

Background Air Quality

for NZ Transport Agency State Highway Assessments



Technical Report for
New Zealand Transport Agency

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1. Introduction

This report contains the technical detail of default background values developed for the NZTA. The *NZTA Default National Background* MSEXcel spreadsheets (hereafter referred to as the “supporting spreadsheets”) contain all data and calculations used for this project.

1.1 Source data

The most up to date monitoring data from air pollution monitoring sites around New Zealand were obtained from a number of agencies including:¹

- relevant regional councils,
- the Ministry for the Environment (MfE) website²
- NZTA’s national (nitrogen dioxide) passive monitoring network from 2007 – 2011,
- NZTA’s air quality data warehouse³ and
- the *Updated Health and Air Pollution in New Zealand (HAPINZ) Study* (Kuschel *et al.*, 2012).

Data were gathered and assessed for the period 2005 to 2010, however, in some instances, data from pre-2005 has been included if no other data were available for the area. Years with <75% valid data have not been used in the analysis. The following averaging periods were extracted from the available data:

PM₁₀

- annual average
- 24-hour highest value
- 24-hour second highest value (99.9%ile)

Nitrogen dioxide (NO₂) background sites⁴

- annual average
- 24-hour highest value
- 24-hour second highest value (99.9%ile)

¹ This report was issued as a draft for review in July 2012 and finalised in April 2013.

² By airshed at <http://www.mfe.govt.nz/laws/standards/airsheds/>. Accessed February 2012.

³ NZTA (in preparation) *Air quality data warehouse*. Stage 3 data as at July 2012.

⁴ Background monitoring sites are at least 50 m from a busy road or 100 m from a state highway, in accordance with the NZTA definition of background monitoring sites for the national monitoring network.

- 1-hour highest value
- 1-hour second highest value

Monitoring data collected and used for this project are provided in the 'Raw Data' sheet of the supporting spreadsheets. Each monitoring site is allocated to a census area unit depending upon the location of the site. If a monitoring site's location was not available, then monitoring values have been assigned to a centrally located census area unit within the respective airshed or area.⁵

The following monitoring data were removed for the reasons stated:

- 24-hour PM₁₀ levels measured on 25 September 2009 in Auckland. These elevated levels were attributable an Australian dust storm.⁶
- One exceedance of the 24-hour PM₁₀ levels measured in Canterbury in 2009. These elevated levels were attributable to a (separate) Australian dust storm.⁷
- The maximum and second highest 24-hour PM₁₀ values measured at Patumahoe in 2008. These days were considered outliers.⁸

⁵ This was only for data from MfE's website (which does not specify monitoring locations).

⁶ The Australian dust storms were considered as an exceptional event as defined by the national environmental standards for air quality, and therefore removed.

⁷ <http://www.mfe.govt.nz/environmental-reporting/air/air-quality/pm10/nes/canterbury/christchurch.html> (date not provided)

⁸ For further information, refer to Auckland Council (in-press).

2. Particulate matter

2.1 Annual PM₁₀

Summary PM₁₀ monitoring data are provided in Appendix A.

As mentioned in Section 1.1, monitoring data were screened to remove any years with <75% valid data.

For census area units where monitoring data were available:

- We averaged all available years of data to estimate a default background annual average for the census area unit in which that monitor was located.

For census area units where monitoring data were not available:

- We used the estimated annual PM₁₀ value provided in the exposure model of the *2011 Updated Health and Air Pollution in New Zealand (HAPINZ) Study* for each census area unit (Kuschel et al.).

2.2 24-hour PM₁₀

Default background values for 24-hour PM₁₀ are defined for all airsheds in New Zealand, and are also defined for each census area unit in New Zealand in the maps and supporting spreadsheet. Airsheds and census area units do not necessarily align, so Appendix D explains how the default background values were assigned to census area units and airsheds.

Summary PM₁₀ monitoring data are provided in Appendix A.

In order to derive default background 24-hour PM₁₀ values for locations without monitoring data, we undertook a variety of correlation analyses as detailed in Appendix B. As a result of these analyses, the default background 24-hour PM₁₀ was calculated based on correlations between:

- annual PM₁₀ and peak (ie second highest) 24-hour PM₁₀
 - National correlation $R^2 = 0.81$ (not including Auckland)
 - Auckland correlation $R^2 = 0.70$

The following sections outline how we assigned PM₁₀ 24-hour values to each census area unit and/or airshed.

2.2.1 Default background calculations for 24-hour PM₁₀

For all airsheds and census area units, where monitoring data were available:

- We used the average of second highest measured values (ie the 99.9%ile) over all available years as a default background 24-hour PM₁₀ value.
 - This method provides some smoothing for inter-annual variability and noise in the dataset; and
 - Values are relatively conservative.
- For airsheds with one monitor, the (average monitored) default background value was applied to all census area units in the airshed (except for census areas units excluded from the airshed as described in Appendix D). For airsheds with more than one monitor, the method is described in Section 2.2.2 below.

Where monitoring data were not available:

- A default background 24-hour PM₁₀ value was estimated from the annual PM₁₀ in that census area unit⁹ using the national correlation ($R^2=0.81$) as shown in by Equation 1 below.

$$\text{24-hour PM}_{10} = 1.8963 \times \text{annual PM}_{10}^{0.5383} \quad \text{Equation 1}$$

- The national correlation was applied to each census area unit, with the exception of Auckland and Northland region airsheds.
- For airsheds, the default background value was applied to all census area units in the airshed (except for census areas units excluded as described in Appendix D).

2.2.2 Exceptions – Northland, Auckland, Rotorua, Christchurch and Timaru

Northland (annual and 24-hour PM₁₀)

The national correlation was not applied for the following Northland airsheds without monitoring data:

- Dargaville
- Kerikeri
- Marsden Point, and
- Northland region

⁹ From the *Updated Health and Air Pollution in New Zealand (HAPINZ) Study*, Kuschel et al.

The annual average PM₁₀ for Kaitaia was very low in both 2007 and 2008 (annual average 6µg/m³ for both years). Similarly, the second highest 24-hour PM₁₀ values were very low (15µg/m³ in 2007 and 11µg/m³ in 2008). The average of these measured values was the same as the estimate calculated from the national correlation (13µg/m³).

Given the lack of domestic heating issues in Northland, we decided not to use the national correlation for Northland airsheds. Instead:

- We assigned the Kaitaia annual and second highest 24-hour PM₁₀ averages to airsheds without monitoring data (ie, all airsheds except Whangarei for which monitoring data were available).

Auckland (24-hour PM₁₀)

- The Auckland region correlation ($R^2 = 0.70$) was used for all Auckland region census area units without monitoring data (shown by Equation 2).

$$\text{24-hour PM}_{10} = 0.6799 \times \text{annual PM}_{10}^{0.8595} \quad \text{Equation 2}$$

Rotorua and Christchurch airsheds (annual and 24-hour PM₁₀)

- The Rotorua and Christchurch airsheds had more than one monitoring site with available data, therefore:
 - Default background PM₁₀ values in the airsheds were presented by census area unit;
 - Census area units with a monitoring site used default background values generated from that monitoring site;¹⁰
 - Census area units without a monitoring site used annual PM₁₀ default background values from the *Updated Health and Air Pollution in New Zealand (HAPINZ) Study*; and
 - Census area units without a monitoring site used 24-hour PM₁₀ default background values estimated using the national correlation as given in **Equation 1**.
- Although the Rotorua correlation was $R^2 = 0.96$ (Appendix B), this was not adopted for the Rotorua airshed as the resulting default background values did not vary greatly from those calculated using the national correlation.

Timaru (annual and 24-hour PM₁₀)

- The Timaru airshed had two monitoring sites with available data, therefore:
 - Data from the Washdyke monitoring site was used for the Washdyke census area unit.

¹⁰ The monitoring site value is assigned to the entire census area unit, regardless of whether the census area unit meets the 20% threshold described in Appendix D.

- Data from the monitoring site at Anzac Park¹¹ was applied to the rest of the Timaru airshed (except for census area units excluded as described in Appendix D).

¹¹ Sourced from Mfe website at <http://www.mfe.govt.nz/laws/standards/airsheds/>. Accessed February 2012

3. Nitrogen dioxide

For the purposes of this guide, the default background values are intended to represent “background” as defined below:

Background air quality is the level of contaminant across the airshed from all sources excluding nearby roads. This includes contributions from natural sources (eg volcanoes, forest fires, wind-blown dust, etc.) and from anthropogenic sources such as industry, domestic heating and ‘remote’ roads. It is assumed that background air quality does not change over time.

‘Nearby’ roads are any state highway within 100 m or any busy local roads within 50 m.

‘Remote’ roads are any roads not defined as ‘nearby’ roads.

The cumulative concentration of nitrogen dioxide (NO₂) at a given receptor can then be estimated as follows:

$$\text{Total NO}_2 = \text{Default background NO}_2 + \text{the nearby road contribution} \quad \text{Equation 3}$$

The nearby road contribution at a given receptor should be estimated using the NZ Transport Agency screening model¹² or dispersion modelling.

To determine appropriate values for default background values, we collated and reviewed ambient monitoring results from all NZTA background monitoring sites (ie, at least 100 m from a state highway and 50 m from a busy local road).

Details of all background monitoring sites are included in Appendix C (Table C-1).

3.1 Annual nitrogen dioxide

The available data from all background monitoring sites in New Zealand are summarised in Appendix C (Table C-2).

The monitoring results show that the annual average NO₂ concentration at background monitoring sites in major urban areas is typically between 9 µg/m³ and 16 µg/m³.

All background sites are located at least 100 m from a state highway and at least 50 m from a busy local road. However, these roads, as well as other small local roads could still influence the concentration of NO₂ at the “background” monitoring sites. The overall size and density of the surrounding urban area could also affect the background concentration.

However, there is no obvious pattern in the background monitoring results. We investigated whether there is any clear correlation between measured concentrations and the following:

¹² NZTA Air Quality Screening Model. Available at www.air.nzta.govt.nz

- distance to nearest busy road;
- density of vehicle kilometres travelled across the census area unit where the monitor is located;
- total population of the urban area where the monitor is located.

We did not find any clear relationship. This is reasonable for background sites with relatively low levels of NO₂ (and supports the use of default background values).

The default background value is based on the highest measured value at a background monitoring site. We adopted this conservative approach because:

- The default background values are intended to be used in combination with the NZTA screening model¹³ (or the NIWA regression equation¹⁴) which is intended to provide a realistic (not conservative) estimate of the nearby road contribution to NO₂;
- The method for using the default background values requires users to estimate the contribution of state highways within 100 m or busy roads within 50 m. This is consistent with the definition of background monitoring sites.

On this basis, the default background values are as shown in Table 1:

Table 1: NO₂ annual average default background values

Location ¹⁵	Annual average (µg/m ³)
Auckland central	19
Other main urban areas	16
Secondary or minor urban area	13
Rural	4

Validation

The default background values proposed for Auckland central and other main urban areas are consistent with recommendations and findings from the development of the NIWA regression model.¹⁶ The NIWA regression model has been developed and validated based on the results of monitoring in Auckland.

¹³ *Ibid.*

¹⁴ NIWA (2010) *A regression approach to assessing urban NO₂ from passive monitoring – Application to the Waterview Connection*. NIWA client report AKL-2010-023 prepared for NZTA. June 2010

¹⁵ These areas are based on Statistics New Zealand definitions. See Statistics New Zealand geographic definitions at <http://www.stats.govt.nz/Census/about-2006-census/2006-census-definitions-questionnaires/definitions/geographic.aspx>

¹⁶ NIWA (2010) *op.cit.*

To confirm that the default background annual average NO₂ background values are appropriately conservative, and are applicable outside Auckland, we used the results of NZTA passive monitoring as follows:

- All state highway monitoring sites which are not in Auckland, and are not classified as intersection sites, were identified.
- Any of these sites with other major roads within 100 m were eliminated.
- The nearest available traffic data were obtained for all remaining sites from the NZTA spatial viewer system.
- The contribution of the state highway to NO₂ concentration at the monitoring site was estimated using the NZTA screening model.¹⁷
- The cumulative concentration for the monitoring site location was then estimated using Equation 3:

$$\text{Total NO}_2 = \text{Default background NO}_2 + \text{the nearby road contribution} \quad \text{Equation 3}$$

The results of this analysis are summarised in Table 2. The results show that the estimated cumulative concentration is higher than the measured concentration for all 18 locations.

This validation exercise shows that the screening model will provide a conservative estimate of roadside annual average NO₂ when combined with the conservative default background values shown in Table 1.

¹⁷ We actually used the regression equation which is used to estimate NO₂ in the NZTA screening tool (as described in the screening tool user notes).

Table 2: Results of the NO₂ validation exercise

NZTA site_ID	Site_name	Area	Region	Distance to state highway (m)	Annual Average Daily Traffic (vehicles per day, 2010)	Estimated contribution of road to NO ₂ (µg/m ³)	default background NO ₂ (µg/m ³)	Estimated cumulative NO ₂ (µg/m ³)	Monitored annual average NO ₂ * (µg/m ³)
WEL012	Nelson St / McLauchlan St	Blenheim	Marlborough	3.1	9018	3.3	13	16	14
CHR002	Main North Rd / Queen Elizabeth II Dr	Redwood	Canterbury	1.5	20104	12	16	28	24
DUN002	Dunedin Southern Motorway / Barnes Dr	Caversham	Otago	40	20935	1.5	16	18	14
DUN011	Dunedin Southern Motorway / Old Brighton Rd	Fairfield	Otago	3	23794	8.9	16	25	14
NAP001	Wainui Rd / Craig Rd	Kaiti	Gisborne	1.6	12196	6.9	16	23	13
CHR001	Tainui St / School Lane	Greymouth	West Coast	1	11924	9.2	13	22	13
HAM001	Cambridge Rd / Morrinsville Rd	Hillcrest	Waikato	2.9	35393	14	16	30	26
HAM012	Te Rapa Rd / Ann Michele St	Pukete	Waikato	4	31380	9.8	16	26	25
DUN005	Dee St / Don St	Invercargill	Southland	1	16695	13	16	29	26
WEL004	Main Rd South / Ihakara St	Paraparaumu	Wellington	3.2	25403	9.2	16	25	18
WEL063	Main Rd South / Rimutaka St	Paraparaumu	Wellington	5	25243	6.8	16	23	19
WEL003	Western Hutt Rd / Riddlers Cres	Petone	Wellington	40	40405	2.8	16	19	15
WEL011	Richmond Deviation / Melia Pl	Richmond	Tasman	60	17947	1.0	16	17	14
WAN001	Northgate / Paynters Ave	Fitzroy	Taranaki	1	28908	22	16	38	21
WAN005	Pioneer Hwy / Maxwells Line	Awapuni	Manawatu / Wanganui	1	9086	7.0	16	23	13
DUN004	Stanley St / Sydney St	Queenstown	Otago	3	15284	5.8	13	19	19
WAN002	London St / Grey St	Wanganui	Manawatu / Wanganui	1	10958	8.4	16	24	14
WEL007	Wellington Urban Motorway / Bolton St	Lambton Quay	Wellington	30	45337	3.8	16	22	19

* The annual average is the average of all available years of data between 2007 and 2011

3.2 Short-term nitrogen dioxide

There is very limited continuous monitoring data for NO₂ outside Auckland. Monitoring data from available background monitoring sites is provided in Appendix C (Table C3) and is summarised below in Table 3.

Table 3: Summary of continuous NO₂ monitoring data for background sites

Site Type	Location	Site Name*	Annual average NO ₂ concentration (µg/m ³)**	Average 24-hour NO ₂ concentration (µg/m ³)**	Average 1-hour NO ₂ concentration (µg/m ³)**
Auckland central	Auckland - Central	AC Kingsland	19	47	72
	Auckland - Central	AC Musick Point	8	33	59
Main urban area	Auckland - Western	AC Glen Eden	8	22	47
	Christchurch	ECAN Coles Pl	15	37	65
	Christchurch	ECAN Burnside	14	36	64
Secondary or minor urban area	Waiuku	AC Waiuku	8		56
	Pukekohe	AC Pukekohe	13	35	63
	Paraparaumu	NZTA Mackays to Peka Peka	-	24	51
Rural	Patumahoe	AC Patumahoe	4	16	35
	Waiheke	AC Waiheke	4		29

* AC= Auckland Council. ECAN = Environment Canterbury

** The annual average is the average of all available years of data

Because of this limitation, background values for 99.9th percentile 1-hour NO₂ and 24-hour NO₂ were calculated from the default background annual average value using the following empirical equations (NIWA, 2010).

$$99.9^{\text{th}} \text{ percentile 1-hr NO}_2 = (2.31 \times \text{mean NO}_2) + 28 \quad \text{Equation 4}$$

$$\text{maximum 24-hr NO}_2 = (0.694 \times 99.9^{\text{th}} \text{ percentile 1-hr NO}_2) - 2.5 \quad \text{Equation 5}$$

Calculated background values are shown in Table 4. These calculated values were then compared to the measured data (averaged over the available years of data) at any available continuous monitoring sites (as shown in Table 3 above).

Table 4: Short-term NO₂ calculated from the annual average default background value

Location	Annual average default background NO ₂ value (µg/m ³)	Calculated 24-hour NO ₂ (µg/m ³)	Calculated 1-hour NO ₂ (µg/m ³)
Auckland central	19	47	72
Other main urban areas	16	43	65
Secondary or minor urban area	13	38	58
Rural	4	23	37

This comparison shows good agreement and confirms that the calculated hourly and 24-hour NO₂ was at least as conservative as the measured NO₂ concentration with the exception of hourly NO₂ at Pukekohe. This is classified as a secondary urban area.

The default background values are therefore:

- calculated from the annual average default background value using Equation 3 and Equation 4, with the exception of;
- the small towns hourly default background value, which is based on the measured 99.9th percentile 1-hour NO₂ value (averaged over the available years of data) from Pukekohe.

On this basis, the default background values are shown in Table 5.

Table 5: Default background values for NO₂

Location ¹⁸	Annual average NO ₂ value (µg/m ³)	24-hour average NO ₂ value (µg/m ³)	1-hour average NO ₂ value (µg/m ³)
Auckland central	19	47	72
Other main urban areas	16	43	65
Secondary or minor urban area	13	38	58
Rural	4	23	37

¹⁸ These areas are based on Statistics New Zealand definitions. See Statistics New Zealand geographic definitions at <http://www.stats.govt.nz/Census/about-2006-census/2006-census-definitions-questionnaires/definitions/geographic.aspx>

4. References

Auckland Council (in-press). *Use of Background Air Quality Data in Resource Consent Applications*. Prepared by Emission Impossible Ltd and Kevin Rolfe & Associates Ltd for Auckland Council. Auckland Council Guideline Document.

Kuschel G, Metcalfe J, Rolfe K, Guria J, Wilton E, Hayles S and Woodward A. (2012). *Updated Health and Air Pollution in New Zealand (HAPINZ) Study*. Prepared for the Ministry for the Environment, Ministry for Transport, and Health Research Council. Available at www.hapinz.org.nz

MfE (2011). *2011 Users' Guide to the Revised National Environmental Standards for Air Quality*. Publication number ME 1068. Wellington: Ministry for the Environment

NIWA (2010). *A regression approach to assessing urban NO₂ from passive monitoring – Application to the Waterview Connection*. NIWA client report AKL-2010-023 prepared for NZTA. June 2010.

Appendix A Summary PM₁₀ monitoring data

Table A-1 Average peak 24-hour and annual PM₁₀ (averaged over all years available data)

Region	Territorial local authority	Census area unit	Airshed	2nd highest 24-hr PM ₁₀ (µg/m ³)	Annual PM ₁₀ (µg/m ³)
Northland	Far North District	Kaitaia East	Kaitaia	13	6
Northland	Whangarei District	Whangarei Central	Whangarei	35	14
Auckland	Rodney District	Warkworth	Warkworth	38	16
Auckland	Rodney District	Kumeu	Kumeu & Riverhead	39	16
Auckland	Rodney District	Orewa	Auckland Urban	38	14
Auckland	Rodney District	Army Bay	Auckland Urban	26	11
Auckland	Rodney District	Helensville	Helensville	32	13
Auckland	North Shore City	Westlake	Auckland Urban	41	17
Auckland	Waitakere City	Glen Eden East	Auckland Urban	35	13
Auckland	Waitakere City	Fairdene	Auckland Urban	35	15
Auckland	Auckland City	Auckland Central West	Auckland Urban	41	19
Auckland	Auckland City	Epsom North	Auckland Urban	45	23
Auckland	Auckland City	Kingsland	Auckland Urban	40	15
Auckland	Auckland City	Ellerslie South	Auckland Urban	42	18
Auckland	Auckland City	Waiheke Island	Waiheke Island	27	12
Auckland	Franklin District	Eden Road-Hill Top	Auckland region	32	12
Auckland	Manukau City	Pakuranga North	Auckland Urban	54	17
Auckland	Manukau City	Millhouse	Auckland Urban	30	12
Auckland	Franklin District	Pukekohe North	Pukekohe	39	15
Auckland	Franklin District	Waiuku	Waiuku	37	15
Waikato	Waikato District	Huntly East	Huntly	41	15
Waikato	Waikato District	Ngaruawahia	Ngaruawahia	33	13
Waikato	Hamilton City	Peachgrove	Hamilton City	45	15
Waikato	Waitomo District	Te Kuiti	Te Kuiti	56	17
Waikato	Hauraki District	Waihi	Waihi	36	12

Region	Territorial local authority	Census area unit	Airshed	2nd highest 24-hr PM ₁₀ (µg/m ³)	Annual PM ₁₀ (µg/m ³)
Waikato	South Waikato District	Tokoroa Central	Tokoroa	76	18
Waikato	Matamata-Piako District	Matamata North	Matamata	34	13
Waikato	South Waikato District	Putaruru	Putaruru	60	15
Waikato	Taupo District	Turangi	Turangi	28	11
Waikato	Taupo District	Taupo Central	Taupo	60	15
Bay of Plenty	Tauranga City	Otumoetai South	Bay of Plenty region	27	13
Bay of Plenty	Tauranga City	Greerton	Bay of Plenty region	25	11
Bay of Plenty	Rotorua District	Ngāpuna	Rotorua	60	15
Bay of Plenty	Rotorua District	Mangakakahi	Rotorua	104	23
Bay of Plenty	Rotorua District	Kuirau	Rotorua	39	13
Bay of Plenty	Whakatane District	Trident	Bay of Plenty Regional	37	14
Gisborne	Gisborne District	Tiniroto	Gisborne region	23	12
Gisborne	Gisborne District	Gisborne Airport	Gisborne region	25	9
Hawke's Bay	Napier City	Marewa	Napier	62	16
Hawke's Bay	Hastings District	Mayfair	Hastings	85	18
Taranaki	New Plymouth District	New Plymouth Central	Taranaki region	35	
Manawatu-Wanganui	Ruapehu District	Taumarunui Central	Taumarunui	42	15
Manawatu-Wanganui	Rangitikei District	Taihape	Taihape	39	13
Wellington	Lower Hutt City	Homedale East	Wainuiomata	41	12
Wellington	Kapiti Coast District	Raumati South	Kapiti Coast	59	
Wellington	Upper Hutt City	Upper Hutt Central	Upper Hutt	29	11
Wellington	Lower Hutt City	Waterloo West	Lower Hutt	29	14
Wellington	Wellington City	Linden	Porirua	29	14
Wellington	Wellington City	Willis St-Cambridge Tce	Wellington City	29	14
Wellington	Wellington City	Karori Park	Karori	28	12
Wellington	Masterton District	Masterton Central	Wairarapa	50	15
Marlborough	Marlborough District	Picton	Marlborough region	27	10
Marlborough	Marlborough District	Redwoodtown	Blenheim	55	16

Region	Territorial local authority	Census area unit	Airshed	2nd highest 24-hr PM ₁₀ (µg/m ³)	Annual PM ₁₀ (µg/m ³)
Nelson	Nelson City	Washington	Nelson A	80	22
Nelson	Nelson City	Tahuna Hills	Nelson B	65	21
Tasman	Tasman District	Richmond East	Richmond	78	22
West Coast	Buller District	Reefton	Reefton	89	23
Canterbury	Kaikoura District	Kaikoura Township	Canterbury region	58	21
Canterbury	Waimakariri District	Rangiora West	Rangiora	78	19
Canterbury	Waimakariri District	Kaiapoi South	Kaiapoi	99	22
Canterbury	Christchurch City	Mona Vale	Christchurch	76	26
Canterbury	Christchurch City	Aorangi	Christchurch	84	20
Canterbury	Christchurch City	St Albans East	Christchurch	116	19
Canterbury	Christchurch City	Woolston South	Christchurch	102	25
Canterbury	Ashburton District	Ashburton Central West	Ashburton	82	21
Canterbury	Timaru District	Geraldine	Geraldine	59	20
Canterbury	Timaru District	Washdyke	Timaru	60	21
Canterbury	Timaru District	Parkside	Timaru	113	28
Canterbury	Waimate District	Waimate	Waimate	67	18
Otago	Waitaki District	Oamaru Central	Oamaru	53	
Otago	Dunedin City	Otago University	Dunedin	61	22
Otago	Dunedin City	Mosgiel East	Mosgiel	80	19
Otago	Clutha District	Milton	Milton	137	24
Otago	Clutha District	Balclutha	Balclutha	56	19
Otago	Central Otago District	Roxburgh	Roxburgh	31	
Otago	Central Otago District	Ranfurlly	Ranfurlly	43	
Otago	Central Otago District	Naseby	Naseby	30	
Otago	Central Otago District	Clyde	Clyde	95	17
Otago	Central Otago District	Alexandra	Alexandra	121	23
Otago	Central Otago District	Cromwell	Cromwell	108	19
Otago	Queenstown-Lakes District	Arrowtown	Arrowtown	108	24

Region	Territorial local authority	Census area unit	Airshed	2nd highest 24-hr PM ₁₀ (µg/m ³)	Annual PM ₁₀ (µg/m ³)
Southland	Southland District	Edendale Community	Southland region	19	10
Southland	Southland District	Wallacetown	Southland region	35	14
Southland	Gore District	Central Gore	Gore	53	15
Southland	Gore District	Mataura	Southland region	47	22
Southland	Southland District	Winton	Southland region	35	13
Southland	Invercargill City	Strathern	Invercargill	80	17
Southland	Invercargill City	Bluff	Southland region	21	8
Southland	Southland District	Te Anau	Southland region	14	6

Appendix B PM_{10} correlation analyses

In order to derive default background 24-hour PM_{10} values, a variety of correlation analyses were undertaken with the available data.

Method 1 – straight correlation analysis

We investigated correlations between the monitored annual average for each site and the second highest 24-hour PM_{10} value for each year (for each site). This yielded the following correlations:

- National correlation $R^2 = 0.69$ for all sites
- North island correlation $R^2 = 0.53$ for all north island sites
- North island correlation of $R^2 = 0.72$ for all north island sites not including Auckland region sites
- South island correlation $R^2 = 0.29$ for all south island sites.

Method 2 – grouping data

We then grouped airsheds with similar air quality (based on the number of exceedances per year, emissions density, etc.) to see if it improved the correlations developed in Method 1. We were particularly interested in assessing the impact of grouping airsheds in the South Island on the established correlations.

This was of limited value as shown in the following correlations:

- Group 1: North Island sites > 10 exceedances (Hastings, Rotorua, Taupo, Tokoroa) $R^2 = 0.75$
- Group 2: South Island sites < 10 exceedances (Blenheim, Geraldine, Gore, Invercargill, Otago 3 airsheds, Rangiora and Waimate) $R^2 = 0.20$
- Group 3: South Island sites > 10 exceedances (Ashburton, Christchurch, Kaiapoi, Nelson A & B, Otago 1 & 2 airsheds, Reefton, Richmond and Timaru) $R^2 = 0.09$

Method 3 – smoothing available data

We then investigated correlations between the *average* of monitored annual averages for each site for all years available, and the average of the second highest 24-hour PM₁₀ values for all years available (for each site).

This yielded the following correlations:

- National correlation $R^2 = 0.77$ for all sites (**Figure A-1**)
- **National correlation $R^2 = 0.81$ not including Auckland (Figure A-2)**

Method 4 – airsheds with multiple monitors

We then investigated correlations for airsheds with multiple monitors. This looked at the correlation (if any) between the annual PM₁₀ average for each monitoring site and the second highest 24-hour PM₁₀ average and yielded the following:

- **Auckland (n = 18) correlation $R^2 = 0.70$ for Auckland region sites only (Figure A-3)**
- Christchurch (n = 4) correlation of $R^2 = -0.31$ ie, no correlation
- Rotorua (n = 3) correlation of $R^2 = 0.96$ for Rotorua sites only

It is interesting to note that a negative R^2 value (ie, no correlation) was established for Christchurch. This means that the second highest PM₁₀ value (per year) bears no relation to the annual average PM₁₀ value.

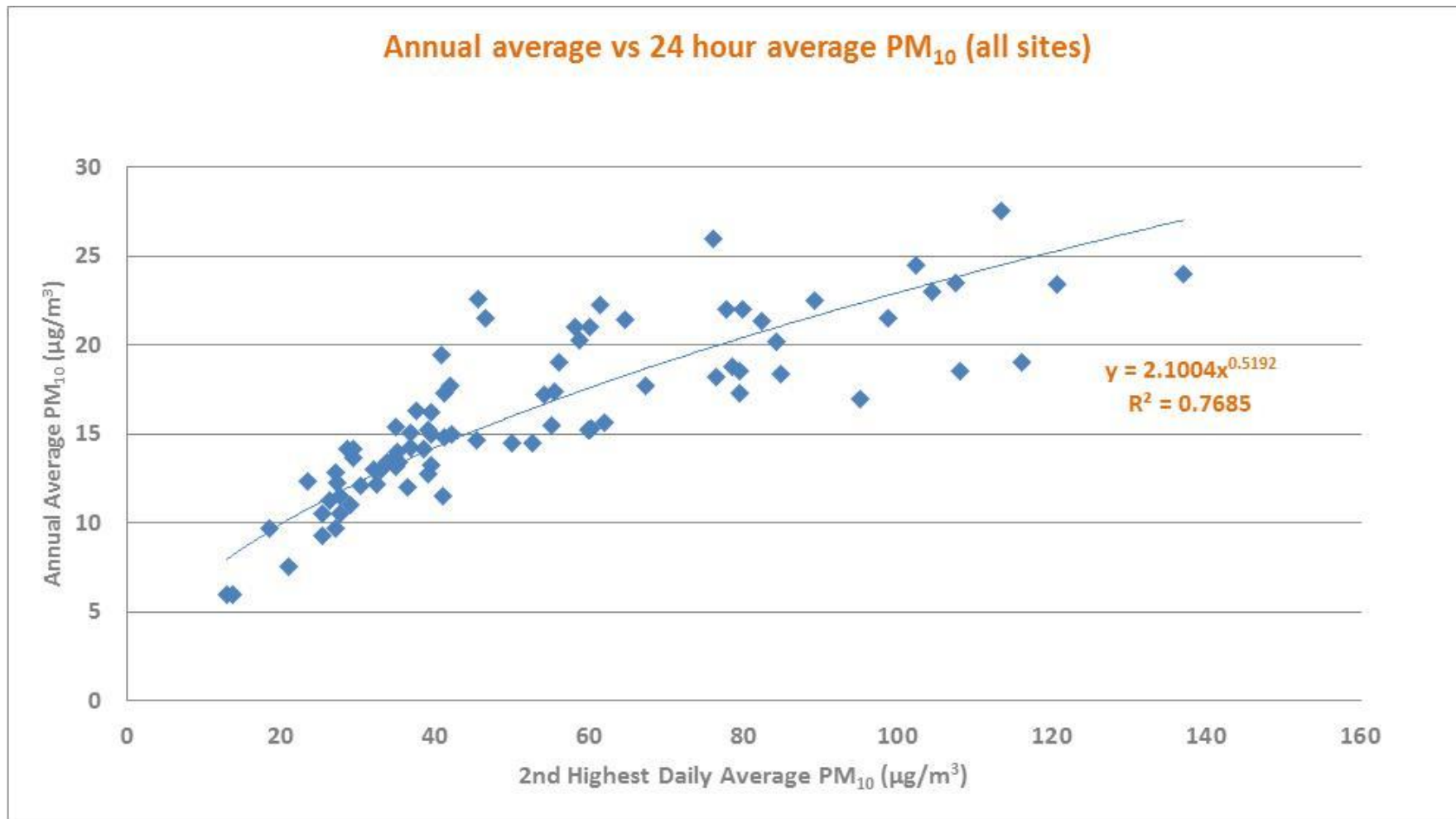


Figure A-1 National peak to mean PM₁₀ (all monitoring sites)

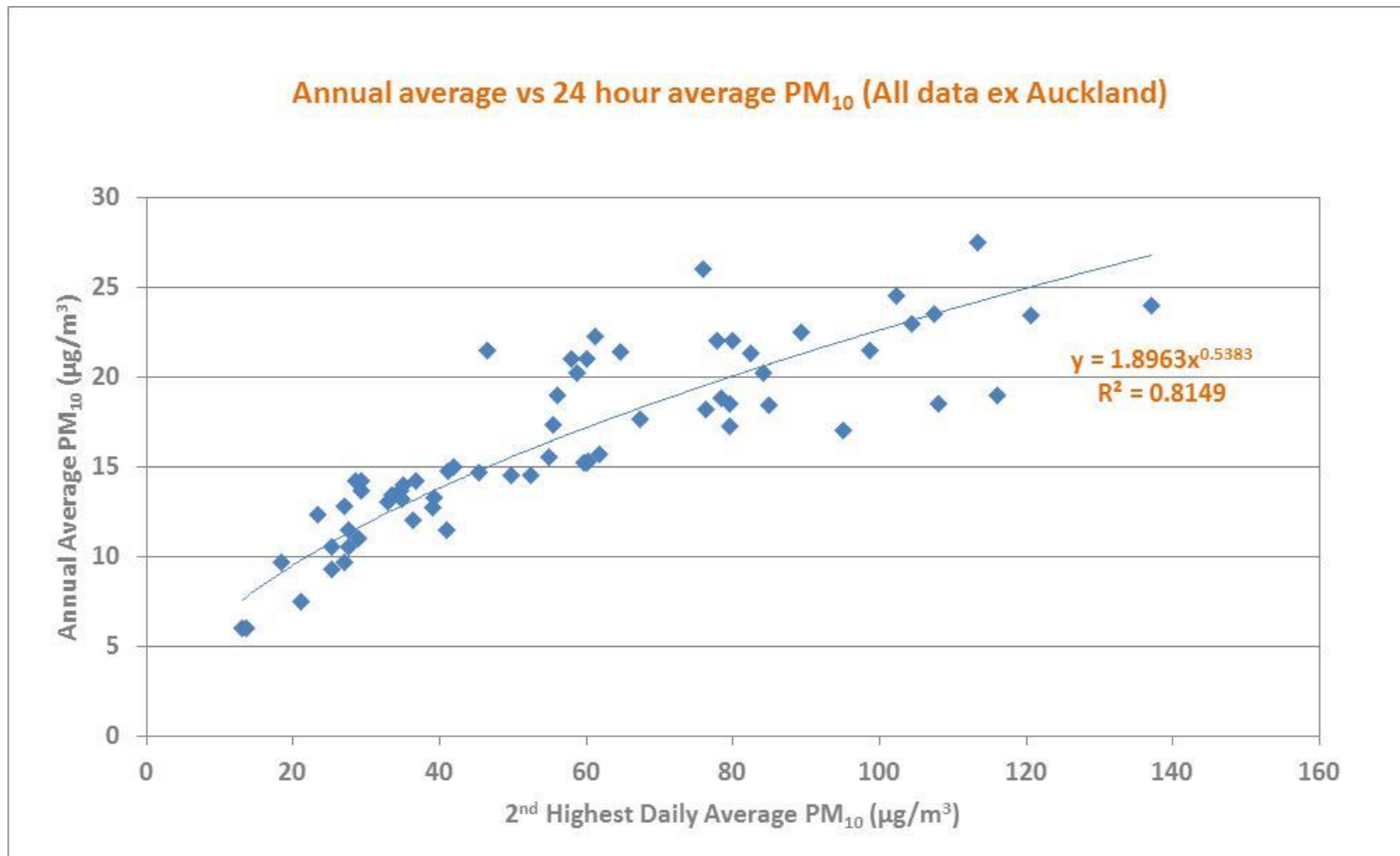


Figure A-2 National peak to mean PM₁₀ (all monitoring sites except Auckland) – this correlation used in generate default background 24-hour PM₁₀ values

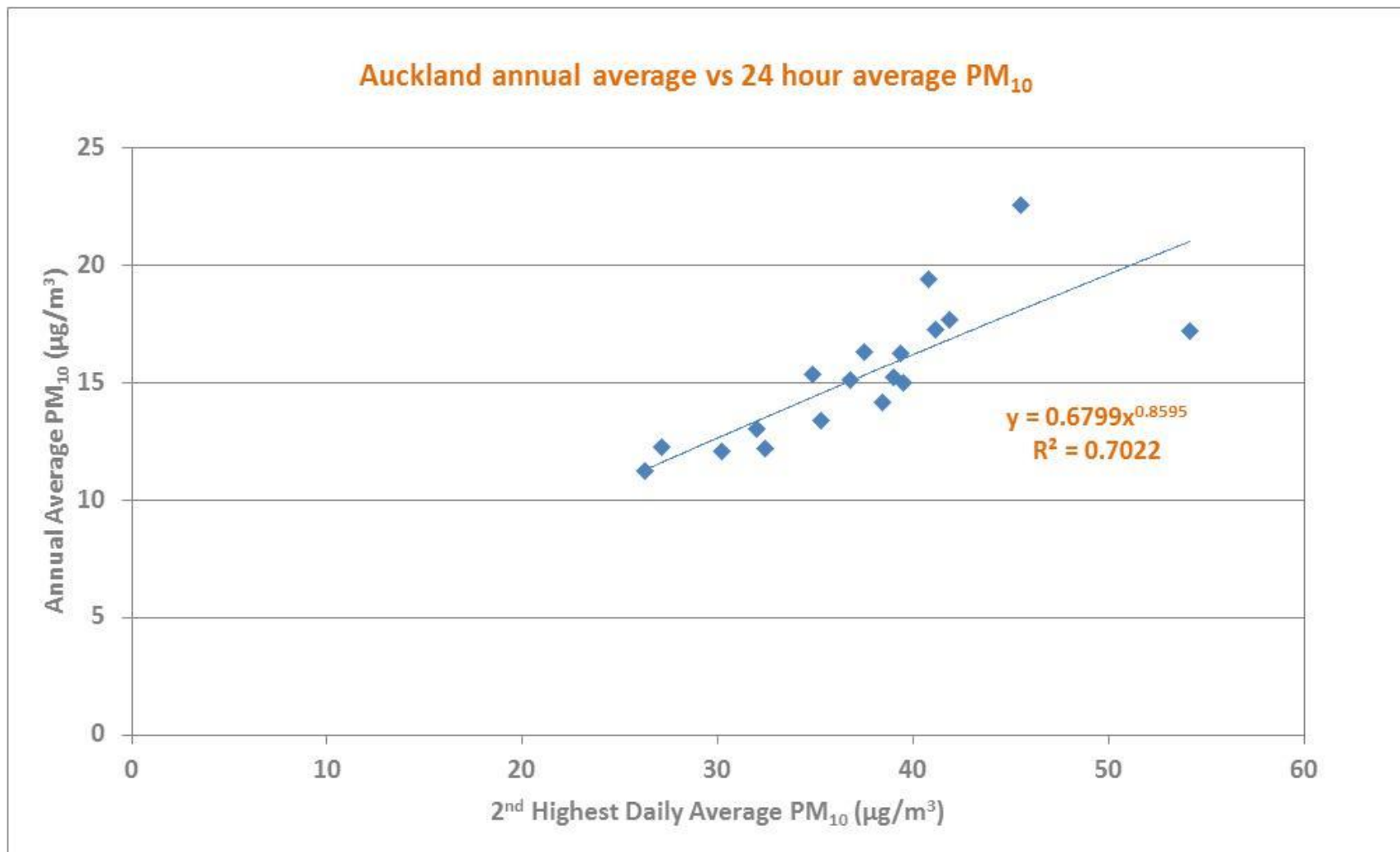


Figure A-3 Auckland peak to mean PM₁₀

Appendix C Nitrogen dioxide data

Table C-1. Nitrogen dioxide background monitoring sites

Site Type	Location	Site Name	Monitoring Agency**	Monitor Type	Nearest Busy Road or state highway (m)
Main Urban Area	Whangarei	Korau Rd	NZTA	Passive	80
	Auckland – Northern	Woodcote Dr	NZTA	passive	60
	Auckland - Central	Waterbank Cres	NZTA	Passive	150
		Kingsland	AC	Continuous	50
		Musick Point	AC	Continuous	1000
	Auckland - Western	Glen Eden	NZTA	Passive*	250
		Glen Eden	AC	Continuous	250
	Auckland - Southern	Botany	NZTA	Passive	250
	Hamilton	Seamer Pl	NZTA	Passive	93
	Tauranga	Seaforth Gr	NZTA	Passive	280
	Rotorua	Lighthouse St	NZTA	Passive	190
	Hastings	Amanda Pl	NZTA	Passive	100
	Napier	Hastie Pl	NZTA	Passive	600
	Palmerston North	Tyndall St	NZTA	Passive	100
	New Plymouth	Benbow Pl	NZTA	Passive	240
	Wellington	GWRC Duncan Park	NZTA	Passive*	60
	Wellington	Thames St	NZTA	Passive	150
	Lower Hutt	GWRC Birch Lane	NZTA	Passive*	100
	Upper Hutt	GWRC Savage Park	NZTA	Passive*	69
	Nelson	Totara St	NZTA	Passive	90
	Christchurch	Nash Rd	NZTA	Passive	440
	Christchurch	ECan Coles Pl	NZTA	Passive*	155
	Christchurch	ECan Coles Pl	ECan	Continuous	155
	Christchurch	Ecan Burnside	ECan	Continuous	100
	Dunedin	Durham St	NZTA	Passive	50
	Invercargill	Terrace St	NZTA	Passive	50
Secondary or minor urban area	Waiuku	AC Waiuku	AC	Continuous	N/A
	Pukekohe	AC Pukekohe	AC	Continuous	75
	Paraparaumu	Mackays to Peka Peka	NZTA	Continuous	970m
Rural	Patumahoe	AC Patumahoe	AC	Continuous	100
	Waiheke	AC Waiheke	AC	Continuous	N/A

* = Triplicate monitoring site

** AC = Auckland Council; ECan = Environment Canterbury

Table C-2: Annual average nitrogen dioxide data at background sites

Site Type	Location	Site Name	Annual average NO ₂ concentration (µg/m ³)								
			2005	2006	2007	2008	2009	2010	2011	Average	
Main Urban Area	Whangarei	Korau Rd							-	11	11
	Auckland - Northern	Woodcote Dr						13	13	14	13
	Auckland - Central	Waterbank Cres			-	17	16	17	19	19	17
		Kingsland	19	18							19
		Musick Point	8	9	8	7	8	7			8
	Auckland - Western	Glen Eden					10	10	10	10	10
		Glen Eden		8	8	8	8	8			8
	Auckland - Southern	Botany					18	14	17	16	16
	Hamilton	Seamer Pl						13	12	13	13
	Tauranga	Seaforth Gr						-	11	11	11
	Rotorua	Lighthouse St						-	9	9	9
	Hastings	Amanda Pl						12	12	12	12
	Napier	Hastie Pl						11	10	11	11
	Palmerston North	Tyndall St						-	16	16	16
	New Plymouth	Benbow Pl						-	10	10	10
	Wellington	GWRC Duncan Park						11	12	11	11
	Wellington	Thames St						10	11	10	10
	Lower Hutt	GWRC Birch Lane						13	13	13	13
	Upper Hutt	GWRC Savage Park						9	9	9	9
	Nelson	Totara St						13	12	12	12
	Christchurch	Nash Rd			12	12	11	15	16	13	13
	Christchurch	ECan Coles Pl						15		15	15
	Christchurch	ECan Coles Pl	16	14							15
	Christchurch	Ecan Burnside	15	15	13	13	12				14
	Dunedin	Durham St						12	14	13	13
	Invercargill	Terrace St						-	-	-	-
Secondary or minor urban area	Waiuku	AC Waiuku					8			8	
	Pukekohe	AC Pukekohe			12	15				13	
Rural	Patumahoe	AC Patumahoe			4	4	4	4		4	
	Waiheke	AC Waiheke					4	4		4	

* AC= Auckland Council; ECan = Environment Canterbury

** this is the average of all available years of data

Site Type	Location	Site Name*	Annual average NO ₂ (µg/m ³)**	Average 24-hour NO ₂ concentration (µg/m ³)							Avg**
				2005	2006	2007	2008	2009	2010	2011	
Main urban area	Auckland - Central	AC Kingsland	19	47							47
	Auckland - Central	AC Musick Point	8	32		34	34				33
	Auckland - Western	AC Glen Eden	8			22	22				22
	Christchurch	ECan Coles Pl	15	36	37						37
	Christchurch	Ecan Burnside	14	39	40	34	34	31			36
Secondary or minor urban area	Waiuku	AC Waiuku	8								
	Pukekohe	AC Pukekohe	13			29	42				35
	Paraparaumu	NZTA Mackays to Peka Peka	-							24	24
Rural	Patumahoe	AC Patumahoe	4			15	17				16
	Waiheke	AC Waiheke	4								

Site Type	Location	Site Name*	Annual average NO ₂ (µg/m ³)**	Average 1-hour NO ₂ concentration (µg/m ³)							Avg**
				2005	2006	2007	2008	2009	2010	2011	
Main urban area	Auckland - Central	AC Kingsland	19	72	72						72
	Auckland - Central	AC Musick Point	8	61	57	58	58	61			59
	Auckland - Western	AC Glen Eden	8			47	47				47
	Christchurch	ECan Coles Pl	15	63	66						65
	Christchurch	Ecan Burnside	14	73	69	57	61	58			64
Secondary or minor urban area	Waiuku	AC Waiuku	8					56			56
	Pukekohe	AC Pukekohe	13			53	73				63
	Paraparaumu	NZTA Mackays to Peka Peka	-							51	51
Rural	Patumahoe	AC Patumahoe	4				36	34			35
	Waiheke	AC Waiheke	4						29		29

* AC= Auckland Council; ECan = Environment Canterbury

** this is the average of all available years of data

Appendix D Airsheds and census area units

Default background values for 24-hour PM₁₀ are defined for all airsheds in New Zealand, and are also defined for each census area unit in New Zealand in the maps and supporting spreadsheet. This section of the report explains how the default background values were assigned to census area units.

We obtained spatial files for census area units from Statistics New Zealand. Regional councils kindly provided spatial files for all gazetted airsheds.

Census area units (CAUs) are areas classified by Statistics New Zealand, which either define, or aggregate to define regional councils, territorial authorities, urban areas and statistical areas.¹⁹ Census area units can vary in size depending upon whether it is defining an urban or rural area, populated areas, industrial areas, or port areas.

Airsheds are areas designated by regional councils for the purposes of managing air quality. Airsheds are gazetted by the Minister for the Environment and may be viewed on the Ministry for the Environment website.²⁰ Typically, airsheds comprise a number of underlying census area units.

Generally, the same (monitored or default background) PM₁₀ value was assigned to all census area units in the entire airshed.

In cases where there were multiple monitoring sites within an airshed, PM₁₀ values were calculated by census area unit (as described in Section 2.2.2). Default background PM₁₀ values are calculated by census area unit for the following areas:

- Auckland region,
- Hamilton city,
- Tauranga city,
- Wellington region,
- Christchurch city, and
- Dunedin city (includes airsheds North, South and Central Dunedin, Port Chalmers and Green Island).

All other airsheds report only one default background value for all census area units included in the airshed. Exceptions to this are Northland, Rotorua and Timaru, which are discussed in further detail in Section 2.2.2.

However, because of their different purposes, airshed boundaries do not necessarily align with census area unit boundaries. In some instances, only a small proportion of a census

¹⁹ See Statistics NZ Geographic Definitions <http://www.stats.govt.nz/Census/about-2006-census/2006-census-definitions-questions/definitions/geographic.aspx>

²⁰ <http://www.mfe.govt.nz/environmental-reporting/air/air-quality/pm10/nes/>

area unit is contained within an airshed. Figure E-1 presents an example of this using the Rotorua airshed. The Ngāpuna census area unit (highlighted in blue) includes the Whakarewarewa Forest area, while the airshed splits the Ngāpuna census area unit to exclude the forest from the airshed.

To ensure that PM₁₀ values were assigned to appropriate census area units, the percentage area of each census area unit within the airshed was calculated. We then applied the following threshold test:

- If **more than 20%** of the area of the census area unit fell within the airshed, then the census area unit was **included** as part of the airshed.²¹
- If **less than 20%** of the area of the census area unit fell within the airshed, then the census area unit was **excluded** from the airshed.

In the case of the Rotorua airshed (Figure D-1), more than 20% of the Ngāpuna census area unit is within the Rotorua airshed. The Ngāpuna census area unit (including the Whakarewarewa forest) was therefore, included in the Rotorua airshed.

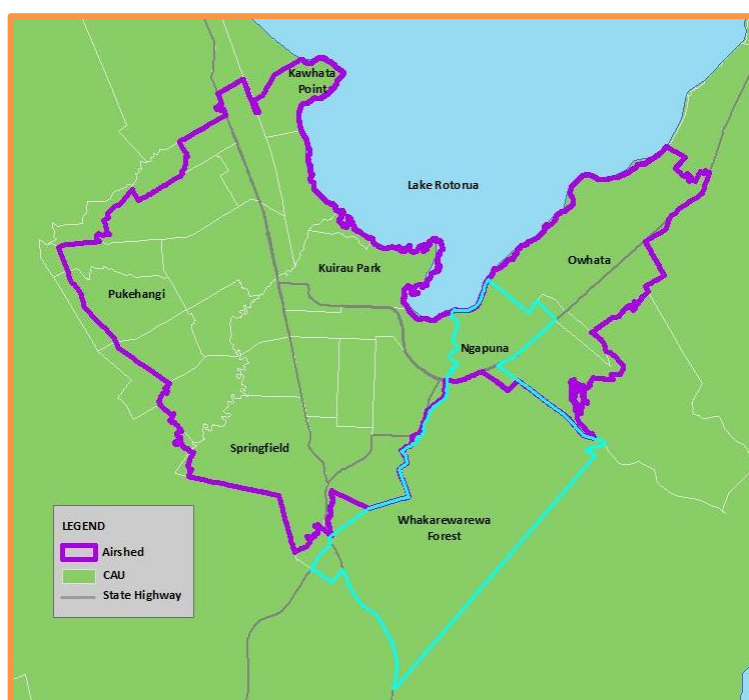


Figure D-1 Airshed boundary vs census area unit boundaries

Some census area units do not require default background PM₁₀ values to be calculated. These are areas identified as:

²¹ See "GIS Calculations" in the 'Defaults' sheet of the supporting spreadsheets.

- area outside the region
- coastal waters
- harbours
- tidal inlets
- estuaries
- lakes, and
- other water bodies.

The 'Area Outside' sheet in the supporting spreadsheets details all census area units that are classified as above. Default values have not been calculated for these census area units.