

Waterview Operational Air Quality Monitoring Report April to June 2019

Document No: [Subject]

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1 INTRODUCTION

1.1 OVERVIEW

The Waterview Tunnel opened on 2 July 2017. This report includes analysis of validated air quality monitoring data for Waterview Tunnel Joint Operations (WTJO) for the period April to June 2019 to satisfy the reporting requirements of Waterview Connection BOI Operational Air Quality Condition OA.4.

1.2 WATERVIEW OPERATIONAL AIR QUALITY REQUIREMENTS

Waterview Connection BOI Operational Air Quality Conditions OA.2 – OA.8 (refer Appendix A) set out the requirements for monitoring of ambient air quality in the vicinity of the tunnel portals and of emissions from one of the tunnel portals.

Two ambient air quality stations (located near the northern and southern end of the Waterview Tunnel) and one portal analyser are required to be operated for a minimum period of two years. The two ambient stations measure concentrations of particulate matter less than 10 microns and 2.5 microns in diameter (PM₁₀ and PM_{2.5}) and nitrogen dioxide (NO₂) as well as wind speed and wind direction. The portal analyser measures concentrations of NO₂.

Condition OA.2 stipulates that the results of ambient monitoring are to be compared with the National Environmental Standards for Air Quality (NESAQ) and Auckland Regional air quality targets. The relevant criteria are set out in Table 1.

Table 1. WTJO ambient air quality criteria

Pollutant	Threshold concentration	Averaging period
Fine particles (PM ₁₀)	50 µg/m ³ 20 µg/m ³	24-hour Annual
Fine particles (PM _{2.5})	25 µg/m ³ 10 µg/m ³	24-hour Annual
Nitrogen dioxide	200 µg/m ³ 100 µg/m ³ 40 µg/m ³	1-hour 24-hour Annual

1-hour average NO₂ concentrations at the portal air quality monitoring station have been expressed as a rolling average, in accordance with condition OA.8.

Monitoring at the ambient air quality and portal air quality stations and is required to continue until the Air Quality Peer Review Panel (required under condition OA.7) recommend that it is no longer necessary. Results are required to be reported monthly for the first 12 months and quarterly thereafter for a period of at least 12 months (OA.4). The Waterview Tunnel has been operational for 24 months. The minimum period of reporting has been completed in accordance with condition OA.4. No further reporting of air quality monitoring results is required.

1.3 MONITORED PARAMETERS AND LOCATIONS

Monitoring locations are shown in Appendix B. Locations and types of instrumentation have been agreed with Auckland Council and the Air Quality Peer Review Panel.

The portal monitoring station has been installed at the rear of 93 Hendon Avenue near the Southern portal to monitor NO₂ in accordance with the requirements of consent condition OA.2 and to demonstrate compliance with consent condition OA.8. A Cavity Attenuated Phase Shift Spectroscopy (CAPS) NO₂ analyser is used for this purpose. The portal station is located approximately 80 m from the southern tunnel portal on the residential boundary (40 m from SH20). SH20 is screened from the nearest receptors within the southern approach trench.

Two ambient air quality monitoring stations have been installed in accordance with conditions OA.2 and OA.3 to monitor the following:

- PM₁₀ and PM_{2.5} (BAM-1020 analysers)
- NO₂ (Chemiluminescence NO_x analyser)
- Wind speed and wind direction

The southern ambient air quality station is located near 5 Barrymore Road in the approximate location of the original pre-construction baseline monitoring for the WTJO. It is also located adjacent to the residential area at Hendon Avenue, approximately 470 m from the southern tunnel portal (25 m from SH20) where SH20 achieves grade.

Under condition OA.2, the northern ambient air quality station is required to be located at Waterview School subject to agreement by the School. However, this agreement was not secured and the station was instead located in the approximate location of the original pre-construction baseline monitoring for the WTJO, near the operation maintenance building in agreement with Auckland Council and the Peer Review Panel. This location is approximately 100 m from the northern tunnel portal downwind in the prevailing wind direction (25 m from SH20, 330 m SH16 and 20 m from Great North Road), with no obstruction between the adjacent traffic sources and air quality station.

1.4 DATA MANAGEMENT

Data are downloaded and checked daily by suppliers Ecotech and monthly reports of validated monitoring results are provided to the WTJO. A daily summary of results (non-validated data) is provided to the WTJO and, in the event that WTJO air quality criteria are exceeded, email/text alerts are sent, so investigation can be initiated.

Ecotech calibrates the air quality stations on a monthly basis and attends the site if a fault is detected during the daily checks. Calibration and equipment fault reports are forwarded to the WTJO.

The valid data exception reports for April to June 2019 are attached as Appendix C.

2 MONITORING RESULTS AND ANALYSIS

2.1 SUMMARY STATISTICS

Monitoring sites used for compliance monitoring should achieve at least 95% data capture and a minimum of 75% valid data when calculating averages¹. Averages were not calculated where data did not meet the minimum 75% valid data requirement (i.e. due to calibration or data loss). As shown in Table 2, data capture for the April to June 2019 period met the minimum requirement for all measured parameters at all air quality monitoring stations, with the exception of NO₂ measured at the northern air quality station in May 2019.

Low data capture of NO₂ at the northern ambient air quality station in May 2019 was due to an overnight calibration being out of tolerance on 11 May 2019. This fault was corrected on 13 May 2019.

Table 2. Data capture statistics

AQ Station	Parameter	% data capture		
		April 2019	May 2019	June 2019
Northern ambient air quality station	Nitrogen dioxide (NO ₂)	100 %	91.1 %	99.7 %
	Particulate matter (PM _{2.5})	100 %	97.8 %	100 %
	Particulate matter (PM ₁₀)	100 %	98.8 %	100 %
Southern ambient air quality station	Nitrogen dioxide (NO ₂)	100 %	99.9 %	97.2 %
	Particulate matter (PM _{2.5})	100 %	100 %	100 %
	Particulate matter (PM ₁₀)	100 %	100 %	100 %
Portal air quality station	Nitrogen dioxide (NO ₂)	100 %	100 %	100 %

A summary of the monitored levels of NO₂, PM_{2.5} and PM₁₀ against the WTJO air quality criteria is shown in Table 3 for April to June 2019. As requested by the Peer Review Panel, maximum rolling annual average PM₁₀, PM_{2.5} and NO₂ have been included for comparison to the WTJO criteria.

Table 3 shows that measured air quality concentrations were below the WTJO ambient air quality criteria for the April to June 2019 period for all contaminants and monitoring sites. Data measured in previous months is summarised in Appendix D and original baseline data in Appendix F.

Table 3. Air quality monitoring results

AQ Station	Description	Concentration in µg/m ³			WTJO air quality criteria in µg/m ³
		April 2019	May 2019	June 2019	
Northern ambient air quality station	Maximum 1-hour average NO ₂	60.5	83.6	82.1	200
	Maximum 24-hour average NO ₂	34.8	48.2	48.0	100
	Maximum rolling annual average NO ₂	24.6	24.4	24.7	40
	Maximum daily average PM _{2.5}	9.8	11.9	20.0	25
	Maximum rolling annual average PM _{2.5}	8.1	7.9	7.7	10
	Maximum daily average PM ₁₀	21.3	32.9	28.8	50
	Maximum rolling annual average PM ₁₀	16.5	15.9	15.8	20
Southern ambient air quality station	Maximum 1-hour average NO ₂	52.8	68.4	74.7	200
	Maximum 24-hour average NO ₂	32.9	35.5	40.4	100
	Maximum rolling annual average NO ₂	17.5	17.6	17.6	40
	Maximum daily average PM _{2.5}	11.1	12.7	20.5	25

¹ MfE 2009. Good Practice Guide for Air Quality Monitoring and Data Management 2009. Wellington. Ministry for the Environment.

AQ Station	Description	Concentration in $\mu\text{g}/\text{m}^3$			WTJO air quality criteria in $\mu\text{g}/\text{m}^3$
		April 2019	May 2019	June 2019	
	Maximum rolling annual average PM _{2.5}	7.5	7.3	7.4	10
	Maximum daily average PM ₁₀	17.0	31.6	31.7	50
	Maximum rolling annual average PM ₁₀	14.1	13.7	13.9	20
Portal air quality station	Maximum rolling 1-hour average NO ₂	70.7	72.2	81.4	200
	Maximum rolling annual average NO ₂	17.6	18.0	18.0	40

2.2 EXCEEDENCES OF AIR QUALITY CRITERIA

The Waterview Connection BOI Operational Air Quality Condition OA.5 requires that when an exceedance of the WTJO air quality criteria occur, an investigation is undertaken into the cause of the exceedance and reported to the Air Quality Peer Review Panel and Auckland Council.

There were no exceedances of the WTJO air quality criteria in the April to June 2019 monitoring period.

2.3 POLLUTION ROSES

Pollution roses based on the hourly monitoring data are provided in Appendix E for April to June 2019. The pollution roses show the following:

- The highest NO₂ concentrations at the northern station were measured in winds from the west quadrant, from the direction of the adjacent SH20 alignment.
- The highest concentrations of PM_{2.5} and PM₁₀ at the northern station were measured in wind directions ranging from the east to northeast from the direction of the Unitec campus and Mt Albert residential area. A possible secondary source of PM₁₀ was also measured in winds from the south in the general direction of the SH20 portal and Great North Road, but was not apparent in the pollution rose for PM_{2.5}.
- The highest NO₂ concentrations at the portal and southern stations were measured in winds from the southern quadrant, from the direction of the SH20 alignment.
- The highest concentrations of PM₁₀ and PM_{2.5} at the southern station were measured in winds ranging from north to east-northeast, from the direction of the Owairaka residential area. A secondary source of PM_{2.5} and PM₁₀ was measured in winds to the south-southeast to east-southeast from the direction of the SH20 alignment and New Windsor residential area beyond.

The NO₂ pollution roses indicate that the main source of NO₂ at the monitoring sites is likely to be traffic emissions.

The PM₁₀ and PM_{2.5} pollution roses at the monitoring sites indicate that the highest concentrations were measured in winds where the monitoring sites were upwind of the SH20 alignment, with a secondary source of particulate in the direction of the SH20 alignment. This indicates that traffic emissions were not the predominant source of fine particulate over the monitoring period, and indicates the presence of other influences on fine particulate concentrations (most likely from the nearby residential areas).

2.4 TRAFFIC DATA AND POLLUTANT TRENDS

The daily traffic flow through the Waterview tunnel during April to June 2019 is shown in Figure 1 with daily average NO₂ concentrations measured at the three stations. The traffic flow generally shows a distinct weekly pattern, increasing from Monday to Friday and dropping off at the weekend, with the lowest traffic flow on Sundays. Due to a hardware issue, some losses of traffic data occurred between 19 May and 22 May 2019 and between 28 May and 14 June 2019.

The weekly pattern of NO₂ concentrations show a good correlation with daily traffic flow. The northern air quality station recorded the highest NO₂ concentrations over the period. However, this may be due to the northern station being located close to other high traffic routes (330 m SH16 and 20 m from Great North Road). The portal and southern stations show similar NO₂ concentrations to each other, and do not have other high traffic routes nearby.

The weekly patterns of PM_{2.5} and PM₁₀ concentrations show a weak correlation with daily traffic flows, as shown in Figure 2. PM₁₀ concentrations at the northern station were generally higher than measured at the southern station, however PM_{2.5} concentrations at the southern station were generally higher than those measured at the northern station.

The hourly average diurnal patterns of NO₂ concentrations show the highest concentration occurring in the morning between 7 am and 10 am and in the evening between 5 pm and 8 pm as shown in Figure 3. This largely correspond to peak traffic times.

Diurnal patterns in PM₁₀ and PM_{2.5} show some increase in concentrations coinciding with morning peaks in traffic, but concentrations continue to increase well into the evening after the afternoon peak in traffic as shown in Figure 4.

Trends in the monthly average NO₂ concentration since May 2017 are shown in Figure 5. The figure shows the changes in NO₂ after tunnel opening in July 2017 and the seasonality of NO₂ concentrations. Monthly average NO₂ concentrations increased from April through to June 2019. This appears to continue the seasonal trend in monthly NO₂ concentrations that was measured over the corresponding period in 2018, with NO₂ concentrations likely to increase to a winter peak in June/July 2019.

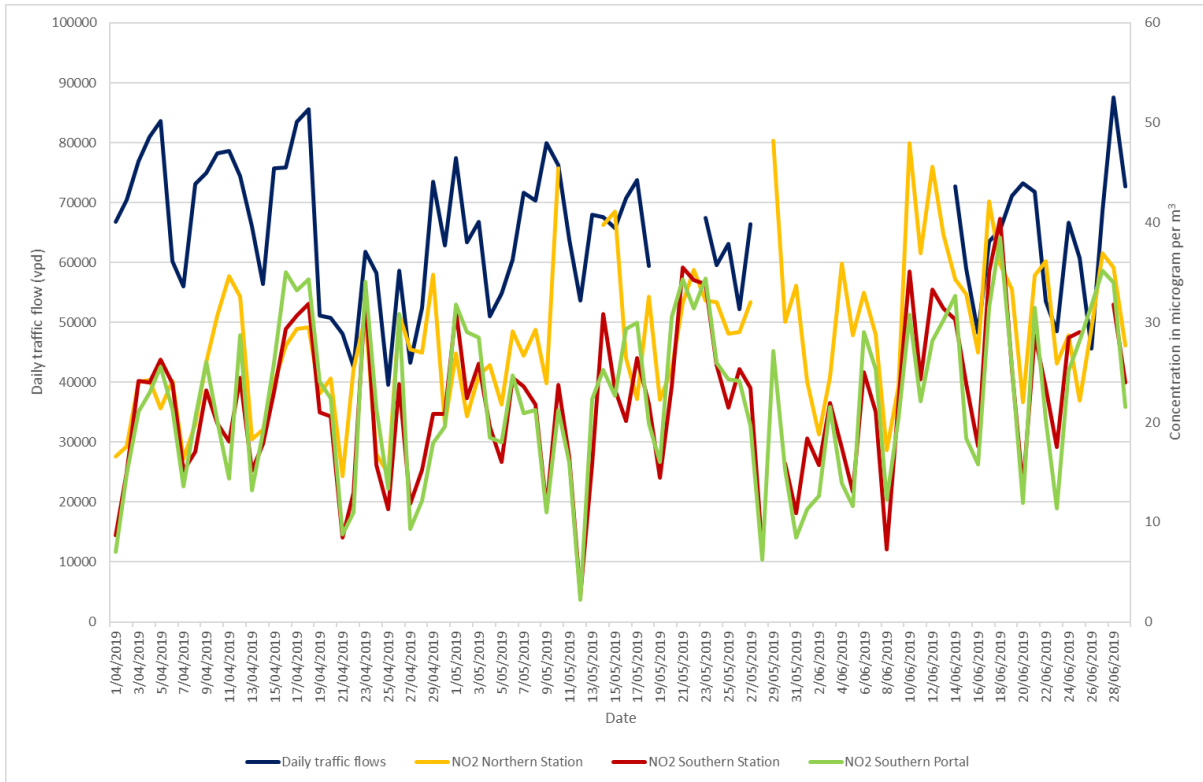


Figure 1: Waterview tunnel daily traffic flows and daily average NO₂

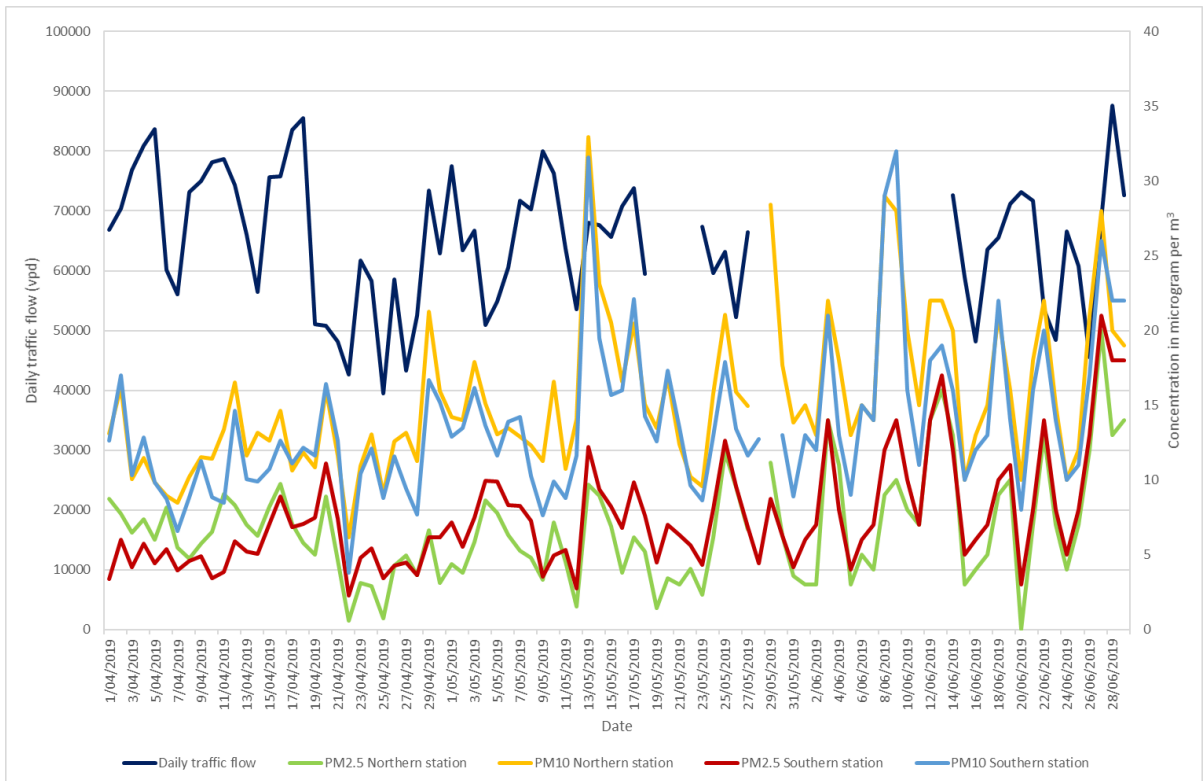


Figure 2: Waterview tunnel daily traffic flows and daily average PM_{2.5} and PM₁₀

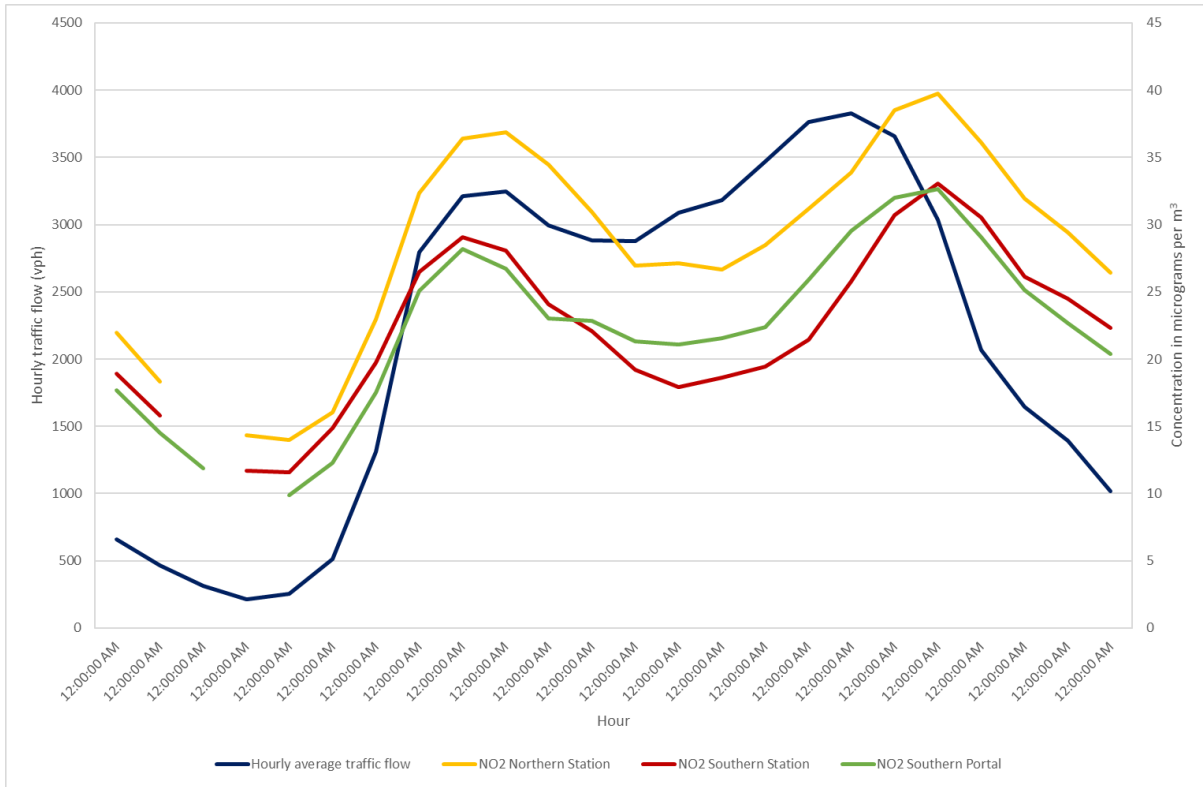


Figure 3: Diurnal hourly average NO₂ concentrations

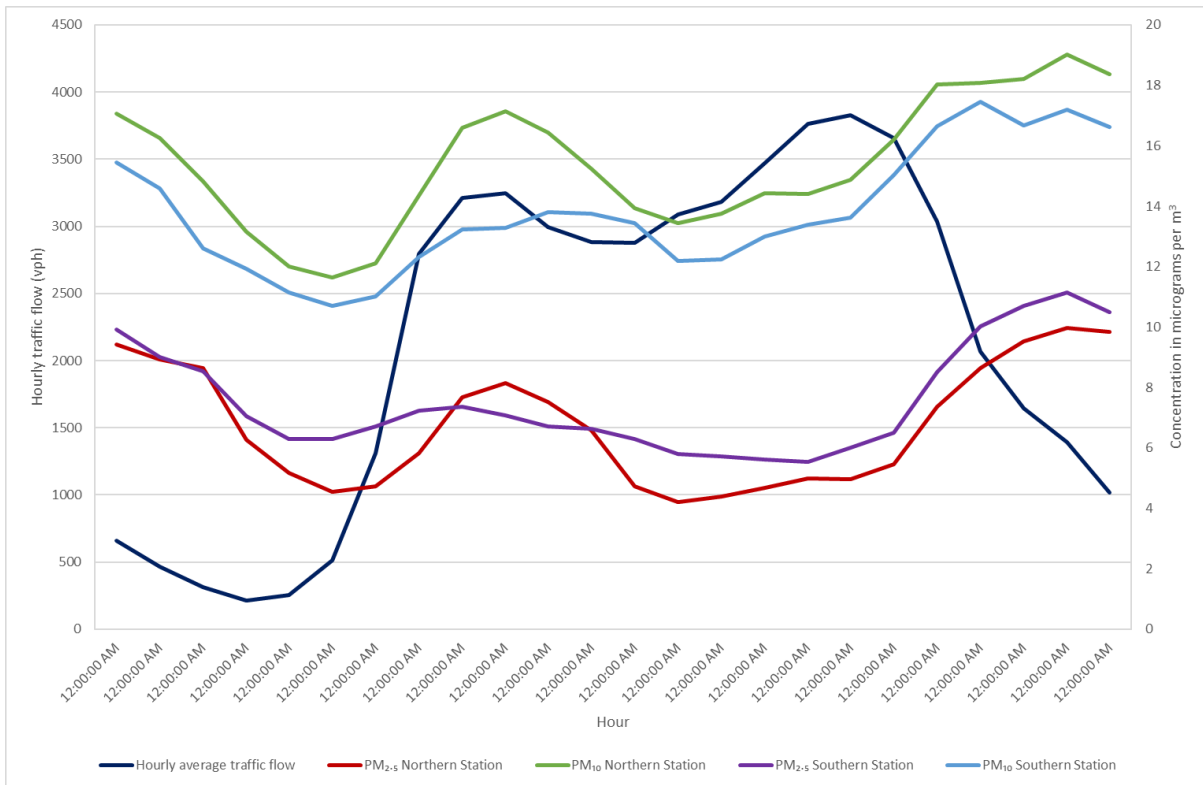


Figure 4: Diurnal hourly average PM_{2.5} and PM₁₀ concentrations

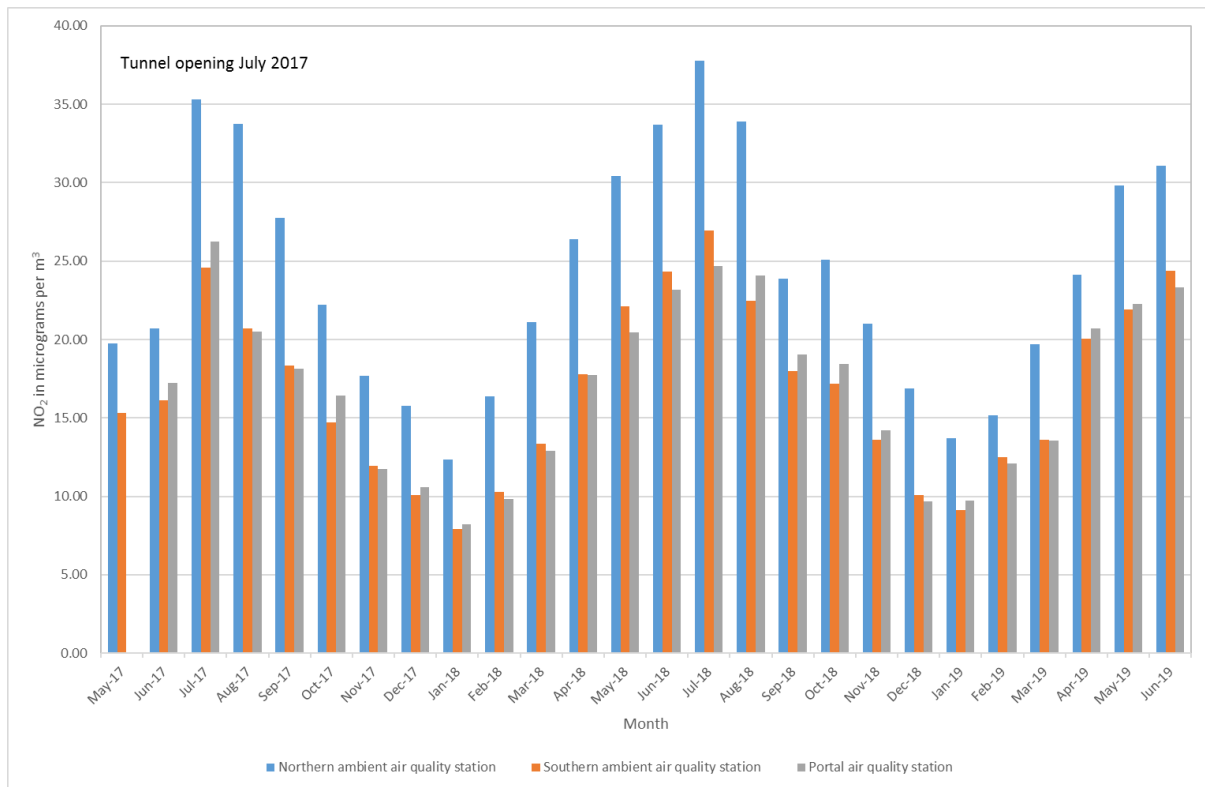


Figure 5: Monthly average NO₂ concentrations

3 CONCLUSION

This air quality monitoring report has been prepared in accordance with Waterview Connection BOI Operational Air Quality Condition OA.4. It includes analysis of validated air quality monitoring data for the period April to June 2019.

The Waterview Tunnel has been operational for 24 months. The minimum period of reporting has been completed in accordance with condition OA.4. No further reporting of air quality monitoring results is required.

The analysis of NO₂, PM_{2.5} and PM₁₀ data for the two ambient air quality stations and NO₂ data for the portal air quality station has shown that measured air quality concentrations were below the WTJO ambient air quality criteria for the period April to June 2019.

The recommended minimum data capture rate of 95% was achieved at all locations for the period April to June 2019 with the exception of NO₂ measured at the northern air quality station in May 2019. Low data capture of NO₂ at the northern ambient air quality station in May 2019 was due to an overnight calibration being out of tolerance on 11 May 2019. This fault was corrected on 13 May 2019.

The highest concentrations of NO₂ were recorded at the northern station. This may be explained by the northern station being located near other major traffic sources in addition to the Waterview Tunnel. By contrast, the southern and portal stations are not located near to other major traffic sources. Analysis of NO₂ pollution roses and diurnal trends indicates that the main source of NO₂ at the monitoring locations is traffic emissions.

The concentrations of PM₁₀ were slightly higher at the northern station than at the southern station, whereas PM_{2.5} concentrations at the southern station were generally higher than those measured at the northern station. The PM₁₀ and PM_{2.5} pollution roses for the northern and southern stations indicate that the highest concentrations were measured in winds where the monitoring sites were upwind of the SH20 alignment, with a secondary source of particulate in the direction of the SH20 alignment. Diurnal patterns in PM₁₀ and PM_{2.5} show some increase in concentrations coinciding with morning peaks in traffic, but concentrations continue to increase well into the evening after the afternoon peak in traffic. This indicates that traffic emissions were not the predominant source of fine particulate over the monitoring period, and that other sources dominate fine particulate concentrations (most likely from the nearby residential areas).

APPENDIX A: AIR QUALITY CONDITIONS

OA.1 The vents used to discharge emissions in the tunnels shall discharge vertically into air at a height of 15m, as follows: (a) The northern ventilation stack will be at a height of 15m. This height shall be calculated from the lowest existing ground level along the Great North Road boundary, adjacent to the ventilation stack; and (b) The southern ventilation stack will be at a height of 15m calculated from the post-construction ground level of the Alan Wood Reserve averaged at a distance of 10m from the exterior walls the ventilation stack location and shall not be impeded by any obstruction that may in the opinion of the Peer Review Panel (Condition OA. 7) decrease the vertical efflux velocity (in other words, the average velocity of material emitted into the atmosphere).

OA.2 Prior to the tunnels becoming operational, the NZTA shall establish two ambient air quality monitoring stations and one portal air quality monitoring station. The location and types of these monitoring stations shall be selected by the NZTA in consultation with the Auckland Council and Peer Review Panel (Condition OA.7), providing that one ambient monitoring station will be located within the Waterview Primary School (subject to agreement by the School).

Ambient air quality shall be monitored continuously in real time, to monitor potential effects associated with the operation of the ventilation system from the tunnels. Ambient monitoring shall include fine particulates (PM₁₀ and PM_{2.5}) and nitrogen dioxide. Portal monitoring shall include nitrogen dioxide. Results shall be compared with the relevant National Environmental Standards for air quality and Auckland Regional air quality targets (as identified in Chapter 4 of the Auckland Regional Plan: Air, Land and Water, 2010). Monitoring shall be undertaken at each site until the Peer Review Panel recommends that monitoring is no longer necessary. The locations, operation and maintenance schedules of the continuous monitors shall, as far as practicable, comply with the requirements of AS/NZ 3580.1.1: 2007 Method for Sampling and Analysis of Ambient Air – Guide to Siting Air Monitoring Equipment, and with methods specified in the National Environment Standards.

OA.3 Continuous monitoring of wind speed and direction shall be undertaken at each ambient air quality monitoring location as required by Condition OA.2. The locations of wind speed and direction monitors shall, as far as practicable, comply with the requirements of AS 2923:1987 Ambient Air – Guide for the Measurement of Horizontal Wind for Air Quality Applications.

OA.4 For the first 12 months of tunnel operation, the results of the ambient air quality monitoring shall be reported via validated reports and issued for information via the Project website (monthly). Following this period, and for a period of at least 12 months, reporting shall take place quarterly as follows: Quarter 1 (December to February) by 31 March, Quarter 2 (March to May) by 30 June, Quarter 3 (June to August) by 30 September and Quarter 4 (September to December) by 31 December.

OA.5. If the monitoring required by Condition OA.2 shows that concentrations of contaminants in ambient air at the monitoring locations exceeds the relevant National Environmental Standards for air quality, or Regional Air Quality Targets (as identified in Chapter 4 of the Auckland Regional Plan: Air, Land and Water), the NZTA shall undertake an investigation into the cause of the exceedance and report this to the Peer Review Panel (Condition OA.7) and the Major Infrastructure Team Manager, Auckland Council.

OA.6. The air quality monitoring shall be undertaken in general accordance with the Operational Air Quality Management Procedure (Appendix O of Technical Report G.1 Assessment of Air Quality Effects) submitted with this application.

OA.7. A Peer Review Panel shall be appointed by NZTA with the agreement of Major Infrastructure Team Manager, Auckland Council for the purpose of reviewing the ambient air quality monitoring programme and results. The Peer Review Panel shall consist of two independent experts in air quality with experience in ambient air quality monitoring and emissions from motor vehicles. The Peer Review Panel shall review all ambient monitoring, relevant traffic data and tunnel emissions and provide a summary report including any interpretation and recommendations to NZTA, Auckland Council and the Community Liaison Group(s) within 6 months of the tunnels becoming operational and annually thereafter.

O.A.8 The tunnel ventilation system shall be designed and operated to ensure that any air emitted from the tunnel portals does not cause the concentration of nitrogen dioxide (NO₂) in ambient air to exceed 200 micrograms per cubic metre, expressed as a rolling 1 hour average, at any point beyond the designation boundary that borders an air pollution sensitive land use.

Advice Note: The above standard reflects the National Environmental Standard for Nitrogen Dioxide (NO₂) concentration in ambient air.

APPENDIX B: MONITORING LOCATIONS

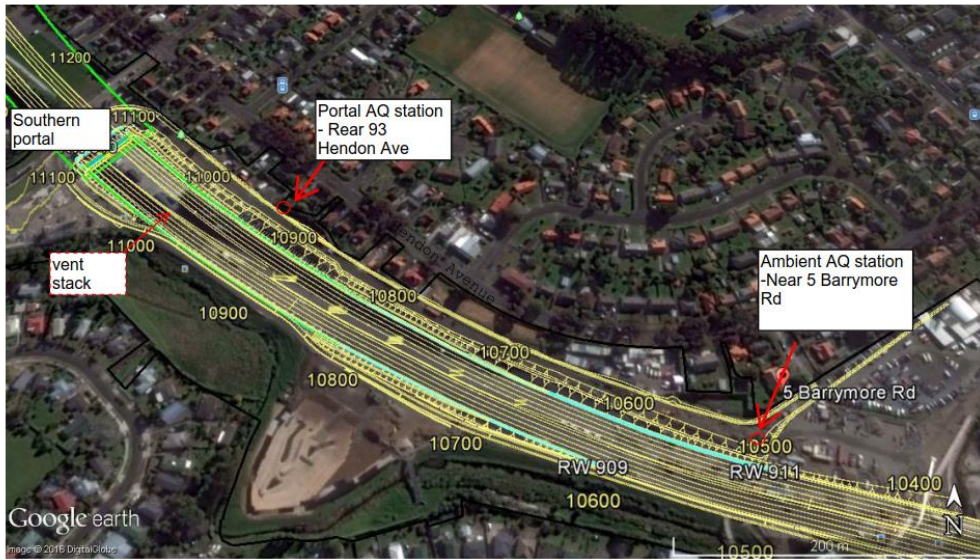


Figure B 1: Southern area stations



Figure B 2: Northern area station

APPENDIX C: VALID DATA EXCEPTION REPORT

North ambient air quality station

Start Date	End Date	Reason	Change Details
01/04/19 01:00	30/06/19 01:40	Automatic daily overnight span calibration check from approximately 1:00 - 1:40	NO, NO2, NOx
18/04/19 11:00	18/04/19 12:00	Scheduled monthly maintenance - instrument filter tape replacement and stabilisation	PM2.5,PM10
18/04/19 11:15	23/04/19 13:50	Scheduled 3 monthly maintenance - instrument calibration and stabilisation	NO, NO2, NOx
11/05/19 01:45	13/05/19 15:45	Overnight calibration out of tolerance	NO, NO2, NOx
11/05/19 07:00	30/05/19 21:35	Intermittent power interruption and instrument stabilisation	All channels
12/05/19 00:00	15/05/19 00:00	Intermittent instrument fault - count error	PM2.5,PM10
13/05/19 15:50	13/05/19 16:25	Non scheduled maintenance - instrument calibration and stabilisation	NO, NO2, NOx
28/05/19 11:00	28/05/19 18:50	Scheduled 6 monthly maintenance - instrument calibration and stabilisation	All channels
07/06/19 16:50	07/06/19 17:20	Non scheduled maintenance - instrument calibration and stabilisation	NO, NO2, NOx
25/06/19 14:00	25/06/19 16:10	Scheduled monthly maintenance - instrument calibration and stabilisation	All channels
25/06/19 16:10	27/06/19 12:40	Applied linear multiplier A = 0.9368, B = 0.9390 to correct baseline	NO, NO2, NOx
27/06/19 12:45	27/06/19 14:25	Non scheduled maintenance - instrument calibration and stabilisation	NO, NO2, NOx

South ambient air quality station

Start Date	End Date	Reason	Change Details
01/04/19 01:00	30/06/19 01:30	Automatic daily overnight span calibration check from approximately 1:00 - 1:30	NO, NO2, NOx
01/04/19 01:35	17/04/19 15:25	Applied linear multiplier A= 0.1 and B = 0.932 to correct baseline	NO, NO2, NOx
17/04/19 15:00	17/04/19 16:00	Scheduled monthly maintenance - instrument filter tape replacement and stabilisation	PM2.5,PM10
17/04/19 15:30	17/04/19 17:30	Scheduled 3 monthly maintenance - instrument calibration and stabilisation	NO, NO2, NOx
10/05/19 14:00	10/05/19 14:25	Non scheduled maintenance - instrument calibration and stabilisation	NO, NO2, NOx
29/05/19 10:00	29/05/19 16:10	Scheduled 6 monthly maintenance - instrument calibration and stabilisation	All channels
26/06/19 11:00	26/06/19 14:50	Scheduled monthly maintenance - instrument calibration and stabilisation	All channels

Start Date	End Date	Reason	Change Details
26/06/19 14:55	27/06/19 09:55	Overnight calibration out of tolerance	NO, NO2, NOx
27/06/19 10:00	27/06/19 10:30	Non scheduled maintenance - instrument calibration and stabilisation	NO, NO2, NOx

Portal air quality station

Start Date	End Date	Reason	Change Details
01/04/19 02:00	30/06/19 02:30	Automatic daily overnight span calibration check from approximately 2:00 - 2:30	NO2
01/04/19 23:45	30/06/19 23:50	Automatic daily background check, nightly for 5 minutes between 23:45 and 23:50	NO2
17/04/19 12:55	17/04/19 13:20	Scheduled monthly maintenance - instrument calibration and stabilisation	NO2
17/04/19 15:30	17/04/19 15:30	Additional instrument background check	NO2
30/05/19 12:00	30/05/19 15:50	Intermittent additional instrument background check	NO2
30/05/19 13:20	30/05/19 14:45	Scheduled 6 monthly maintenance - instrument calibration and stabilisation	NO2
26/06/19 15:30	26/06/19 17:40	Intermittent additional instrument background check	NO2
26/06/19 16:10	26/06/19 16:30	Scheduled monthly maintenance - instrument calibration and stabilisation	NO2

APPENDIX D: PREVIOUS MONTHLY DATA

AQ Station	Description	Pre Tunnel Opening Concentration in $\mu\text{g}/\text{m}^3$		Post Tunnel Opening Concentration in $\mu\text{g}/\text{m}^3$																								Project air quality criteria in $\mu\text{g}/\text{m}^3$
		May 2017	June 2017	July 2017	Aug 2017	Sept 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	June 2018	July 2018	Aug 2018	Sept 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	June 2019	
Northern ambient air quality station	Maximum 1-hour average NO_2	65.5	58.2	96.8	93.2	91.3	77.9	62.1	57.8	53.6	62.9	62.1	69.8	83.5	87.5	101.5	101.1	75.8	83.4	63.2	65.5	44.1	53.9	59.8	60.5	83.6	82.1	200
	Maximum 24-hour average NO_2	30.2	36.9	46.4	54.1	44.8	39.4	26.5	31.7	24.7	30.2	34.3	42.7	46.4	45	50.3	50.3	44.2	43.4	33.5	27.3	23.2	24.1	29.4	34.8	48.2	48.0	100
	Maximum daily average $\text{PM}_{2.5}$	32.7	24.9	24.8	16.9	14.0	10.5	11.3	10.8	16.0	13.1	11.3	14.4	21.8	27	19	14.8	11.2	10.3	12.8	11.7	14.8	12.2	11.0	9.8	11.9	20.0	25
	Maximum daily average PM_{10}	35.7	33.3	31.0	26.4	26.9	31.3	35.1	24.4	36.0	27.6	31	32.8	29.9	36.8	31.4	24.5	22.1	25.7	29.5	28.5	37.7	20.8	19.1	21.3	32.9	28.8	50
Southern ambient air quality station	Maximum 1-hour average NO_2	64.1	70.3	73.3	63.5	73.4	61.9	50.5	44.7	32.8	51.7	41.1	57.0	64.8	62.4	73.5	72.7	56.9	61.1	50.7	41.3	38.1	44.4	46.9	52.8	68.4	74.7	200
	Maximum 24-hour average NO_2	30.0	30.8	38.2	34.7	27.4	25.5	20.7	16.9	18.5	17.9	22.8	29.6	36.5	38.8	39.7	38.9	27.7	25.9	26.0	17.1	14.6	20.8	28.1	32.9	35.5	40.4	100
	Maximum daily average $\text{PM}_{2.5}$	23.2	19.1	26.5	12.6	12.1	13.3	9.8	8.1	14.0	9.8	11	15.9	21.9	26.4	21.3	16.1	12	9.8	12.8	13.7	-	11.3	7.8	11.1	12.7	20.5	25
	Maximum daily average PM_{10}	35.8	31.8	31.8	28.8	31.6	37.9	22.0	20.1	34.0	26.7	23.9	27.3	26.5	34.1	30.2	21.7	18.5	20.3	25.8	28.8	27.2	-	18.6	17.0	31.6	31.7	50
Portal air quality station	Maximum rolling 1-hour average NO_2	70.8	80.6	86.9	73.8	84.9	62.6	63.5	51.2	46.7	46	51	67.4	78.7	87.8	86.9	75.5	76.1	70.5	65.8	16.9	48.5	47.6	50.7	70.7	72.2	81.4	200

It should be noted that construction activities on site in the vicinity of the stations, including vehicle movements on haul roads, will have contributed to measured particulate levels pre tunnel opening. Baseline measurements of $\text{PM}_{2.5}$ were also elevated in May 2017 during the night time due to domestic smoke from adjacent residential properties.

APPENDIX E: POLLUTION ROSES

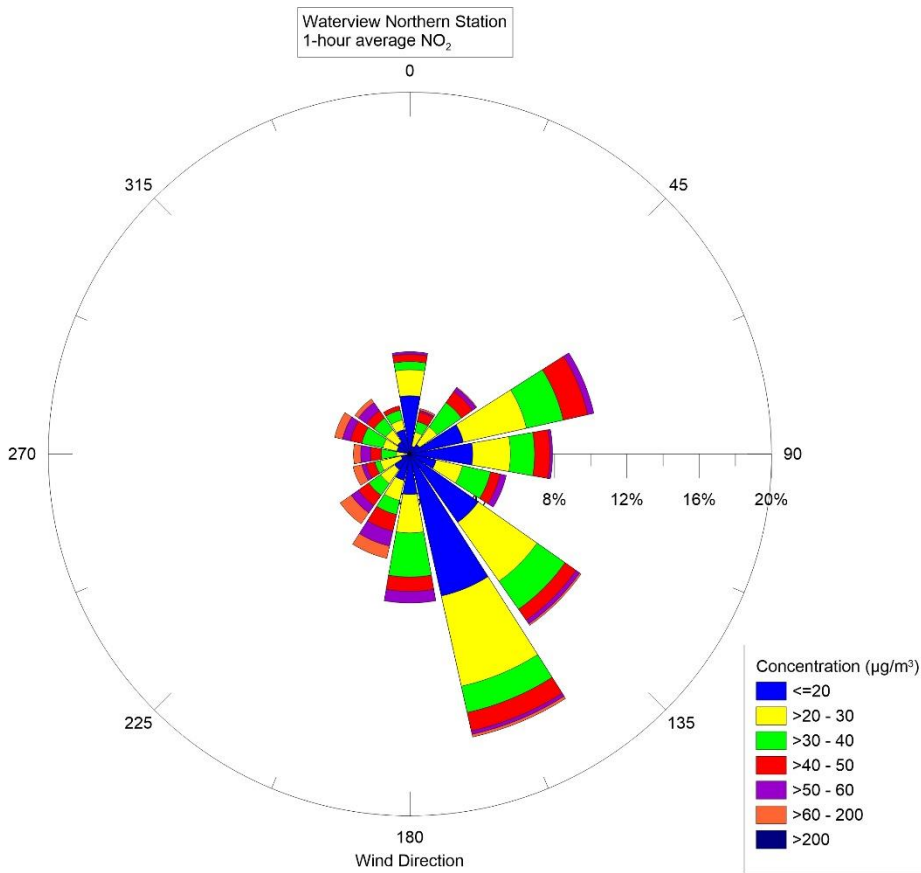


Figure D 1: Northern station 1-hour average NO₂, April to June 2019

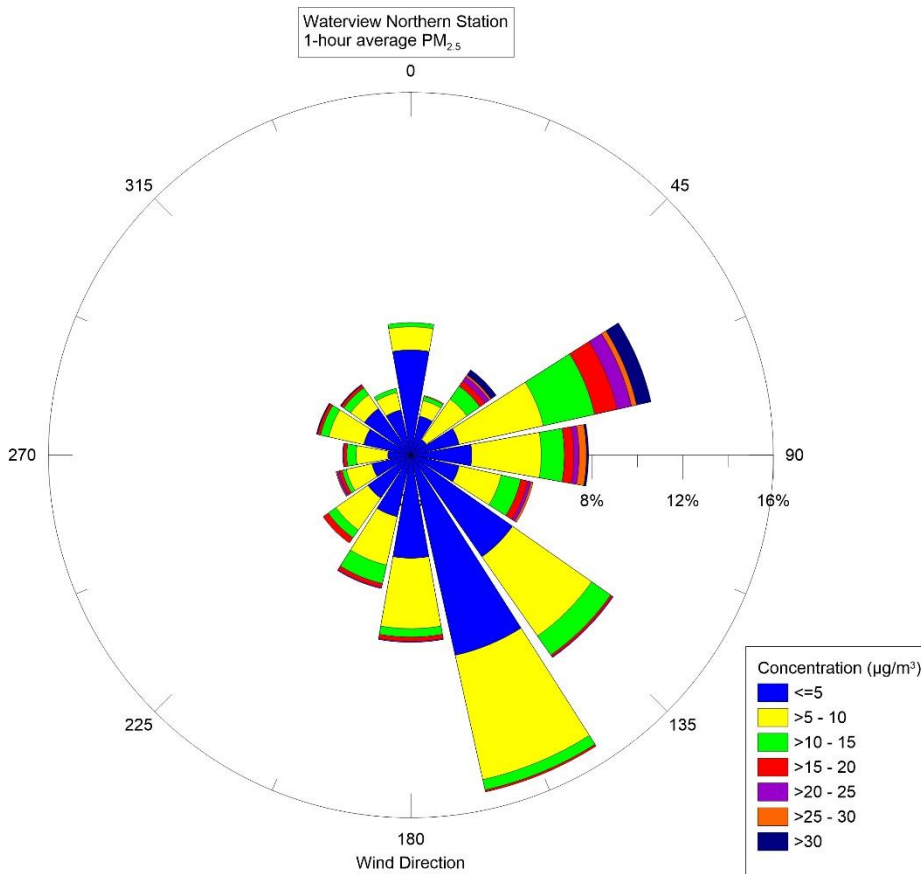


Figure D 2: Northern station 1-hour average PM_{2.5}, April to June 2019

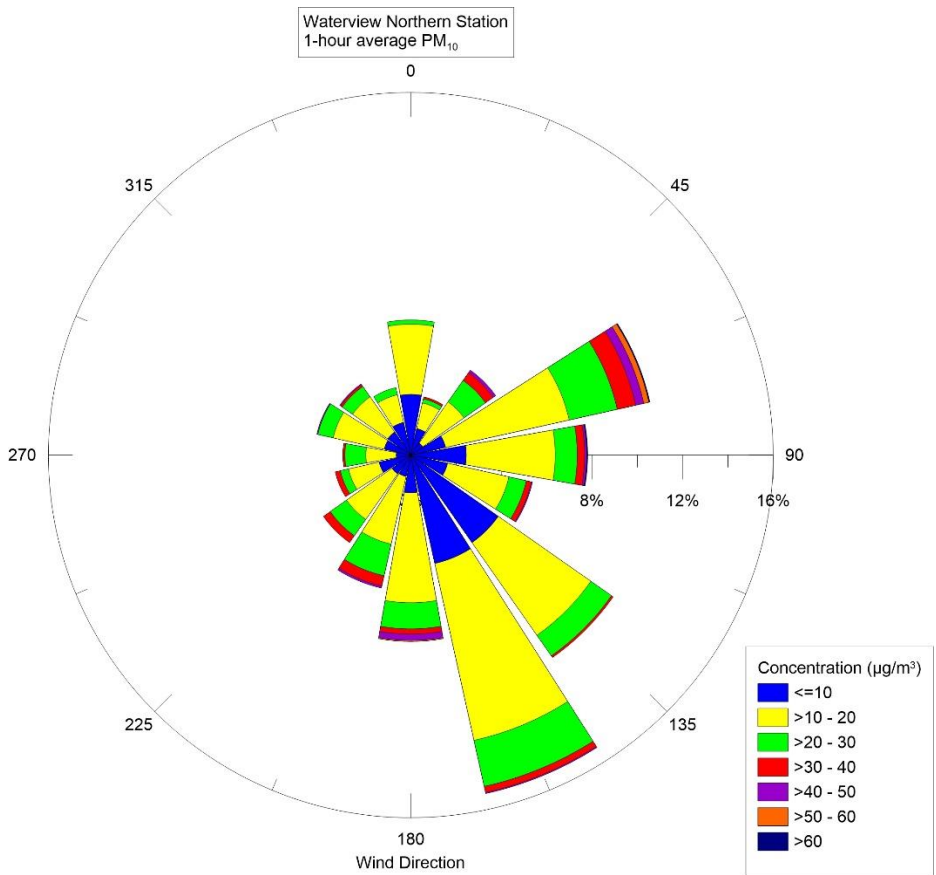


Figure D 3: Northern station 1-hour average PM₁₀, April to June 2019

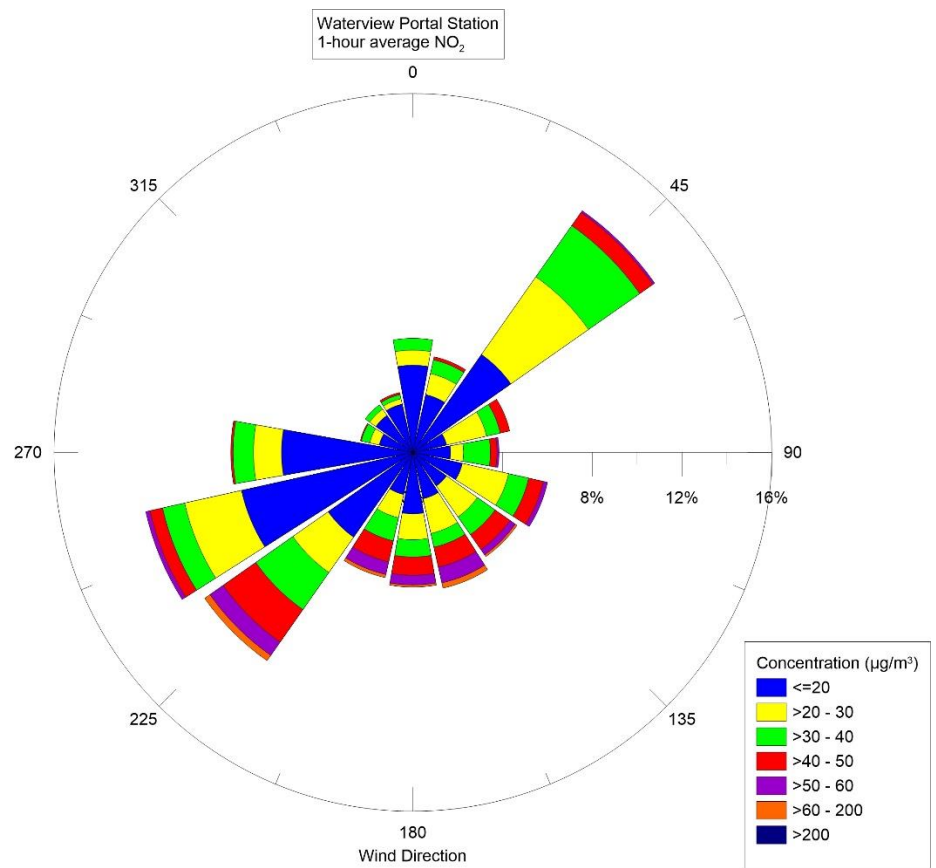


Figure D 4: Portal station 1-hour average NO₂, April to June 2019 (wind measured at Southern Station)

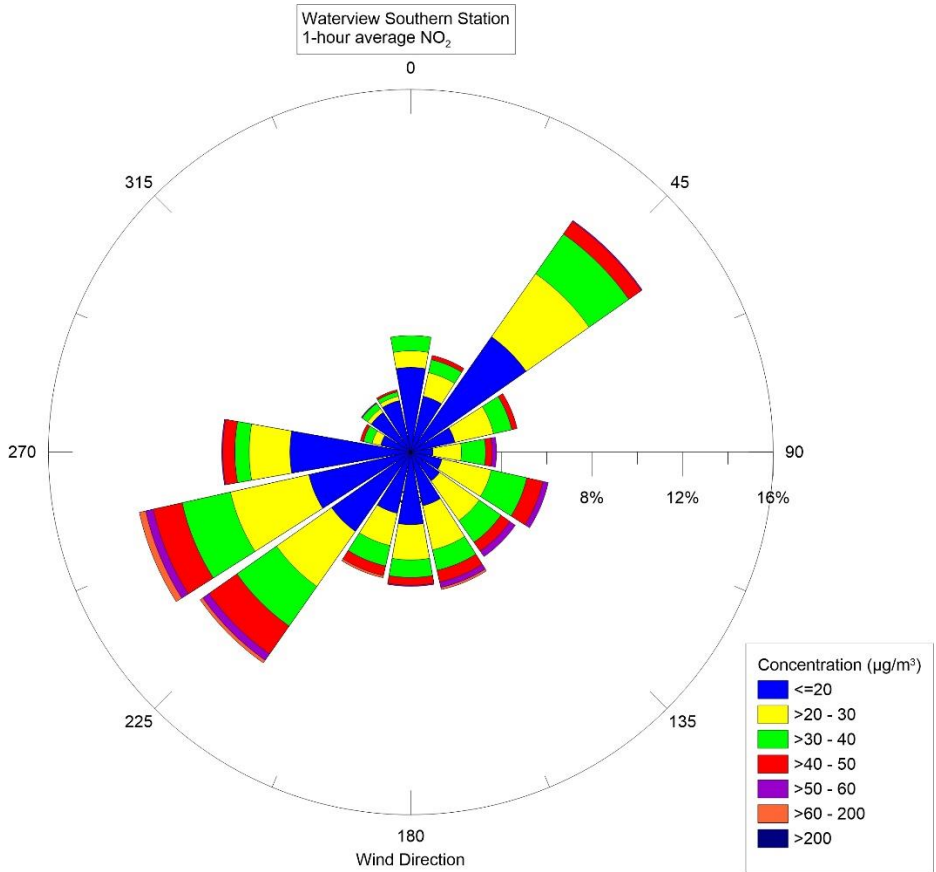


Figure D 5: Southern station 1-hour average NO₂, April to June 2019

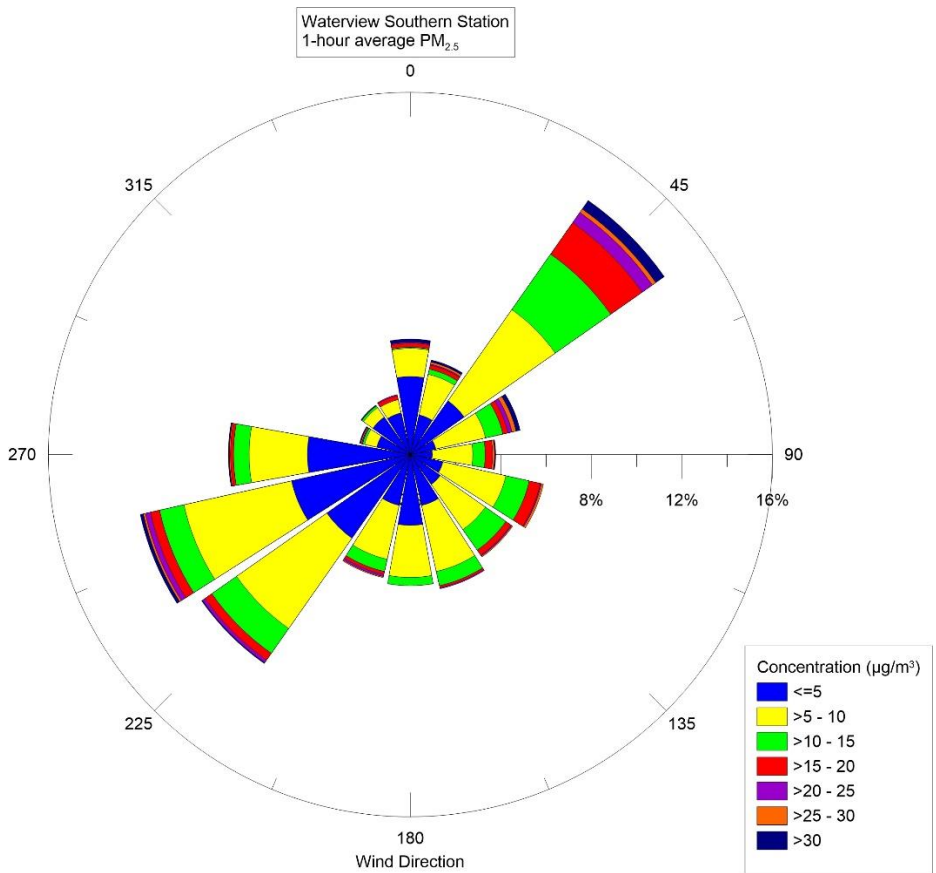


Figure D 6: Southern station 1-hour average PM_{2.5}, April to June 2019

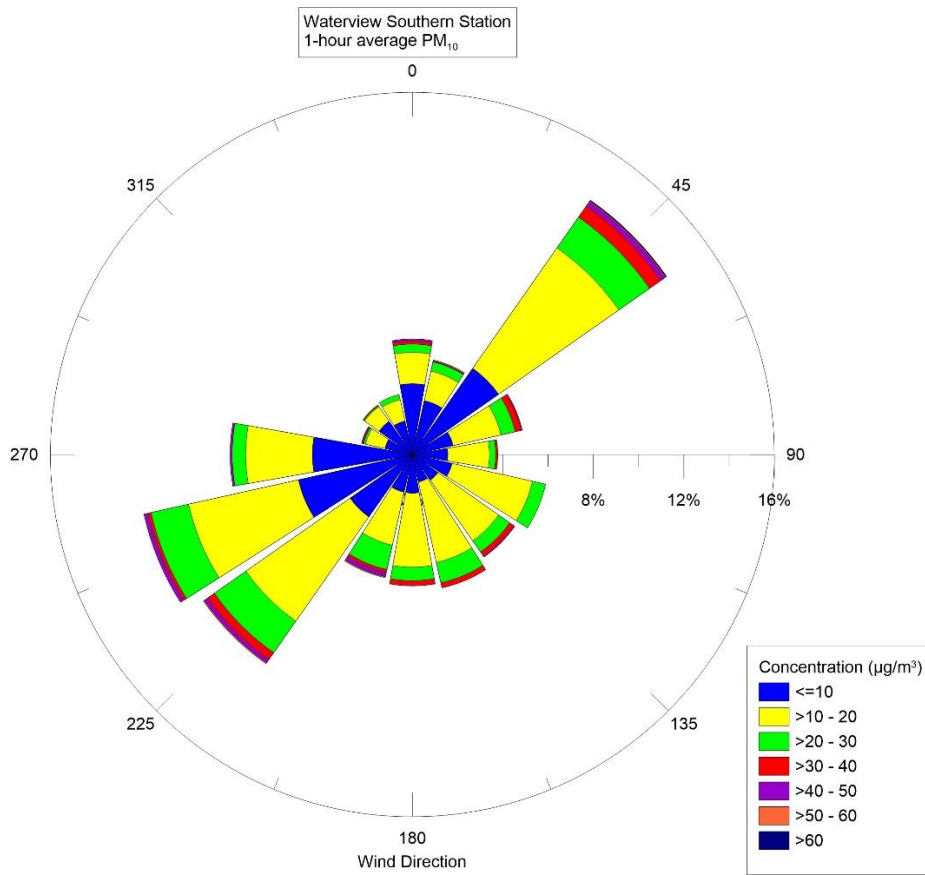


Figure D 7: Southern station 1-hour average PM₁₀, April to June 2019

APPENDIX F: ORIGINAL BASELINE MONITORING DATA

Air Quality Station	Description	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06					
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO ₂												
	Maximum 24-hour average NO ₂												
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀												
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO ₂	55	59	59	53	112	39	57					
	Maximum 24-hour average NO ₂	25	34	31	26	86	17	19					
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀	32	44	23	22	19	63	22					
Air Quality Station	Description	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO ₂								55	66	61	50	44
	Maximum 24-hour average NO ₂								29	36	28	30	23
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀								25	32	28	28	24
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO ₂	28	35	37	53	56	56	61	51	61	44	42	38
	Maximum 24-hour average NO ₂	10	13	15	27	34	32	28	20	25	18	17	13
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀	21	19	19	19	32	35	22	31	17	24	24	14
Air Quality Station	Description	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO ₂	38	43	46	57	71	71	81	71	62	66	119	62
	Maximum 24-hour average NO ₂	20	23	27	27	39	42	41	38	34	35	35	30
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀	29	21	22	24	37	31	33	16	18	20	27	18
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO ₂	26	38	42	54	59	67	58	52	45	43	34	36
	Maximum 24-hour average NO ₂		20	19	25	30	38	32	21	21	16	13	14
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀	24	18	21	19	37	27	30	17	15	19	22	15

Air Quality Station	Description	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO ₂	74	265				55	103	99	77	93	83	80
	Maximum 24-hour average NO ₂	37	48				26	56	48	44	45	30	39
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀	20	29	26	29	27	50	43	32	135	31	33	25
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO ₂	29	32	38	40	51	62	44	51	37			
	Maximum 24-hour average NO ₂	9	15	18	20	24	30	22	20	18			
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀	17	26	20	21	25	38	30	28	117			
Air Quality Station	Description	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO ₂	52	57	58	56	55	23	265	70	41	93	101	85
	Maximum 24-hour average NO ₂	29	30	33	33	28	11	46	22	22	30	34	27
	Maximum daily average PM _{2.5}						16	29	34	10	10	13	8
	Maximum daily average PM ₁₀	21	27	23	20	28	20	35	39	26	27	22	30
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO ₂												
	Maximum 24-hour average NO ₂												
	Maximum daily average PM _{2.5}												
	Maximum daily average PM ₁₀						44	40	37	24	26	22	30

Results taken from: *Ambient Air Quality Monitoring Summary Report, Beca 09 May 2011.*