Mount Maunganui Ambient Sulphur Dioxide Monitoring

Prepared by Shane Iremonger, Environmental Scientist

Bay of Plenty Regional Council
Environmental Publication 2011/03
September 2010

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ISSN: 1175-9372 (Print)
ISSN: 1179-9471 (Online)

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Cover Photo:
Mount Maunganui port and industrial area, October 2009.

Acknowledgements

Glenn Ellery and Charl Naude for the accurate preparation of the data sets is acknowledged, as are the efforts of the entire Data Services team, in the collection of the ambient air quality data.

Arthur Tsitsiras and Mike Reid of Ballance Agri Nutrients Ltd for the Ballance site SO_2 dataset.

Dr Bruce Graham for his peer review.

Executive summary

The international understanding of adverse health effects due to ambient SO_2 exposure continues to improve and exposure limits are being refined as this information becomes available. Some of this work was reflected in the National Environmental Standard (NES) for New Zealand, whereby a multilevel standard was adopted in 2004. However, more recent work by the World Health Organisation (WHO) and United States Environmental Protection Agency (EPA) has resulted in a significant lowering of their recommendations for ambient limits.

The SO_2 emission source situation at Mount Maunganui is a complex one with a number of source types. Industry is the largest single source with consents being issued for these activities. The traffic contribution is also noticeable in the datasets and depending on proximity to roadways the concentrations can vary markedly. Other sources include shipping and train activity.

Monitoring of ambient SO_2 was undertaken at Mount Maunganui for a short period in 1994 and more recently has been part of the Bay of Plenty Regional Council's on-going environmental monitoring programme for air quality. This monitoring began in 2005 at the Totara Street site which is currently still operational. Several other sites have also been introduced since then, one operated by the Council in 2007 at Maru Street and one by Ballance Agri-Nutrients Ltd at the neighbouring Chevron industrial site.

The "peak" Totara site recorded exceedances of the NES in the earlier part of the record, however since 2007 no exceedances have been recorded. The other two monitoring sites (Maru and Chevron) have not registered any exceedances of the NES, although under certain meteorological conditions elevated levels have been recorded.

Current monitoring data suggests we do not have a problem with industrial emissions causing non-compliance with the current NES (but should await further developments). The prudent approach which should be taken is to continue to monitor ambient SO_2 and meteorology at the Totara site, to ensure that up-to-date data is available should any decision be made in the future to lower the NES.

At this time the spatial understanding of SO_2 distributions has been improved by the several years of monitoring at the Regional Council's Maru site and this equipment can now be returned to Rotorua to support the long term H2S exposure study which is currently underway.

The Ballance Agri Nutrient Ltd consent requires three years of ambient monitoring to be undertaken (c.8.6). Advice note 3 of the consent states –

> "*As a general guide, for the first 12 months the site should be located within 100 metres of the Tasman Quay boundary of the Ballance site and to the east of this boundary. The location of the monitor may then be changed from time to time to allow coverage of multiple locations, but all decisions regarding such changes should be agreed with the Regional Council and shall be documented in the Monitoring Management Plan."*

Joint discussion with Ballance Agri Nutrients Ltd, the Community Advisory Group established under the consent, Chevron New Zealand and the Regional Council should be undertaken to discuss the possibility of a new monitoring location for the equipment currently located at Chevron New Zealand. The two years of monitoring data recorded at the Chevron site now provides a valuable understanding of near field receptor concentrations and fulfils the expected monitoring regime outlined in the advice note. Further value could now be gained by moving the site to a position to the north of the Totara site (on a similar wind line from the main sources) to ensure the ground level concentrations are not greater than those monitored at Totara and to also determine the extent of the north/northeastern SO_2 boundary for industrial impacts.

Contents

Tables and Figures

Part 1: Introduction

The purpose of this report is to summarise the ambient sulphur dioxide (SO_2) data recorded from the Bay of Plenty Regional Council's two monitoring sites (Figure 1) located within the southern sector of the Mount Maunganui industrial area. Data recorded at the Ballance Agri-Nutrient Ltd site (Chevron) has also been investigated.

Figure 1 Mount Maunganui industrial area (southern sector) with the two Bay of Plenty Regional Council monitoring sites, 1 = Totara Street, 2 = Maru Street, 3 = Ballance Agri-Nutrients Ltd monitoring site.

Part 2: Background information

2.1 Sulphur dioxide

Sulphur dioxide is a colourless, soluble gas with a characteristic pungent smell, which forms sulphurous acid when combined with water.

Sulphur dioxide is produced mainly from the combustion of fossil fuels that contain sulphur, such as coal and oil (for example, coal being burnt in a home fireplace for heating and diesel-powered vehicles). Sulphur dioxide is also produced from some industrial processes, such as fertiliser manufacturing, aluminium smelting and steel making.

Natural sources of sulphur dioxide include volcanic activity.

2.2 Health effects

Inhalation is the main route of exposure to sulphur dioxide that is of interest with regard to its effects on health. Sulphur dioxide can cause respiratory problems, such as bronchitis, and it can irritate the nose, throat and lungs. It may cause coughing, wheezing, phlegm and asthma attacks. The effects are worse when exercising. Sulphur dioxide has also been linked to cardiovascular disease.

The population groups that are most sensitive to sulphur dioxide are children, adults with lung disease and asthmatics.

2.3 Guidelines and standards

International and national guidelines exist for sulphur dioxide and these are presented in Table 1 and individually discussed in the following sections.

Table 1 Guidelines and standards for ambient SO_2.

	SO_2 (µg/m^3) averaging period			
	10 minute	**1 hour**	**24 hour**	**Annual**
New Zealand Ambient Air Quality Guidelines 1994.	500	350	125	50
New Zealand Ambient Air Quality Guidelines 2002.		350	120	
New Zealand National Environmental Standard for Air Quality.		350/570		
WHO	500		20	
USEPA		~200 (75ppb)		

2.3.1 New Zealand Ambient Air Quality Guidelines

The Ministry for the Environment (MfE) is responsible for providing guidance and advice on the management of air quality throughout New Zealand. In 1994 MfE published the first ambient air quality guidelines for New Zealand[1]. These included values for SO_2 of 500 µg/m^3 (10 minute), 350 µg/m^3 (1 hour average), 125 µg/m^3 (24-hour average) and 50 µg/m^3 (annual average). Revisions to these were proposed in a discussion document[2], which also outlined results from a number of technical reports relating to health impacts of different contaminants. In 2002 the MfE released the resulting updated Ambient Air Quality Guidelines[3]. The guidelines for SO_2 were:

- 350 µg/m^3 (1 hour average)
- 120 µg/m^3 (24 hour average)

2.3.2 New Zealand National Environmental Standard for Air Quality

A new Regulation for ambient air quality in New Zealand was promulgated in September 2004, as a National Environmental Standard (NES-AQ)[4] under s43 of the Resource Management Act, 1991 (RMA). The NES-AQ specifies health-based limits for ambient air concentrations of fine particulate (PM_{10}), carbon monoxide, nitrogen dioxide, ozone and sulphur dioxide. The NES for sulphur dioxide is given in Table 2.

The Regulation also specifies requirements for monitoring of these pollutants, in the event that the standards are breached. It establishes an air quality management regime, based on controls over the issuing of resource consents in those areas where the limits are exceeded, or likely to be exceeded.

A key element of this control regime is the designation of “airsheds” under sub-clause 14 of the Regulation. These are to be specified by the Minister for the Environment by a notice in the Gazette.

Regional councils were invited to nominate specific airshed(s) for their region by 1July 2005.

In response to the Ministry for the Environment’s request to nominate airsheds, Bay of Plenty Regional Council has currently designated only one airshed (for PM_{10}) for the Bay of Plenty region, this is the Rotorua Airshed[5].

[1] MfE, 1994, *Ambient Air Quality Guidelines*, Ministry for the Environment publication, 58p.
[2] MfE, 2000, *Proposals for Revised and New Ambient Air Quality Guidelines. Discussion Document*. Ministry for the Environment publication.
[3] MfE, 2002, *Ambient Air Quality Guidelines for New Zealand*, Air Quality Report Number 32, Ministry for the Environment publication, 58p.
[4] Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004 SR 2004/309 (2004/433 and 2005/214).
[5] New Zealand Gazette, 2005, *Bay of Plenty Regional Airshed Notice,* New Zealand Gazette, No. 141, 25 August 2005.

Table 2 National Environmental Standards for SO_2.

	Standard value	
Contaminant	**Threshold concentration**	**Permissible excess**
Sulphur dioxide	350 micrograms per cubic metre expressed as a 1-hour mean.	9 hours in a 12-month period
	570 micrograms per cubic metre expressed as a 1-hour mean.	Not to be exceeded at any time

2.3.3 World Health Organisation

In 2006 the World Health Organisation (WHO) published a set of global air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide[6].

The guidelines for SO_2 developed by WHO are as follows:

- 20 µg/m^3 as a 24-hour average
- 500 µg/m^3 as a 10-minute average

The first of these is based on the results of controlled studies involving exercising asthmatics, which indicate that a proportion experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes.

The second is considered a precautionary approach for the protection of public health and is based on recent epidemiological evidence, including a study in Hong Kong where a rapid reduction in the sulphur content of fuels has been linked to substantial reductions in health effects (e.g. childhood respiratory disease and all-age mortality). Recent time-series studies on hospital admissions for cardiac disease in Hong Kong and London have also produced no evidence of a threshold for health effects at 24-hour SO_2 concentrations in the range of 5-40 µg/m^3.

The WHO has outlined a staged approach with interim targets (IT). IT-1 of 125 µg/m^3 is formerly the WHO Air Quality Guideline[7], IT-2 of 50 µg/m^3 is an intermediate goal based on controlling either motor vehicle emissions, industrial emissions and/or emissions from power production.

2.3.4 United States Environmental Protection Agency

In 2010 the United States Environmental Protection Agency (EPA) issued a new health standard[8] for SO_2. It is claimed that this one hour standard will protect millions of Americans from short term exposure to SO_2, which is primarily emitted from power plants and other industrial facilities. The EPA has set the one hour SO_2 standard at 75 ppb or approximately 200 µg/m^3.

[6] WHO, 2006, *Air Quality Guidelines Global Update 2005 - Particulate matter, ozone, nitrogen dioxide and sulphur dioxide*, World Health Organization, 2006.
[7] WHO, 2000, *Air quality guidelines for Europe, 2nd ed*. Copenhagen, World Health Organization Regional Office for Europe, 2000 (WHO Regional Publications, European Series No. 91).
[8] http://epa.gov/air/criteria.html

2.4 SO_2 anthropogenic sources

2.4.1 Ballance Agri Nutrients Ltd (BOPRC Consent No. 64800)

The sulphuric acid plant stack located in the south west corner of the Mount Maunganui industrial area is the main source of SO_2 emissions.

Molten sulphur is burnt with dried air creating a temperature of over 1,100ºC. The resulting sulphur dioxide gas from the boiler is fed through a ceramic filter to remove particulate matter and then passed over three beds of vanadium pentoxide catalyst, followed by an absorption tower, a fourth catalyst bed, and a second absorption tower. The catalyst converts the SO_2 to SO_3, which is dissolved in sulphuric acid in the absorption towers. The conversion efficiency of SO_2 to SO_3 is dependent on the performance of the catalyst but is typically over 99%.

The only SO_2 discharge mitigation available currently on the acid plant is related to the degree of conversion of SO_2 to SO_3 as the higher the percentage converted, the less SO_2 is discharged. There is only a small amount of absorption of SO_2 in the absorption towers as SO_2 has limited solubility in H_2SO_4.

SO_2 is also discharged from the manufacturing plant stack.

The mixer[9], den[10] and other strategic points inside the building are extracted to a four stage scrubbing system. Scrubber liquor is sprayed in the ducting prior to the first void tower. The waste gases then pass through two venturi scrubbers where they are scrubbed with low strength scrubber liquor, and finally with clean makeup water.

The gases then pass to a salt water void tower with two recycle sprays and a fresh salt water spray on the exit as makeup.

Fugitive emissions from the granulation plant are also ducted to the salt void tower. Sodium hydroxide is added to the salt water makeup spray to control the pH between five and six. This aids in reducing sulphur dioxide emissions. From the salt void tower, the waste gases are ducted to the manufacturing plant stack.

The consent has a SO_2 limit of 90 kg/hr for the acid plant stack and 10 kg/hr for the manufacturing plant stack.

2.4.2 Hexion Specialty Chemicals (NZ) Ltd (BOPRC Consent No. 61693)

Hexion Specialty Chemicals (NZ) Ltd, located near the southern boundary of the Mount Maunganui industrial area, refines two pulp mill by-products by distillation. These products can produce odours as they contain residual amounts of sulphide compounds. The site also operates two high temperature incinerators that produce combustion gases and particulate matter.

[9] The mixer is where metered ground rock which is stored in silos is introduced to concentrated H_2SO_4 and water (70% sulphuric acid).
[10] The den comprises a slow moving and circulating belt and is where the chemical reaction and physical setting of the superphosphate occurs for a period of up to 25 minutes. During this stage the liquid content is being reduced and dissolved chemicals, mainly calcium sulphate and monocalcium phosphate, crystallise to a solid form.

The two main raw materials used on site are Crude Sulphate Turpentine (CST) and Crude Tall Oil (CTO). These products are sourced from kraft pulp mills both within New Zealand and overseas. CST is a by-product of condensing the vapour generated during the steaming of the wood chips used as raw material for the pulping process, while CTO is a by-product of the used cooking liquor after it has been concentrated. The fatty acids present in wood are converted into a soap form during cooking and this soap is separated from the liquor. The soap is treated with sulphuric acid to convert it back into an oil, which is sent to Hexion for refining.

Crude Tall Oil is separated into several components such as pitch, rosin, and tall oil in three distillation columns. These components are used in various products such as paper size, resins, soaps and glues. The gases that are dissolved in the CTO, and vapours drawn off under vacuum during the distillation process, are burned in two High Temperature (HT) furnaces.

Sulphur dioxide is one of the combustion gases generated by the HT furnaces.

The consent has a SO_2 limit of 74 kg/hr from the HT furnace stack.

2.4.3 New Zealand Marine Services Ltd (BOPRC Consent No. 64391)

New Zealand Marine Services Limited operates an oil collection and disposal facility near the southern boundary of the Mount Maunganui industrial area. Oil contaminated with water is collected from ships berthed at the Port of Tauranga, Ports of Auckland and from Wellington, and processed to extract the water and produce dry oil, which is then sold as fuel oil. A 4,500kW Aquaheat TP300E thermal oil heater is used to provide heat to the processing plant, 24 hours/day, five days/week, 52 weeks of the year. The heater is run on heavy fuel oil produced by the plant. Discharges include sulphur dioxide (SO_2), steam, particulates, and other combustion gases, discharged to a 6 m high flue.

The consent requires that the permit holder shall ensure that the concentration of sulphur in the fuel used in the thermal oil heater does not exceed 0.5% w/w (which is equivalent to an emission rate of approximately 3.4 kg/hr assuming that all sulphur is converted to SO_2).

2.4.4 Allied Asphalts Ltd (BOPRC Consent No. 62740)

Allied Asphalts Limited owns and operates an asphalt plant in the south-eastern area of the Mount Maunganui industrial area. A computer automatically runs plant operations, controlling input rates, production rate and temperature. The plant can produce up to 80 tonnes/hr of standard mix (road chip, sand and crusher dust coated in road grade bitumen), though normally the plant averages 50 to 60 t/hr. It should be noted that this is a batch type operation rather than a continuous process, and does not operate on a ‘24/7’ basis.

The aggregates are fed by conveyor into the dryer/mixing drum, where they are dried and heated to 150ºC by the gas burner as they are lifted to create an aggregate “curtain”. Bitumen is fed in about halfway down the mixing drum, coating the heated aggregate. In theory, the bituminous “curtain” collects fine particulate and dust. The resulting mixture is fed in to the expansion chamber, where the gas velocity drops, and heavier particulate falls from the air column. The exhaust gases in the stack pass through a venturi water scrubber that entraps fine particulate. The water is then discharged to a settling pond on the property, and from there reused in the scrubber. Lime is added to the scrubber water to keep an alkaline pH to enable greater removal of SO_2 from the stack gases. The stack is 18 m high.

The permit holder is required to ensure that the sulphur content of fuel used to heat the asphalt plant does not exceed 2% w/w (which is equivalent to an emission rate of approximately 13.6 kg/hr assuming that all sulphur is converted to SO_2).

2.4.5 Higgins Contractors Ltd (BOPRC Consent No. 63317)

Higgins Contractors Limited owns and operates an asphalt plant in the south-eastern area of the Mount Maunganui industrial area. A computer automatically runs plant operations, controlling input rates, production rate and temperature. The plant can produce up to 60 t/hr of standard mix (road chip, sand and crusher dust coated in road grade bitumen), though normally the plant averages about 80% of this rate.

The process used at this plant is much the same as that described above for Allied Asphalts Ltd.

The permit holder is required to ensure that the sulphur content of fuel used to heat the asphalt plant does not exceed 2% w/w.

2.4.6 Motor vehicles

Recent legislation[11] has resulted in reductions of the sulphur content of petrol and diesel. Table 3 shows estimates from the 2001 Bay of Plenty air emission inventory which was undertaken prior to the fuel specification changes (pre 2006 sulphur content was 600mg/kg, post 2006 the sulphur content was 50 mg/kg) and hence would be regarded now as conservative even though traffic volume has increased in that time (Hewletts Road ADT- ~21,000 in 2001 to ~26,000 in 2008, with heavy vehicle contribution remaining around 8% for both years). An emission inventory is currently being updated for Tauranga and will provide more recent information on this particular source.

Table 3 SO_2 emissions calculated for transport sources for 2001.

SO_2 tonnes per year	Transport				
	Motor vehicles	Aviation	Shipping	rail	Total
District					
Taupo	12	0	0	0	12
WBOP	115	0	0	9	124
Tauranga	116	0.1	390	4	510
Rotorua	117	0.1	0	0	117
Whakatane	83	0.0	0	12	95
Kawerau	7	0	0	0	7
Opotiki	27	0	0	0	27
Total	477	0.2	390	25	891
Urban areas					0
Tauranga	95	0.1	257	0.5	352
Rotorua	57	0.1	0	0	57
Whakatane	12	0	0	0	12

[11] Engine Fuel Specifications Regulations 2008 (SR 2008/138). Petrol - 50 mg/kg, Diesel 50 mg/kg (10 mg/kg by 1 January 2009), note the limit for sulphur does not apply to sale for marine use.

2.4.7 Shipping

In a research paper, Endresen[12] provides substantial authoritative data on SO_2 emissions from global commercial shipping. A key assumption of Endresen's work is that marine bunker fuel has a sulphur content of 2.1%. These data indicate that: kg.SO_2 per km = 0.17 * (Deadweight tonnage)$^{0.25}$. This calculation is suitable for vessels underway, but for determining emissions while in port the following work was undertaken for the reference year 2001 in the Bay of Plenty Emission Inventory[13].

> *"Tauranga is a major shipping port for New Zealand. Commercial shipping movement and time-in-port information was obtained from the Port of Tauranga. A total of 1,259 ships entered the port in 2001 (the annual average for 2006 to 2009 was 1,236 vessels). The duration of the stay was on average 1.5 days and ships had an average gross registered tonnage of 17,800. Emission factors for shipping were from the NIP EET[14] for a gross registered tonnage of 10,000 - 50,000. It was assumed that the auxiliary engines were run while in port, and the main engines were run while entering and leaving the harbour. The average berthing time was 25 minutes. The contribution of shipping to the Tauranga urban area was assumed to be that of running the auxiliary engines while in port. An annual estimation of 390 tonnes of SO_2 was determined for this shipping configuration."*

2.4.8 Trains

The region has an active rail network linking the main trunk line to the major Port in Tauranga and servicing the forestry industry in Whakatane district. For the region-wide inventory SO_2 was estimated on the basis of 0.2% weight sulphur in the fuel. The SO_2 annual emission for the Tauranga rail network was calculated at 4.2 tonnes, but due to reductions in the sulphur content of diesel (see discussion in Section 2.4.6) this figure would now be conservative. Only part of the Tauranga network is in the Mount industrial area so once again the figure would be conservative for that emitted into this area of interest.

2.4.9 Aircraft

Almost all commercial aircraft use aviation kerosene in jet engines. Specifications for Jet A1 fuel vary, and generally have a 0.3% sulphur limit.

The most fuel-intensive part of a flight is the take-off and climb to a height of 3,000 m. Data from Boeing indicate that typical fuel use during taxi, takeoff and climb is in the region of 10,000 L for a 747 and 2,500 L for a 737. In contrast, the fuel use by on-ground auxiliary power units is about 1% of the take-off and climb fuel and can be ignored.

In contrast with the three main airports, SO_2 emissions at the other regional airports in New Zealand are considered to be trivial.

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[12] Endresen, O, 2007, *A historical reconstruction of ships' fuel consumption and emissions*. Journal of Geophysical Research Vol 112, D12301, doi:10.1029/2006JD007630.
[13] SKM, 2003, *Bay of Plenty Regional Air Emission Inventory*, Version 2, p.76.
[14] Australian National Pollutant Inventory Emission Estimation Techniques.

2.4.10 **Natural emissions**

New Zealand has two significant natural sources of SO_2 discharge to air, the volcanoes of White Island and Mount Ruapehu. SO_2 emissions from other geothermal vents in the Taupo Volcanic Zone are minor because (unlike CO_2 and H_2S) SO_2 generated from the active magma bodies is scrubbed out by underground geothermal fluids before the gas is vented to air.

The emission rates of SO_2 recorded for White Island indicate high emissions occurring routinely, with a peak of 2,500 tonnes per day measured in 2000.

There has also been an automated monitoring system in place on White Island since July 2006. The average of the hourly average data from the automated monitoring system on White Island is 162 tonnes per day.

Part 3: Earlier monitoring and investigations

3.1 ESR monitoring, 1994

Monitoring of a range of gaseous contaminants was undertaken at the same site in Totara Street as where the current SO_2 monitoring is being undertaken. The period of monitoring for SO_2 was 14 October to 15 December 1994. The recorded data summary is as follows – 10 min average = 322 $\mu g/m^3$, 1 hour average = 226$\mu g/m^3$ and 24 hour average = 42$\mu g/m^3$.

Sulphur dioxide results displayed a random pattern. The peaks, when they occurred were short and sharp, although several of these occured close together over a period of several hours. The highest of the peaks mainly coincided with winds coming from the direction of Eka Nobel (now Hexion) and BOP Fertilizer Works (now Ballance). Smaller peaks were seen to coincide with winds from the petrol storage facility and the Port of Tauranga[15].

3.2 Other New Zealand monitoring

The recent MfE report card[16] summarised monitoring data from throughout the country. The following trends were reported:

> *"Recent trend - Sulphur dioxide was reported on in Environment New Zealand 2007[17]. Since then, results for the 1-hour and 24-hour maximums and annual averages for the Auckland and Christchurch (St Albans) sites have been relatively constant while results for the Tauranga and Christchurch (Woolston) sites have fluctuated.*
>
> *In 2006, there were 24 exceedances and 11 breaches of the 1-hour national standard for sulphur dioxide. Twenty-one of the exceedances and all 11 of the breaches occurred at the Tauranga site.*
>
> *In 2008, the only site to exceed (but not breach) the 1-hour national standard for sulphur dioxide was Christchurch (Woolston).*
>
> *Long term trend - Annual levels of sulphur dioxide at the Christchurch (St Albans) site show a general decreasing (improving) trend. This reflects the continuing reductions in the amount of sulphur in diesel fuel and coal use over this period.*
>
> *The annual levels at the Auckland site have fluctuated over this period. The increasing levels at this site in the mid- to late-1990s coincided with an increase in the registration of new and used diesel vehicles and levels subsequently decreased with the improvement in fuel quality."*

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[15] Hally, V. M. et al, 1995, *Ambient Air Monitoring in Mt Maunganui, September – December 1994,* MESC Report 95-400, prepared for Environment Bay of Plenty, p.25.

[16] MfE, 2010, *Air Quality (Four Pollutants)*, Environmental Report Card, INFO487 report, http://www.mfe.govt.nz/environmental-reporting/report-cards/air/2010/index.html.

[17] http://www.mfe.govt.nz/publications/ser/enz07-dec07/html/chapter7-air/index.html

3.3 New Zealand Sulphur Dioxide Industrial Emission Inventory – 2007[18]

MfE was requested by the National Air Quality Working Group to prepare a policy position on the WHO 2005 guidelines for SO_2. This Environet Ltd report undertakes one of the first steps towards determining a policy position on SO_2 in New Zealand by quantifying the SO_2 output from industrial discharges.

The purpose of this inventory and report was to identify industry in New Zealand with significant discharges of SO_2 and to quantify the daily SO_2 emissions.

Industries with significant SO_2 emissions were identified using information from resource consent databases provided by regional councils. Key industry sources included were coal, light fuel oil (LFO) or used oil-fired boilers with a net rated heat output of 3 MW or greater, fertiliser manufacturing plants, asphalt plants (fired by LFO or waste oil), refineries, steel works, aluminium smelters, cement kilns, power stations and other combustion processes greater than 3 MW burning coal, LFO or used oil.

Of a total of 245 industries considered, 133 met these criteria and were included in the inventory. A further 16 boilers that were slightly below the 3 MW rating were also included in the inventory. Sulphur dioxide emission estimates were made based on fuel use, production or emissions data provided by the industry or regional councils. The resulting maximum daily SO_2 emissions for each industry are shown in Figure 2.

[18] Wilton, E., et.al., 2008, *New Zealand Sulphur Dioxide Industrial Emission Inventory – 2007*, prepared for the Ministry for the Environment, 48p.
http://www.environet.co.nz/environet/documents/SO2_InventoryFinalEnvironetCover.pdf

Figure 2 *Maximum daily SO_2 industry emissions in New Zealand.*

Part 4: Mt Maunganui Meteorology

The wind climate is important when discussing air quality. A summary of a period of record from the Tauranga Aero meteorological site shows the effect of seasonal patterns (Figure 3). A dominant SW quadrant contribution in the annual windrose will result in contaminants being transported from the industrial area and impacting on the residential zone to the northeast of the industrial area. Calm conditions contribute less than 5% at this site.

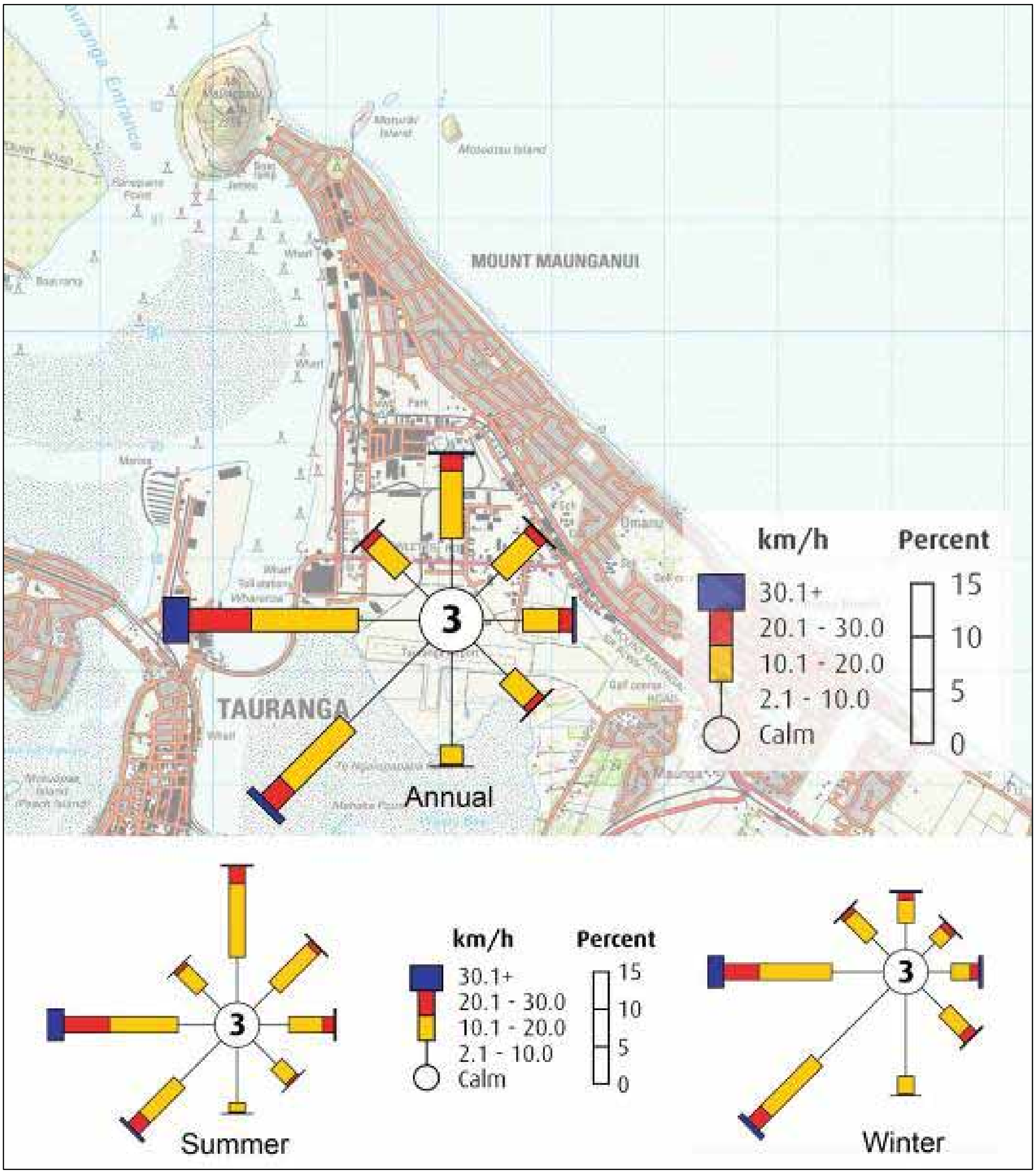


Figure 3 Wind patterns for Mount Maunganui.

Part 5: Recent Monitoring Data

This section summarises the ambient 10 minute SO_2 data collected from the two Bay of Plenty Regional Council monitoring sites and the Ballance Agri-Nutrients Ltd monitoring site (hereafter referred to as Chevron).

5.1 Monitoring method

The MfE Good Practice Guide[19] and the NES-AQ regulations[20] recommend a set of methodologies for ambient air quality monitoring. For SO_2 the latest method is - Australian Standard AS3580.4.1:2008, Methods for sampling and analysis of ambient air, Determination of sulphur dioxide, Direct-reading instrumental method.

The data recording interval is 10 minutes.

Both council monitoring sites are checked daily with programmed internal zero/span routines. Multi-point checks are performed on a monthly basis or following significant setup changes of the instrumentation.

Meteorological data is recorded at the Totara Street site, and is also recorded at the nearby Tauranga Airport as well.

The operation of the two sites by Bay of Plenty Regional Council is undertaken in accordance with the Environmental Data Services Field Practice Manual[21], and the MfE guidance document[19]. Operation includes routine maintenance of the site and instrumentation and calibration of the monitoring equipment.

The Environmental Data Services Air Quality Office Practice Manual[22] outlines procedures for the provision of quality assured data.

As a form of external audit on the instrument operation an inspection programme is conducted using Ecotech Pty Ltd every 18 months. Ecotech is an ISO 9001 and NATA accredited company. Reports from Ecotech provide calibration, service results and comments regarding the operation of the site and instrumentation.

5.2 Monitoring sites

5.2.1 Totara Street

The data presented for this site in this report is from January 2005 to present.

This site is bounded immediately to the west by Totara Street which has an annual average daily traffic flow (AADT) of approximately 10,000 vehicles per day (vpd). Hewletts Road, ~300 m to the south has an AADT of ~30,000 vpd[23]. These flows are predicted to increase as improvements to Hewletts Road are finalised and the second Mount Maunganui/Tauranga Harbour Bridge has now been commissioned. This site is impacted by a wide range of sources (industrial and various forms of

[19] Ministry for the Environment. 2009. *Good Practice Guide for Air Quality Monitoring and Data Management 2009.* Wellington: Ministry for the Environment.

[20] Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004 SR 2004/309 (2004/433 and 2005/214).

[21] Environment Bay of Plenty, 1998, *Field Practice Manual*, Internal document.

[22] Environment Bay of Plenty, 1999, *Air Quality Office Practice Manual*, Internal document.

[23] New Zealand Transport Agency, 2009, *State Highway Traffic Data Booklet*, http://www.nzta.govt.nz/resources/state-highway-traffic-volumes/.

transport combustion). These sources surround the site for within a minimum of 500 m in all directions. The open coastline is 1.5 km to the northeast at its closest point and the harbour/land interface is located 500 m to the west and south of the monitoring site. This topographic setting results in complex meteorological patterns as temperature variation creates and drives localised airmass circulation.

5.2.2 Maru Street

The data presented for this site in this report is from June 2007 to present.

The site is located on the western side of Maru Street on property owned by Ballance Agri Nutrients Ltd. The sampling inlet is situated 160 m from Maru Street (AADT ~1000 vpd) and 260 m north of Hewletts Road (AADT ~30,000 vpd). The site was set up to run in tandem with the Totara Street SO_2 instrument, with the intention that the two sets of parallel data would allow a degree of differentiation between the two main industrial emitters of this contaminant, and other possible sources. The Maru St site location was determined on the basis of site availability and the potential areas of impact shown in the modelling data presented as part of the consent renewal application for Ballance[24].

5.2.3 Chevron – Ballance monitoring site

The data presented for this site in this report is from November 2008 to present.

As per condition 8.6 of Resource Consent 64800, Ballance Agri-Nutrients Ltd is required to undertake ambient monitoring of SO_2 at an agreed location with the Regional Council.

In September 2008, Ballance Agri-Nutrients Ltd commissioned Watercare Services Ltd to conduct continuous ambient monitoring of sulphur dioxide (SO_2) and the relevant meteorological parameters.

The monitoring site is located approximately 240 m east of Ballance at 161 Hewletts Road. The monitoring shed is located beside the office buildings of Chevron at 212 Totara Street, 200 m from Hewletts Road (State Highway 29). The surrounding area is a flat industrial park with the Hexion site directly across the road to the east, Port of Tauranga to the west and Tauranga Airport to the southwest of the monitoring shed. Several fuel storage tanks are located between the Ballance plant and the monitoring shed.

5.3 Monitoring results

The monitoring presented in the following sections is from the sites described in Section 5.2.

5.3.1 SO_2, wind speed and wind direction data

The data presented below shows the dominating influence of the fertiliser works on the SO_2 profile for the southern Mount Maunganui area. The fine resolution 10 minute data set for each site combined with the wind data from the Totara Street site graphically shows this dominating profile (Figure 4).

[24] URS, 2007, Assessment of Effects of the Air Discharge from Ballance Agri-Nutrients Ltd, Mt. Maunganui. March 2007, Prepared for Ballance Agri Nutrients Ltd.

The emissions from Hexion are reflected in the Totara Street pollution rose and will also be a component of the south-westerly radials in the Maru rose. The stack height of the Hexion plant and the close proximity of the Chevron site means that the Hexion emissions have very little impact at this monitoring location.

Traffic influences and port related activities are also represented in the Totara and Chevron pollution roses and to a lesser extent at the Maru site. This will be examined further later in this section.

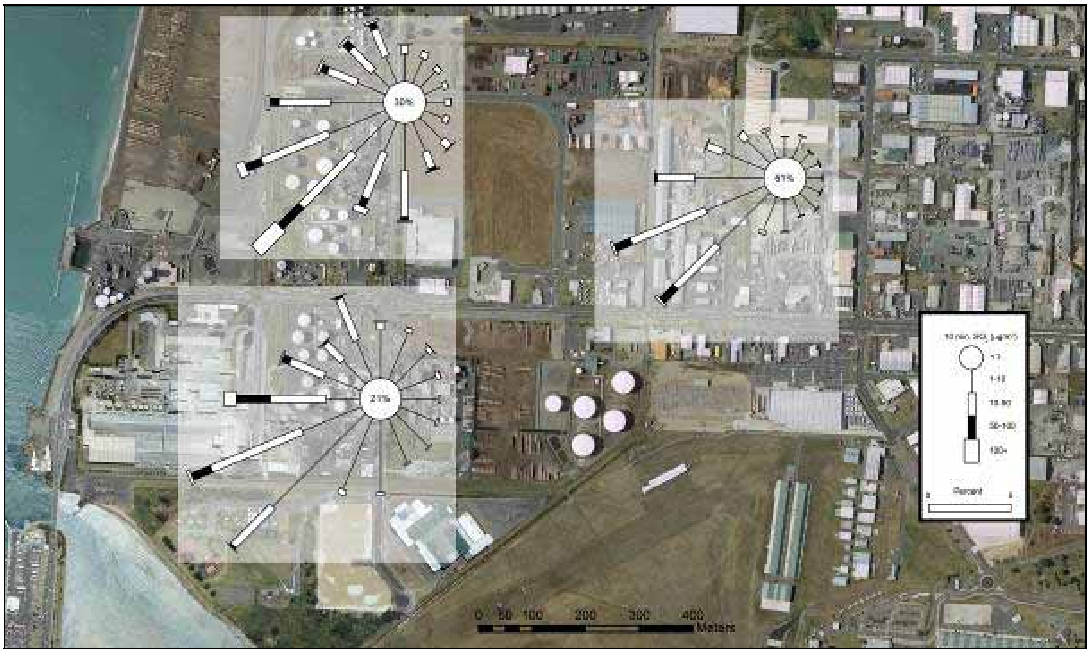


Figure 4 *SO_2 roses for the three monitoring sites, 10 minutes data, full period of record.*

The relationship[25] between wind speed, wind direction and SO_2 concentration is shown for the Totara dataset in Figure 5. The scatter plots in Figure 6 show the relationship between concentration and wind direction. The role of wind speed is important in controlling ground level concentrations as can be seen in Figure 5, where lower wind speeds provide greater concentrations with levels diminishing as the velocity increases. The prominent industry quadrant is also evident in this three dimensional plot.

[25] The distance-weighted least squares method fits a curve to the data by using the following procedure. A polynomial (second-order) regression is calculated for each value on the *X* variable scale to determine the corresponding *Y* value such that the influence of the individual data points on the regression decreases with their distance from the particular *X* value. This method provides a sensitive method for revealing non-salient overall patterns of data.

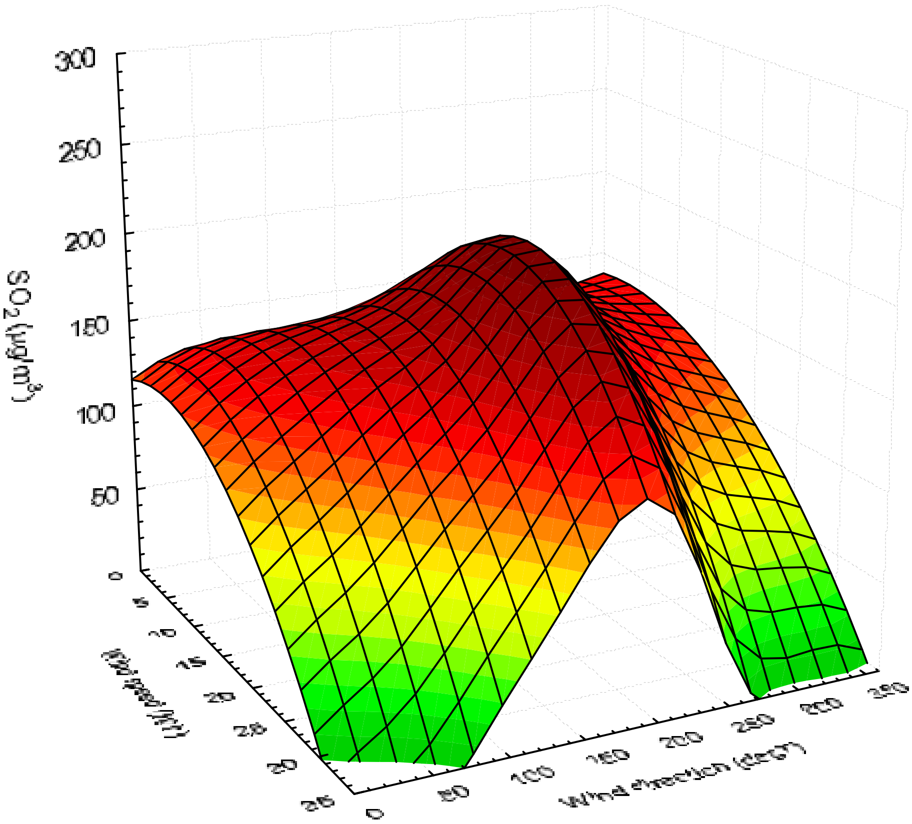


Figure 5 Relationship between SO_2 concentration, wind speed and wind direction. 10 minute data, full period of record from Totara monitoring station.

This direction component can be investigated more closely with the following plot from each site (Figure 6). The Totara plot shows elevated readings in a clockwise arc from 160° to 360°, the strong effect of the Ballance operation and to a lesser degree Hexion can be seen (190° to 240°) but interlaced with this will be the contribution from traffic sources and emissions from shipping. An elevated baseline is seen across the remaining arc for Totara when compared with data from the other two sites.

The Chevron data shows the influence of the Ballance operation and NZ Marine Services Ltd (which is from a considerably lower stack), and a few elevated results from the Hexion direction (45° to 100°) when the meteorology is conducive. Contributions from transport on Hewletts Road and Totara Street are evident. For the clockwise arc from east to southwest (representing the airport and the harbour) the concentrations are at a minimum.

The data collected from the Maru Street site shows similar looking elevated results when looking at wind direction from the southwest. Contributions in the sector will be from both main industrial premises and Hewletts Road. Differentiation would require fine resolution operational data and traffic flow information to try and determine percentage contributions from these sources. The roadway contribution is not as evident though, as the values for 160° to 200°, are generally low which reflects the 300m separation between source and monitoring site. However it should be noted that the values within the peak sector are generally a fifth of those recorded at the Totara Street site.

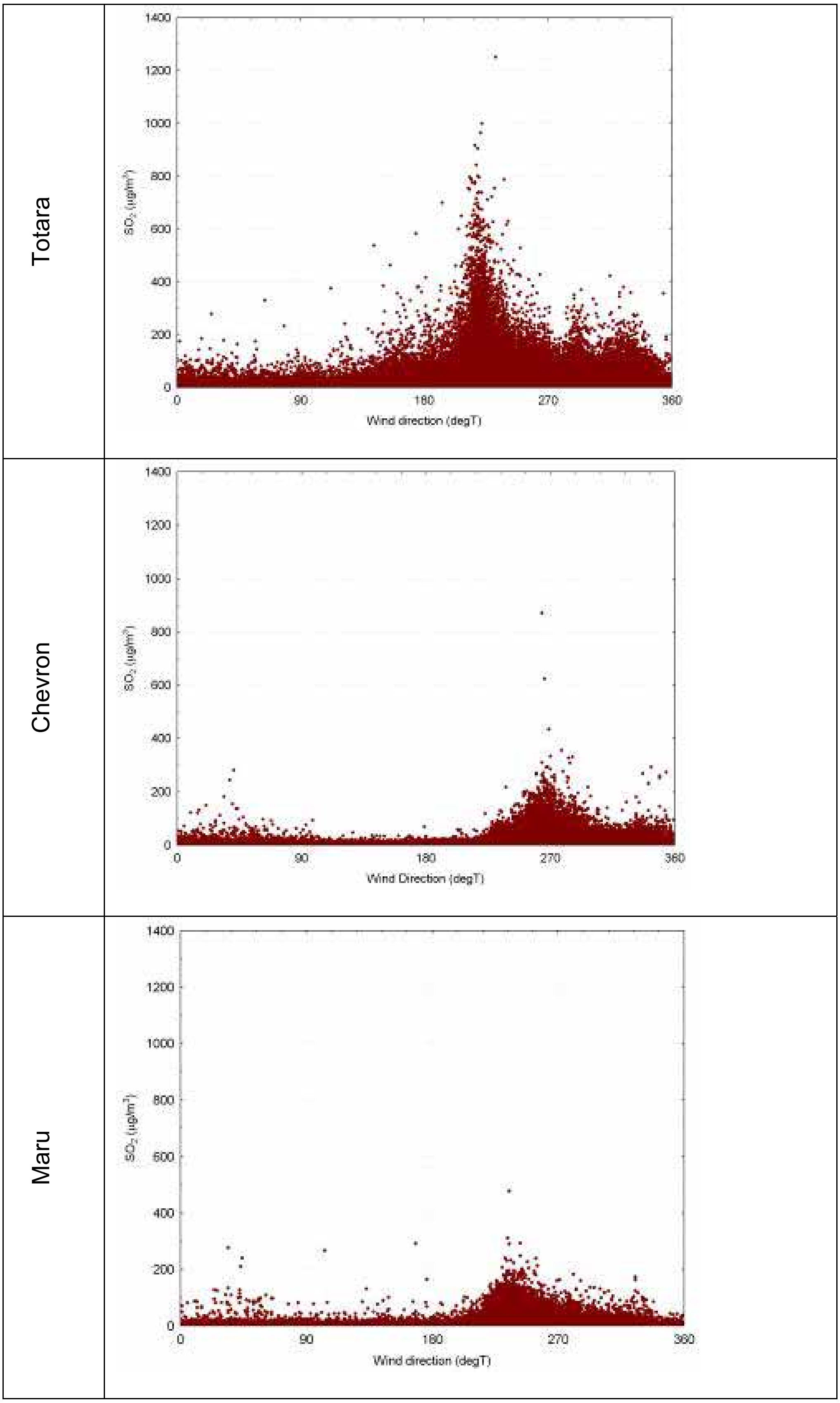


Figure 6 10 minute SO_2 data with wind direction patterns.

5.3.2 SO_2 and traffic count data

The latest traffic count data (7 day collection period from 11 May (Tuesday) to 18 May (Monday) 2010) from TCC was obtained. Shown graphically (Figure 7) with wind direction and SO_2 measured from Totara Street, several points were identified;

- SO_2 concentrations are typically low when wind directions are outside the zone of influence of the Totara Street carriageway, Ballance and Hexion.
- For most days the SO_2 baseline increases as traffic volume increases. 12 May is an exception when winds were from the NE quadrant were transporting vehicle emissions away from the site.
- Source plume behaviour is complex and relationships between these several parameters do not always allow for trends to be detected over short time periods. An example is that wind directions from the Ballance operation do not always result in elevated SO_2 readings.

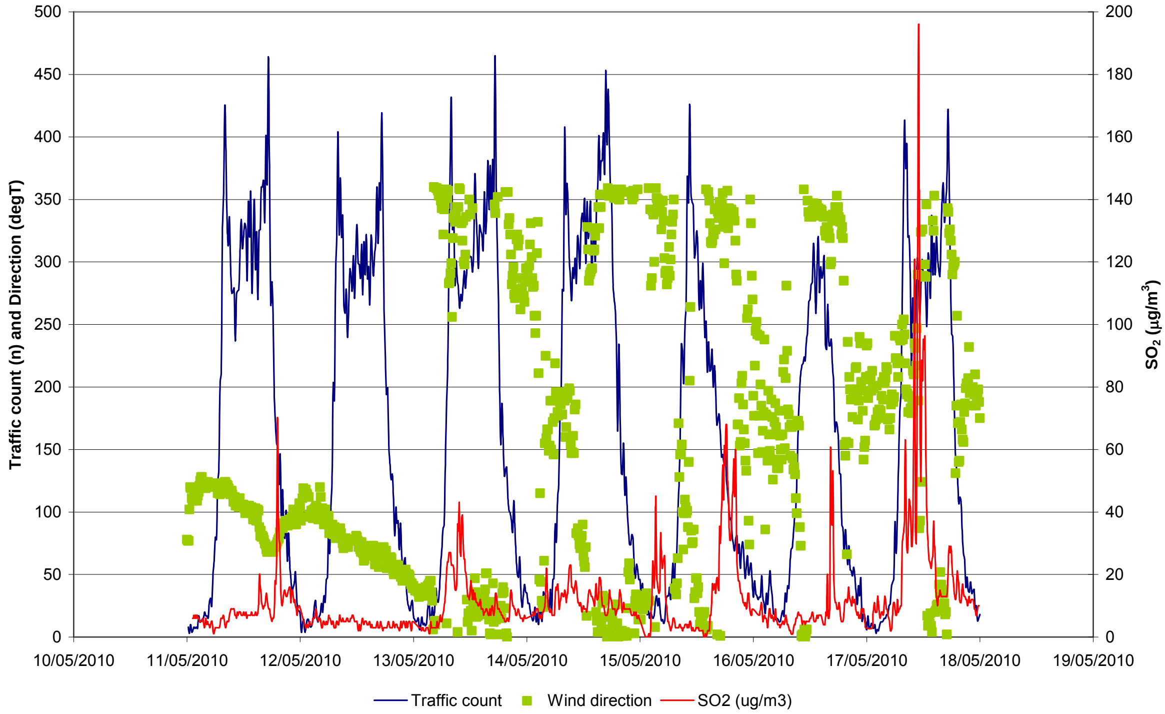


Figure 7 10 minute SO_2 data with wind direction and traffic volumes for Totara Street.

5.3.3 SO_2 diurnal data

To investigate the traffic contribution further, diurnal SO_2 plots (Figure 8) were produced for each site. No adjustments have been made for daylight saving as the council monitoring sites maintain a NZST profile year round. Definite traffic related increases can be seen in each plot with Totara understandably showing the most pronounced effect. At the Totara site a morning peak with hourly values up to ~70$\mu g/m^3$ is followed by a gradual recession during the day as volumes stabilise, and emissions get better dispersed, as wind speeds typically increase.

The Chevron data also shows the effect of transport but in a way which reflects the greater separation distance and southerly position in relation to the major roadways. As ambient emissions increase in the area during the day a northerly drift (as a result of sea breeze circulation patterns) results in concentrations increasing later in the day.

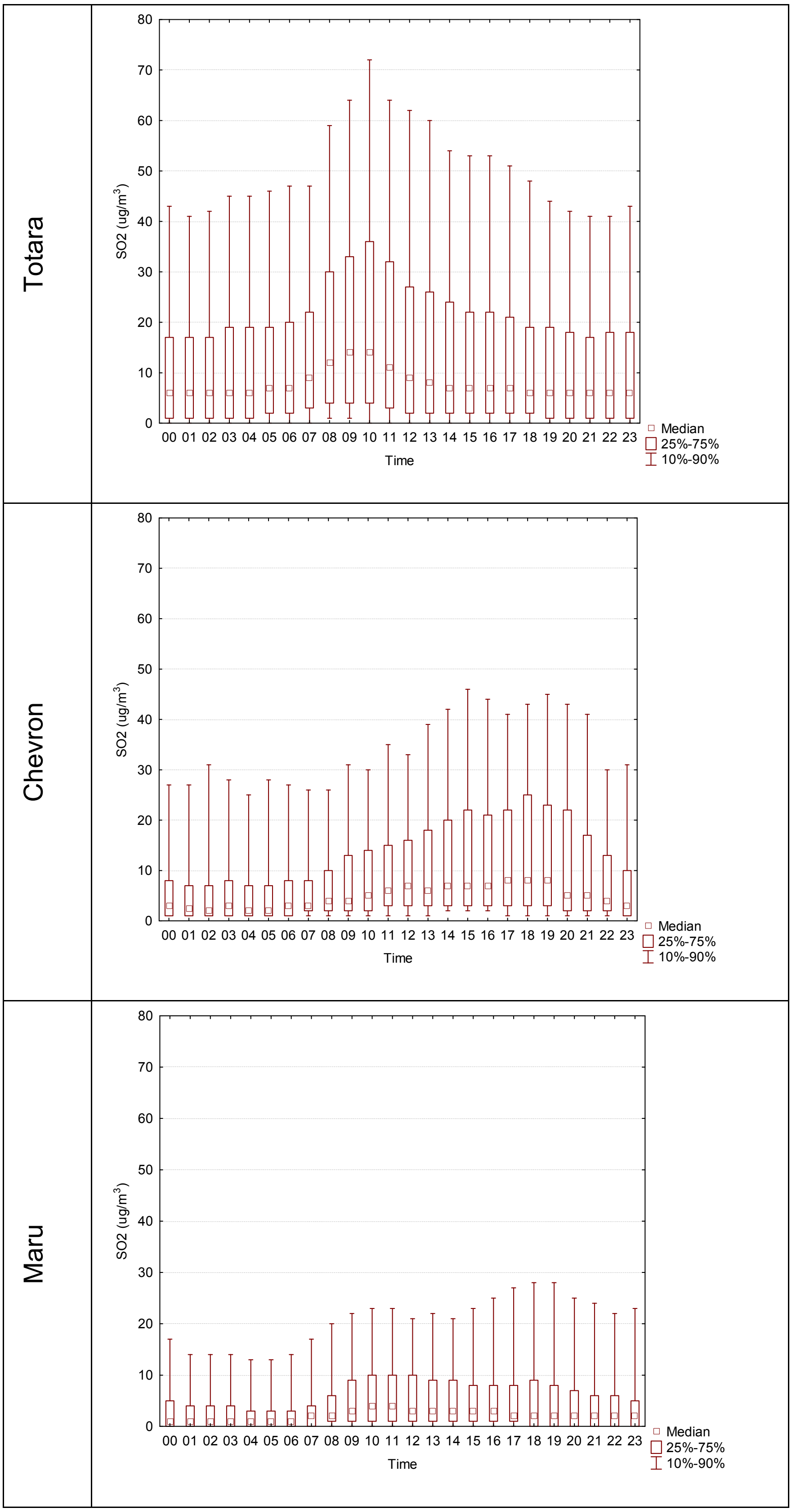


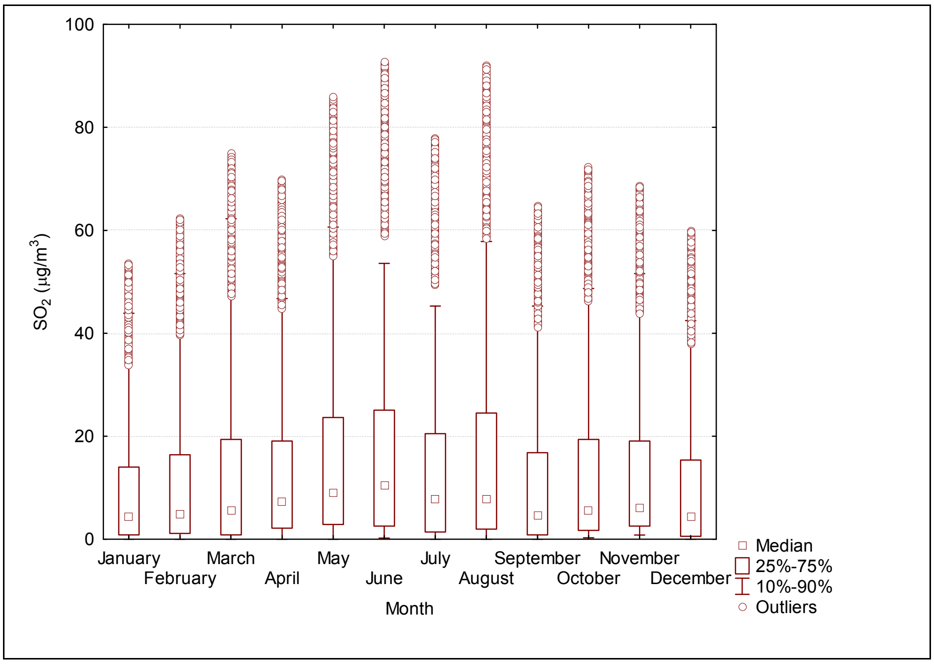
Figure 8 Diurnal SO_2 plots for the three monitoring sites. 1 hour values.

Maru shows a daytime build-up, but levels are a fraction of the others as a result of the greater separation distances from the main roadways and the main industrial emission sources.

5.3.4 SO_2 seasonal data

Figure 9 shows an analysis of the data on a monthly basis. As shown, there is an underlying seasonal pattern, with increases in monitored concentration in the more settled winter period. Daily sea breeze effects in the non-winter period result in greater dispersion potential and also movement of the SO_2 emissions away from the monitoring sites and across the section of the harbour between Whareroa Point and Te Ngaiopapapa Point which are to the south of the Mount Maunganui industrial area.

Variations in the levels of production in the two main industries also contribute to the variation in ground level concentrations and the patterns around the more elevated levels (Figure 9). Fertilizer production varies in relation to seasonal customer demands, while the production pattern for Hexion extends over an approximate 4 week cycle, with the greatest SO_2 emissions occurring at the start of this period.



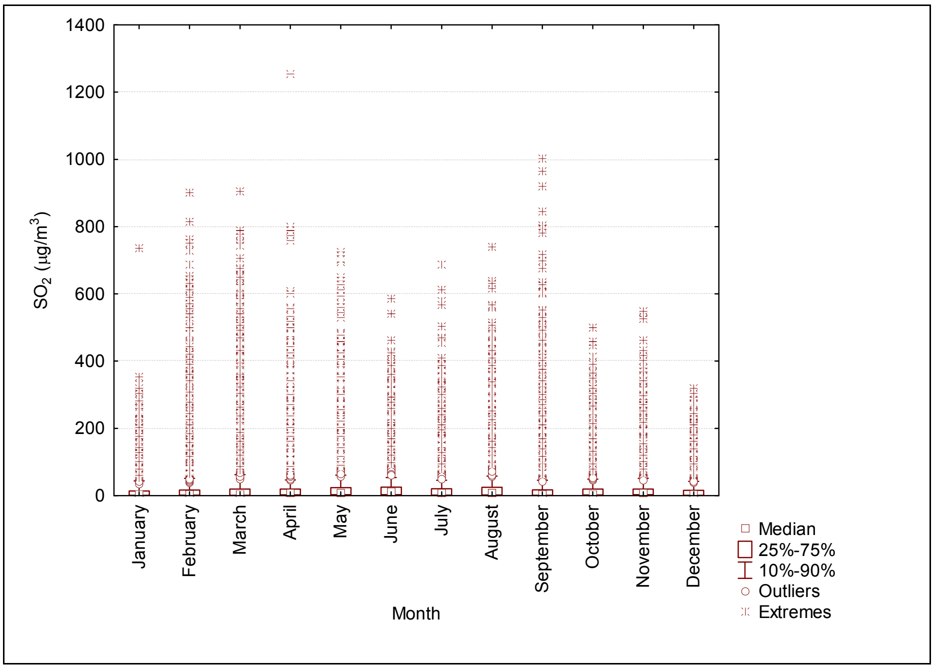


Figure 9 *Monthly box plot using 10 minute data from Totara monitoring site. Note extreme values included on the lower plot.*

5.4 Comparison with recent dispersion modelling

Dispersion modelling gives the ability to undertake a desktop exercise to determine ground level concentrations of the contaminant based on a measured or assumed emission profile and the meteorological dataset of typically a year to address seasonal influences. This exercise was undertaken recently by Ballance Agri Nutrients (report dated March 2007) as part of their consent renewal. At the time of the modelling exercise (using AUSPLUME®) only a limited dataset of ambient data existed[26] for which model validation could be performed.

A summary of the model results from the AEE[24] are shown in Table 4. It should be noted that the results in this table are for the worst case location. A summary of the ambient monitoring results is shown in Table 5.

Table 4 *A summary of results from the Ballance consent application dispersion modelling exercise. Note - The background 1 hour value is taken from the pollution rose and the background 24 hour value is adjusted from the 1 hour value using a ratio of averaging periods.*

Compound	Maximum Predicted Off-site Concentration ($\mu g/m^3$)	Background ($\mu g/m^3$)	Assessed Result ($\mu g/m^3$)	Guideline Value ($\mu g/m^3$)
Sulphur Dioxide (1 hour)*	280	50	330	350
Sulphur Dioxide (24 hour)	89	26	115	120
Sulphur Dioxide (Annual)	19.6			20

* 99.9%ile

[26] There is some uncertainty around some of the elevated levels recorded at the Totara site in 2005 and 2006 as a result of calibration frequency.

Table 5 Summary statistics from the three monitoring sites to date.

Totara						
	No.	**Mean**	**Median**	**Max.**	**99.9%**	**Modelled 99.9% (with background)**
1 hour	43335	20	7	674	350	200 (250)
24 hour	1807	20	13	192	170	50 (76)
Maru						
	No.	**Mean**	**Median**	**Max.**	**99.9%**	**Modelled 99.9%**
1 hour	27629	7	2	239	119	260 (310)
24 hour	1151	7	3	63	62	70 (96)
Chevron						
	No.	**Mean**	**Median**	**Max.**	**99.9%**	**Modelled 99.9%**
1 hour	15409	12	4	258	140	170 (220)
24 hour	642	12	8	83	82	40 (66)

Without consideration of a spatial component, the values in Table 4 align reasonably well with the values for the Totara monitoring site in Table 5, particularly for the 1 hour value. For the 24 hour value, Totara results are nearly 30% greater than the maximum modelled value.

However when investigating how well the model does in determining where the maximum GLC[27] will occur, the results are not as favourable (Table 5 and Figures 10 and 11). Due to the height of the stacks the maximum GLC's are predicted to be occurring at a distance of 500 to 1000m from the modelled sources. These maximums occur in a north easterly direction from the source area as a result of the prevailing south westerly wind pattern. The modelling outputs show the maximum zone would be around or near the Maru site (Figures 10 and 11). However at the Maru site the recorded maximum 1 hour value (99.9%ile) is less than half of the modelled value and the recorded 24 hour value is two thirds of the modelled level.

For the Totara site the recorded values are higher than modelled values by a factor of 1.4 and 2.2 for the 1 and 24 hour values respectively.

For the close in site at Chevron the 1 hour figure is less by a factor of 1.6 and the 24 hour value greater by a factor of 1.2.

[27] Ground level concentration.

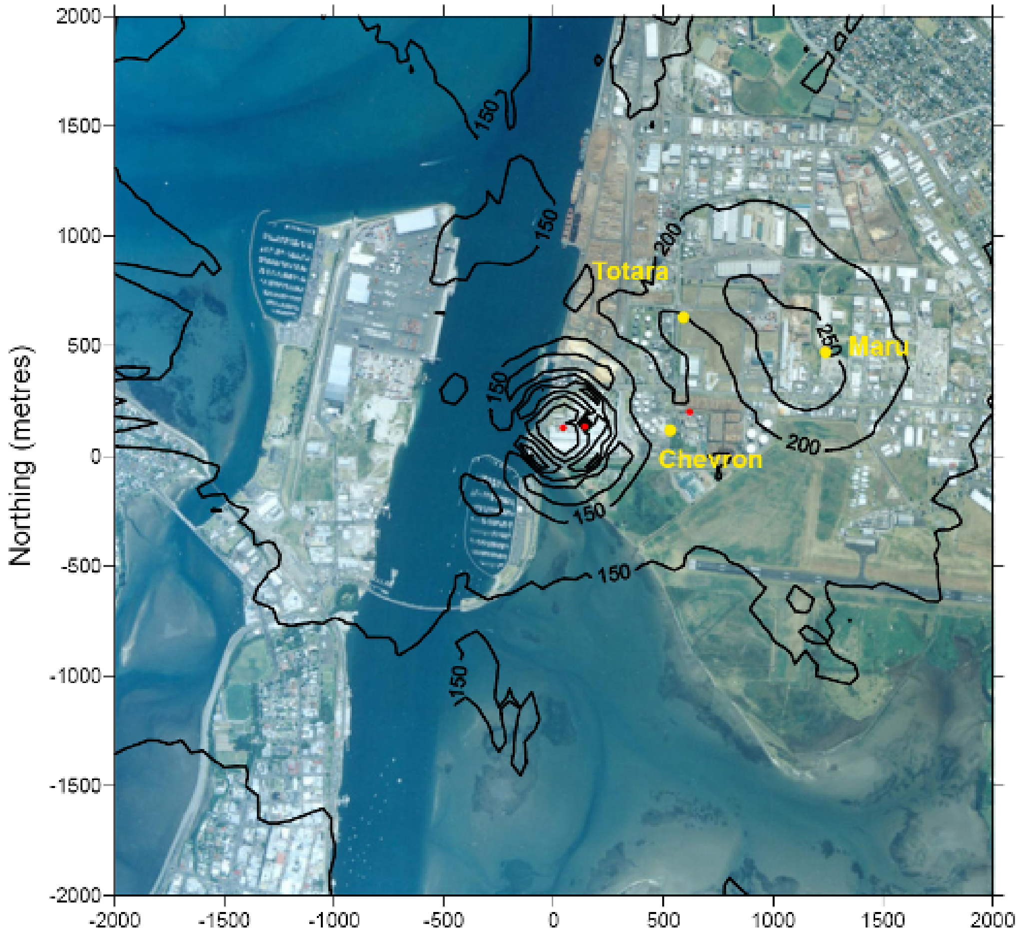


Figure 10 *Maximum (99.9%ile 1-hr average) ground level concentrations predicted by the dispersion model for Ballance and Hexion excluding background. Red dots are the industrial sources. Monitoring sites in yellow.*

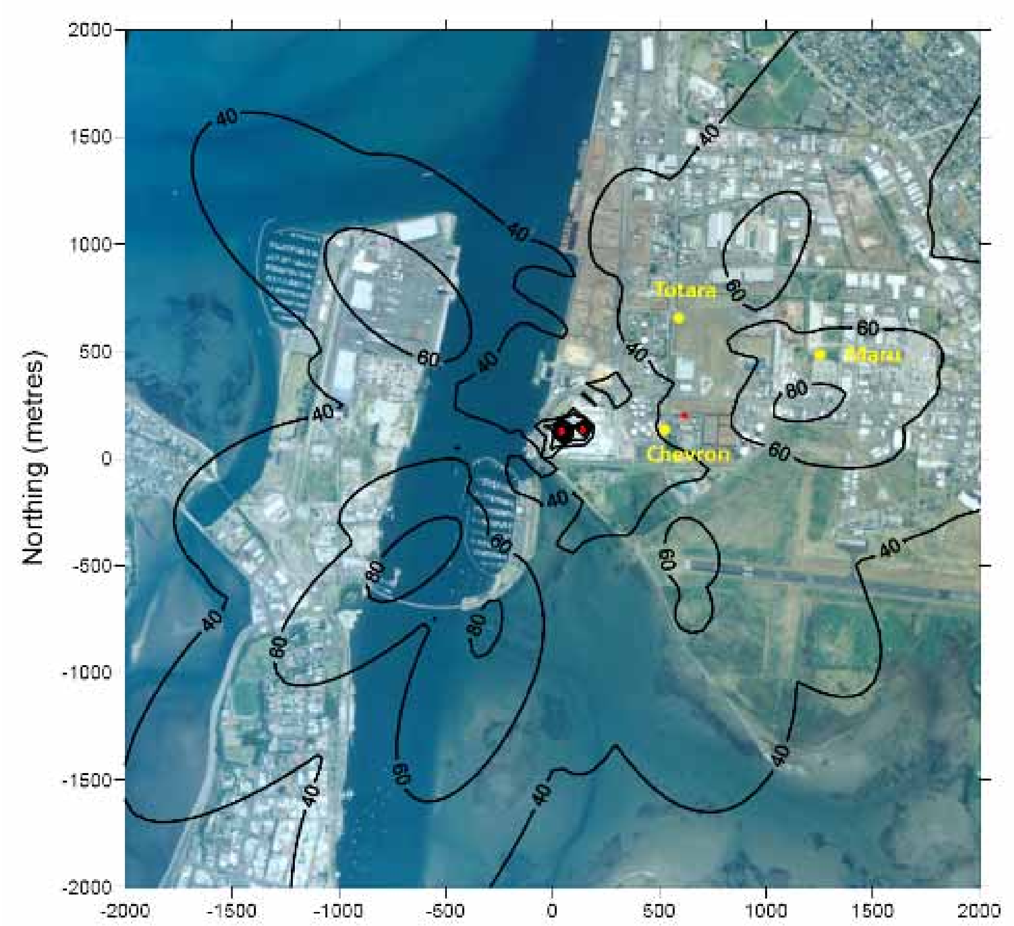


Figure 11 *Maximum (99.9%ile 24-hr average) ground level concentrations predicted by the dispersion model for Ballance and Hexion excluding background. Red dots are the industrial sources. Monitoring sites in yellow.*

Overall the modelling shows a mixture of conservative and underestimated results when compared with the three monitoring site dataset statistics. If the Totara site can be termed an elevated SO_2 monitoring location (recognising that it was originally chosen for the ESR monitoring program (see Section 3.1) and is now the location for the BOPRC monitoring programme as a site ideally positioned in relation to the major SO_2 emissions in the area) then based on the presented data the model predicts the 1 hour concentration well and under predicts the 24 hour concentration, but fails to identify both of these spatially.

The under prediction goes against the conservatism of the modelled approach, whereby it is assumed all sources are emitting at their consented SO_2 limit. It also reinforces the recommendation in the MfE good practice guide for dispersion modelling[28] that a factor of 2 should be applied to such modelling exercises when conditions are complex and/or poorly understood or represented.

The above summary of results reinforces the fact that the ambient monitoring should be continued at the Totara site and supported by the monitoring required by Ballance Agri Nutrients Ltd at several other locations to confirm ongoing compliance with the NES.

It should be noted that no exceedances of the NES have occurred since 2007 at the Totara site.

[28] MfE, 2004, *Good Practice Guide for Atmospheric Dispersion Modelling*, Air Quality Technical Report 27.

Part 6: Conclusion

The international understanding of adverse health effects due to ambient SO_2 exposure continues to improve and exposure limits are being refined as this information becomes available. Some of this work was reflected in the National Environmental Standard for New Zealand, whereby a multilevel standard was adopted in 2004. However, more recent work by the WHO and USEPA has resulted in a significant lowering of their recommendations for ambient limits.

The Ministry for the Environment has prepared a detailed national inventory in response to the WHO recommendations, so that an updated national position could be developed. However, at the time of writing this report no direction has been given by the Ministry regarding the adoption (or otherwise) of the much lower WHO guidelines.

Monitoring of ambient SO_2 was undertaken at Mount Maunganui for a short period in 1994 and more recently has been part of the Bay of Plenty Regional Council's on-going environmental monitoring programme for air quality. This monitoring began in 2005 at the Totara Street site which is currently still operational. Several other sites have also been introduced since then, one operated by the council in 2007 at Maru Street and one by Ballance Agri-Nutrients Ltd at the neighbouring Chevron industrial site.

Along with introducing some background information this report has analysed the collected ambient data from the above mentioned sites. Where applicable, the analysis included consideration of meteorological data and traffic volume data supplied by the Tauranga City Council.

The SO_2 emission source situation at Mount Maunganui is a complex one with a number of source types. Industry is the largest single source with consents being issued for these activities. The traffic contribution is also noticeable in the datasets and depending on proximity to roadways the concentrations can vary markedly. Other sources include shipping and train activity.

The "peak" [29] Totara site recorded exceedances of the NES in the earlier part of the record, however since 2007 no exceedances have been recorded. The other two monitoring sites (Maru and Chevron) have not registered any exceedances of the NES, although under certain meteorological conditions elevated levels have been recorded.

Diurnal and monthly patterns exist at all sites. Diurnal patterns at lower concentrations are strongly influenced by transport sources. Monthly patterns are strongly influenced by seasonal weather trends and also the seasonal variations in some of the industrial emissions due to finished product demands.

The relationship between the modelling results and the monitoring data is one of reasonable agreement at the Totara monitoring site (discounting the spatial factor) but has over-predicted for some other locations, such as further east at Maru Street.

Current monitoring data suggests we do not have a problem with industrial emissions causing non-compliance with the current NES (but should await further developments). The prudent approach which should be taken is to continue to monitor ambient SO_2 and meteorology at the Totara site, to ensure that up-to-date data is available should any decision be made in the future to lower the NES.

[29] The use of the term 'peak' applies not just in relation to transport, because it is located next to the roadside verge, but also for industrial sources as it downwind (prevailing) of the main SO_2 industrial emitter.

At this time the spatial understanding of SO_2 distributions has been improved by the several years of monitoring at the regional council's Maru site and this equipment can now be returned to Rotorua to support the long term H_2S exposure study which is currently underway.

The Ballance Agri Nutrient Ltd consent requires 3 years of ambient monitoring to be undertaken (c.8.6). Advice note 3 of the consent states –

> "*As a general guide, for the first 12 months the site should be located within 100 metres of the Tasman Quay boundary of the Ballance site and to the east of this boundary. The location of the monitor may then be changed from time to time to allow coverage of multiple locations, but all decisions regarding such changes should be agreed with the Regional Council and shall be documented in the Monitoring Management Plan.*"

Joint discussion with Ballance Agri Nutrients Ltd, the Community Advisory Group established under the consent, Chevron New Zealand and the regional council should be undertaken to discuss the possibility of a new monitoring location for the equipment currently located at Chevron New Zealand. The two years of monitoring data recorded at the Chevron site now provides a valuable understanding of near field receptor concentrations and fulfils the expected monitoring regime outlined in the advice note. Further value could now be gained by moving the site to a position to the north of the Totara site (on a similar wind line from the main sources) to ensure the ground level concentrations are not greater than those monitored at Totara and to also determine the extent of the north/northeastern SO_2 boundary for industrial impacts.

Appendices

Appendix 1 – SO_2 monitoring equipment

Table A.1 Detailed site information.

Site Title	Totara Street*	Maru Street*
Location	Corner Waimarie and Totara Street, within Tauranga City Council compound.	Located within the Ballance depot at Maru Street, Mount Maunganui.
Land/site owner	Tauranga City Council	Balance Agri Nutrients Ltd
Site height above sea level	3 metres	4 metres
Region	Bay of Plenty	Bay of Plenty
Co-ordinates	U14: 9138, 8838 (NZMG 2791384 6388383)	U14: 9209, 8823 (NZMG 2792093 6388235)
Directions to site	Located at Waimarie/Totara Streets intersection.	Travelling along Hull Road, turn into Maru Street. Proceed along Maru Street for approximately 700 m, where the sign-posted Ballance depot is located on the left. Turn into the depot, and the monitoring station is located adjacent to the small office/staff room building.
Contaminant monitored	SO_2	SO_2
Monitoring objectives	Assess commercial contribution, and vehicle peak emissions at busy intersection in Mount Maunganui.	Assess commercial contribution in Mount Maunganui, specifically helpful to triangulate specific sources.
Site type	Commercial and peak traffic SO_2	Commercial, traffic and point source SO_2
Equipment	EC9850	EC9850
Site topography	Flat area with empty paddock to east, busy road running (Totara Street) north/south to the west, and surrounded by industrial activity.	Flat area with empty paddock to south, busy site access way immediately north. Surrounded by industrial activity, primarily agri nutrients storage and transportation.
Location and direction of major sources	Busy road (Totara Street) to the west from 190 degrees to 350 degrees, and commercial source direction is 360 degrees.	Commercial source direction is 360 degrees. Primary point sources located to the south and south-west.
Planned development of site	Permanent site.	Temporary site.