



14 August 2017

## WEST GATE TUNNEL PROJECT

# Ambient Air Quality Monitoring Data Comparison

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REPORT



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## AMBIENT AIR QUALITY MONITORING DATA COMPARISON

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### Executive Summary

Hourly average pollutant data from the Environment Protection Authority (EPA) Victoria's ambient air quality monitoring station (AAQMS) in Footscray were used as background concentrations for the West Gate Tunnel Project (WGTP) air quality impact assessment. Pollutants were:

- particulate matter with equivalent aerodynamic diameters less than 10 microns and 2.5 microns (PM<sub>10</sub> and PM<sub>2.5</sub>)
- carbon monoxide (CO)
- nitrogen dioxide (NO<sub>2</sub>).

Data from five additional AAQMSs in the project area (Yarraville, Spotswood and Brooklyn) are compared with Footscray data to assess whether Footscray AAQMS concentrations are generally representative of background concentrations in the project area. In addition, Footscray data was compared with data obtained from the EPA Victoria AAQMS at Alphington, to evaluate the stringency of the statistical analysis procedure. Both Footscray and Alphington are generally considered to be representative of urban air quality in Melbourne.

The results show that the datasets are broadly consistent with Footscray. Observed differences are attributable to local sources (e.g. major roads) in close proximity to three of the WGTP AAQMS, together with the limited data available (less than 12 months) and instrument measurement uncertainty.

The WGTP air quality impact assessment includes an assessment of vehicle emissions on major roads to which the background concentrations are added, therefore using the elevated concentrations from these roadside monitoring locations as representative background concentrations would in effect be double-counting. The annual average incremental PM<sub>10</sub> and PM<sub>2.5</sub> increases at Francis Street predicted by the model show good agreement with the mean difference between the Footscray and Francis Street AAQMS datasets, suggesting that the approach of using five years of EPA Victoria Footscray data as background concentrations for the WGTP air quality impact assessment is appropriate.



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### 1.0 INTRODUCTION

Hourly average pollutant data from the Environment Protection Authority (EPA) Victoria's ambient air quality monitoring station (AAQMS) in Footscray were used as background concentrations of particulate matter with equivalent aerodynamic diameters less than 10 microns and 2.5 microns (PM<sub>10</sub> and PM<sub>2.5</sub>), carbon monoxide (CO) and nitrogen dioxide (NO<sub>2</sub>) for the West Gate Tunnel Project (WGTP) air quality impact assessment.

Predicted surface road and road tunnel ventilation structure concentrations obtained from the air quality model were added to the background concentrations to give a cumulative impact. Results from the Footscray AAQMS were used as they were considered generally representative of background pollutant concentrations in the project area. However, background pollutant concentrations can vary as a result of local emission sources.

An additional five ambient monitoring stations were commissioned by Western Distributor Authority (WDA) within the project area. This report compares the data from these stations, and a second EPA Victoria AAQMS at Alphington, with that of Footscray, to establish whether Footscray AAQMS concentrations are generally representative of the background concentrations for the project area. Data from the EPA Victoria AAQMS at Alphington has been included to provide context in relation to the stringency of the statistical analysis procedures employed. Both Footscray and Alphington are generally considered to be representative of urban air quality in Melbourne, with data from both stations evaluated in the existing conditions section of the WGTP air quality impact assessment report.

The datasets available for comparison were as follows:

**Table 1: AAQMS datasets**

Location	Pollutants	Start date	Review date
Footscray (EPA Victoria)	PM <sub>10</sub> , PM <sub>2.5</sub> , CO & NO <sub>2</sub>	1 August 2016	30 June 2017
Alphington (EPA Victoria)	PM <sub>10</sub> , PM <sub>2.5</sub> , CO & NO <sub>2</sub>	1 August 2016	30 June 2017
Donald McLean Reserve (WGTP)	PM <sub>10</sub> & PM <sub>2.5</sub>	25 January 2017	30 June 2017
Francis Street, Yarraville (WGTP)	PM <sub>10</sub> & PM <sub>2.5</sub>	1 September 2016	30 June 2017
Primula Avenue, Brooklyn (WGTP)	PM <sub>10</sub> , PM <sub>2.5</sub> , CO & NO <sub>2</sub>	8 November 2016	30 June 2017
Woods Street, Yarraville (WGTP)	PM <sub>10</sub> & PM <sub>2.5</sub>	3 February 2017	30 June 2017
Yarraville Gardens, Yarraville (WGTP)	PM <sub>10</sub> & PM <sub>2.5</sub>	1 August 2016	30 June 2017

The locations of the Footscray and WGTP AAQMSs are provided in Table 2 and shown in Figure 1.

**Table 2: Footscray and WGTP AAQMS locations**

AAQMS	Coordinates
Footscray	37°48'17.54"S 144°52'21.88"E
Donald McLean Reserve	37°49'35.28"S 144°52'55.25"E
Francis Street	37°49'15.59"S 144°53'38.41"E
Primula Avenue	37°49'27.28"S 144°50'45.72"E
Woods Street	37°48'50.40"S 144°53'27.60"E
Yarraville Gardens	37°48'43.20"S 144°54'0.00"E



## AMBIENT AIR QUALITY MONITORING DATA COMPARISON



Figure 1: AAQMS locations



### 2.0 AMBIENT AIR QUALITY MONITORING DATA

Validated ambient air quality data has been provided by EPA Victoria (Footscray and Alphington AAQMSs) and Ecotech Pty. Ltd. (WGTP AAQMSs). Ecotech Pty. Ltd. (Ecotech) operates the WGTP stations on behalf of WDA.

The *State Environment Protection Policy (Ambient Air Quality)*<sup>1</sup> [SEPP(AAQ)] establishes in Victorian legislation the pollutant standards contained in the *National Environment Protection (Ambient Air Quality) Measure*<sup>2</sup>, referring to them as environmental quality objectives (EQOs). For the purpose of evaluating performance against the EQOs, air quality is to be measured at performance monitoring stations, with the station operator appropriately accredited by the National Association of Testing Authorities (NATA). Both EPA Victoria and Ecotech are accredited by NATA for conducting ambient air quality monitoring for both the pollutants and test methods used.

Performance monitoring stations are defined and located such that they represent air quality experienced by the general population in a region. EQOs should therefore not be used for evaluating ambient air quality data obtained from near road monitoring stations. A number of the WGTP AAQMSs were located in order to assess near road concentrations, consequently *State Environment Protection Policy (Air Quality Management)* [SEPP(AQM)] Schedule B intervention levels (ILs) apply. For convenience all datasets have been plotted against both the SEPP(AAQ) EQOs and SEPP(AQM) ILs.

The 24 hour average PM<sub>10</sub> and PM<sub>2.5</sub> concentrations from each station are presented in Figure 2 and Figure 3. The plots indicate that the 24 hour average concentrations at each station are broadly consistent. The SEPP(AAQ) PM<sub>10</sub> EQO of 50 µg/m<sup>3</sup> was exceeded on one occasion at Francis Street and Donald McLean Reserve and twice at Primula Avenue, however the SEPP(AQM) PM<sub>10</sub> IL of 60 µg/m<sup>3</sup> was not exceeded. The SEPP (AAQ) PM<sub>2.5</sub> EQO of 25 µg/m<sup>3</sup> was exceeded at all stations on at least one occasion (Primula Avenue) and up to six times (Donald McLean Reserve). The SEPP(AQM) PM<sub>2.5</sub> IL of 36 µg/m<sup>3</sup> was not exceeded at any station.

The daily maximum 8 hour average CO and daily maximum 1 hour average NO<sub>2</sub> concentrations from Footscray, Alphington and Primula Avenue AAQMSs are presented in Figure 4 and Figure 5. The plots indicate that, whilst there is a general trend in the datasets, Alphington CO concentrations are typically greater than Footscray and Footscray NO<sub>2</sub> concentrations are typically greater than Alphington. Primula Avenue CO and NO<sub>2</sub> concentrations are generally greater than both Footscray and Alphington, albeit still at a low level, with the SEPP(AAQ) CO EQO of 9.0 ppm and the SEPP(AAQ) NO<sub>2</sub> EQO of 120 ppb not exceeded at any station. Consequently the SEPP(AQM) NO<sub>2</sub> IL of 140 ppb was also not exceeded.

The daily maximum 1 hour average CO concentrations from Primula Avenue are presented in Figure 6, with no exceedances of the SEPP(AQM) CO IL of 29 ppm indicated. Lines representing the SEPP(AAQ) CO EQO and SEPP(AQM) CO IL are not shown in Figures 4 and 6 due to the low concentrations recorded.

Mean pollutant concentrations for each AAQMS are provided in Table 3. In order to compare the concentrations at each of the stations with Footscray AAQMS, only those days or hours are included where both stations report data ('data pairs'), therefore the mean Footscray concentration varies depending on which station is under consideration.

Data capture percentages for each pollutant and AAQMS are provided in Table 4. The National Environment Protection Council Peer Review Committee<sup>3</sup> notes that, when assessing ambient air quality monitoring data, an average concentration is only valid when it is based on at least 75 per cent of the expected samples in the averaging period, whilst also noting that it is desirable to have data capture percentages higher than 95 per cent. The 75 per cent criterion applies to all averaging periods, ranging from one hour to annual.

<sup>1</sup> *State Environment Protection Policy (Ambient Air Quality)*, Victorian Government Gazette, Melbourne, Victoria 2016

<sup>2</sup> *National Environment Protection (Ambient Air Quality) Measure*, Australian Government, February 2016

<sup>3</sup> *Data Collection and Handling*, National Environment Protection Council, Peer Review Committee, Technical Paper No. 5, May 2001



## AMBIENT AIR QUALITY MONITORING DATA COMPARISON

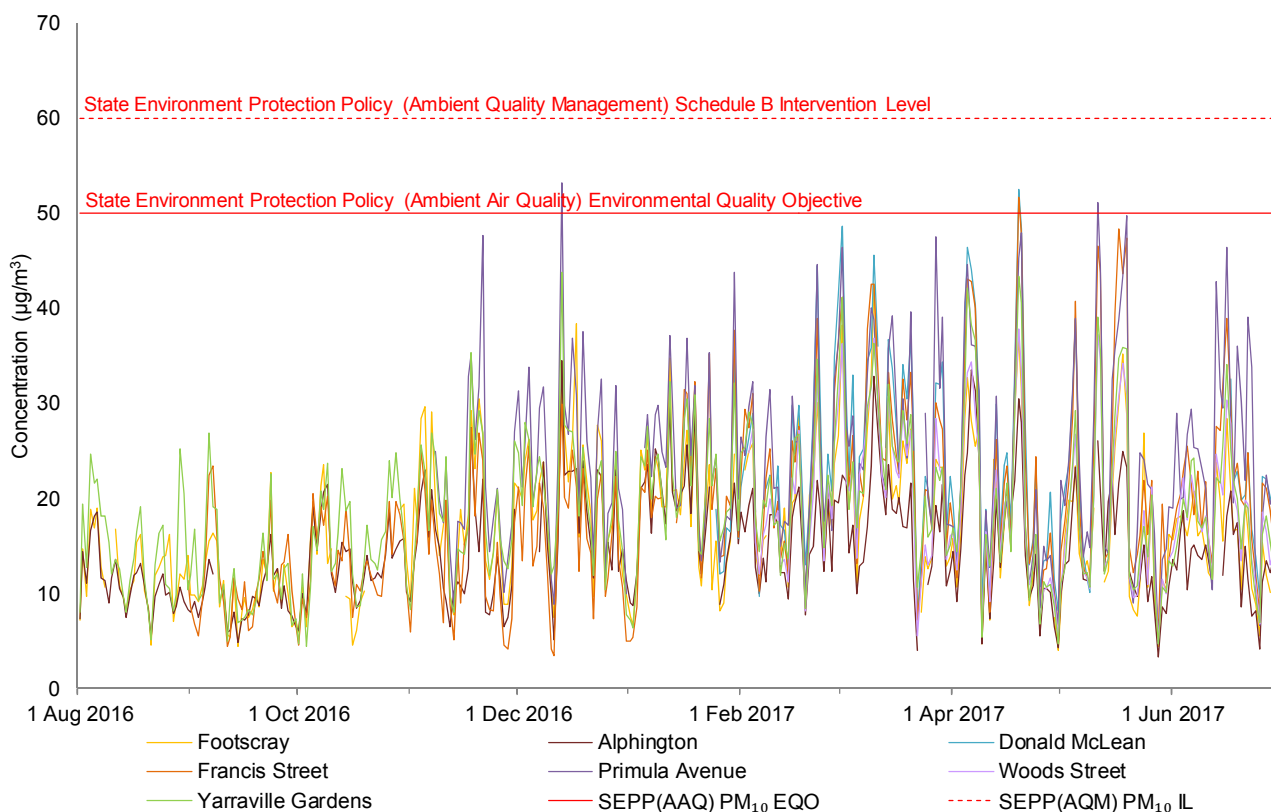


Figure 2: 24 hour average  $PM_{10}$  concentrations

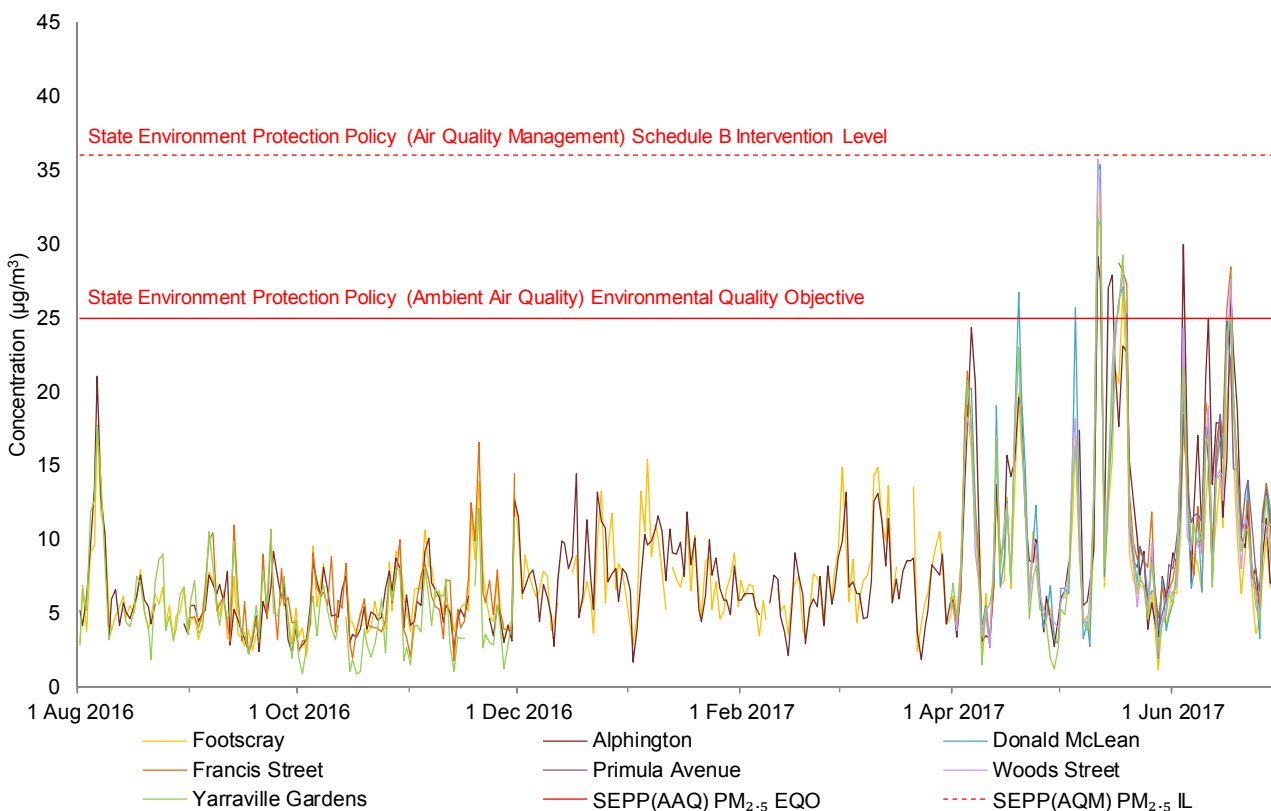


Figure 3: 24 hour average  $PM_{2.5}$  concentrations



## AMBIENT AIR QUALITY MONITORING DATA COMPARISON

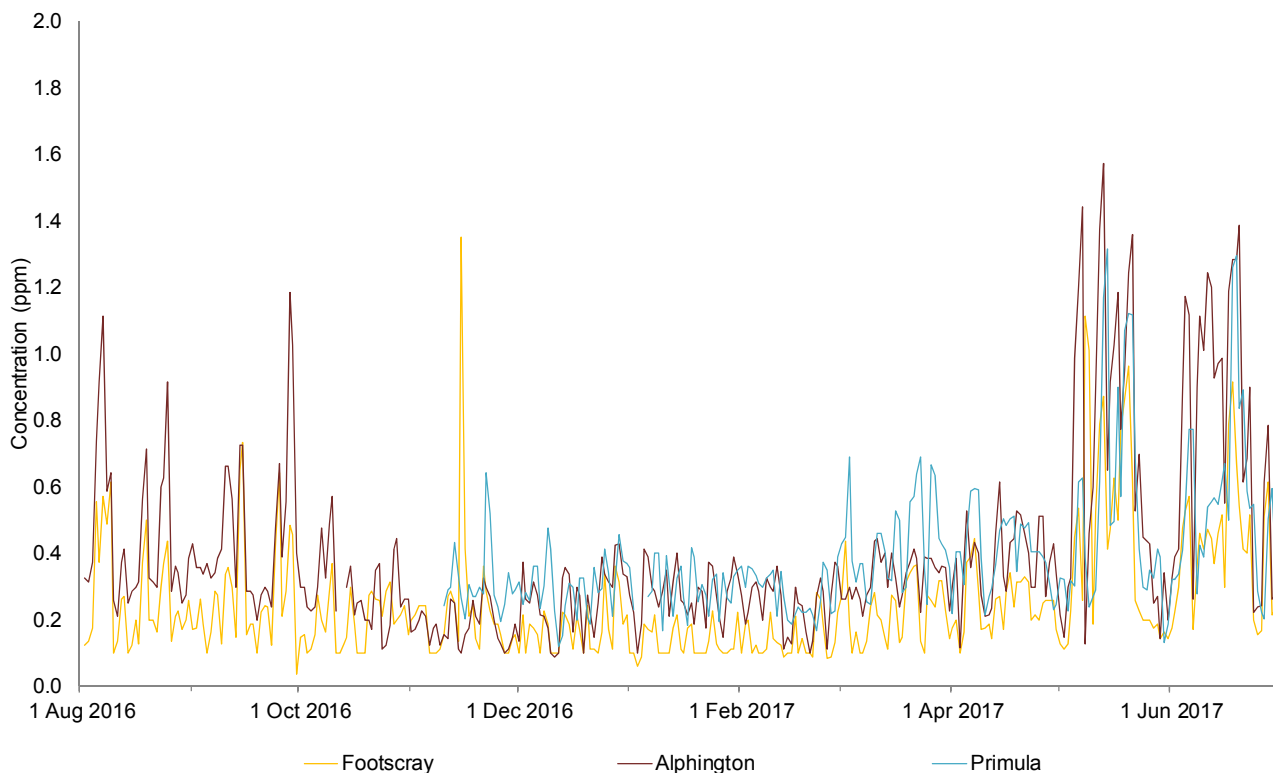


Figure 4: Daily maximum 8 hour average CO concentrations

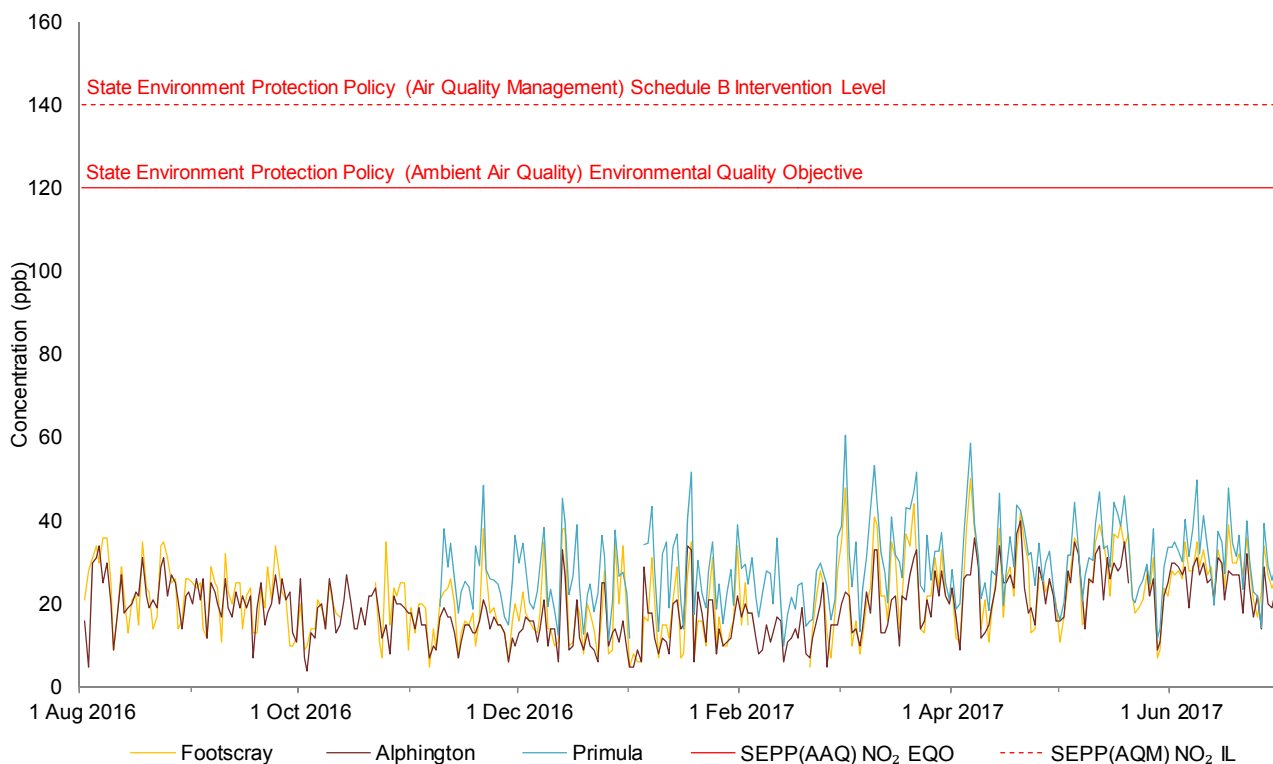


Figure 5: Daily maximum 1 hour average NO<sub>2</sub> concentrations



## AMBIENT AIR QUALITY MONITORING DATA COMPARISON

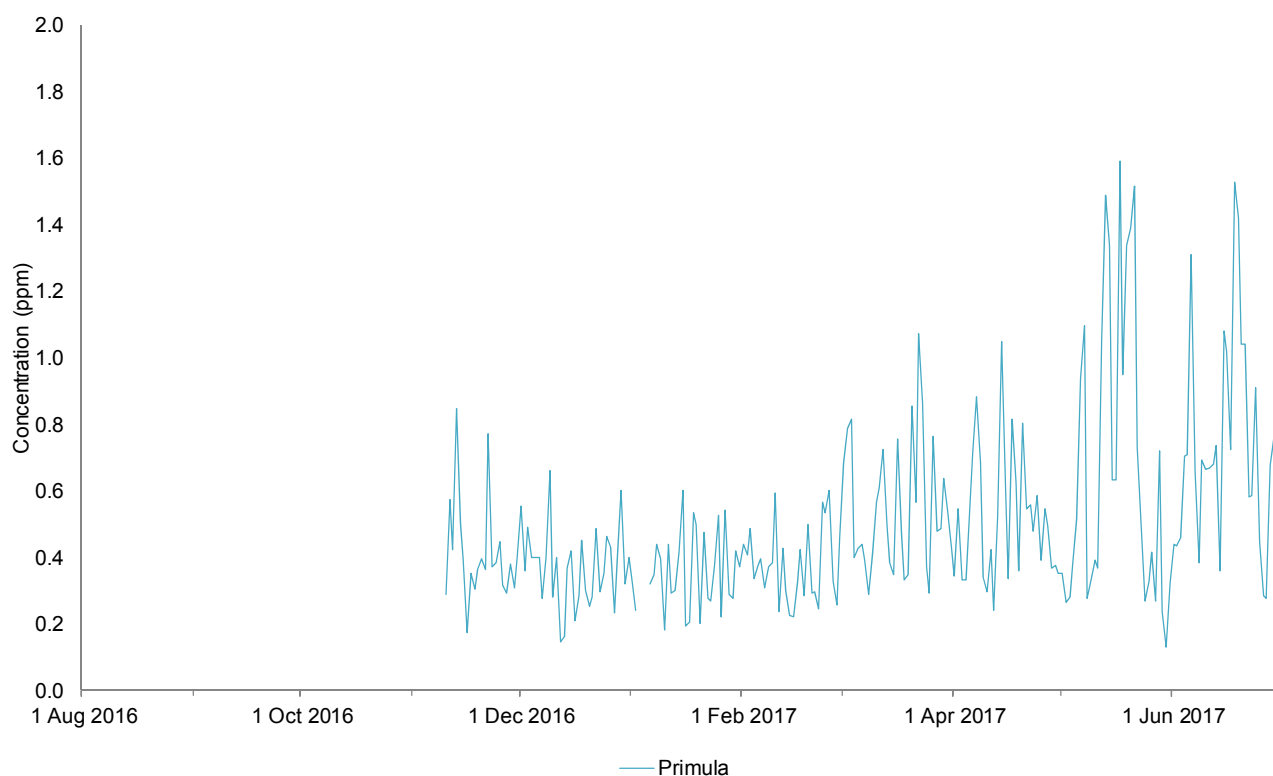


Figure 6: Daily maximum 1 hour average CO concentrations

Table 3: Mean pollutant concentrations

AAQMS	PM <sub>10</sub> (µg/m <sup>3</sup> )		PM <sub>2.5</sub> (µg/m <sup>3</sup> )		CO (ppm)		NO <sub>2</sub> (ppb)	
	AAQMS	Footscray	AAQMS	Footscray	AAQMS	Footscray	AAQMS	Footscray
Alphington	14.7	16.9	8.3	7.7	0.24	0.15	9.3	10.8
Donald McLean Reserve	24.5	18.5	13.7	11.1	NM	NA	NM	NA
Francis Street	19.0	17.3	8.5	7.4	NM	NA	NM	NA
Primula Avenue	24.4	18.7	12.0	9.2	0.27	0.16	18.2	11.5
Woods Street	19.3	18.3	11.3	10.0	NM	NA	NM	NA
Yarraville Gardens	18.4	16.9	7.8	8.0	NM	NA	NM	NA

NM – Not monitored at this station

NA – Not applicable

Table 4: Data capture statistics

AAQMS	Monitoring period commencement	PM <sub>10</sub> 24 h average (%)	PM <sub>2.5</sub> 24 h average (%)	CO 8 h average (%)	NO <sub>2</sub> 1 h average (%)
Footscray	1 August 2016	92.2	93.4	97.3	85.8
Alphington	1 August 2016	95.2	95.2	95.2	91.1
Donald McLean Reserve	25 January 2017	75.2	56.1	NM	NM
Francis Street	1 September 2016	99.3	49.2	NM	NM
Primula Avenue	8 November 2016	97.0	18.3	97.9	93.9
Woods Street	3 February 2017	100	62.2	NM	NM
Yarraville Gardens	1 August 2016	100	62.6	97.3	85.8

NM – Not monitored at this station.



## AMBIENT AIR QUALITY MONITORING DATA COMPARISON

WGTP AAQMS data has been validated by Ecotech, notably with several months of PM<sub>2.5</sub> data invalidated due to instrumentation issues following commission. Consequently data capture percentages for PM<sub>2.5</sub> at all WGTP AAQMSs are below the 75 per cent criterion, with Primula Avenue data extremely limited (18 per cent). Data capture percentages for PM<sub>10</sub>, CO and NO<sub>2</sub> comply with the 75 per cent criterion at all stations.

It is therefore considered inappropriate to make judgements on compliance against the SEPP(AAQ) annual average EQO criteria for PM<sub>2.5</sub> given both the low data capture percentages and the lack of a minimum of 12 months of data.

SEPP(AQM) does not specify annual average ILs for any of the pollutants monitored, however for stations where there is data over a reasonable period (Footscray, Alphington, Francis Street and Yarraville Gardens), compliance is indicated with the SEPP(AAQ) annual average EQOs for PM<sub>10</sub> and NO<sub>2</sub> of 20 µg/m<sup>3</sup> and 30 ppb respectively. There is no SEPP(AAQ) annual average EQO for CO.



### 3.0 AIR QUALITY DATASET COMPARISON

Two statistical methods have been used to compare the 24 hour average PM<sub>10</sub> and PM<sub>2.5</sub> and one hour average CO and NO<sub>2</sub> concentrations for each data pair:

- **Paired T-test (two tails)** - A paired t-test is used to determine whether the mean difference between paired data is statistically significant. The difference between each 24 hour result is calculated, and the null hypothesis is tested i.e. whether the mean difference between paired results is zero. A two-tailed hypothesis has been used because the direction of the difference between the two paired samples is not of concern.
- **Orthogonal regression** – Examines the linear relationship between two datasets. This analysis is more appropriate than a simple linear regression because both datasets contain measurement error.

To assess the outcome of each method, we have used the following criteria for determining a statistical difference between each dataset:

- For the paired t-test, a p-value of 0.05 or less i.e. there is a 95% probability that the mean difference between paired results is greater than zero.
- For orthogonal regression, the slope is different from 1 by  $>2u^1$ , and the intercept is different from 0 by  $>2u^2$ , where  $u^1$  and  $u^2$  are the standard uncertainties of the slope and intercept. These criteria have been adopted from the European Council method for demonstrating equivalence of methods used to monitor particulate matter in ambient air<sup>4</sup>.

A summary of the statistical data comparison between Footscray and other AAQMS data is provided in Table 5 and Table 6. Full results of the statistical tests are provide in Appendix A.

**Table 5: Footscray statistical analysis summary PM<sub>10</sub> and PM<sub>2.5</sub>**

AAQMS	PM <sub>10</sub>		PM <sub>2.5</sub>	
	Paired t-test	Orthogonal regression	Paired t-test	Orthogonal regression
Alphington	Mean difference > 0	Not equivalent	Mean difference > 0	Not equivalent
Donald McLean Reserve	Mean difference > 0	Not equivalent	Mean difference > 0	Not equivalent
Francis Street	Mean difference > 0	Not equivalent	Mean difference > 0	Not equivalent
Primula Avenue	Mean difference > 0	Not equivalent	Mean difference > 0	Not equivalent
Woods Street	Mean difference > 0	Not equivalent	Mean difference > 0	Not equivalent
Yarraville Gardens	Mean difference > 0	Not equivalent	Mean difference = 0	Not equivalent

**Table 6: Footscray statistical analysis summary CO and NO<sub>2</sub>**

AAQMS	CO		NO <sub>2</sub>	
	Paired t-test	Orthogonal regression	Paired t-test	Orthogonal regression
Alphington	Mean difference > 0	Not equivalent	Mean difference > 0	Not equivalent
Primula Avenue	Mean difference > 0	Not equivalent	Mean difference > 0	Not equivalent

<sup>4</sup> Guide to the *Demonstration of Equivalence of Ambient Air Monitoring Methods*, European Council Working Group on Guidance for the Demonstration of Equivalence, 2005.



## 4.0 DISCUSSION

We have considered a statistical difference to occur between AAQMS datasets when both the paired t-test and the orthogonal regression analysis indicate that the results are not from the same dataset. Based on this approach, the statistical outcomes of the analysis are described in Table 7.

**Table 7: Statistical outcome**

AAQMS	Statistical difference to Footscray			
	PM <sub>10</sub>	PM <sub>2.5</sub>	CO	NO <sub>2</sub>
Alphington	Yes	Yes	Yes	Yes
Donald McLean Reserve	Yes	Yes	N/A	N/A
Francis Street	Yes	Yes	N/A	N/A
Primula Avenue	Yes	Yes	Yes	Yes
Woods Street	Yes	Yes	N/A	N/A
Yarraville Gardens	Yes	No	N/A	N/A

Other than PM<sub>2.5</sub> at Yarraville Gardens, the results suggest that the remaining datasets are statistically different.

The mean concentration of the monitoring stations provides a simple comparison of the concentrations indicating which, in general, reports higher or lower concentrations. The mean difference of the concentrations (the mean of the difference between each daily or hourly data pair) in conjunction with the 95 per cent confidence interval for the mean difference also provides some indication of the spread of the data pairs. A low mean difference (relative to the Footscray mean concentration) and a narrow 95 per cent confidence interval indicates a good correlation between the stations.

Comparisons between stations should be regarded as indicative only given the limited amount of data available for comparison (a minimum of 12 months data covering all meteorological conditions is considered necessary to provide a valid comparison) and the method measurement uncertainty<sup>5</sup>.

### PM<sub>10</sub>

PM<sub>10</sub> 24 hour average concentrations recorded at Footscray are generally greater than those recorded at Alphington (mean difference of 2.2 µg/m<sup>3</sup>) and lower than at the WGTP AAQMSs (Table 8).

**Table 8: Mean PM<sub>10</sub> concentrations**

Comparison AAQMS	AAQMS (µg/m <sup>3</sup> )	Footscray (µg/m <sup>3</sup> )	Mean difference (µg/m <sup>3</sup> )	Confidence level (95%; µg/m <sup>3</sup> )
Alphington	14.7	16.9	2.2	±0.41
Donald McLean Reserve	24.5	18.5	-5.9	±0.81
Francis Street	19.0	17.3	-1.7	±0.62
Primula Avenue	24.4	18.7	-5.7	±0.73
Woods Street	19.3	18.3	-1.0	±0.38
Yarraville Gardens	18.4	16.9	-1.6	±0.39

The highest mean differences are at Donald McLean Reserve (-5.9 µg/m<sup>3</sup>) and Primula Avenue (-5.7 µg/m<sup>3</sup>). Donald McLean Reserve and Primula Avenue are near, and therefore directly influenced by, the West Gate Freeway. These stations would be expected to experience higher concentrations than Footscray. The mean differences for the remaining stations are within 5.5 to 9.8 per cent of the Footscray mean concentration. The 95 per cent confidence level of the mean difference is less than ±1 µg/m<sup>3</sup> for all stations. This suggests

<sup>5</sup> Reported measurement uncertainty: Ecotech Pty Ltd PM<sub>10</sub> (TEOM) and PM<sub>2.5</sub> (BAM) = ±5 µg/m<sup>3</sup>, CO (EC9830) = ±1.1 ppm NO<sub>2</sub> (EC9841) = ±16 ppb; EPA Victoria PM<sub>10</sub> (TEOM) = ±5 µg/m<sup>3</sup>, PM<sub>2.5</sub> (BAM) = ±5.7 µg/m<sup>3</sup>.



## AMBIENT AIR QUALITY MONITORING DATA COMPARISON

that while the paired t-test and orthogonal regression comparisons indicated a statistical difference between the Footscray dataset and the Alphington, Francis Street, Woods Street and Yarraville Gardens datasets, in the context for which the Footscray dataset has been used, this difference can be considered insignificant.

The WGTP Environment Effects Statement (EES) surface road modelling assessed predicted baseline (existing roads with forecast 2022 traffic) impacts along Francis Street. The results from the assessment suggest that the maximum annual average PM<sub>10</sub> concentration along Francis Street is predicted to be 1.3 µg/m<sup>3</sup> above background (vehicle tail-pipe emissions only). This corresponds reasonably well with the 1.7 µg/m<sup>3</sup> mean difference in concentration between Francis Street and Footscray, suggesting that Footscray AAQMS PM<sub>10</sub> data could be considered representative of the background conditions in the project area.

### PM<sub>2.5</sub>

PM<sub>2.5</sub> concentrations recorded at Footscray are generally lower than those recorded at all other AAQMSs (Table 9).

**Table 9: Mean PM<sub>2.5</sub> concentrations**

Comparison AAQMS	AAQMS (µg/m <sup>3</sup> )	Footscray (µg/m <sup>3</sup> )	Mean difference (µg/m <sup>3</sup> )	Confidence level (95%; µg/m <sup>3</sup> )
Alphington	8.3	7.7	-0.60	0.31
Donald McLean Reserve	13.7	11.1	-2.6	0.62
Francis Street	8.5	7.4	-1.1	0.37
Primula Avenue	12.0	9.2	-2.8	0.53
Woods Street	11.3	10.0	-1.3	0.42
Yarraville Gardens	7.8	8.0	-1.5	0.29

As with PM<sub>10</sub>, the greatest mean differences are for Donald McLean Reserve (-2.6 µg/m<sup>3</sup>) and Primula Avenue (-2.8 µg/m<sup>3</sup>) due to their proximity to the West Gate Freeway. The mean differences for the remaining stations range from 2.5 to 23 per cent of the Footscray mean concentration. The 95 per cent confidence level of the mean difference is less than ±0.7 µg/m<sup>3</sup> for all stations.

The baseline (2022 traffic) results from the WGTP EES surface road modelling assessment suggest that the maximum annual average PM<sub>2.5</sub> concentration along Francis Street is predicted to be 1.2 µg/m<sup>3</sup> above background (vehicle tail-pipe emissions only). This corresponds reasonably well with the 1.1 µg/m<sup>3</sup> mean difference concentration between Francis Street and Footscray, suggesting Footscray AAQMS data could be considered representative of the background conditions in the project area.

### CO

CO 8 hour average concentrations recorded at Footscray are generally lower than those recorded at Alphington and Primula Avenue (Table 10), however, all values are relatively low compared to the SEPP(AAQ) EQO.

**Table 10: Footscray mean CO concentrations**

Comparison AAQMS	AAQMS (ppm)	Footscray (ppm)	Mean difference (ppm)	Confidence level (95%; ppm)
Alphington	0.24	0.15	-0.089	±0.004
Primula Avenue	0.27	0.16	-0.12	±0.003

### NO<sub>2</sub>

NO<sub>2</sub> concentrations recorded at Footscray are generally greater than those recorded at Alphington and lower than those recorded at Primula Avenue (Table 11).



## AMBIENT AIR QUALITY MONITORING DATA COMPARISON

**Table 11: Footscray mean NO<sub>2</sub> concentrations**

Comparison AAQMS	AAQMS (ppb)	Footscray (ppb)	Mean difference (ppb)	Confidence level (95%; ppb)
Alphington	9.3	10.8	1.5	0.15
Primula Avenue	18.2	11.5	-6.7	0.21

The WGTP EES surface road modelling assessment did not include the Primula Avenue AAQMS location, however receptor locations along the West Gate Freeway can be considered representative of Primula Avenue, being a high traffic roadside monitoring location. The maximum annual average NO<sub>2</sub> concentration along the West Gate Freeway was predicted to be 4.4 ppb above background. The Primula Avenue dataset only includes approximately 7.5 months of data, however, the WGTP EES result can still be considered comparable with the 6.7 ppb mean difference concentration between Footscray and Primula Avenue AAQMS.

### Summary

The mean concentrations presented in Table 3 are presented in Table 12 expressed as ratios with respect to Footscray mean concentrations. Ratios between 0.9 and 1.1 indicate a mean concentration within approximately 10 per cent of the Footscray mean concentration. In general, there is good agreement between Footscray and Alphington, Francis Street, Woods Street (PM<sub>10</sub> only) and Yarraville Gardens. Donald McLean Reserve and Primula Avenue have higher mean concentration ratios as expected due to their proximity to the West Gate Freeway.

**Table 12: Ratios of mean concentrations to Footscray**

AAQMS	PM <sub>10</sub>	PM <sub>2.5</sub>	CO	NO <sub>2</sub>
Alphington	0.9	1.1	1.0	0.8
Donald McLean Reserve	1.4	1.6	N/A	N/A
Francis Street	1.1	1.1	N/A	N/A
Primula Avenue	1.4	1.6	1.5	1.6
Woods Street	1.1	1.5	N/A	N/A
Yarraville Gardens	1.1	1.0	N/A	N/A



### 5.0 CONCLUSIONS

Comparisons between stations should be regarded as indicative only given the limited amount of data available for comparison (a minimum of 12 months data covering all meteorological conditions is considered necessary to provide a valid comparison) and the method measurement uncertainty.

Whilst no statistical equivalency between the Footscray AAQMS and other AAQMS datasets was demonstrated using the paired t-test and orthogonal regression methods, this is perhaps expected given the different sources of pollutants local to each station, prevailing winds and the relatively tight test criteria.

The differences between the datasets indicated by these methods can however be considered of minor consequence given the clear visual trends apparent in the time series plots and the x-y (orthogonal regression) scatter plots (Appendix A) that show that the datasets are broadly consistent.

Mean concentration ratios of between approximately 0.9 and 1.1 suggest that, as might be expected, Footscray pollutant concentrations are similar to Alphington, Francis Street, Woods Street and Yarraville Gardens. Pollutant concentrations greater than those measured at Footscray are to be expected at Donald McLean Reserve and Primula Avenue due to their proximity to the West Gate Freeway. The WGTP air quality impact assessment includes an evaluation of the impact of vehicle emissions on major roads to which background concentrations are added, therefore using elevated concentrations from these roadside monitoring locations would in effect be double-counting.

The predicted annual average incremental  $PM_{10}$  and  $PM_{2.5}$  increases at Francis Street show good agreement with the mean difference between the Footscray and Francis Street AAQMS datasets suggesting that the approach of using five years of EPA Victoria Footscray data as background concentrations for the WGTP air quality impact assessment, to which predicted local surface road and ventilation stack impacts are added, is appropriate.



### 6.0 IMPORTANT INFORMATION

Your attention is drawn to the document, Important Information Relating to this Report (LEG04, RL2), which is attached to this report (Appendix B). The statements presented in this document are intended to advise you of what your realistic expectations of this technical report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this letter are aware of the responsibilities each assumes in so doing. We would be pleased to answer any questions the reader may have regarding this document.



## Report Signature Page

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# **APPENDIX A**

## **Statistical Analysis Results**



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## APPENDIX A Statistical Comparisons

### 1.0 DATASETS COMPARISON: PM<sub>10</sub>

The following sections present the results of the statistical and visual comparisons between Footscray AAQMS and the other AAQMS PM<sub>10</sub> concentration datasets.

#### 1.1 Footscray and Alphington

**Table 1: Statistics summary: PM<sub>10</sub> – Footscray and Alphington**

Statistic*	Footscray	Alphington
Mean (µg/m <sup>3</sup> )	16.9	14.7
Maximum (µg/m <sup>3</sup> )	42.5	34.6
Minimum (µg/m <sup>3</sup> )	4.0	3.4
Mean difference (µg/m <sup>3</sup> )	2.2	
CI (95%) of mean difference (µg/m <sup>3</sup> )	1.8 – 2.6	
N = no. of 24 hour periods	292	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 1.1x10 <sup>-21</sup> )	
Orthogonal regression	Not equivalent (slope = 1.0, u <sup>1</sup> = 0.022 (pass), intercept = -2.2, u <sup>2</sup> = 0.51 (fail))	

\* Only paired data included in the analysis

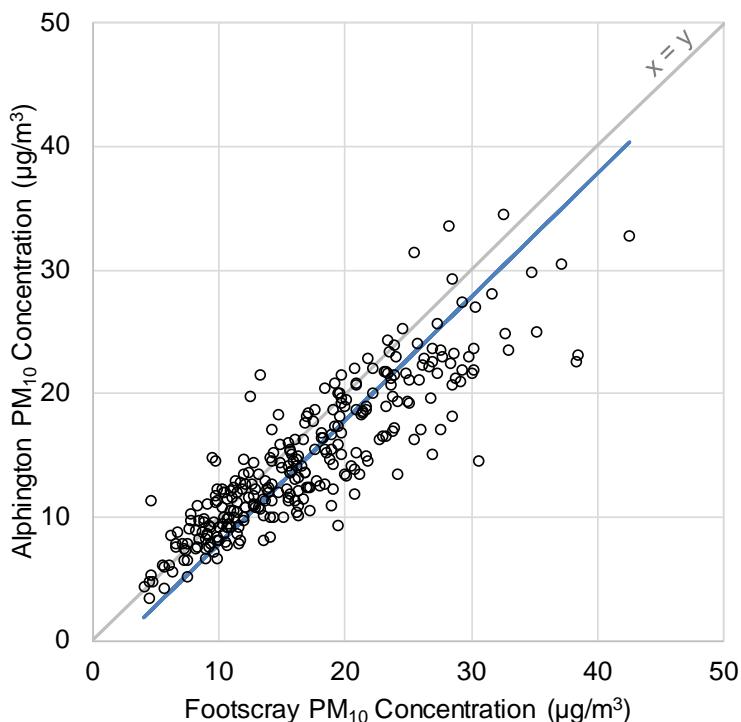


Figure 1: Orthogonal regression: PM<sub>10</sub> – Footscray vs Alphington



## APPENDIX A

### Statistical Comparisons

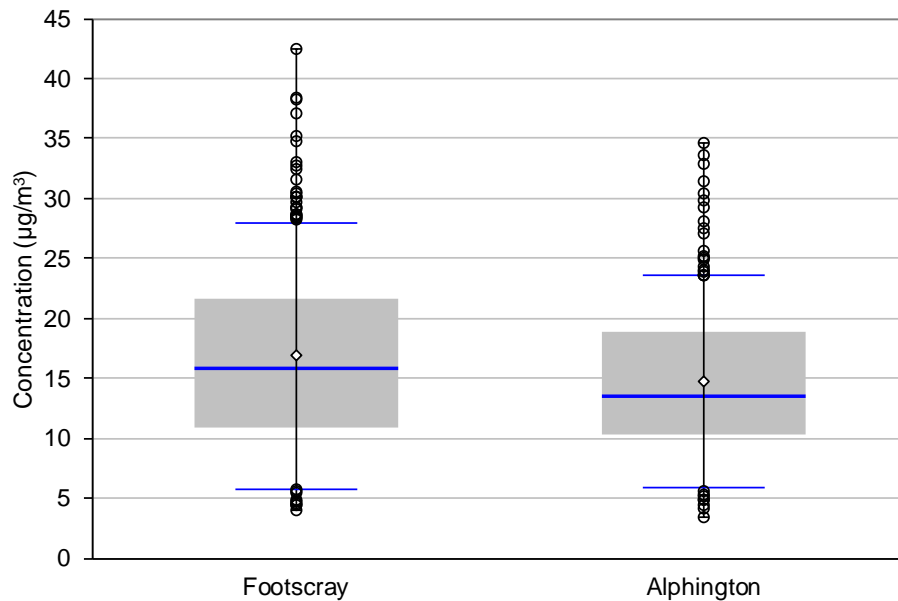


Figure 2: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>10</sub> – Footscray vs Alphington

## 1.2 Footscray and Donald McLean Reserve

Table 2: Statistics summary: PM<sub>10</sub> – Footscray and Donald McLean Reserve

Statistic*	Footscray	Donald McLean Reserve
Mean (µg/m³)	18.5	24.5
Maximum (µg/m³)	42.5	52.6
Minimum (µg/m³)	4.0	8.3
Mean difference (µg/m³)	-5.9	
CI (95%) of mean difference (µg/m³)	-5.1 – -6.8	
N = no. of 24 hour periods	108	
<b>Test*</b>	<b>Outcome</b>	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 4.9x10 <sup>-27</sup> )	
Orthogonal regression	Not equivalent (slope = 1.3, u <sup>1</sup> = 0.050 (fail), intercept = -0.37, u <sup>2</sup> = 1.0 (pass))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

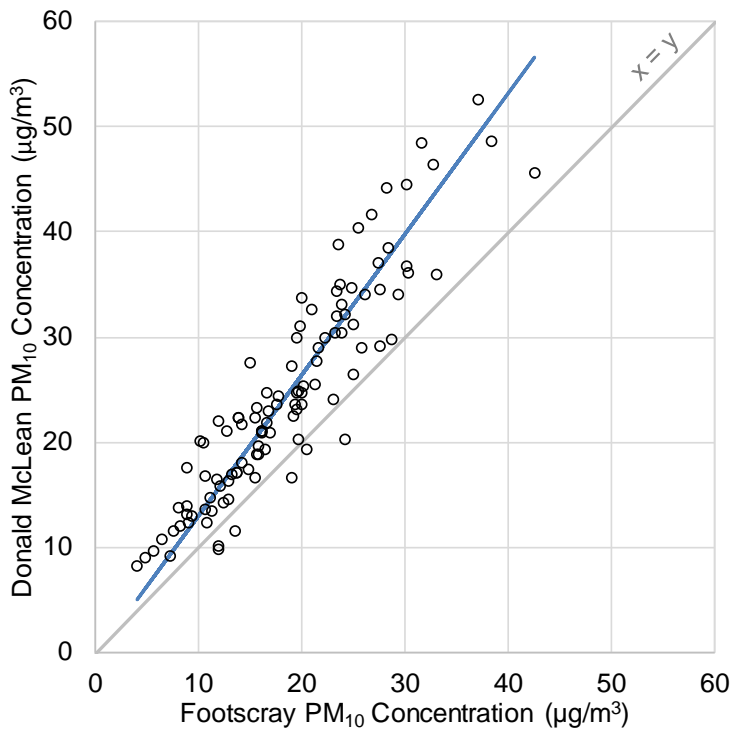


Figure 3: Orthogonal regression: PM<sub>10</sub> – Footscray vs Donald McLean Reserve

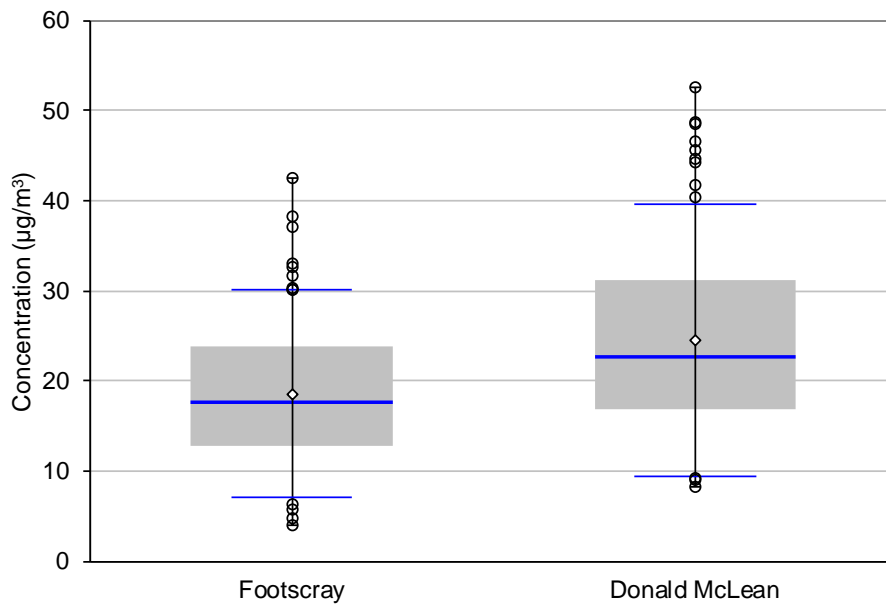


Figure 4: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>10</sub> – Footscray vs Donald McLean Reserve



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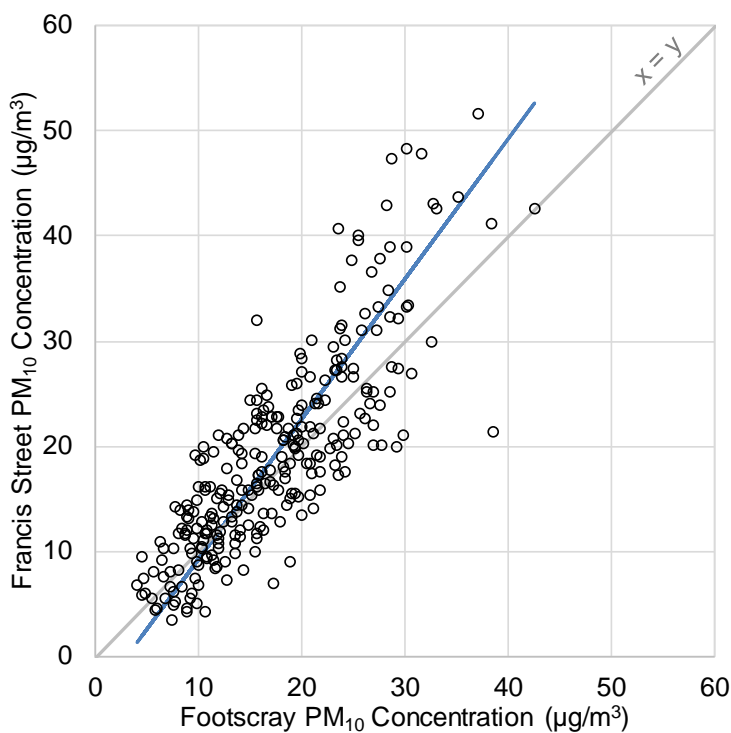
### Statistical Comparisons

### 1.3 Footscray and Francis Street

**Table 3: Statistics summary: PM<sub>10</sub> – Footscray and Francis Street**

Statistic*	Footscray	Francis Street
Mean (µg/m³)	17.3	19.0
Maximum (µg/m³)	42.5	51.7
Minimum (µg/m³)	4.0	3.5
Mean difference (µg/m³)	-1.7	
CI (95%) of mean difference (µg/m³)	-1.1 – -2.3	
N = no. of 24 hour periods	277	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 1.1 x10 <sup>-7</sup> )	
Orthogonal regression	Not equivalent (slope = 1.3, u <sup>1</sup> = 0.043 (fail), intercept = -4.0, u <sup>2</sup> = 0.80 (fail))	

\* Only paired data included in the analysis



*Figure 5: Orthogonal regression: PM<sub>10</sub> – Footscray vs Francis Street*



## APPENDIX A

### Statistical Comparisons

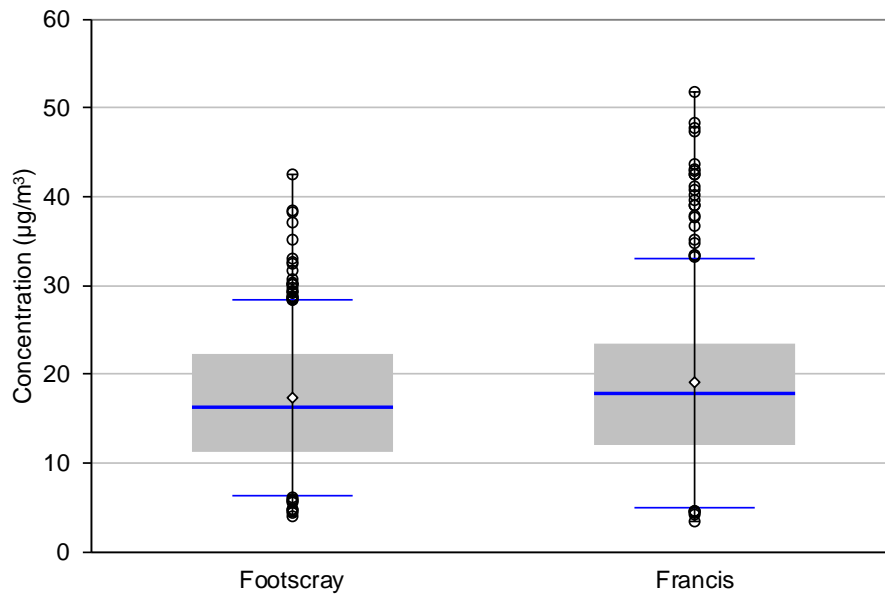


Figure 6: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>10</sub> – Footscray vs Francis Street

## 1.4 Footscray and Primula Avenue

Table 4: Statistics summary: PM<sub>10</sub> – Footscray and Primula Avenue

Statistic*	Footscray	Primula Avenue
Mean (µg/m <sup>3</sup> )	18.7	24.4
Maximum (µg/m <sup>3</sup> )	42.5	53.2
Minimum (µg/m <sup>3</sup> )	4.0	4.7
Mean difference (µg/m <sup>3</sup> )	-5.7	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-5.0 – -6.4	
N = no. of 24 hour periods	217	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 7.0x10 <sup>-37</sup> )	
Orthogonal regression	Not equivalent (slope = 1.4, u <sup>1</sup> = 0.051 (fail), intercept = -2.2, u <sup>2</sup> = 1.0 (fail))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

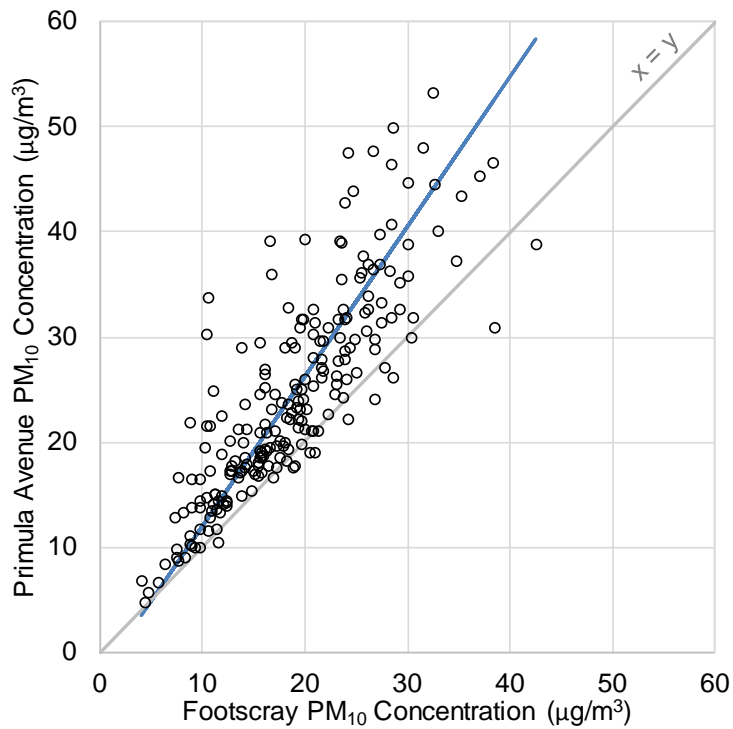


Figure 7: Orthogonal regression: PM<sub>10</sub> – Footscray vs Primula Avenue

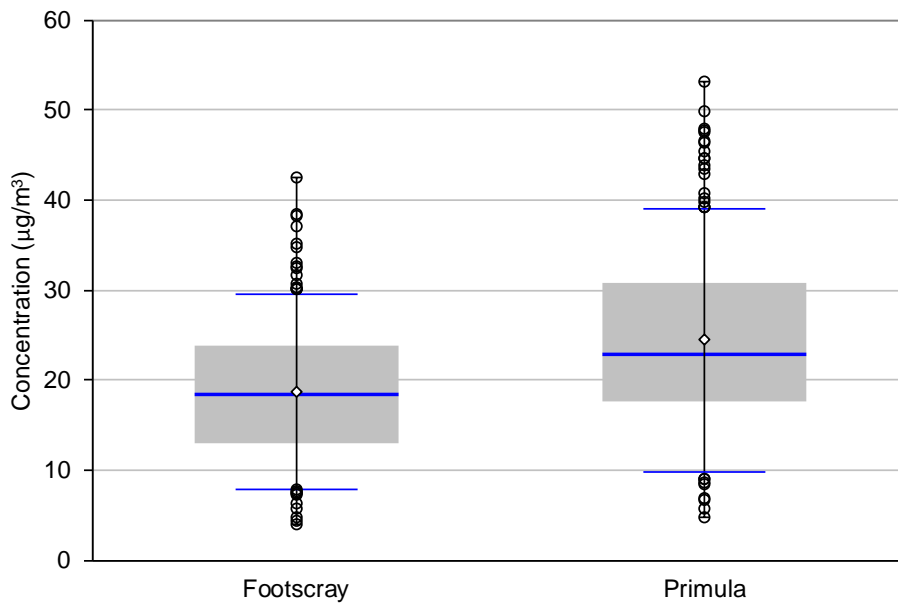


Figure 8: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>10</sub> – Footscray vs Primula Avenue



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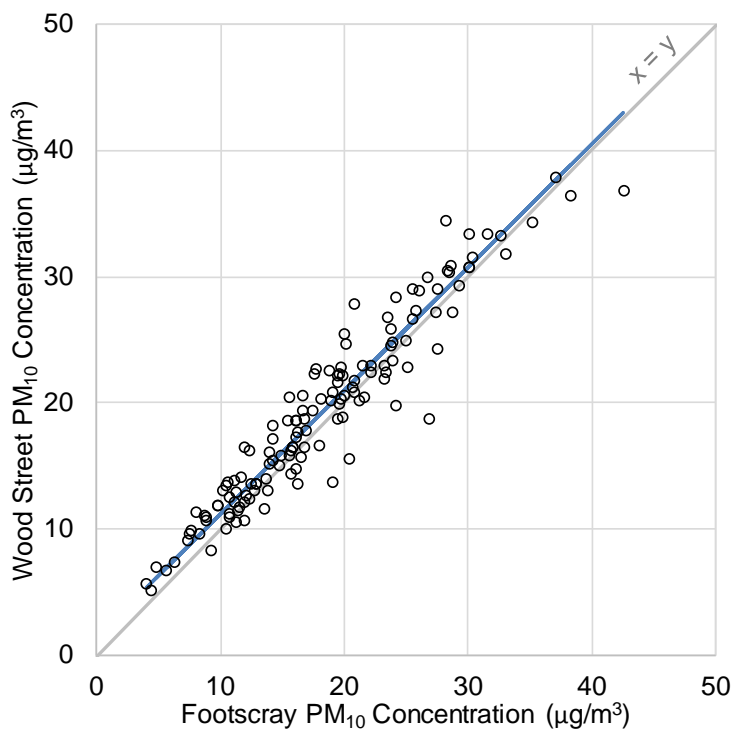
### Statistical Comparisons

## 1.5 Footscray and Wood Street

**Table 5: Statistics summary: PM<sub>10</sub> – Footscray and Wood Street**

Statistic*	Footscray	Wood Street
Mean (µg/m <sup>3</sup> )	18.3	19.3
Maximum (µg/m <sup>3</sup> )	42.5	37.8
Minimum (µg/m <sup>3</sup> )	4.0	5.1
Mean difference (µg/m <sup>3</sup> )	-1.0	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-0.7 – -1.4	
N = no. of 24 hour periods	138	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = $2.2 \times 10^{-7}$ )	
Orthogonal regression	Not equivalent (slope = 0.98, $u^1 = 0.024$ (pass), intercept = 1.4, $u^2 = 0.49$ (fail))	

\* Only paired data included in the analysis



*Figure 9: Orthogonal regression: PM<sub>10</sub> – Footscray vs Wood Street*



## APPENDIX A

### Statistical Comparisons

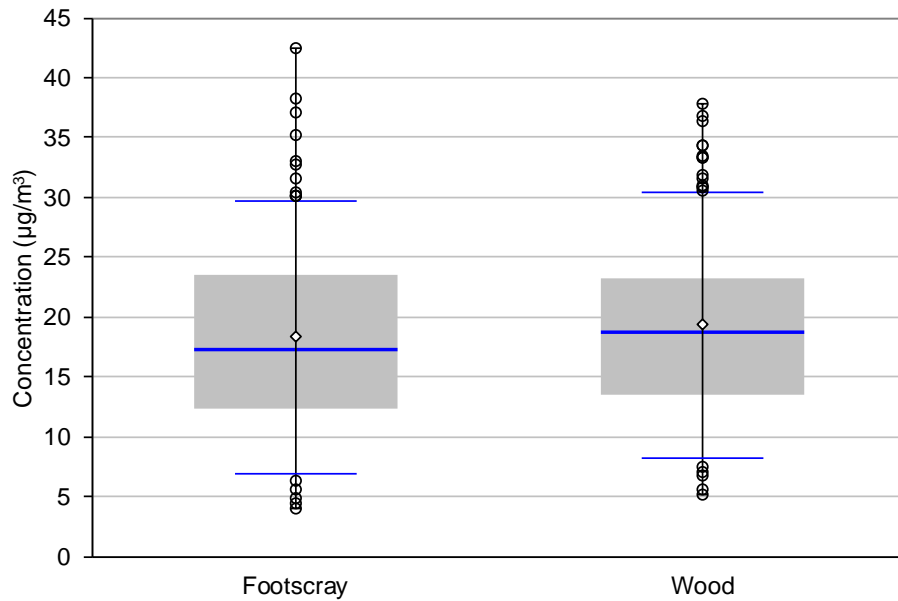


Figure 10: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>10</sub> – Footscray vs Wood Street

## 1.6 Footscray and Yarraville Gardens

Table 6: Statistics summary: PM<sub>10</sub> – Footscray and Yarraville Gardens

Statistic*	Footscray	Yarraville Gardens
Mean (µg/m <sup>3</sup> )	16.9	18.4
Maximum (µg/m <sup>3</sup> )	42.5	43.8
Minimum (µg/m <sup>3</sup> )	4.0	4.5
Mean difference (µg/m <sup>3</sup> )	-1.6	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-1.2 – -2.0	
N = no. of 24 hour periods	308	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 2.0x10 <sup>-14</sup> )	
Orthogonal regression	Not equivalent (slope = 1.07, u <sup>1</sup> = 0.027 (fail), intercept = 0.46, u <sup>2</sup> = 0.50 (pass))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

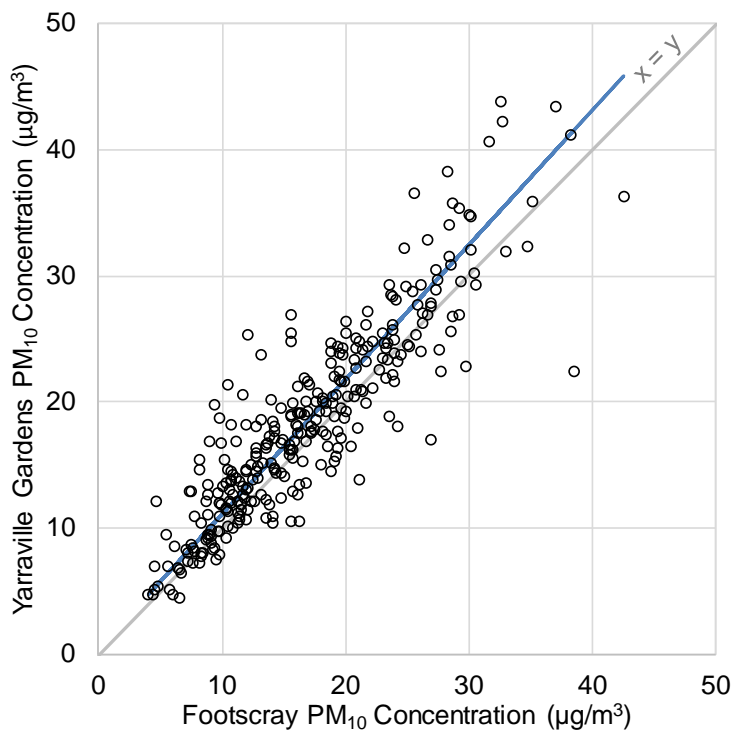


Figure 11: Orthogonal regression:  $PM_{10}$  – Footscray vs Yarraville Gardens

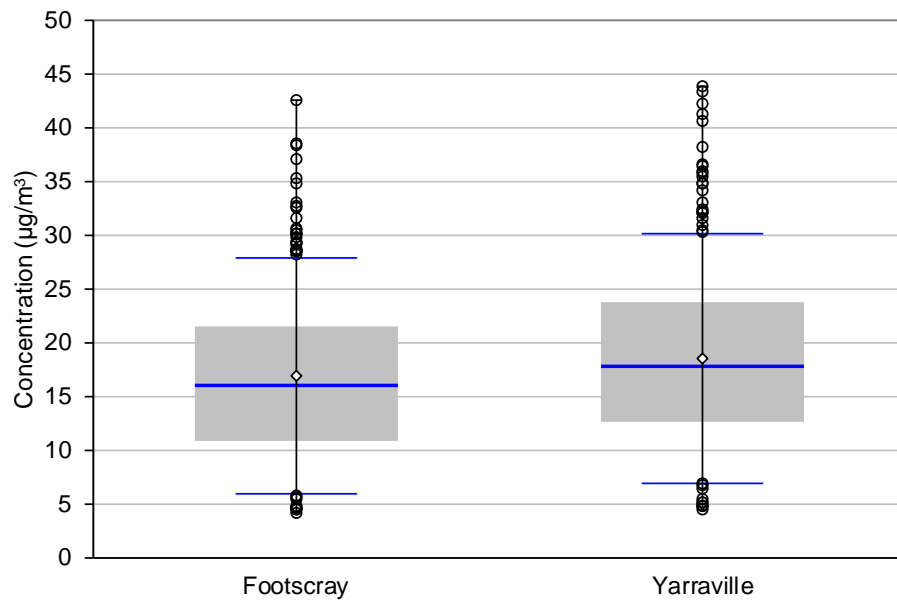


Figure 12: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD):  $PM_{10}$  – Footscray vs Yarraville Gardens



## APPENDIX A

### Statistical Comparisons

## 2.0 DATASETS COMPARISON: PM<sub>2.5</sub>

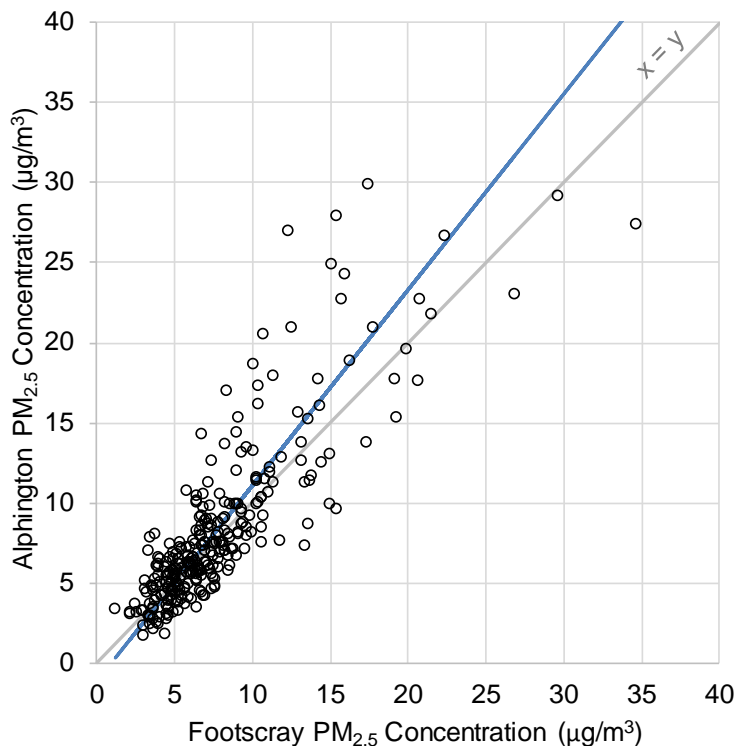
The following sections present the results of the statistical and visual comparisons between Footscray AAQMS and the other AAQMS PM<sub>2.5</sub> concentration datasets.

### 2.1 Footscray and Alphington

**Table 7: Statistics summary: PM<sub>2.5</sub> – Footscray and Alphington**

Statistic*	Footscray	Alphington
Mean (µg/m <sup>3</sup> )	7.7	8.3
Maximum (µg/m <sup>3</sup> )	34.6	30.0
Minimum (µg/m <sup>3</sup> )	1.2	1.8
Mean difference (µg/m <sup>3</sup> )	-0.60	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-0.28 – -0.92	
N = no. of 24 hour periods	296	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 2.0x10 <sup>-4</sup> )	
Orthogonal regression	Not equivalent (slope = 1.2, u <sup>1</sup> = 0.037 (fail), intercept = -1.1, u <sup>2</sup> = 0.32 (fail))	

\* Only paired data included in the analysis



*Figure 13: Orthogonal regression: PM<sub>2.5</sub> – Footscray vs Alphington*



## APPENDIX A

### Statistical Comparisons

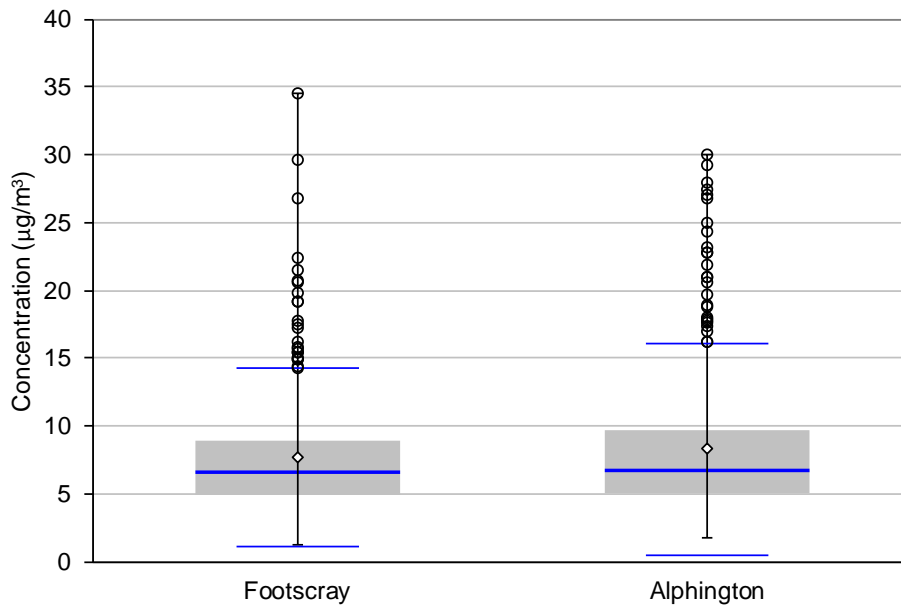


Figure 14: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>2.5</sub> – Footscray vs Alphington

## 2.2 Footscray and Donald McLean Reserve

Table 8: Statistics summary: PM<sub>2.5</sub> – Footscray and Donald McLean Reserve

Statistic*	Footscray	Donald McLean Reserve
Mean (µg/m <sup>3</sup> )	11.1	13.7
Maximum (µg/m <sup>3</sup> )	34.6	38.8
Minimum (µg/m <sup>3</sup> )	1.2	2.0
Mean difference (µg/m <sup>3</sup> )	-2.6	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-2.0 – -3.2	
N = no. of 24 hour periods	108	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 4.1x10 <sup>-13</sup> )	
Orthogonal regression	Not equivalent (slope = 1.3, u <sup>1</sup> = 0.050 (fail), intercept = -1.2, u <sup>2</sup> = 0.58 (fail))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

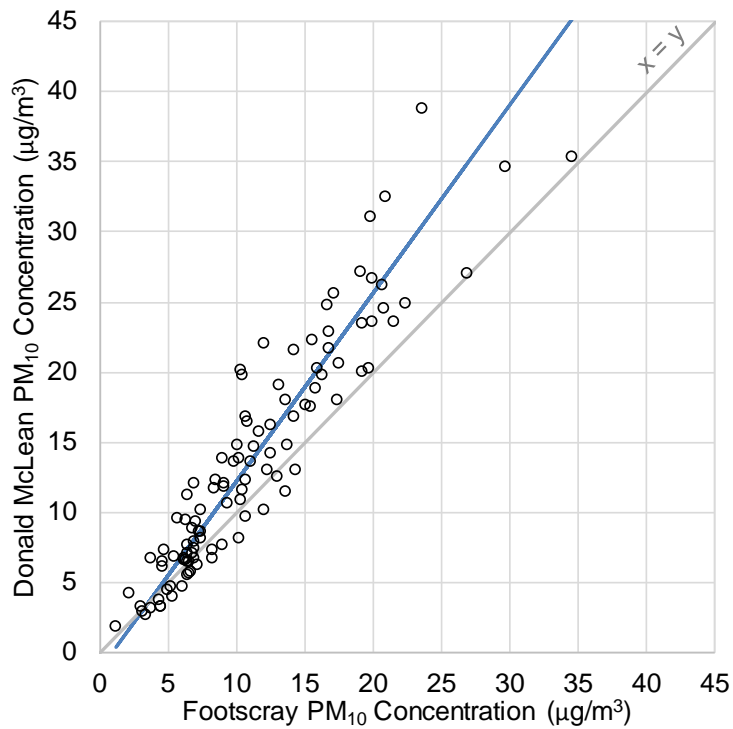


Figure 15: Orthogonal regression: PM<sub>2.5</sub> – Footscray vs Donald McLean Reserve

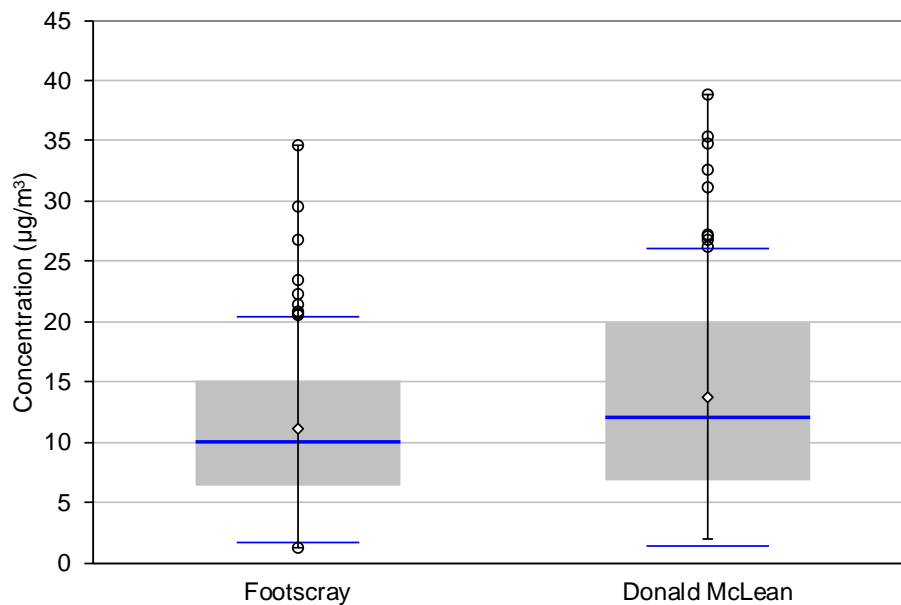


Figure 16: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>2.5</sub> – Footscray vs Donald McLean Reserve



## APPENDIX A

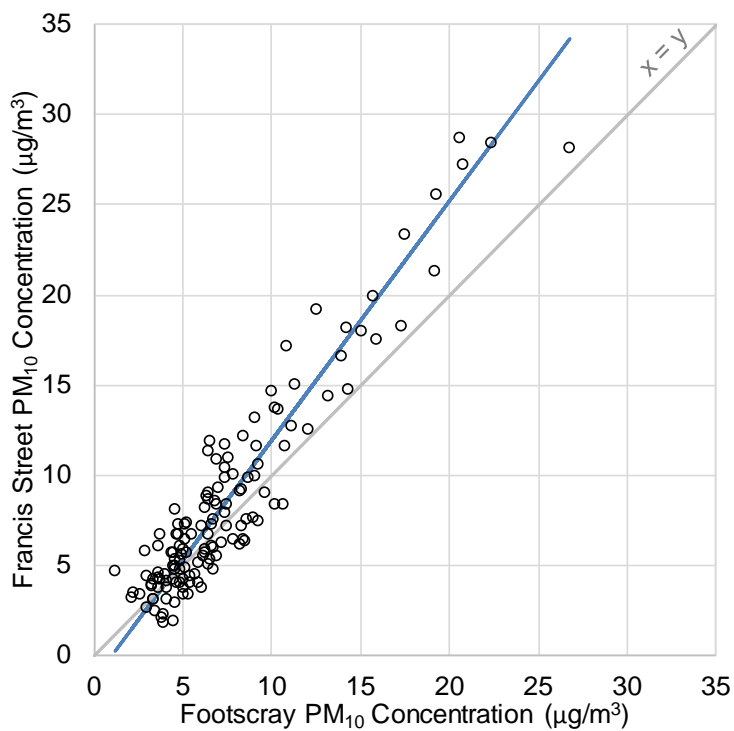
### Statistical Comparisons

## 2.3 Footscray and Francis Street

**Table 9: Statistics summary: PM<sub>2.5</sub> – Footscray and Francis Street**

Statistic*	Footscray	Francis Street
Mean (µg/m <sup>3</sup> )	7.4	8.5
Maximum (µg/m <sup>3</sup> )	26.8	28.8
Minimum (µg/m <sup>3</sup> )	1.2	1.8
Mean difference (µg/m <sup>3</sup> )	-1.1	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-0.7 – -1.5	
N = no. of 24 hour periods	137	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 4.4 x10 <sup>-8</sup> )	
Orthogonal regression	Not equivalent (slope = 1.3, u <sup>1</sup> = 0.038 (fail), intercept = -1.3, u <sup>2</sup> = 0.33 (fail))	

\* Only paired data included in the analysis



*Figure 17: Orthogonal regression: PM<sub>2.5</sub> – Footscray vs Francis Street*



## APPENDIX A

### Statistical Comparisons

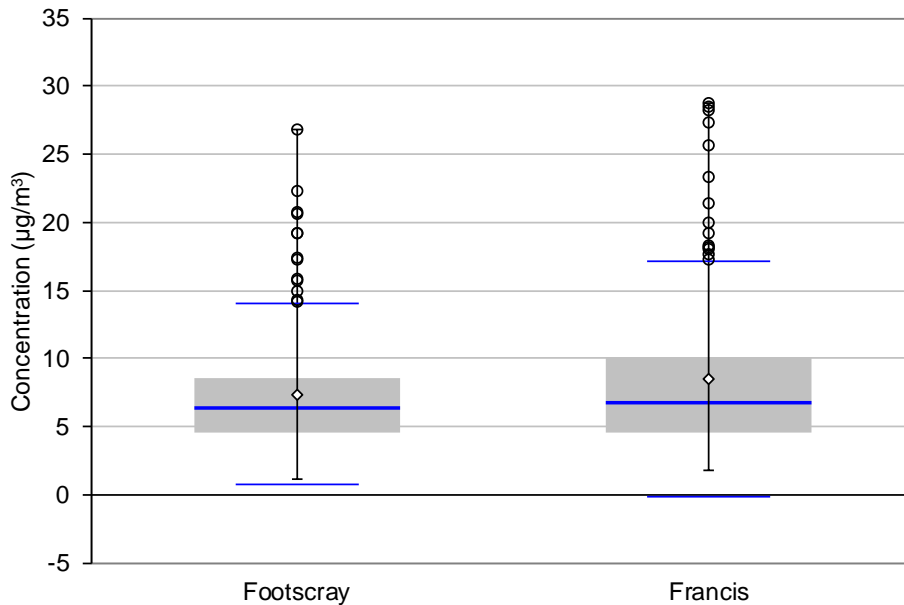


Figure 18: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>2.5</sub> – Footscray vs Francis Street

## 2.4 Footscray and Primula Avenue

Table 10: Statistics summary: PM<sub>2.5</sub> – Footscray and Primula Avenue

Statistic*	Footscray	Primula Avenue
Mean (µg/m <sup>3</sup> )	9.2	12.0
Maximum (µg/m <sup>3</sup> )	22.3	25.2
Minimum (µg/m <sup>3</sup> )	1.2	3.9
Mean difference (µg/m <sup>3</sup> )	-2.8	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-2.2 – -3.3	
N = no. of 24 hour periods	43	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 2.7x10 <sup>-13</sup> )	
Orthogonal regression	Not equivalent (slope = 1.0, u <sup>1</sup> = 0.057 (pass), intercept = 2.5, u <sup>2</sup> = 0.59 (fail))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

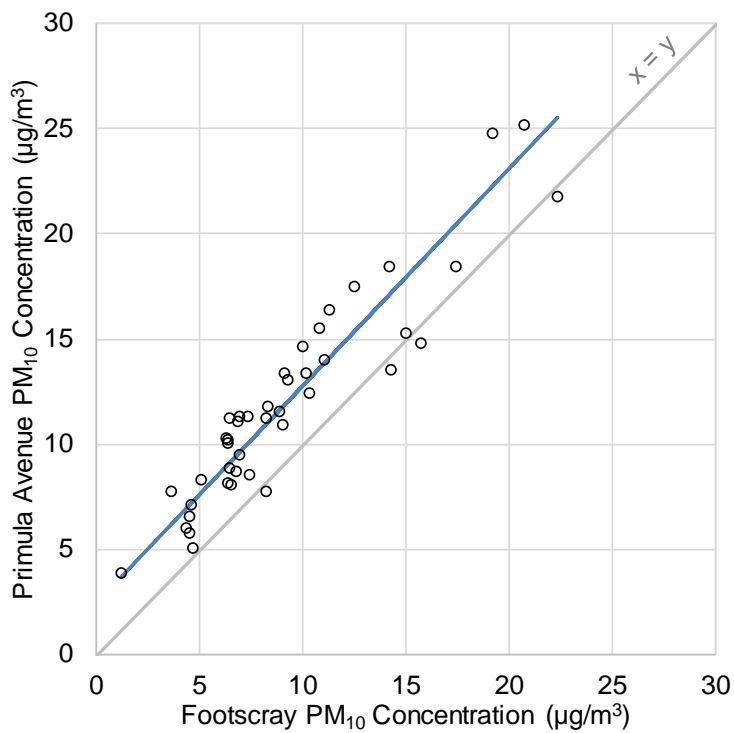


Figure 19: Orthogonal regression: PM<sub>2.5</sub> – Footscray vs Primula Avenue

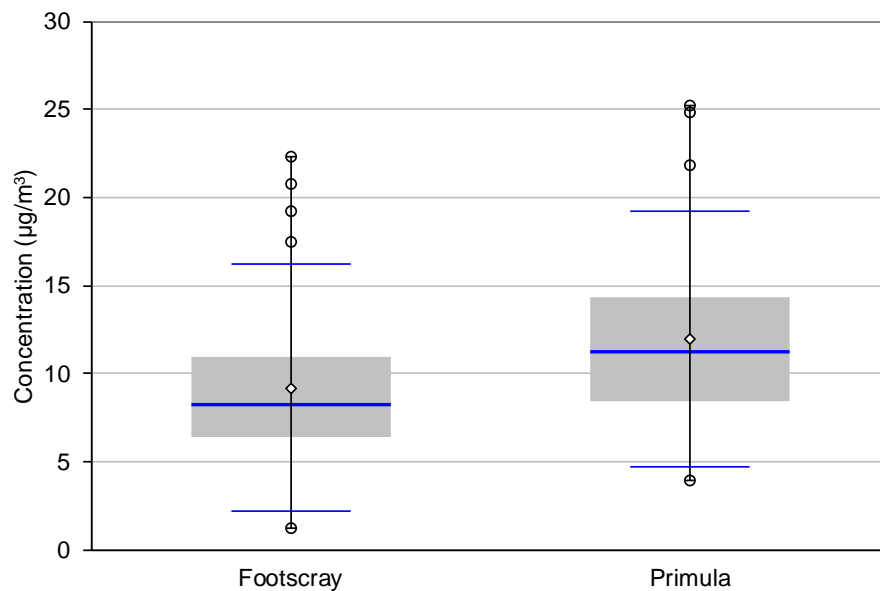


Figure 20: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>2.5</sub> – Footscray vs Primula Avenue



## APPENDIX A

### Statistical Comparisons

## 2.5 Footscray and Wood Street

Table 11: Statistics summary: PM<sub>2.5</sub> – Footscray and Wood Street

Statistic*	Footscray	Wood Street
Mean (µg/m <sup>3</sup> )	10.0	11.3
Maximum (µg/m <sup>3</sup> )	34.6	35.8
Minimum (µg/m <sup>3</sup> )	1.2	2.5
Mean difference (µg/m <sup>3</sup> )	-1.3	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-0.8 – -1.7	
N = no. of 24 hour periods	92	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 2.1x10 <sup>-8</sup> )	
Orthogonal regression	Not equivalent (slope = 1.14, u <sup>1</sup> = 0.033 (fail), intercept = -0.13, u <sup>2</sup> = 0.39 (pass))	

\* Only paired data included in the analysis

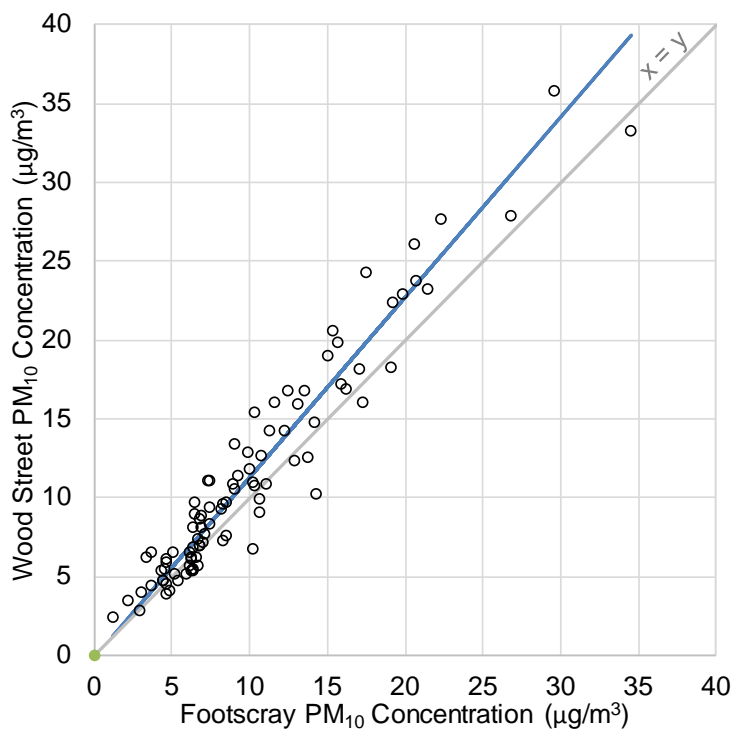


Figure 21: Orthogonal regression: PM<sub>2.5</sub> – Footscray vs Wood Street



## APPENDIX A

### Statistical Comparisons

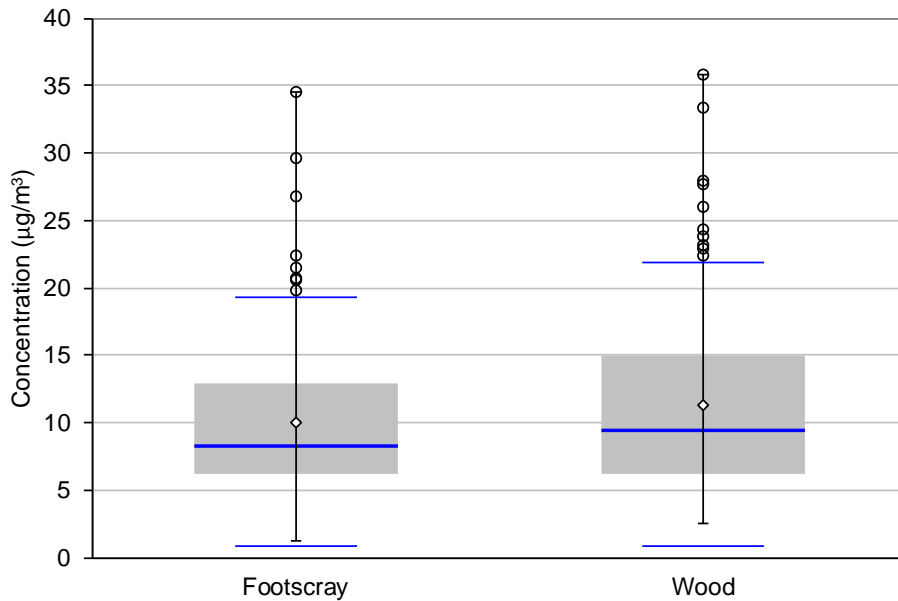


Figure 22: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>2.5</sub> – Footscray vs Wood Street

## 2.6 Footscray and Yarraville Gardens

Table 12: Statistics summary: PM<sub>2.5</sub> – Footscray and Yarraville Gardens

Statistic*	Footscray	Yarraville Gardens
Mean (µg/m <sup>3</sup> )	7.8	8.0
Maximum (µg/m <sup>3</sup> )	34.6	31.6
Minimum (µg/m <sup>3</sup> )	1.2	0.9
Mean difference (µg/m <sup>3</sup> )	-1.5	
CI (95%) of mean difference (µg/m <sup>3</sup> )	-0.1 – -0.4	
N = no. of 24 hour periods	198	
Test*	Outcome	
Paired t-test	Null hypothesis accepted (mean difference = 0; p-value = 0.32)	
Orthogonal regression	Not equivalent (slope = 1.2, u <sup>1</sup> = 0.028 (fail), intercept = 1.4, u <sup>2</sup> = 0.26 (fail))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

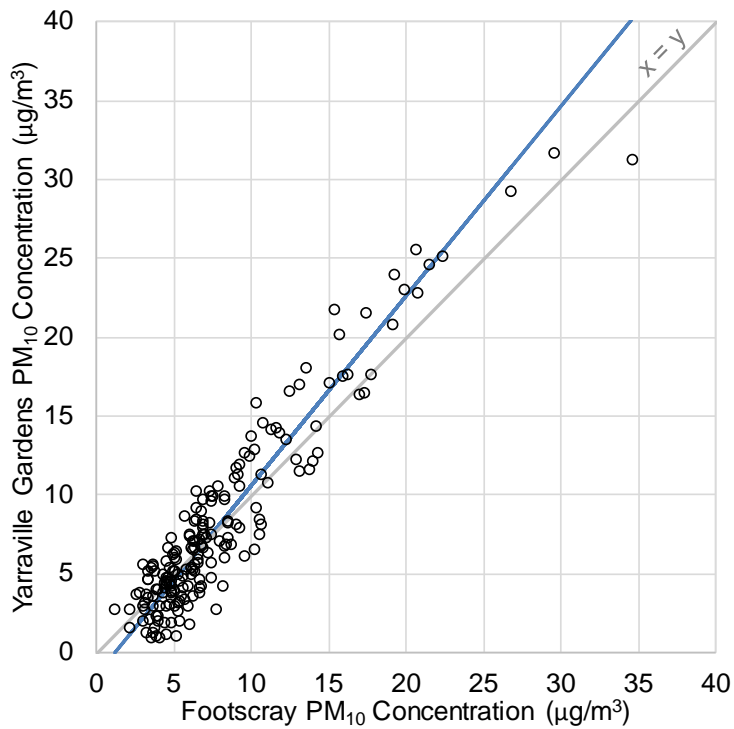


Figure 23: Orthogonal regression: PM<sub>2.5</sub> – Footscray vs Yarraville Gardens

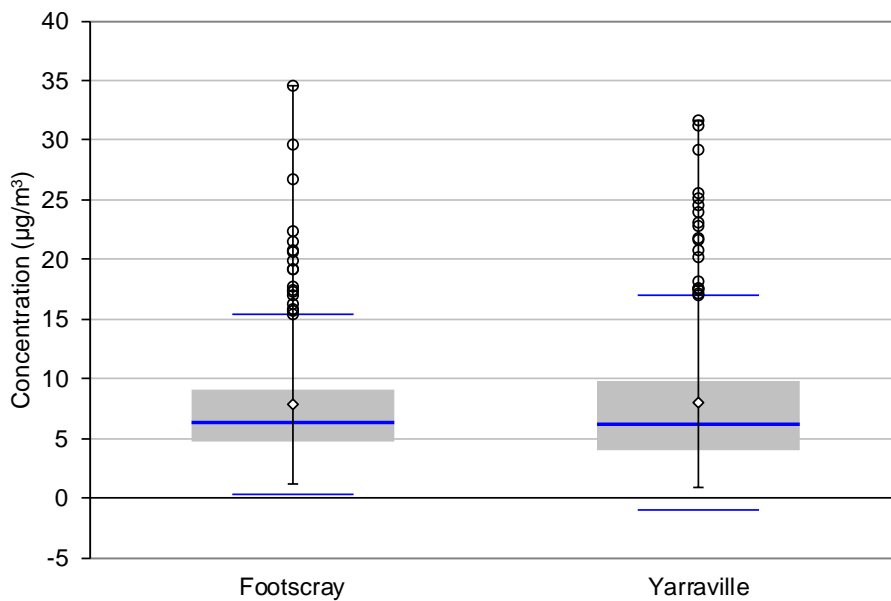


Figure 24: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): PM<sub>2.5</sub> – Footscray vs Yarraville Gardens



## APPENDIX A Statistical Comparisons

### 3.0 DATASETS COMPARISON: CO

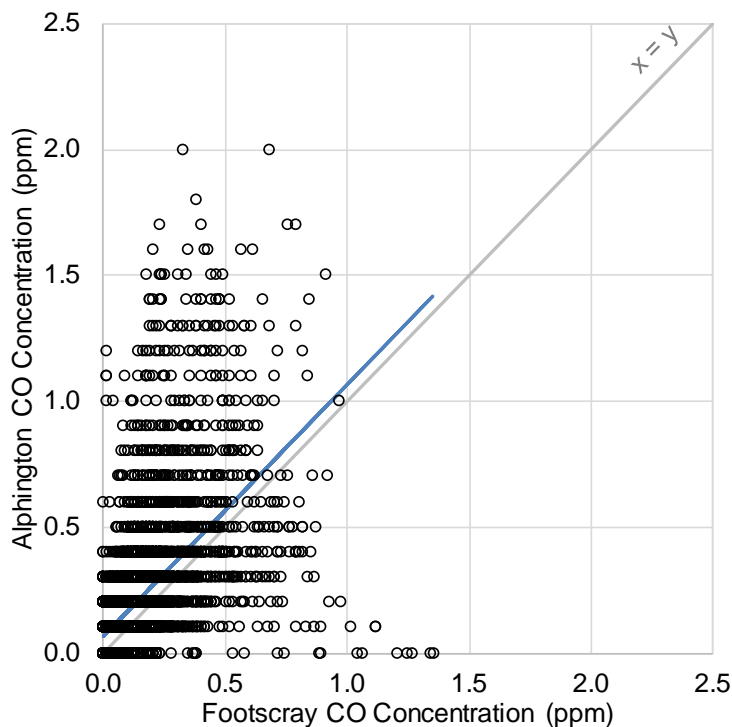
The following sections present the results of the statistical and visual comparisons between Footscray, Alphington and Primula Avenue AAQMS CO concentration datasets.

#### 3.1 Footscray and Alphington

**Table 13: Statistics summary: CO – Footscray and Alphington**

Statistic*	Footscray	Alphington
Mean (ppm)	0.15	0.24
Maximum (ppm)	1.3	2.0
Minimum (ppm)	0.0	0.0
Mean difference (ppm)	-0.089	
CI (95%) of mean difference (ppm)	-0.1 – -0.1	
N = no. of 8 hour periods	7175	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 0)	
Orthogonal regression	Not equivalent (slope = 1.0, $u^1 = 0.025$ (pass), intercept = 0.067, $u^2 = 0.0044$ (fail))	

\* Only paired data included in the analysis



*Figure 25: Orthogonal regression: CO – Footscray vs Alphington*



## APPENDIX A

### Statistical Comparisons

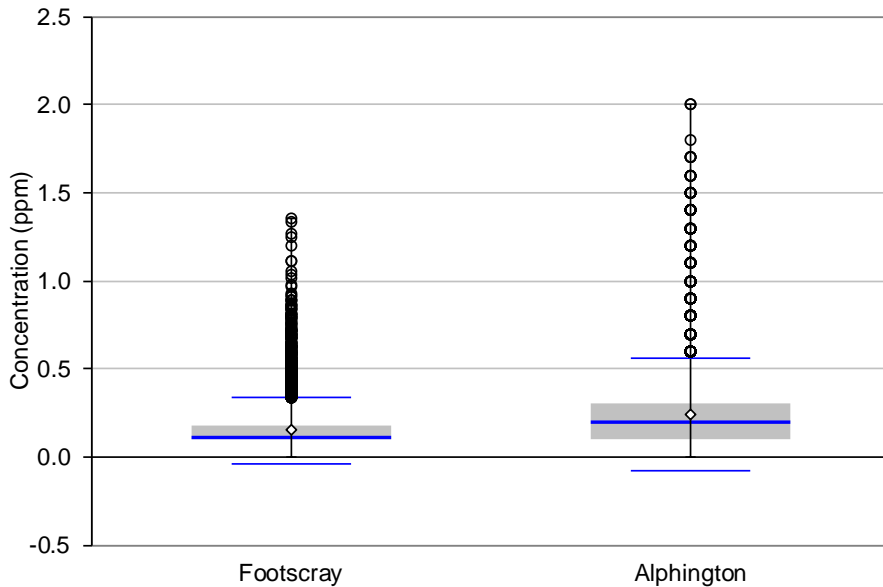


Figure 26: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): CO – Footscray vs Alphington

### 3.2 Footscray and Primula Avenue

Table 14: Statistics summary: CO – Footscray and Primula Avenue

Statistic*	Footscray	Primula Avenue
Mean (ppm)	0.16	0.27
Maximum (ppm)	1.3	1.3
Minimum (ppm)	0.0	0.0
Mean difference (ppm)	-0.12	
CI (95%) of mean difference (ppm)	-0.12 – -0.12	
N = no. of 8 hour periods	5404	
test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 0)	
Orthogonal regression	Not equivalent (slope = 1.0, $u^1 = 0.019$ (pass), intercept = 0.11, $u^2 = 0.027$ (fail))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

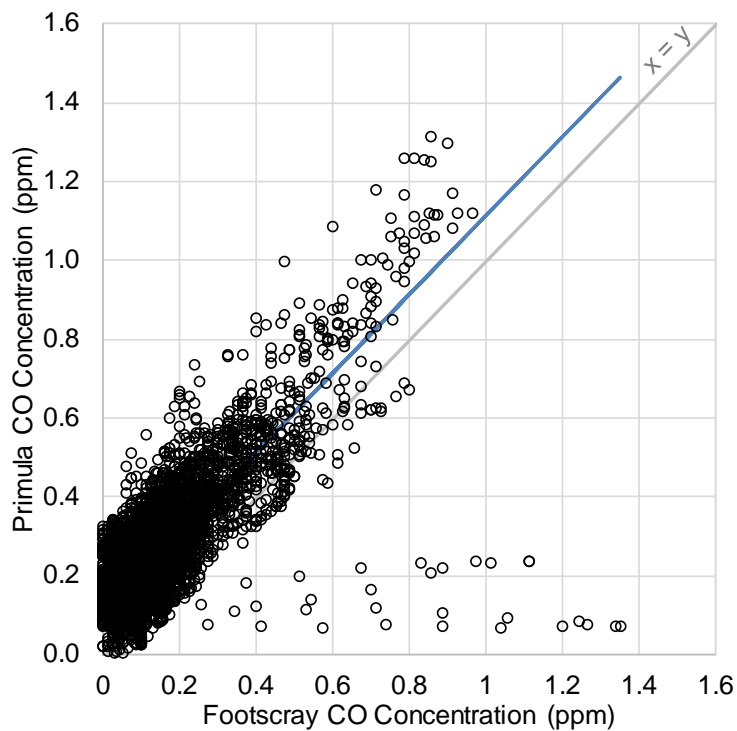


Figure 27: Orthogonal regression: CO – Footscray vs Primula Avenue

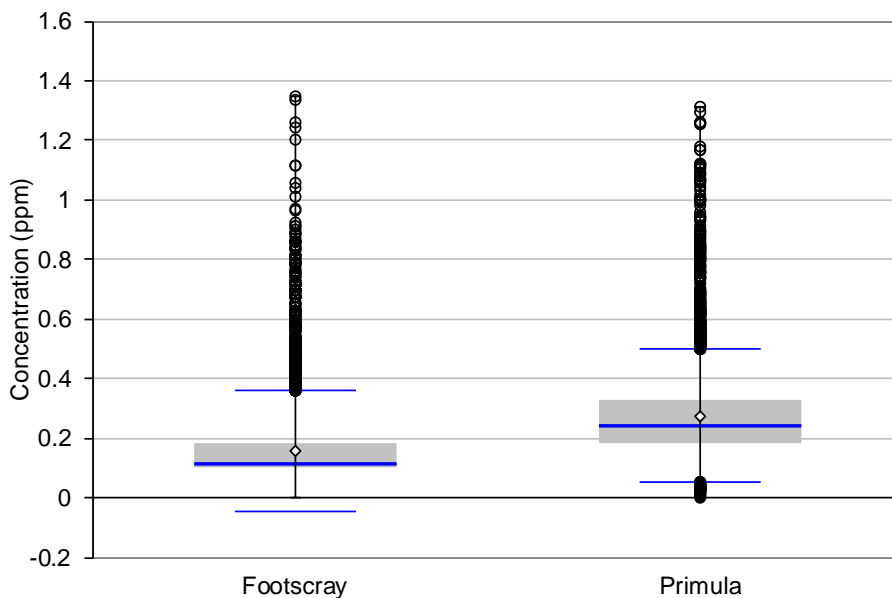


Figure 28: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): CO – Footscray vs Primula Avenue



## 4.0 DATASETS COMPARISON: NO<sub>2</sub>

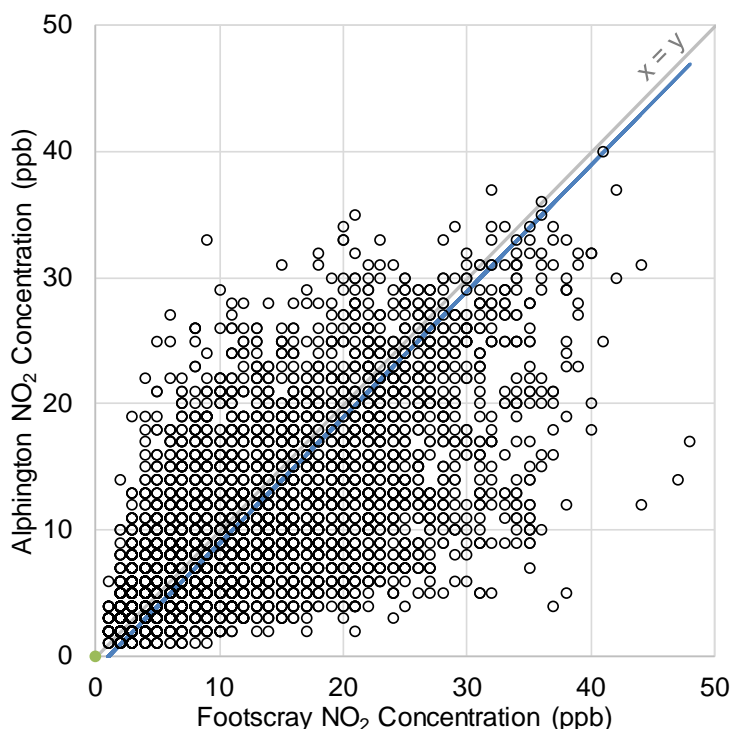
The following sections present the results of the statistical and visual comparisons between Footscray, Alphington and Primula Avenue AAQMS NO<sub>2</sub> concentration datasets.

### 4.1 Footscray and Alphington

**Table 15: Statistics summary: NO<sub>2</sub> – Footscray and Alphington**

Statistic*	Footscray	Alphington
Mean (ppb)	10.8	9.3
Maximum (ppb)	48	40
Minimum (ppb)	1.0	1.0
Mean difference (ppb)	1.5	
CI (95%) of mean difference (ppb)	1.4 – 1.7	
N = no. of 1 hour periods	6231	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = $6.0 \times 10^{-92}$ )	
Orthogonal regression	Not equivalent (slope = 1.0, $u^1 = 0.011$ (pass), intercept = -1.06, $u^2 = 0.12$ (fail))	

\* Only paired data included in the analysis



*Figure 29: Orthogonal regression: NO<sub>2</sub> – Footscray vs Alphington*



## APPENDIX A

### Statistical Comparisons

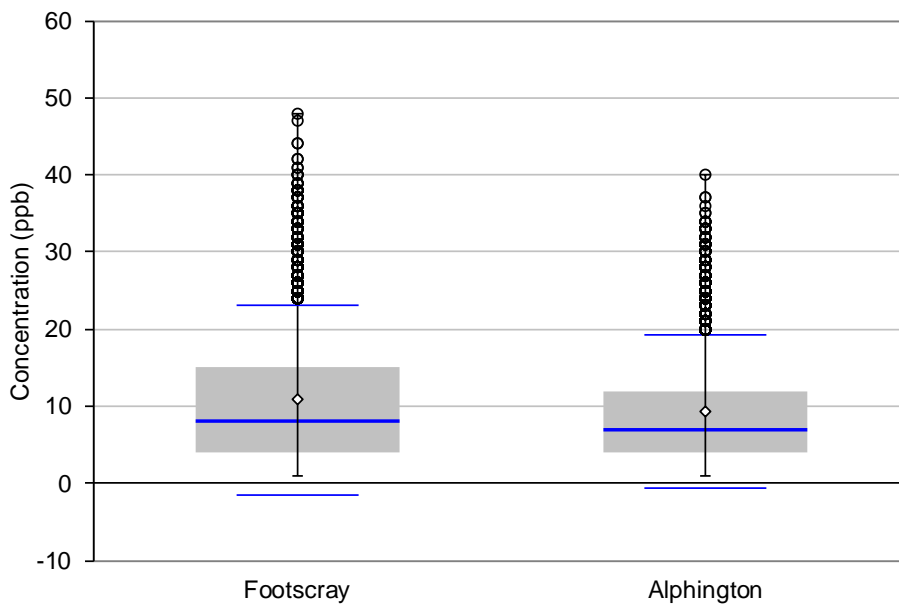


Figure 30: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): NO<sub>2</sub> – Footscray vs Alphington

## 4.2 Footscray and Primula Avenue

Table 16: Statistics summary: NO<sub>2</sub> – Footscray and Primula Avenue

Statistic*	Footscray	Primula Avenue
Mean (ppb)	11.5	18.2
Maximum (ppb)	50	61
Minimum (ppb)	1	1.7
Mean difference (ppb)	-6.7	
CI (95%) of mean difference (ppb)	-6.5 – -6.9	
N = no. of 1 hour periods	4558	
Test*	Outcome	
Paired t-test	Null hypothesis rejected (mean difference > 0; p-value = 0)	
Orthogonal regression	Not equivalent (slope = 1.0, u <sup>1</sup> = 0.016 (pass), intercept = 7.8, u <sup>2</sup> = 0.20 (fail))	

\* Only paired data included in the analysis



## APPENDIX A

### Statistical Comparisons

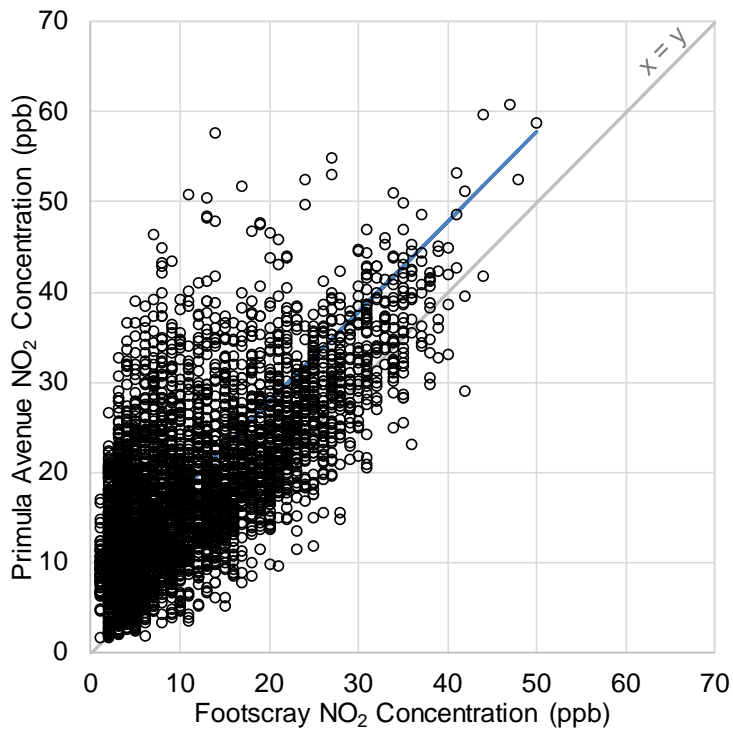


Figure 31: Orthogonal regression: NO<sub>2</sub> – Footscray vs Primula Avenue

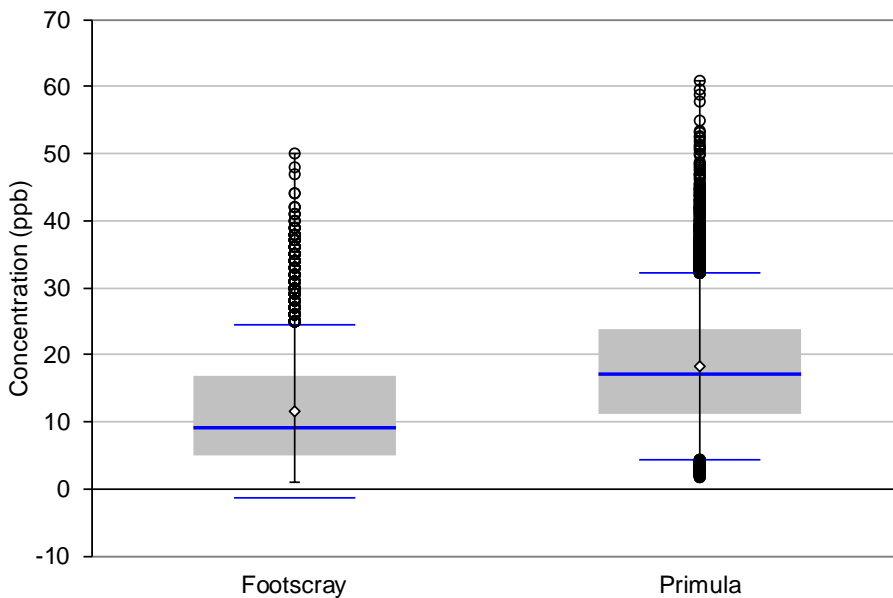


Figure 32: Box whisker plot (50<sup>th</sup> percentile, 1.5 SD): NO<sub>2</sub> – Footscray vs Primula Avenue

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# **APPENDIX B**

## **Important Information Relating to this Report**



## IMPORTANT INFORMATION RELATING TO THIS REPORT

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