg/m^3	Annual	NA

3. Results

Summary statistics for air quality indicators measured during the 2016 calendar year are presented in Table 3.1. For sites where there is less than 75 percent data capture for the calendar year no summary statistics are reported apart from the maxima.

PM_{10} was the only pollutant that failed to meet the NES-AQ, and only at the Masterton East site. During winter there were quite a few days in Masterton and Wainuiomata where levels of $PM_{2.5}$ failed to meet the World Health Organization (WHO) guideline. These exceedances are shown in Table 3.1 in red.

Masterton East had a greater number PM_{10} exceedances and days above the $PM_{2.5}$ guideline than Masterton West. Poorer air quality is found at Masterton East because on cold and cloudless nights cold air slowly drains across Masterton from the west carrying fine particles from home fires towards the lower lying area on the east side leading to a build-up of air pollution.

Wind roses showing summaries of wind speeds and wind direction observations at selected sites are presented in Appendix 3.

Table 3.1: 2016 air quality indicator summary statistics

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
PM_{10} 24-hour average µg/m^3						
Mean (annual)	11.3	11.2	10.5	13.9	15.1	10.7
Maximum	26	28	27	57	65	32
Median	10.7	10.4	9.7	11.0	10.6	9.8
Std deviation	4.6	4.4	4.7	8.9	12.1	5.2
25th percentile	8.1	8.1	7.0	8.0	7.6	7.0
75th percentile	13.6	13.1	13.1	16.7	17.3	12.8
95th percentile	19.1	20.3	19.8	33.5	41.8	20.5
99th percentile	24.4	23.6	23.4	42.6	57.2	28.9
No. > 50	0	0	0	1	10	0
Valid data (24hr)	86%	99.7%	99%	96%	93%	99%
Data capture	89.6%	99.4%	99.3%	97.1%	95.3%	99.2%
$PM_{2.5}$ 24-hour average µg/m^3						
Mean (annual)	5.5			8.8	10.5	6.1
Maximum	13			49	58	36
Median	5.2			5.4	6.0	4.8
Std deviation	2.4			8.1	10.7	5.0
25th percentile	3.8			3.9	4.2	3.4
75th percentile	7.1			10.3	12.1	6.6
95th percentile	9.5			26.2	35.2	14.7

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
99th percentile	12.0			37.0	50.1	29.2
No. > 25	0			19	35	10
Valid data (24hr)	89%			98%	99%	98%
Data capture	86.2%			97.9%	99.6%	98.6%
Carbon monoxide 8-hour moving average mg/m3						
Mean (annual)	0.22		0.17	0.29		
Maximum	0.98		1.29	2.45		
Median	0.19		0.11	0.18		
Std deviation	0.12		0.17	0.30		
25th percentile	0.13		0.07	0.12		
75th percentile	0.26		0.18	0.32		
95th percentile	0.47		0.55	0.96		
99th percentile	0.66		0.85	1.50		
No. > 10	0		0	0		
Carbon monoxide 1-hour average mg/m3						
Mean (annual)	0.22		0.17	0.29		
Maximum	1.78		1.82	4.49		
Median	0.18		0.10	0.16		
Std deviation	0.16		0.20	0.37		
25th percentile	0.11		0.07	0.11		
75th percentile	0.26		0.17	0.28		
95th percentile	0.50		0.59	1.04		
99th percentile	0.89		1.05	1.93		
No. > 30	0		0	0		
Data capture	98.7%		88.6%	99.1%		
Nitrogen dioxide 1-hour average µg/m3						
Mean (annual)	14.0		5.4	6.7		
Maximum	61.5		44.4	50.8		
Median	12.4		2.8	4.2		
Std deviation	9.9		6.4	6.7		
25th percentile	6.4		1.4	2.5		
75th percentile	19.2		6.8	8.1		
95th percentile	33.9		19.8	21.1		
99th percentile	45.0		30.1	33.8		
No. > 200	0		0	0		
Data capture	98.1%		91.8%	96.4%		

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
Nitrogen dioxide 24-hour average µg/m^3						
Mean (annual)	14.0		5.4	6.7		
Maximum	32.4		18.8	20.6		
Median	12.8		4.2	5.6		
Std deviation	6.2		4.1	4.2		
25th percentile	9.6		2.0	3.6		
75th percentile	17.9		7.8	9.3		
95th percentile	26.9		13.5	15.7		
99th percentile	29.9		16.1	18.1		
No. > 100	0		0	0		

3.1 PM_{10} exceedances

The NES-AQ for PM_{10} allows an airshed to exceed the threshold concentration of 50 µg/m^3 (24-hour average) on one day per 12 month period – known as a 'permissible exceedance'. Airsheds that average more than one exceedance per year are designated as polluted by the NES-AQ and new industries that seek resource consent to discharge PM_{10} into these airsheds may face restrictions.

The Masterton Urban airshed is the only one in the region that is designated as polluted (due to poor air quality in winter as a result of emissions from home fires). Table 3.2 shows the exceedance dates and concentrations measured at the two monitoring sites in Masterton. A total of 10 exceedance days meant there were nine breaches of the NES-AQ in the airshed.

A temporary monitoring site in Carterton during winter 2016 measured two exceedances of the PM_{10} NES-AQ on 4 and 5 June (Queen's Birthday weekend). During this period (between 3 and 6 June) wind speeds measured at the monitoring site were low (less than 1 m/s), daily average temperatures were below 6^{o}C and overnight temperature minima were below zero degrees. From 1 to 8 June there was a strong high pressure system (anticyclone) situated over central New Zealand. This anticyclone was slow moving and persisted for eight consecutive days bringing very stable atmospheric conditions unfavorable for dispersion of emissions from home heating (Mitchell, 2016).

Table 3.2: PM_{10} NES-AQ exceedance days recorded in 2016

Date	Masterton (East) 24-hour average ($\mu g/m^3$)	Masterton (West) 24-hour average ($\mu g/m^3$)	Carterton 24-hour average ($\mu g/m^3$)
3 June	53		
4 June	65		52
5 June	58		54
6 June	52		
8 June	56		
14 June	53		
17 June	53		
3 July	59	57	
7 July	61		
22 July	57		
TOTAL EXCEEDANCES	10	1	2
Total breaches	9	0	1

3.2 $PM_{2.5}$ days above the WHO guideline

The WHO guideline value for $PM_{2.5}$ is 25 $\mu g/m^3$ expressed as a 24-hour average. Table 3.3 shows the dates when the concentration of $PM_{2.5}$ exceeded the 24-hour WHO guideline value. The WHO guideline allows three days per year to exceed the 24-hour guideline limit.

Over the winter period Masterton fails to meet the daily WHO guideline for $PM_{2.5}$ more frequently than the daily PM_{10} standard. Wood smoke mainly contains the smaller $PM_{2.5}$ sized particles so most of the PM_{10} measured on still winter nights is actually $PM_{2.5}$ particles, meaning it is easier to exceed the $PM_{2.5}$ daily limit of 25 $\mu g/m^3$ than the PM_{10} limit of 50 $\mu g/m^3$. $PM_{2.5}$ is a better indicator of health impacts across the population than PM_{10} because smaller particles are more damaging to health (World Health Organization, 2006).

Table 3.3: $PM_{2.5}$ days above WHO 24-hour guideline value recorded in 2016

Date	Masterton (East) 24-hour average (µg/m^3)	Masterton (West) 24-hour average (µg/m^3)	Carterton 24-hour average (µg/m^3)	Wainuiomata 24-hour average (µg/m^3)
25 April	32			
2 June	45	36	32	27
3 June	47		39	30
4 June	58	38	49	31
5 June	52	29	54	26
6 June	49	32	28	
7 June	42		34	36
8 June	49	32	47	31
9 June	30		33	27
13 June			26	
14 June	43	36		
15 June	31			
16 June	31	26		
17 June	45	38	39	
21 June	26			
25 June	29			
28 June	27			
2 July	38	30	38	
3 July	53	49		
4 July	27			
6 July	35	27		
7 July	53			
10 July	41	30	26	
11July				26
12 July	30			26
16 July			30	29
21 July	30			
22 July	47	39	31	
26 July	36	30	26	
1 August	27	29		
2 August	No data available	32		
8 August	32	29	28	
10 August	39	31		
15 August	34			

Date	Masterton (East) 24-hour average ($\mu g/m^3$)	Masterton (West) 24-hour average ($\mu g/m^3$)	Carterton 24-hour average ($\mu g/m^3$)	Wainuiomata 24-hour average ($\mu g/m^3$)
16 August	33			
17 August	36		31	
18 August	32			
29 August	42	35		
12 September	28			
TOTAL DAYS ABOVE GUIDELINE	35	19	17	10
Total breaches	32	16	14	7

Acknowledgements

The work of Darren Li in operating and maintaining monitoring equipment and stations is gratefully acknowledged

References

Carslaw DC and Ropkins K. 2015. *Openair: Open-source tools for the analysis of air pollution data.* R package version 1.5. http://CRAN.R-project.org/package=openair

Davy P. 2005. *Nominated airsheds for the Wellington Region.* Greater Wellington Regional Council, Publication No. GW/RINV-T-05/113, Wellington.

Ministry for the Environment. 2002. *Ambient air quality guidelines – 2002 update*. Air Quality Report No. 32, Wellington.

Ministry for the Environment. 2009. *Good-practice guide for air quality monitoring and data management 2009.* Report No. ME 933. Ministry for the Environment, Wellington.

Mitchell T. 2016. *Carterton winter air quality: 2010 to 2016.* Greater Wellington Regional Council, Publication No. GW/ESCI-T-16/96, Wellington.

R Core Team. 2015. *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

World Health Organization. 2006. *WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide – global update 2005.* Retrieved from http://www.who.int/phe/health_topics/outdoorair_aqg/en/

Appendix 1: Monitoring site metadata

Site Name	Lower Hutt		
Station	Birch Lane		
Hilltop site ID	108		
Location			
Address	Phil Evans Reserve, 46 Oxford Tce, Waterloo, Lower Hutt		
Map reference	Easting	Northing	
NZTM	1761032	5435863	
NZMG	2671054	5997577	
WGS84	Lat: -41.212603	Long: 174.920871	
Site details			
Site type	Residential / Commerical		
Airshed	Lower Hutt Valley		
Altitude	0 m		
Nearest Road	100 m		
Nearest Tree	10 m		
Site Classification (MfE, 2009)	Residential		
(AS/NZ 3580.1.1:2007)	Neighbourhood		

Parameters measured			
	Instrument	Start date	End date
PM_{10} (µg/m^3)	FH62	14/12/2010	
PM_{10} (µg/m^3)	TEOM	5/04/2001	13/12/2011
Carbon monoxide (ppm)	M300E	25/10/2001	11/01/2012
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E	13/08/2001	11/01/2012
Meteorological	RH, Temp, WS, WD, global solar radiation, rain, Barometric Pressure	25/10/2001	
Mast height	10m		
Internal temperature	25°C		

Data acquisition			
Sampling rate	AQ - 10 seconds, Met - 3 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483	5/04/2001	2/06/2015
Logger	Campbell CR1000	2/06/2015	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP	0001395574UN55D		

Monitoring notes		
Passive NO_2 in triplicate measured by NZTA	Start date	End date
	1/03/2010	

Site Name	**Masterton East**		
Station	Chanel College		
Hilltop site ID	3579		
Location			
Address	Herbert Street	Masterton	
Map reference	Easting	Northing	
NZTM	1823279.81	5462375.21	
NZMG	2733294.01	6024095.93	
WGS84	Lat: -40.959262	Long: 175.653116	
Site details			
Site type	Type: Residential	Scale: Neighbourhood	
Airshed	Masterton Urban		
Altitude	105m		
Nearest Road	75m		
Nearest Tree	15m		
Site Classification (MfE, 2009)	Residential (peak)		

Parameters measured			
	Instrument	Start date	End date
PM_{10} (µg/m^3)	5014i	17/05/2012	
$PM_{2.5}$ (µg/m^3)	5014i + VSCC	2/12/2013	
Meteorological	RH, Temp, BP, WS, WD	11/05/2012	
Mast height	6m		
Internal temperature	25°C		
Data acquisition			
Sampling rate	AQ - 10 seconds, Met - 5 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483	11/05/2012	17/11/2015
Logger	Campbell CR1000	17/11/2015	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP			

Monitoring notes			
		Start date	End date
Fine and coarse PM measured by GNS Science	GENT	1/07/2010	1/09/2010

Site Name	Masterton West		
Station	Wairarapa College		
Hilltop site ID	2637		
Location			
Address	83 Pownall Street	Masterton	
Map reference	Easting	Northing	
NZTM	1822756	5463164	
NZMG	2732764	5463158	
WGS84	Lat: -40.952364	Long: 175.646546	
Site details			
Site type	Type: Residential	Scale: Neighbourhood	
Airshed	Masterton Urban		
Altitude	161m		
Nearest Road	124m		
Nearest Tree	5m		
Site Classification (MfE, 2009)	Residential		
(AS/NZ 3580.1.1:2007)	Neighbourhood		
Parameters measured			
	Instrument	Start date	End date
PM_{10} (µg/m^3)	5014i	17/12/2015	
	FH62 (inlet 40°C)	18/06/2007	16/12/2015
	5014i	25/05/2012	2/12/2013
	TEOM	9/10/2002	1/01/2011
	High Volume Sampler	17/04/2003	30/03/2005
$PM_{2.5}$ (µg/m^3)	5014i	11/12/2015	
	SHARP 5030	28/01/2011	10/12/2015
Carbon monoxide (ppm)	M300E	9/10/2002	
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E	1/01/2003	
Meteorological	Temp, WS, WD, RH, BP, soil moisture, soil temperature, rainfall, net solar radiation	4/06/2002	
Mast height	15m		
Internal temperature	25°C		
Data acquisition			
Sampling rate	AQ -10 seconds, Met-5 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483	9/10/2002	3/02/2014
Logger	Campbell CR1000	4/02/2014	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP			
Monitoring notes			
Fine and coarse PM measured by GNS Science	GENT	Start date	End date
		27/06/2002	3/11/2004

Site Name	Upper Hutt		
Station	Savage Park		
Hilltop site ID	2468		
Location			
Address	15 Savage Cres, Upper Hutt		
Map reference	Easting	Northing	
NZTM	1773804	5445684	
NZMG	2683825	6007400	
WGS84	Lat: -41.121549	Long: 175.070348	
Site details			
Site type	Type: Residential	Scale: Neighbourhood	
Airshed	Upper Hutt Valley		
Altitude	43 m		
Nearest Road	69 m		
Nearest Tree	11 m		
Site Classification (MfE, 2009)	Residential		

Parameters measured			
	Instrument	Start date	End date
PM_{10} ($\mu g/m^3$)	FH62	8/11/2005	
Carbon monoxide (ppm)	M300E	30/09/2005	
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E	19/09/2005	
Meteorological	RH, Air Temp, Soil Temp, WS, WD, solar radiation, rain, Barometric Pressure	14/09/2005	
Mast height	10m		
Internal temperature	25°C		

Data acquisition			
Sampling rate	AQ - 10 seconds, Met - 5 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483	14/09/2005	27/06/2013
	Campbell CR1000	28/06/2013	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP			

Monitoring notes		
Passive NO_2 in triplicate measured by NZTA	Start date	End date
	1/03/2010	1/11/2012

Site Name	Wainuiomata		
Station	Wainuiomata Bowling Club		
Hilltop site ID	2579		
Location			
Address	Moohan Street	Wainuiomata	
Map reference	Easting	Northing	
NZTM	1763651	5429685	
NZMG	2673674	5991399	
WGS84	Lat: -41.267695	Long: 174.953745	
Site details			
Site type	Type: Residential	Scale: Neighbourhood	
Airshed	Wainuiomata		
Altitude	80m		
Nearest Road	20m		
Nearest Tree	10m		
Site Classification (MfE, 2009)	Residential		

Parameters measured			
	Instrument	Start date	End date
PM_{10} (µg/m^3)	FH62 (inlet 40°C)	30/06/2006	
$PM_{2.5}$ (µg/m^3)	FH62 + VSCC (inlet 40°C)	1/05/2012	
PM_{10} (µg/m^3)	High Volume Sampler	20/09/2000	6/10/2007
Meteorological	RH, Aiir Temp, Soil Temp, WS, WD, BP, solar radiation, soil moisture	1/01/2005	
Mast height	10m		
Internal temperature	25°C		

Data acquisition			
Sampling rate	AQ - 10 seconds, Met - 3 seconds		
Logger average	10-minute		
Logger - Met	iQuest DS-4483	20/09/2000	23/06/2015
Logger - Met	Campbell CR1000	23/06/2015	
Logger - AQ	iQuest DS-4483	30/06/2006	6/07/2015
Logger - AQ	Campbell CR1000	6/07/2015	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP	0001454109UN341		

Monitoring notes			
		Start date	End date
Fine and coarse PM measured by GNS Science	GENT	1/09/2006	25/09/2008
Inorganic arsenic	High Volume sampler PM_{10}	25/10/2011	31/10/2013

Site Name	Wellington central			
Station	Willis Street AQ			
Hilltop site ID	4795			
Location				
Address	Intersection Wellington urban motorway and Willis Street, Te Aro, Wellington			
Map reference	Easting	Northing		
NZTM	1748360	5427132		
NZMG	2658382	5988844		
WGS84	Lat: -41.293625	Long: 174.771919		
Site details				
Site type	Peak transport			
Airshed	Wellington City			
Altitude	24m			
Nearest Road	8m			
Nearest Tree	30m			
Site classification (MfE, 2009)	Traffic			
(AS/NZ 3580.1.1:2007)	Peak transport			
	Mobile station		*Fixed station*	
Parameters measured				
	Instrument		Start date	End date
PM_{10} (µg/m^3)	FH62 (mobile station)		20/01/2015	14/09/2015
PM_{10} (µg/m^3)	SHARP 5030 (fixed station)		8/01/2016	
$PM_{2.5}$ (µg/m^3)	SHARP 5030 (fixed station)		8/01/2016	
Carbon monoxide (ppm)	M300E (mobile station)		20/01/2015	14/09/2015
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E (mobile station)		20/01/2015	14/09/2015
Carbon monoxide (ppm)	M300E (fixed station)		17/12/2015	
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E (fixed station)		16/12/2015	
Black carbon (ng/m3)	AE33 (fixed station)		5/10/2016	
Meteorological	RH (%), Temperature (°C), Wind speed (m/s), Wind direction (degrees), Barometric Pressure		5/01/2016	
Mast height	4m			
Internal temperature	25°C			
Data acquisition				
Sampling rate	AQ -10 seconds, Met - 3 seconds			
Logger average	10-minute			
Logger	iQuest DS-4483		20/01/2015	14/09/2015
Logger	Campbell CR1000		3/12/2015	
Telemetry	GPRS			
Modem	iQuest ICE3			
ICP	0001441727UN448			
Monitoring notes				
Passive NO_2 in triplicate measured by NZTA			1/01/2015	
Black carbon measured by NIWA			10/03/2015	

Appendix 2: Air quality indicators, methods and reporting units

Carbon monoxide

Carbon monoxide (CO) is a colourless and odourless gas produced by the incomplete combustion of carbon-containing fuels such as petrol and diesel used in motor vehicles, or wood and coal used for domestic heating or in industrial boilers. Motor vehicles are the main source of carbon monoxide in urban areas.

When inhaled, carbon monoxide reduces the oxygen carrying capacity of the blood and, depending on its concentration, causes a range of adverse health effects.

Nitrogen dioxide

Nitrogen dioxide (NO_2) arises from combustion processes, with vehicle emissions being the main source in urban areas. Vehicle exhausts contain a mixture of nitrogen dioxide and nitric oxide (NO), collectively known as oxides of nitrogen (NOx). Most of the NOx discharged from vehicle exhausts is in the form of nitric oxide which is subsequently converted to nitrogen dioxide by oxidation.

Nitrogen dioxide appears as a brown gas in the atmosphere and can be seen as a haze over some cities during periods of calm weather and heavy traffic congestion. As well as contributing to poor visibility, nitrogen dioxide has adverse health effects such as lung inflammation and eye, nose and throat irritation.

Particulate matter

Particulate matter (PM) is a mixture of airborne solid particles and liquid droplets. Particulate matter concentrations are typically classified by particle size. PM_{10} includes all particles smaller than 10 microns (μm) in diameter and $PM_{2.5}$ includes all particles smaller than 2.5 μm in diameter.

PM arises from human activities and natural sources. Sources of PM in the Wellington Region include:

- Domestic solid fuel heating (eg, wood burners)
- Motor vehicles, particularly diesel vehicles
- Industrial combustion processes
- Quarrying activities
- Natural sources such as sea salt and wind-blown soil particles.

Domestic fires and vehicles produce very fine particles less than 2.5 microns in diameter ($PM_{2.5}$). Road dust and natural sources (such as sea salt and soil) produce particles that are typically larger than 2.5 microns and are commonly described as the 'coarse' fraction of PM_{10}.

Epidemiological studies show adverse health effects from both short-term and long-term exposure to PM_{10}. However, a threshold below which there are no observed adverse effects has not been reliably established to date (World Health Organization, 2006). The adverse health effects associated with exposure to PM_{10} range from increases in the number of restricted activity days to increases in hospital admissions and premature deaths for people with existing lung and heart disease. The fine component of PM_{10} (ie, $PM_{2.5}$) is more strongly associated with harmful health impacts because the smaller the particle the deeper it can penetrate into the lungs.

Data capture and reporting

All pollutants are measured continuously with instruments that are connected by digital interface to data loggers. Ambient air is sampled at 10 to 20 second intervals (depending on the number of instruments at a site) and these measurements are reported as 10-minute averages at New Zealand Standard Time (NZST). These 10-minute averages are then aggregated to hourly averages where there is at least 75% data capture (ie, at least five 10-minute averages must be present for a 1-hour average to be considered valid and included in the data set). Hourly averages apply to the preceding hour (eg, a 1-hour average at 17:00 refers to data collected between 16:00 and 16:59).

PM_{10} 24-hour averages are calculated from 1-hour averages between midnight to midnight (00:00 to 23:59) and require at least 18 hours of data for each 24-hour period to be included in the data set. PM_{10} values are rounded up to the nearest whole number for reporting purposes in accordance with MfE (Ministry for the Environment, 2009) recommendations. An exceedance of the NES-AQ is therefore 51 $\mu g/m^3$ or higher.

For comparison with the NES-AQ for carbon monoxide, 8-hour moving means are calculated on the hour for the preceding 8-hour period using 1-hour averages. At least 6 hours (ie, at least 75% data capture) must be present for an 8-hour mean to be considered valid and included in the data set. Carbon monoxide 8-hour moving means and nitrogen dioxide 1-hour averages are rounded to one decimal place for reporting purposes in accordance with MfE (Ministry for the Environment, 2009) recommendations.

Measurement methods

Variable	Instrument	Method	Units
PM_{10}	Thermo Andersen series FH62 C14 beta attenuation monitor and Thermo Scientific 5014i beta attenuation monitor	Automated method equivalent to the United States Code of Federal Regulations (CFR)[2] EQPM-1102-150 Method 9.11: Determination of suspended particulate matter – PM_{10} beta attenuation monitors in accordance with AS/NZS 3580.9.11:2008	µg/m^3
$PM_{2.5}$	Thermo Scientific 5030 SHARP monitor + Very Sharp Cut Cyclone particle size separator	EQMP-0609-184[3] Method 9.12: Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors in accordance with AS/NZS 3580.9.12:2013	µg/m^3
$PM_{2.5}$	Thermo Andersen series FH62 C14 beta attenuation monitor + Very Sharp Cut Cyclone particle size separator.	Does not have USEPA equivalency	µg/m^3
$PM_{2.5}$	Thermo Andersen 5014i + Very Sharp Cut Cyclone particle size separator.	EQPM-0609-183 Method 9.12: Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors in accordance with AS/NZS 3580.9.12:2013	µg/m^3
Carbon monoxide	API 300 series analysers	Gas Filter Correlation Infrared in accordance with AS 3580.7.1:2011 Method 7.1: Determination of carbon monoxide – Direct-reading instrumental method	Parts per million (ppm) converted to mg/m^3 by multiplying by 1.25 (0^{o}C)
Nitrogen dioxide	API 200 series analysers	Chemiluminescence in accordance with AS 3580.5.1:2011 Method 5.1: Determination of oxides of nitrogen – Direct-reading instrumental method	Parts per billion (ppb) and is converted to µg/m^3 by multiplying by 2.05 (0^{o}C)

[2] Title 40 – Protection of the Environment, Volume 2, Part 50, Appendix J: Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere.
[3] Title 40 – Protection of the Environment, Volume 2, Part 50, Appendix L: Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere.

Appendix 3: Wind roses

The below wind roses were created using R statistical software (R Core Team, 2015) and the 'openair' package (Carslaw and Ropkins, 2015). They show the proportion (percentage) of time that the wind is coming from a particular angle (30^{o} increments) and wind speed range (shown on the right-hand scale in metres per second). The wedge points towards the direction the wind is blowing from.

Figure A3.1: Wind roses showing wind speed (m/s) and direction recorded at air quality monitoring stations during 2016 (mast height is shown in brackets)