Mount Maunganui Air Quality Monitoring Review 2024

24 September 2024

Author:

Lou Wickham

PREPARED FOR: **Toi Te Ora Public Health**

CLIENT REPORT No: **FW 24034**

REVIEWED BY: **Rachael Nicoll**

ACKNOWLEDGEMENTS

The author wishes to acknowledge Shane Iremonger, Reece Irving and Glen Ellery of Bay of Plenty Regional Council who assisted with provision of data for this review.

Manager

Daniel Bohnen

Service Lead (ESR)
Manager Risk Assessment Food and Social Systems

Author

Lou Wickham

Director
Emission Impossible Ltd

Peer reviewer

Paul Baynham

Lead Scientist
Mote

Peer reviewer

Rachael Nicoll

Senior Air Quality Specialist
Emission Impossible Ltd

CONTENTS

CONTENTS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CONTENTS

LIST OF FIGURES

CONTENTS

LIST OF FIGURES

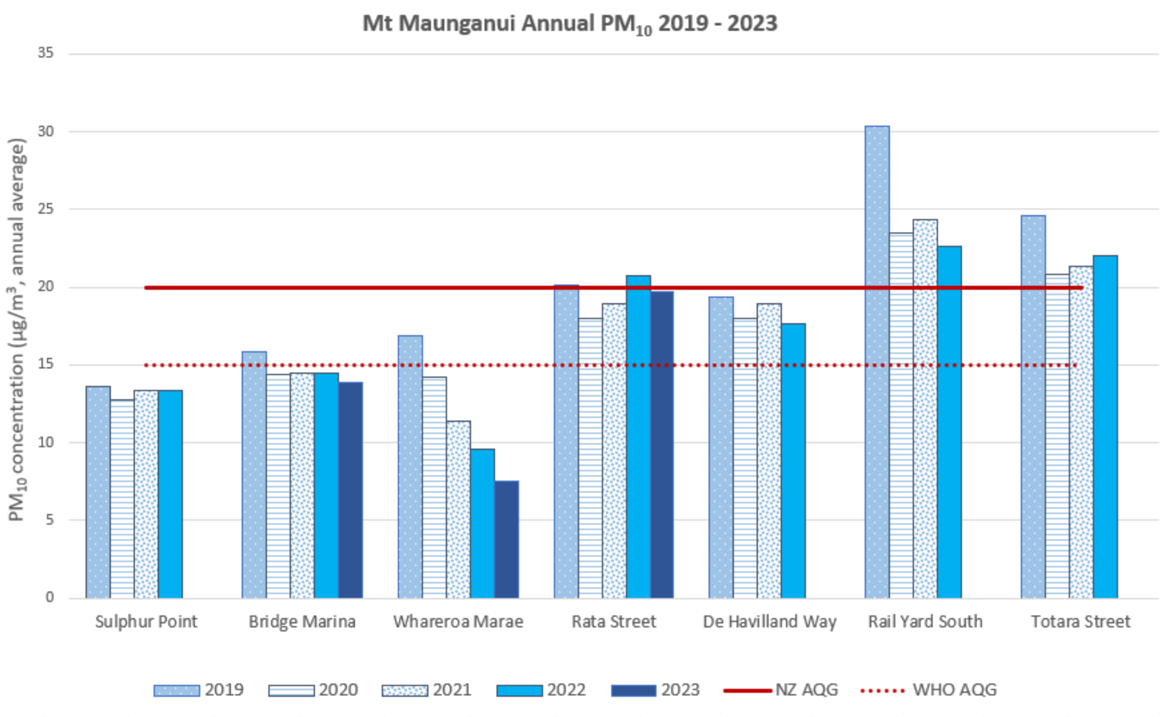
EXECUTIVE SUMMARY

This report is an independent review of all available Bay of Plenty Regional Council (BOPRC) ambient air quality monitoring data from the Mount Maunganui area for the period ending 30 May 2024. Prepared for Toi Te Ora, this report focuses on pollutants where evidence has advanced the most on health effects from exposure (WHO 2021), specifically particulate matter less than 10 micrometres in diameter (PM_{10}), particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).

Figure E-1 presents annual average concentrations of PM_{10} measured in the Mount Maunganui Airshed between 2019 and 2023 for comparison with the New Zealand and WHO air quality guidelines (AQG). Three monitoring sites that were predominantly upwind of the Mount Maunganui Airshed (Sulphur Point, Tauranga Bridge Marina and Whareroa Marae) met the New Zealand Ambient Air Quality Guideline (AQG) and, in more recent years, all met the WHO AQG. The four remaining monitoring locations consistently exceeded the WHO annual AQG and all, except one (De Havilland Way), consistently exceeded the New Zealand annual AQG for PM_{10}.

WHO AQG have no regulatory status in New Zealand. However, the WHO AQG provide global guidance on thresholds and limits for key air pollutants that pose important risks to public health and offer quantitative, health-based recommendations for air quality management derived from the best available epidemiological evidence.

FIGURE E-1: Annual PM_{10} concentrations measured in the Mount Maunganui Airshed: 2019 – 2023.



Typically, a period of 10 years of data is required to undertake robust trend analysis. The monitoring to date suggests, despite some improvements in some specific locations (Whareroa Marae), there has been little change in chronic levels of PM_{10} within the Mount Maunganui Airshed. This suggests continued efforts will be needed to reduce chronic exposure to PM_{10} in the Mount Maunganui area.

Annual concentrations of $PM_{2.5}$ have historically exceeded the WHO AQG at Totara Street. This monitoring site has been decommissioned and there are not yet sufficient data on which to estimate long-term concentrations in other (new) monitoring locations. The historical, elevated annual levels warrant continued monitoring and investigation of $PM_{2.5}$.

There is a significant data record of SO_2 monitoring from Totara Street going back to 2006, a period of 18 years. Peak (short-term) levels of SO_2 over this period show a clear, and significant, reduction. These reductions coincide with mandated changes in regulations (i.e., MARPOL Annex VI which reduced emissions from ships) and regulatory action by BOPRC of key sources (for example, successive prosecutions against Ballance Agri-Nutrients Ltd).

Ambient levels of SO_2 were below national environmental standards and most WHO AQG in 2023. Occasional short-term exceedances of the WHO 10-minute AQG for SO_2 continue to occur at Whareroa Marae and Tauranga Bridge Marina. BOPRC is to be supported for playing a significant role in reducing the public's exposure to the adverse health effects of short-term excursions of SO_2.

There are not yet sufficient data on which to make informed conclusions regarding chronic exposure to NO_2 in the Mount Maunganui Airshed and Mount Maunganui. NO_2 is a precursor pollutant that contributes to the formation of $PM_{2.5}$. The historically elevated levels in annual NO_2 and lack of any declining trend warrants continued monitoring and investigation.

Daily levels of NO_2 measured to date have exceeded the WHO AQG once and appear to show a source to the northwest of Whareroa Marae. WHO (2021) allows for 3 – 4 exceedances of daily guidelines in a year. It is too soon to know if annual levels will meet the WHO AQG.

BOPRC are to be commended for the extensive reference-grade monitoring that has been, and is being, undertaken in Mount Maunganui. This ambient air quality monitoring is essential for managing potential effects of industrial emissions and informing the public about the health effects of air pollution in Mount Maunganui. The establishment of a new monitoring site at Ranch Road (PM_{10}, $PM_{2.5}$ and NO_2) is a welcome addition and will inform residential exposure in Omanu to industrial emissions from the Mount Maunganui Airshed. Similarly, the introduction of $PM_{2.5}$ and NO_2 monitoring at Whareroa Marae is welcome.

Caution is advised regarding the use of low-cost sensors and data interpretation by members of the public. The sensors have unknown data quality and the adopted air quality index is based on (US) air quality standards that are much less stringent than those referenced in this review.

1. Introduction

This report has been prepared for Toi Te Ora Public Health. It focuses on “classical” pollutants, i.e. the pollutants where evidence has advanced the most on health effects from exposure (WHO 2021).

This report is an independent summary and review of available Bay of Plenty Regional Council (BOPRC) ambient air quality monitoring data for particulate matter less than 10 micrometres in diameter (PM_{10}), particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$) and sulphur dioxide (SO_2) for the period ending 30 May 2024.[1] Available data for newly installed nitrogen dioxide (NO_2) monitoring are also reviewed and discussed.

Monitoring for all these pollutants is undertaken in accordance with reference methods in Schedule 2 of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NESAQ). Data from these monitors will typically be of a high standard and can be relied upon to inform assessment of the public health impacts of air pollution.

Figure 1 presents the Mount Maunganui Airshed (MMA) and current and historical BOPRC ambient air quality monitoring locations. With respect to these locations, it is important to note that:

- Whareroa Marae is a traditional pa site and key marae for Ngai Tukairangi and Ngāti Kuku hapū of the Ngāi Te Rangi Iwi. Whareroa Pā has been present for around 150 years, making it one of the oldest kāinga (settlements) in the area. There is also a papa kāinga (original home or village) and kohanga reo at Whareroa Marae (refer Figure 2).
- The Rail Yard South, Totara Street and Totara Street Rail Crossing monitoring sites are industrial (only) locations.
- The new monitoring site at Ranch Road is residential (only).
- All other monitoring locations are surrounded by a mix of commercial, industrial and residential activities (refer Figure 1 and Figure 2). There is also some residential activity at the marinas.

With respect to public exposure to air pollutants, it is relevant to note:

- Whareroa Marae is located inside the southern boundary of the MMA;
- five childcare facilities (including the kohanga reo at Whareroa Marae) are inside the MMA;[2]
- there are a number of residential locations adjacent to the airport inside the MMA; and
- people live at the marinas located at Tauranga Bridge and Sulphur Point.

[1] Additional data to end June or July 2024, where available, are also included.
[2] Bambinos Early Childhood Centre (Tawa St), Newton Street Childcare Ltd, Little Einsteins Montessori (MacDonald St), BestStart MacDonald Street and Te Kohanga Reo o Whareroa (Whareroa Marae).

FIGURE 1: Current (yellow) and historical BOPRC (white italic) reference PM_{10} monitoring locations in Mount Maunganui as at 15 June 2024.

FIGURE 2: Whareroa Marae and Tauranga Bridge Marina air quality monitoring sites in relation to shipping berths and some local industries.

It is also important to note that there are approximately 10,000 workers inside the MMA every working day.[3] Exposure of these workers to *ambient* air pollution is not addressed by workplace occupational exposure standards (WES) because:

- S36 of the Health and Safety at Work Act limits the primary duty of care to the persons conducting the business or undertaking (PCBU). In practice this limits responsibility for emissions to those discharged from each individual site only within each individual site.
- A WES is a guidance value that refers to the airborne concentration of a substance at which it is believed that nearly all workers can be repeatedly exposed day after day without coming to harm. However, the range of individual susceptibility to hazardous and toxic substances is wide, and it is possible that some workers may experience discomfort or develop occupational illness from exposure at levels below the WES (Worksafe 2024).

From a broader public health perspective, the census area units of Mount Maunganui North and Omanu are home to around 17,000 people[4] and are adjacent to, and downwind of, the MMA.

1.1 HEALTH EFFECTS OF KEY POLLUTANTS

The following sections provide a brief overview of adverse health effects known to be caused by, or associated with, public exposure to key contaminants.

1.1.1 Particulate matter

Particulate Matter (PM) is a collective term for solid and liquid particles suspended in the air and small enough to be inhaled. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water.

PM is classified by particle size defined through aerodynamic diameter as follows:

- PM_{10} – particulate less than 10 microns; known as coarse particulate
- $PM_{2.5}$ – particulate less than 2.5 microns; known as fine particulate
- PM_1 – particulate less than 1 micron; known as ultrafine particulate

In general, $PM_{2.5}$ and smaller tend to be more closely associated with anthropogenic activities such as combustion, whereas $PM_{10-2.5}$ can have a substantial natural source component. The primary anthropogenic sources of PM in the Mount Maunganui Airshed are industry, shipping and port activities (including cargo and bulk solid materials storage and handling) and transport. BOPRC has concluded that natural sources, such as marine sea salt, can also be significant on occasion.[5]

Different sizes of PM can result in different health effects. This is because they deposit in different parts of the respiratory tract, they have diverse sources, and they can interact through different biological mechanisms (WHO, 2013). In general, the smaller a particle is, the farther into the respiratory tract it can penetrate to interact and cause adverse health effects.

[3] 2018 Census employed statistical areas (SA) and did not employ census area units (CAU) so a direct comparison cannot be made. Estimate of around 10,000 comprises SA2 (Mount Maunganui Central), SA1 – 7013954 and SA1 – 7013955 main means of travel to work (2)(4)(7), by workplace address (12) for the employed census usually resident population count aged 15 years and over (5).
[4] For the year 2019. ESR, (2023).
[5] In 2022, BOPRC concluded that an exceedance of the national environmental standard for PM_{10} in the Mount Maunganui Airshed was due to marine aerosols.

There is scientific consensus that exposure to particulate pollution causes predominantly respiratory and cardiovascular effects, ranging from subclinical functional changes (e.g. reduced lung function) to symptoms (increased cough, exacerbated asthma) and impaired activities (e.g. school or work absenteeism) through to doctors' or emergency room visits, hospital admissions and death (WHO, 2006). The effects, in terms of escalating severity, are described as increased visits to doctors for many individuals, hospital admission for some individuals and death for a few individuals. People with pre-existing heart or lung disease, young children, and the elderly, are most likely to suffer adverse health effects. The exposure-response relationship is essentially linear and there is no 'safe' threshold; adverse health effects are observed at all measured levels (USEPA 2020; WHO 2013, WHO, 2021).

In 2013, the International Agency for Research on Cancer (IARC) classified particulate matter (as a component of outdoor pollution) as carcinogenic based on an increased risk of lung cancer (IARC, 2013). Additional research further indicates particulate matter is associated with atherosclerosis, adverse birth outcomes, and childhood respiratory disease (WHO, 2013) as well as Alzheimer's disease and other neurological endpoints, cognitive impairment, diabetes, systemic inflammation and aging (WHO, 2016).

More recently, WHO has concluded that chronic exposure to PM is causal, or likely to be causal, for (WHO, 2021):

- All-cause mortality
- Cardiovascular mortality (all, cerebrovascular, ischaemic heart disease)
- Respiratory mortality (any, chronic obstructive pulmonary disease, acute lower respiratory infections)
- Lung cancer

1.1.2 Sulphur dioxide

Sulphur dioxide arises naturally from volcanic sources, with White Island being New Zealand's largest source of sulphur dioxide (PAE, 2009). The main sources of sulphur dioxide in Mount Maunganui are shipping and industry. Away from industrial and volcanic sources, background levels of sulphur dioxide in New Zealand are typically very low, less than 5 µg/m^3 as a one-hour average.

Sulphur dioxide can cause respiratory problems, such as bronchitis, and it can irritate the nose, throat and lungs. This is because inhaled sulphur dioxide readily reacts with the moisture of mucous membranes to form sulphurous acid (which is a severe irritant). It may cause coughing, wheezing, phlegm and asthma attacks (MfE, 2014). The speed with which people show health effects from exposure to SO_2 necessitates a focus on acute exposure.

Studies have shown that asthmatics and people with lung disease are particularly sensitive to sulphur dioxide. Children may also be more sensitive to the effects of sulphur dioxide due to their relatively higher respiration rate and smaller body mass.

In 2021, WHO published two systematic reviews and meta-analyses on the effects of short-term exposure to ambient sulphur dioxide (SO_2). Orellano *et al.,*2021 found that short term increases in SO_2 increased the risk of all-cause mortality (daily SO_2) and respiratory mortality (1-hour SO_2) with a high certainty of evidence. In general, concentration response functions showed linear behaviour with no thresholds. Orellano *et al.,*2021 considered that the epidemiological evidence supported a causal relationship. Zheng *et al.,*2021 found that short term increases in SO_2 correlated with increased risk of asthma-associated emergency room visits and hospital admissions. Children and to a lesser extent the elderly are more susceptible. The positive correlation between daily SO_2 and asthma-associated emergency room visits and hospital admissions was judged as having a moderate certainty of evidence and warrants further investigation. SO_2 was not found to have a daily threshold of effects.

SO_2 is a precursor pollutant that contributes to the formation of $PM_{2.5}$.

1.1.3 Nitrogen dioxide

Nitrogen dioxide (NO_2) is a reddish brown coloured acidic gas with a characteristic pungent odour. In New Zealand generally the main source of nitrogen dioxide is motor vehicles. In Mount Maunganui, ships and industry are also likely to be significant sources of nitrogen dioxide.

Long-term exposure to NO_2 increases the risk of premature death (mortality) and respiratory illnesses (morbidity) (WHO, 2021). Epidemiolocal studies have also shown that symptoms of bronchitis in asthmatic children increase with long-term exposure to NO_2. Reduced lung function is also linked to measured levels of NO_2 within cities of Europe and North America (WHO, 2006). Recent evidence suggests exposure may increase the risk of premature death and trigger heart attacks (USEPA, 2016).

Short-term exposure to high concentrations of nitrogen dioxide (NO_2) causes significant inflammation of the airways and respiratory problems and can also trigger asthma attacks (WHO, 2021).

NO_2 is both a primary and secondary pollutant i.e., it is both emitted directly and is created from other pollutants (for example, oxides of nitrogen) downwind. NO_2 is also a precursor pollutant that contributes to the formation of $PM_{2.5}$.

1.2 STANDARDS AND GUIDELINES

This report reviews available ambient air quality monitoring data on PM_{10}, $PM_{2.5}$, SO_2 and NO_2 from the Mount Maunganui Airshed for Toi Te Ora Public Health. Comparison is made with the ambient air quality standards in the NESAQ, specifically the short-term national environmental standards for PM_{10}, SO_2 and NO_2.

New Zealand has no *long-term* national environmental standards. This is unfortunate because the World Health Organisation (WHO) suggests, and the epidemiological evidence supports, greater priority should be placed on long-term AQG and/or standards as long-term exposure to pollutants has more significant health consequences (WHO 2021).

To address this gap, this review compares long-term monitoring data with global air quality guidelines published by the World Health Organisation (WHO, 2021). Whilst the WHO AQG have no regulatory status in New Zealand, they do offer evidence-informed recommendations on air quality levels that pose important risks to public health. WHO (2021) allows for 3 – 4 exceedances of daily guidelines in a year to account for unusual meteorology.

The WHO air quality guidelines (AQG) are based on the lowest long-term exposures that are, with at least moderate certainty, associated with adverse health effects and represent the most up to date science. It is important to note that the WHO approach to setting guidelines does not identify safe levels and is not based on a defined level of acceptable risk (i.e., the guidelines are not “no adverse effect levels”). Regional councils and Waka Kotahi have adopted the WHO AQG for reporting purposes (see for example, Land Air Water Aoetearoa and Waka Kotahi, 2023).

Where relevant, reference is also made to New Zealand air quality guidelines for annual PM_{10} and daily SO_2 (MfE 2002) noting that these guidelines are now somewhat dated. Reference is also made to the 10-minute and daily WHO AQG for SO_2 as these specifically address documented acute elevation of risk over timescales of minutes (WHO, 2000) to one or a few days (WHO, 2021).

Table 1, which follows, presents air quality standards and health-based guidelines referenced in this report.

TABLE 1: Ambient air quality standards and guidelines for PM_{10}, $PM_{2.5}$, SO_2 and NO_2

Time Average / Jurisdiction (Year)	Standard / Guideline (µg/m³)	Permitted Exceedances per Year
PM_{10}		
Annual		
WHO (2021)	15	0
New Zealand (2002) [a]	20	0
24-hours		
WHO (2021)	45	3 – 4
New Zealand (2004) [b]	**50**	**1**
$PM_{2.5}$		
Annual		
WHO (2021)	5	0
24-hours		
WHO (2021)	15	3 – 4
SO_2		
24-hours		
WHO (2021)	40	3-4
New Zealand (2002) [a]	120	0
1-hour		
New Zealand (2004) [b]	**350**	**9**
	570	**0**
10-minutes		
WHO (2000)	500	0
NO_2		
Annual		
WHO (2021)	10	0
24-hour		
WHO (2021)	25	3-4
1-hour		
New Zealand (2004) [b]	**200**	**9**

[a] National ambient air quality guideline [b] **National environmental standard**

1.3 CONTEXT

1.3.1 COVID-19

In 2020 and 2021, in response to the COVID-19 pandemic, the New Zealand Government shut international borders and imposed national and regional lockdowns restricting travel and movement except for essential services. The lockdowns affecting Mount Maunganui were phased in through a series of alert levels as shown in Table 2.

Between April 2020 and December 2021, no passenger vessels visited the Port. On 3 December 2021, New Zealand moved to a traffic light COVID response system. Since this time there have been no social restrictions in the Mount Maunganui Airshed.

The social restrictions introduced to combat COVID-19 would have reduced manufacturing activity and associated vehicle movements in the Mount Maunganui Airshed resulting in reductions in particulate emissions and potentially some other pollutants, however, exact details are not known.

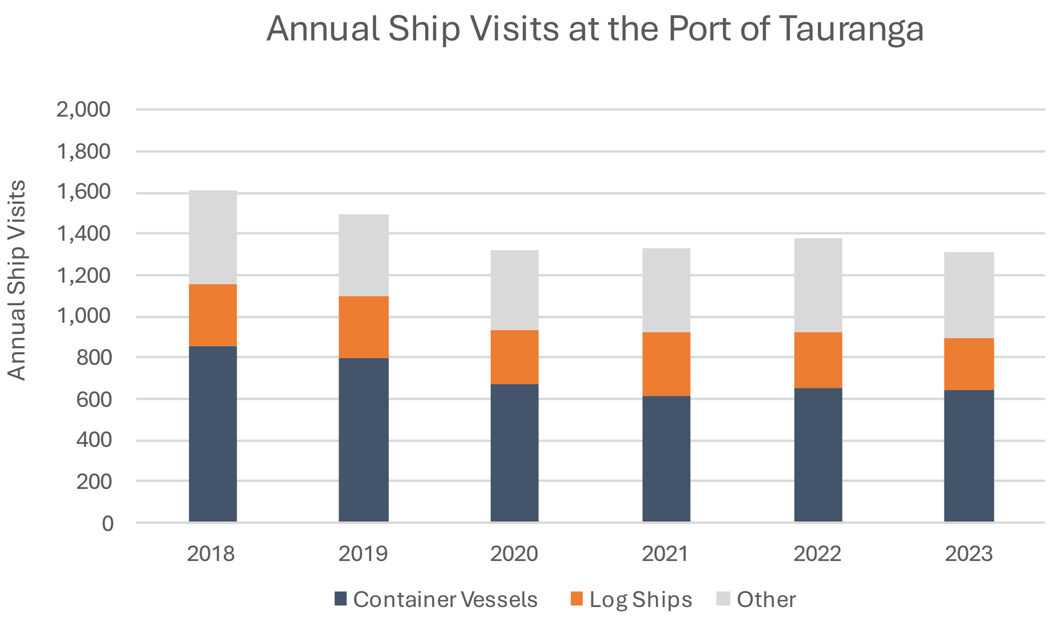
Figure 3 shows annual shipping for POTL for the years 2018 – 2023. This shows that the global pandemic reduced ship visits through the Port with total ship visits down by 19% in the three years ending 31 December 2022, compared with 2018 and 2019.[6] Shipping has yet to rebound to the high levels seen in 2018 and 2019.

TABLE 2: COVID-19 Alert Levels affecting Mount Maunganui Airshed in 2020 - 2021

DATE	LEVEL	DURATION (DAYS)	DETAILS
23 Mar 2020	3	3	Schools shut. Essential activities & construction work only.
26 Mar 2020	4	33	Everything shut except essential activities*
28 Apr 2020	3	16	Schools shut. Essential activities & construction work only.
18 Aug 2021	4	14	Everything shut except essential activities*
1 Sep 2021	3	7	Schools shut. Essential activities & construction work only.
2020 - 2021		47	Days at Alert Level 4
		73	Days at Alert Level 3 & 4

*NB: The Port of Tauranga, an essential activity, remained open at all times

FIGURE 3: Total ship visits to the Port of Tauranga: 2018 – 2023. [Source: POTL]



[6] Difference calculated from average total ship visits in 2018 and 2019 compared with the average total ship visits in 2020, 2021 and 2022.

1.3.2 MARPOL Annex VI

On 1 January 2020 new shipping regulations came into force, which require all ships flagged to states that have ratified Annex VI of the MARPOL treaty to burn low sulphur fuel or implement abatement technology to reduce emissions of SO_2 and NO_2. SO_2 and NO_2 are precursor pollutants that contribute to the formation of $PM_{2.5}$ in the atmosphere. New Zealand ratified the treaty in 2022.

Most, if not all, ships visiting the Port of Tauranga are flagged to states other than New Zealand. This means the implementation of Annex VI on 1 January 2020 is likely to have impacted on ambient levels of key contaminants in the Mount Maunganui Airshed from that date.

1.4 BOPRC MONITORING NETWORK

This section overviews BOPRC's reference monitoring for ambient air quality in the Mount Maunganui area. Reference monitoring refers to monitoring in accordance with Schedule 2 of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NESAQ). Data from these monitors will typically be of a high standard and can be relied upon to inform assessment of the public health impacts of air pollution.

BOPRC commenced monitoring in the Mount Maunganui area for sulphur dioxide (SO_2) at Totara Street in January 2005 (refer Figure 1).

In September 2015, following public health complaints, BOPRC commenced monitoring for SO_2 at Whareroa Marae. This monitoring showed that ambient levels of SO_2 breached the upper limit national environmental standard for SO_2 (Figure 4) and frequently exceeded WHO air quality guidelines by a significant margin (refer Figure 5).

Some of the SO_2 exceedances were attributed to emissions from a fertiliser manufacturer (Ballance Agri-Nutrients Ltd) located adjacent and to the north of Whareroa Marae as shown in Figure 2. Successful regulatory action by BOPRC resulted in:

- Ballance Agri-Nutrients Limited being convicted and fined $60,000 for discharges of SO_2 in May 2014; and
- Ballance Agri-Nutrients Limited being convicted and fined $82,500 for discharges of SO_2 in May 2017.

Successive improvements in mitigation by Ballance Agri-Nutrients Ltd resulted in significant reductions in short-term concentrations of SO_2 measured at Whareroa Marae after 2016.

In late 2018, BOPRC commenced monitoring for PM_{10} at seven locations, including Totara Street and Whareroa Marae (Figure 1). BOPRC also commenced monitoring for $PM_{2.5}$ at Totara Street (only). On 31 October 2019, BOPRC gazetted the Mount Maunganui Airshed (MMA), which was deemed to be polluted for the purposes of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NESAQ).[7]

[7] Regulation 17(4) of the NESAQ provides that an airshed is polluted if there is, on average, more than one exceedance of the ambient standard for PM_{10} in any 12-month period. (Schedule 1 of the NESAQ permits one exceedance of the ambient standard in any 12-month period).

FIGURE 4: (Historical) hourly levels of sulphur dioxide (µg/m^3) measured at Whareroa Marae between 26 Sept 2015 and 24 May 2016. [Source: BOPRC]

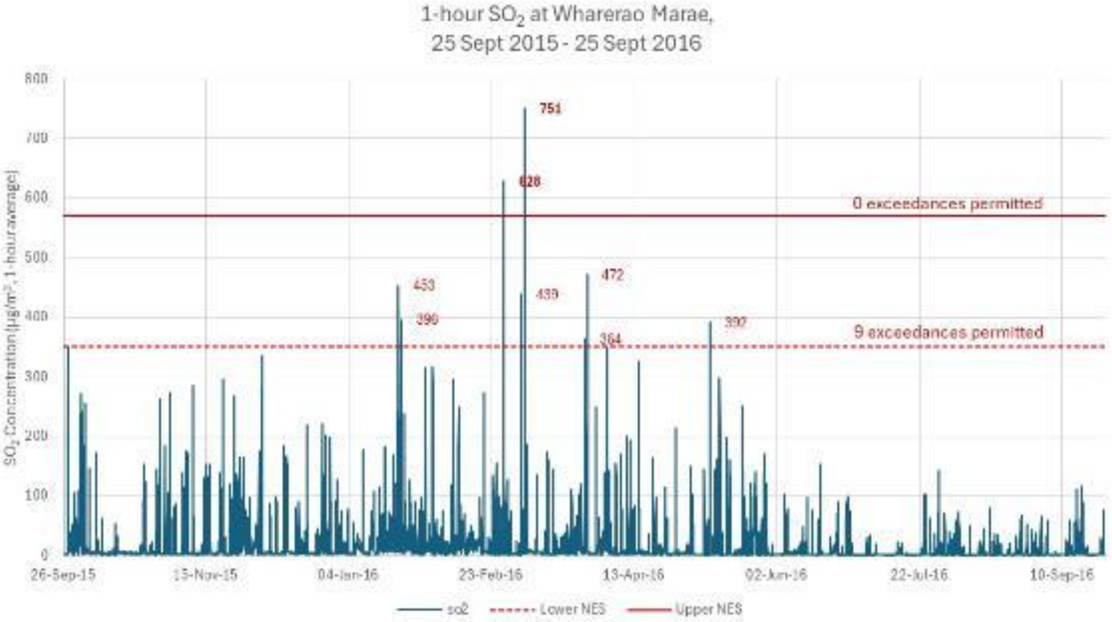
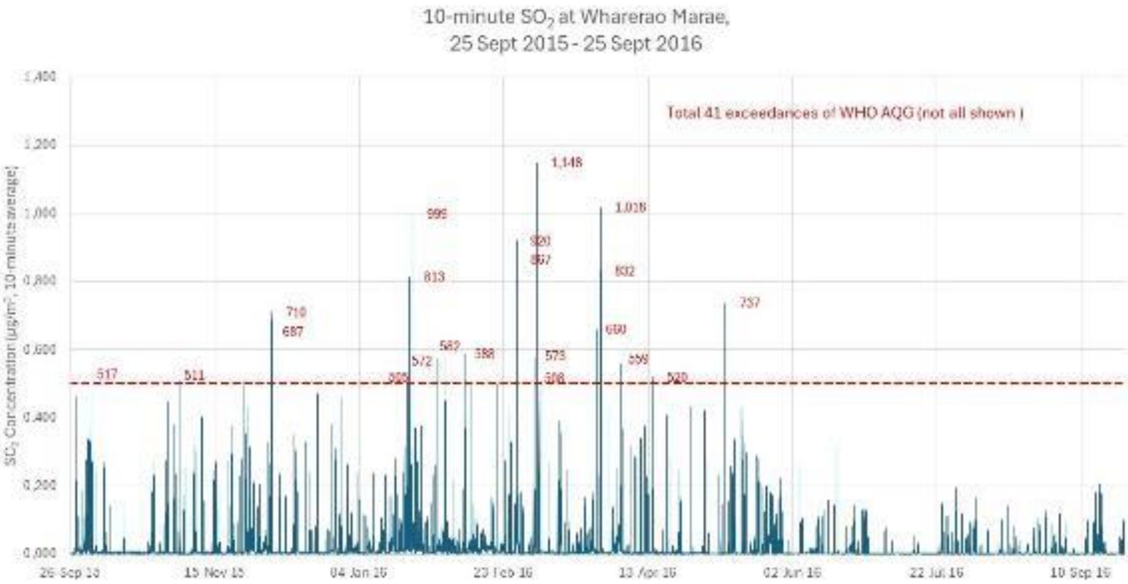


FIGURE 5: (Historical) 10- minute levels of sulphur dioxide (µg/m^3) measured at Whareroa Marae between 25 Sep 2015 and 25 Sep 2016. [Source: BOPRC]



In 2023, BOPRC made the following changes to their monitoring network:

- monitoring sites at Sulphur Point, De Havilland Way and Rail Yard South were decommissioned.
- the PM_{10} monitoring instrument was removed from the Totara Street monitoring site and deployed at Totara Street Rail Crossing.
- the $PM_{2.5}$ monitoring instrument was removed from the Totara Street monitoring site and deployed at Whareroa Marae.
- a new monitoring site was established at Ranch Road in Mount Maunganui with instruments for PM_{10}, $PM_{2.5}$. This is the first monitoring site completely outside the MMA in an entirely residential location.

BOPRC's rationale for these changes is explained in Appendix A.

Table 3 presents an overview of all BOPRC 'reference' ambient air quality monitoring (operated by Watercare Limited) undertaken at the locations in Figure 1.

TABLE 3: BOPRC reference monitoring sites for PM_{10}, $PM_{2.5}$, SO_2 and NO_2

Site	Pollutant	Monitoring	Location Type
Otumoetai			
	PM_{10}	Dec 1997 –	Residential
Tauranga Bridge Marina			
	PM_{10}	Aug 2018 –	Commercial / Industrial / Residential
	SO_2	Apr 2016 –	
Whareroa Marae			
	NO_2	Aug 2023 –	Commercial / Industrial / Residential
	$PM_{2.5}$	Aug 2023 –	
	PM_{10}	Aug 2018 –	
	SO_2	Sep 2015 –	
Ranch Road			
	PM_{10}	Feb 2024 –	Residential
	NO_2	TBA (2024 –) [a]	
	SO_2	TBA (2024 –) [a]	
Rata St			
	$PM_{2.5}$	TBA (2024 –) [a]	Commercial / Industrial / Residential
	PM_{10}	Dec 2018 –	
	SO_2	Dec 2018 –	
Totara St Rail Crossing			
	PM_{10}	Jan 2024 –	Industrial
	SO_2	Jan 2024 –	
Totara St			
	$PM_{2.5}$ [b]	*Aug 2018 – Jul 2023*	Industrial
	PM_{10} [b]	*Aug 2018 – Jul 2023*	
	SO_2	Mar 2006 –	
Sulphur Point [b]			
	PM_{10} [b]	*Aug 2018 – Jul 2023*	*Commercial / Industrial / Residential*
	SO_2 [b]	*Aug 2018 – Jul 2023*	
De Havilland Way			
	PM_{10} [b]	*Oct 2018 – Jul 2023*	*Commercial / Industrial / Residential*
Rail Yard South			
	PM_{10} [b]	*Oct 2018 – Jan 2023*	*Industrial*
	SO_2 [b]	*Oct 2018 – Jan 2023*	

[a] Personal comms. S Iremonger, BOPRC. 20 Aug 2024. [b] *Monitors and/or site have been decommissioned.*

1.5 REPORT LAYOUT AND METHODOLOGY

Summary ambient air quality monitoring data are tabulated in Appendix B. Additional graphs of monitoring data are provided in Appendix C.

The following sections review air quality against standards and guidelines and discuss trends apparent in the available monitoring data. Data are presented by pollutant for the Mount Maunganui Airshed first, and then by monitoring location (west to east, north to south).

Smoothed trend and 95% confidence intervals have been calculated using the OpenAir library in R statistical computing platform. The smooth line is essentially determined using Generalized Additive Modelling using the mgcv package (Wood 2006).

Theil-Sen estimates have been prepared using the OpenAir library in R. The Theil–Sen estimator is a method for robustly fitting a line to sample points in the plane (simple linear regression) by choosing the median of the slopes of all lines through pairs of points. The advantage of the using the Theil-Sen estimator is that it tends to yield accurate confidence intervals even with non-normal data and heteroscedasticity (non-constant error variance). It is also resistant to outliers — both characteristics can be important in air pollution.

Because seasonal effects can be important for air pollution, data were deseasonalised first using the stl function (seasonal trend decomposition using loess) as recommended by Carslaw (2019).

All data are quality assured from BOPRC. Please note:

- All data exclude exceptional events approved by the Minister for the Environment.[8] Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable using techniques that regional councils may implement in order to attain and maintain the NES for PM_{10}. Appendix B provides further details on each event.
- Tabulated exceedances for the Mount Maunganui Airshed do not (double) count exceedances that occur at the same time at multiple locations. For example, an exceedance of the daily NES for PM_{10} that occurs at two monitoring stations on the same day is only one exceedance for the airshed. Appendix C tabulates exceedances for each site individually.[9]
- Tabulated data include 99th percentile values for each pollutant for each time average. This is the value below which 99% of the data lies. When presented as an airshed value, this is the value calculated for all monitoring data at all sites in the airshed.

For example, Table 4 shows the 99th percentile daily concentration of PM_{10} was 49 µg/m^3 for the Mount Maunganui Airshed in 2019. This means that 99% of the time in 2019 (361 out of 365 days), daily concentrations of PM_{10} were below 49 µg/m^3 at all seven sites monitoring PM_{10} in the Mount Maunganui Airshed.

[8] https://environment.govt.nz/acts-and-regulations/regulations/national-environmental-standards-for-air-quality/applying-to-have-a-breach-of-an-air-quality-standard-excluded/
[9] To be clear, exceedances of a national environmental standard for more than one pollutant (e.g. exceedance of a standard for PM_{10} and an exceedance of a standard for SO_2) would be treated separately (this has not occurred to date).

1.5.1 Monitoring data – inclusions and exclusions

This report reviews and discusses available, quality-assured ambient air quality monitoring data for PM_{10}, $PM_{2.5}$, SO_2 and NO_2. Relevant meteorological parameters (wind speed, wind direction) are also included. BOPRC also measured rainfall but data are not quality assured or available publicly. This review references rainfall data from Tauranga Airport.

BOPRC also measures total suspended particulate (TSP). There are no health-based ambient criteria for TSP as it is primarily an indicator of dust nuisance. However, the long-term TSP data can provide useful context for trend analysis, especially when correlated with other pollutants such as PM_{10}. These aspects of TSP (only) are discussed.

BOPRC carried out monitoring for hydrogen sulphide (H_2S) at Whareroa Marae between September 2015 and October 2020, after which time, BOPRC switched to monitoring total reduced sulphur (TRS) compounds. There are no health-based ambient criteria for TRS compounds and so this monitoring is excluded from this review. An air pollution health risk assessment for Mount Maunganui (ESR 2023b) reported that, during all years of monitoring, hydrogen sulphide regularly exceeded ambient criteria set to protect against offensive and objectionable odour. No additional analysis is possible in the absence of any data on H_2S.

BOPRC previously undertook ambient monitoring of hydrogen fluoride (HF) at Whareroa Marae, however, due to instrument failure there are insufficient data to assess current levels. This monitoring is excluded from this review.

There are other pollutants with harmful effects on health that may be present in the Mount Maunganui Airshed at elevated concentrations. These include toxic pollutants such as benzene and polycyclic aromatic hydrocarbons. These cannot be reviewed because there are no robust ambient air quality monitoring data available.

Methyl bromide (associated with fumigation of logs at the port) was also excluded from this review.

2. METEOROLOGY

Mount Maunganui lies in the rain shadow of the Kaimai Mamaku ranges to the west and south. Consequently, day-to-day variations of weather are largely determined by the direction of the wind and most of the rainfall is received during periods of onshore north to northeast winds (Chappell, 2013).[10]

Being on the coast, Mount Maunganui experiences regular afternoon sea breezes in the summer. BOPRC (2023) notes:

> *Given the general east west orientation of the open coastline within the Bay of Plenty, these onshore winds are from the northern quadrant. They typically develop in the late morning as thermal differences develop between the sea surface and the adjacent landmass. This phenomenon can result in often complex boundary layer wind patterns (and associated dispersion/dilution characteristics) which has been demonstrated in recent air dispersion modelling exercises.*

2.1 WIND DIRECTION

Figure 6 presents a wind rose prepared from all available 10-minute wind speed and wind direction data collected at Whareroa Marae between September 2015 and May 2024. Figure 7 presents the same data by season over the same period. These wind roses present winds *from* a specified direction (i.e. a west wind blows from west to east).

The data show a predominance of winds from the south-west quadrant in all seasons and in all years. Winds from the west, south-west, west south-west and south south-west combine to more than 40% of all winds. The other predominant wind is from the north-west (nearly 10%).

Figure 8 presents wind roses for each year (including partial years 2015 and 2024) for Whareroa Marae. This shows little inter-annual variability.

[10] NIWA, 2013.

FIGURE 6: Wind rose of 10-minute wind speed (m/s) and wind direction measured at Whareroa Marae: September 2015 – May 2024.

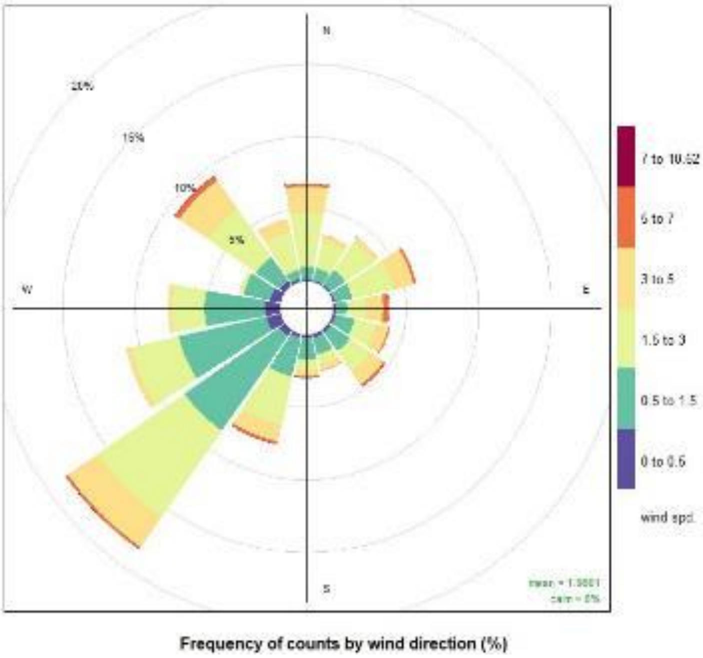


FIGURE 7: Seasonal wind roses of 10-minute wind speed (m/s) and wind direction measured at Whareroa Marae: September 2015 – May 2024.

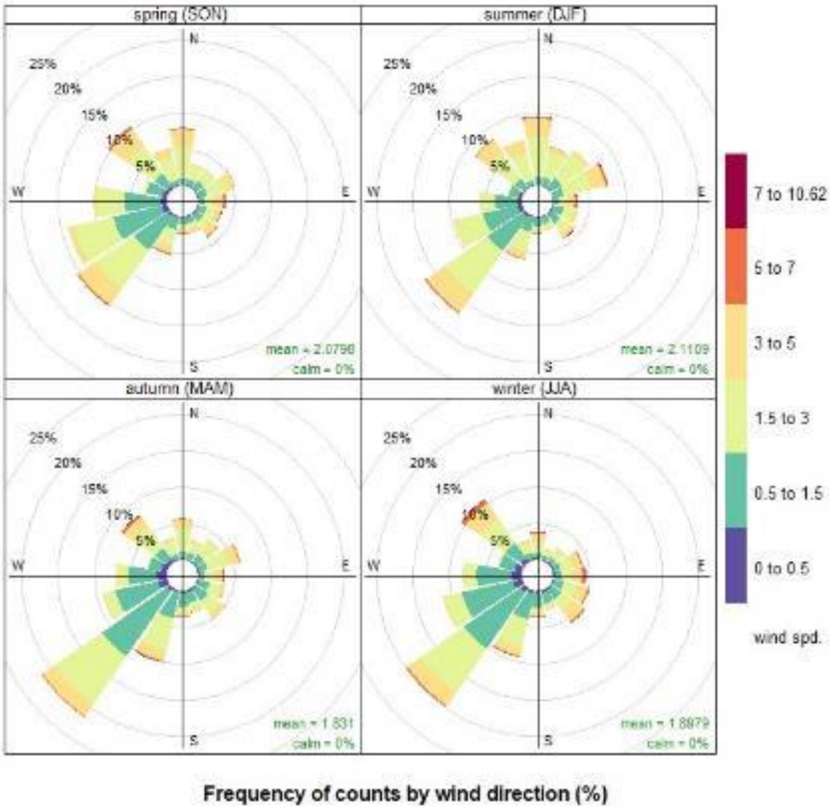
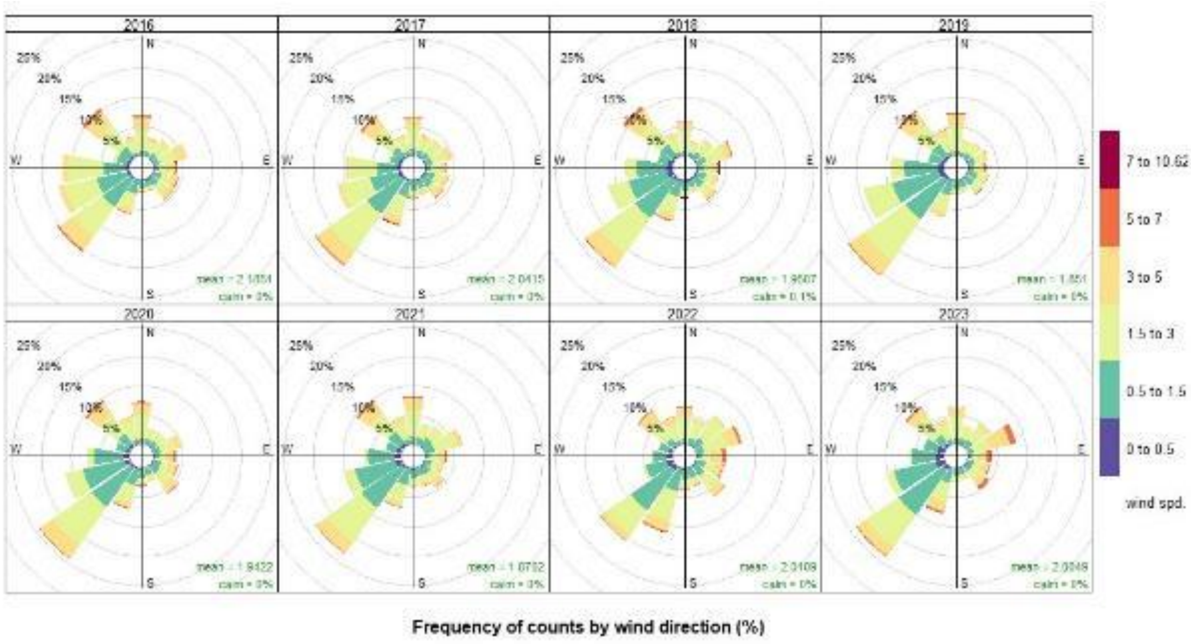


FIGURE 8: Annual wind roses of 10-minute wind speed (m/s) and wind direction measured at Whareroa Marae: 2016 – 2023.



2.2 WIND SPEED

Figure 9 presents a wind rose showing frequency of wind speeds and directions (from) measured at Tauranga Bridge Marina between April 2016 and May 2024.

Figure 10 presents a time variation plot of wind speeds (in m/s) measured at Whareroa Marae by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right).

Caution is needed when viewing the plots in Figure 10 as the y-axis is automatically generated to show variation, even when the variation is only slight. For example, the bottom right-hand plot appears to show a weekday/weekend split, however, the difference in windspeed is less than 0.04 m/s, which is not significant.

Figure 10 shows a highly consistent (normal) diurnal pattern, with wind speeds rising to a moderate to fresh breeze during daylight hours and reducing to a gentle breeze at night. Spring and summer are the windiest times of the year, with winter showing more settled conditions. MfE (2016) notes that dust deposits on paved surfaces can be thrown into the air by wind or by vehicle movements. Dust pick-up by wind is usually only significant at wind speeds above 5 metres per second (10 knots), but vehicle re-entrainment can occur under any wind conditions.[11]

The data suggest the Whareroa Marae meteorological station receives slightly lower wind speeds than those measured at Tauranga Bridge Marina (compare Figure 9 with Figure 6). This likely reflects the buildings around the Whareroa Marae monitoring site location, and it being less exposed to coastal breezes than Tauranga Bridge Marina.

This is consistent with the exploration of the impacts of buildings and land use on localised wind fields in the MMA in BOPRC, (2023).

[11] Ministry for the Environment, 2016. *Good Practice Guide for Assessing and Managing Dust*. Wellington. November. [Online]

FIGURE 9: Windrose of 10-minute wind speed (m/s) and wind direction measured at Tauranga Bridge Marina: April 2016 – May 2024.

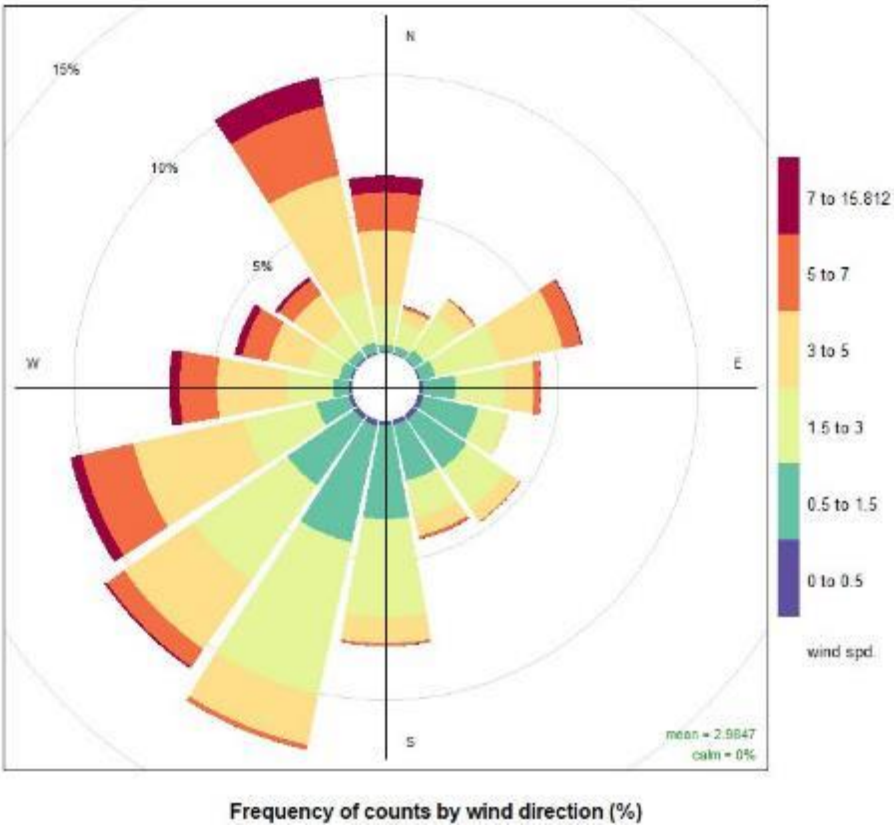
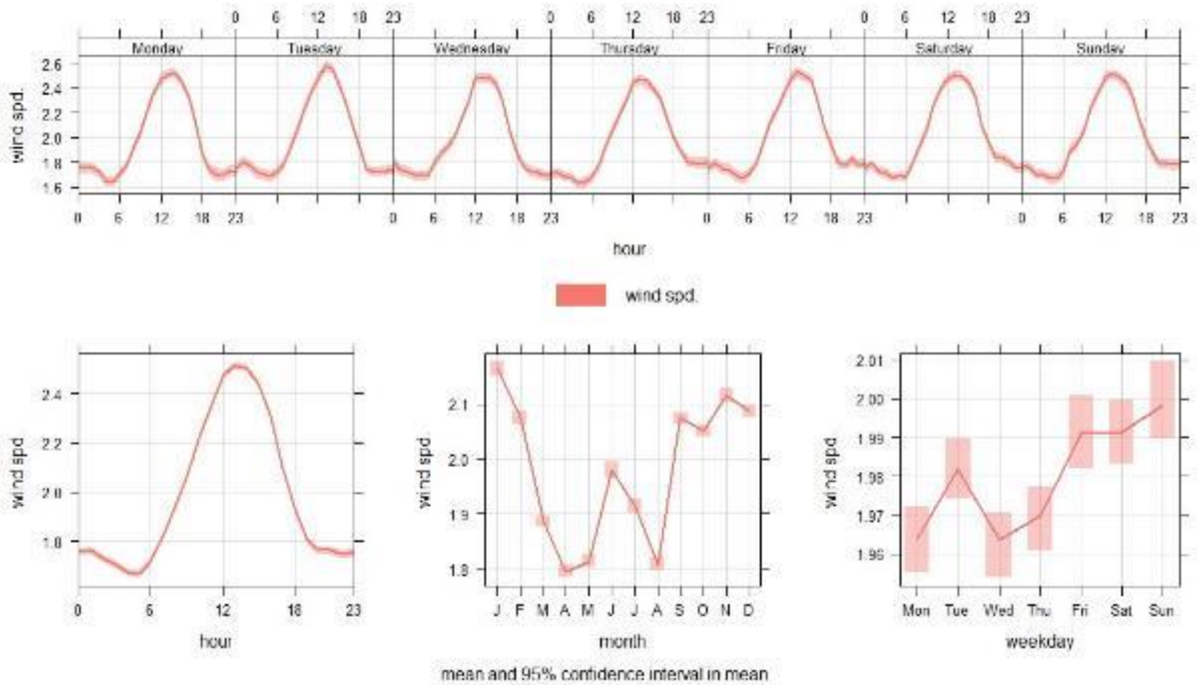


FIGURE 10: Mean wind speeds (m/s) with 95% confidence intervals measured at Whareroa Marae by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): August 2018 – May 2024.



2.3 RAIN

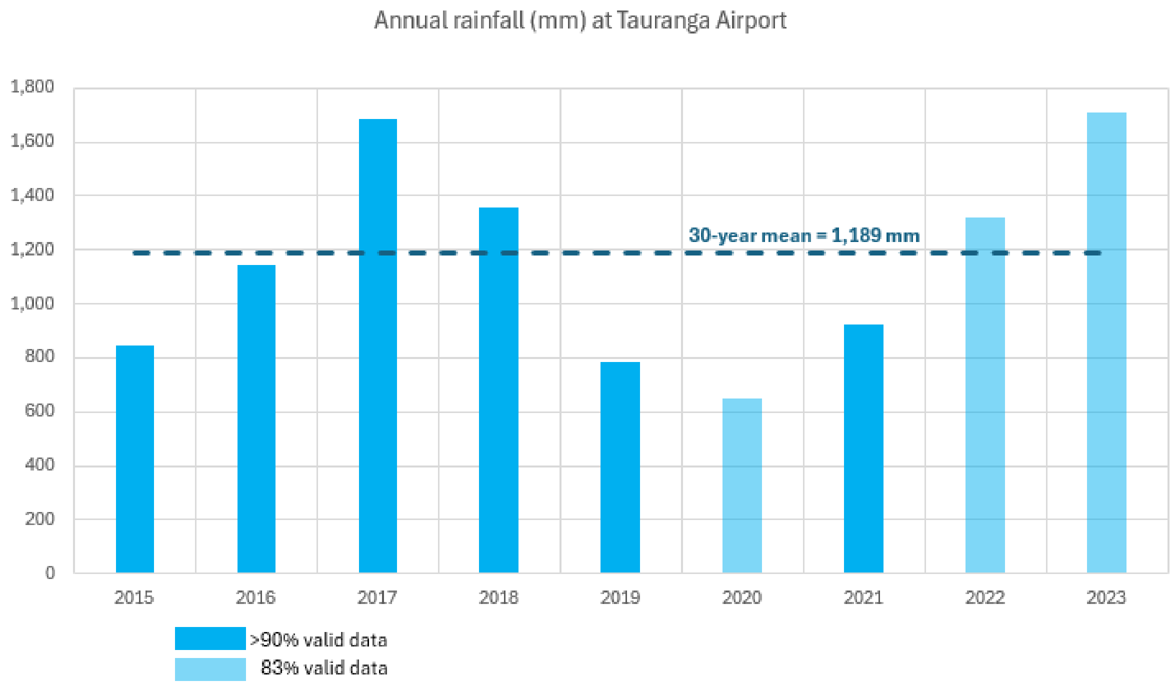
Rainfall is one of the primary mechanisms for removal of PM_{10}, although this can be less effective for finer ($PM_{2.5}$) fractions (Guo *et al.*, 2016). This occurs by precipitation scavenging in which the pollutant is removed via two modes (Rasmussen et al.,1975):

- The first is termed 'rainout' which involves absorption of gases in the cloud.
- The second is called 'washout'' which involves both absorption and particle capture by falling raindrops.

Rainfall is also important for SO_2 and NOx, both of which are subject to precipitation scavenging. SO_2 is also chemically reactive and readily soluble in water.

Figure 11 presents annual precipitation data collected at Tauranga Airport for the period 2015 - 2023.[12] This shows that, in contrast to some other years, 2017 – 18 and 2022 – 2023 were wetter than usual (Chappell, 2013). This will likely impact on both short-term and long-term levels of pollutants in those years.

FIGURE 11: Annual precipitation from Tauranga Airport: 2015 – 2023. [Source: CliFlo]



2.4 EL NIÑO – SOUTHERN OSCILLATION INDEX

As with the rest of New Zealand, the Bay of Plenty is subject to the El Niño - Southern Oscillation, the movement of warm equatorial water across the Pacific Ocean and the atmospheric response.

During a La Niña phase, north-easterly winds tend to become more common, bringing moist, rainy conditions to north-eastern areas of the North Island. Generally speaking, increased rainfall will help to reduce air pollution by precipitation scavenging.

[12] Data from the rain gauges at BOPRC monitoring sites are not quality assured.

During El Niño, New Zealand tends to experience stronger or more frequent winds from the west in summer, which can encourage dryness in eastern areas and more rain in the west. This will likely increase fugitive dusts in the Mount Maunganui Airshed. In winter, the winds tend to blow more from the south, causing colder temperatures across the country. In spring and autumn, south-westerly winds are more common.

Figure 12 presents an indicator of this, the Southern Oscillation Index (SOI) which measures changes in atmospheric pressures across the Pacific. This shows an El Niño phase from July 2015 to April 2016 and from 2020 to 2022, a La Niña phase has been experienced. It should be noted that this graph stops at the end of 2022. Since then, NIWA reports an El Niño phase for most of 2023 (Figure 13).

FIGURE 12: Historical overview - Southern Oscillation Index as a three-month rolling average from 1990 – 2022. [Source: StatsNZ]

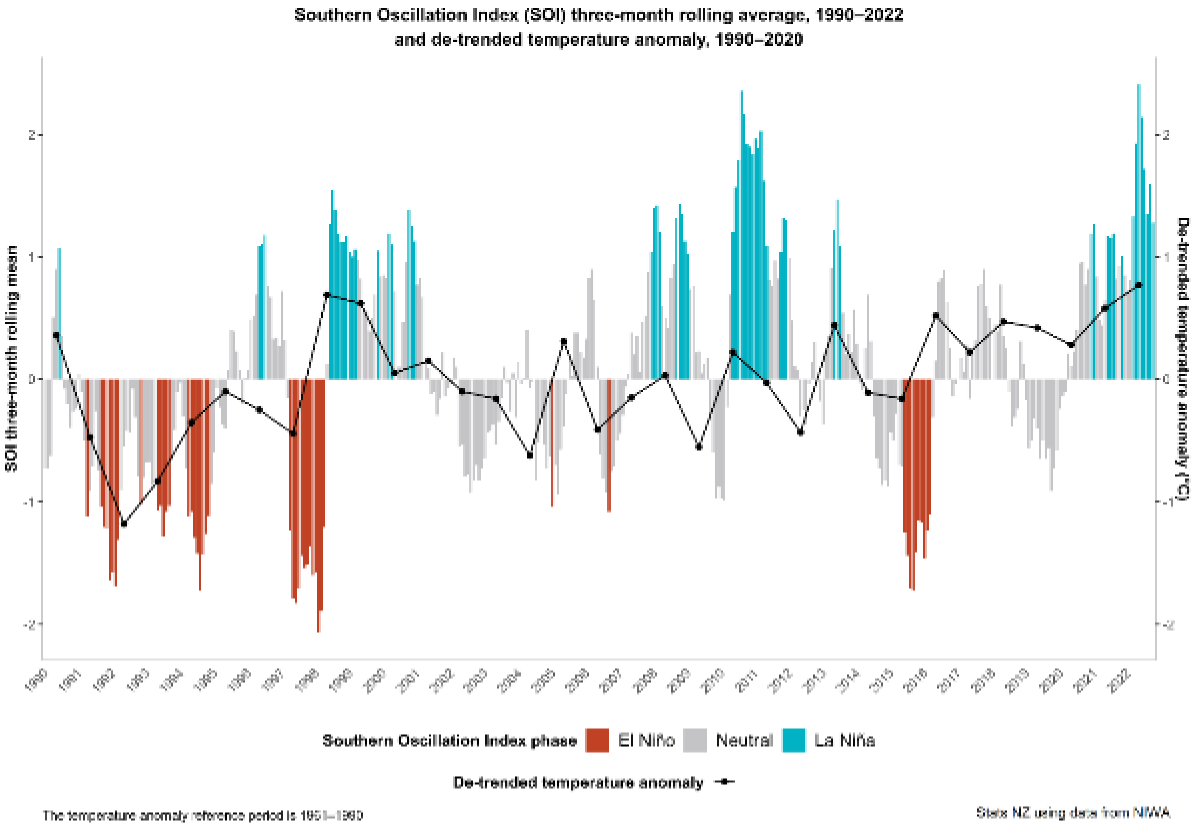
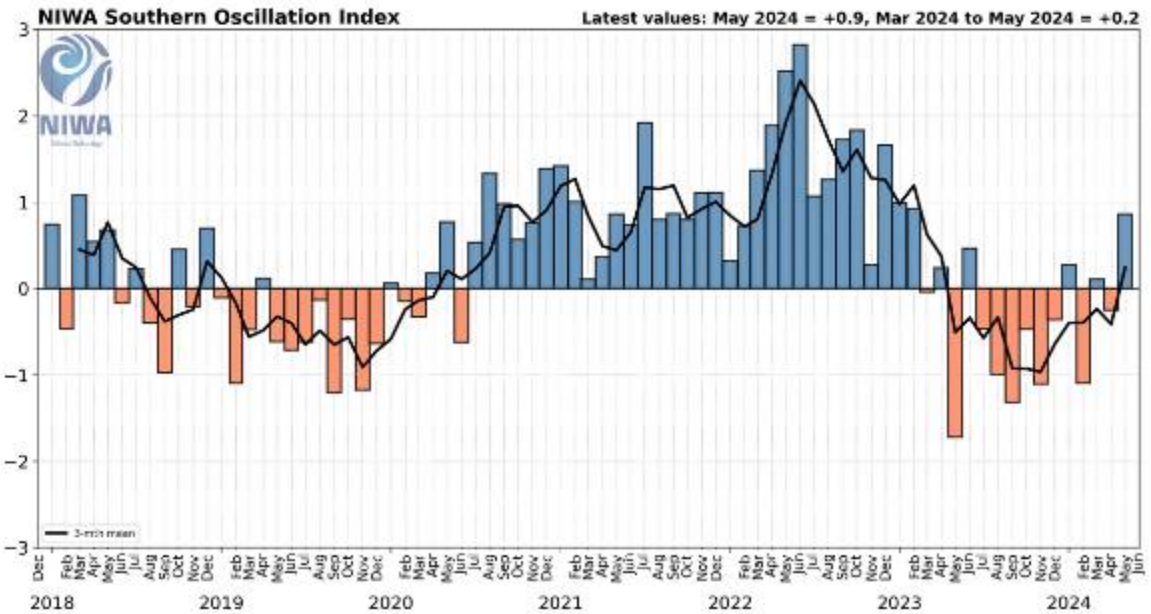


FIGURE 13: Recent trends - Southern Oscillation Index as a monthly value Dec 2017 – May 2024. [Source: NIWA]



3. PM_{10}

Tables B1 – B7 in Appendix B and Figures C1 – C10 in Appendix C provide summary PM_{10} statistics for all sites for 2019 through 2023 and for sites with partial years of monitoring in 2018 and 2024.

3.1 MOUNT MAUNGANUI AIRSHED

There were significant changes to BOPRC's monitoring network during 2023 (refer Appendix A):

- the Sulphur Point, Rail Yard South, De Havilland Way monitoring sites were decommissioned; and
- the PM_{10} monitor at Totara Street was moved to a new location (Totara Street Rail Crossing).

Table 4 provides summary PM_{10} statistics for all comparison with air quality standards and guidelines for all available monitoring data and locations.

TABLE 4: Mount Maunganui Airshed PM_{10} summary statistics: August 2018 – May 2024 [a]

Year	Maximum daily PM_{10} (µg/m³)	99th Percentile daily PM_{10} (µg/m³)	Exceedances per year NES (no.)	Exceedances per year WHO AQG (no.)	Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		[1 permitted]	[3-4 permitted]	[WHO AQG = 15]
Seven sites: Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, De Havilland Way, Rata St, Rail Yard South and Totara St					
2018 [b]	***62 [b]***	*44 [b]*	**3**	*4*	*- [b]*
2019	**70**	**49**	**19**	**37**	14 – **30**
2020	**115**	40	**7**	**13**	13 – **23**
2021	**52**	40	**2**	**6**	11 – **24**
2022	62	41	1	**10**	10 – **23**
Three sites: Tauranga Bridge Marina, Whareroa Marae and Rata St					
2023	**65**	42	**2**	**11**	8 – **20**
Four sites: Tauranga Bridge Marina, Whareroa Marae, Rata St, Totara Rail Crossing and Ranch Road [b]					
2024 [b]	***58 [b]***	*38 [b]*	***2 [b]***	*3 [b]*	*- [b]*

[a] Excluding approved exceptional events.
[b] *Partial data only with monitoring commencing or ceasing at different times in different locations (refer Table 1)*
Exceedance of national environmental standard in red. Exceedance of WHO guideline in blue.

Figure 14 (which follows) presents annual average concentrations of PM_{10} measured in the Mount Maunganui Airshed at all monitoring locations with a full year of data for the period 2019 – 2023. The World Health Organisation (WHO) suggests, and the epidemiological evidence supports, greater priority should be placed on long-term AQG and/or standards as these have more significant health consequences (WHO 2021).

FIGURE 14: Annual PM_{10} concentrations measured in the Mount Maunganui Airshed: 2019 – 2023.

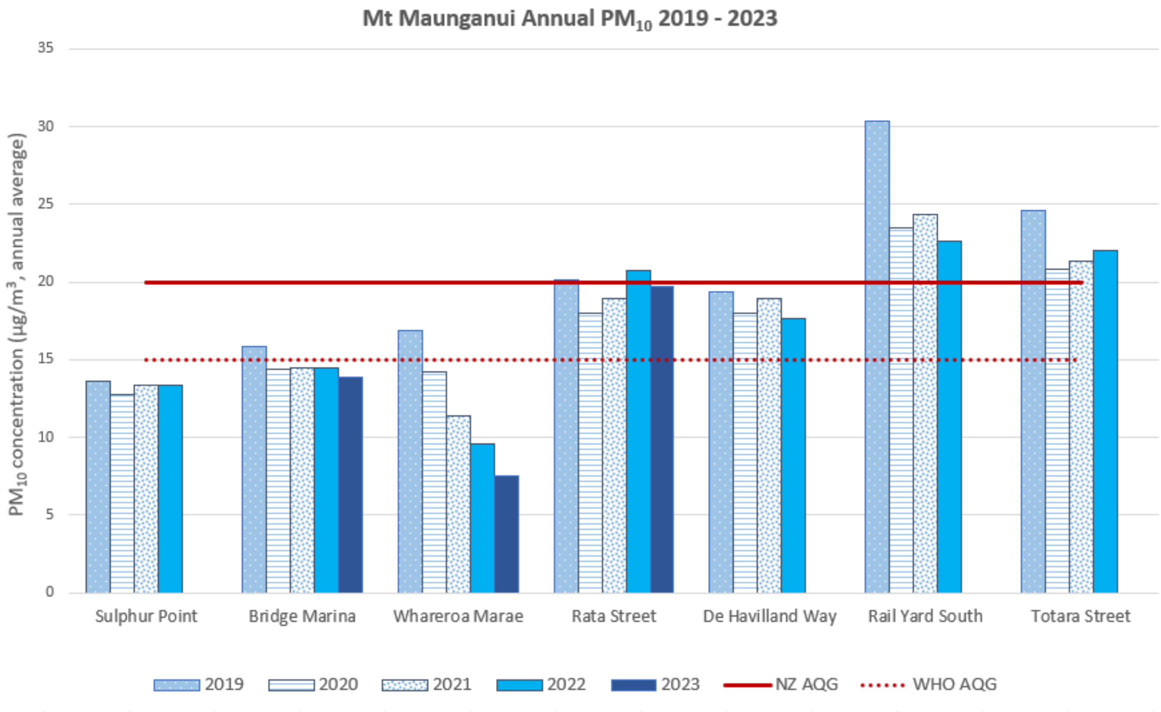


Figure 15 (which follows) presents the range of annual mean PM_{10} concentration for each monitoring location on a map during the period of monitoring.

The data show that Sulphur Point, Tauranga Bridge Marina and Whareroa Marae (all predominantly upwind of the airshed) met the New Zealand Ambient Air Quality Guideline (AQG) and, in more recent years, all met the WHO AQG. The remaining four monitoring locations consistently exceeded the WHO annual AQG and, except De Havilland Way, consistently exceeded the New Zealand annual AQG for PM_{10}.

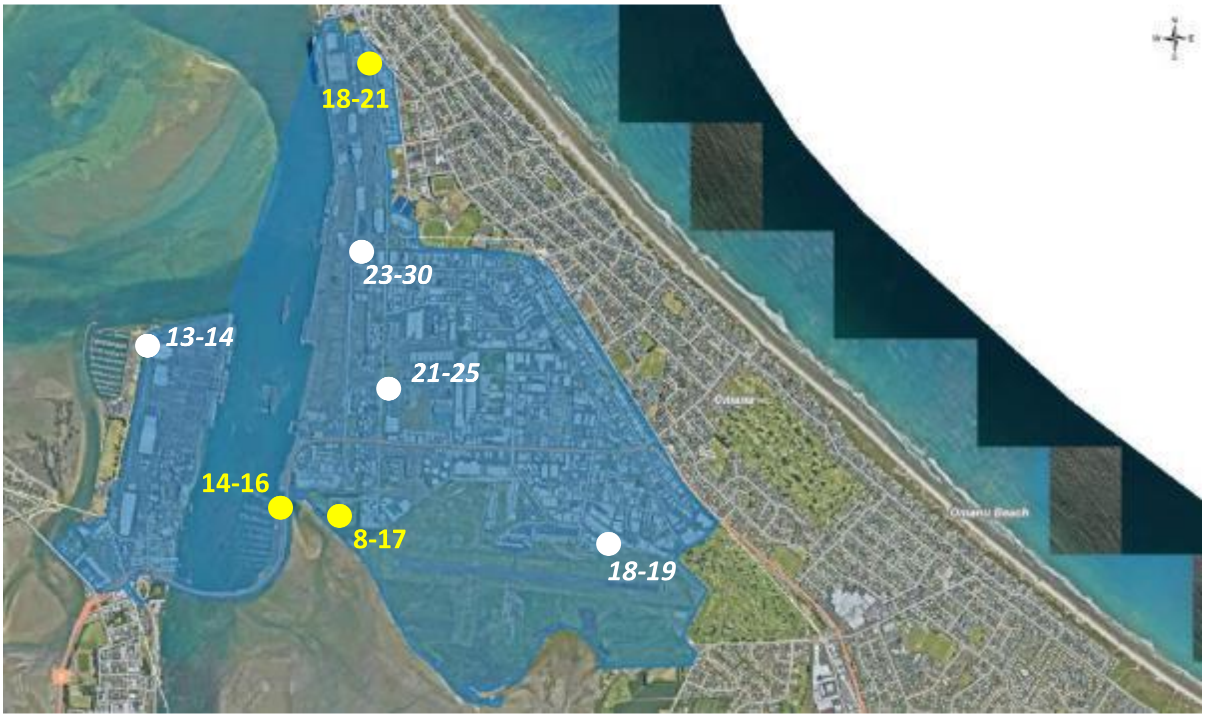
As noted in section 2:

- the years 2022 and the early part of 2023 were in a La Niña phase and wetter than average. This can influence (depress) maximum daily and annual concentrations of PM_{10} through the increased volume, timing and frequency of rainfall.
- the years 2019 and 2023 were in an El Niño phase which would see increased winds and dryness, with likely increased fugitive dust.

Typically, a period of 10 years of data is required to undertake robust trend analysis. However, Table 4 suggests some consistency in the 99th percentile daily PM_{10} concentration measured in the Mount Maunganui Airshed in the last four years (2020 – 2023).

The 99th percentile concentration is a helpful statistic for considering acute (i.e. daily) exposure to PM_{10}, being a more stable statistic for trend analysis than the maximum daily concentration as it excludes outlier maximum concentrations due to extraordinary meteorology. This consistency is notable given changes in annual rainfall and in the number and location of monitoring sites during this period.

FIGURE 15: Annual mean PM_{10} concentrations (µg/m^3, 2019 – 2022 white, 2019 – 2023 yellow) measured in the Mount Maunganui Airshed.



3.2 TAURANGA BRIDGE MARINA

Annual levels of PM_{10} for Tauranga Bridge Marina are presented in Figure 14 for the period 2019 – 2023. These have been reasonably consistent over the monitoring period and, except for 2019, consistently below the WHO AQG.

Figure 16 presents monthly concentrations of PM_{10} with a smoothed trend line and 95% confidence intervals for the period 2019 – 2023. There also shows little apparent change over the monitoring period August 2018 – May 2024.

Figure 17 presents a time series plot of daily concentrations of PM_{10} measured at Tauranga Bridge Marina for comparison with the national environmental standard and the WHO guideline for PM_{10}. Daily PM_{10} concentrations occasionally exceed the NES and WHO AQG but not more than the number of permitted exceedances.

FIGURE 16: Monthly PM_{10} concentrations (µg/m³) measured at Tauranga Bridge Marina with smoothed trend line and 95% confidence intervals for fit: August 2018 – May 2024.

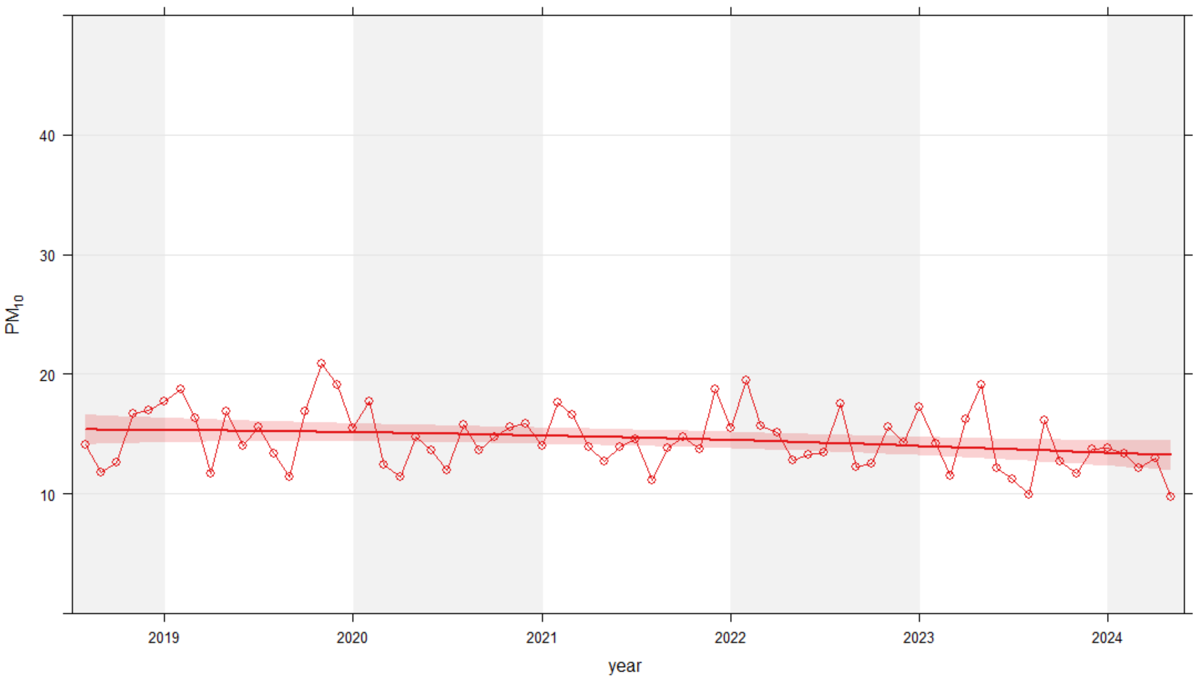
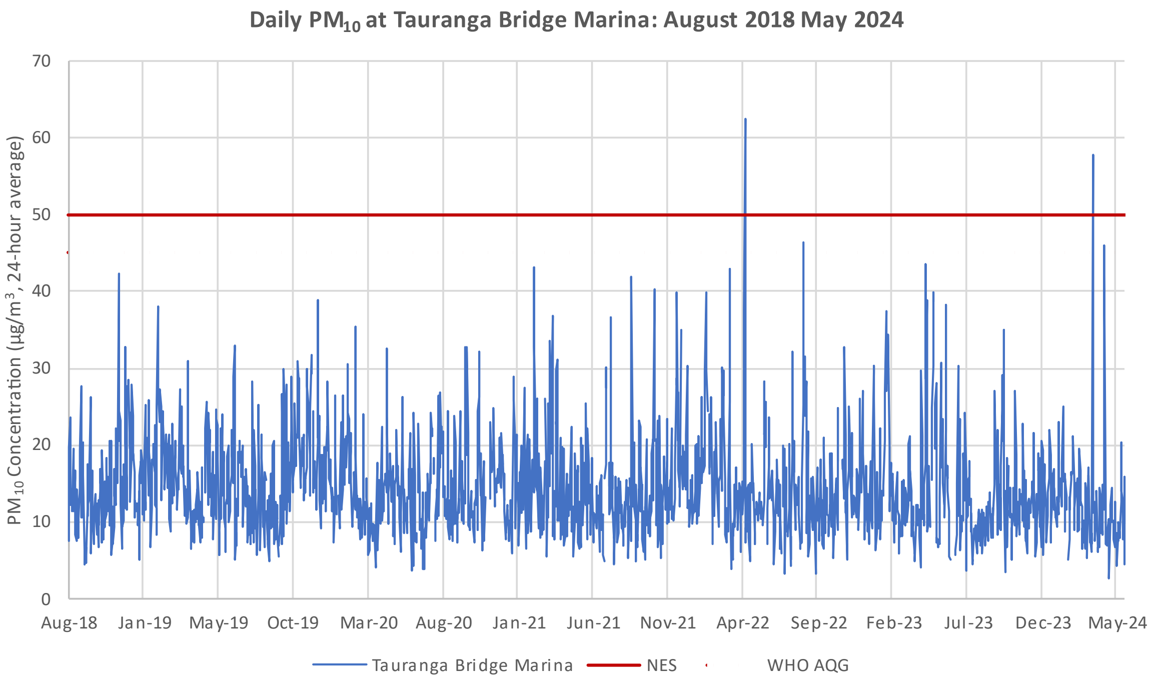


FIGURE 17: Time series plot of daily PM_{10} concentrations (µg/m³) measured at Tauranga Bridge Marina: August 2018 – May 2024.



3.3 WHAREROA MARAE

Whareroa Marae

Figure 18 presents annual PM_{10} measured at Whareroa Marae for the years 2019 – 2023 for comparison with the New Zealand (20 µg/m^3) and WHO (15 µg/m^3) AQG. Figure 18 also has a fitted trend line which shows a strong (reducing) linear correlation with year (R^2 = 0.99).[13]

Figure 19 presents monthly PM_{10} concentrations with a smoothed trend line and 95% confidence intervals for Whareroa Marae for the full monitoring record period of August 2018 – May 2024. Figure 20 presents the same data with a deseasonalised Theil-Sen trend estimate and 95% confidence intervals (refer section 1.6 for more information). Whilst typically 10 years of data are required to inform a trend analysis these both appear to show a significant decrease over the nearly six-year period.

Figure 21 presents a time series plot of daily concentrations of PM_{10} measured at Whareroa Marae between 2019 and May 2024 for comparison with the national environmental standard and the WHO guideline for PM_{10}. Since early 2021, daily levels of PM_{10} at Whareroa Marae have remained below relevant standards and guidelines. Current levels of daily and annual PM_{10} at Whareroa Marae are well below New Zealand and WHO guidelines.

The recent uptick in daily PM_{10} (Figure 21) and monthly PM_{10} (Figure 19 and 20) concentrations at Whareroa Marae evident in the summer of 2023-24 may be consistent with increased dust during an El Nino phase (Figure 13).

Figure 22 presents a time variation plot of hourly PM_{10} concentrations by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right), with 95% confidence intervals measured at Whareroa Marae for the years 2019 – 2023.

This shows that hourly PM_{10} concentrations are higher during weekdays than weekends, which is consistent with industrial emissions being higher during the working week. Monthly levels of PM_{10} appear highest in the spring and summer time and lowest during the wetter parts of the year (winter). This is consistent with rain in winter and autumn reducing daily concentrations of PM_{10} and higher soil moisture content. It is also quite different to wintertime PM_{10} concentrations in other parts of New Zealand which typically have elevated PM_{10} during winter due to solid fuel combustion for domestic fires (Kuschel et al., 2022).

[13] This means that 99% of the variance of the data is explained by the (dotted) straight line equation

FIGURE 18: Annual concentrations of PM_{10} (µg/m³) measured at Whareroa Marae: 2019 – 2023.

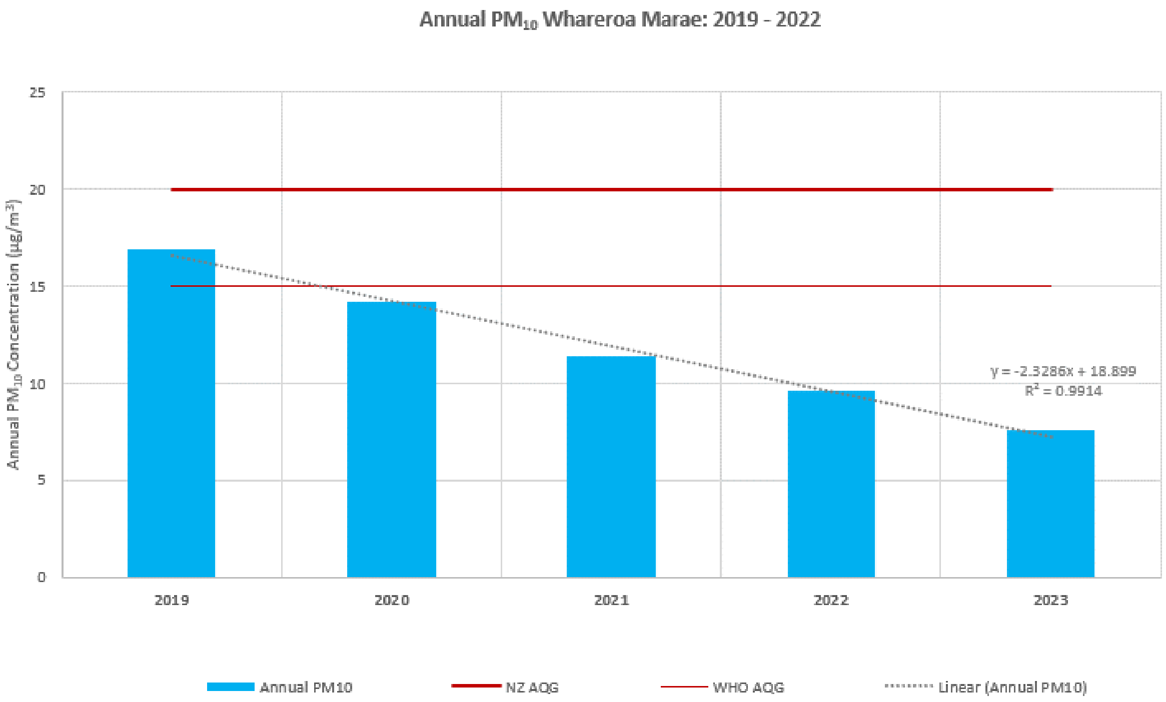


FIGURE 19: Monthly PM_{10} concentrations (µg/m³) measured at Whareroa Marae with smoothed trend line and 95% confidence intervals for fit: August 2018 – May 2024.

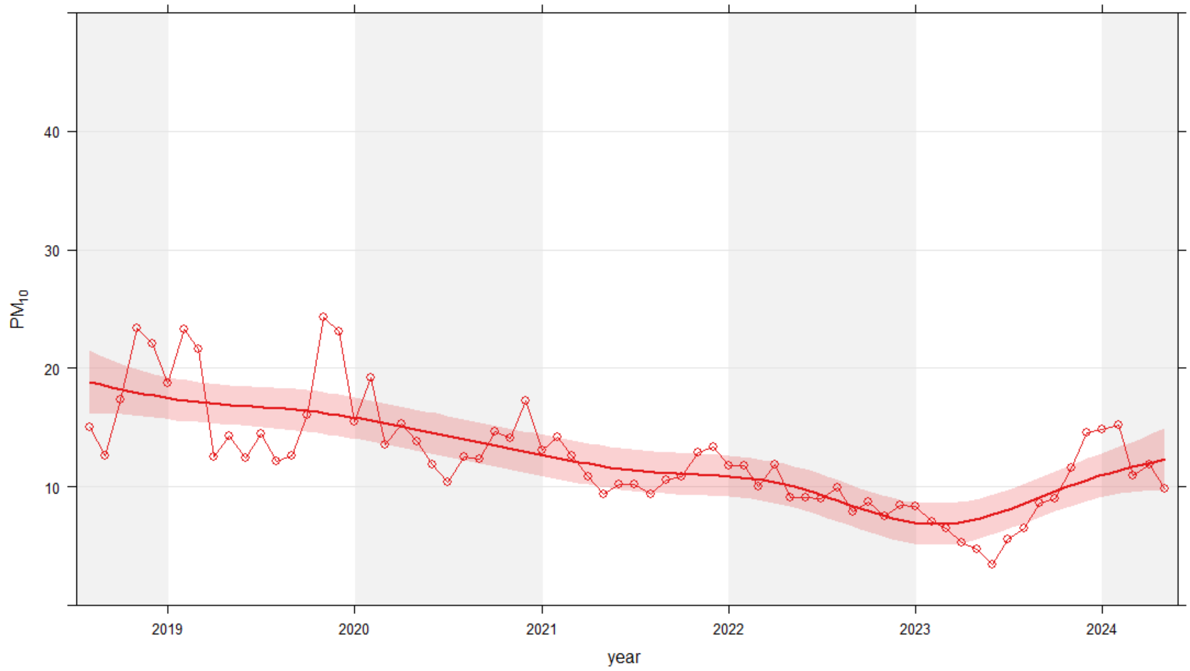


FIGURE 20: Monthly PM_{10} concentrations (µg/m^3) measured at Whareroa Marae with deseasonalised Theil Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods: August 2018 – May 2024. The overall trend is shown at the top as -2.09 (µg/m^3) per year and the 95% confidence intervals in the slope from -2.43 – -1.61 µg/m^3/year. The ∗ ∗ ∗ show that the trend is significant to the 0.001 level.

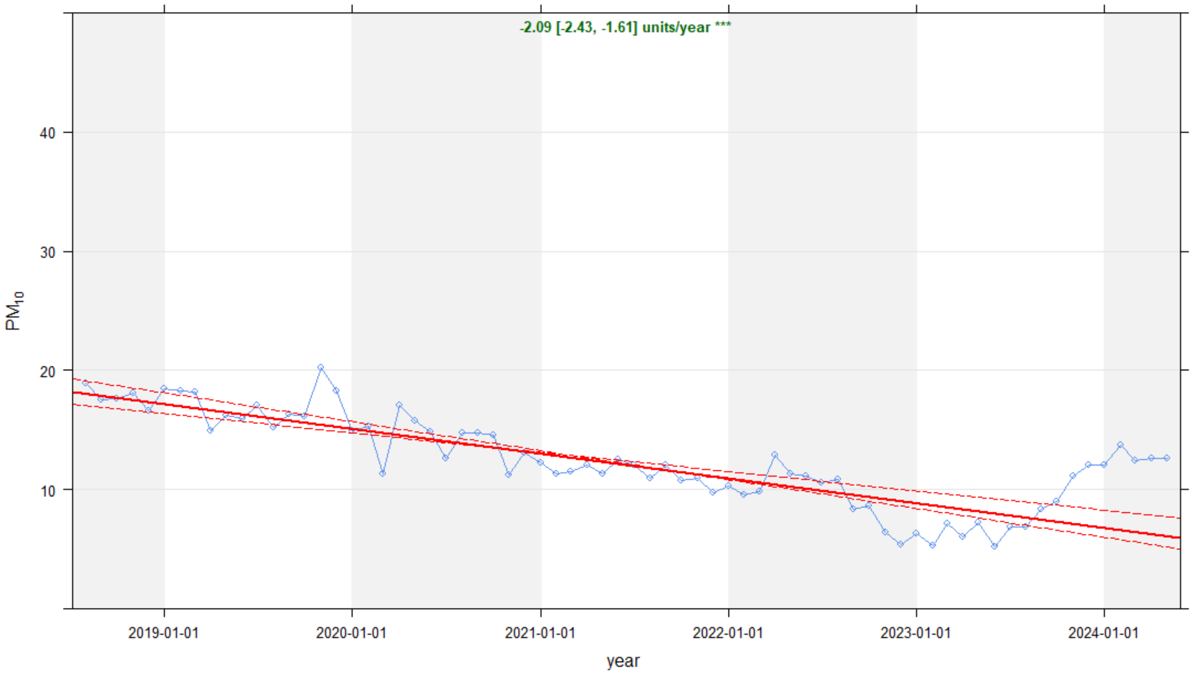


FIGURE 21: Time series plot of daily PM_{10} concentrations (µg/m^3) measured at Whareroa Marae: August 2018 – May 2024.

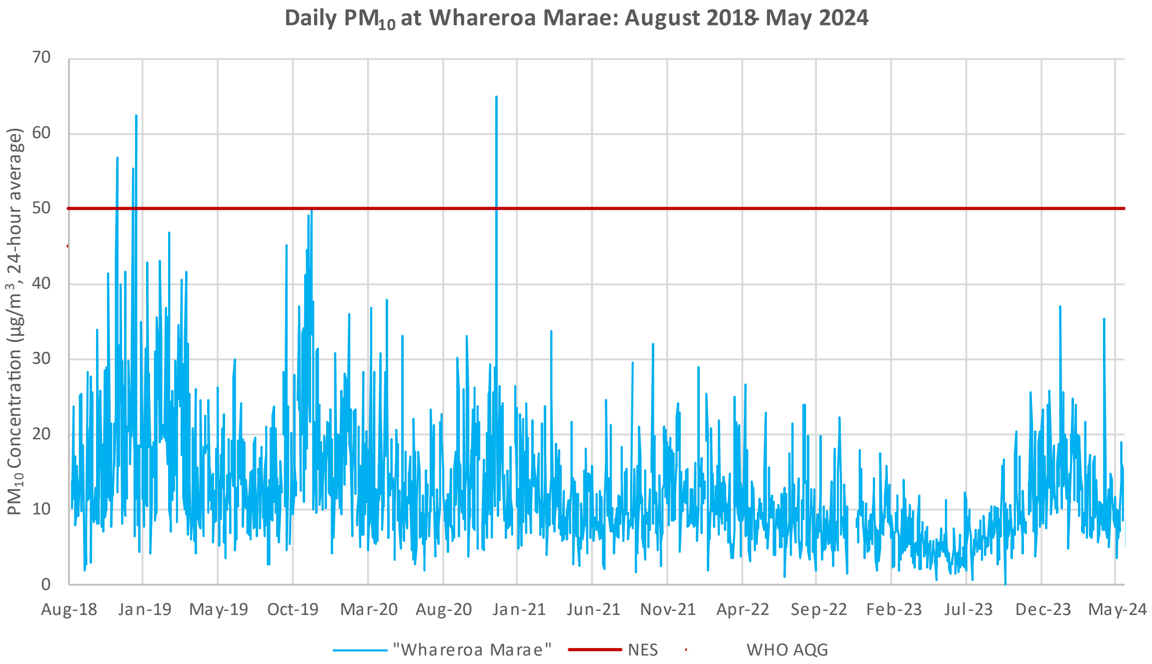
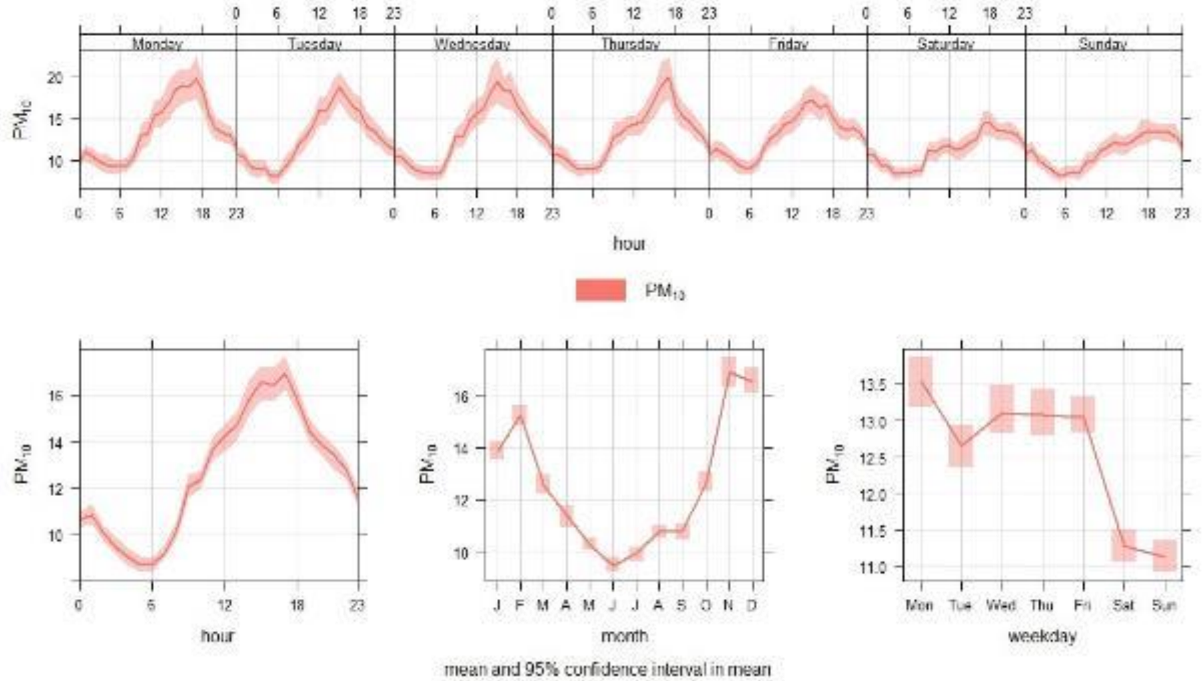


FIGURE 22: Mean hourly PM_{10} concentrations (µg/m^3) with 95% confidence intervals measured at Whareroa Marae by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): August 2018 – May 2024.



3.4 RANCH ROAD

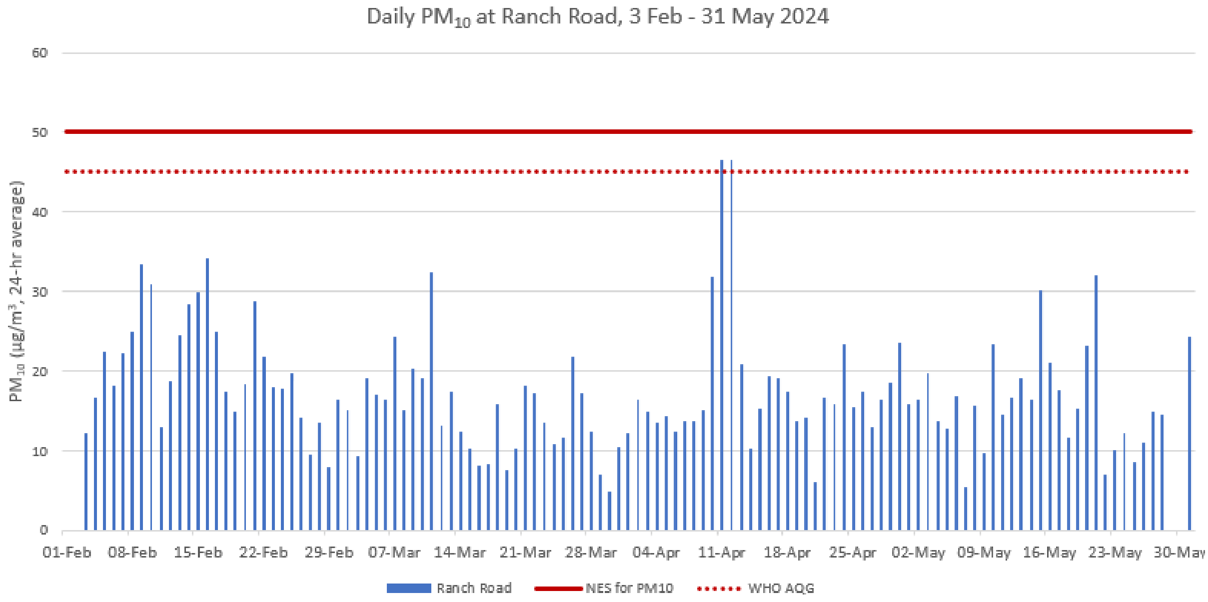
BOPRC commenced monitoring for PM_{10} at Ranch Road on 3 February 2024 so there is not yet a full year of monitoring data.

Figure 23 presents a time series plot of daily concentrations of PM_{10} measured at Ranch Road to end May 2024 for comparison with the national environmental standard and the WHO guideline for PM_{10}. The maximum daily PM_{10} concentration (47 µg/m^3) exceeded the WHO AQG on 11 and 12 April 2024 but there was no exceedance of the NES.[14]

The 4-month average PM_{10} concentration was 17 µg/m^3. There are not yet sufficient data to predict if long-term concentrations of PM_{10} at Ranch Road will meet the WHO annual PM_{10} guideline (15 µg/m^3).

[14] WHO (2021) recommends 3 – 4 exceedances of daily guidelines are permitted in a year.

FIGURE 23: Time series plot of daily PM_{10} concentrations (µg/m3) measured at Ranch Road: February – May 2024.



3.5 RATA STREET

Annual levels of PM_{10} for Rata Street are presented in Figure 14 for the period 2019 – 2023. Annual PM_{10} concentrations at Rata Street consistently exceed the WHO AQG and occasionally also exceed the New Zealand AQG.

Figure 24 presents monthly concentrations of PM_{10} with a smoothed trend line and 95% confidence intervals for the period December 2018 and May 2024 at Rata Street. Figure 25 presents the same data with a deseasonalised Theil-Sen trend estimate and 95% confidence intervals (refer section 1.6 for more information). There is no obvious trend (i.e. ambient levels of PM_{10} at Rata Street do not appear to be increasing or decreasing).

Figure 26 presents a time series plot of daily concentrations of PM_{10} measured at Rata Street over the entire monitoring record ending 31 May 2024 for comparison with the national environmental standard and the WHO guideline for PM_{10}. Figure 26 shows that Rata Street occasionally breaches the NES for PM_{10} (i.e. exceeds more than the permitted amount of once in any 12-month period).

Figure 27 presents a time variation plot of monthly (left hand side) and daily (right hand side) mean concentrations of PM_{10}, with 95% confidence intervals, measured at Rata Street for the period December 2018 – May 2024. These have a strong resemblance to the time variation plots for Whareroa Marae (Figure 22), with higher hourly PM_{10} concentrations during weekdays than weekends, which is consistent with industrial emissions being higher during the working week.

Monthly levels of PM_{10} appear highest in the spring and summer time and lowest during the wetter parts of the year (winter). This is consistent with rain in winter and autumn reducing daily concentrations of PM_{10}. It is also quite different to wintertime PM_{10} concentrations in other parts of New Zealand which typically have elevated PM_{10} during winter due to solid fuel combustion for domestic fires (Kuschel et al., 2022).

FIGURE 24: Monthly PM_{10} concentrations (µg/m³) measured at Rata Street with smoothed trend line and 95% confidence intervals for fit: January 2019 – May 2024.

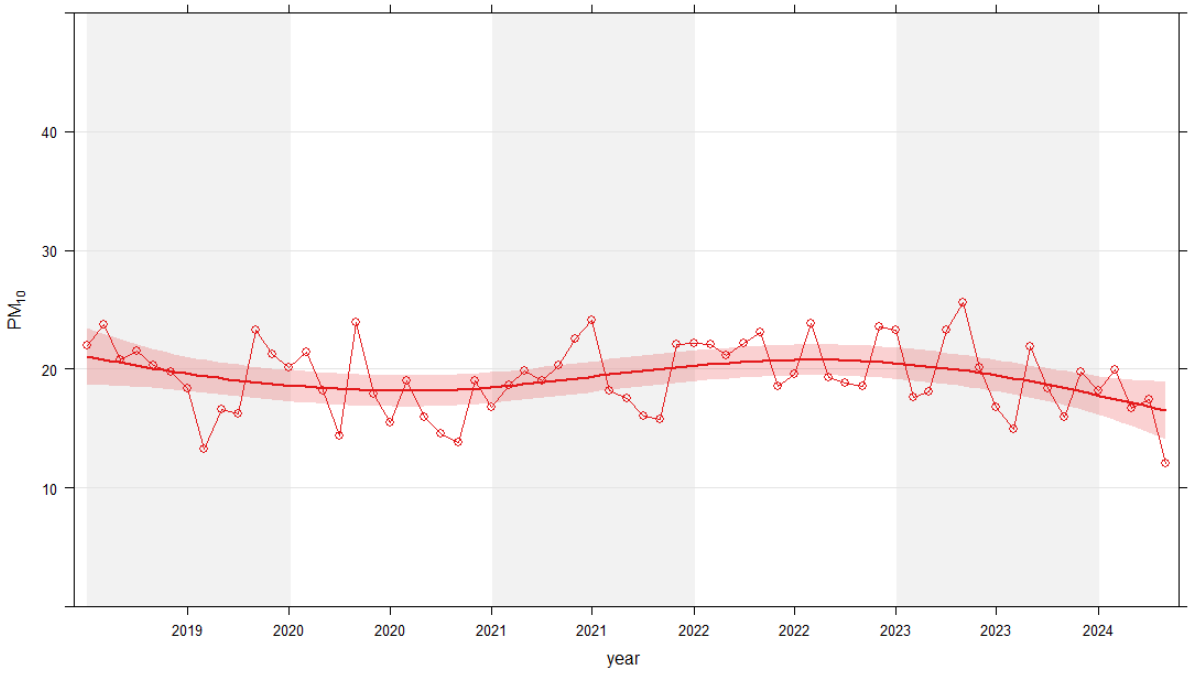


FIGURE 25: Monthly PM_{10} concentrations (µg/m³) measured at Rata Street with deseasonalised Theil Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods.

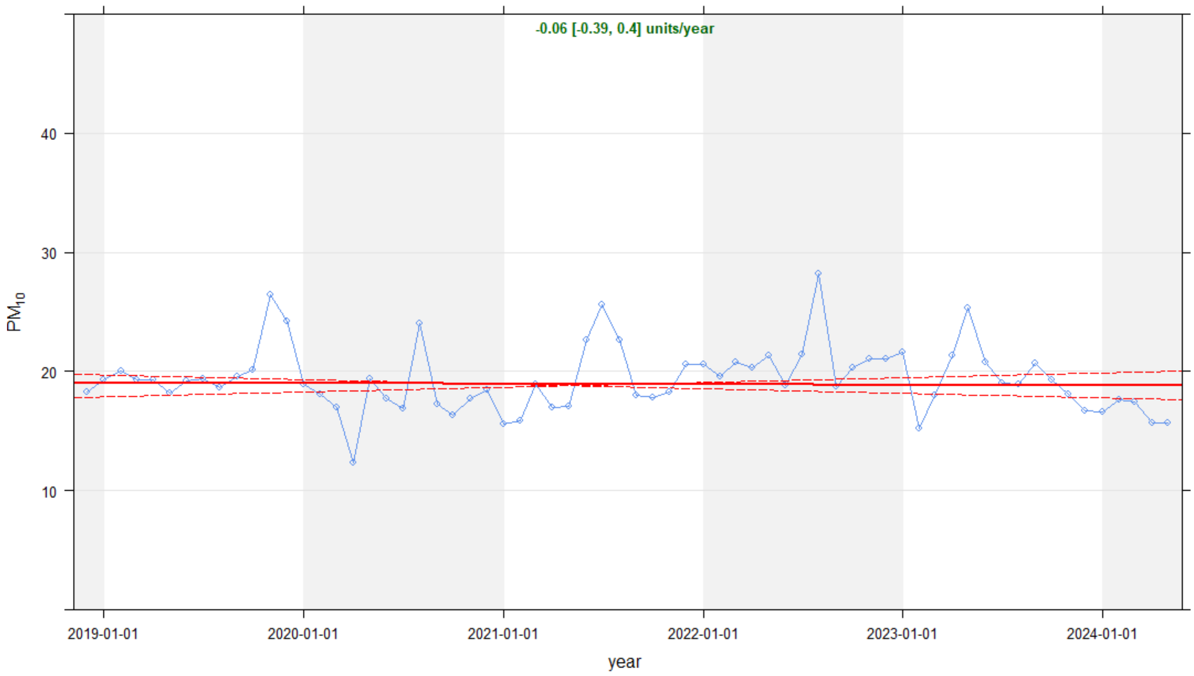


FIGURE 26: Time series plot of daily PM_{10} concentrations (µg/m^3) measured at Rata Street: December 2018 – May 2024.

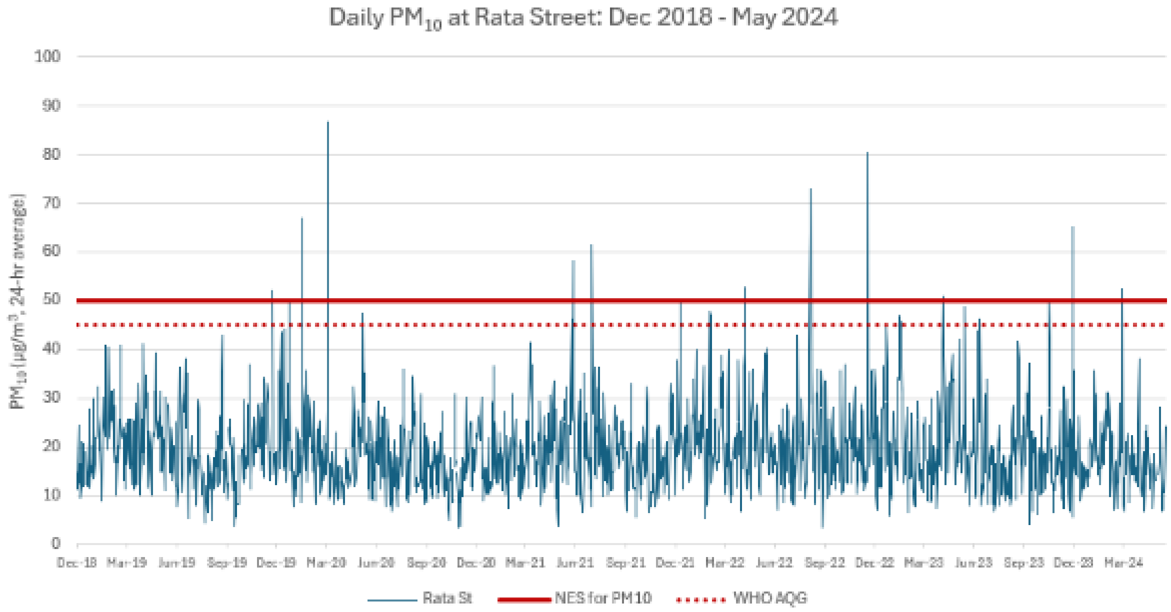
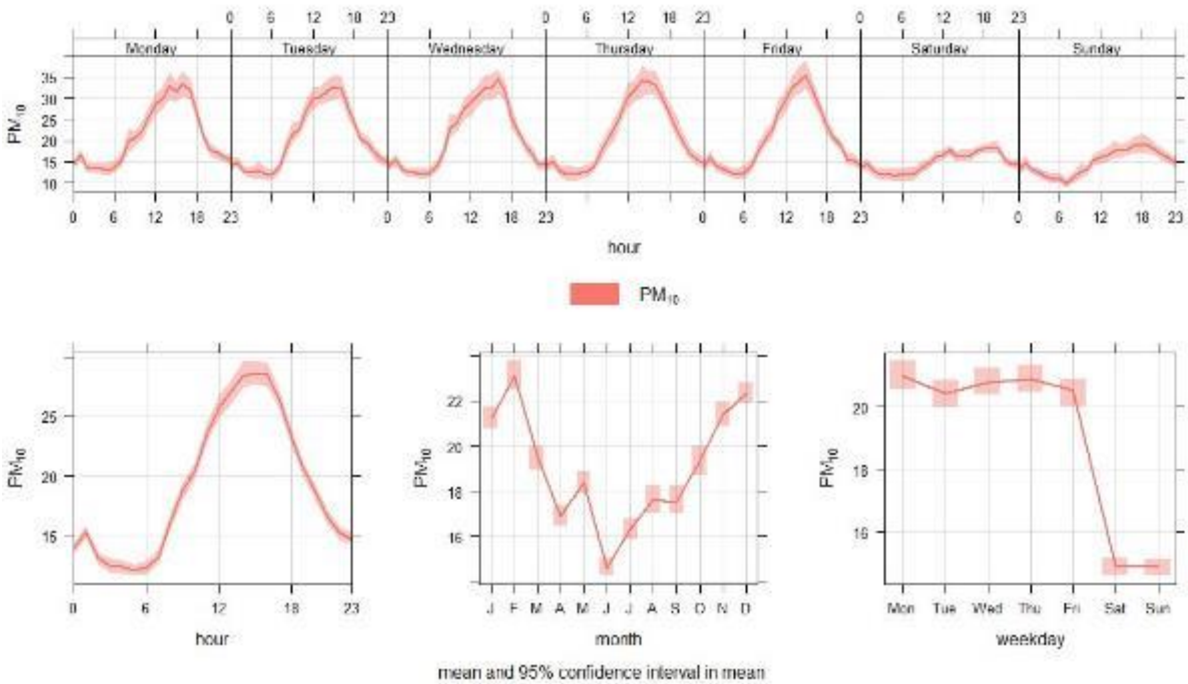


FIGURE 27: Mean hourly PM_{10} concentrations (µg/m^3) with 95% confidence intervals measured at Rata Street by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): December 2018 – May 2024 (5+ years).



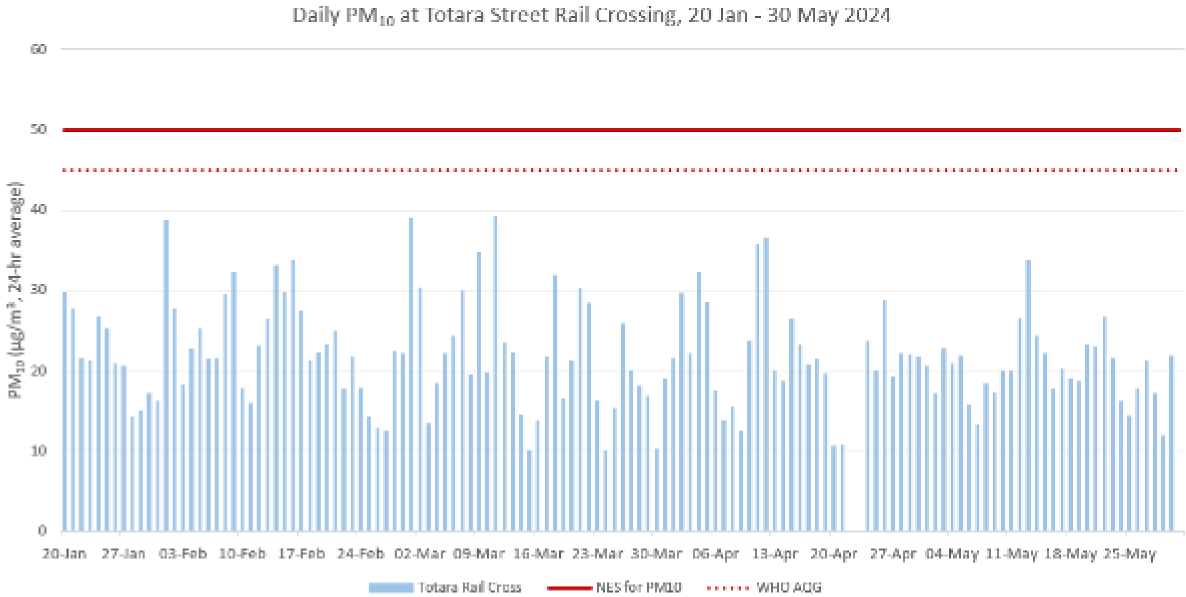
3.6 TOTARA STREET RAIL CROSSING

BOPRC redeployed the PM_{10} monitoring instrument from Totara Street to Totara Street Rail Crossing in January 2024 so there is not yet a full year of monitoring data for considering long-term PM_{10}.

Figure 28 presents a time series plot of daily concentrations of PM_{10} measured at Totara Street Rail Crossing to date for comparison with the national environmental standard and the WHO guideline for PM_{10}. Daily levels of PM_{10} have remained below the NES and WHO AQG to date.

The (nearly) 5-month average PM_{10} concentration was 22 µg/m^3. There are not yet sufficient data to determine an annual average concentration of PM_{10} but it appears unlikely the site will meet the WHO annual PM_{10} guideline (15 µg/m^3). This is consistent with historical (elevated) levels of annual PM_{10} measured at Totara Street only a few hundred metres away.

FIGURE 28: Time series plot of daily PM_{10} concentrations (µg/m^3) measured at Totara Street Rail Crossing: January – May 2024.



3.7 DISCUSSION – PM_{10}

All sites have less than 10 years of data which are not sufficient for drawing robust conclusions. However, it is pleasing to see a significant reduction in daily and annual PM_{10} concentrations measured at Whareroa Marae, with both daily and annual PM_{10} concentrations now below health-based standards and guidelines.

Figure 29 presents annual polar plots (pollution roses) of hourly PM_{10} concentrations measured at Whareroa Marae as a function of wind direction for the years 2019 – 2023. This appears to show a source of elevated concentrations of PM_{10} to the west of Whareroa Marae in 2019, that is not present in other years. Historical satellite photographs of Whareroa Marae show the establishment of a container storage facility to the west of Whareroa Marae in 2018 that appears to have been unsealed until sometime in 2021 (refer Appendix D).

Figure 30 presents monthly PM_{10} for Whareroa Marae with deseasonalised Theil-Sen trend estimate and 95% confidence intervals (refer section 1.6 for more information) split by wind direction (8 points of the compass). This indicates significant reductions in long-term PM_{10} from sources to the north and northwest (likely the adjacent fertiliser manufacturer), and a smaller reduction in ambient PM_{10} from sources east of the Marae (likely the adjacent container storage facility).

The reduction in annual PM_{10} at Whareroa Marae may, however, be unique to Whareroa Marae. Trend analyses of available data (Figure 31 and Figure 32, Theil-Sen analyses in Appendix E) show no significant change in long-term levels of PM_{10} at most other monitored locations in the Mount Maunganui Airshed except for Rail Yard South. This suggests continued efforts will be needed to reduce overall chronic exposure to PM_{10} in the Mount Maunganui area.

Long term trend analysis is discussed further in Section 7.2.

FIGURE 29: Annual polar plots of hourly PM_{10} concentrations (µg/m^3) as a function of wind direction (from) measured at Whareroa Marae: August 2018 – May 2024 (5 years+). [NB: 2018 and 2024 partial plots only]

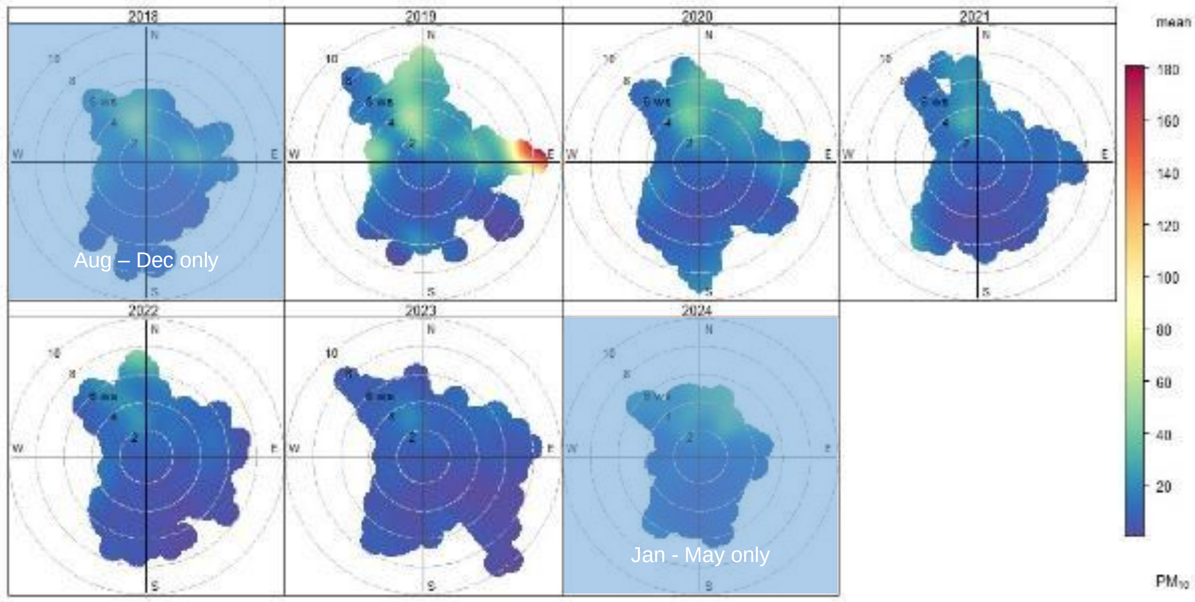


FIGURE 30: Trends in PM_{10} at Whareroa Marae split by eight wind sectors. Monthly PM_{10} concentrations (µg/m^3) measured at Whareroa Marae with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines).

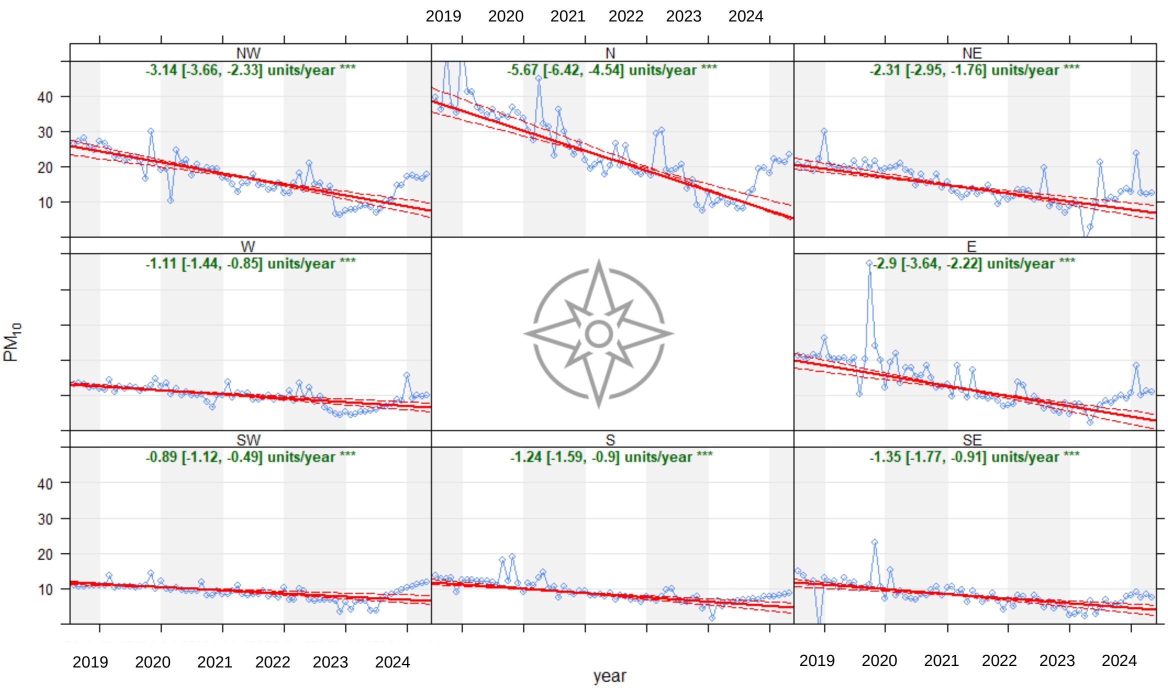


FIGURE 31: Monthly PM_{10} concentrations (µg/m³) measured at Whareroa Marae (red), Sulphur Point (blue) and Tauranga Bridge Marina (green) with smoothed trend line and 95% confidence intervals for fit: August 2018 – May 2024.

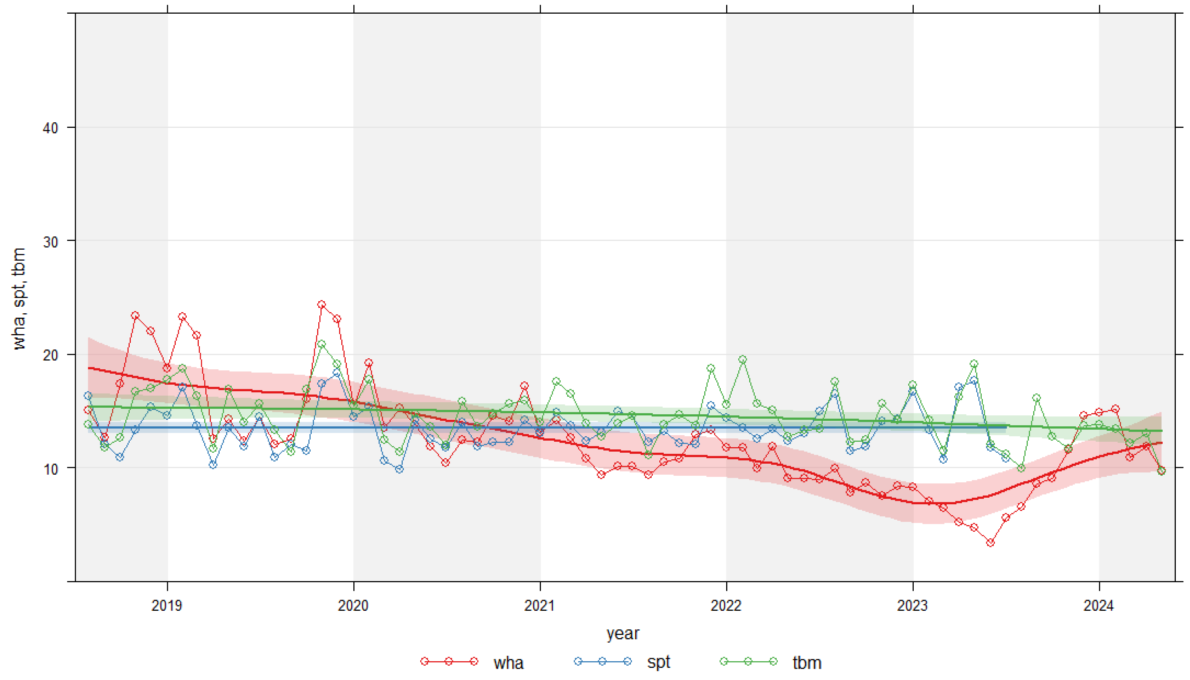
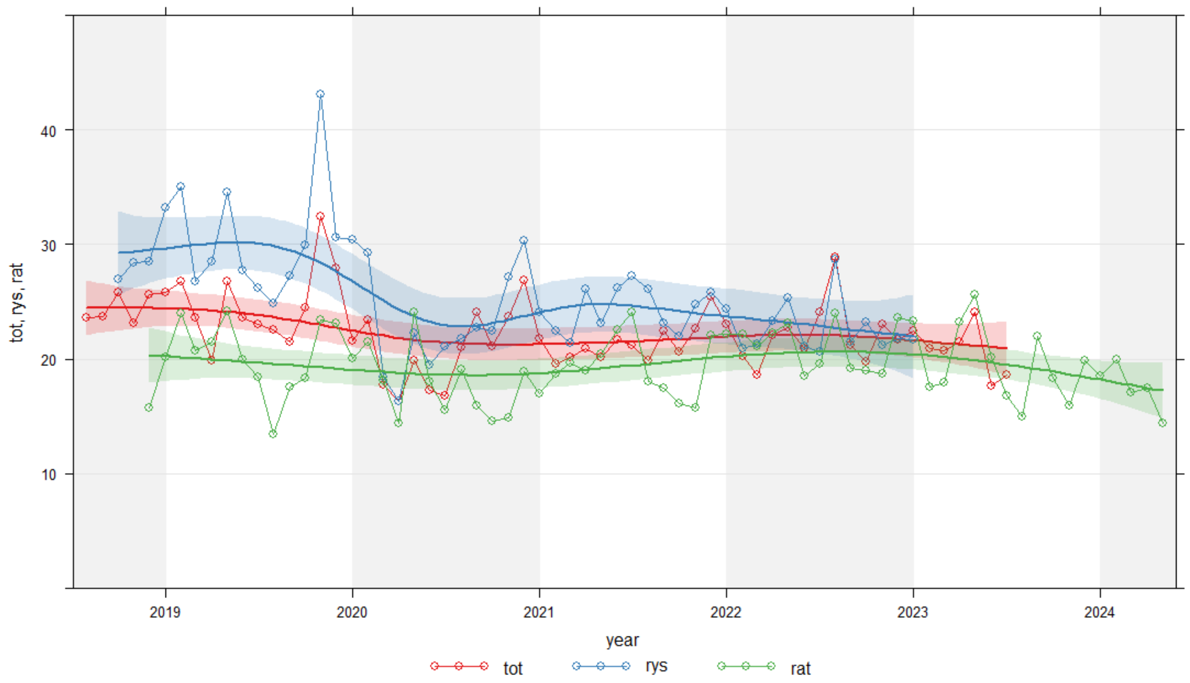


FIGURE 32: Monthly PM_{10} concentrations (µg/m³) measured at Totara Street (red), Rail Yard South (blue) and Rata Street (green) with smoothed trend line and 95% confidence intervals for fit: August 2018 – May 2024.



4. $PM_{2.5}$

$PM_{2.5}$ is now measured at two locations in Mount Maunganui (Whareroa Marae and Ranch Road) however, the instruments were both installed recently and do not have a full year of data.

Table 5 provides summary statistics for $PM_{2.5}$ measured in Mount Maunganui to date. Annual levels of $PM_{2.5}$ have historically exceeded the WHO AQG.

TABLE 5: Mount Maunganui $PM_{2.5}$ summary statistics: 2019 – 2023

Year	Maximum daily $PM_{2.5}$ (µg/m³)	99th percentile daily $PM_{2.5}$ (µg/m³)	Exceedances [a] per year WHO AQG (no.)	Annual Mean $PM_{2.5}$ (µg/m³)
	[WHO AQG = 15]		[3-4 permitted]	[WHO AQG = 5]
Totara Street				
2019	17	15	2	**7.9**
2020	17	13	1	**6.2**
2021	18	11	2	**6.3**
2022	10	10	0	**5.2**
Whareroa Marae *(6 months only)*				
Nov 2023 –	*10*	*9.4*	*0*	*NA*
Ranch Road *(4 months only)*				
Feb 2024 –	*9.2*	*8.1*	*0*	*NA*

[a] Data exclude exceptional events.

4.1 WHAREROA MARAE

Figure 33 presents a time series plot of daily concentrations of $PM_{2.5}$ measured at Whareroa Marae between November 2023 and May 2024 (six months) for comparison with the national environmental standard and the WHO AQG for PM_{10}. The maximum daily $PM_{2.5}$ concentration measured (10 µg/m³) was well below the daily WHO guideline for $PM_{2.5}$ (15 µg/m³).

The 6-month average $PM_{2.5}$ concentration was 4.4 µg/m³. There are not yet sufficient data to predict if long-term concentrations of $PM_{2.5}$ at Ranch Road will meet the WHO annual $PM_{2.5}$ guideline (5.0 µg/m³).

Figure 34 presents $PM_{2.5}$ and PM_{10} measured at Whareroa Marae to date. The average ratio of $PM_{2.5}$:PM_{10} over the monitoring period was 0.35 (max 0.73, min 0.07). This is consistent with other industrial locations in New Zealand (Kuschel et al., 2022).

FIGURE 33: Time series plot of daily $PM_{2.5}$ concentrations (µg/m³) measured at Whareroa Marae: November 2023 – May 2024.

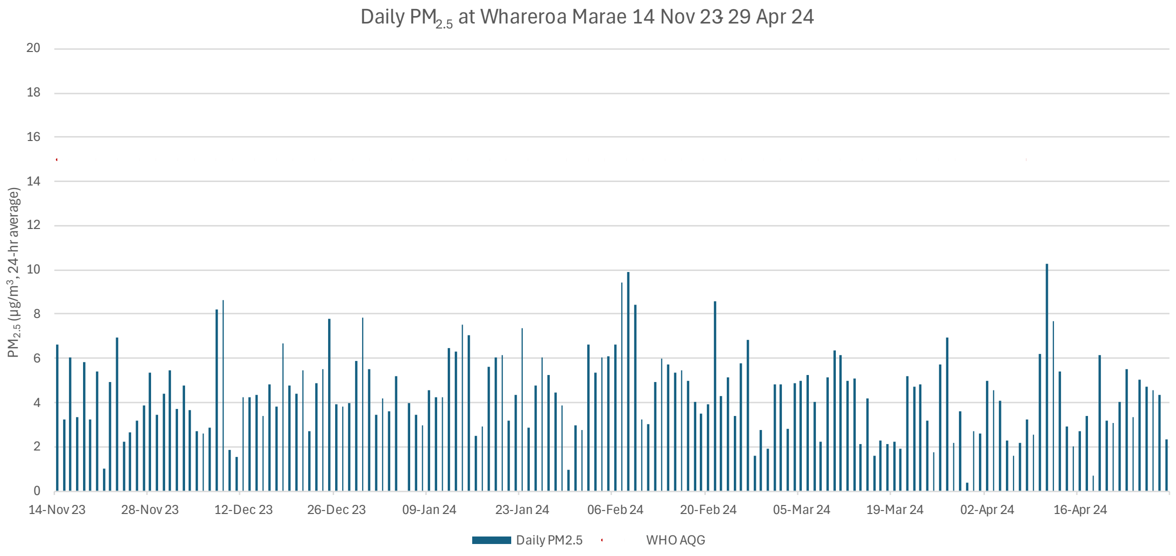
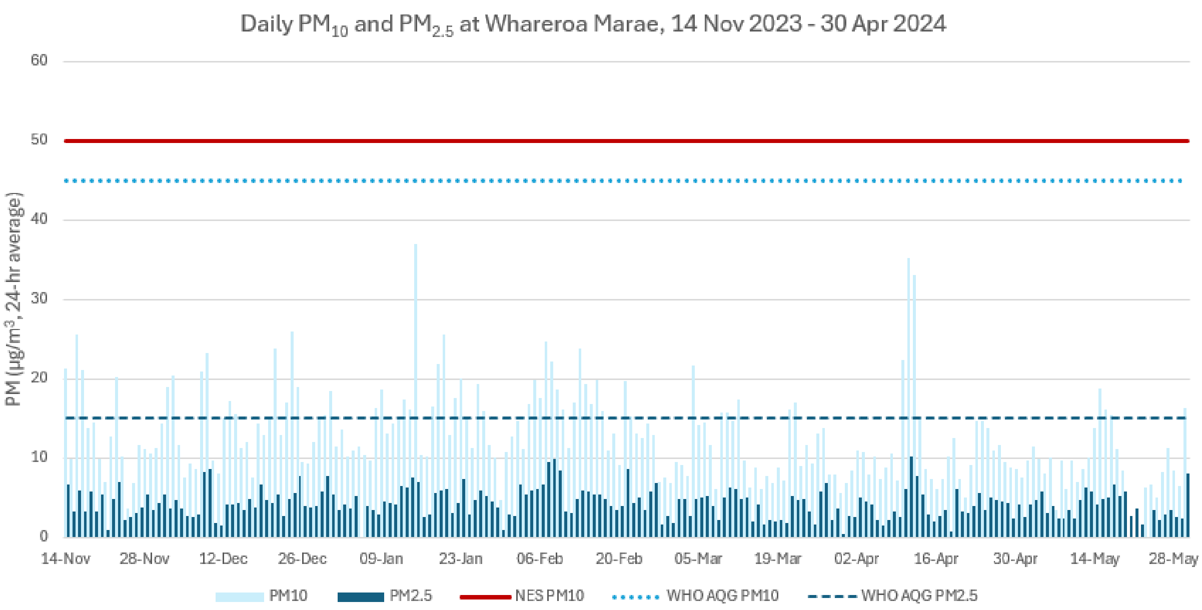


FIGURE 34: Time series plot of daily PM_{10} and $PM_{2.5}$ concentrations (µg/m³) measured at Whareroa Marae: November 2023 – May 2024.



4.2 RANCH ROAD

Figure 35 presents a time series plot of daily concentrations of $PM_{2.5}$ measured at Ranch Road between February 2024 and May 2024 (four months only) for comparison with the national environmental standard and the WHO guideline for $PM_{10.}$ The maximum daily $PM_{2.5}$ concentration measured (9.2 µg/m^3) was well below the daily WHO guideline for $PM_{2.5}$ (15 µg/m^3).

The (nearly) 3-month average $PM_{2.5}$ concentration was 4.6 µg/m^3. There are not yet sufficient data to predict if long-term concentrations of $PM_{2.5}$ at Ranch Road will meet the WHO annual $PM_{2.5}$ guideline (5.0 µg/m^3).

Figure 36 presents $PM_{2.5}$ and PM_{10} measured at Ranch Road to date. The average ratio of $PM_{2.5}$:PM_{10} over the monitoring period was 0.31 (max 0.66, min 0.11). This is low compared with annual fractions measured in other residential areas in New Zealand (mean 0.53, Kuschel et al., 2022), and more akin to fractions measured in industrial areas (noting the data are only for five months).

FIGURE 35: Time series plot of daily $PM_{2.5}$ concentrations (µg/m^3) measured at Ranch Road: November 2023 – May 2024.

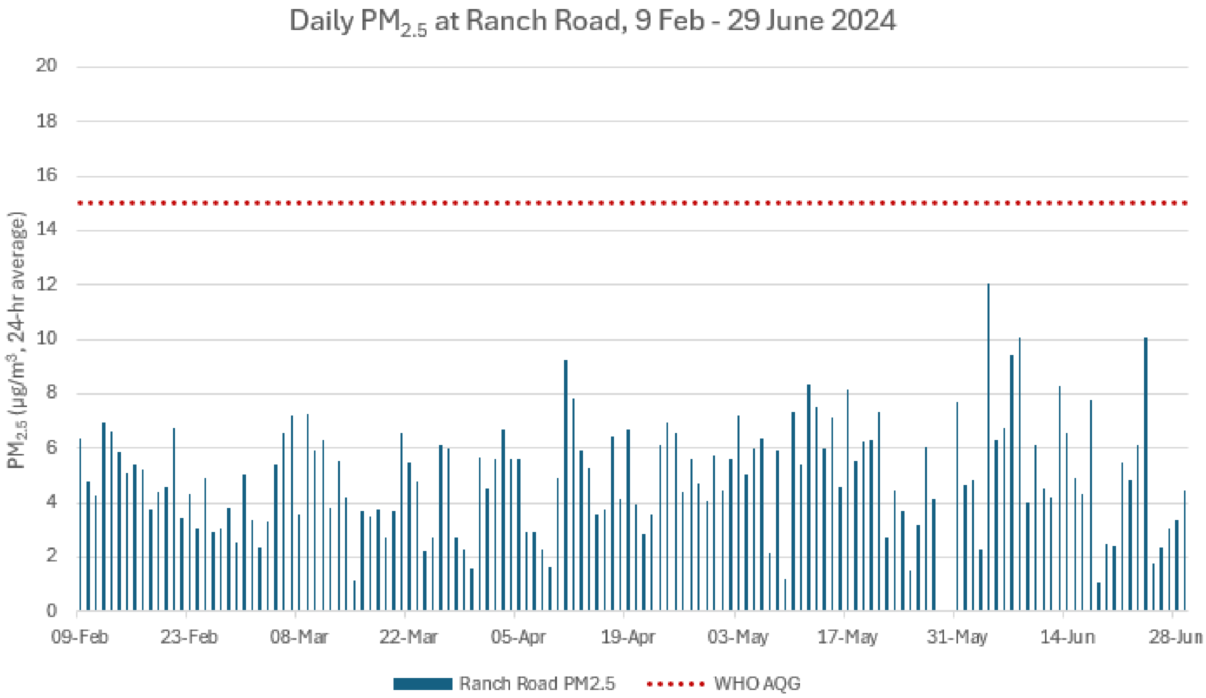
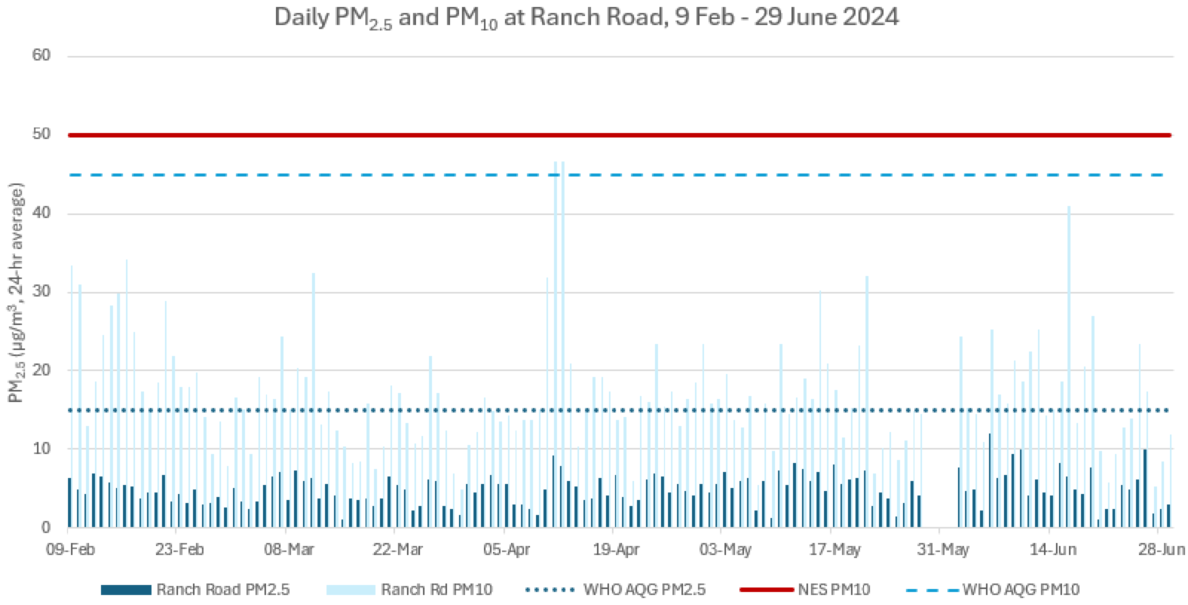


FIGURE 36: Time series plot of daily PM_{10} and $PM_{2.5}$ concentrations (µg/m³) measured at Ranch Road: Feb – Jun 2024.



4.3 DISCUSSION – $PM_{2.5}$

The inclusion of reference monitoring for $PM_{2.5}$ at Whareroa Marae and Ranch Road is very welcome however, there are not yet sufficient data on which to make informed conclusions regarding chronic exposure to $PM_{2.5}$ in the Mount Maunganui Airshed and Mount Maunganui.

Historical, elevated annual levels of $PM_{2.5}$ measured at the Totara Street location warrant continued monitoring and investigation.

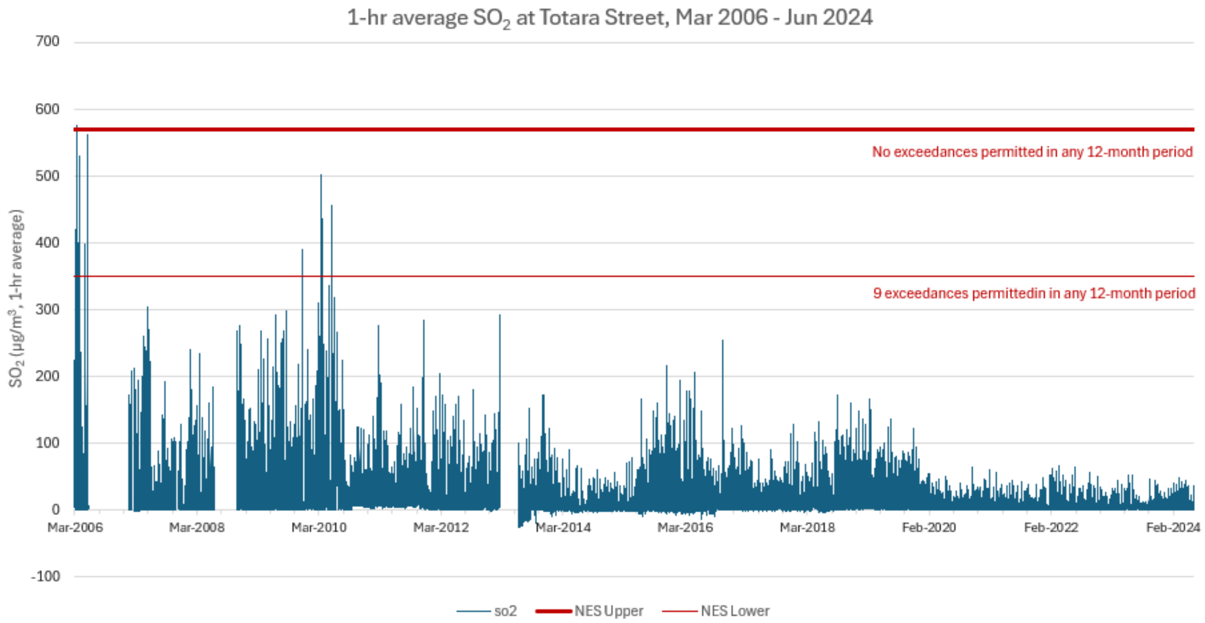
5. SULPHUR DIOXIDE

5.1 MOUNT MAUNGANUI AIRSHED

Historical SO_2 data & long-term trends (Totara Street)

BOPRC commenced monitoring SO_2 in March 2006 at Totara Street which is a considerable data record for a pollutant with short-term exposure periods of interest (i.e. 10-minutes and 1-hour time averages). Figure 37 presents 1-hour average SO_2 concentrations measured at Totara Street for the available data record (March 2006 – June 2024).

FIGURE 37: Time series plot of hourly SO_2 concentrations (µg/m^3) measured at Totara Street: March 2006 – June 2024.



The first year of monitoring, 2006, was intermittent but still recorded 16 exceedances of the lower NES (9 are permitted) and one breach of the (not to be exceeded) upper NES for SO_2. Seven exceedances of the lower NES for SO_2 (9 are permitted) were measured in 2010. BOPRC (2011) notes some uncertainty around some of the elevated levels during this period due to calibration frequency.[15] Issues with the instrument (see negative data in 2013) resulted in it being replaced in September 2013.

It is evident even from the time series record that hourly levels of SO_2 measured at Totara Street have significantly reduced over the years. There have been no recorded exceedances of a NES for SO_2 at Totara Street since 2010.

Whilst SO_2 is a fast-acting pollutant with no long-term criteria it is still of interest to consider long-term trends. Figure 38 presents monthly SO_2 concentrations with a smoothed trend line and 95% confidence intervals for Totara Street for the full monitoring record of March 2006 to June 2024 – a period of over 18 years. Figure 39 presents the same data with a deseasonalised Theil-Sen trend estimate and 95% confidence intervals (refer section 1.6 for more information). The long-term data record shows a statistically significant and very clear downwards trend in ambient SO_2.

[15] BOPRC, (2011). *Mount Maunganui ambient sulphur dioxide monitoring*. Environmental Publication 2011/03. [Online]. At page 25.

FIGURE 38: Monthly SO_2 concentrations (µg/m^3) measured at Totara Street with smoothed trend line and 95% confidence intervals for fit: March 2006 – June 2024.

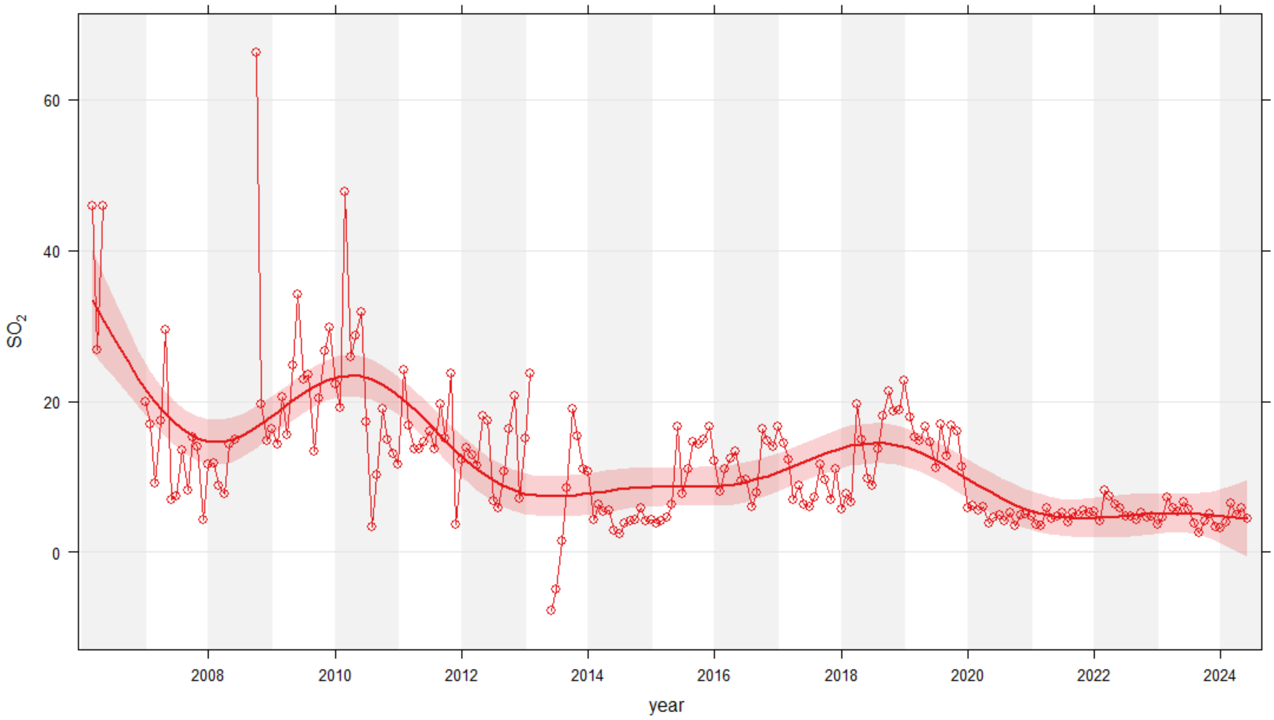


FIGURE 39: Monthly SO_2 concentrations (µg/m3) measured at Totara Street with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods: March 2006 and June 2024. The overall trend is shown at the top as -.92 (µg/m^3) per year and the 95% confidence intervals in the slope from -1.07 – -0.77 µg/m^3/year. The ∗ ∗ ∗ show that the trend is significant to the 0.001 level (refer Appendix E for more information).

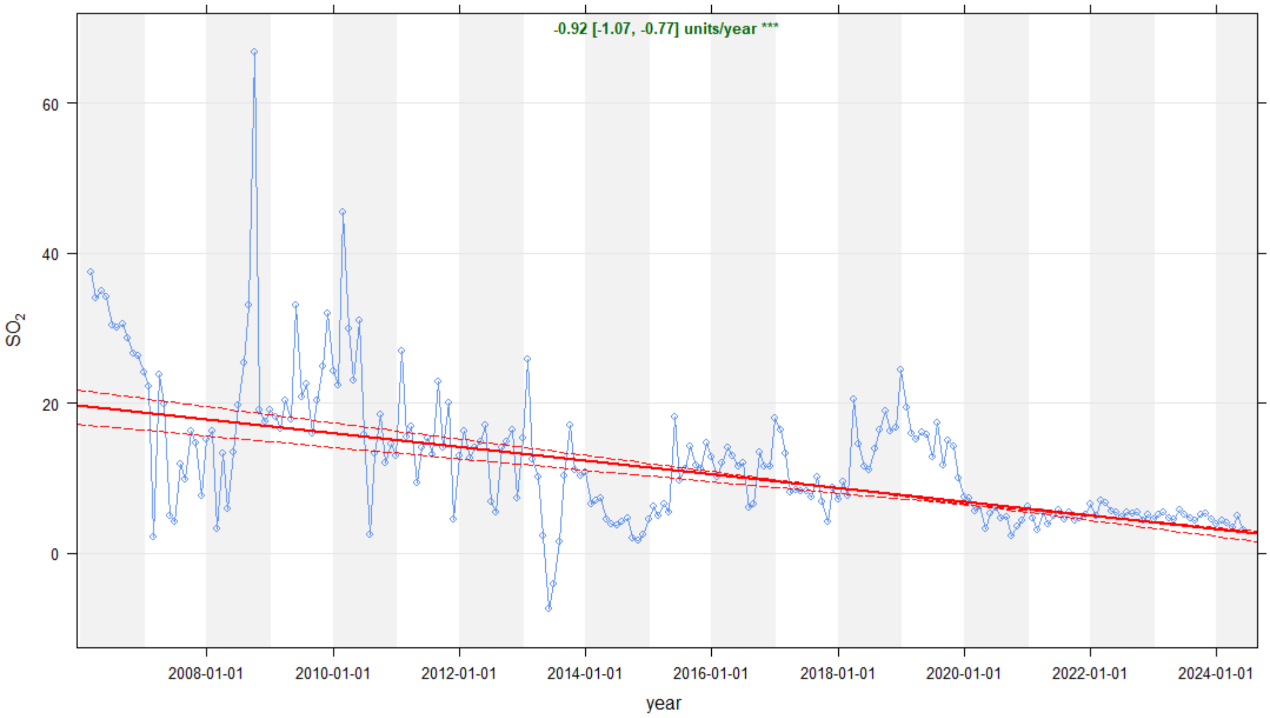


Table 6 provides historical statistics for **1-hour** SO_2 concentrations measured at Totara Street for comparison with national standards.

TABLE 6: Totara Street 1-hr SO_2 summary statistics: 2006 – 2014

Year	Maximum 1-hour SO_2 ($\mu g/m^3$)	99th Percentile 1-hour SO_2 ($\mu g/m^3$)	Exceedances Lower NES per year (no.)	Exceedances Upper NES per year (no.)
	[NES = 350 / 570]	[NES = 350 / 570]	[9 permitted]	[0 permitted]
2006	**576**	310	**16**	**1**
2007	305	128	0	0
2008	277	137	0	0
2009	391	144	1	0
2010	502	168	7	0
2011	284	96	0	0
2012	204	93	0	0
2013	291	96	0	0
2014	92	44	0	0

Recent SO_2 monitoring (last ten years)

BOPRC commenced monitoring for SO_2 in other locations in the MMA after 2015 (refer Table 1). This additional monitoring reveal SO_2 to be highly spatially and temporally variable (ESR 2011).

There were significant changes to BOPRC's monitoring schedule during 2023 that affect comparison of SO_2 data from different locations in the MMA. The (industrial) Rail Yard South monitoring site and the (commercial/industrial/residential) Sulphur Point monitoring site were decommissioned in January 2023 and July 2023 respectively. Peak SO_2 concentrations at these two sites were typically lower than those measured elsewhere in the MMA (ESR 2023).

Summary SO_2 statistics for all monitoring locations are tabulated in Appendix B, with summary plots in Appendix C.

Table 7 provides summary statistics for **1-hour** SO_2 concentrations in the Mount Maunganui Airshed for comparison with national standards (i.e. calculated from a combined dataset for all monitoring sites) for all years of monitoring.

Table 8 provides summary statistics for **10-minute** and **daily** SO_2 concentrations in the Mount Maunganui Airshed for comparison with WHO AQG for recent years only (2019 – 2023).

These are discussed further in the sections that follow.

TABLE 7: Mount Maunganui Airshed 1-hr SO_2 summary statistics: 2015 – 2024

Year	Maximum 1-hour SO_2 (µg/m^3)	99th Percentile 1-hour SO_2 (µg/m^3)	Exceedances Lower NES per year (no.)	Exceedances Upper NES per year (no.)
	[NES = 350 / 570]	[NES = 350 / 570]	[9 permitted]	[0 permitted]
Two sites: Totara St and Whareroa Marae				
2015	349	149	0	0
Three sites: Totara St, Whareroa Marae and Tauranga Bridge Marina				
2016	**751**	98	8	**2**
2017	280	105	0	0
Six sites: Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, Rata St, Rail Yard South and Totara St				
2018	254	86	0	0
2019	**575**	118	4	**1**
2020	251	35	0	0
2021	312	35	0	0
2022	204	33	0	0
Four sites: Tauranga Bridge Marina, Whareroa Marae, Rata St and Totara St				
2023	286	23	0	0
2024 [a]	*180* [a]	*32* [a]	*0* [a]	*0* [a]

[a] *1 Jan – 30 Jun only*

TABLE 8: Mount Maunganui Airshed 10-minute and daily SO_2 summary statistics: 2019 – 2024

Year	10-minute SO_2 (µg/m^3)		Daily SO_2 (µg/m^3)		Exceedances per year (no.)	
	Maximum	99th Percentile	Maximum	99th Percentile	10-minute	Daily
	[WHO AQG = 500]		[WHO AQG = 40]		[0 permitted]	[3-4permitted]
Six sites: Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, Rata St, Rail Yard South and Totara St						
2019	**775**	136	**140**	**71**	**10**	**113**
2020	432	39	54	20	0	4
2021	**1,247**	37	42	19	**1**	1
2022	396	35	43	18	0	1
Four sites: Tauranga Bridge Marina, Whareroa Marae, Rata St and Totara St						
2023	**1,423**	25	21	14	**1**	0
2024 [a]	*237* [a]	*36* [a]	*44* [a]	*17* [a]	*0* [a]	[a]

[a] *1 Jan – 30 Jun only (NB: No data available for Tauranga Bridge Marina monitor after 30 April 2024)*

5.2 TAURANGA BRIDGE MARINA

BOPRC commenced monitoring for SO_2 in April 2016 at Tauranga Bridge Marina. Figure 40 presents a time series plot of **1-hour** concentrations of SO_2 measured at Tauranga Bridge Marina between April 2016 and April 2024[16] for comparison with national environmental standards. There have been no exceedances of the NES for SO_2 recorded at Tauranga Bridge Marina.

Figure 41 presents a time series plot of **10-minute** concentrations of SO_2 measured at Tauranga Bridge Marina over all the years monitored for comparison with the WHO AQG. This shows that 10-minute concentrations of SO_2 occasionally spike at Tauranga Bridge Marina, with one exceedance (1,247 µg/m^3) of the WHO AQG in 2021.

Figure 42 presents a time series plot of **daily SO_2** concentrations measured at Tauranga Bridge Marina for comparison with the New Zealand and WHO daily AQG for SO_2. This shows occasional exceedances, but always less than the 3 – 4 permitted exceedances in the WHO guidance.

Figure 43 presents a time variation plot of hourly SO_2 concentrations by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right), with 95% confidence intervals measured at Tauranga Bridge Marina for the monitoring period April 2016 – May 2024. This shows a similar pattern to Whareroa Marae (refer Figure 49), albeit with smaller variation and lower concentrations (refer y-axis on both plots). It is also interesting to note that unlike for PM_{10} there is no significant weekend reduction in ambient concentrations.

Whilst SO_2 is a fast-acting pollutant with no long-term criteria it is still of interest to consider long-term trends. Figure 44 presents **monthly SO_2** concentrations with a smoothed trend line and 95% confidence intervals for Tauranga Bridge Marina for the entire monitoring period from April 2016 – April 2024. This appears to show a slow increase until 2019, after which time monthly concentrations decline.

Figure 45 presents the same data with deseasonalised Theil-Sen trend estimate and 95% confidence intervals (refer section 1.6 for more information). The straight-line fit shows a statistically significant decrease in ambient SO_2 that is particularly evident after 2020.

[16] NB: No data available for Tauranga Bridge Marina SO_2 monitor after 30 April 2024.

FIGURE 40: Time series plot of 1-hour SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina: April 2016 – April 2024.

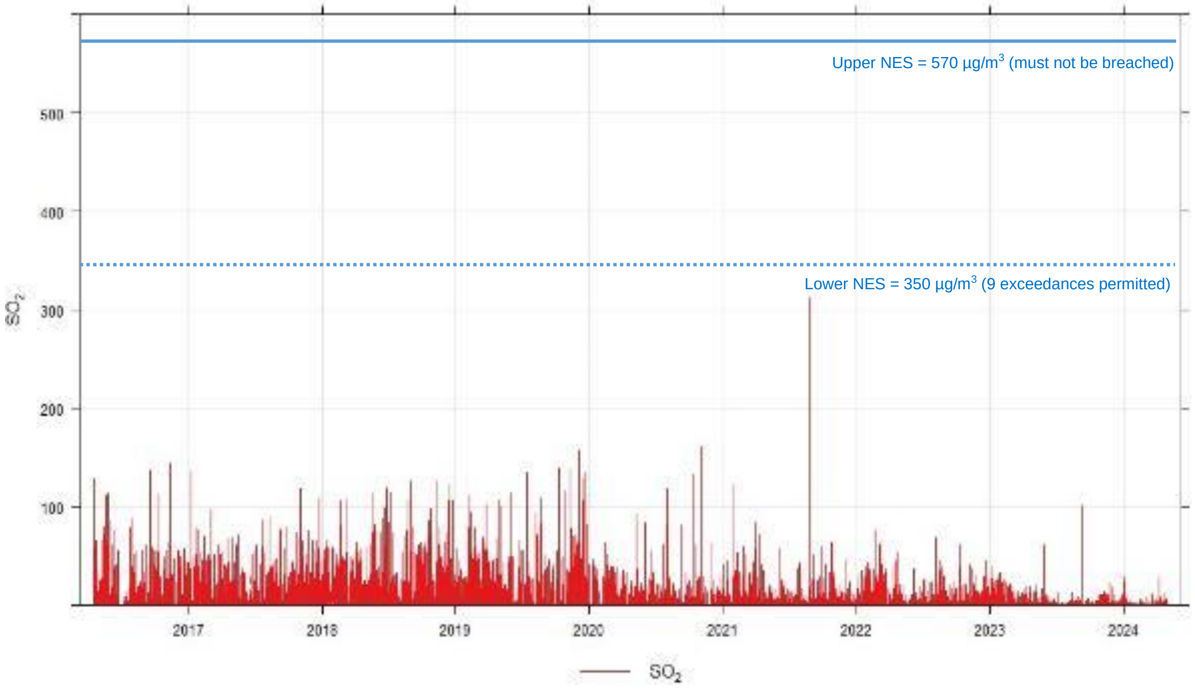


FIGURE 41: Time series plot of 10-minute SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina: April 2016 – April 2024.

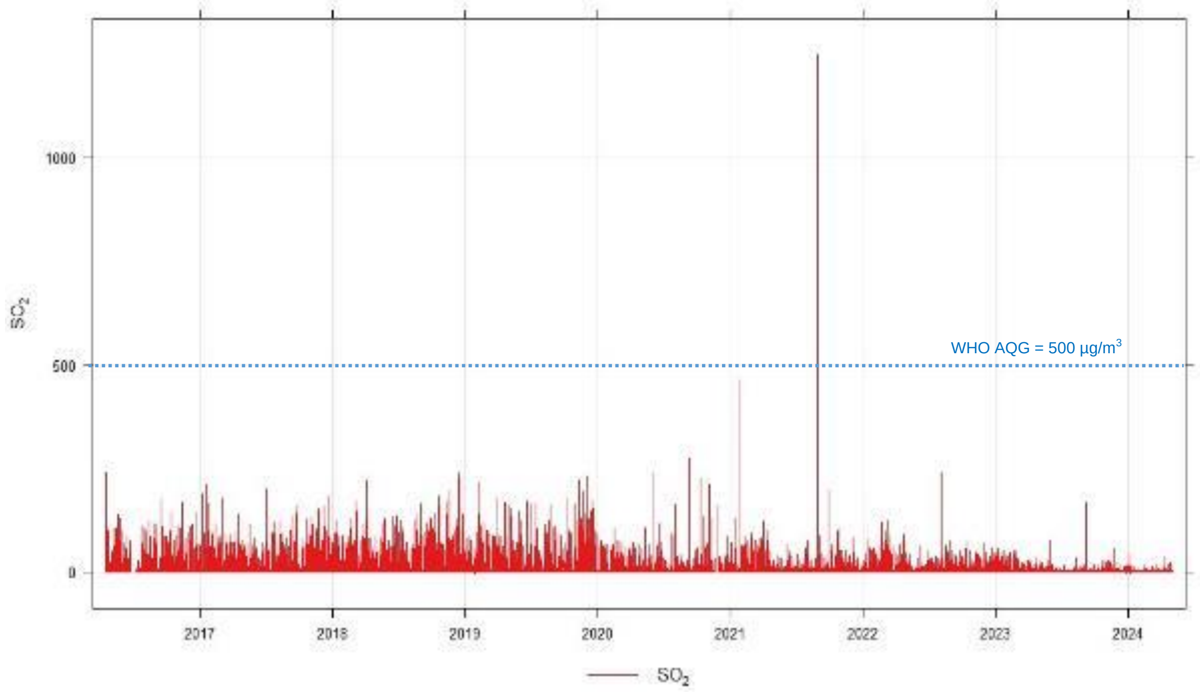


FIGURE 42: Time series plot of daily SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina: April 2016 – April 2024.

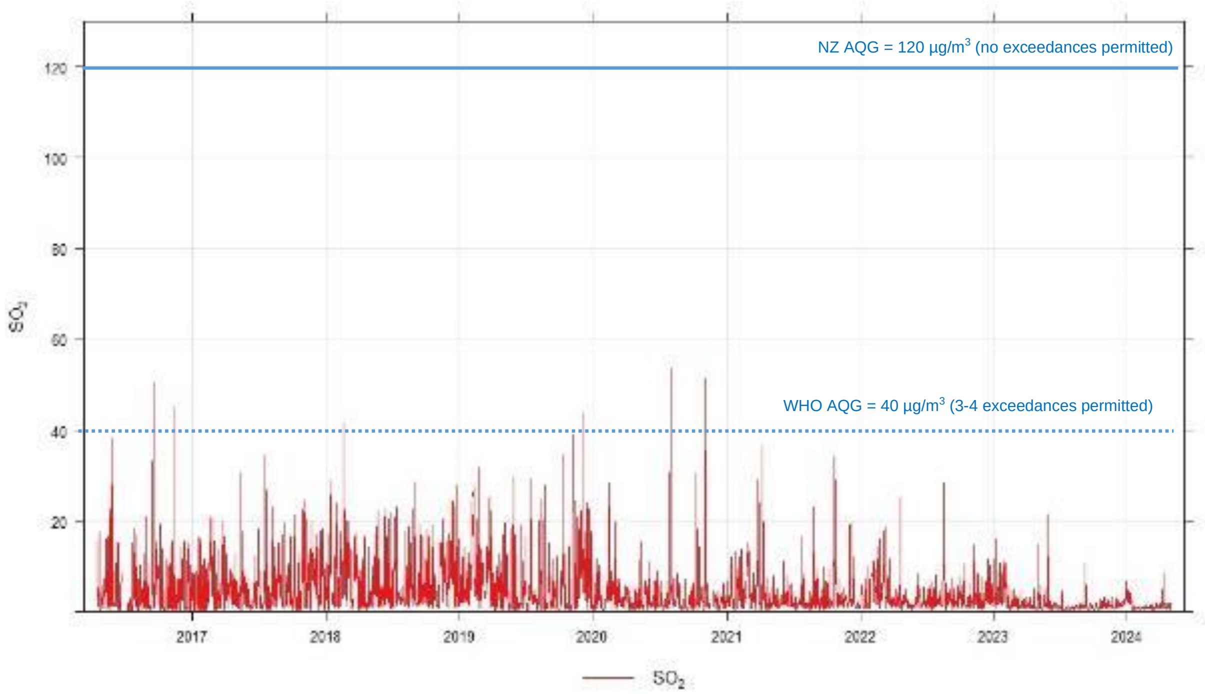


FIGURE 43: Mean hourly SO_2 concentrations (µg/m^3) with 95% confidence intervals measured at Tauranga Bridge Marina by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): April 2016 – April 2024.

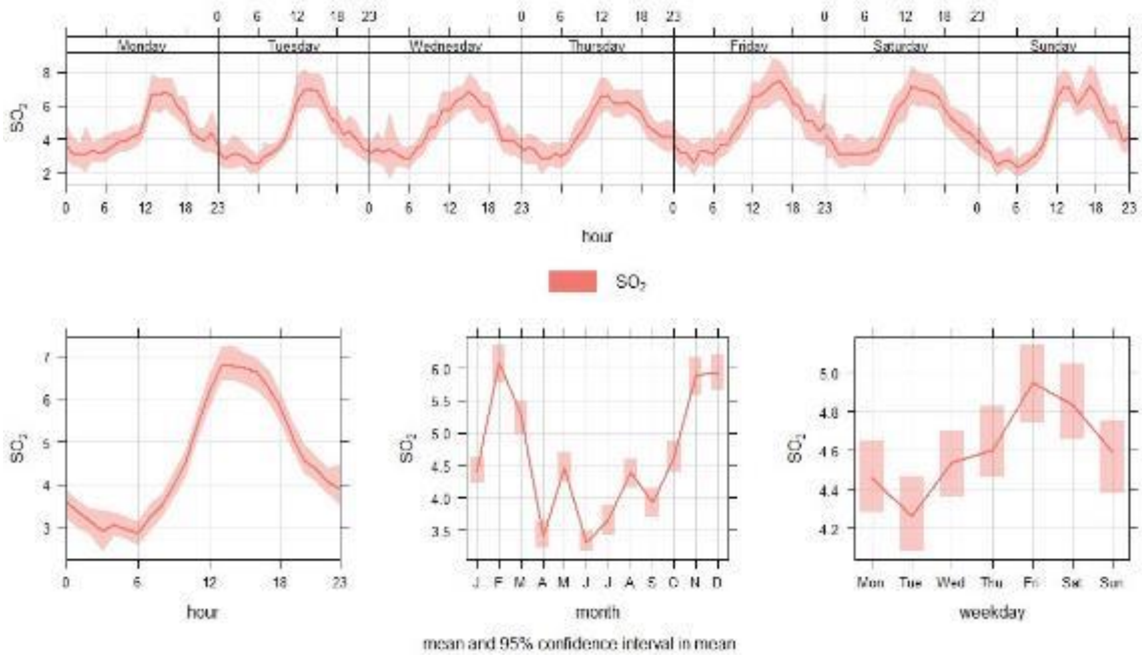


FIGURE 44: Monthly SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina with smoothed trend line and 95% confidence intervals for fit: April 2016 – April 2024.

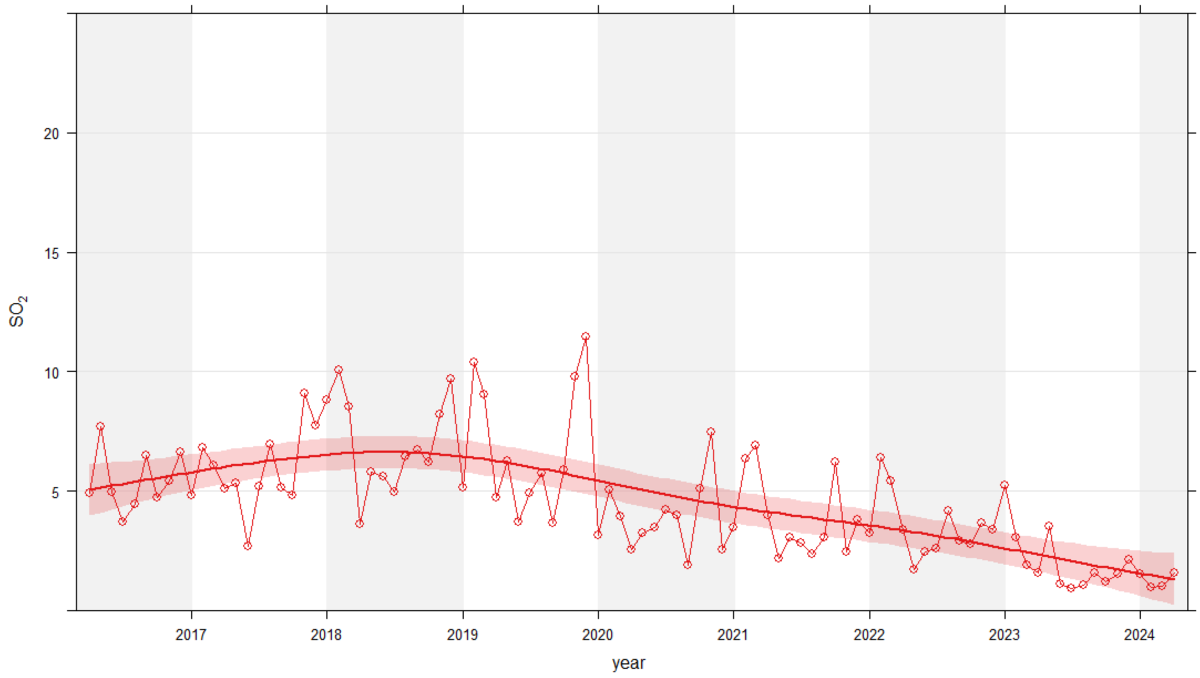
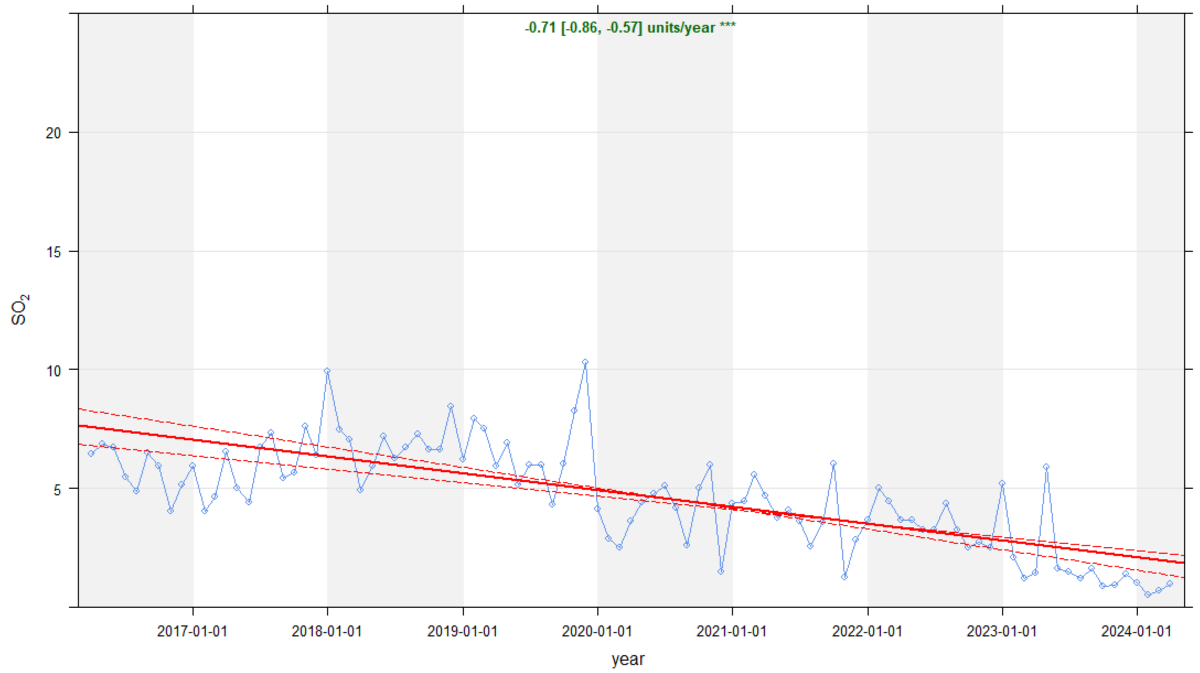


FIGURE 45: Monthly SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina April 2016 – April 2024 with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. The overall trend is shown at the top as -0.71 (µg/m^3) per year and the 95% confidence intervals in the slope from -0.86 – -0.57 µg/m^3/year. The $* * *$ show that the trend is significant to the 0.001 level.



5.3 WHAREROA MARAE

Figure 46 presents a time series plot of **1-hour** concentrations of SO_2 measured at Whareroa Marae over all the years monitored for comparison with national environmental standards. The first year of monitoring records eight exceedances of the lower (9 are permitted) and two breaches of the (not to be exceeded) upper NES for SO_2. As noted in the introduction, regulatory action by BOPRC and mitigation by Ballance Agri-Nutrients Ltd resulted in significant reductions in short-term concentrations of SO_2 measured at Whareroa Marae after 2016.

Figure 47 presents a time series plot of **10-minute** concentrations of SO_2 measured at Whareroa Marae over all the years monitored for comparison with the WHO AQG. There was one exceedance of the 10-minute WHO AQG (500 µg/m^3) for SO_2 in 2023. This was a short peak concentration of 1,423 µg/m^3 measured at Whareroa Marae on 16 February 2023 at 2:30 pm (NZST).[17] The wind was blowing from the northwest during this elevated period, which aligns with the direction of the adjacent fertiliser manufacturer. There are no other known, significant sources of SO_2 in this direction.

Exceedance of a WHO (global) AQG has no regulatory status in New Zealand which is different to a 'breach' of a national environmental standard for SO_2. However, research shows that exposure to sulphur dioxide at 286 µg/m^3 can cause bronchoconstriction in adults with mild asthma (Sheppard *et al.* 1981).

Figure 48 presents a time series plot of **daily SO_2** concentrations measured at Whareroa Marae for comparison with the New Zealand and WHO daily AQG for SO_2. This shows occasional exceedances of the WHO daily guideline at both locations (but not more than the three – four permitted each year).

Figure 49 presents a time variation plot of SO_2 concentrations by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right), with 95% confidence intervals measured at Whareroa Marae for the entire monitoring period September 2015 – May 2024. Figure 49 shows no significant difference in weekday or weekend concentrations, which is consistent with continuous industrial processing. Hourly concentrations of SO_2 increase during the day, peaking between midday and 6 pm and reducing overnight until 6 am. This likely coincides with winds being more frequently directed towards the monitor, as wind speeds typically increase during the day which would act to increase dispersion and reduce concentrations. Monthly levels of SO_2 show a consistent, and significant, reduction in July. This likely synchronises with Ballance Agri-Nutrients mid-year annual shut down.[18] Reduced concentrations of SO_2 may also be expected during the wetter parts of the year, consistent with higher humidity and rain in winter and autumn.

Figure 50 presents **monthly SO_2** for Whareroa Marae over the entire monitoring period of nearly 10 years from September 2015 – May 2024.This shows a significant long-term decline. Figure 51 presents the same data with deseasonalised Theil Sen trend estimate and 95% confidence intervals (refer section 1.6 for more information). This shows a statistically significant decrease in ambient SO_2 over this period.

Figure 52 presents the same data split by wind direction. This shows source/s to the north and northwest (likely the adjacent fertiliser manufacturer) has/have significantly reduced their SO_2 emissions during this period.

[17] 3:30 pm in New Zealand Daylight Savings Time
[18] https://www.nzherald.co.nz/bay-of-plenty-times/business/stack-work-went-like-clockwork/CJOGRI2ZTMSWJ72BJMJM5LF6G4/

FIGURE 46: Time series plot of 1-hour SO_2 concentrations (µg/m³) measured at Whareroa Marae: September 2015 – May 2024.

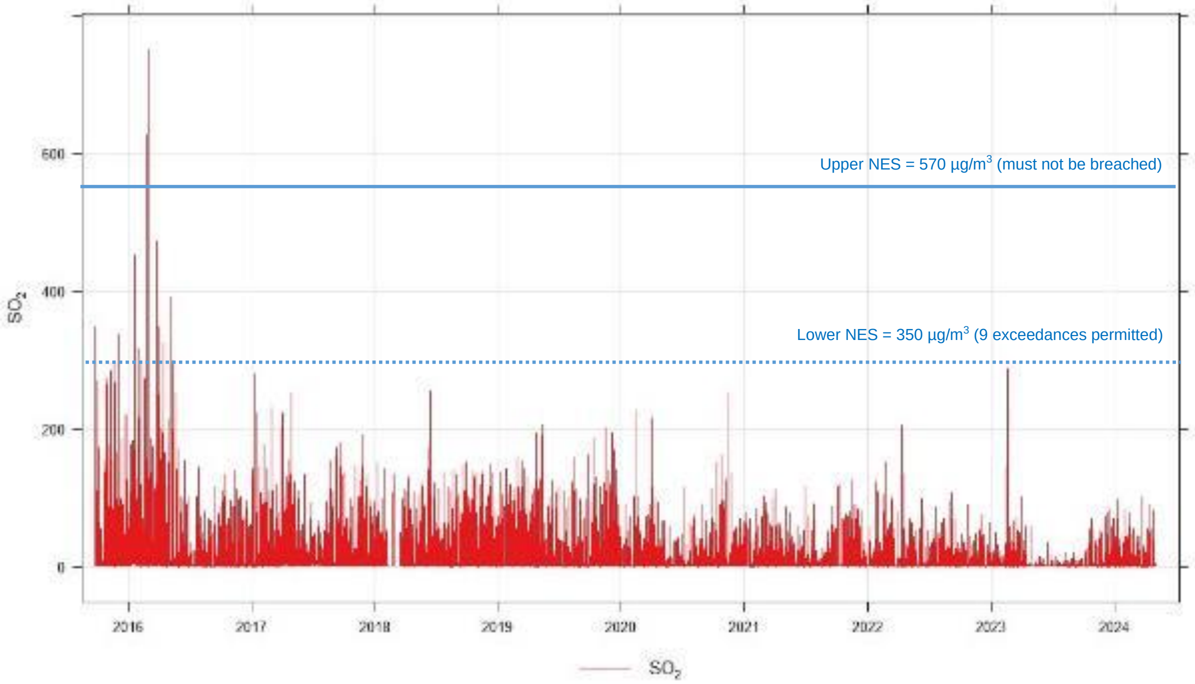


FIGURE 47: Time series plot of 10-minute SO_2 concentrations (µg/m³) measured at Whareroa Marae: September 2015 – May 2024.

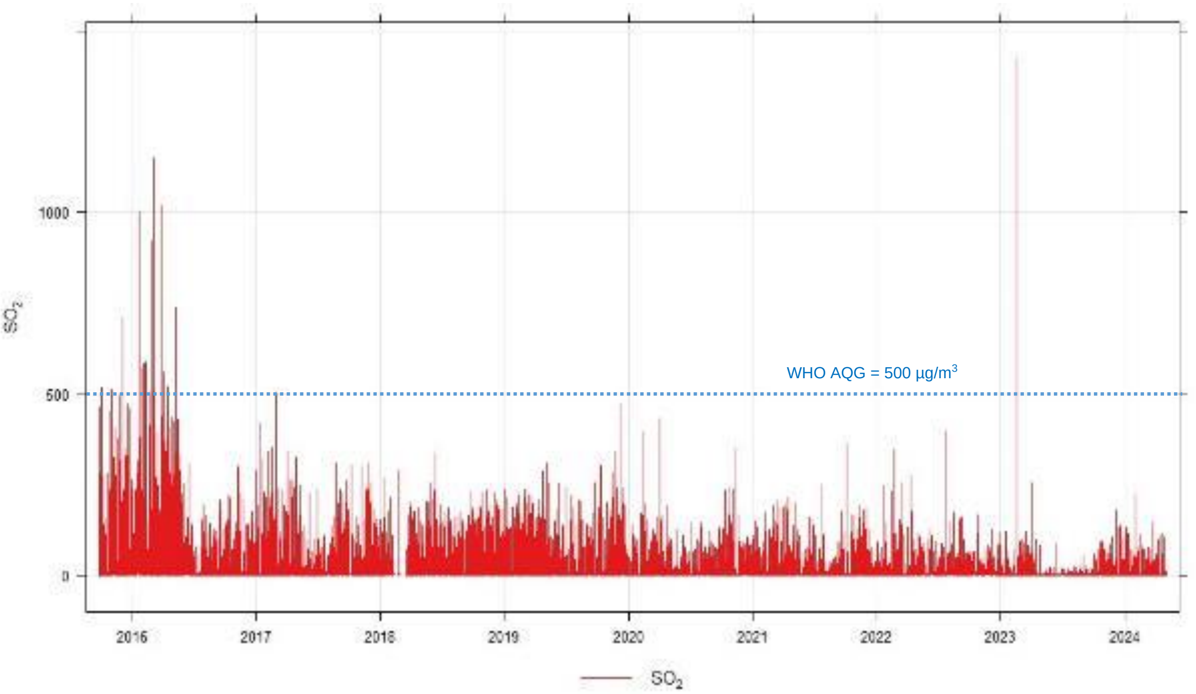


FIGURE 48: Time series plot of daily SO_2 concentrations (µg/m³) measured at Whareroa Marae: September 2015 – May 2024.

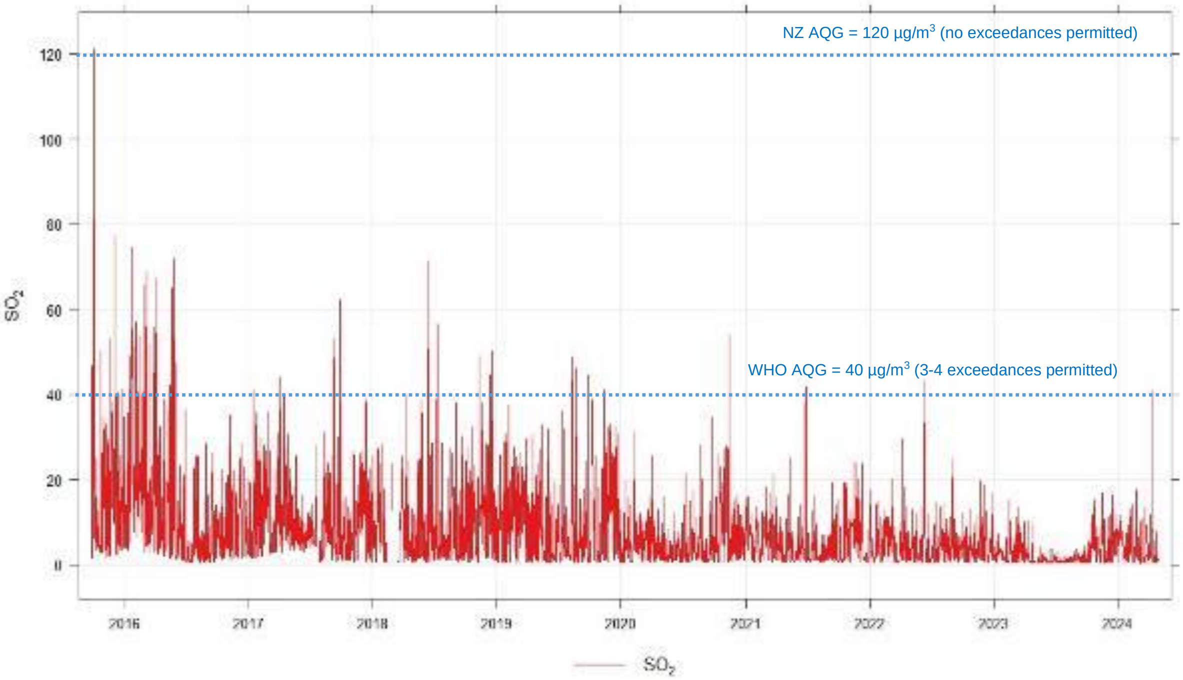


FIGURE 49: Mean hourly SO_2 concentrations (µg/m³) with 95% confidence intervals measured at Whareroa Marae by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): September 2015 – May 2024.

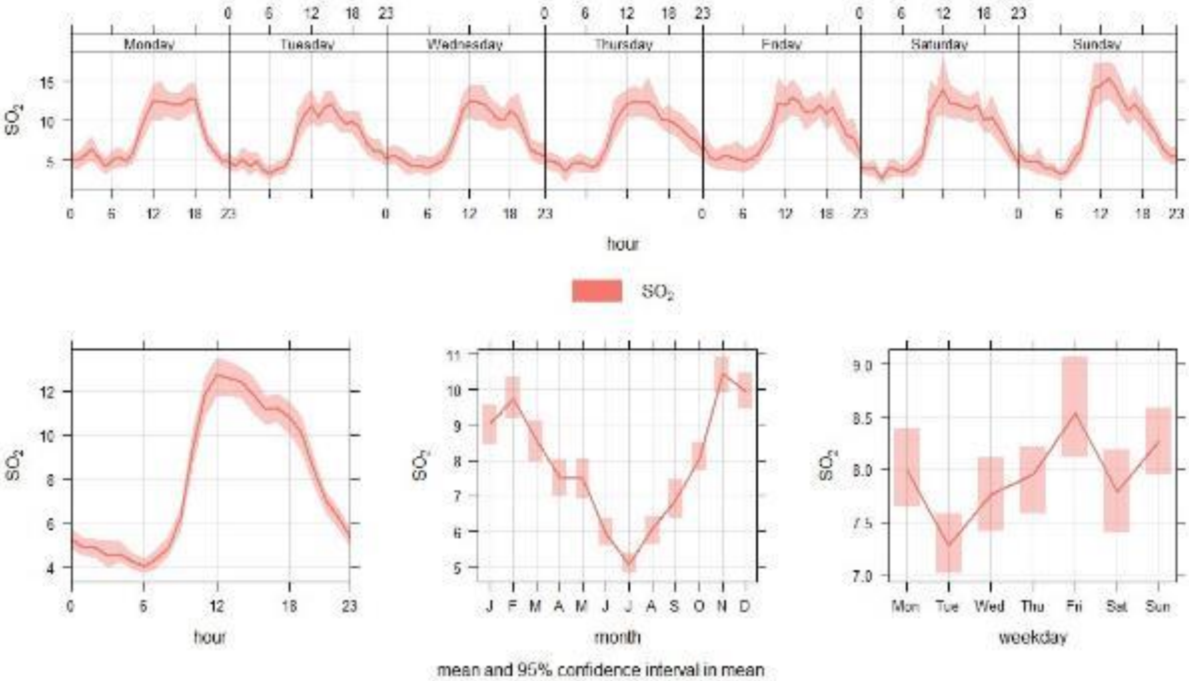


FIGURE 50: Monthly SO_2 concentrations (µg/m^3) measured at Whareroa Marae with smoothed trend line and 95% confidence intervals for fit: September 2015 – May 2024.

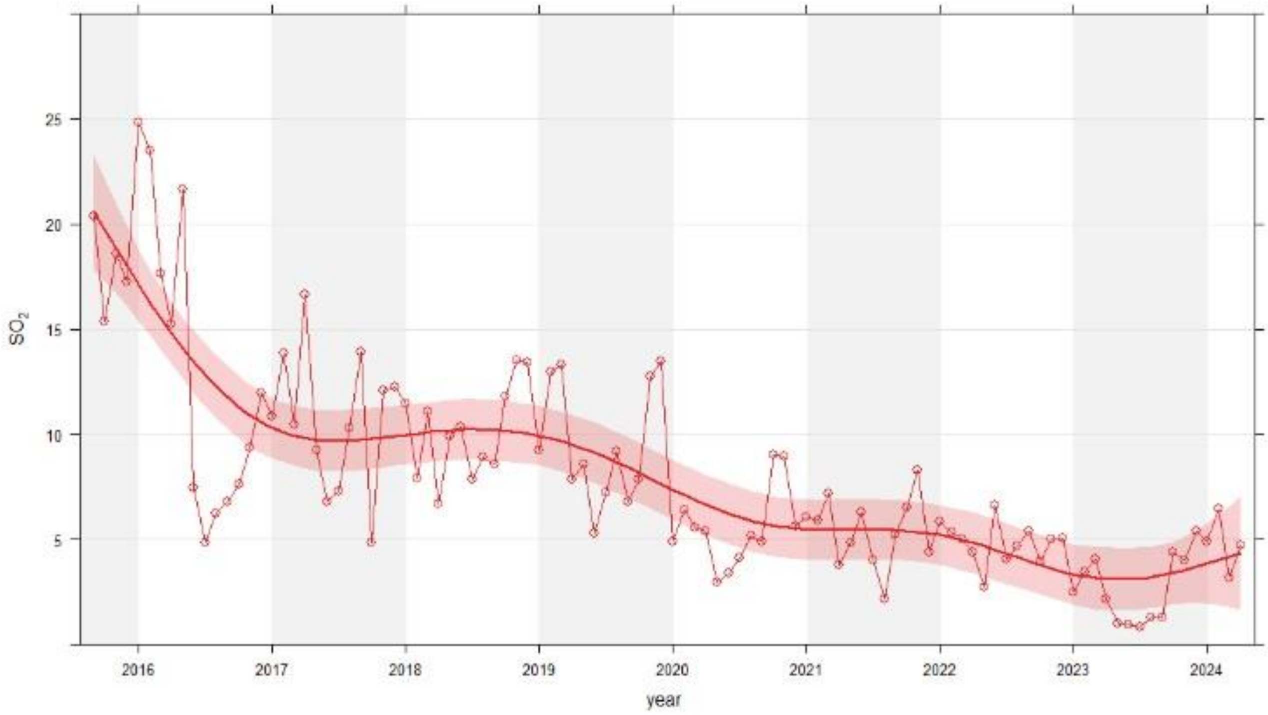


FIGURE 51: Monthly SO_2 concentrations (µg/m^3) measured at Whareroa Marae with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. The overall trend is shown at the top as -1.36 (µg/m^3) per year and the 95% confidence intervals in the slope from -1.62 – -1.11 µg/m^3/year. The ∗ ∗ ∗ show that the trend is significant to the 0.001 level.

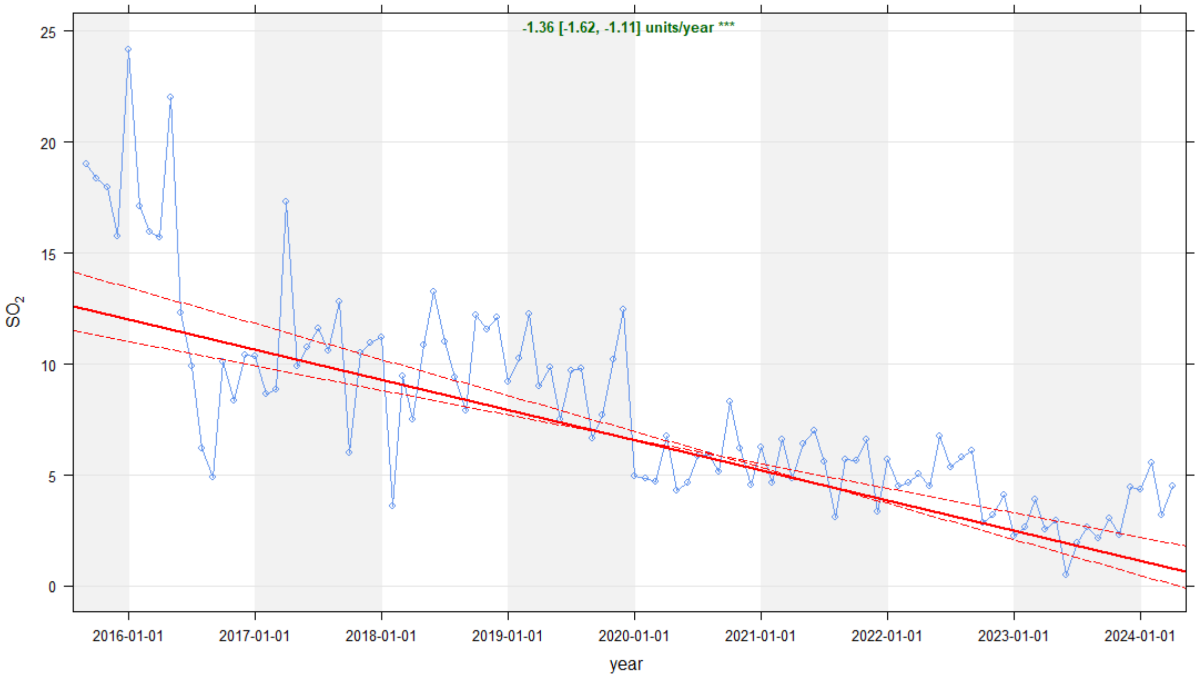
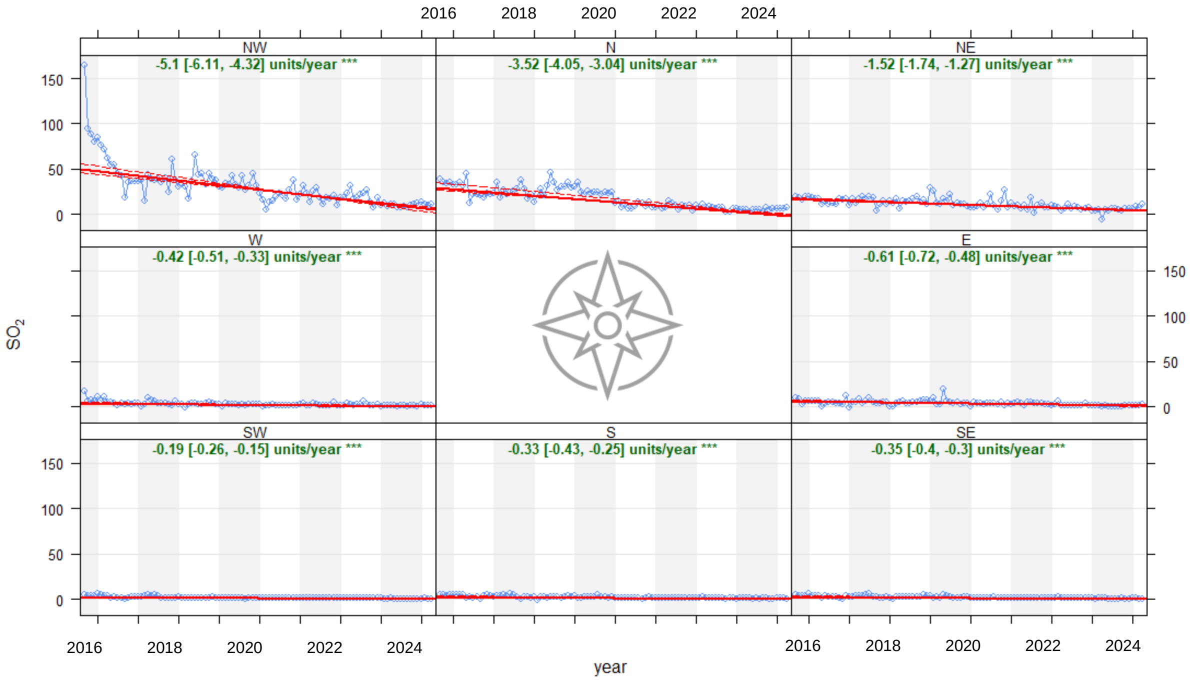


FIGURE 52: Trends in SO_2 at Whareroa Marae split by eight wind sectors. Monthly SO_2 concentrations (µg/m^3) measured at Whareroa Marae with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines).



5.4 RATA STREET

Figure 53 presents a time series plot of **1-hour** concentrations of SO_2 measured at Rata Street over the entire monitoring period for comparison with the national environmental standards for SO_2. There have been no exceedances of national standards for SO_2 since early 2019.

Figure 54 presents a time series plot of **10-minute** concentrations of SO_2 measured at Rata Street for comparison with the WHO guideline for SO_2. There have been no exceedances of the WHO 10-minute guideline for SO_2 at Rata Street since late 2019.

Figure 55 presents a time series plot of **daily** concentrations of SO_2 measured at Rata Street for comparison with the New Zealand and WHO daily guidelines. There have been no exceedances of either since late 2019.

Figure 56 presents a time variation plot of hourly SO_2 concentrations by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right), with 95% confidence intervals measured at Rata Street for the entire monitoring period December 2018 – May 2024. The hourly patterns of SO_2 concentrations at Rata Street are different to Whareroa Marae (Figure 49) and Tauranga Bridge Marina (Figure 43) peaking in the early morning (6 – 9 am) with more variance. This may be indicative of the limited dispersion of ship emissions in the early morning compared with later in the day when convective dispersion would reduce concentrations measured at Rata Street.

What is evident in all time series plots of SO_2 at Rata Street, is a significant step change reduction that appears to coincide with ships implementing Annex VI of MARPOL on 1 January 2020.

FIGURE 53: Time series plot of 1-hour SO_2 concentrations (μg/m³) measured at Rata Street: December 2018 – May 2024.

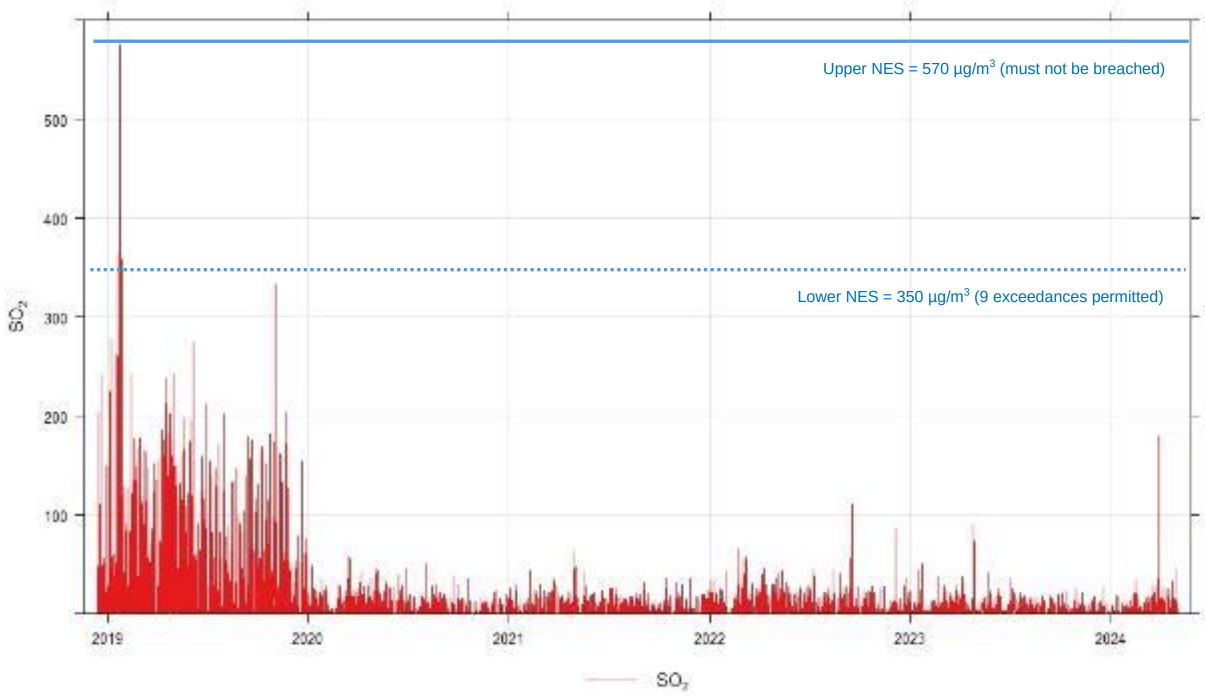


FIGURE 54: Time series plot of 10-minute SO_2 concentrations (μg/m³) measured at Rata Street: December 2018 – May 2024.

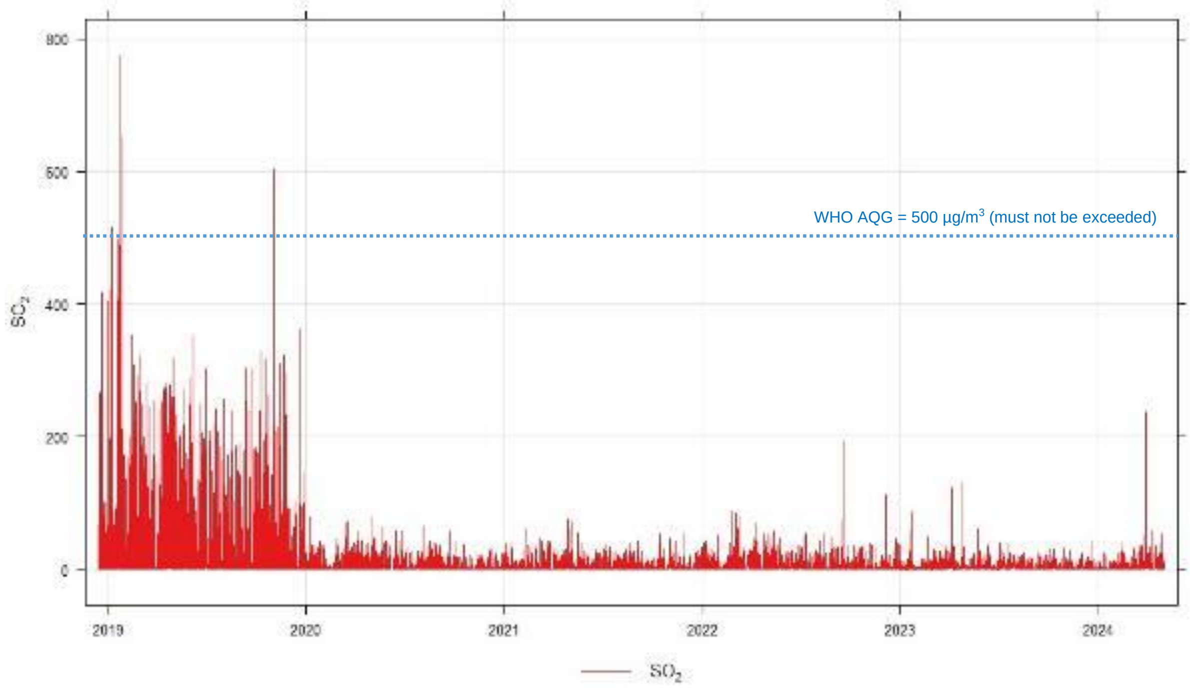


FIGURE 55: Time series plot of daily SO_2 concentrations (µg/m^3) measured at Rata Street: December 2018 – May 2024.

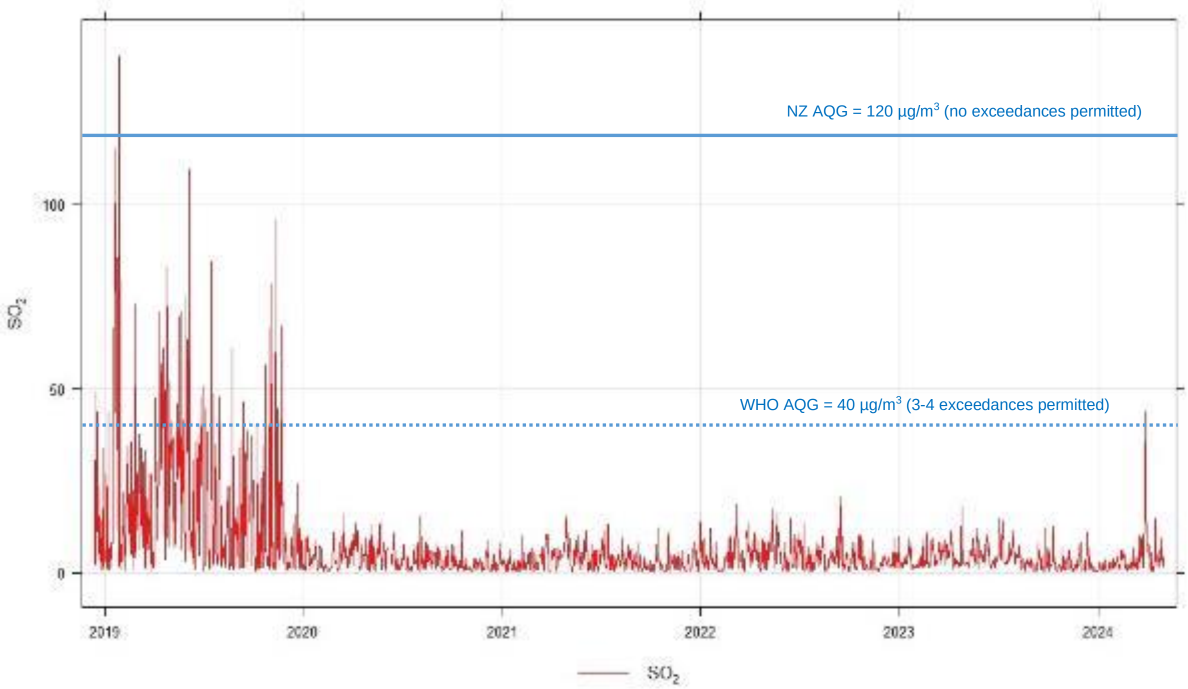
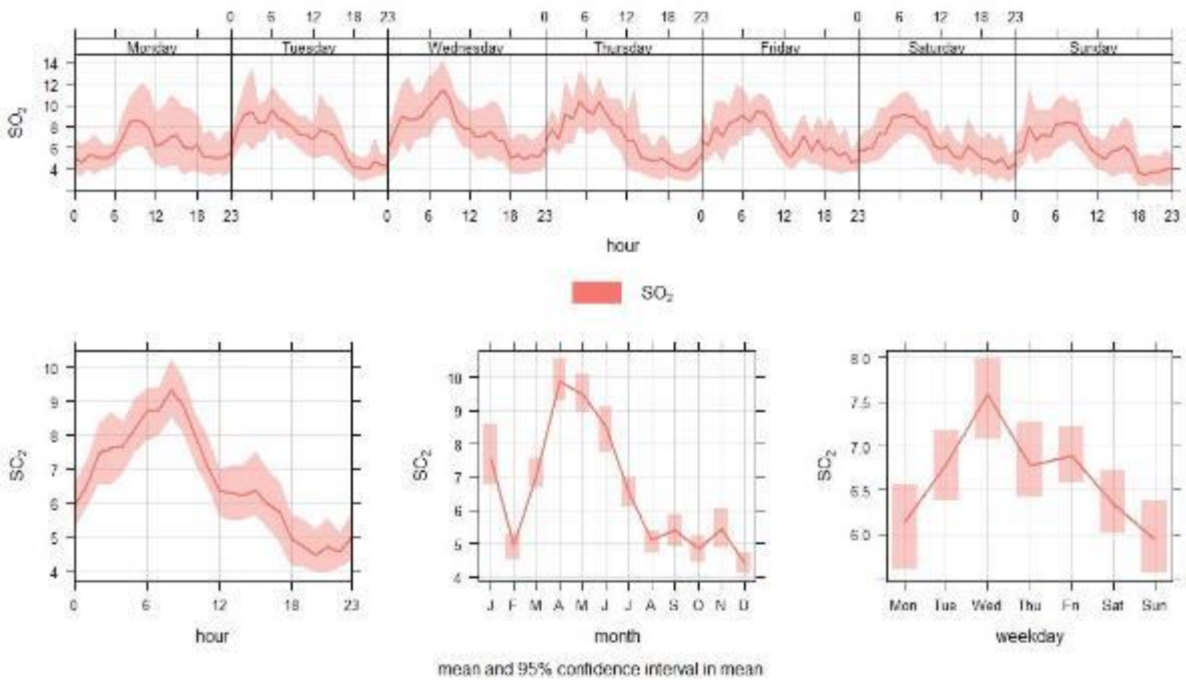


FIGURE 56: Mean hourly SO_2 concentrations (µg/m^3) with 95% confidence intervals measured at Rata Street by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): December 2018 – May 2024 (5+ years).



5.5 DISCUSSION – SO_2

The long-term monitoring record from Totara Street shows a clear, and significant, reduction in peak (short-term) levels of SO_2 over the period 2007 – 2024 (refer Figure 38 and Figure 39).

ESR (2023) noted the significant reduction in short-term SO_2 concentrations in early January 2020 at all monitoring locations in the Mount Maunganui Airshed coincided with the introduction of MARPOL Annex VI which mandated reductions in emissions of SO_2 from ships. However, ESR (2023) also noted a clear difference in the time-series records of short-term levels of SO_2 measured at Whareroa Marae and Tauranga Bridge Marina between 2019 and 2022 and those measured at other monitoring locations in the Mount Maunganui Airshed.

Analysis of long-term trends by wind direction (Figure 52) supports source/s to the northwest of Whareroa Marae have also significantly reduced SO_2 emissions. This is most likely the adjacent fertiliser manufacturer; Ballance Agri-Nutrients Ltd report reductions in average and maximum SO_2 emissions associated with key plant improvements after 2016 as shown in Figure 57.

FIGURE 57: Ballance Agri-Nutrients Ltd plot of maximum (blue) and average (green) monthly SO_2 emissions (kilograms per hour) coinciding with changes to operation and plant 2014 - 2020. [Source: Ballance Agri-Nutrients Ltd]

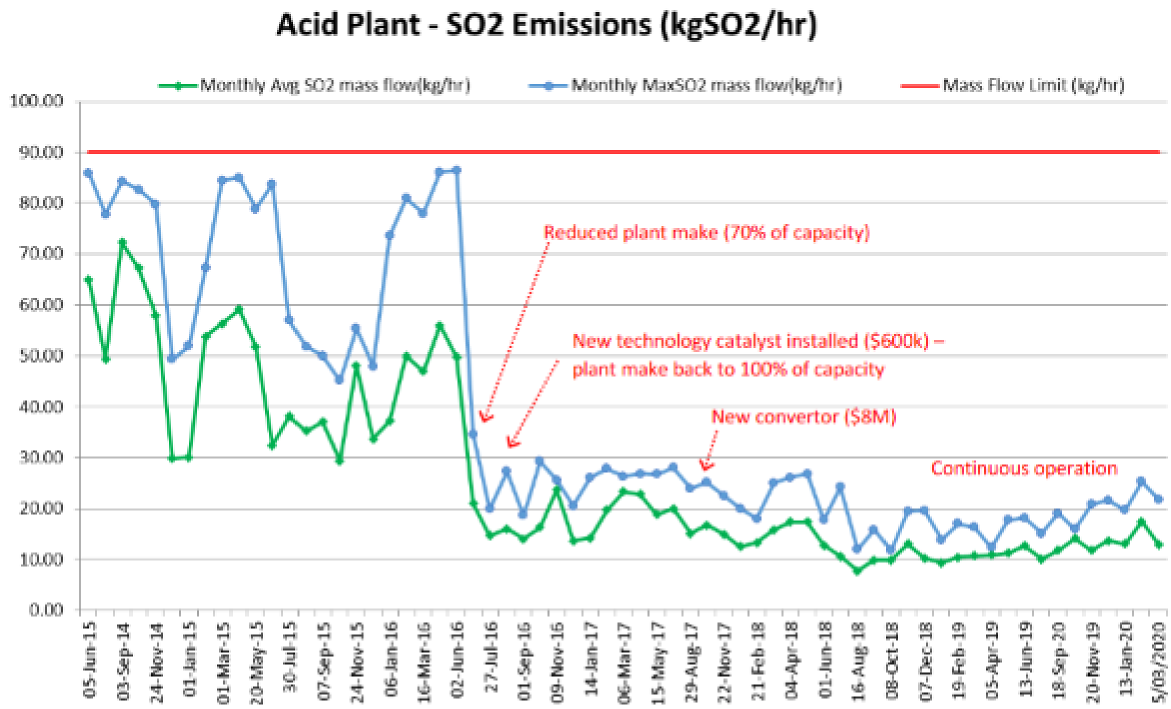


Figure 58 presents annual polar plots (pollution roses) of **hourly SO_2** concentrations measured at Whareroa Mare as a function of wind direction for the years 2016 - 2023. This shows that, whilst concentrations have significantly reduced over the years, the adjacent fertiliser works continues to be a significant influence on short-term concentrations of SO_2 at Whareroa Marae. This is also evident by comparing a 10-minute polar plot of SO_2 for the years 2016 and 2023 (Figure 59).

However, ongoing improvements such as reduced maximum consented emission rates show that challenges remain in consistently maintaining healthy short-term levels of SO_2 in the MMA with recent company reporting (Figure 60) showing two consent limit exceedances. BOPRC is to be supported for playing a significant role in reducing the public's exposure to the adverse health effects of short-term excursions of SO_2.

FIGURE 58: Polar Plot of hourly SO_2 concentrations (µg/m^3) as a function of wind direction (from) measured at Whareroa Marae: September 2015 – May 2024 (8 years+). [NB: 2015 and 2024 partial plots only]

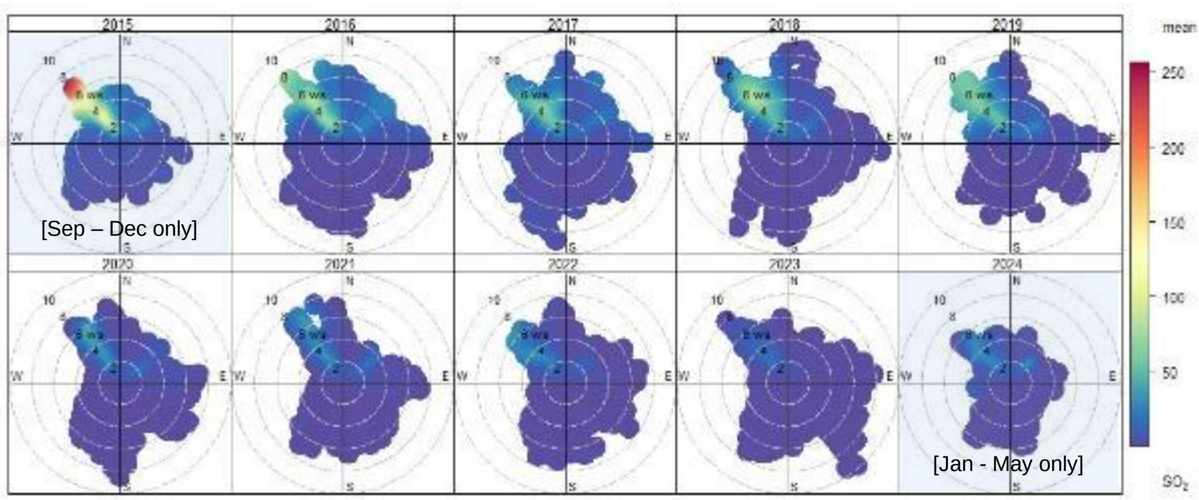


FIGURE 59: Polar Plot of 10-minute SO_2 concentrations (µg/m^3) as a function of wind direction (from) measured at Whareroa Marae: 2016 (left hand side) and 2023 (right hand side). NB: Note change in legend between plots

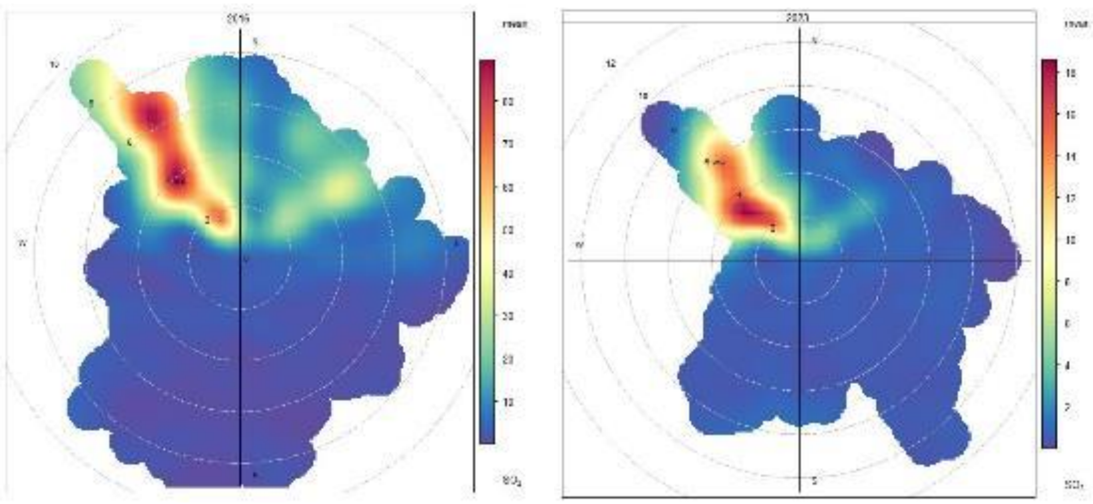
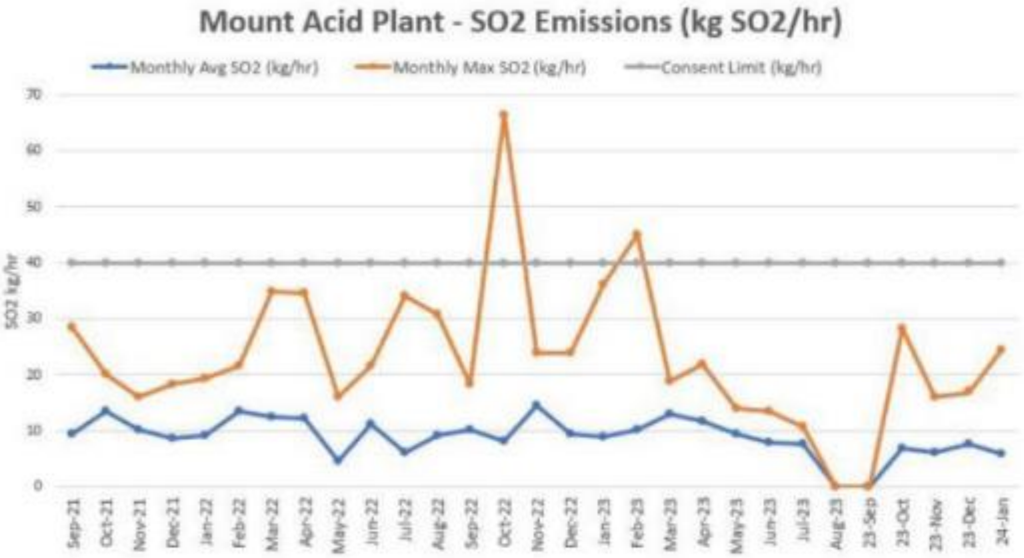


FIGURE 60: Ballance Agri-Nutrients Ltd plot of maximum (orange) and average (blue) monthly SO_2 emissions (kilograms per hour) 2021 – 2024. [Source: Ballance Agri-Nutrients Ltd]



6. NITROGEN DIOXIDE

6.1 MOUNT MAUNGANUI

Waka Kotahi NZ Transport Agency has been monitoring NO_2 at several locations near State Highway 2 in Mount Maunganui since 2007. Typically, people do not spend long periods of time at the roadside, so the data are *not* representative of wider population exposure to long-term concentrations. The monitoring is also undertaken using passive samplers which do not meet the regulatory requirements to assess compliance with air quality standards and guidelines; passive monitoring data are, on average, 33% higher than the continuous data collected using approved regulatory methods (Waka Kotahi 2023).[19] However, long-term passive data can help identify where concentrations are higher relative to other locations and can inform trend analysis.

Figure 61 presents annual concentrations of NO_2 measured at State Highway 2 locations in Mount Maunganui and Te Maunga using passive samplers for the period 2007 – 2023.

There is reasonable consistency in annual levels at all monitoring locations which supports the data being representative (of roadside locations). Figure 61 also suggests that, even allowing for a 33% over-estimate in passive monitoring compared with regulatory methods, annual *roadside* levels of NO_2 would exceed the WHO guideline in Mount Maunganui and Te Maunga.

Considering the overall trends, Figure 61 suggests a small incremental increase in annual NO_2 over the period 2007 – 2018. However, since then (2019 – 2023) there is no clear trend. It remains unclear why an elevated result was measured at one site during 2021. Waka Kotahi NZTA traffic volume data for this period show a slow, steady increase (Figure 62) over the period 2011 – 2022.

It is also relevant to note:

- Construction of the Baypark to Bayfair link, with significant traffic route changes and congestion, commenced in May 2017 and is still underway.[20]
- 2019 has only 67% (Maunganui Road) and 42% (Te Maunga Lane) valid data. Good practice requires 75% valid data for calculation of an annual average; and
- 2020 and 2021 were subject to measures introduced to combat COVID-19 which likely influenced traffic volumes.

Waka Kotahi monitoring data show a general decline in NO_2 concentrations (improved air quality) across almost all monitoring areas in New Zealand (Waka Kotahi 2022).

[19] Passive samplers rely on the pollutant diffusing into a tube where it is captured on a medium and then later analysed at a laboratory. Tubes are typically exposed for one month..

[20] https://www.nzta.govt.nz/projects/baypark-to-bayfair-link/

FIGURE 61: Long-term monitoring of annual NO_2 concentrations (µg/m³) measured near State Highway 2 in Mount Maunganui: 2007 – 2023 [Source: NZTA][21]

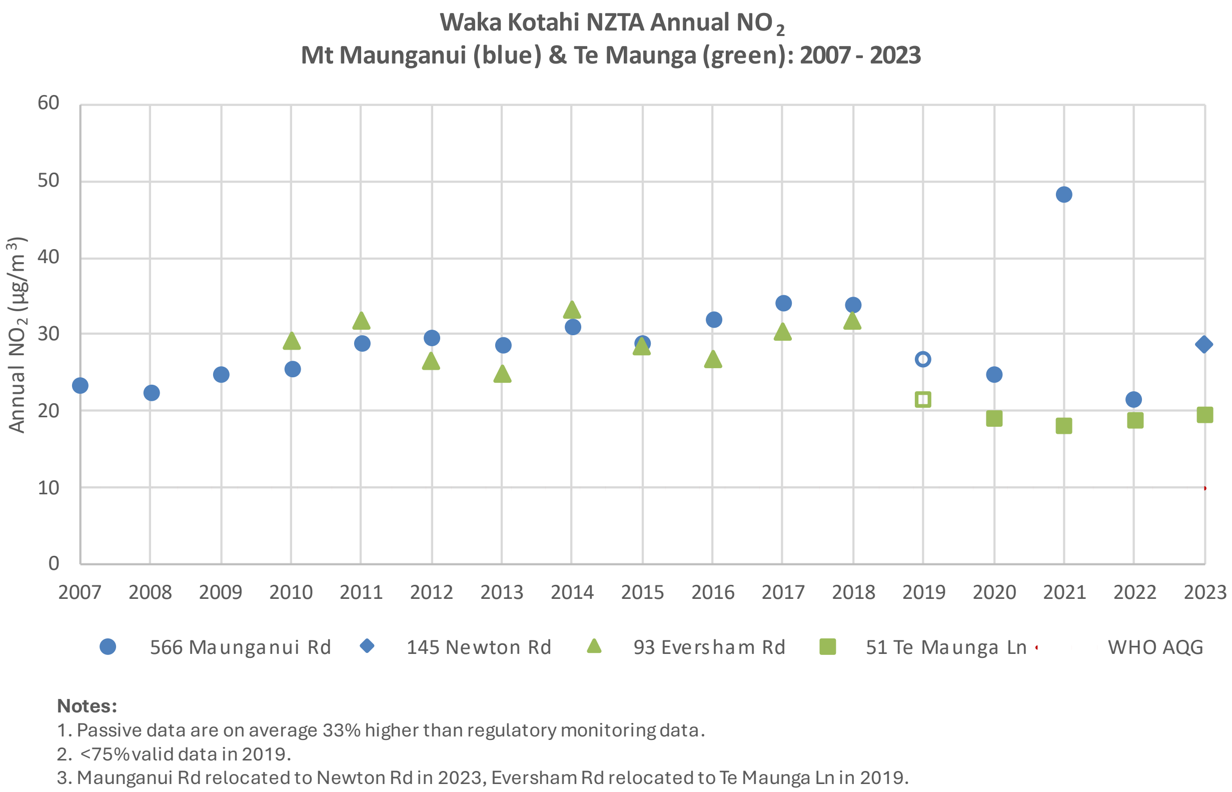
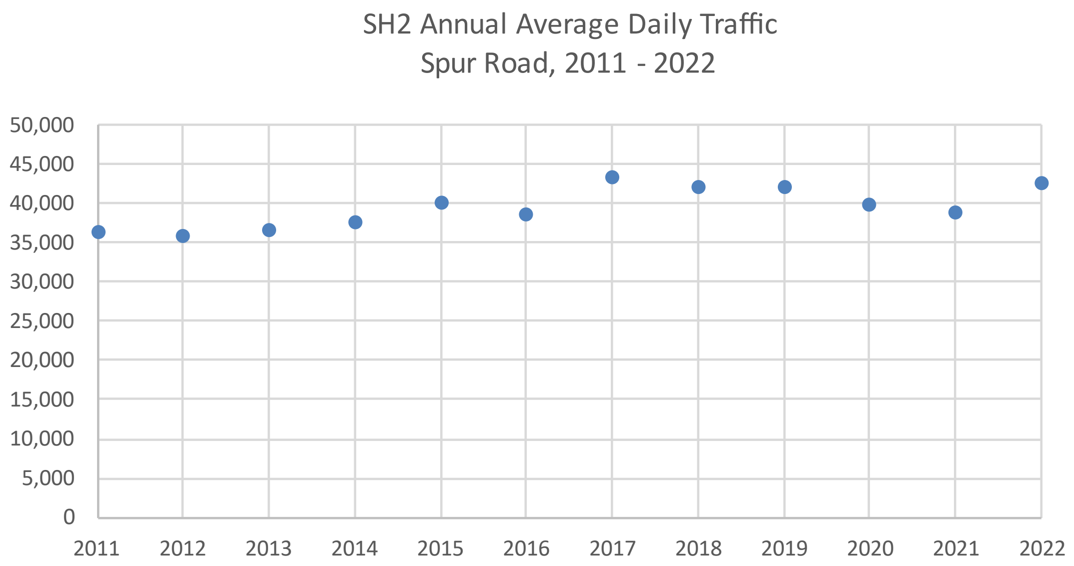


FIGURE 62: Annual Average Daily Traffic at Spur Road: 2011 – 2022 [Source: NZTA]



[21] https://www.nzta.govt.nz/assets/resources/air-quality-monitoring/docs/Ambient-air-quality-nitrogen-dioxide-monitoring-2007-2023-monthly-summary.xlsx [Accessed 22 August 2024]

6.2 WHAREROA MARAE

BOPRC commenced continuous monitoring for NO_2 at Whareroa Marae in September 2023 so there is not yet a full year of data.

Figure 63 presents a time series plot of hourly concentrations of NO_2 measured at Whareroa Marae between November 2023 and May 2024 (6 months only) for comparison with the national environmental standard (200 µg/m^3), which is equivalent to the hourly WHO AQG for NO_2. All concentrations measured were well below both criteria.

Figure 64 presents a time series plot of daily concentrations of NO_2 measured at Whareroa Marae between November 2023 and May 2024 (6 months only) for comparison with the WHO AQG (25 µg/m^3 with 3 – 4 exceedances permitted in a year). Daily levels of NO_2 exceeded the WHO AQG once on 22 September 2023. A review of the meteorological data for this day shows winds were all from due north.

Figure 65 presents a polar plot (pollution rose) for hourly NO_2 concentrations measured at Whareroa Marae to date. This suggests key sources of NO_2 (to date) are to the northwest and due north of Whareroa Marae.

FIGURE 63: Time series plot of hourly NO_2 concentrations (µg/m^3) measured at Whareroa Marae: August 2023 – May 2024.

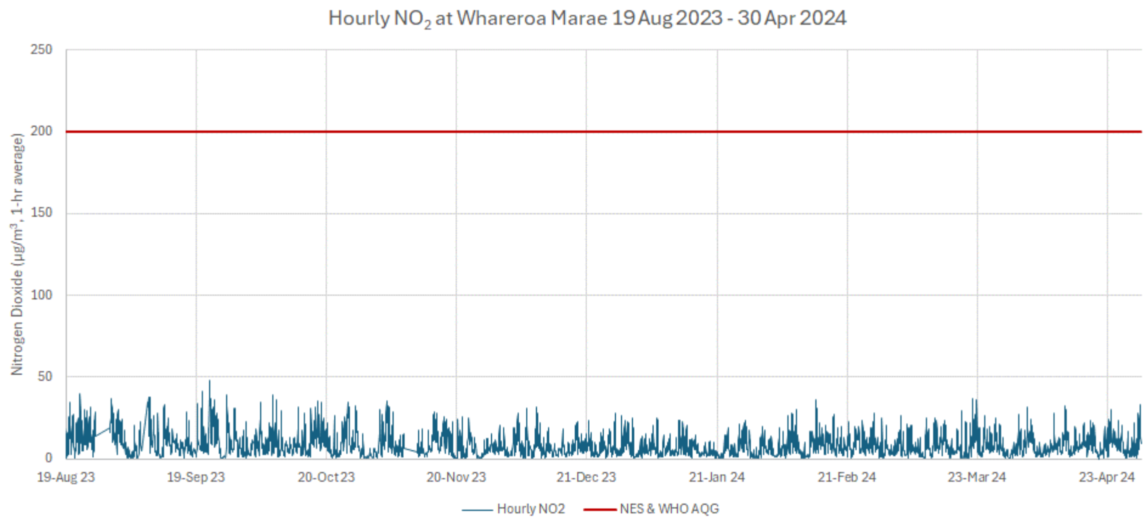


FIGURE 64: Time series plot of daily NO_2 concentrations (µg/m^3) measured at Whareroa Marae: November 2023 – May 2024.

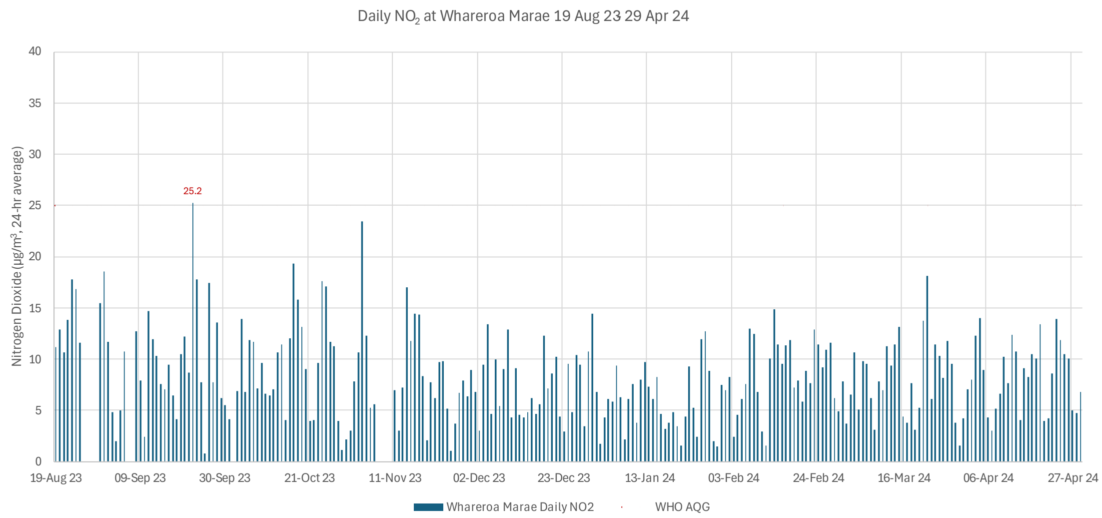
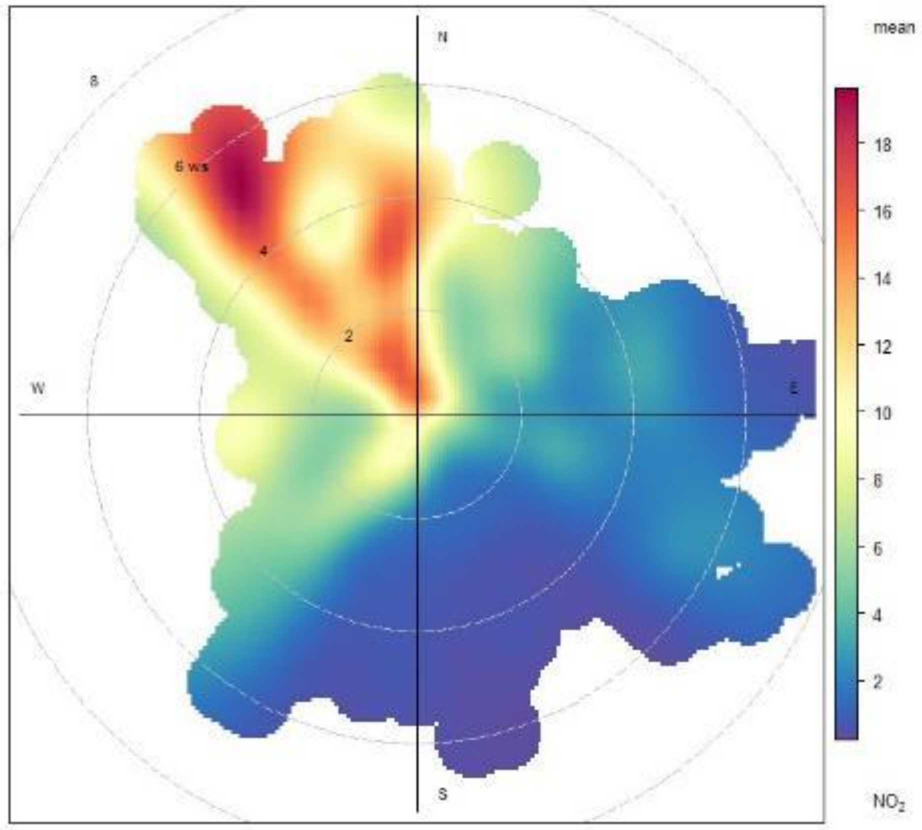


FIGURE 65: Polar Plot of hourly NO_2 concentrations (µg/m^3) as a function of wind direction measured at Whareroa Marae: August 2023 – April 2024 (8 months only).



6.3 DISCUSSION – NO_2

There are not yet sufficient data on which to make informed conclusions regarding chronic exposure to NO_2 in the Mount Maunganui Airshed and Mount Maunganui.

The inclusion of regulatory monitoring for NO_2 at Whareroa Marae, and the impending introduction to Ranch Road, are welcome additions.

NO_2 is a precursor pollutant that contributes to the formation of $PM_{2.5}$. The historically elevated levels in annual NO_2 and lack of any declining trend warrants continued monitoring and investigation.

7. REVIEW

BOPRC are to be commended for the air quality monitoring that has been, and is being, undertaken in Mount Maunganui. BOPRC have identified an issue; they are working cooperatively with industry to reduce emissions and are monitoring to see if it is effective. This is good policy in practice (i.e. closed loop).

It is further notable that clear, and significant, reduction in peak (short-term) levels of SO_2 coincides with mandated changes in regulations (i.e., MARPOL Annex VI which reduced emissions from ships) and successful emissions reductions performed by Ballance Agri-Nutrients Ltd following formal enforcement action by BOPRC. This supports BOPRC's ambient air quality monitoring for informing the public about the sources and health effects of air pollutants in Mount Maunganui.

The following discussion takes an overview of the monitoring programme in its entirety.

7.1 CHANGES IN MONITORING LOCATIONS

Section 3A of the Health Act 1956 provides the role of Toi Te Ora is to improve, promote and protect public health. This includes the health of *all* members of the community, including the overall health and wellbeing of workers, who spend part of their day exposed to air pollution within the Mount Maunganui Airshed, and residents who spend part or all of their day within the wider Mount Maunganui area. In practice Health New Zealand treats all people presenting to hospital as a result of discharges to air, noting such incidents have occurred in the past in Mount Maunganui.[22]

It is important, therefore, that BOPRC continues to provide robust, quality assured ambient air quality monitoring data from locations within the Mount Maunganui Airshed as part of its regulatory responsibility. The removal of monitoring instruments from three industrial locations will see an increased focus on the Rata Street monitoring location. This is the only remaining site that is both industrial and commercial/residential – *and* predominantly downwind of the Mount Maunganui Airshed. Typical daily (as represented by the 99^{th} percentile concentration) and annual concentrations of PM_{10} at Rata Street remain consistently elevated compared with more upwind locations (Tauranga Bridge Marina and Whareroa Marae). The impending addition of $PM_{2.5}$ monitoring at this location is welcome.

The establishment of a new monitoring site at Ranch Road (with NO_2 and SO_2 to be added in the near future) is a welcome addition and will inform residential exposure in the wider Mount Maunganui area. Similarly, the introduction of $PM_{2.5}$ and NO_2 monitoring at Whareroa Marae is welcome.

7.2 LONG-TERM TRENDS (TSP)

There are no health-based ambient criteria for TSP as it is primarily an indicator of dust nuisance. However, the long-term TSP data can provide useful context for trend analysis, especially when correlated with other pollutants such as PM_{10}. This section discusses these aspects of TSP (only).

Figure 66 presents monthly average TSP as a smoothed trend with 95% percentile confident intervals for Totara Street (red) and Whareroa Marae (grey) for the period August 2016 – May 2024. This is nearly 10 years of data. Figure 66 shows very stable monthly levels of TSP at Whareroa Marae which is at odds with the significant decline in ambient PM_{10} measured at Whareroa Marea since 2019 (Figure 18).

[22] 22 May 2017 (Balance Agri-Nutrients – SO_2), 4 May 2014 (Balance Agri-Nutrients – SO_2), 1999 (Balance Agri-Nutrients – SO_2). [Online] 8 March 2018 (Port of Tauranga - undetermined). [Online]

Figure 67 presents monthly average TSP (red), PM_{10} (blue) and $PM_{2.5}$ (green) concentrations with 95% percentile confident intervals for Totara Street for the five years ending 31 July 2023. This plot appears to highlight the unusual nature of the COVID-19 social restrictions in early 2020, as the ratio of PM_{10} to TSP changed from an average of 81% (all years) to 95% (January – April 2020) i.e., there was a reduction in the larger size fractions of particulate. This period most likely coincides with a unique reduction in logs going through the Port.

The different trends in long-term TSP concentrations at Totara Street (no clear trend) and Whareroa Marae (very stable levels) likely reflect localised differences in meteorology. BOPRC noted significant changes in local wind flows at the Totara Street site due to the establishment of a container terminal adjacent to the monitoring station in 2017 (BOPRC 2023). This is evident in the annual wind roses for Totara Street which show significant variation (Figure 68), variation that is not evident in the annual wind roses for Whareroa Marae (Figure 8).

FIGURE 66: Monthly total suspended particulate (TSP) concentrations (μg/m³) measured at Totara Street (red) and Whareroa Marae (grey) with smoothed trend line and 95% confidence intervals for fit: August 2016 – May 2024.

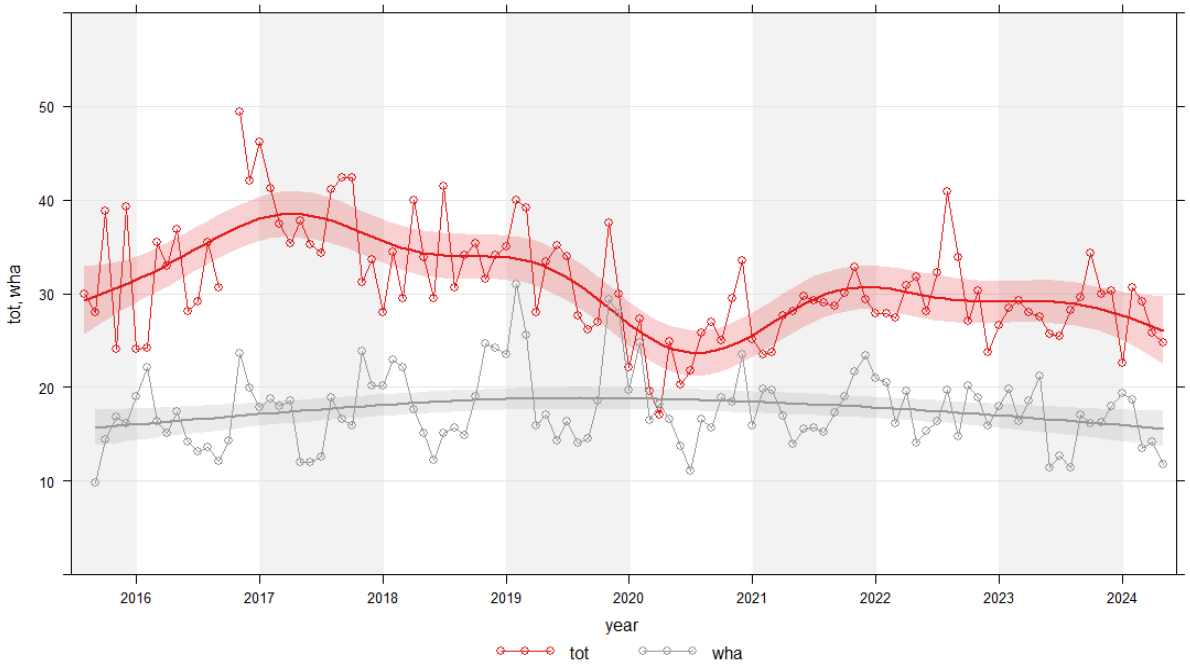


FIGURE 67: Monthly TSP (red), PM_{10} (blue) and $PM_{2.5}$ (green) concentrations (µg/m^3) measured at Totara Street with smoothed trend line and 95% confidence intervals for fit: August 2018 – May 2024.

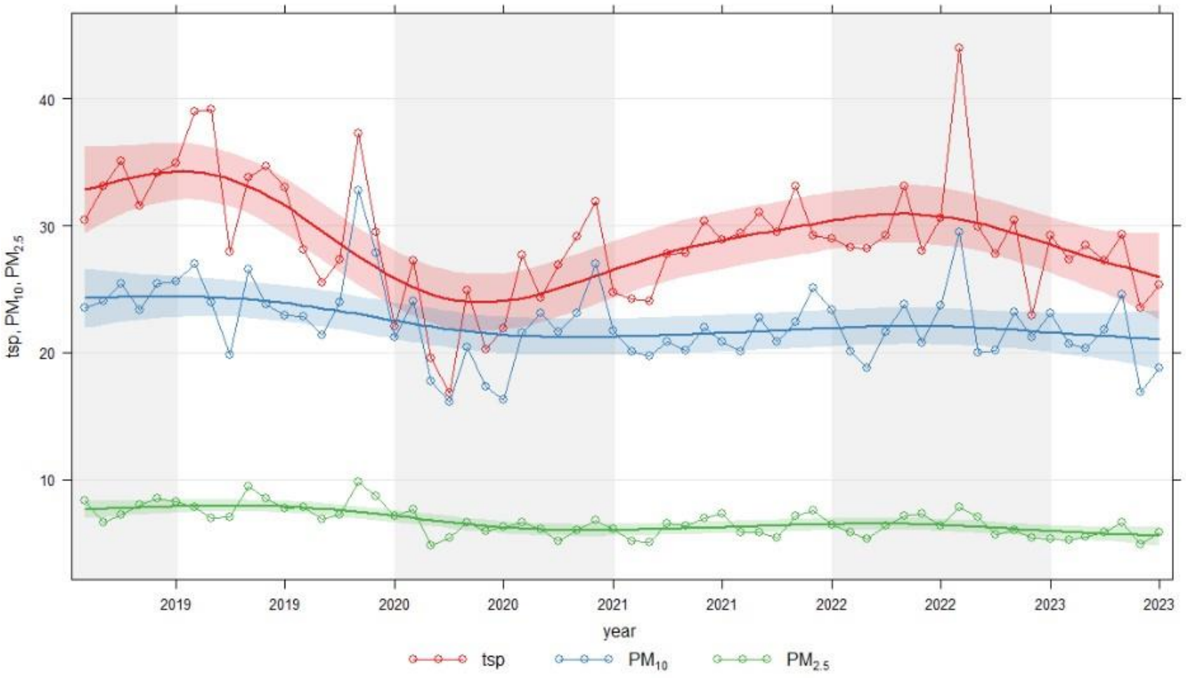
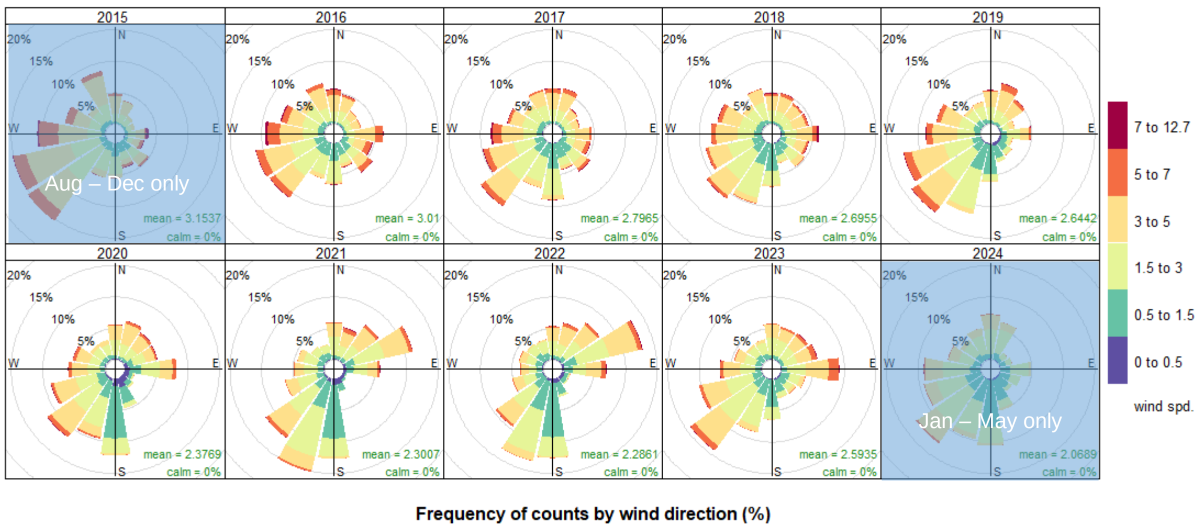


FIGURE 68: Wind rose of 10-minute wind speed (m/s) and wind direction measured at Totara Street: August 2015 – May 2024. [NB: 2018 and 2024 partial plots only]

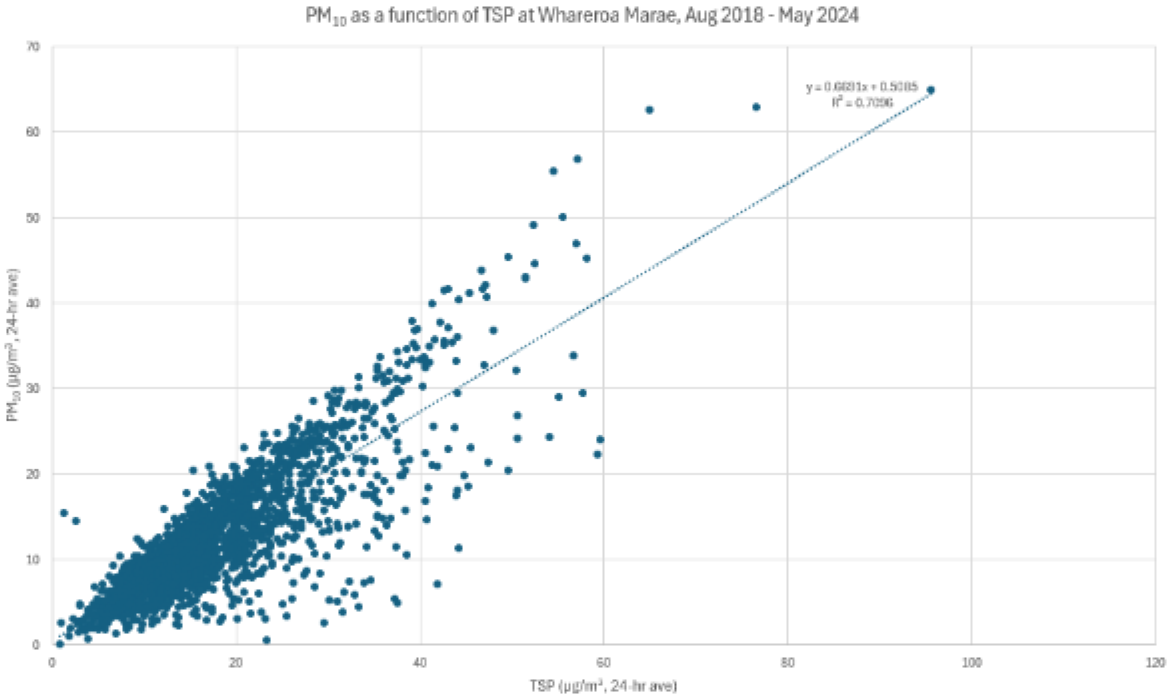


7.3 SOURCE APPORTIONMENT

It is understood that BOPRC is collaborating with the Port of Tauranga Ltd on source apportionment research of particulate matter within the Mount Maunganui airshed and wider area.[23] This research will be a welcome addition.

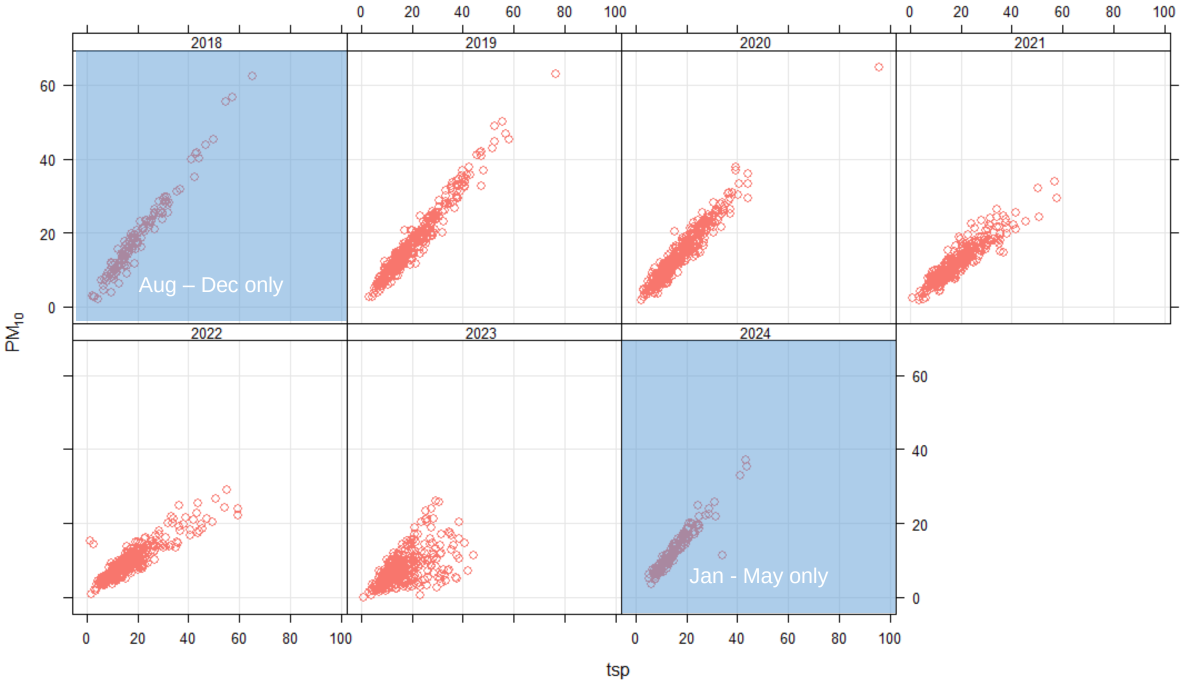
Figure 69 is a scatterplot of daily PM_{10} as a function of TSP measured at Whareroa Marae for all data to date. Figure 70 presents the same data by year. There is a strong correlation in all years except 2023, suggesting a prevalence of industrial sources. The lack of a correlation in 2023 *may* signal the removal of industrial sources contributing to PM_{10}, however, further data are required before robust conclusions can be drawn.

FIGURE 69: Daily PM_{10} concentrations (µg/m^3) as a function of TSP measured at Whareroa Marae: August 2018 – May 2024 (5 years+). [NB: 2018 and 2024 partial plots only]



[23] Personal comms. S Iremonger, BOPRC. 20 August 2024.

FIGURE 70: Annual polar plots of daily PM_{10} concentrations (μg/m³) as a function of TSP measured at Whareroa Marae: August 2018 – May 2024 (5 years+). [NB: 2018 and 2024 partial plots only]



7.4 LOW-COST SENSORS

In February 2024, BOPRC installed 11 low-cost (Clarity) sensors at residential locations as shown in Figure 71 to provide real-time air quality information for residents.[24]

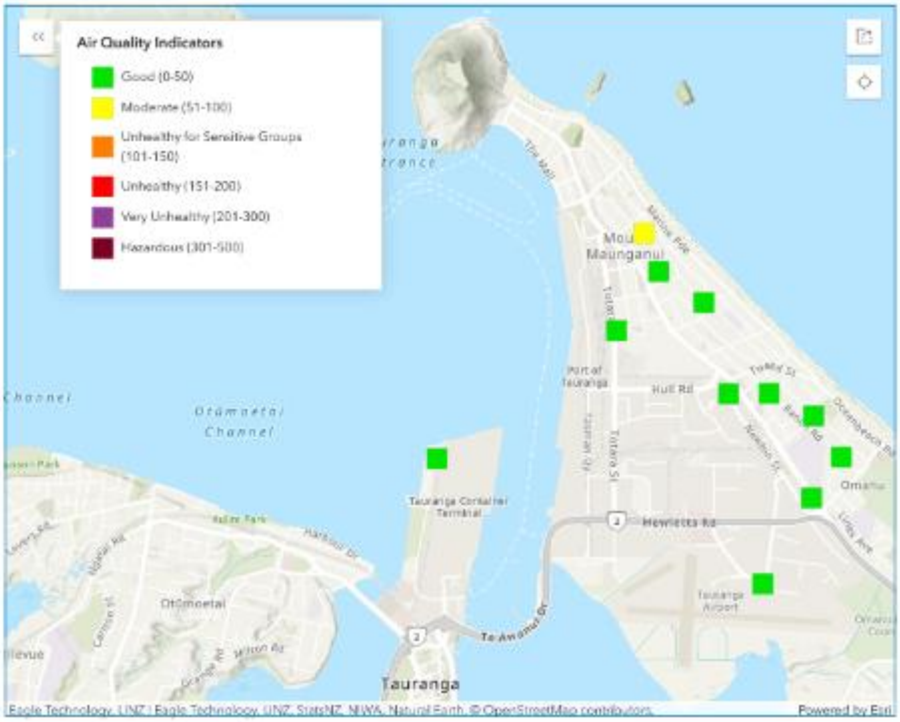
Most commercially available low-cost sensors are calibrated in a laboratory and have had limited validation and testing in real-world environments or comparison with reference methods. Data quality is unknown and may vary from sensor to sensor in different weather conditions and pollution environments (USEPA 2022). This can limit credibility regarding accuracy.

BOPRC states that the sensors provide an indication of air quality as follows (BOPRC 2024):[25]

> *The displayed reading is established from the measurement of fine particles 10 or 2.5 microns or less — shortened to PM_{10} and $PM_{2.5}$ – and nitrogen oxide (NO_2).*
>
> *The air quality reading is an indication of air quality at that time. The higher the number, the greater the level of air pollution and the greater the health concern. For example, a reading of 50 or below would represent good air quality, while a reading over 300 would represent hazardous air quality.*
>
> *Guidance is provided to manage your health and adjust outdoor activities in response to higher pollutant levels. Use your own judgement and consult a medical practitioner if severe or prolonged negative health effects are present.*
>
> ***Note:** index and health indicators are referenced from the US Environmental Protection Agency*.

[24] Data from BOPRC reference monitors is quality assured and typically only available after more than a month.
[25] https://www.boprc.govt.nz/environment/air/mount-maunganui-residential-air-quality/

FIGURE 71: Air Quality indicator monitoring as at 7 pm, 22 August 2024. [Source: BOPRC website]



The USEPA Air Quality Index is a numeric scale for reporting air quality that describes how clean or polluted the air is at a given location, and any associated health effects that may result from exposure to the air (USEPA 2022). An AQI value of 100 generally corresponds to an ambient air concentration equal to the level of the short-term (US) national ambient air quality standards (NAAQS) for protection of public health. AQI values at or below 100 are generally considered to be satisfactory.

However, there is no supporting technical information to support independent verification of the relevance of the USEPA AQI with respect to the Clarity sensors.[26] It is further unclear *which* USEPA AQI is being referred to; the NAAQS for $PM_{2.5}$ were revised on 7 February 2024 with subsequent updates to the USEPA AQI taking effect from May 2024 (USEPA 2024).[27]

All US NAAQS for PM are significantly higher than New Zealand NES and WHO AQG and not particularly health protective. By way of comparison:

- the US daily NAAQS for $PM_{2.5}$ (35 µg/m^3) is more than double the WHO daily AQG (15 µg/m^3);
- the US daily NAAQS for PM_{10} (150 µg/m^3) is three times the NZ daily NES (50 µg/m^3).

BOPRC states (Appendix A):

> *If levels become elevated at any of the Clarity sites, Council will consider installing additional NESAQ compliant monitors.*

Given the disparity in criteria, this suggests that if the sensors indicate potentially high levels of these contaminants, then levels will be *very* high compared with New Zealand NES and WHO AQG.

[26] Manufacturer specifications of Node-S Clarity PM and O_2 sensor make no reference to USEPA air quality index or provide any calibration information.
[27] https://www.epa.gov/system/files/documents/2024-02/pm-naaqs-air-quality-index-fact-sheet.pdf

BOPRC further notes:

> *Air sensors can fill in a gap in our network by providing an indication of air quality, however these are not regularly calibrated and therefore we anticipate are not quite as accurate.*
>
> *While air sensors are useful for providing general information about air quality, they do have limitations. Occasionally they could report questionable data points and give a bias that may result in data that systematically over or underestimates the actual pollutant concentration.*

It is understood that BOPRC have co-located a Clarity sensor with the Rata Street regulatory monitoring site which should provide valuable information for calibration purposes.[28] Until such time as supporting data (for example, details of pre-deployment calibration, site commissioning, co-location with regulatory monitoring, maintenance, etc.) are available, the Clarity sensors will suffer limited credibility and their data should be viewed with caution.

[28] Personal comms S Iremonger, BOPRC. 20 August 2024

REFERENCES

Bay of Plenty Regional Council, 2023. *Ambient Air Quality Data Update 2023.* Whakatane. July. [Online]

BOPRC, 2011. *Mount Maunganui ambient sulphur dioxide monitoring*. Environmental Publication 2011/03. [Online].

Carslaw, D. 2019. *The openair manual - opensource tools for analysing air pollution data*. University of York and Ricardo Energy & Environment. Version 12th November 2019. [Online]

Chappell, P. 2013. *The Climate and Weather of Bay of Plenty*. 3rd Edition. NIWA Science & Technology Series. [Online]

ESR, 2023. *Mount Maunganui Air Quality Monitoring Review 2022.* Prepared for Toi Te Ora Public Health. 1 June 2023. [Online]

Guo L-C., et al., 2016. The washout effects of rainfall on atmospheric particulate pollution in two Chinese cities. *Environ Pollut.* Aug: 215:195-202. doi:10.1016/j.envpol.2016.05.003

International Agency for Research on Cancer (IARC), 2013. IARC: Outdoor air pollution a leading *environmental cause of cancer deaths*. [Online: www.iarc.who.int]

Kuschel G., Metcalfe J., Sridhar S., Davy P., Hastings K., Mason K., Denne T., Berentson-Shaw J., Bell S., Hales S., Atkinson J., and Woodward A., 2022. Health and Air Pollution in New Zealand 2016 (HAPINZ 3.0). Report prepared for Ministry for the Environment, Ministry of Health, Te Manatū Waka Ministry of Transport and Waka Kotahi NZ Transport Agency. Auckland. New Zealand. March. [Online: https://ehinz.ac.nz]

Ministry for the Environment (MfE), 2002. Ambient Air Quality Guidelines 2002 Update. Wellington. [Online: www.environment.govt.nz]

MfE, 2014. *2011 users' guide to the revised National Environmental Standards for Air Quality*. Updated 2014. Ministry for the Environment. Wellington. September.

MfE, 2016. *Good Practice Guide for Assessing and Managing Dust*. Wellington. November. [Online]

Orellano *et al.,* 2021. Short-term exposure to sulphur dioxide (SO_2) and all-cause and respiratory mortality: A systematic review and meta-analysis. *Env Int*. Vol 150. May. 2021. 106434. https://doi.org/10.1016/j.envint.2021.106434

Pacific Air & Environment (PAE), 2009. *National Assessment of Industrial Sulphur Dioxide Emission in NZ*. Report for Ministry for the Environment. 25 March 2009.

Port of Tauranga Ltd, 2020. *POTL - Integrated Annual Report 2020*. [Online]

Rasmussen K., et al., 1974. Global Emissions and Natural Processes for Removal of Gaseous Pollutants. *Water, Air & Soil Pollution*. Vol 4:33-64.

Sheppard D, Saisho A, Nadel JA, Boushey HA. Exercise increases sulfur dioxide-induced bronchoconstriction in asthmatic subjects. *Am Rev Respir Dis*. 1981 May;123(5):486-91. doi: 10.1164/arrd.1981.123.5.486. PMID: 7235370.

Statistics New Zealand, 2020. *Where we live versus where we work.* June 16. [Online]

United States Environmental Protection Agency (USEPA), 2016. *Integrated Science Assessment for Oxides of Nitrogen—Health Criteria*. EPA/600/R-15/068. [Online: www.federalregister.gov]

USEPA, 2020. *Integrated Science Assessment for Particulate Matter*. [Online: www.epa.gov]

USEPA, 2022. *Enhanced Air Sensor Guidebook.* Office of Research and Development Center for Environmental Measurement and Modeling. EPA/600/R-22/213. September. [Online]

USEPA, 2024. *Particulate matter National Ambient Air Quality Standards Air Quality Index Factsheet*. 24 May. [Online]

Waka Kotahi NZ Transport Agency, 2023. *Ambient Air Quality (Nitrogen Dioxide) Monitoring Programme.* Annual Report 2007-2021. Prepared by Tonkin + Taylor Limited. December. Version 1.0. [Online]

Wood, S. N. (2006). *Generalized Additive Models: An Introduction with R*. Chapman and Hall/CRC (cit. on pp. 61, 216).

Worksafe, 2024. *Applying the workplace exposure standards*. [Online]

World Health Organisation (WHO), 2000. *Air Quality Guidelines for Europe*. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: https://www.who.int/]

WHO, 2006. *Air Quality Guidelines Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: https://www.who.int/]

WHO, 2013. *Review of evidence on health aspects of air pollution – REVIHAAP Project -Technical Report*. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: www.euro.who.int]

WHO, 2016. *WHO Expert Consultation: Available evidence for the future update of the WHO Global Air Quality Guidelines (AQGs)*. Meeting Report. Bonn. Germany. 29 Sep – 10 Oct 2015. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: www.euro.who.int]

WHO, 2021. WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva. Switzerland. [Online: www.who.int]

Zheng et al., 2021. Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency department visits and hospital admissions due to asthma. A systematic review and meta-analysis. *Env Int*. Vol 150. February 2021. 106435. https://doi.org/10.1016/j.envint.2021.106435

APPENDIX A: BOPRC MEMO RE CHANGES TO AIR QUALITY MONITORING NETWORK

MEMORANDUM

To:	Rachael Zame
	Special Counsel for Cooney Lees Morgan
From:	Karen Parcell
	Team Leader Kaiwhakatinana
	Shane Iremonger
	Team Leader Science
Date	8 July 2024
Subject:	**Review of Air Monitoring Locations with the Mount Maunganui Airshed**

Background

1. The suitability of the Rail Yard South monitor for assessment of compliance with the PM_{10} standard of the National Environmental Standards for Air Quality (**NESAQ**) was extensively canvassed by the Environment Court[29].

2. During the proceedings, some parties raised concerns with the suitability of the monitor in this location particularly as 16 out of 20 exceedances (measured up to November 2019) were recorded at this site. The monitor is located on industrial land in close proximity to a range of dusty activities, and some distance from any residential area.

3. A key matter of contention was whether people needed to be present on a 24-hour a day basis (for example in a residential dwelling) for the PM_{10} Standard to apply. The Court found that in order to be considered appropriate for NESAQ compliant monitoring, a monitor had to be located where people could be present for 24 hours.

4. Although no party raised concerns with the location of the Totara Street monitor, the Court extrapolated its concerns with Rail Yard South to Totara Street as it is also located in the middle of an industrial area and is even further away from residential zones.

5. The Court noted that while it cannot direct Council to review its monitoring programme or locations, it strongly recommended that Council investigate and assess the suitability of these monitors, particularly in relation to residential areas.

Proposed monitoring programme

6. Air quality monitors come at a cost (about $500,000 per year for the Mount Maunganui network), therefore Council regularly assesses its monitoring network to ensure it provides valuable information. Council staff recently assessed all monitors in the region and made changes to the network.

[29] [205-220] Environment Court Decision No. [2023] NZEnvC 001

7. When the monitoring programme was expanded in 2018 it initially ringfenced the Port of Tauranga which was believed to be the main source (or sources) of particulates. Council now has a better understanding of particulates in the Mount and can adjust the monitoring coverage accordingly.

8. There are currently four particulate (PM_{10}) monitoring sites in the Tauranga area that comply with the requirements of the NESAQ. Three monitoring sites are within the Mount Maunganui Airshed (**MMA**) boundary, as well as a new site at Ranch Road being located outside the MMA boundary but within the residential area. Some sites also measure other contaminants such as sulphur dioxide, volatile organic compounds and nitrogen oxides. Three sites exclusively monitor volatile organic compounds and these are not discussed in this report.

9. A map showing the location of all monitoring sites (and contaminants monitored) is attached.

10. Two monitoring sites, including Rail Yard South, have been removed and the reasons for these removals are discussed below. Rail Yard South has been replaced with Totara Street Rail Crossing monitoring site which is 110 metres to the northeast of the previous site.

11. The three "residential" sites, Whareroa Marae, Rata Street, and a new site at Ranch Road, measure both $PM_{10,}$ and also $PM_{2.5}$. This smaller, more harmful fraction of particulates is not currently considered to be a significant issue within the MMA (compared to airsheds with residential burning sources such as Rotorua). However, Council will monitor to ensure that this is the case, particularly in the residential areas.

12. Council attempted to find a monitoring site within the residential area but despite several attempts, was unsuccessful. The value of land is high and at a premium, and monitors take up valuable space. Council has installed the Ranch Road monitor on Council roadside reserve land on the northern boundary of Mount Maunganui College and Ōmanu School where it is also close to dwellings.

13. Council has also installed **Clarity** monitors around the residential area of Mount Maunganui (outside the MMA boundary) to determine indicative levels of PM_{10}, $PM_{2.5}$, and nitrogen dioxide in residential areas. These monitors are not NESAQ compliant but will indicate potentially high levels of these contaminants. If levels become elevated at any of the Clarity sites, Council will consider installing additional NESAQ compliant monitors. The Clarity monitoring sites are a new addition to the monitoring network therefore have not been reviewed at this early stage.

14. In addition to dust and particulate monitors, all sites include a full suite of meteorological instrumentation including ambient temperature, wind speed, wind gust, wind direction, relative humidity, rainfall, and atmospheric pressure.

Removed sites

DeHavilland Way

15. Previously measured PM_{10} but was removed in July 2023. This monitor experienced a number of false positives due to a truck-wash being located only a few metres away. The monitor was also due to be replaced with an industry funded monitoring site for compliance with Rule AREA2-R1 (the interim permitted activity rule or IPAR).

Rail Yard South

16. This site was previously monitoring PM_{10}. In late 2022 a sinkhole opened up next to the monitor. This placed the monitor at risk therefore Council removed it in January 2023. An alternative site was found at Totara Street Rail Crossing, discussed below.

New sites

Totara Street Rail Crossing (moved from Rail Yard South)

17. The monitor from the Rail Yard South site was moved to a new site on Council roadside reserve land across from Dominion Salt on Totara Street. It monitors TSP and $PM_{10.}$

Ranch Road

18. Ranch Road is a new 'super site', installed in 2024 and monitoring TSP, PM_{10} and $PM_{2.5}$. This site is located on Council reserve land in close proximity to residential areas.

Existing sites

Tauranga Bridge Marina

19. Installed in 2019. Currently measuring total suspended particulates (**TSP**) and PM_{10}. No changes have been made to this site. A slight positional change has been forced on Council due to the construction of protection works for the Marina. This will result in the site being repositioned 15m to the east of the current location.

Rata Street

20. This site has been in place since 2019. Currently monitoring TSP and PM_{10} and has been expanded to include $PM_{2.5}$.

Tauranga Bridge Marina

21. Installed in 2019. Currently measuring TSP and PM_{10}. No changes have been made to this site. A slight positional change has been forced on Council due to the construction of protection works for the Marina. This will result in the site being repositioned 15 metres to the east of the current location.

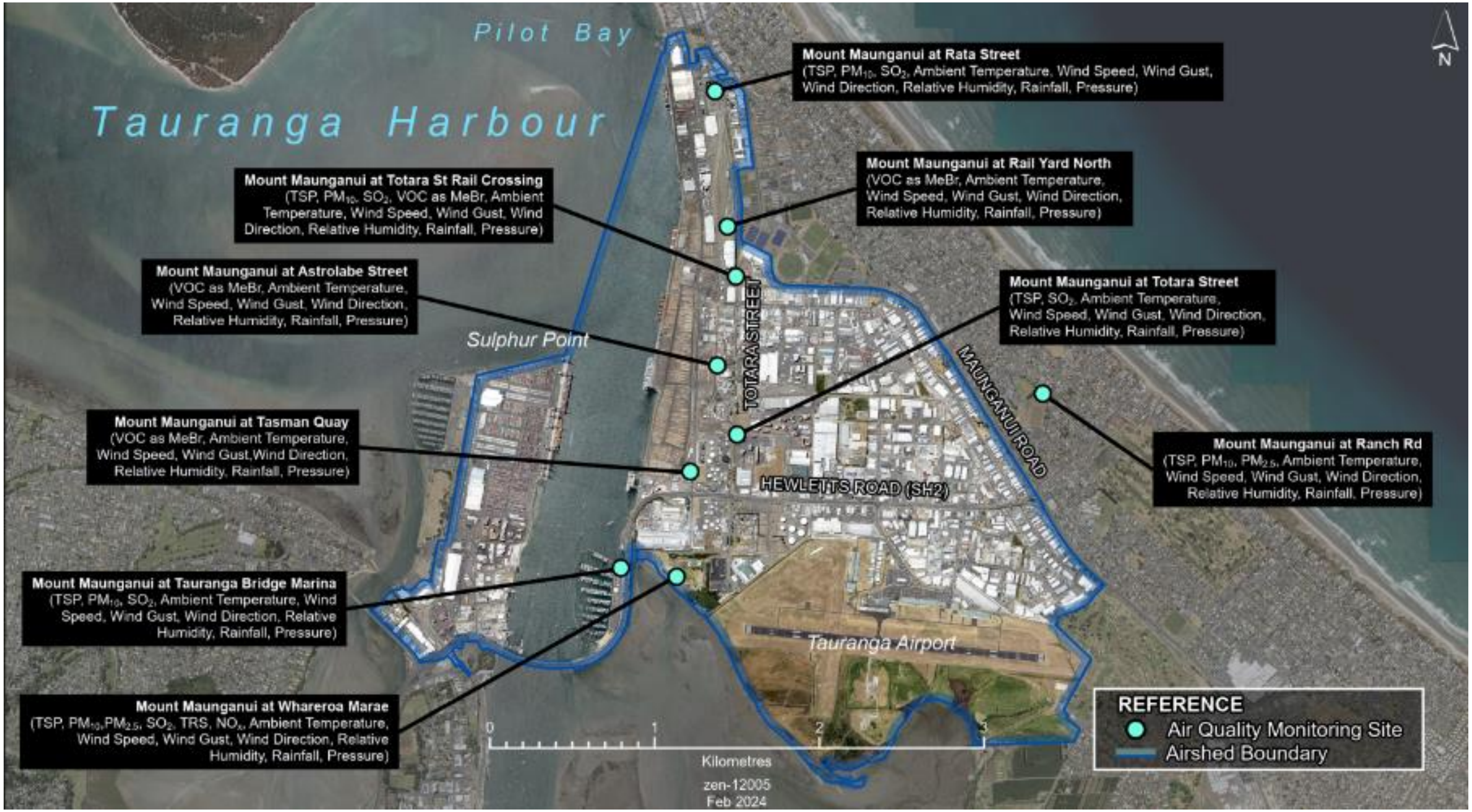
Totara Street

22. Has been monitoring PM_{10} and $PM_{2.5}$ since August 2018 and TSP since August 2015. Council recently removed the PM_{10} monitor but this site continues to monitor TSP.
23. This site provides long term data however the neighbouring site is used for container storage. These containers are stacked to heights that compromise the data collected. This monitoring site remains in place but Council is considering its long-term usefulness.

Whareroa Marae

24. This monitoring site has been in place since 2019. No changes have been made to this site which is monitoring TSP, PM_{10} and $PM_{2.5}$

Map of Mount Maunganui Airshed monitoring sites.



APPENDIX B: TABULATED SUMMARY MONITORING RESULTS

Tables of summary air quality data are presented by pollutant (PM_{10} followed by SO_2) and then by monitoring location (west to east, followed by north to south).

Exceedance of standards and guidelines are summed for each site in these tables. NB: Total count of exceedances for the Mount Maunganui Airshed presented elsewhere in this report do not include events that occur on the same day. This avoids double counting when comparing with standards and guidelines that permit a number of exceedances in a 12-month period.

All data presented exclude exceptional events. Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable using techniques that regional councils may implement in order to attain and maintain the NES for PM_{10}. Assessment of exceptional events is undertaken by the Minister for the Environment on a case-by-case basis on written application by a regional council.

If the Minister decides that an exceedance was caused by exceptional circumstances, that exceedance is excluded when determining whether the standard for the relevant contaminant has been breached in that airshed. However, the regional council is still required to give public notice of the exceedance. For further information on exceptional events, refer to mfe.govt.nz.

It should be noted that the Rail Yard South, Totara Street and Totara Street Rail Crossing monitoring sites are entirely industrial locations. The Ranch Road monitoring site is entirely residential. All other monitoring locations are a mix of residential, commercial and industrial activities (refer Figure 1).

Table B-1: Summary PM_{10} statistics in Mount Maunganui; Jan – May 2024: NB Partial year only

Monitoring Location	Maximum daily PM_{10} (μg/m^3)	99th percentile daily PM_{10} (μg/m^3)	Exceedances per year (no.)	
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]
Mount Maunganui Airshed				
Bridge Marina	*58*	*44*	*1*	*2*
Whareroa Marae	*37*	*34*	*0*	*0*
Rata Street	*52*	*38*	*1*	*1*
*Totara St Rail Crossing**	*39*	*39*	*0*	*0*
Mount Maunganui				
*Ranch Road**	*47*	*45*	*0*	*2*

** Sites commenced monitoring 20 Jan 2024 (Totara St Rail Crossing) and 3 Feb 2024 (Ranch Road)*

Table B-2: Summary PM_{10} statistics in Mount Maunganui Airshed for 2023

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
*Sulphur Point***	*37*	*35*	*0*	*0*	-
Bridge Marina	44	38	0	0	14
Whareroa Marae	26	22	0	0	8
*De Havilland Way***	*51*	*46*	*1*	*3*	-
Rata Street*	**65**	**46**	**2**	**6**	**20**
*Rail Yard South***	*46*	*45*	*0*	*1*	-
*Totara Street***	*46*	*41*	*0*	*1*	-

*Excludes 1 exceptional event approved by the Minister for the Environment (19 April 2023).
*** Partial data - site discontinued in 2023 (refer Table 1 for details)*

Table B-3: Summary PM_{10} statistics in Mount Maunganui Airshed for 2022*

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	37	31	0	0	13
Bridge Marina	62	39	1	2	14
Whareroa Marae	29	24	0	0	10
De Havilland Way	45	41	0	0	**18**
Rata Street	53	41	1	3	**21**
Rail Yard South	50	42	0	3	**23**
Totara Street	50	45	0	3	**22**

*Excludes two exceptional events approved by the Minister for the Environment (18 Aug 2022 at Rata St, Rail Yard South, Bridge Marina and De Havilland Way and 19 Aug 2022 at the same sites and also at Totara St due to wave action).

Table B-4: Summary PM_{10} statistics in Mount Maunganui Airshed for 2021*

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	32	27	0	0	13
Bridge Marina	43	38	0	0	14
Whareroa Marae	34	26	0	0	11
De Havilland Way	49	43	0	1	**19**
Rata Street	50	38	0	2	**19**
Rail Yard South	52	44	1	2	**24**
Totara Street	51	40	1	1	**21**

*Excludes five exceptional events approved by the Minister for the Environment (2-4 Feb 2021 at De Havilland Way due to asphalting adjacent to the monitor, and 9-10 Jun 2021 at Rata St due to wave action). Also omits two exceedances measured on 6 and 7 September 2021 by Ballance Agri-Nutrients at their monitoring station on the boat ramp. [Source: BOPRC]

Table B-5: Summary PM_{10} statistics in Mount Maunganui Airshed for 2020

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	28	25	0	0	13
Bridge Marina	35	32	0	0	14
Whareroa Marae	65	34	1	1	14
De Havilland Way	45	40	0	0	**18**
Rata Street	**87**	41	**2**	4	**18**
Rail Yard South	**115**	**52**	**5**	**9**	**23**
Totara Street	47	39	0	1	**21**

Table B-6: Summary PM_{10} statistics in Mount Maunganui Airshed for 2019

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	31	27	0	0	14
Bridge Marina	39	31	0	0	**16**
Whareroa Marae	50	45	0	3	**17**
De Havilland Way	**63**	47	**3**	4	**19**
Rata Street	44	41	0	0	**20**
Rail Yard South	**70**	**63**	**16**	**32**	**30**
Totara Street	57	43	1	1	**25**

*Excludes 1 exceptional event approved by the Minister for the Environment (6 Dec 2019 at all sites due to Australian bush fires). One exceedance permitted in any 12-month period.

Table B-7: Summary PM_{10} statistics in Mount Maunganui Airshed for 2018 [NB: Partial Year Only]*

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)	
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]
*Sulphur Point**	*29*	*28*	*0*	*0*
*Bridge Marina**	*42*	*31*	*0*	*0*
*Whareroa Marae**	***62***	***56***	***3***	*3*
*De Havilland Way**	*50*	*45*	*0*	*1*
*Rata Street**	*25*	*24*	*0*	*0*
*Rail Yard South**	*46*	*45*	*0*	*1*
*Totara St**	*44*	*43*	*0*	*0*

[b] *Partial data only with monitoring commencing at different times in different locations (refer Table 1)*

Table B-6: Summary SO_2 statistics (10-minute average) in Mount Maunganui for 2023

Monitoring location	Maximum 10-minute SO_2 (µg/m³)	99th percentile 10-minute SO_2 (µg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
*Sulphur Point**	-	-	-
Bridge Marina	168	19	0
Whareroa Marae	1,423	36	1
Rata Street	129	20	0
*Rail Yard South**	-	-	-
Totara Street	115	26	0

** Site discontinued in 2023*

Table B-7: Summary SO_2 statistics (10-minute average) in Mount Maunganui for 2022

Monitoring location	Maximum 10-minute SO_2 (µg/m³)	99th percentile 10-minute SO_2 (µg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	137	34	0
Bridge Marina	239	33	0
Whareroa Marae	396	59	0
Rata Street	192	29	0
Rail Yard South	76	21	0
Totara Street	282	34	0

Table B-8: Summary SO_2 statistics (10-minute average) in Mount Maunganui for 2021

Monitoring location	Maximum 10-minute SO_2 (µg/m³)	99th percentile 10-minute SO_2 (µg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	127	31	0
Bridge Marina	1,247	45	1
Whareroa Marae	361	70	0
Rata Street	75	24	0
Rail Yard South	82	21	0
Totara Street	96	29	0

Table B-9: Summary SO_2 statistics (10-minute average) in Mount Maunganui for 2020

Monitoring location	Maximum 10-minute SO_2 (µg/m³)	99th percentile 10-minute SO_2 (µg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	142	35	0
Bridge Marina	275	44	0
Whareroa Marae	432	72	0
Rata Street	80	27	0
Rail Yard South	109	22	0
Totara Street	90	34	0

Table B-10: Summary SO_2 statistics (10-minute average) in Mount Maunganui for 2019

Monitoring location	Maximum 10-minute SO_2 (µg/m³)	99th percentile 10-minute SO_2 (µg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	287	106	0
Bridge Marina	232	76	0
Whareroa Marae	472	113	0
Rata Street	**775**	197	**10**
Rail Yard South	393	154	0
Totara Street	359	85	0

Table B-11: Summary SO_2 statistics (1-hour average) in Mount Maunganui for 2023

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
*Sulphur Point**	-	-	-	-
Bridge Marina	101	18	0	0
Whareroa Marae	286	31	0	0
Rata Street	90	19	0	0
*Rail Yard South**	-	-	-	-
Totara Street	53	24	0	0

** Site discontinued in 2023*

Table B-12: Summary SO_2 statistics (1-hour average) in Mount Maunganui for 2022

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	80	33	0	0
Bridge Marina	76	30	0	0
Whareroa Marae	204	53	0	0
Rata Street	111	27	0	0
Rail Yard South	58	19	0	0
Totara Street	67	32	0	0

Table B-13: Summary SO_2 statistics (1-hour average) in Mount Maunganui for 2021

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	96	28	0	0
Bridge Marina	312	39	0	0
Whareroa Marae	125	59	0	0
Rata Street	63	22	0	0
Rail Yard South	38	18	0	0
Totara Street	60	27	0	0

Table B-14: Summary SO_2 statistics (1-hour average) in Mount Maunganui for 2020

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	100	33	0	0
Bridge Marina	161	40	0	0
Whareroa Marae	251	60	0	0
Rata Street	57	25	0	0
Rail Yard South	68	20	0	0
Totara Street	64	29	0	0

Table B-15: Summary SO_2 statistics (1-hour average) in Mount Maunganui for 2019

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	208	96	0	0
Bridge Marina	157	65	0	0
Whareroa Marae	206	97	0	0
Rata Street	**575**	173	4	**1**
Rail Yard South	226	126	0	0
Totara Street	167	72	0	0

Table B-16: Summary SO_2 statistics (24-hour average) in Mount Maunganui for 2023

Monitoring Location	Maximum daily SO_2 (µg/m³)	99th percentile daily SO_2 (µg/m³)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
*Sulphur Point**	-	-	-	-
Bridge Marina	21	13	0	0
Whareroa Marae	17	14	0	0
Rata Street	18	13	0	0
*Rail Yard South**	-	-	-	-
Totara Street				

** Site discontinued in 2023*

Table B-17: Summary SO_2 statistics (24-hour average) in Mount Maunganui for 2022

Monitoring Location	Maximum daily SO_2 (µg/m³)	99th percentile daily SO_2 (µg/m³)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	26	19	0	0
Bridge Marina	28	17	0	0
Whareroa Marae	43	24	0	1
Rata Street	20	17	0	0
Rail Yard South	13	10	0	0
Totara Street	29	17	0	0

Table B-18: Summary SO_2 statistics (24-hour average) in Mount Maunganui for 2021

Monitoring Location	Maximum daily SO_2 (µg/m³)	99th percentile daily SO_2 (µg/m³)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	39	19	0	0
Bridge Marina	36	24	0	0
Whareroa Marae	42	24	0	1
Rata Street	15	13	0	0
Rail Yard South	12	11	0	0
Totara Street	26	14	0	0

Table B-19: Summary SO_2 statistics (24-hour average) in Mount Maunganui for 2020

Monitoring Location	Maximum daily SO_2 (µg/m³)	99th percentile daily SO_2 (µg/m³)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	24	18	0	0
Bridge Marina	54	29	0	3
Whareroa Marae	54	28	0	1
Rata Street	16	13	0	0
Rail Yard South	17	12	0	0
Totara Street	19	15	0	0

Table B-20: Summary SO_2 statistics (24-hour average) in Mount Maunganui for 2019

Monitoring Location	Maximum daily SO_2 (µg/m³)	99th percentile daily SO_2 (µg/m³)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	**93**	**60**	0	**11**
Bridge Marina	44	33	0	1
Whareroa Marae	**48**	**42**	0	**5**
Rata Street	**140**	**90**	**1**	**50**
Rail Yard South	**92**	**72**	0	**62**
Totara Street	54	40	0	4

APPENDIX C: SUMMARY PLOTS

Summary plots present a time series plot with labels for:

- minimum, maximum, mean, median and 95th percentile concentrations
- percent valid data, missing data (each year)

Summary plots also include a histogram to the right showing data distribution.

These are for overlapping periods of data from late 2018 until end May 2024 (i.e. longer historical records for Totara Street and Whareroa excluded).

Time variation plots are for the full period of monitoring undertaken at each site (dates provided). Time variation plots present average concentrations by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right).

Caution is needed when viewing time variation plots because the scales are generated automatically to showcase variation for each time period (e.g. by hour of day). This means that a difference that appears large on the graph may in fact be only slight. For example, the difference in weekday and weekend concentrations of PM_{10} at Sulphur Point is only 1 µg/m^3.

Similarly, caution is also needed when comparing time variation plots for different monitoring sites. For example, the range of hourly PM_{10} concentrations (12 – 16 µg/m^3) by hour of day by day of week measured at Sulphur Point for 4+ years (top plot Figure B-2) is not as large as that measured at Whareroa Marae (10 – 20 µg/m^3) over 5+ years (top plot Figure B-3).

Plots generated from monitoring sites with only a few months of data (e.g. Ranch Road) are included for interest only as there are not yet sufficient data from which to draw any firm conclusions.

Plots are presented:

- for PM_{10} followed by SO_2; and
- west (predominantly upwind of the Mount Maunganui Airshed) to east (predominantly downwind), and then north to south (generally least to most industrial parts of the airshed).

It should be noted that Rail Yard South, Totara Street and Totara Street Rail Crossing are entirely industrial locations. Ranch Road is entirely residential. All other monitoring locations are a mix of residential, commercial and industrial activities.

Figure C-1: Summary plots of daily **PM₁₀** (µg/m³) at Rata Street (RAT), Rail Yard South (RYS), Sulphur Point (SPT), Tauranga Bridge Marina (TBM), Totara Street (TOT) and Whareroa Marae (WHA) for overlapping period; **August 2018 – May 2024**.

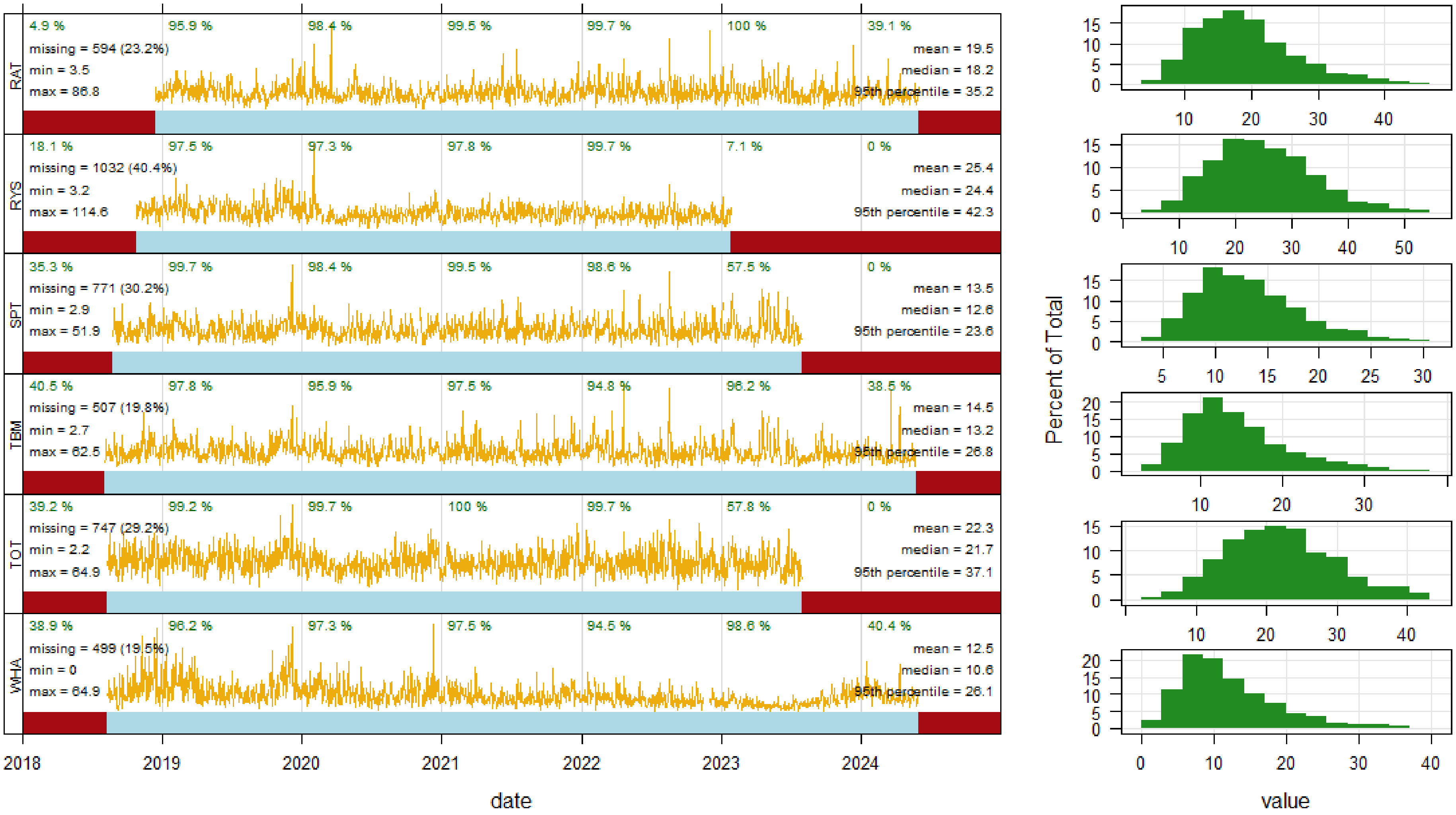


Figure C-2: Mean concentrations of **PM_{10}** (µg/m^3) with 95% confidence intervals measured at **Sulphur Point** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Aug 2018 – July 2023**.

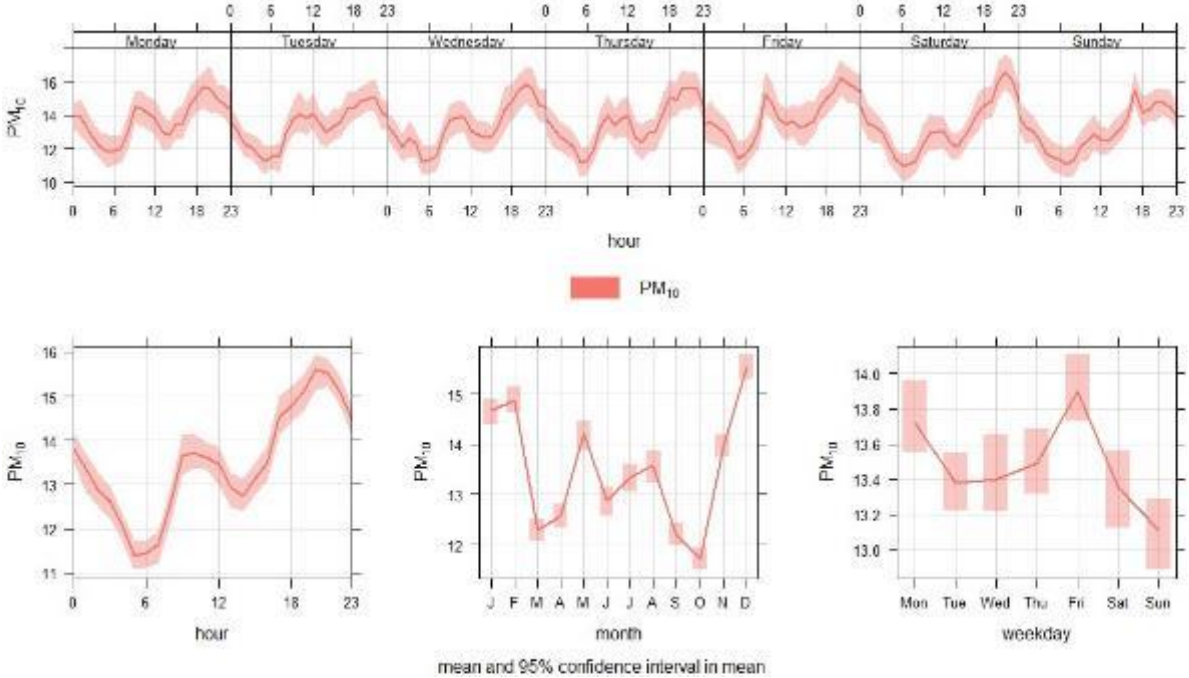


Figure C-3: Mean concentrations of **PM_{10}** (µg/m^3) with 95% confidence intervals measured at **Tauranga Bridge Marina** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Aug 2018 – May 2024**.

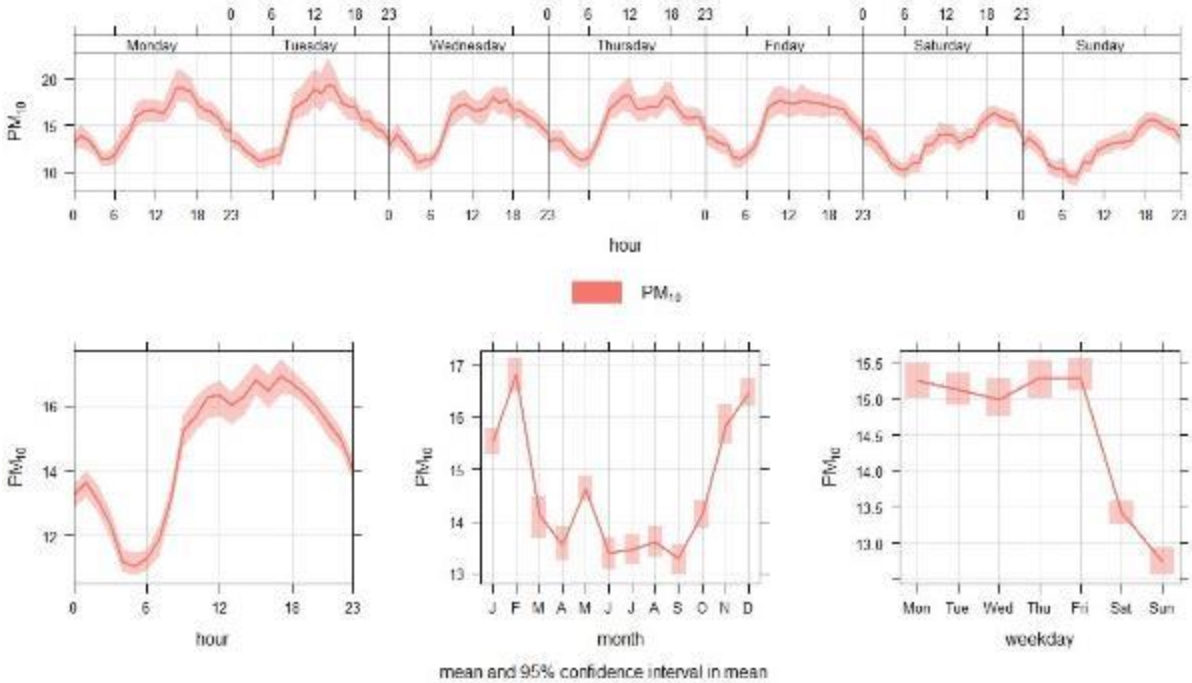


Figure C-4: Mean concentrations of **PM_{10}** (µg/m³) with 95% confidence intervals measured at **Whareroa Marae** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Aug 2018 – May 2024**.

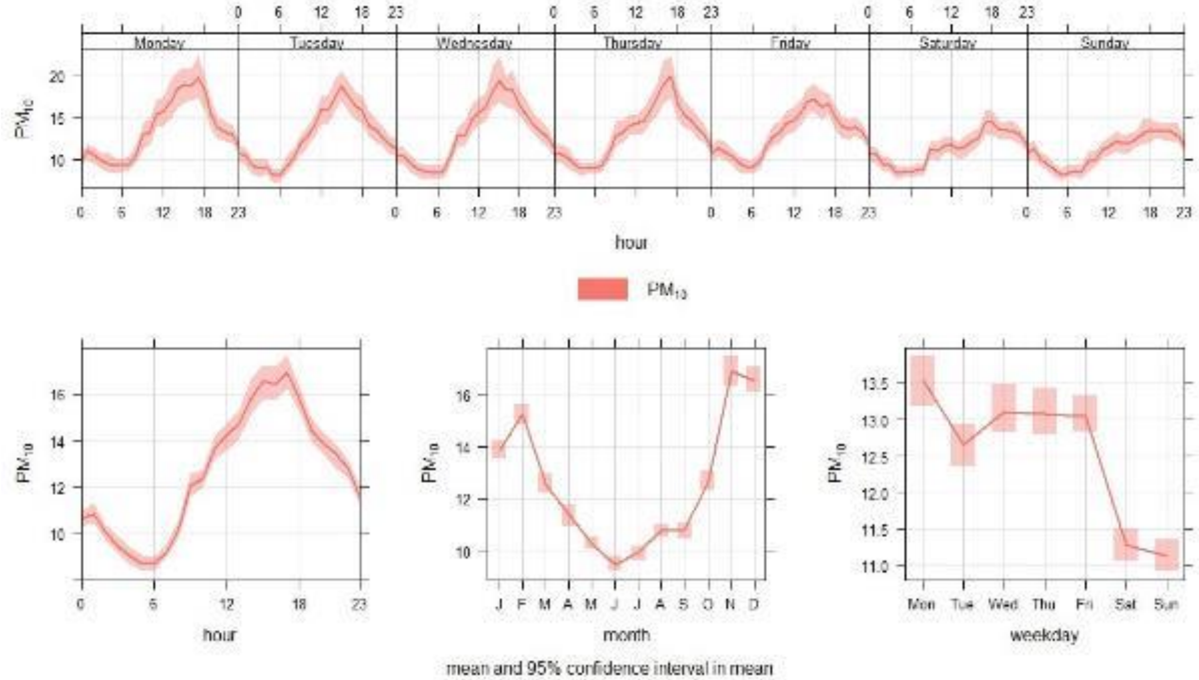


Figure C-5: Mean concentrations of **PM_{10}** (µg/m³) with 95% confidence intervals measured at **De Havilland Way** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Oct 2018 – Jul 2023**.

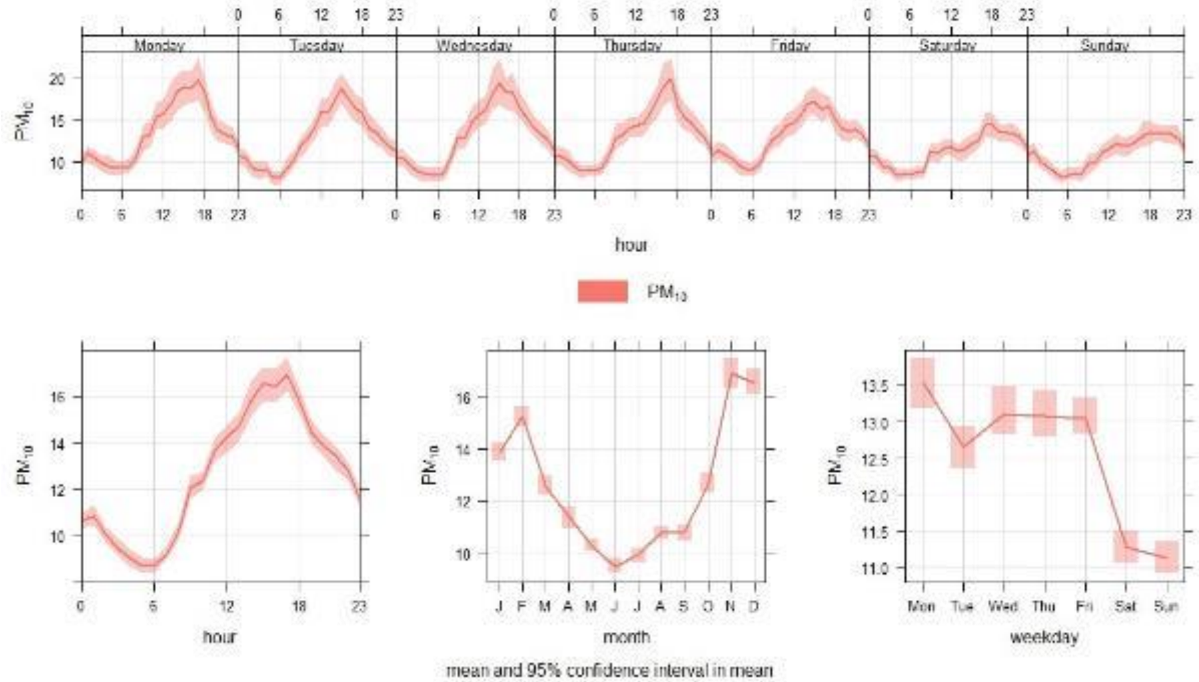


Figure C-6: Mean concentrations of **PM_{10}** (µg/m^3) with 95% confidence intervals measured at **Ranch Road** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Feb – May 2024 (4 months only)**.

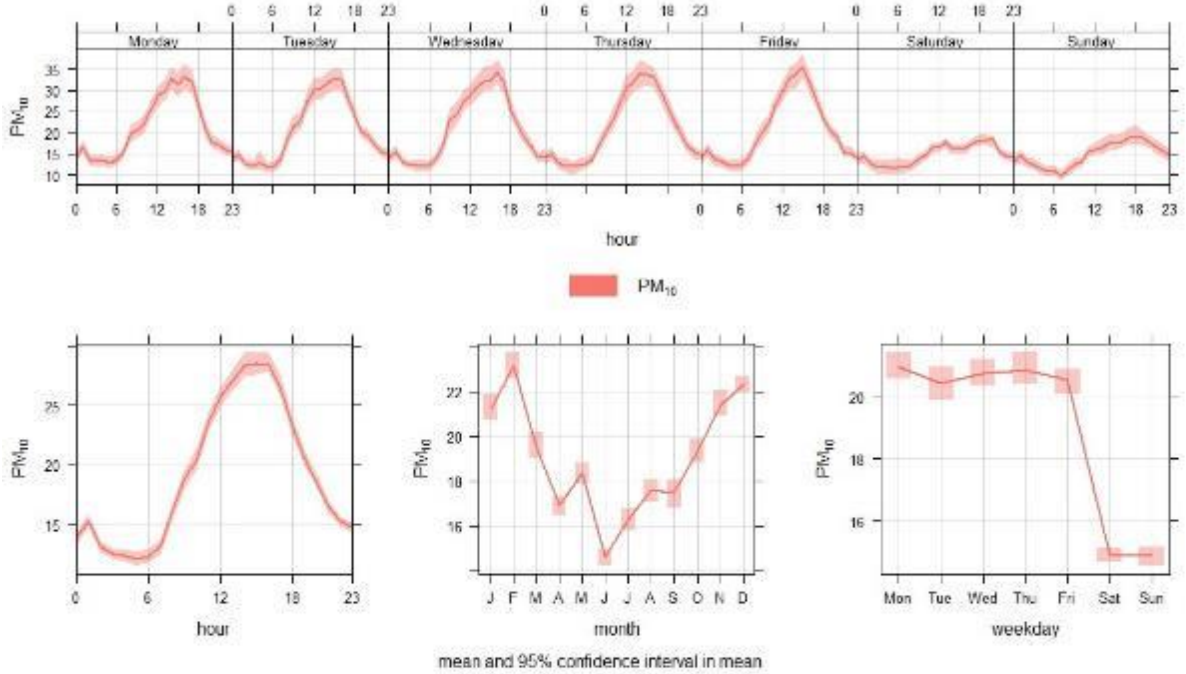


Figure C-7: Mean concentrations of **PM_{10}** (µg/m^3) with 95% confidence intervals measured at **Rata Street** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Dec 2018 – May 2024**.

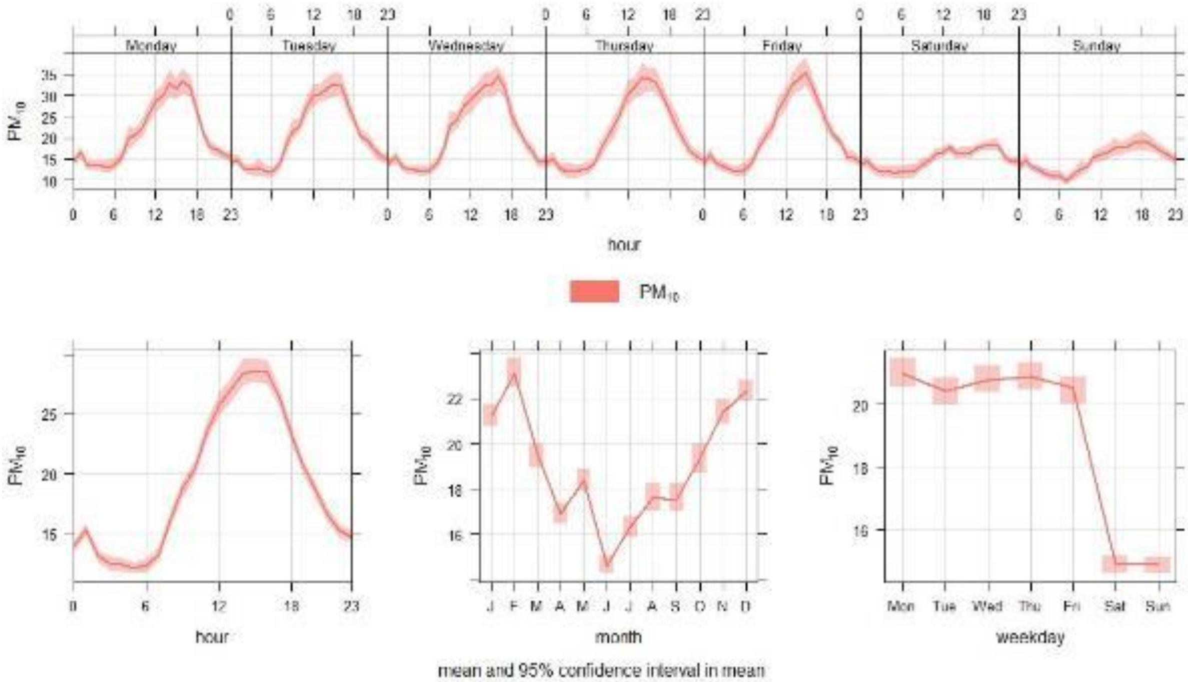


Figure C-8: Mean concentrations of **PM_{10}** (µg/m^3) with 95% confidence intervals measured at **Rail Yard South** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Oct 2018 – Jan 2023**.

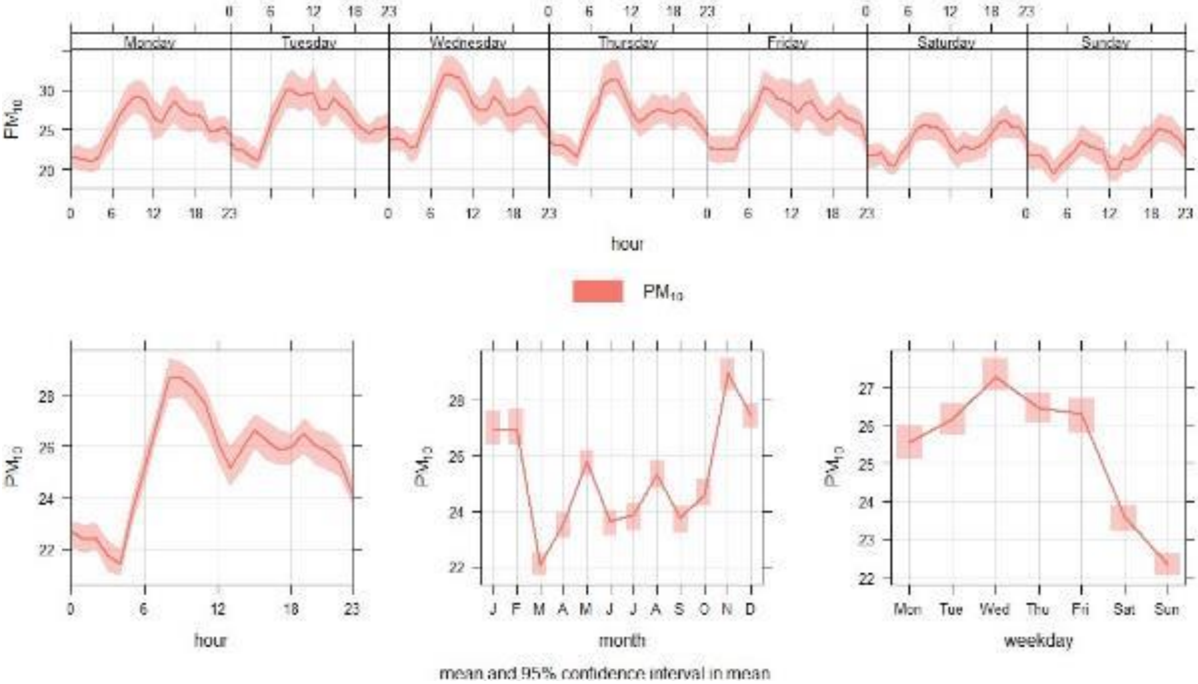


Figure C-9: Mean concentrations of **PM_{10}** (µg/m^3) with 95% confidence intervals measured at **Totara Street Rail Crossing** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Jan – May 2024 (5 months only)**.

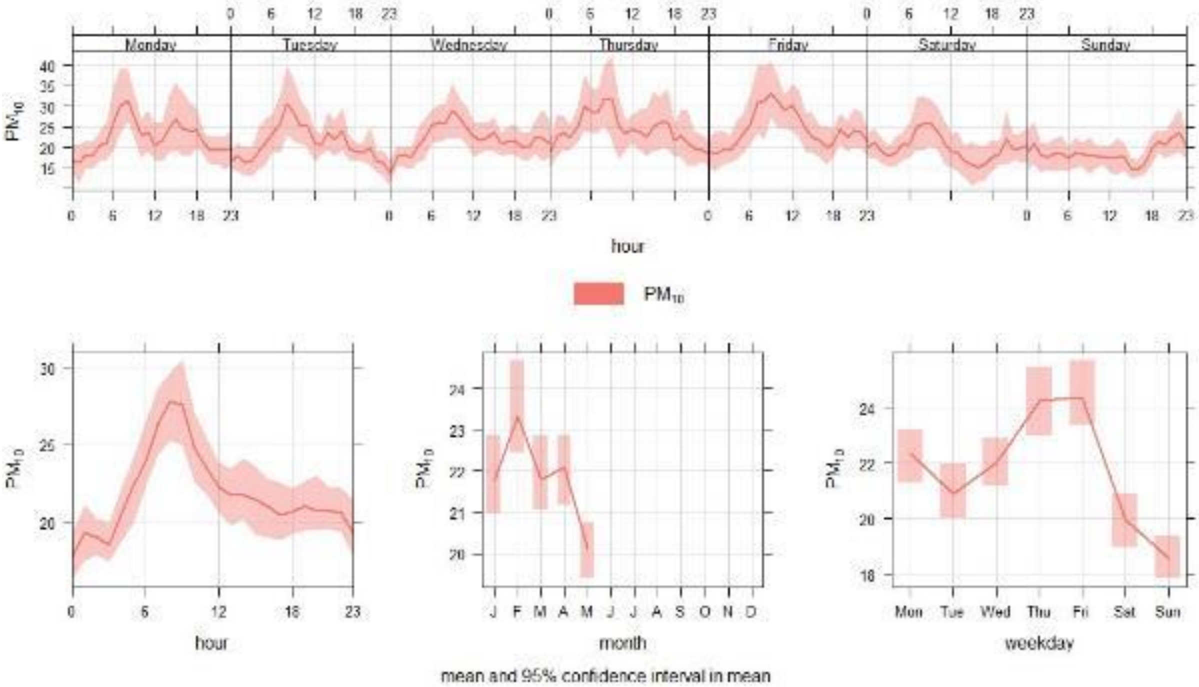


Figure C-10: Mean concentrations of **PM₁₀** (µg/m³) with 95% confidence intervals measured at **Totara Street** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Aug 2018 – Jul 2023**.

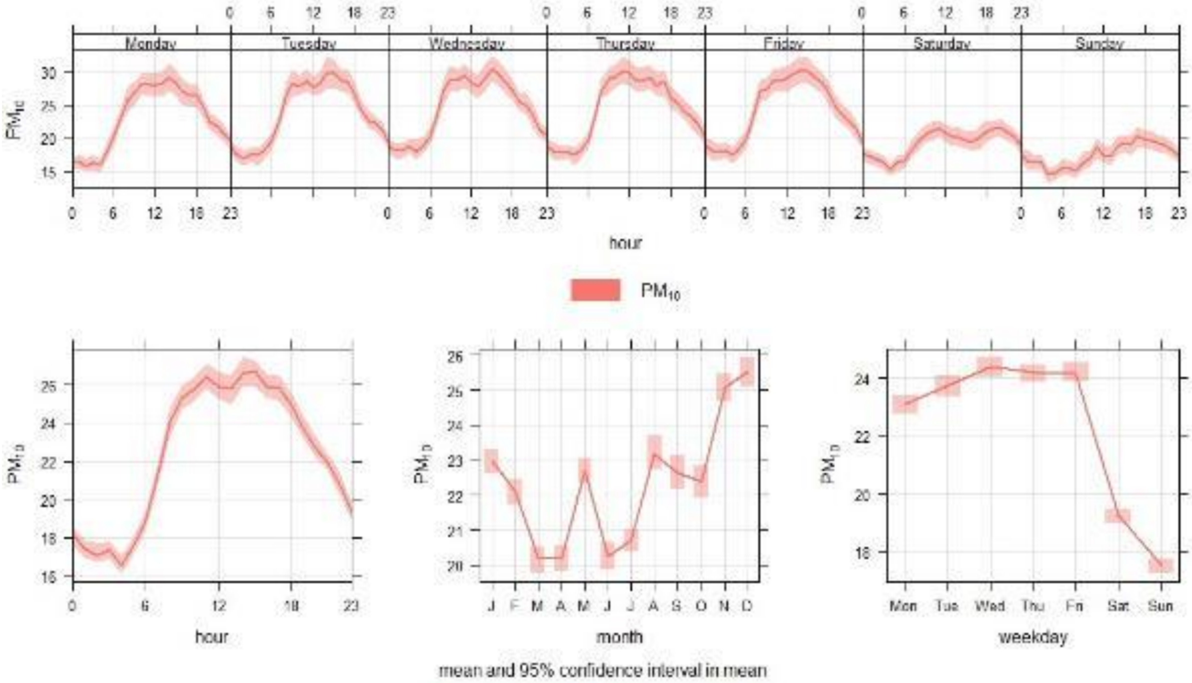


Figure C-11: Summary plots of **10-minute SO_2** (µg/m³) at Rata Street (RAT), Rail Yard South (RYS), Sulphur Point (SPT), Tauranga Bridge Marina (TBM), Totara Street (TOT) and Whareroa Marae (WHA) for overlapping period: **December 2018 – May 2024**.

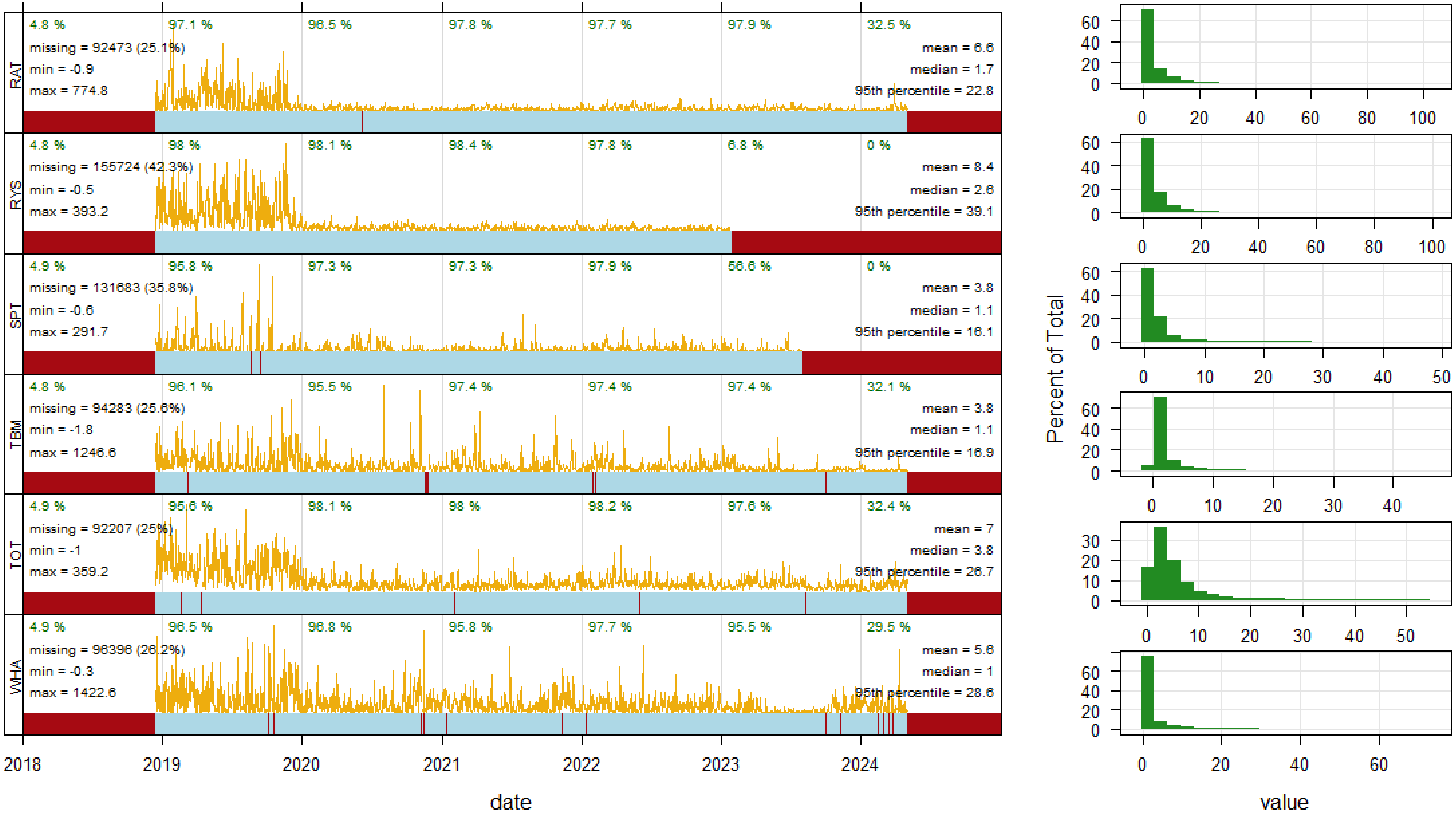


Figure C-12: Summary plots of **1-hour SO_2** (µg/m[3]) at Rata Street (RAT), Rail Yard South (RYS), Sulphur Point (SPT), Tauranga Bridge Marina (TBM), Totara Street (TOT) and Whareroa Marae (WHA) for overlapping period: **December 2018 – May 2024**

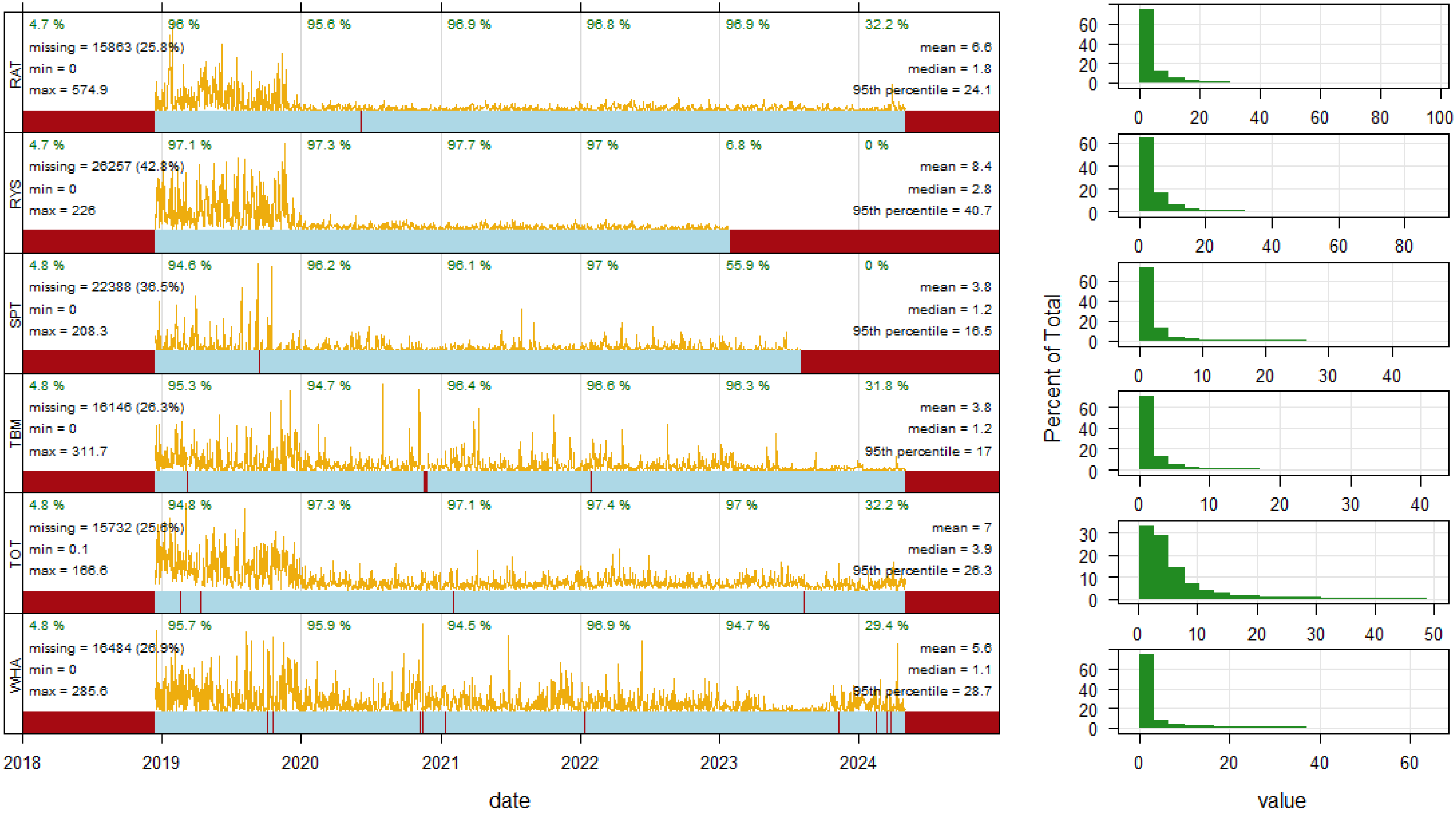


Figure C-13: Summary plots of **1-day SO_2** ($\mu g/m^3$) at Rata Street (RAT), Rail Yard South (RYS), Sulphur Point (SPT), Tauranga Bridge Marina (TBM), Totara Street (TOT) and Whareroa Marae (WHA) for overlapping period: **December 2018 – May 2024**.

Figure C-14: Mean concentrations of **SO_2** ($\mu g/m^3$) with 95% confidence intervals measured at **Sulphur Point** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Aug 2018 – Jul 2023**.

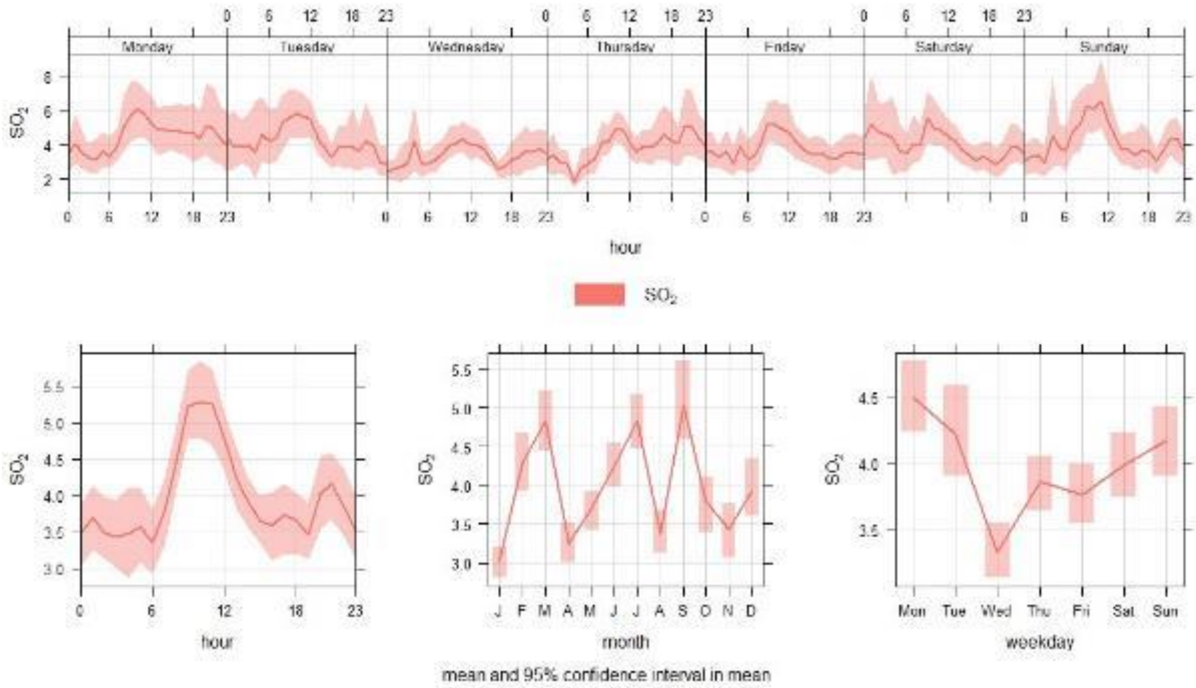


Figure C-15: Mean concentrations of **SO_2** ($\mu g/m^3$) with 95% confidence intervals measured at **Tauranga Bridge Marina** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Aug 2018 – Apr 2024**.

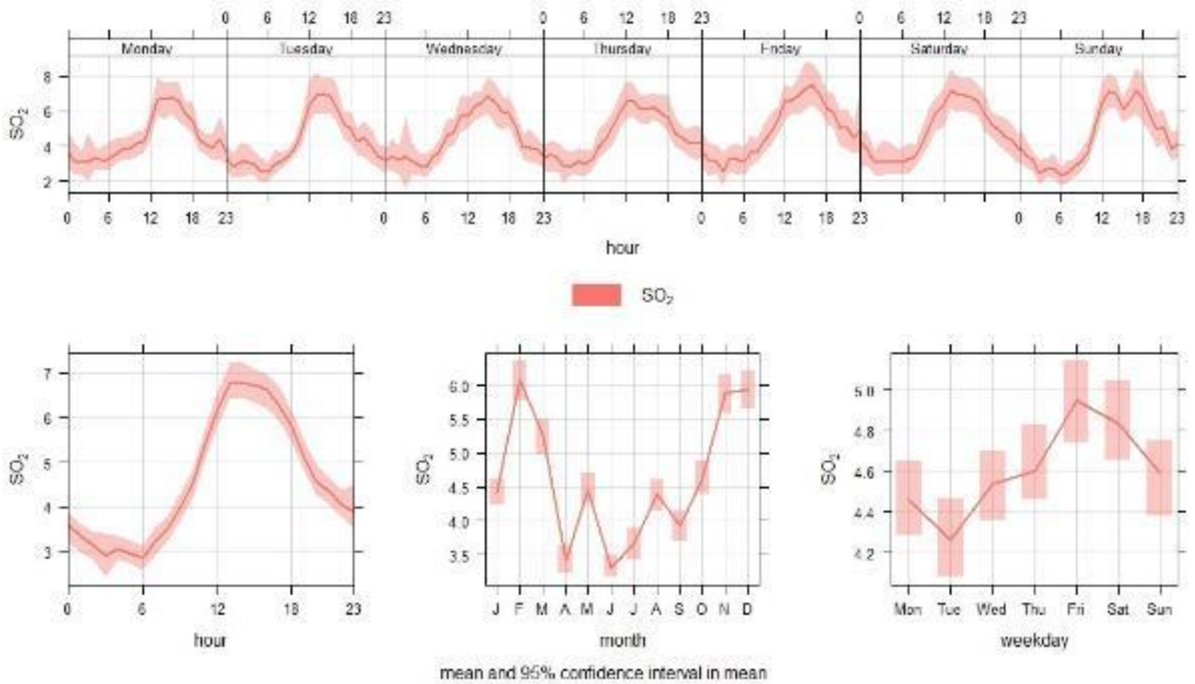


Figure C-16: Mean concentrations of **SO_2** (µg/m^3) with 95% confidence intervals measured at **Whareroa Marae** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Sep 2015 – May 2024**.

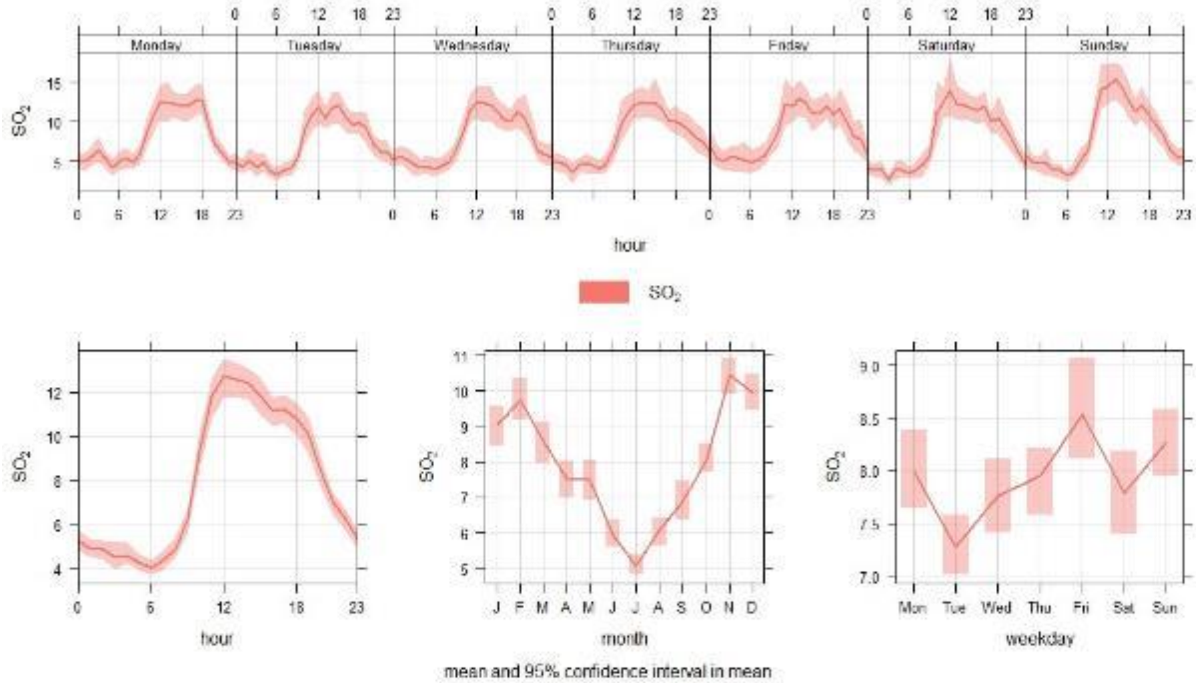


Figure C-17: Mean concentrations of **SO_2** (µg/m^3) with 95% confidence intervals measured at **Rata Street** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Dec 2018 – May 2024**.

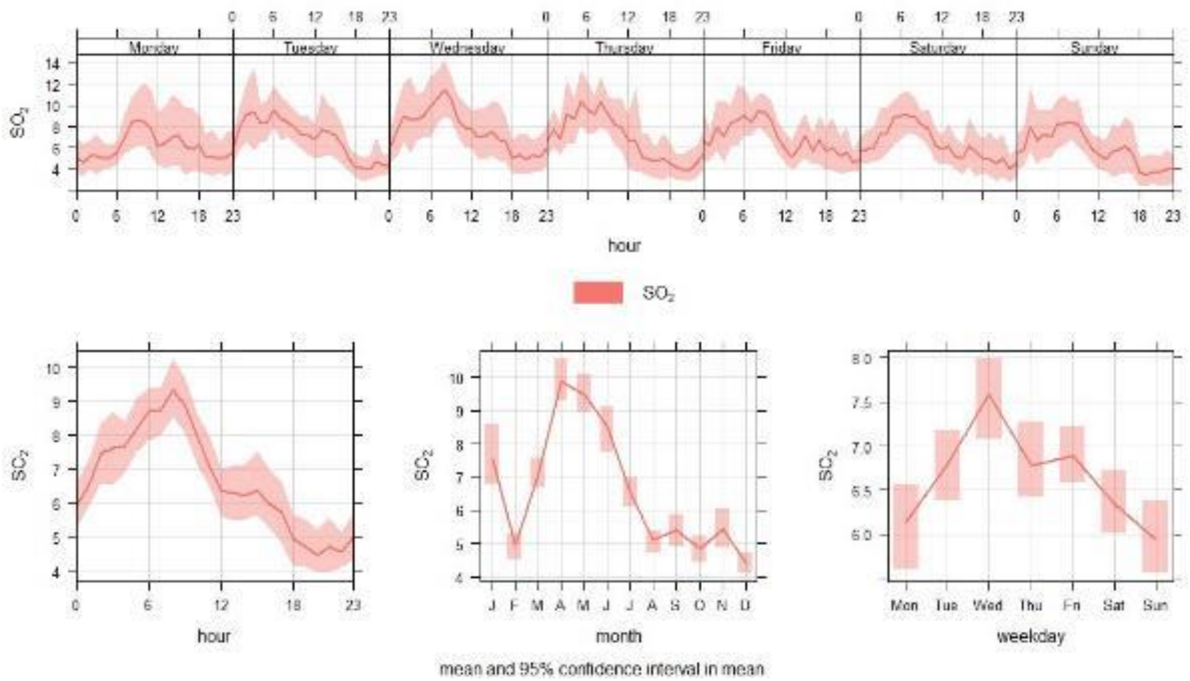


Figure C-18: Mean concentrations of **SO_2** (µg/m^3) with 95% confidence intervals measured at **Rail Yard South** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Oct 2018 – Jan 2023**.

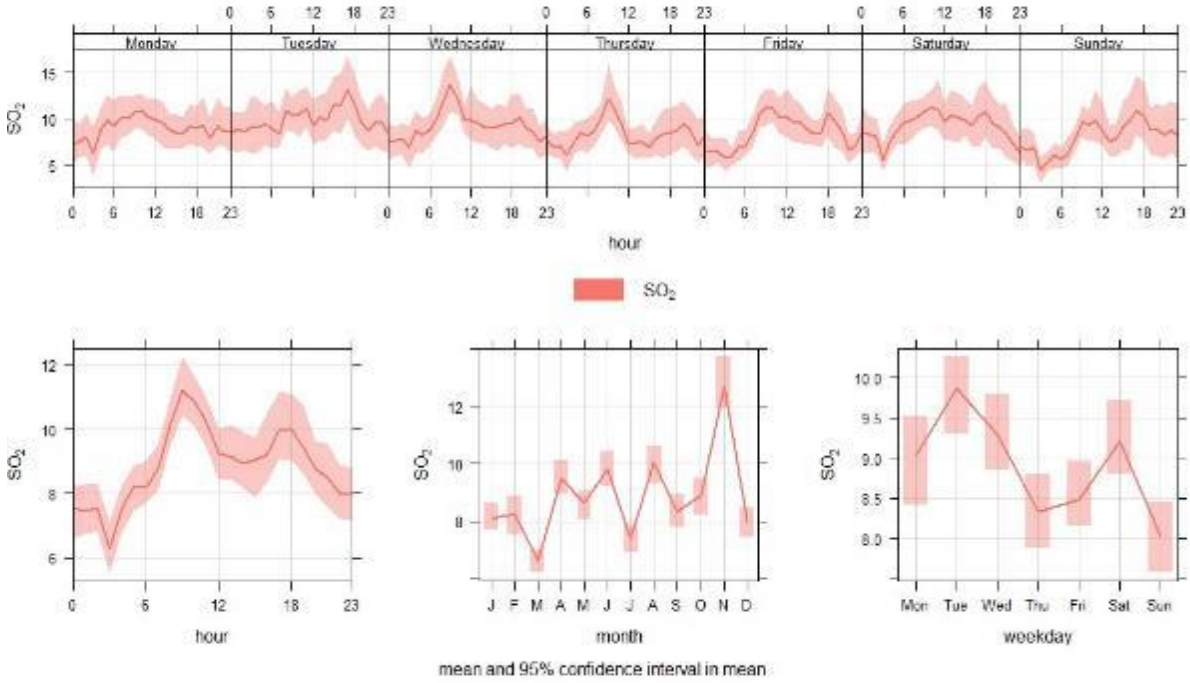
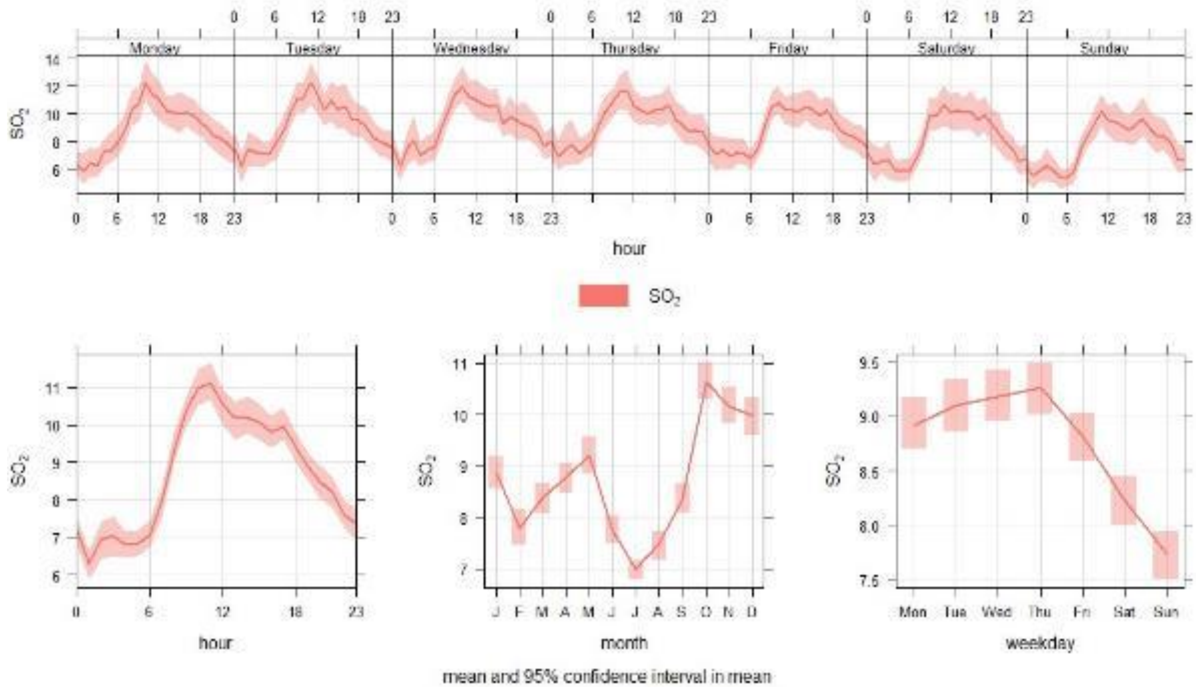


Figure C-19: Mean concentrations of **SO_2** (µg/m^3) with 95% confidence intervals measured at **Totara Street** by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): **Jan 2015 – May 2024**.



APPENDIX D: DEVELOPMENT NEAR WHAREROA MARAE


Whareroa Marae
WHA
Jun 2015


Whareroa Marae
WHA
Mar 2016


Whareroa Marae
WHA
May 2017


Wharenoa Marae
WHA
Mar 2018


Wharenoa Marae
WHA
Jan 2019


Wharenoa Marae
WHA
Jan 2021


Whareroa Marae
Jan 2022


Whareroa Marae
Aug 2023


Whareroa Marae
Feb 2024

APPENDIX E: THEIL-SEN PLOTS

The **Theil–Sen estimator** is a method for robustly fitting a straight line to sample points in the plane (simple linear regression) by choosing the median of the slope of all lines through all pairs of points. Carslaw (2019) notes:

> *The advantage of the using the Theil-Sen estimator is that it tends to yield accurate confidence intervals even with non-normal data and heteroscedasticity (non-constant error variance). It is also resistant to outliers — both characteristics can be important in air pollution.*
>
> *…*
>
> *The Theil-Sen function is typically used to determine trends in pollutant concentrations over several years. However, it can be used to calculate the trend in any numeric variable. It calculates monthly mean values from daily, hourly or higher time resolution data, as well as working directly with monthly means. Whether it is meaningful to calculate trends over shorter periods of time (e.g. 2 years) depends very much on the data. It may well be that statistically significant trends can be detected over relatively short periods but it is another matter whether it matters. Because seasonal effects can be important for monthly data, there is the option to deseasonalise the data first.*

The following plots are monthly PM_{10} concentrations (µg/m^3) with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. The overall trend is shown at the top of each plot in green font with the 95% confidence intervals in the slope in brackets. Note also that the symbols shown next to each trend estimate relate to how statistically significant the trend estimate is: $p < 0.001$ = ***, $p < 0.01$ = **, $p < 0.05$ = * and $p < 0.1$ = +.

FIGURE E-1: Monthly PM_{10} concentrations (µg/m^3) measured at Sulphur Point with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. There is no statistically significant trend.

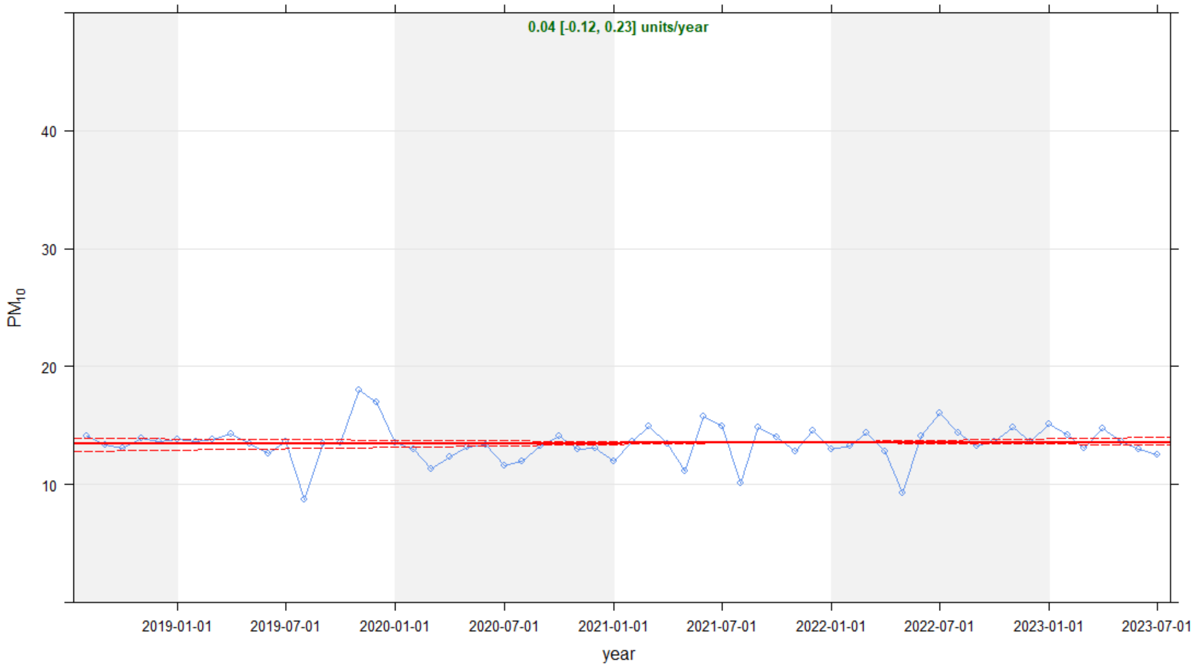


FIGURE E-2: Monthly PM_{10} concentrations ($\mu g/m^3$) measured at Rata Street with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. There is no statistically significant trend.

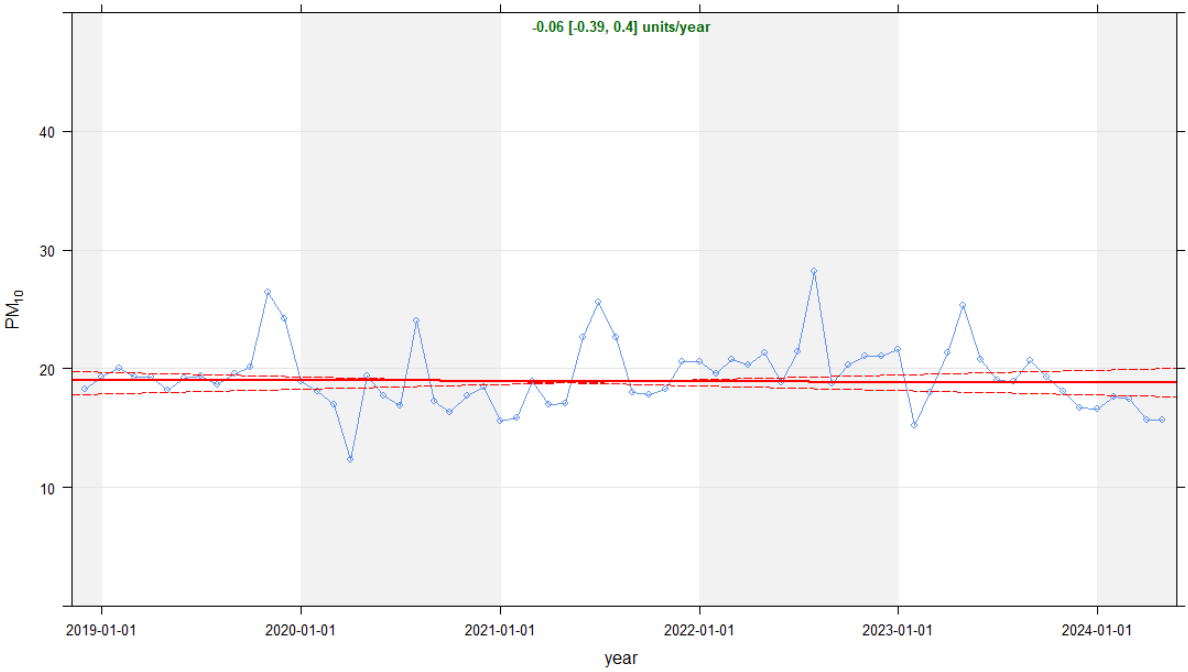


FIGURE E-3: Monthly PM_{10} concentrations ($\mu g/m^3$) measured at Tauranga Bridge Marina with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. The slight reducing overall trend is shown at the top as -0.49 ($\mu g/m^3$) per year and the 95% confidence intervals in the slope from -0.62 – -0.4 $\mu g/m^3$/year. The ∗ ∗ ∗ show that the trend is significant to the 0.001 level.

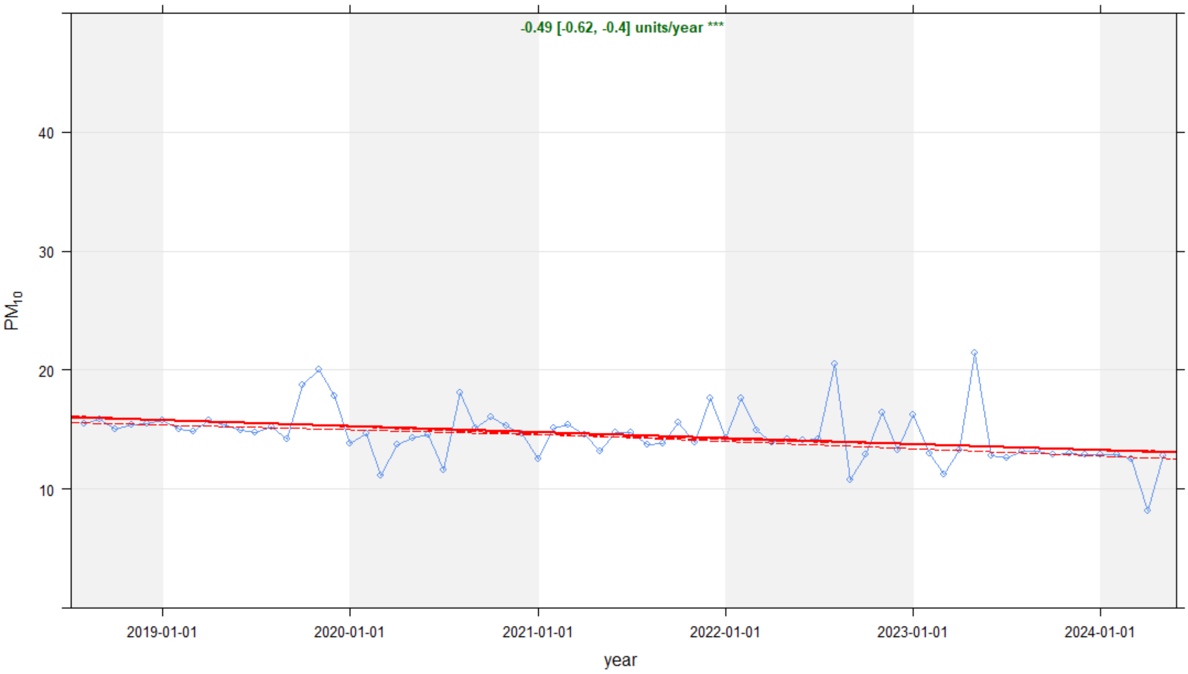


FIGURE E-4: Monthly PM_{10} concentrations (µg/m³) measured at Totara Street with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. The reducing overall trend is shown at the top as -0.61 (µg/m³) per year and the 95% confidence intervals in the slope from -0.89 – -0.17 µg/m³/year. The ∗ shows that the trend is significant to the 0.05 level.

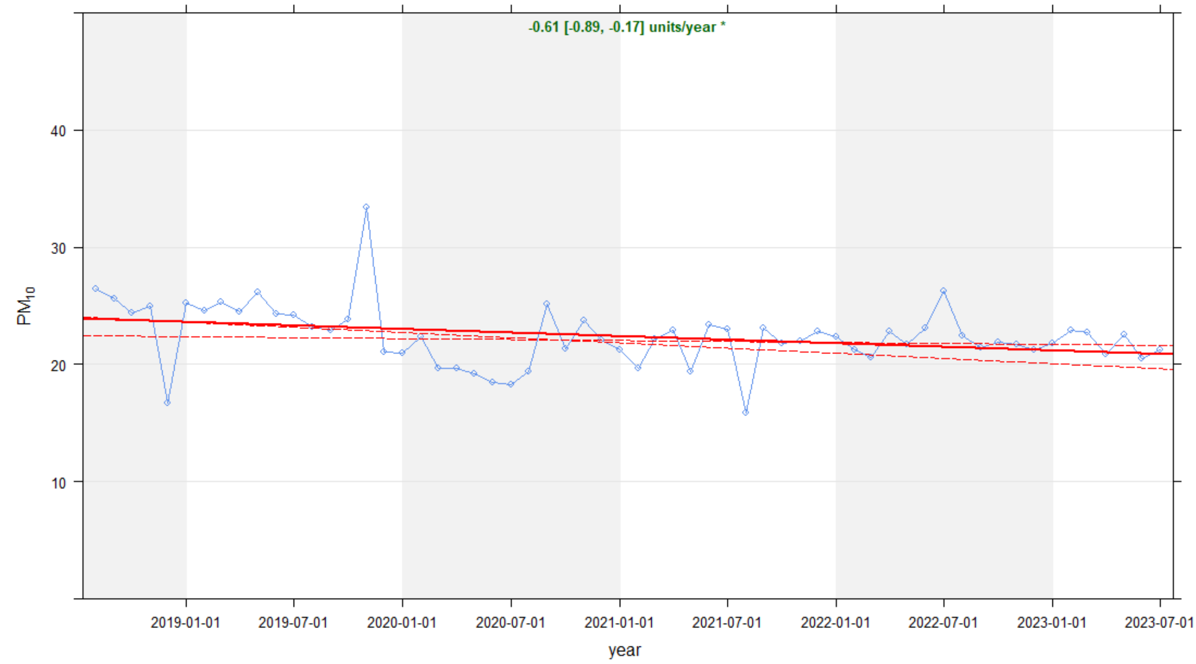


FIGURE E-5: Monthly PM_{10} concentrations (µg/m³) measured at Rail Yard South with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. The unusual but significant reducing overall trend is shown at the top as -2.07 (µg/m³) per year and the 95% confidence intervals in the slope from -2.23 – -1.07 µg/m³/year. The ∗ ∗ ∗ show that the trend is significant to the 0.001 level.

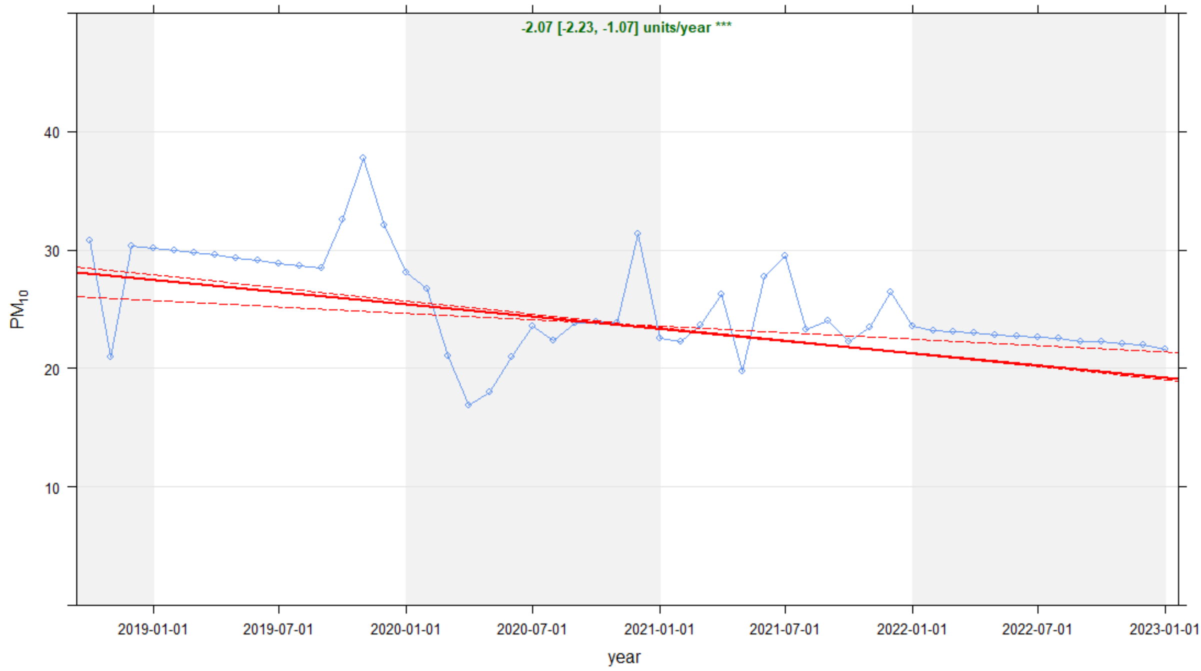
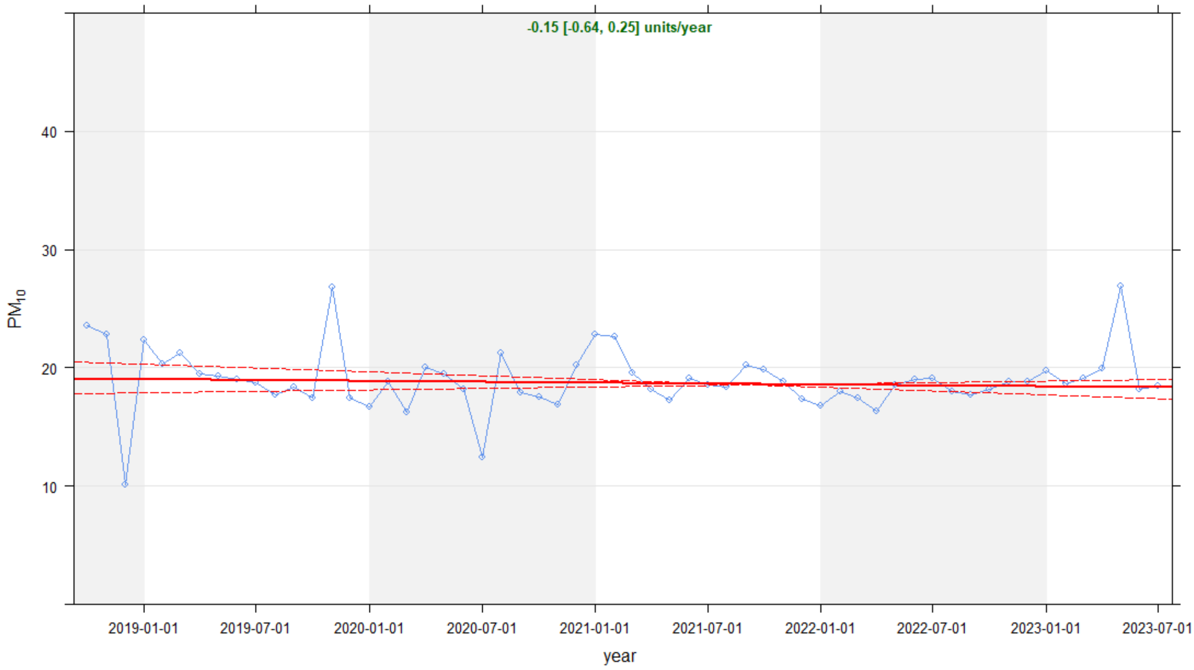


FIGURE E-6: Monthly PM_{10} concentrations (µg/m^3) measured at De Havilland Way with deseasonalised Theil-Sen trend estimate (solid red line) and 95% confidence intervals (dashed red lines) for the trend based on resampling methods. There is no statistically significant trend.



Science for Communities

INSTITUTE OF ENVIRONMENTAL
SCIENCE AND RESEARCH LIMITED

Kenepuru Science Centre
34 Kenepuru Drive, Kenepuru, Porirua 5022
PO Box 50348, Porirua 5240
New Zealand
T: +64 4 914 0700 **F:** +64 4 914 0770

Mt Albert Science Centre
120 Mt Albert Road, Sandringham, Auckland 1025
Private Bag 92021, Auckland 1142
New Zealand
T: +64 9 815 3670 **F:** +64 9 849 6046

NCBID – Wallaceville
66 Ward Street, Wallaceville, Upper Hutt 5018
PO Box 40158, Upper Hutt 5140
New Zealand
T: +64 4 529 0600 **F:** +64 4 529 0601

Christchurch Science Centre
27 Creyke Road, Ilam, Christchurch 8041
PO Box 29181, Christchurch 8540
New Zealand
T: +64 3 351 6019 **F:** +64 3 351 0010

www.esr.cri.nz