THE WEST COAST
REGIONAL COUNCIL

State of the Environment Report

West Coast Ambient Air Quality

May, 2004

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This report provides information on air quality monitoring conducted at Westport, Reefton, Runanga, Greymouth and Hokitika over the period from 2001-2003. Parameters measured include: 24 hour particulate matter less than 10 micron (PM_{10}), continuous and monthly sulphur dioxide, and monthly volatile organic compounds: benzene, toluene, ethyl-benzene and xylene. A human health risk assessment is provided.

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Cover photo: Greymouth looking north from Arnott Heights

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EXECUTIVE SUMMARY

This report provides results from ambient air quality monitoring carried out in five West Coast towns from 2001-03. Concentrations of particulate matter under 10 micron (PM_{10}) were measured using a High-Volume sampler, sampling 1 day in 3, in Greymouth in 2001, in Westport in 2002 and in Reefton in 2003. Sulphur dioxide concentrations were measured using a continuous fluorescence instrument in Greymouth in 2001 and in Reefton in 2003. Monthly average concentrations of sulphur dioxide and benzene, toluene, ethyl benzene and xylene (BTEX) were measured in Westport, Reefton, Runanga, Greymouth and Hokitika during each of the three winters during the programme, using passive sampling techniques.

Westport and Reefton had similar concentrations of PM_{10}, with 3 and 4 samples (respectively) above national guidelines. PM_{10} concentrations in Greymouth were much lower with no exceedence of guidelines. Concentrations in Hokitika are likely to intermediate between those measured in Greymouth and in Westport, while in Runanga concentrations are likely to be marginally higher than those measured in Greymouth. Sulphur dioxide concentrations were low Greymouth, Hokitika and Runanga. Westport and Reefton had similar or higher concentrations without exceedence of guidelines. Benzene concentrations were low in all towns well below the Guideline of 10 µg/m^3 as an annual average. A summary of results is presented in Table A.

Table A: Concentrations of Pollutants Found in Five West Coast Towns

	INICATOR	Westport	Reefton	Runanga	Greymouth	Hokitika
PM_{10}	No. of exceedences / no. of samples	**3** / 31	**4** / 35	-	0 / 29	-
	Maximum concentration (µg/m^3). Guideline= 50 µg/m^3	**56**	**55**	-	46	-
	Ranking out of 39 New Zealand towns for PM_{10} (1 = best air quality)*	12	11	-	1=	-
Sulphur dioxide	Maximum 1 hour average (% of guidelines)	-	167 (48%)	-	30.6 (11%)	-
	Maximum 24 hour average (% of guidelines)	-	55 (73%)	-	14.7 (8%)	-
	Maximum monthly average**	36.3	29.3	9.3	4.2	11.1
	Average monthly**	24.4	19.8	2.8	3.2	10.5
Benzene	Average monthly**	2.0	2.9	2.0	1.5	1.6
	Maximum monthly average**	2.4	3.6	4.2	?	2.8

- = not measured

* From information supplied by Ministry for the Environment in 2002. All towns with no measured exceedences are recorded as "1="

** Measured by passive sampler

Data in **bold** exceed guidelines.

Air quality in Reefton and Westport compares favourably to cities/towns such as Christchurch, Alexandra, Kaiapoi, Timaru, Nelson and Richmond which all had maximum PM_{10} concentrations over 100% of guidelines. The number of exceedences per year for Reefton and Westport are slightly above and equal to (respectively) the median for all New Zealand towns where ambient air quality monitoring is conducted. Such monitoring is usually only undertaken for localities with over 1000 people and were there are significant sources of air pollution. The maximum measured PM_{10} concentrations on the West Coast are about one quarter of the maximum 24-hour average concentrations in Christchurch.

Air pollution in West Coast towns in winter results predominantly from domestic solid fuel burners. Such pollution is strongly affected by meteorological conditions. Wind speeds in Reefton are very low, causing frequent temperature inversions during particularly cold winter weather. However, Westport has the highest wind speeds and lowest frequency of calms compared with Reefton and Greymouth, but showed the highest levels of pollution. The prevailing wind in Westport is a light southerly to east-south-easterly, which blows along the long axis of the town. This gives the longest distance of wind travel over built-up areas from which emissions can be accumulated, and this is probably a factor in the high concentrations found. However this factor is unlikely to explain fully the concentrations being as high as they are compared with Greymouth and Reefton. The lower frequency of calm conditions in Greymouth compared with Reefton is consistent with the low levels of PM_{10} in Greymouth. The much lower concentrations of sulphur dioxide in Greymouth are evidently associated with lower sulphur content of coal burned in Greymouth than in Westport and Reefton.

An assessment of the health risks for the people living in the West Coast towns indicates that exposures to PM_{10} concentrations constitute the largest risk compared to other pollutants. The best estimate of mortality in the 5 towns monitored in this programme is that 5-8 premature deaths per year may be attributable to PM_{10} exposures on the West Coast. Two or three of these is estimated to occur in Greymouth and Runanga combined, where the largest population is located, although the mortality risks per 1000 population are lowest there. Although the mortality risks per 1000 population are highest in Reefton, the small population there means that about 1 premature death every 2 years is predicted. One or two premature deaths per year are predicted for each of Westport and Hokitika, but in the absence of measured PM_{10} concentrations in Hokitika, the estimate for that town is quite uncertain. It is possible that all these estimates are too high because of the small size of the West Coast towns. A higher proportion of the people living in small towns are adjacent to open areas and will be exposed to lower pollutant concentrations than those living near the centre where most of the PM_{10} measurements were made. As a result, the mortality risks reported above may be slightly over-estimated.

No adverse health effects are anticipated from the measured concentrations of sulphur dioxide. These concentrations are below the MfE ambient air guidelines, which are based on threshold concentrations below which it is generally considered that there are no adverse health effects. There is also a negligible risk to human health from benzene concentrations found is this study.

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ACKNOWLEDGEMENTS

West Coast Regional Council and Air and Environmental Sciences would like to thank the following people and organizations for their assistance to the programme:

- Environment Canterbury, Ken Taylor, Teresa Aberkane and particularly Mark Harvey for providing and calibrating the SO_2 analyser
- K2 Environmental Ltd, Stuart Keer-Keer, for their help in setting up the sites and PM_{10} sample analysis.
- Chris Coll Surveyors Ltd of Westport, Chris Coll, for Hi Vol and passive filter changes.
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- Hagedorn's funeral services of Westport for housing Hi-Vol and donating the cost of electricity used to charity.
- Reefton School, Wayne Wright, for housing the Hi-vol and the SO_2 analyser
- Grey District Council, Runanga Pool, for housing the Hi-vol and the SO_2 analyser
- Buller District Council, Westport Depot, Reefton Bowling Club, Cobden Bowling Club, Greymouth Bowling Club, Mike Shearer and Westland High School for housing the passive samplers.
- Westland Milk Products Ltd for providing data about ambient air quality in Hokitika.

1. INTRODUCTION

This report describes an ambient air monitoring programme carried out by Air and Environmental Sciences and the West Coast Regional Council. The monitoring occurred over three years during the winters of 2001, 2002 and 2003 with a limited amount of summer monitoring in 2004. The results are presented and assessed, in terms of their likely representativeness of typical conditions over the monitoring period, possible health effects and comparisons with air quality data in other New Zealand towns and cities.

The primary objectives of this monitoring programme were:

1. Provide comprehensive data (sulphur dioxide and PM_{10}) to judge the significance of actual or perceived regional air quality issues with respect to public health.

2. Determine whether national air quality guidelines and regional planning objectives and environmental outcomes are being met and identify areas of concern. Such an assessment of air quality shall be in representative areas of higher population density (> 800 persons) where air quality is known or suspected to be poor. This includes 5 population centres: and Westport, Reefton, Runanga, Greymouth and Hokitika.

3. Preliminary assessment of the population at risk from exposure to poor air quality and evaluate potential and actual health effects (eg from passive samplers.
Because an emissions inventory is not available, the assessment of additional mortality attributable to air pollution in West Coast towns has been assessed only on the basis of the monitoring data.

The monitoring programme included:

- continuous fluorescence instrumental measurement of sulphur dioxide concentrations in the towns of Greymouth and Reefton, undertaken in 2001 and 2003 respectively.
- gravimetric measurement of PM_{10}, using a high-volume sampler sampling 1 day in 3, undertaken in Greymouth, Westport and Reefton in 2001, 2002 and 2003 respectively.
- passive sampling for sulphur dioxide and for benzene, toluene ethyl benzene and xylene (BTEX), undertaken in Westport, Reefton, Runanga, Greymouth and Hokitika during the winter months over 2001-2003.

Sulphur dioxide is a colourless gas which forms sulphuric acid when combined with water. Sources include combustion of fossil fuels containing sulphur eg coal and diesel. Sulphur dioxide can affect vegetation around industrial discharges and in cities. It can also form secondary particles that cause haze and reduce visibility. Sulphur dioxide can cause respiratory problems such as bronchitis and irritate noses, throats and lungs. It may cause coughing, wheezing and asthma attacks.

PM_{10} is the concentration of particles that are less that 10 microns in diameter and are easily inhaled into the lungs. The main sources vary greatly between regions with motor vehicles contributing significantly in Auckland and domestic heating fires in most South Island cities

and towns. Other sources include industry, sea spray and agricultural activities. Health effects can include eye, throat and lung irritation and, for those with existing respiratory conditions, worsening asthma or bronchitis. Particle pollution in New Zealand is estimated to cause around 970 premature deaths per year.

Benzene is emitted from a range of sources including motor vehicles, evaporation from petrol, cigarette smoke and home heating fires. Benzene is a harmful air pollutant and its most significant adverse effects is an increased risk of cancer resulting from prolonged exposure.

2. MONITORING SITES

Detailed descriptions of all sites are contained in Air and Environmental Sciences Report to the West Coast Regional Council: "Ambient Air Monitoring Programme 2001 – 2003: The Overview". In this section, brief details of the monitoring sites used are given. Subsequently, in Section 5, maps of the area around the sampling sites are given, together with the locations of the sites, as part of consideration of the geographic and meteorological characteristics of the sites in relation to the pollutants measured.

2.1 GREYMOUTH

Monitoring was conducted at 3 sites in Greymouth, as described in more detail below. Figure 1 is a photograph of Greymouth taken from Arnott's Heights showing the location of the monitoring sites. Figure 13 is a map showing the location of these sites.

2.1.1 Greymouth Site 1: Palmerston Street Site

A site was established at 47 Palmerston Street, which is next door to the site of previous monitoring carried out in 1994. This was used for instrumental monitoring of sulphur dioxide, PM_{10} using a Hi-vol sampler, and wind speed and direction in 2001. Passive samplers were deployed to measure BTEX and SO_2 in 2001, 2002 and 2003.

Further details on this site are available in the 2001 monitoring report and Air and Environmental Sciences' Report to the West Coast Regional Council: *Ambient Air Monitoring Programme 2001 – 2003: The Overview*.

2.1.2 Cobden Site - Greymouth

Passive samplers were installed at the Cobden Bowling Club in 2001, in order to investigate the possible influences of catabatic winds on pollution levels of the suburbs along the coastline. This was initially established on the southern perimeter fence. However, during the first month, the passive samplers were interfered with, and the location moved to inside the bowling club grounds.

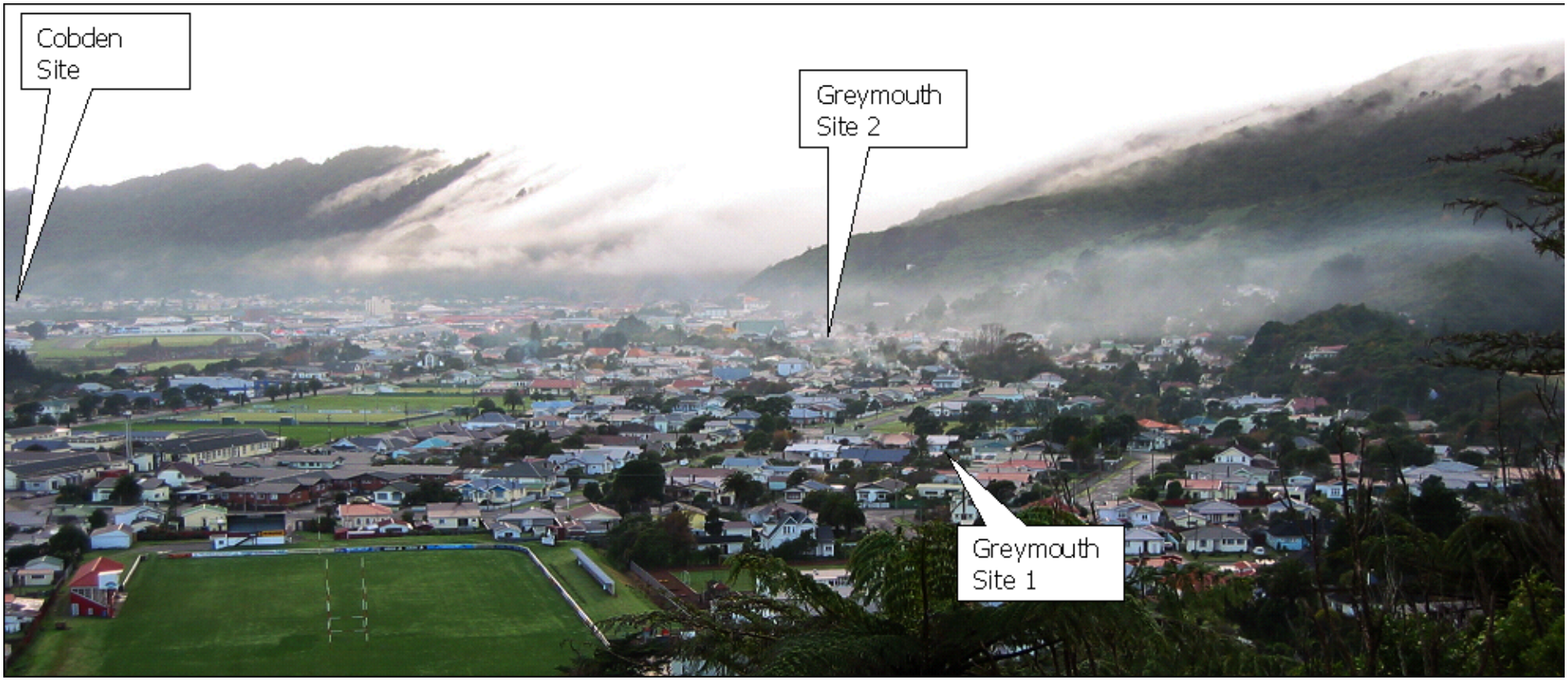
Based on the concentrations of sulphur dioxide and BTEX compounds found during the 2001 monitoring, this site was not used for further monitoring

2.1.3 Greymouth Site 2: Greymouth Bowling Club

Passive samplers were installed during May of 2003, at a new monitoring site in Greymouth, to investigate the air quality in an area closer to the ranges to the east of the township where visual air clarity tends to be poor. The site used was on the fenceline of the Greymouth Bowling Club. The Bowling club site had been used in 1994 and 1995 for monitoring of sulphur dioxide using a bubbler/titration technique and for smoke.

Figure 1. Greymouth from Arnotts Heights, showing the locations of monitoring sites.

Note the "Barber" mist funnelling down the Grey River and over the Cobden and Peters Ranges.



2.2 WESTPORT

Figure 11 is a map showing the locations of the Westport monitoring sites.

2.2.1 Westport Site 1 (Derby Street)

During the first month of the 2001 monitoring program the passive samplers located at St Canices School (near the corner of Brougham and Romilly Streets) were vandalised. As a result the site was re-located across the road (100-200m from the old site) to the east-southeast, to a private residence near the corner of Brougham and Derby Streets.

This site was used for monitoring during the 2002 winter with the Hi-volume sampler mounted on top of the awning over Hagedorn's Funeral Directors and the passive samplers, and the wind speed and wind direction sensors were located at the rear of a warehouse in the property immediately to the north of Hagedorn's.

In 2003, the passive samplers for the programme were again located at this site.

2.2.2 Westport Site 2 (Buller District Council Depot)

Passive samplers were set up at a second Westport site in 2002 to determine the variability of SO_2 and BTEX concentrations across the township. This site was located on a power pole ~30m inside the gate of Buller District Council's depot on Peel St between Mill St and Bentham St.

2.3 REEFTON

Figure 12 is a map showing the locations of the Reefton monitoring sites. Figure 2 is a photograph of the township.

2.3.1 Reefton Site 1 – Reefton School

The Reefton Bowling Club had been used for air monitoring in 1995. However, Reefton Primary School was selected as a monitoring site for the 2001 – 2003 programme because it was central in the township and more secure than the Bowling Club. Power was also readily available for instrumental monitors.

2.3.2 Reefton Site 2 – Reefton Bowling Club

Monitoring for smoke and sulphur dioxide was carried out this site in 1995. This site was used in 2002 and 2003 for passive sampling to determine variability of sulphur dioxide and BTEX concentrations across the township.

Figure 2. Reefton Township looking to the West.

2.4 HOKITIKA

There had been no previous ambient air monitoring undertaken in Hokitika. For this programme, a passive sampling site was established at the Westland High School. The sampler holder was attached to the outside of the school administration building, on the outside of the upstairs balcony off the main staff room.

Figure 17 is a map showing the location of the Hokitika monitoring site.

2.5 RUNANGA

2.5.1 Runanga Site – Runanga Pool

Passive samplers were attached to the top of the 2.5m high perimeter fence on the Grey District Council swimming pool complex, located next to the Runanga School. The site was chosen, as it is secure, central in the township and has power readily available in the event that instrumental analysers might be installed.

Figure 16 is a map showing the location of the Runanga monitoring site.

3. MEASUREMENT METHODS

Instrumental measurement of sulphur dioxide was undertaken using an API 100 SO_2 analyser (supplied by Environment Canterbury), and conformed to AS3580.4.1 (AS2523) *Determination of sulphur dioxide – Direct reading instrumental method.* The data was logged as 10-minute averages and retrieved on a daily basis via telephone link.

PM_{10} was sampled using an HVP-3500AFC automatic flow control outdoor Hi-vol air sampler fitted with a Graseby size selective inlet, and conformed to AS3580.9.6 *Determination of suspended matter (PM_{10}) size selective inlet method*. Samples were taken over a 24-hour period, as far as practical on a one-day-in-three rotation.

Diffusive SO2 passive samplers including analysis were supplied by K2 Environmental, and sourced from Passam ag, who also provided the analyses.

Passam AG samples were used for BTEX in 2001. For 2002 and 2003 Passive Diffusion Monitors were sourced from 3M, to carry out the BTEX passive sampling. The samplers were deployed and retrieved according to the manufacturers instructions, and analysed by AgriQuality NZ.

Appendix 1 describes the quality assurance checks carried out for the programme.

4. MONITORING DATA

Appendices 3 and 5 give detailed charts of sulphur dioxide and PM_{10} concentrations, together with meteorological data for the monitoring in Greymouth in 2001 and in Reefton in 2003. Appendix 4 gives similar charts for Westport for 2002, but without the sulphur dioxide concentrations, which were not monitored instrumentally in Westport. These charts show the data for seven days on each page, allowing detailed inspection of the conditions under which the various concentrations occurred.

4.1 CONTINUOUS INSTRUMENTAL SULPHUR DIOXIDE MONITORING.

Table 1 summarises the data from the continuous instrumental monitoring of sulphur dioxide in Greymouth in 2001 and in Reefton in 2003.

Table 1. Summary of suphur dioxide concentrations measured in Greymouth and Reefton

	Greymouth 2001				Reefton 2003			
	1-hour averages		24-hour averages		1-hour averages		24-hour averages	
	Rolling	Fixed	Rolling	Fixed	Rolling	Fixed	Rolling	Fixed
	µg/m3				µg/m3			
	30 May - 10 September 2001				30 May - 10 September 2001			
Maximum	37.5	37.2	14.7	9.5	167	167	87	72
99.9%ile	27.8	28.8			143	139		
Average	4.9	4.8			25	25		
	June				June			
Maximum	28.5	28.5	14.7	8.5	149	137	87	72
Average	4.5	4.4			24.2	24.1		
	July				July			
Maximum	25.8	25.8	10.6	9.5	167	167	54	51
Average	5.8	5.8			33.5	33.5		
	August				August			
Maximum	37.5	37.2	8.4	7.8	162	161	48	43
Average	4.4	4.4			22.2	22.1		

The maximum 1-hour average concentration of sulphur dioxide was 167 µg/m^3 (48% of the MfE ambient air guideline of 350 µg/m^3), measured in Reefton during July 2003. The concentrations of sulphur dioxide in Greymouth during 2001 were very much lower, with a maximum 1-hour average concentration of 37.5 µg/m^3 (11% of the MfE ambient air guideline).

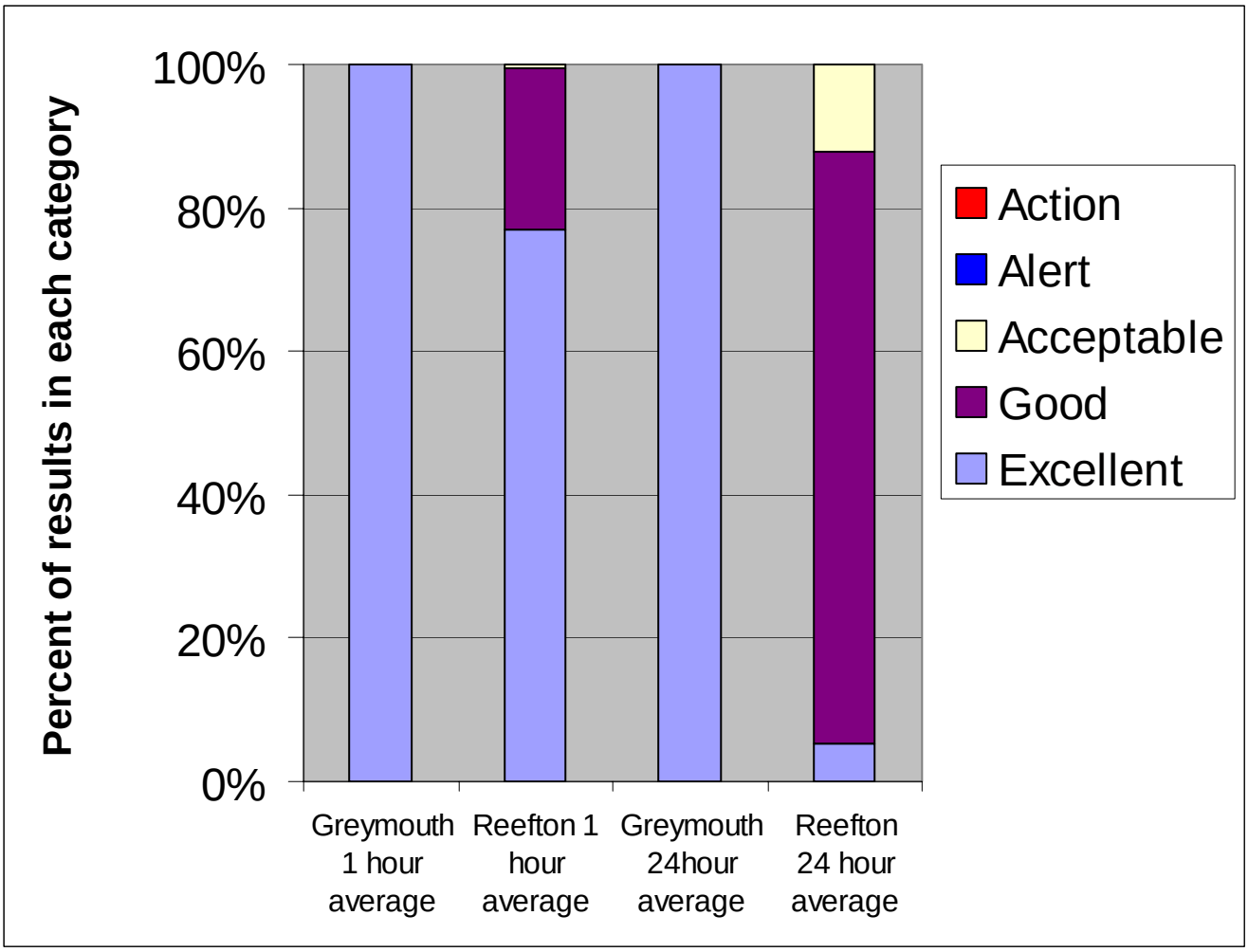
The maximum 24-hour average concentration of sulphur dioxide was 87 µg/m^3 (73% of the MfE ambient air guideline of 120 µg/m^3), measured in Reefton during June 2003. As for the 1-hour averages, the maximum 24-hour average concentration measured in Greymouth

during 2001 was very much lower than that for Reefton, being 14.7 µg/m^3 (8% of the MfE ambient air guideline).

The monthly average concentrations were in the range 12-20% of the maximum monthly 1-hour average concentrations and in the range 30-60% of the maximum monthly 24-hour average concentrations.

Figure 3 gives the breakdown of the sulphur dioxide monitoring data for Greymouth and Reefton according to the MfE Air Quality Guidelines Categories.

Figure 3. Sulphur Dioxide Data Compared to National Guideline Categories



For Greymouth, essentially all of the data is in the "Excellent" category. For Reefton, the great majority of the one-hour averages are in the "Excellent" category, while for the 24-hour averages, the great majority of the data are in the "Good" category, with moderate percentages in the "Excellent" and "Acceptable" categories.

4.1.1 Comparison with sulphur dioxide levels in the other centres.

Table 2 presents summary data for sulphur dioxide for Greymouth and Reefton, together with the same data for the Christchurch, St Albans site for 1996, 1997 and 1999. The St Albans site is the only New Zealand site for which continuous instrumental monitoring data for sulphur dioxide is available, and where the major contributor to winter sulphur dioxide levels is domestic heating emissions.

Table 2. Comparison of sulphur dioxide concentrations in Greymouth, Reefton and Christchurch.

	Greymouth	Reefton	Christchurch St Albans		
	2001	2003	1996	1997	1999
	June-August				
Maximum 1-hr average	37	167	130	116	91
Maximum 24-hr average	15	87	41	55	40
Period average	5	25	12	14	12

The sulphur dioxide concentrations measured in Greymouth are about a third of the average concentrations measured in Christchurch during 1996, 1997 and 1999. The maximum 1-hour average concentration measured in Reefton is about 50% higher than the average maximum 1-hour average in Christchurch for these years. The maximum 24 hour average concentration measured at Reefton and the period average concentration are about double those in Christchurch. This comparison suggests that Reefton might experience some of the highest sulphur dioxide concentrations in the country.

The monthly and period average concentrations of sulphur dioxide measured by passive sampler in Greymouth during 2001 and in Reefton during 2003 were closely similar to the same average concentrations measured by instrumental monitoring confirming the validity of using passive samplers. The passive sampling data for Runanga and Hokitika are similar to those for Greymouth, and the concentrations measured in Westport are similar to those in Reefton. Accordingly, Table 2 also provides an indicative comparison for the sulphur dioxide concentrations in Runanga, Hokitika and Westport.

Figure 4 and Figure 5 are plots of 1 hour average concentrations of sulphur dioxide measured at Greymouth during 2001 and Reefton during 2003.

Figure 4. 1-hour average concentrations of sulphur dioxide in Greymouth

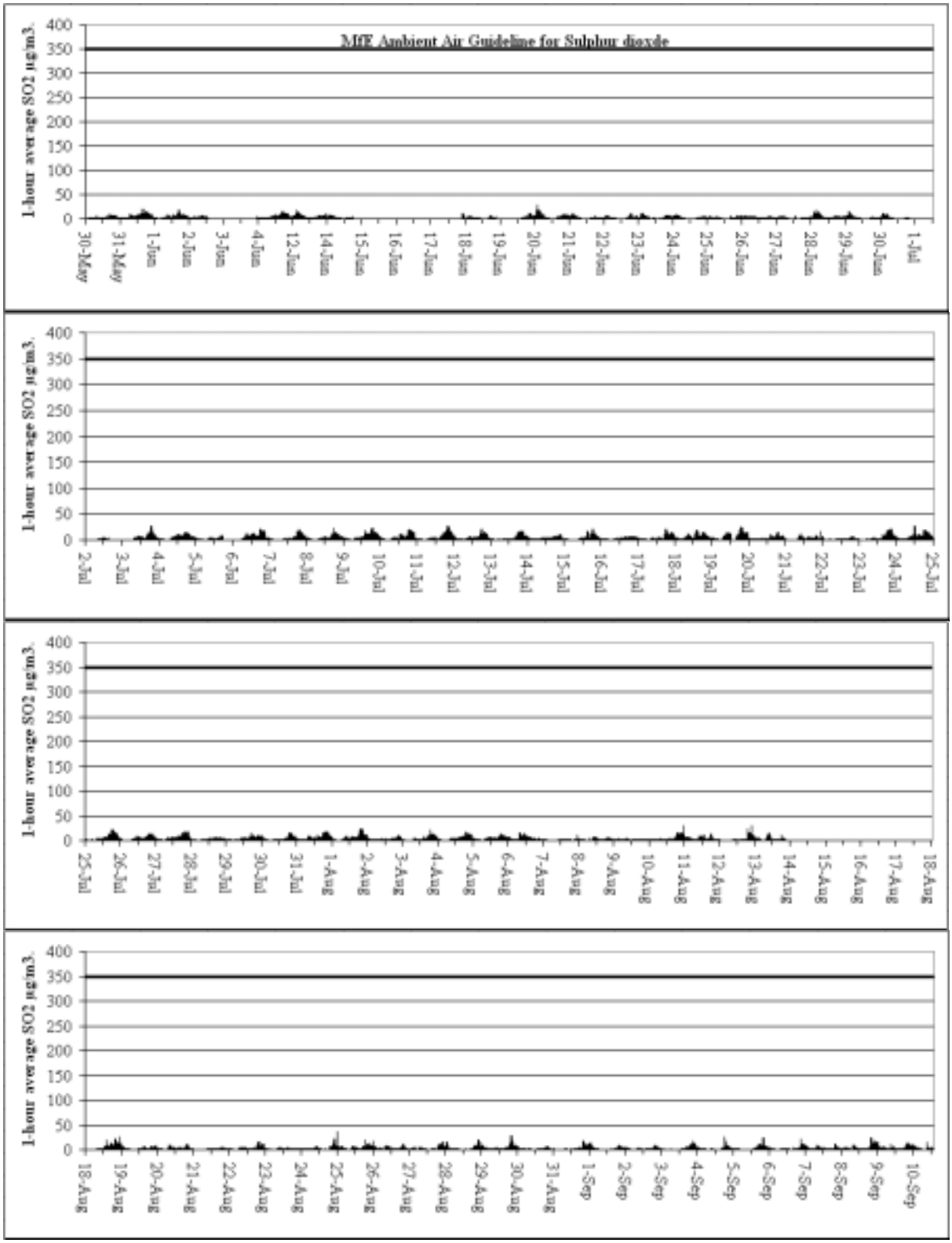
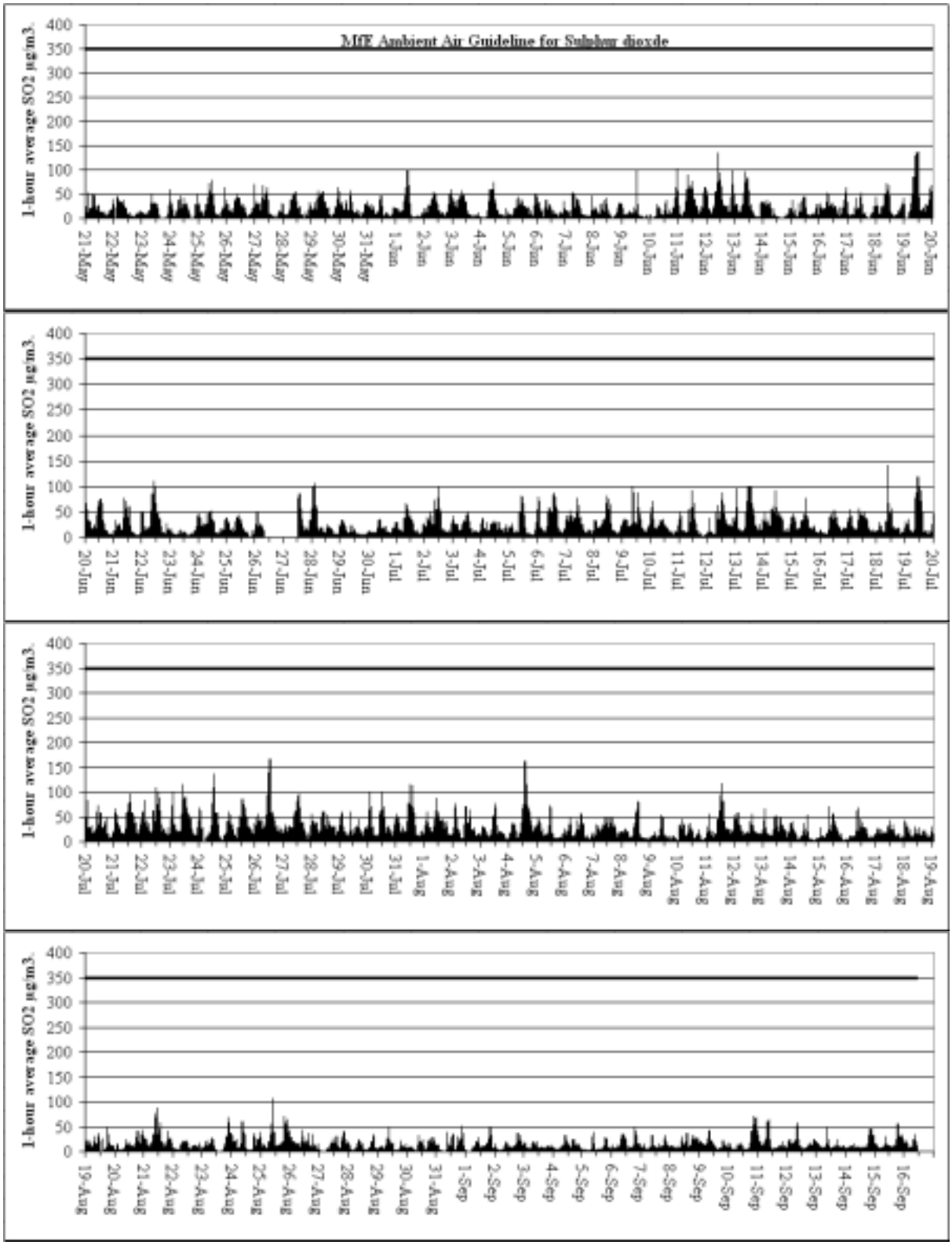


Figure 5. 1-hour average concentrations of sulphur dioxide in Reefton



4.2 PM_{10} CONCENTRATIONS MEASURED BY HI VOLUME SAMPLER.

Table 3 summarises the 24-hour average PM_{10} data from the monitoring at Greymouth in 2001, Westport in 2002 and Reefton in 2003. None of the samples from Greymouth exceeded the MfE ambient air guideline of 50 µg/m^3, but about 10% of the samples from Westport and Reefton exceeded this guideline by up to about 10%.

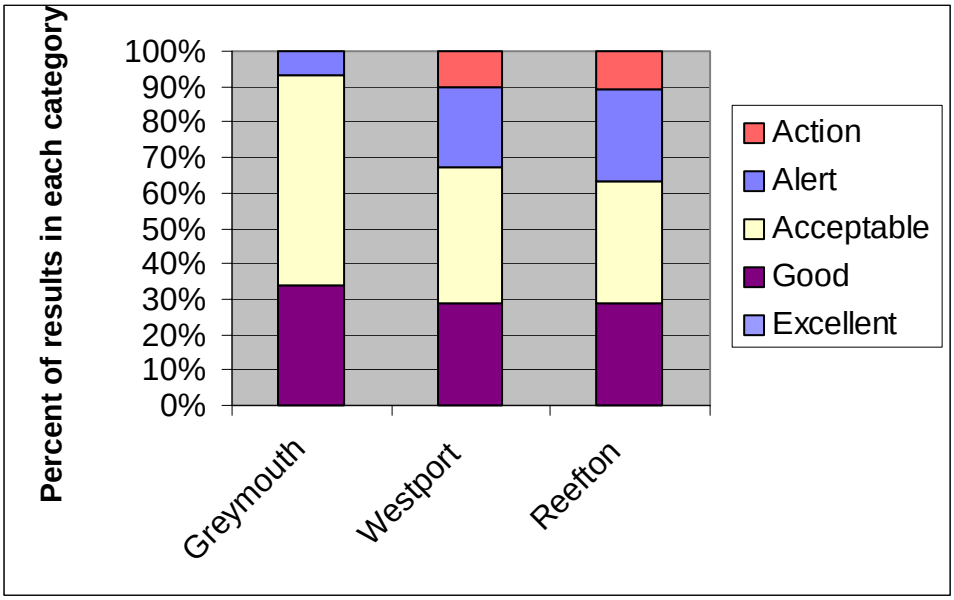
Table 3. Summary of PM_{10} data for Greymouth, Westport and Reefton.

	Greymouth 2001	Westport 2002	Reefton 2003
	24-hour averages µg/m3		
Maximum	6	42	34
Average	21	27	28
Winter average*	21	27	31
Number over 50 µg/m3	0	3	4
% over 50 µg/m3	0%	10%	11%

* June, July and August

Figure 6 gives the breakdown of the PM_{10} monitoring data for Greymouth, Westport and Reefton according to the MfE Air Quality Guidelines Categories.

Figure 6. PM_{10} Data Compared to National Categories



For Greymouth, the great majority of the data are in the "Good" and "Acceptable" categories. At Westport and Reefton, while the majority of the data are in the "Good" and "Acceptable" categories, about 25% are in the "Alert" category and about 10% are in the "Action" category.

Figure 7 to Figure 9 are charts of the PM_{10} concentrations measured at Greymouth, Westport and Reefton.

Figure 7. PM_{10} concentrations in Greymouth in 2001

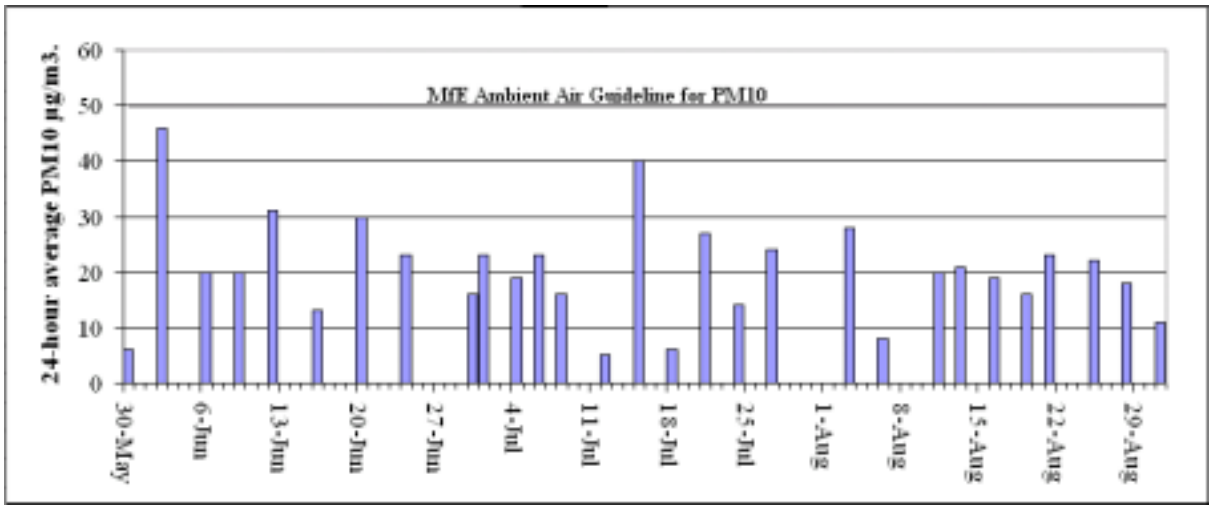


Figure 8. PM_{10} concentrations in Westport in 2002.

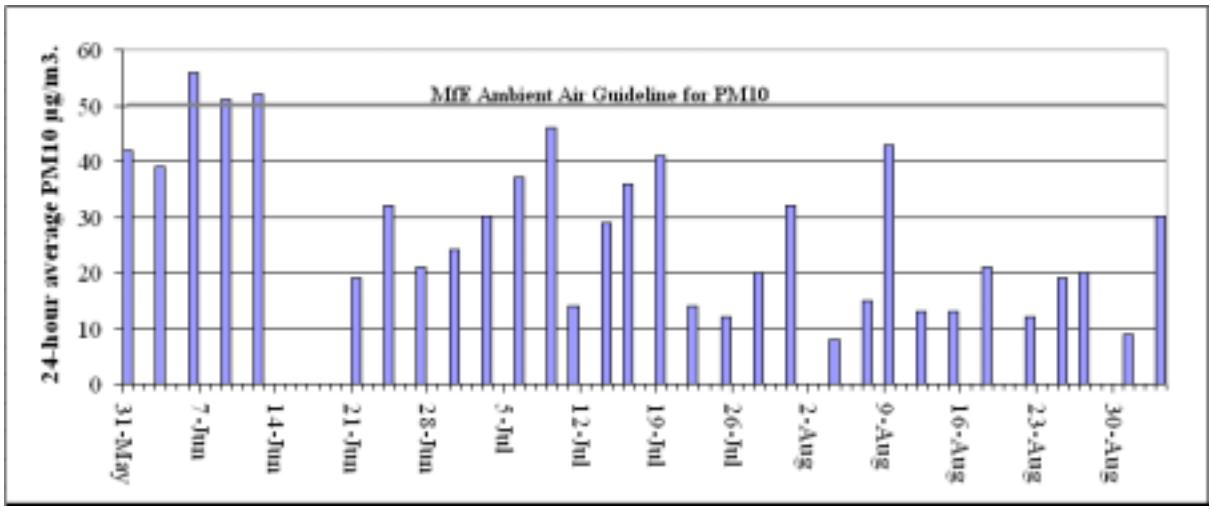
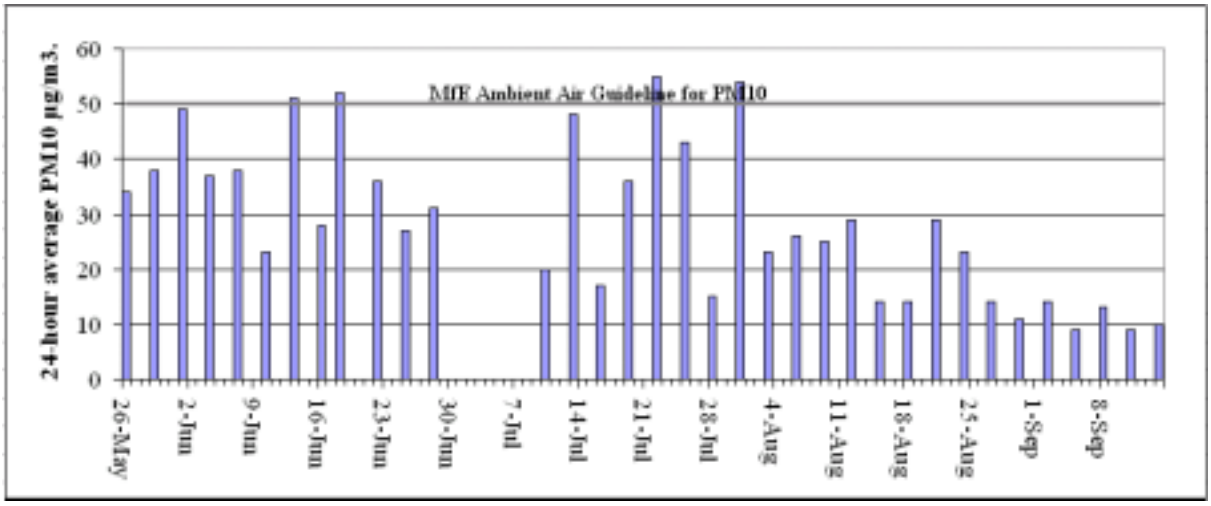


Figure 9. PM_{10} concentrations in Reefton in 2003.



The West Coast Regional Council undertook additional monitoring for PM_{10} at the Palmerston Street site during February and March 2004, in order to obtain an indication of PM_{10} concentrations outside the winter months, to allow improved estimates of annual average PM_{10} concentrations for the health risk assessment. The samples collected in February were also analysed for chloride, from which the contribution to PM_{10} concentrations from sea salt can be calculated. The last sample colleted in February and the first three samples collected in March were not analysed for chloride because the PM_{10} concentrations were very low. The last three sample collected (22 March, 29 March and 4 April were not analysed for chloride because the effects of domestic heating emissions were becoming evident, both from the appearance of the filters and observation of smoke emissions (Trevor James, *pers comm*.) The data obtained are shown in Table 4.

Table 4. Concentrations of PM_{10}, chloride and sea salt in February-April 2004.

	PM10	Chloride	Sea salt
	µg/m^3 0^{o}C		
11-Feb-04	9	7.8	14.1
14-Feb-04	5	2	3.6
20-Feb-04	25	19.5	35.2
26-Feb-04	3	ND	ND
4-Mar-04	4	ND	ND
10-Mar-04	3	ND	ND
16-Mar-04	4	ND	ND
22-Mar-04	12	ND	ND
29-Mar-04	13	ND	ND
4-Apr-04	21	ND	ND

For the two samples containing the highest PM_{10} concentrations, the estimated sea salt contribution is larger than the total PM_{10} concentration, which is probably a consequence of uncertainty with respect to sea salt estimation. These data suggest that the concentrations of

PM_{10} during summer from sources other than sea salt are very low, at least in Greymouth. Similar substantial contributions to PM_{10} concentrations from sea salt would be expected in at least the other coastal West Coast towns, including Westport, Runanga and Hokitika, and possibly also in Reefton.

There may also be a significant sea salt contribution to the higher PM_{10} concentrations measured during late March and early April, but these samples show increasing PM_{10} concentrations as is expected for progression through autumn and the increasing use of domestic heating appliances. Such an increase is consistent with the method used to estimate annual average concentrations in Section (Estimation of annual average PM_{10} concentrations)

The PM_{10} monitoring in Greymouth during February and March 2004 (Table 4) showed an average PM_{10} concentration of 8.7 $\mu g/m^3$. Analyses of the PM_{10} samples for chloride suggest that the concentrations of PM_{10} during summer from sources other than sea salt are very low, at least in Greymouth.

NIWA undertook continuous instrumental monitoring of PM_{10} (using a Tapered Element Oscillating Micro-balance TEOM instrument) at the Hokitika Holiday park, at the south eastern edge of the town from November 2002 until mid-February 2003, for Westland Milk Products Ltd, (SKM, 2003). Over 97% of the records were less than 33 $\mu g/m^3$. The average 24-hour average concentration over the monitoring period was 19 $\mu g/m^3$.

The PM_{10} concentrations measured are higher than appears likely to result predominantly from combustion particulates, because the concentrations in summer in Hokitika are unlikely to be higher than those measured in Greymouth and Westport over winter. A substantial proportion of the PM_{10} measured may be sea salt, as suggested by the summer data for Greymouth (Table 4), but there is no information that can be used to obtain any reliable estimate of this for the Hokitika data.

4.2.1 Comparison with PM_{10} levels in other centres.

Table 5 summarises data from the MfE report *Monitoring of PM_{10} in New Zealand* (MfE, 2003) for the maximum 24-hour average PM_{10} concentrations and exceedances per year of the 50 $\mu g/m^3$ MfE ambient air guideline. The data have been sorted from the largest number of exceedances per year to the smallest, and then by the average maximum annual 24-hour average concentration. The West Coast sites have been placed at their relevant locations within this sorting, and are highlighted.

The number of PM_{10} guideline exceedences per year for Reefton and Westport are slightly above and equal to (respectively) the median for all New Zealand towns where ambient air quality monitoring is conducted. Such monitoring is usually only undertaken for localities with over 1000 people and where there are significant source of air pollution. The estimated number of exceedances per year for Reefton and Westport are about one quarter of those for Christchurch (St Albans) and 12-15% of the average number for Nelson. The maximum measured PM_{10} concentrations are about a quarter of the average maximum 24-hour average concentrations in Christchurch, and about 45% of that in Nelson. The Westport and Reefton concentrations and frequencies of exceedance are slightly below those for Dunedin, but the

placing for Westport could move upwards if 2002, the year in which the PM_{10} concentrations were measured, gave lower PM_{10} concentrations than in an average year.

Both the maximum PM_{10} concentrations and the frequency of exceedance for the Greymouth site lie near the bottom of the table.

Table 5. Comparison of PM_{10} concentrations for Greymouth, Westport, Reefton and other New Zealand cities and towns

	Maximum 24-hour average PM10		Exceedances/yr	
	Average	Maximum	Average	Maximum
Nelson	123	165	74	81
Alexandra	140	193	66	78
Richmond	111	111	60	60
Timaru	130	156	52	62
Kaiapoi	136	136	50	50
Cromwell	73	73	38	38
Christchurch	199	310	38	58
Mosgiel	73	95	26	44
Tokoroa	75	75	24	24
Ashburton	97	100	24	24
Milton	57	57	19	19
Arrowtown	55	55	18	18
Rangiora	92	104	15	19
Dunedin	65	107	13	25
Masterton	87	87	11	11
Upper Hutt	79	85	11	15
Reefton	**55**	**55**	**11**	**11**
Whangarei	57	57	10	10
Westport	**56**	**56**	**9**	**9**
Auckland	51	72	9	12
Otaki	50	50	9	9
Oamaru	61	61	8	8
Balclutha	54	54	8	8
Gisborne	43	70	8	8
Napier	41	64	8	15
Newtown,	42	53	6	6
Hamilton	71	93	6	10
Te Kuiti	59	59	5	5
Rotorua	61	72	3	4
Blenheim	47	56	3	6
Taupo	57	57	2	2
Whakatane	73	73	1	1
Lower Hutt	48	53	1	1
Greymouth	**46**	**46**	**0**	**0**
Tauranga	44	48	0	0
Pongakawa	39	49	0	0
Queenstown	36	36	0	0
Picton	27	27	0	0

4.3 PASSIVE SAMPLING DATA FOR SULPHUR DIOXIDE AND BENZENE.

In this section, only the concentrations for sulphur dioxide and benzene from the passive sampling are presented as well as PM_{10} data for comparison. Appendix 6 contains the concentrations of toluene, ethyl benzene and xylenes that were also measured using the organic vapour passive samplers. Only the data for benzene are presented here, because the concentrations of the other BTEX compounds were in their expected usual ratios to benzene, based on extensive monitoring experience with these compounds. These other BTEX compounds are also of much less concern from the health effects perspective than benzene. Monthly average PM_{10} concentrations are also included here, for convenience in viewing them together with the sulphur dioxide and benzene data.

4.3.1 Greymouth

Table 6 gives the passive sampling data for the Greymouth sites for 2001-2003.

Table 6. Passive sampling data for sulphur dioxide and benzene for Greymouth.

	Passive sampling						Hi Vol		
	SO_2 µg/m3			Benzene µg/m3			PM_{10} µg/m3		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
GREYMOUTH - Palmerston St									
June	3.7	1.3	2.5	1.9			23		
July	4.2	3.2	3.7				20		
August	3.1	4.1	3.1				19		
Average	3.7	2.9	3.1	1.9	1.9	1.6	21		
Maximum 24-hour average							46		
GREYMOUTH - Bowling Club									
June			2.0						
July			2.5						
August			0.6						
Average			1.7			2.2			
GREYMOUTH - Cobden Bowling Club									
June	3.6			1.5					
July	2.5			1.7					
August	1			0.9					
	2.4			1.4					

On average, the sulphur dioxide concentrations were highest at the Palmerston Street site in 2001, and quite similar, but lower, in each of 2002 and 2003. Benzene concentrations were higher in 2002 than in 2003, but it is difficult to be sure whether the benzene concentrations in 2001 were higher or lower than the later measurements. If emissions from burning coal are the major contributor to PM_{10}, the highest concentrations measured in 2001 suggest that the PM_{10} concentrations may have been highest then out of the three years, so that the PM_{10}

measurements would have been done when they were likely to be at their maximum for the 3 year monitoring period.

The concentrations of sulphur dioxide at the Greymouth Bowling Club in 2003 are lower than those at the Palmerston Street site, particularly in August, when the bowling club concentration was about one-fifth of that at the Palmerston Street site. On the other hand, the benzene concentration over the 3-month June-August passive sampling period was higher at the bowling club than at Palmerston Street. The higher benzene concentration may result from the bowling club site being closer to State Highway 6, which is likely to be a source of benzene emissions from motor vehicles.

Concentrations of sulphur dioxide at the Cobden Bowling Club were similar to those measured at the Palmerston Street site in June 2001, but lower than at the Palmerston Street site in July and more so in August 2001. Examination of the wind roses for the Palmerston Street site for June, July and August gives no indication of why the relative concentrations of sulphur dioxide might have changed over the various months of sampling, but the wind directions at the Palmerston Street site are likely not to be representative of the Cobden area.

Overall, as far as can be deduced from the results available, the Palmerston Street site appears likely to be the one likely to give the highest PM_{10} concentrations out of the three the Greymouth sites sampled. The indications are that the PM_{10} sampling may have been done when the PM_{10} concentrations are likely to have been highest out of the 2001-2003 monitoring period.

Further consideration of meteorological and geographic factors is presented in Section 5.

4.3.2 Westport

Table 7 gives the passive sampling results for Westport.

Table 7. Passive sampling data for sulphur dioxide and benzene for Westport.

	Passive sampling						Hi Vol		
	SO_2 µg/m3			Benzene µg/m3			PM_{10} µg/m3		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
WESTPORT - Derby St									
June	**	18.9	27.9	**	2.4			37	
July	29.6	29.8	36.3	2.2	2.4			28	
August	18.3	13.8	30.6	1.6	2.1			18	
Average	24.0	20.8	31.6	1.9	2.1	2.1		28	
Maximum 24-hour average								56	
WESTPORT - Buller District Council Depot									
June		17.1							
July		22.8							
August		23.1							
Average		21.0			2.0				

Because the Buller District Council depot site is located about 1 km south of the Derby Street site and because the prevailing wind direction in Westport is southerly to south-easterly, the Derby Street site would be expected to give higher concentrations than the depot site. This is because the prevailing wind reaching the Derby Street site would have picked up emissions from a larger urban area than the wind reaching the depot.

This is observed for June and July 2002. The substantially higher concentrations at both sites in July compared with June is consistent with the wind roses for those months, which show that June was considerably windier than July.

The meteorology cannot explain the relatively low result for August for the Derby Street site, which would be expected to show a result similar to, but somewhat lower than for July.

The sulphur dioxide concentrations measured at Westport are 7-10 times higher than those measured at Greymouth which suggests that concentrations at Westport could be close to guidelines. It appears that this may result from higher sulphur content of the coal normally burned in Westport compared with that in Greymouth.

If burning coal is the predominant contributor to winter PM_{10} levels, consideration of the sulphur dioxide concentrations measured in 2001, 2002 and 2003 suggests that 2002 may have been the year with the lowest PM_{10} concentrations out of the three years of the monitoring programme.

There is little difference in the benzene concentrations measured at either of the two Westport sites or between years.

4.3.3 Reefton

Table 8 gives the passive sampling results for Reefton.

Table 8. Passive sampling data for sulphur dioxide and benzene for Reefton.

	Passive sampling						Hi Vol		
	SO_2 µg/m3			Benzene µg/m3			PM_{10} µg/m3		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
REEFTON - Primary School									
June	28.9	8.3	22.0	3.5		2.5			37
July	18.7	24.1	29.3	3.6		2.9			36
August	11.6	17.5	18.3			2.2			21
Average	19.7	16.6	23.2	3.5	2.9	2.4			31
Maximum 24-hour average									55
REEFTON - Bowling Club									
June		22.5	19.7						
July		22.4	24.5						
August		13.3	16.8						
Average		19.4	20.3		1.6	1.9			

The concentrations of sulphur dioxide measured in Reefton are slightly lower than those in Westport, but markedly higher than the Greymouth concentrations.

The concentrations are little different between the two Reefton sites, with the concentrations at the bowling club generally being lower than those at Reefton Primary School. The one exception to this is an apparently anomalous result for June 2002, when a low concentration was found that the primary school.

Wind roses show that winds are most frequently from the north-west and south-east, but with moderate frequencies of winds from all directions. There is no clear indication of a significant effect from different wind directions, although north-easterlies were more frequent during June than the other months, and these were also the strongest winds for the monitoring period, being mostly above 3 m/sec.

Wind speeds are generally very low. During the 2003 monitoring period, the monthly average concentrations of sulphur dioxide at both sites were in the order expected from consideration of the proportions of time of low wind speeds. Wind speeds were below 1 m/sec for 52% of the time during June, 65% during July and 41% during August. The higher the proportion of time with low wind speeds, the higher the expected concentration of sulphur dioxide and other pollutants.

Sulphur dioxide concentrations were higher in 2003 than in 2002 for the July and August at both monitoring sites. The July and August figures for 2001 were lower than those for 2002 for the Primary School site. Whether the apparently anomalous low concentration for June 2002 at the primary school is excluded or not, it appears that the general level of sulphur dioxide concentrations was highest for the 2001-2003 period during 2003.

As for the sulphur dioxide concentrations, benzene concentrations were higher at primary school than at the bowling club.

Only limited weight can be placed on the benzene concentrations measured during 2001, because of uncertainties about the reliability of the particular passive samplers used that year. Otherwise, there is no clear pattern in benzene concentrations between the years, with those for the primary school being lower in 2003 than in 2002, and the reverse applying to the bowling club site.

On balance, it seems likely that 2003 may have been the year during 2001-2003 giving the highest concentrations of PM_{10}, if burning coal is the predominant source of winter PM_{10} concentrations.

4.3.4 Hokitika

Table 9 gives the passive sampling results for Hokitika. The monitoring programme did not include PM_{10} measurements at this site.

Table 9. Passive sampling data for sulphur dioxide and benzene for Hokitika.

	Passive sampling						Hi Vol		
	SO_2 µg/m3			Benzene µg/m3			PM_{10} µg/m3		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
HOKITIKA - Westland High School									
June	1.7	**	1.1	2.8					
July	1.9	4	1.4	2.5					
August	11.1	1.1	1.6	1.6					
Average	6.5	2.6	1.4	2.1	2.5	2.1			

** Samplers were either vandalised or blown away by wind.

Apart from the anomalous concentration in August 2001, the sulphur dioxide concentrations at Hokitika are the lowest for any of the sites. The benzene concentrations are generally similar to those in Westport, slightly higher than those at the Greymouth Palmerston Street site and slightly lower than those at the Reefton primary school.

These results do not indicate that PM_{10} concentrations in Hokitika are likely to be of concern compared with those in other of West Coast towns.

A summary of data collected by Westland Milk Products Ltd from Nov 2002 to Feb 2003 is presented in Section 4.2.

4.3.5 Runanga

Table 10 gives the passive sampling results for Runanga. The monitoring programme did not include PM_{10} measurements at this site.

Table 10. Passive sampling data for sulphur dioxide and benzene for Runanga.

	Passive sampling						Hi Vol		
	SO_2 µg/m3			Benzene µg/m3			PM_{10} µg/m3		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
RUNANGA - Pool									
June	9.3	1.6	1.8	2.0					
July	2.5	2.3	2.2	4.2					
August	1.7	1.9	2.3	1.2					
Average	4.5	1.9	2.1	2.7	1.7	1.5			

Apart from a single high result in June 2001, concentrations of sulphur dioxide measured at Runanga are slightly lower than those at the Greymouth Palmerston Street site. The benzene concentrations are also slightly lower than those at the Palmerston Street site. If the fuels used for domestic heating in Runanga are similar to those used in Greymouth, these results do not indicate a potential concern about PM_{10} concentrations in Runanga.

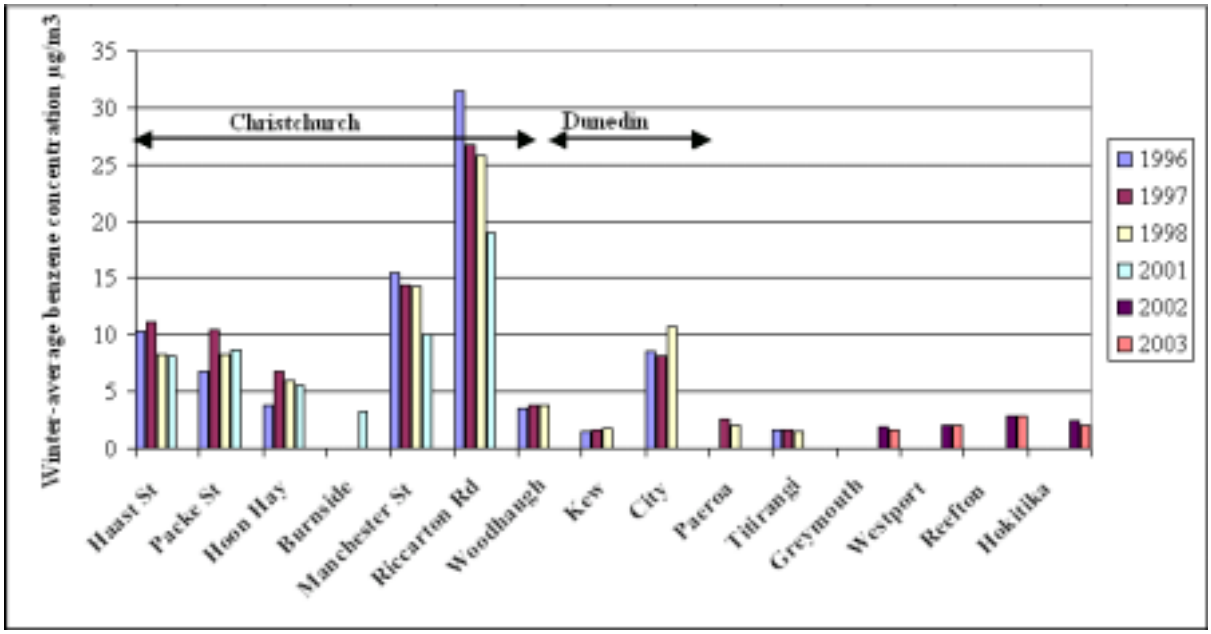
4.3.6 Comparison with air quality in other centres.

Comparison of sulphur dioxide concentrations measured in Greymouth and Reefton by continuous instrumental monitoring are compared with concentrations measured in sulphur dioxide in Table 2. The concentrations measured using passive sampling are similar either to those in Greymouth (for Hokitika and Runanga) or those in Reefton (Westport), so that Table 2 is also suitable for comparison of the concentrations measured using passive sampling.

Figure 10 gives data for benzene concentrations measured during the winter months at a number of sites in Christchurch and Dunedin, in Paeroa and in Titirangi (Auckland), together with the concentrations measured in Greymouth, Westport, Reefton and Hokitika. The Runanga data have been omitted, but are slightly lower than those for Greymouth. The benzene data for 1996-1998 are from the survey of benzene and other aromatic compounds in air in New Zealand, conducted for the Ministry of Health (Stevenson and Narsey, 1999). The 2001 data for the Christchurch sites is from surveys conducted by Environment Canterbury (Gunatilaka, 2003).

Benzene concentrations during winter in the Westport towns range up to about double the lowest concentrations measured in the study for the Ministry of Health, which were found in the outer Auckland suburb of Titirangi, at a bush-clad location where there is only light traffic on the road in the vicinity, and at the seaside suburb of Kew, in Dunedin. They are about the same as the concentrations measured in Paeroa, a small town on the Hauraki Plains. They are about half of the winter concentrations in the Christchurch residential suburbs of St Albans (Packe St) and Hoon Hay.

Figure 10. Winter averages benzene concentrations in West Coast towns and other centres



4.4 COMPARISON WITH EARLIER DATA.

Monitoring of sulphur dioxide and smoke concentrations was conducted in Greymouth in 1994 and 1995, and in Reefton in 1995 (Kingston-Morrison, 1994 and O'Connell 1995). The sulphur dioxide measurements used a bubbler/hydrogen peroxide/titration method. The smoke measurements rely on the extent of blackening of filter paper through which the air sample is drawn. Either instrumental monitoring methods or size-selective gravimetric sampling, such as the high volume PM_{10} sampler used in the 2001-2003 monitoring programme, has largely replaced these methods.

Where particulate material is derived largely from domestic fires, the overwhelming majority of the particulates are less than 10 microns in diameter, so that some approximate correlation between smoke measurements and PM_{10} measurements would be expected, and is commonly observed.

4.4.1 Sulphur dioxide

Table 11 sets out sulphur dioxide concentrations measured in Greymouth and Reefton in 1994 and 1995, and 2001-3. There is a very marked discrepancy between the sulphur dioxide concentrations reported for Greymouth in 1994 and 1995, and the measurements from the 2001-3 programme. On the other hand, the sulphur dioxide concentrations reported for Reefton for 1995 are quite similar to those found in the 2001-3 programme.

Table 11. Sulphur dioxide concentrations from 1994-5 and 2001-3.

	Sulphur dioxide µg/m3					
	1994 Bubbler	1995 Bubbler	2001 Instrument	2001 Passive sampling	2002 Passive sampling	2003 Passive sampling
GREYMOUTH - Palmerston St.						
MAY		63				
JUNE	37	34	6.0	3.7	1.3	2.5
JULY	46	34	5.5	4.2	3.2	3.7
AUGUST	37	21	4.2	3.1	4.1	3.1
Winter average	32		5.0	3.7	2.9	3.1
GREYMOUTH - Works/Bowling Club						
MAY						
JUNE	71					2.0
JULY	37					2.5
AUGUST	47					0.6
REEFTON						
MAY		24				
JUNE		26	24.5	28.9	8.3	22.0
JULY		21		18.7	24.1	29.3
AUGUST		22		11.6	17.5	18.3
Winter average				19.7	16.6	23.2
REEFTON Site 2						
JUNE					22.5	19.7
JULY					22.4	24.5
AUGUST					13.3	16.8
Average					19.4	20.3

The good agreement between the instrumental monthly average concentrations and the monthly passive sampling concentrations gives strong confirmation of the validity of the more recent work, because the instrumental and passive sampling methods employ entirely different chemical and physical principles for the measurement, and are therefore completely independent techniques. When this is combined with the good agreement between the general level of sulphur dioxide reported for Reefton in 1995 and the more recent measurements, the inevitable conclusion appears to be that the earlier Greymouth data are incorrect. There is no known reason why sulphur dioxide concentrations could have decreased about 10-fold of over a period of six years.

4.4.2 Smoke and PM_{10}.

As shown in Table 12, smoke concentrations measured at Palmerston Street in 1995 are similar to the PM_{10} concentrations measured in 2001, although the smoke measurements show a much wider range and the maximum concentration is more than double the maximum PM_{10} concentration measured. The smoke concentrations measured in 1994 were, on

average, about 50% higher than those in 1995. It appears that the measurements were made by different organisations in 1994 and 1995, and it is not clear the extent to which there may have been systematic differences in the measurement technique, or whether the true smoke concentrations in 1994 were markedly higher than those in 1995, and the PM_{10} concentrations measured in 2001.

Table 12. Smoke and PM_{10} concentrations from 1994-5 and 2001-3.

	Smoke µg/m3		Hi Vol PM10 µg/m3	
	1994	1995	2001	2003
GREYMOUTH - Palmerston St.				
MAY	8	39		
JUNE	37	20	23	
JULY	46	13	20	
AUGUST	37	6	19	
Winter average	32	20	21	
Maximum	85	110	46	
GREYMOUTH - Works/Bowling Club				
MAY	6			
JUNE	29			
JULY	42			
AUGUST	32			
Maximum	82/105*			
REEFTON				
MAY		43		
JUNE		47		37
JULY		43		36
AUGUST		38		21
Winter average		43		31
Maximum		91		55

*Maxima for the 2 slightly different locations used as the second site

The smoke concentrations measured at the Works/Bowling Club sites in 1994 were slightly lower than those measured at the Palmerston Street site. This is consistent with the sulphur dioxide measurements in 2003, which indicate lower concentrations at the Bowling Club than at Palmerston Street.

The smoke concentrations measured in Reefton in 1995 are, on average, about 50% higher than the PM_{10} measurements in 2003 and the maximum smoke concentration is 65% higher than the maximum PM_{10} concentration.

Overall, the smoke measurements are higher and more variable than the PM_{10} concentrations measured at the same sites. It is not possible to reach any definite conclusion about whether the different measurements indicate higher levels of pollution in 1994 and 1995 than in 2001 and 2003, or whether the differences simply reflect the different methodologies.

5. METEOROLOGICAL AND GEOGRAPHIC CONSIDERATIONS.

In this section, the meteorological data available for Greymouth, Westport and Reefton are considered, together with the geographical situations of the towns, leading to an improved understanding of the factors contributing to the levels of air pollution measured in this programme.

5.1 FACTORS CONTRIBUTING TO POLLUTION LEVELS IN WEST COAST TOWNS.

High winter PM_{10} concentrations in West Coast towns almost certainly result predominantly from heating emissions from appliances burning coal and/or wood. The actual level of PM_{10} emissions will depend on the fuel burned, the type of appliance and the manner in which the appliance is operated. Sulphur dioxide concentrations result almost exclusively from appliances burning coal, and depend predominantly on the sulphur content of the coal burned.

The maximum concentrations of PM_{10} that will occur in any towns depends on several factors including:

- The intensity of emissions per unit area
- The size of the town and the distance of wind travel over areas from which there are significant emissions
- The meteorology, particularly the frequency of calm or low wind speed conditions

Table 13 brings together information from the 2001 census on the populations of West Coast towns, including a breakdown by suburb of Greymouth, and the percentage of households that burn wood and coal for domestic heating (Statistics NZ website, 2004). The area of the built-up areas and the maximum wind travel (over built-up area) are approximate estimates made from NZMS 260 series maps.

Table 13. Census data for West Coast towns.

	Area	Population	Population	Maximum wind travel	Site wind travel	Percentage of houses burning	
	km2		per km2	km	km	Coal	Wood
Westport	2.1	4000	1907	2.4	1.2	70%	70%
Greymouth South	1.8	3009	1672	1.2	0.8	62%	63%
Cobden	0.8	1638	2048	0.8-1.4	0.7?	86%	87%
Greymouth Central	0.5	942	1884	0.8	-	56%	55%
Blaketown	0.4	1119	2798	0.9*	-	73%	77%
Reefton	0.9	972	1077	1.2	0.7	90%	78%
Hokitika	1.7	3390	1990	1.7	1.0	53%	70%
Runanga	0.7	1302	1963	1.1	0.9	88%	78%

? uncertain because meteorology is uncertain

* including easterly wind travel across Greymouth Central

If the intensity of emissions from domestic heating is proportional to the population density, the emissions intensity for Reefton, with a population density of about 1077/km^2 should be about half of that for most of the Westport towns. The Blaketown suburb of Greymouth should have the highest emissions intensity, with a population density of about 2800/km^2 and Greymouth South, where the Palmerston Street and Bowling Club monitoring sites were located, should have the second lowest with a population density of about 1672/km^2. The other towns and suburbs should have similar emissions intensities, with population densities of approximately 1900-2050/km^2.

In addition to the intensity of emissions, the distance that the air has travelled over areas where there are significant emissions will also affect the concentrations of pollutants. Greater distances of travel should give higher concentrations. Westport has the largest distance of air travel over built-up area at 2.4 km from the southern to the northern edge of the town. The Greymouth suburbs generally have the smallest distances of air travel, for the easterly quarter winds that appear to be predominant there.

Based on these simple factors, and ignoring the critically important meteorological factors, it might be anticipated that Reefton would show the lowest concentrations of pollutants and Westport, or possibly Blaketown, would show the highest concentrations. No monitoring has been done in Blaketown, but the effective distance of wind travel in Table 13 is almost certainly too large, so that it seems unlikely that the relatively high population density would produce a major effect.

Apart from the monitoring sites at the Cobden Bowling Club and Runanga pool, the monitoring sites were located at between half and two-thirds of the maximum distance of air travel over built-up areas. This situation may have different implications depending on the meteorology. For example, at Westport the prevailing light wind is southerly and south-south-easterly, which blows approximately along the greatest distance of wind travel. PM_{10}

concentrations may therefore quite frequently be higher than measured at the monitoring site. On the other hand, at Reefton, the frequencies of winds are approximately evenly distributed between opposite sides of the compass. Sites at either end of the town are therefore likely to show higher concentrations than measured at the monitoring site on some occasions, and lower concentrations than measured at the monitoring site on others. The highest PM_{10} concentrations were measured during light, predominantly northerly quarter winds.

5.2 IMPLICATIONS FROM PASSIVE SAMPLING DATA

5.2.1 From sulphur dioxide data, for sulphur dioxide concentrations

Long-term average sulphur dioxide concentrations, for example from passive sampling, provide a useful indication of likely shorter term average conditions. The passive sampling data shows that Westport and Reefton have much higher concentrations of sulphur dioxide during winter than Greymouth, Hokitika or Runanga.

The maximum 1-hour average sulphur dioxide concentration measured in Reefton was 167 $\mu g/m^3$, 48% of the MfE Ambient Air Guideline. The maximum 24-hour average sulphur dioxide concentration was 87 $\mu g/m^3$, 73% of the MfE Ambient Air Guideline.

Continuous instrumental monitoring of sulphur dioxide was not undertaken in Westport, but the maximum monthly average concentration was about 25% higher than the maximum monthly concentration for Reefton, suggesting that maximum 24-hour average sulphur dioxide concentrations might approach the MfE ambient air guideline at the Derby St site. It is not likely that the 1-hour average sulphur dioxide concentrations there would rise much above about 60-65% of the MfE ambient air guideline, although this possibility cannot be excluded.

A discussed in Section 5.3.1, higher sulphur dioxide concentrations may occur near the northern end of Westport, where maximum concentrations might be up to about 50-60% higher than at Derby Street, because of the greater distance of wind travel over the town in the prevailing wind direction.

Apart from two, single monthly average concentrations that were intermediate between those typical of Greymouth and Reefton, the sulphur dioxide concentrations measured by passive sampling at Hokitika and Runanga were similar to the low concentrations measured at Greymouth. This provides for a good assurance that sulphur dioxide concentrations in these towns are not of concern.

5.2.2 From sulphur dioxide data, for PM_{10} concentrations

Long-term average sulphur dioxide concentrations from passive sampling, provide a useful indication of the likely variations in the general levels of PM_{10} from year to year in the same town, assuming that the proportions of wood and coal burned, and the sulphur content of the coal remain approximately constant. They can also provide a useful indication of the likely variations in the levels of PM_{10} between towns, if there is a reasonable assurance that the

proportions of wood and coal burned, and the sulphur content of the coal, are similar between the towns.

The ratios of average PM_{10}/average sulphur dioxide concentrations in Greymouth, Westport and Reefton show that there are major variations in the sulphur content of the fuel burned, most probably as a result of higher sulphur content in coal burned in Westport and Reefton. Without other means of determining the likely ratio of PM_{10}/sulphur dioxide in emissions, such as might be obtained from an emission inventory, the passive sampling data for sulphur dioxide is of limited value for estimating PM_{10} concentrations in one town from the concentrations of PM_{10} and sulphur dioxide measured in another town.

The passive sampling data for sulphur dioxide is more helpful for consideration of likely variations in PM_{10} concentrations between years in the same town. It is reasonable to assume at least approximately similar ratios of PM_{10} and sulphur dioxide in emissions for the same town from year to year, unless there is information to the contrary.

Comparison of the sulphur dioxide concentrations measured for the 2001, 2002 and 2003 years suggests that the highest levels of pollution were likely to have occurred in 2001 in Greymouth, and in 2003 in Westport and Reefton. Accordingly, the PM_{10} concentrations were probably measured during the year giving the highest concentrations over the monitoring period for both Greymouth and Reefton. However, the passive sampling sulphur dioxide concentrations in Westport were lower in 2002, the year in which the PM_{10} measurements were made, than in the other two years. Accordingly, the PM_{10} concentrations measured there are probably the lowest for the three years of the monitoring programme. Based on the increase in the maximum monthly sulphur dioxide concentrations in 2002 and 2003, the maximum 24-hour average PM_{10} concentration at the Derby St site in 2003 might have been about 20% higher than that measured in 2002. Based on the increase in the winter average concentrations between 2002 and 2003, the winter average PM_{10} concentrations in 2003 might have been about 50% higher than those measured in 2002.

5.2.3 From BTEX data, for PM_{10} concentrations

Passive sampling for BTEX measures long-term average concentrations of benzene, toluene, ethyl benzene and xylenes. Each of these compounds provides similar information about possible sources contributing to pollution levels, but benzene, being carcinogenic, is of much more concern from a health perspective. Accordingly, consideration here is restricted to benzene.

Benzene is emitted both in motor vehicle emissions and from burning coal and wood in domestic heating appliances. When the present study was being designed, it was anticipated that emission factor data for benzene and for PM_{10} would provide a basis for estimating maximum PM_{10} concentrations contributed by domestic heating emissions, if the contribution to benzene concentrations from vehicle emissions could either be estimated approximately, or could be ignored. However, although new data has become available, the variability in the emission factors is such that the best assumption is that there is little difference in the ratio of PM_{10}/benzene emissions from burning coal or wood, and both may be in the range 10-50.

This range of emission factor ratios is too large to make any useful interpretation. At the bottom of the range, the PM_{10} concentrations measured in Greymouth, Reefton and Westport suggest that between 83% (Greymouth) and 110% of the benzene found can be accounted for by heating emissions, assuming a background PM_{10} concentration of 5 $\mu g/m^3$ and negligible contributions to PM_{10} from vehicle emissions. At the top of the range, for the same assumptions, the measured PM_{10} concentrations could account for between 17% (Greymouth) and 22% of the benzene found coming from heating emissions. The most likely situation seems to be that there are similar contributions to the measured concentrations from both motor vehicle emissions and from heating emissions.

The combination of uncertainties about:

- the relative contributions to benzene concentrations from motor vehicle emissions and domestic heating emissions;
- the uncertainty about the relative proportions of coal and wood burned in Hokitika compared with the West Coast towns where PM_{10} has been monitored;
- the PM_{10}/benzene emission factor ratios for coal compared with wood;

means that no reliable estimate of the PM_{10} concentrations in Hokitika can be made from the measured concentrations of sulphur dioxide and benzene in Hokitika and the sulphur dioxide, benzene and PM_{10} concentrations measured in the other towns. It appears that the PM_{10} concentrations may well be intermediate between those measured at Greymouth and Westport, and possibly closer to those in Westport, but this is quite uncertain.

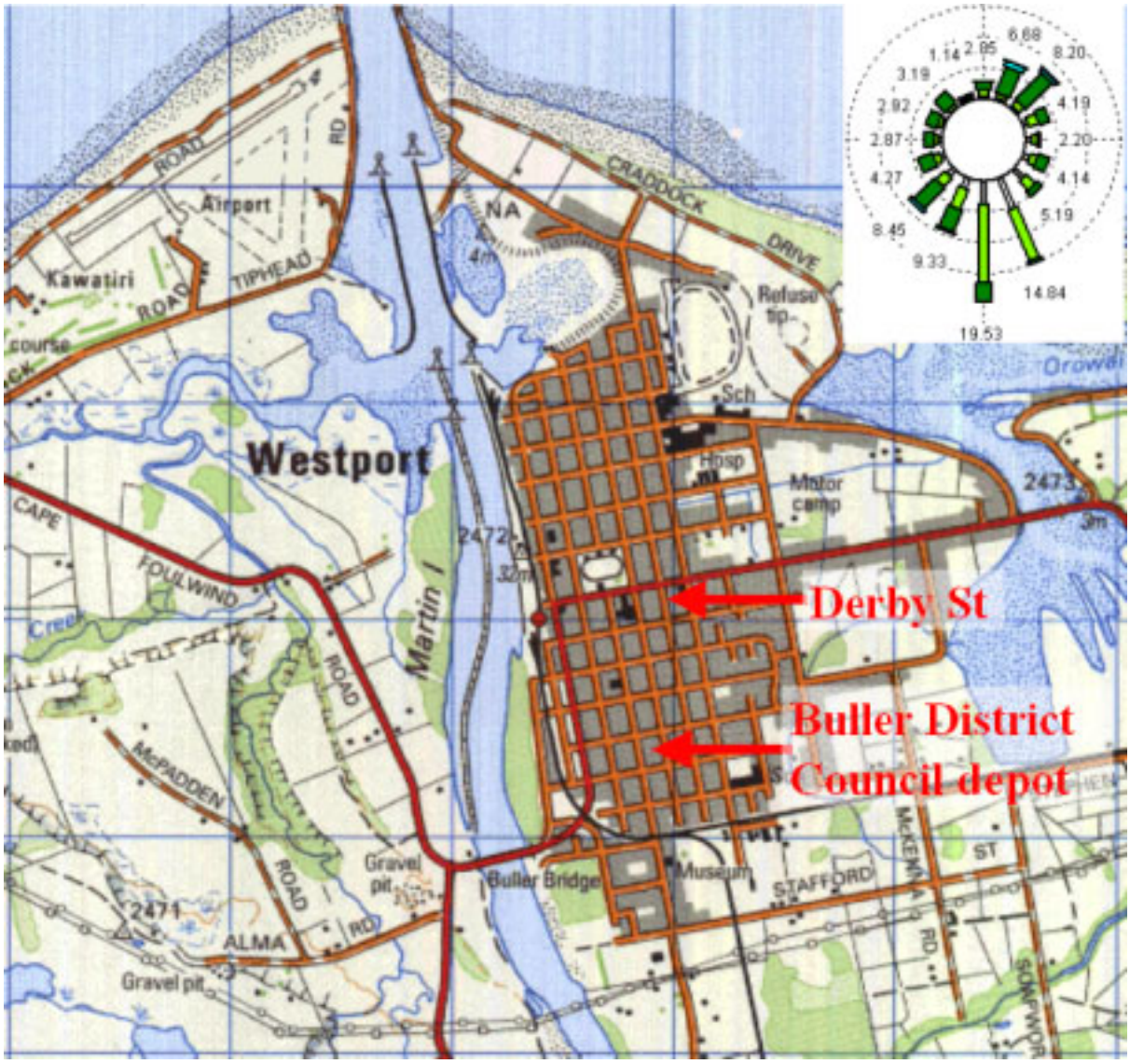
5.3 CONSIDERATION OF INDIVIDUAL TOWNS

As the following consideration of the individual towns shows, the meteorological factors are probably the most important, and outweigh the population density and wind travel distance factors, at least for Reefton, where the concentrations of sulphur dioxide and PM_{10} found were similar to those in Westport.

5.3.1 Westport

Figure 11 shows Westport and its immediate vicinity, with the locations of the sampling sites for the 2001-2003 programme shown by the red arrows. The figure also includes a small wind rose for the June-August 2002 period when PM_{10} measurements were made.

Figure 11. Westport and environs



Westport is much windier than either Greymouth or Reefton. Over the 2002 monitoring period, there were wind speeds below 2 m/sec for more than 12 hours during only 24% of the days. The number of hours of wind speeds below 2 m/sec occurred on 77% of days during the monitoring at Greymouth in 2001, and on 92% of days during the monitoring at Reefton in 2003. The average wind speeds over these monitoring periods were 3.6 m/sec for Westport, 1.7 m/sec for Greymouth and 1.3 m/sec for Reefton.

The relatively high concentrations of PM_{10} and sulphur dioxide found at Westport might be considered surprising in light of the population densities given in Table 13, combined with the windier meteorology of Westport compared with Greymouth and Reefton. A range of factors might account for the relatively high concentrations:

- The levels of emissions per resident may be higher in Westport, for some unknown reason;
- The distance of wind travel across built-up areas to the monitoring site, which is the largest for any of the sites for the Derby Street site, but not for the Council depot site, which still showed relatively high concentrations of sulphur dioxide in 2002;
- The slightly higher wind speeds might result in weaker inversions than in Greymouth and, particularly, in Reefton, so that emissions from domestic chimneys may be mixed down to the level of the sampler intake within shorter distances, giving higher concentrations
- The PM_{10} sampler was mounted higher above the ground in Westport than at the other sites, and may therefore have intercepted higher concentrations in elevated inversion layers under stronger inversion conditions. The intake was about 4.5 m above ground in Westport, compared with 3.3 m in Greymouth and 1.5 m in Reefton.

The Derby Street site would be expected to show higher concentrations than the Buller District Council depot site because of the relatively light prevailing southerly and south south-easterly winds, and the relative locations of the two sites. Because the Buller District Council site is closer to the southern edge of the town, the prevailing winds will not have as great a distance over built-up area from which to accumulate emissions as they will have in traveling to the Derby Street site, about 500 m further into the centre of the town. The differences can evidently be quite marked, with the sulphur dioxide concentration for July 2002 at Derby Street being 30% higher than that at the Council depot site.

Since the built-up area extends for about a further 1200 m north of the Derby Street site, the levels of pollution at the northern end of the town may be substantially higher than those measured at Derby Street. This means that the concentrations of pollutants emitted from the town may be significantly higher near the northern end of the town. While they are unlikely to be double those measured at the Derby Street site, they might well be 50-60% higher. This would give a substantial increase in the frequency of exceedance of the 50 $\mu g/m^3$ 24-hour average PM_{10} concentration and the maximum concentrations. The maximum PM_{10} concentrations might get up to about 130 $\mu g/m^3$ if the measured maximum during 2002 is increased by 60% for movement towards the northern end of town and a further 50% in proportion to the sulphur dioxide concentration increase between 2002 and 2003.

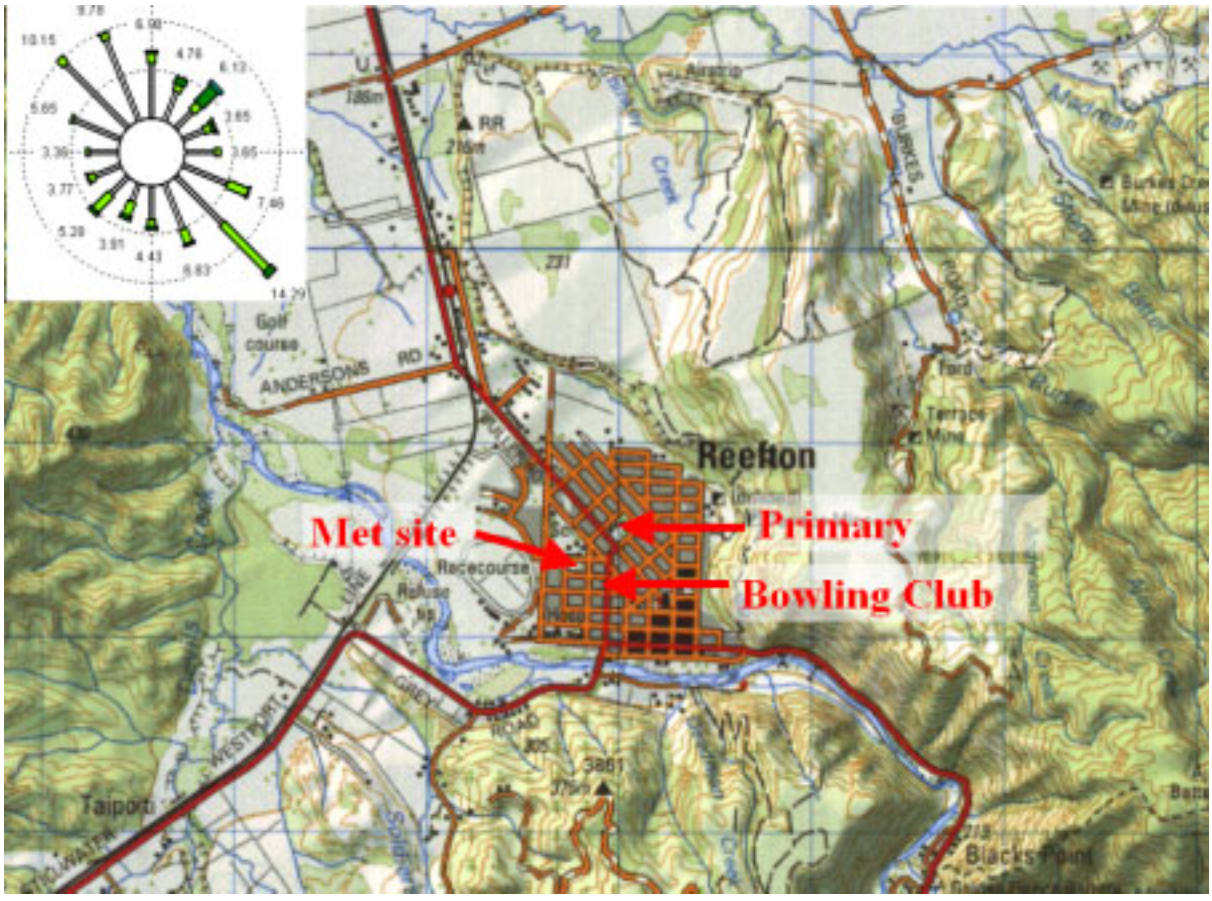
The sulphur dioxide concentrations measured by passive sampling in Westport are higher than those in Reefton, where the maximum 1-hour average from 2003 was 167 µg/m^3 (48% of the MfE guideline) and the 24-hour maximum was 87 µg/m^3 (73% of the MfE guideline). Ratioing up by the three-year average sulphur dioxide concentrations in Reefton and Westport and increasing by 60% for increased wind travel distance suggests a maximum 1-hour average at the northern end of Westport of about 345 µg/m^3, just short of the MfE guideline. The same calculation suggests a maximum 24-hour average of about 180 µg/m^3, well above the MfE guideline.

5.3.2 Reefton

Figure 12 shows Reefton and its immediate vicinity, with the locations of the sampling sites for the 2001-2003 programme shown by the red arrows. The figure also includes a small wind rose for the June-August 2003 period when PM_{10} measurements were made and sulphur dioxide concentrations were measured continuously by instrument.

Wind speeds in Reefton are the lowest for any of the sites for which meteorological data has been gathered in the 2001-2003 programme. Wind speeds were less than 2 m/sec for at least 18 hours per day on 75% of the days over the 2003 monitoring period. Wind speeds were less than 2 m/sec for 24 hours per day on 32% of the days during the monitoring period.

Figure 12. Reefton and environs



The distribution of winds around the compass is much more even at Reefton than at either Greymouth or Westport, although north westerlies, north-north westerlies and south easterlies are about twice or more as frequent as the winds from other directions. The south-easterly/north-westerly direction lines up approximately with the steep-sided Inangahua Valley through which State Highway 7 from Maruia Springs passes, and may be due, in part, to some channelling by this feature.

The very low wind speeds in Reefton are almost certainly the predominant factor resulting in the relatively high PM_{10} concentrations measured compared, for example, with Greymouth, in spite of the lowest population density. However, it is possible that emissions per person might be higher if temperatures over the winter months are usually colder than in the other West Coast towns, leading people to burn more fuel.

The relatively high concentrations measured could also be considered particularly significant because of the location of the PM_{10} sampler at ground level, so that the intake was 1.5 m above ground, giving a direct measure of the air that people are likely to be breathing. The sampler intake was at least 1.8 m higher above ground at Greymouth and Westport.

Both of the monitoring sites are similarly located relative to the edges of the township in the directions of the "prevailing" winds, but the Bowling Club site may be situated downwind of an area of lower emissions intensity during north westerlies, because of the moderately large open area of Reefton secondary school. Because of the approximately even distribution of frequencies of wind directions across the compass (eg northwest-southeast) and the location of the sites near the centre of the town, it is unlikely that substantially higher long-term average concentrations of pollutants would be measured at other sites within the town.

However, it is possible that short-term average concentrations might be higher at other locations than those measured. This could be the case for maximum 24-hour averages, since the maximum PM_{10} concentrations occured on days when there were light winds from the general northerly quarter most of the day, and these winds should give the highest concentrations near the southern end of the town. However, the prevailing wind directions are not nearly as clear as they are at Westport, and while the maximum concentrations might be higher, for example towards the south eastern end of the town, this would be balanced to at least some degree by other days giving much lower concentrations than measured at the primary school site.

2003 showed the highest concentrations of sulphur dioxide by passive sampling at this site for the three-year monitoring period. The PM_{10} is clearly the predominant concern, with 11% of the measured winter concentrations exceeding the MfE Ambient Air Guideline, although there might be in some years, sulphur dioxide concentrations approaching the 24-hour average MfE guideline.

5.3.3 Greymouth.

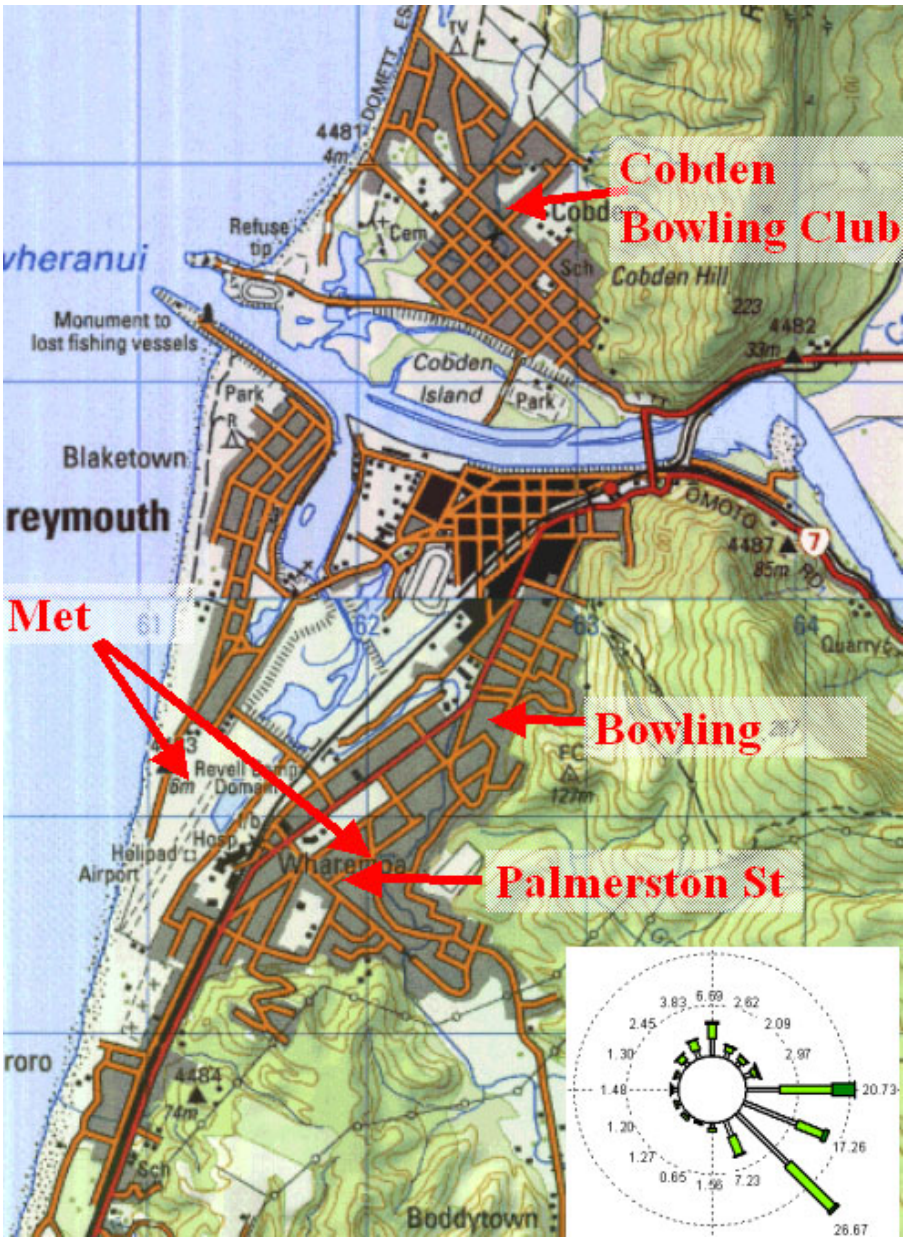
Figure 13 shows Greymouth and its immediate vicinity, with the locations of the sampling sites for the 2001-2003 programme shown by the red arrows. Two meteorological sites are also shown, the one at the airport site with records back to 1978 and is run by the Meteorological Service and the other at the Mardsen-Palmerston St intersection was set up in 2003 and is run by Grey District Council. The figure also includes a small wind rose for data collected from the Palmerston St site in the June-August 2001 period when PM_{10} measurements were made and sulphur dioxide concentrations were measured continuously by instrument.

The wind speeds at the Palmerston Street site are low, with wind speeds less than 2 m/sec for 18 hours per day or more on 50% of days over the monitoring period.

The prevailing wind direction at the Palmerston Street site was between south-east and east, with northerlies and south south-easterlies 6-7% of the time and little wind from other directions. Examination of the charts of wind speed and wind direction over the monitoring period, in Appendix 3, shows that the northerlies usually occur for short periods during the middle of the day, while easterlies or south-easterlies predominate from late afternoon until the following morning. The south-easterlies and easterlies are probably land breezes resulting from sea temperatures being warmer than land temperatures, possibly combined with cold down-slope katabatic flows at night off the hills east of the town. Channelling along the valley in which Boddytown is situated is probably also a factor, emphasising the south-easterly direction.

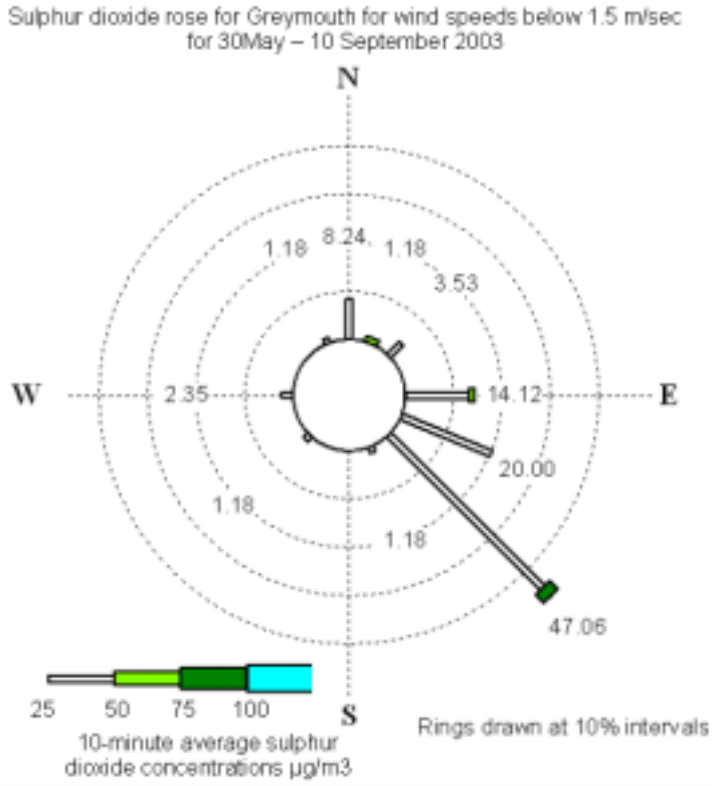
Because of the strongly prevailing easterly and south-easterly flows, the pollution levels at the Palmerston Street site are likely to be determined predominantly by emissions up-wind in these directions. The build-up area extends for 800-1100 m in the general south-easterly direction, into the valley leading to Boddytown. In the easterly direction, the build up area extends only about 300 m from the site. Accordingly, emissions generally south-east of the site are likely to be most important in determining the levels of pollution measured.

Figure 13. Greymouth and environs



The sulphur dioxide rose for wind speeds less than 1.5 m/sec (Figure 14) illustrates this situation. This plots the frequency of occurrence of 10-minute average sulphur dioxide concentrations over 25 µg/m^3 for the various wind directions. Much the largest frequency of elevated sulphur dioxide concentrations and also the highest sulphur dioxide concentrations occur during light winds from the south-east.

Figure 14. Sulphur dioxide rose for wind speeds less than 1.5 m/sec



It is likely that the wind micro-climate at the Bowling Club and the Cobden Bowling Club will be different from that monitored at the Palmerston Street site. The south-easterly component is likely to be less important at both of these other sites, in the absence of a valley in the south-easterly direction. Predominant easterly land breezes appear to be the most likely pattern. If so, at both the Bowling Club and Cobden Bowling Club sites, the distance to which built up areas extend in the easterly direction are quite small, at about 100 m in each case.

On the other hand, local observations (Trevor James *pers comm*) are that there is quite often a northerly wind along State Highway 6 south of the central business area, and that this may result from winds leaving the Cobden Gap fanning out over the coastal flats. This could explain the slightly higher concentrations of benzene at the Greymouth Bowling Club compared with Palmerston Street, since the northerly would carry traffic emissions from SH6 and the central business area more efficiently than to the Palmerston Street site, particularly if the prevailing south-easterly breeze is flowing at Palmerston Street.

Winds fanning out towards the north-west from the Cobden Gap could also explain why, for at least some of the sampling periods, concentrations measured at the Cobden Bowling Club were not much smaller than those at Palmerston Street. The resulting south-easterly flow would pick up emissions from built-up area extending about 800 m up-wind from the monitoring site.

A photograph taken from Arnott's Heights (Figure 15), provided by Trevor James shows a highly visible smoke haze over the houses in the Lydia St to Alexander St area and extending up the hill slightly. This is most likely to be smoke rather than mist due to its colour, and odour at ground level in the mornings and evenings (Trevor James, *pers comm*). If this is largely smoke, the PM_{10} levels might be quite high, but this might be only in an inversion layer some height above ground. However, given that the passive sampling sulphur dioxide and benzene results for the Greymouth Bowling Club site (central in the location of the smoke haze) sampled in 2003 were not significantly different from the Palmerston St site, PM_{10} levels there may not be much higher.

Figure 15. Morning smoke haze over the Lydia St/Alexander St area

Continuous monitoring data, from Nelson for example, shows that the maximum concentrations at ground level can occur when the inversion layer breaks down as the ground heats up during the morning, mixing the pollutants accumulated in the inversion layer down to ground. This may or may not happen in Greymouth, and it is possible that elevated, more polluted levels might be carried away from the town before the inversion breaks up. This could be a factor keeping the PM_{10} levels at ground level lower than they might otherwise be in Greymouth.

The intake for the PM_{10} sampler was 3.3 m above ground at the Palmerston Street site. It is possible that higher concentrations might sometimes have been intercepted from slightly elevated inversion layers than would have occurred at breathing level for people on the ground.

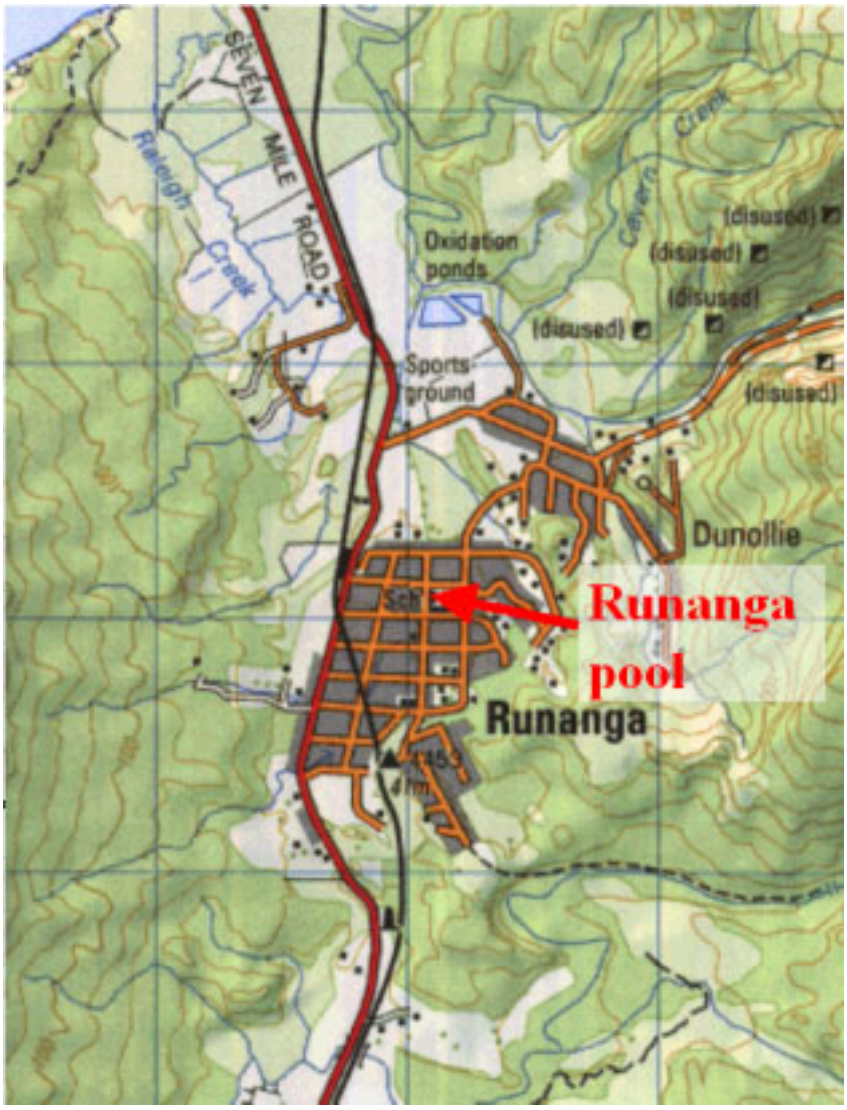
The PM_{10} situation at the Palmerston Street site is obviously better than for Westport or Reefton, with none of the measured concentrations exceeding the MfE Ambient Air Guideline. Concentrations might be a little higher further north-west of the Palmerston Street site, for example in the vicinity of the Raleigh Street/Cowper St intersection. However, a substantial fraction of this is the High School grounds, so the effect is probably not significant. This is because a sulphur dioxide rose for wind speeds of less than 1.5 m/sec shows that sulphur dioxide concentrations over 25 $\mu g/m^3$ (10 minute averages) are predominantly during south-easterly flow, obviously coming down the valley in which Boddytown is situated, and there would be a 50 % greater distance over built-up areas from which emissions could be accumulated.

5.3.4 Runanga

Figure 16 shows Runanga and its immediate vicinity, with the location of the sampling site for the 2001-2003 programme shown by the red arrow.

The location of Runanga in a valley opening to the sea makes it likely that the prevailing wind direction from late afternoon until morning will be that of a land breeze towards the coast, from the south-easterly direction. The sampling site is located towards the northern end of the settlement, and is therefore likely to indicate near-maximum concentrations from emissions in the settlement.

Figure 16. Runanga and environs



It seems likely that the fuel mix burned in Runanga is similar to that in Greymouth and, if so, the PM_{10} concentrations are likely to be lower than in Greymouth, because the monthly average sulphur dioxide concentrations from passive sampling are lower than for Greymouth. The monitoring site is towards the northern end of the town, and it is most likely that the prevailing light winds are south south-easterly land breezes flowing down the valley. Accordingly, the monitoring site can be expected to show about the maximum concentrations.

The one hesitation about concluding that Runanga may have the best air quality of the towns studied is the relatively high sulphur dioxide concentration in June 2001. While this is not a concern in relation to sulphur dioxide concentrations compared with Westport or Reefton, it might possibly indicate high PM_{10} concentrations associated with unusual meteorological conditions. Alternatively, there may have been an unusual sulphur dioxide source near the sampling location, such as someone burning a delivery of relatively high sulphur coal over that month.

Visible smoke hazes are common on cold calm mornings and evenings (Trevor James and Mary Trayes, *pers comm*.).

5.3.5 Hokitika

Figure 17 shows Hokitika and its immediate vicinity, with the location of the passive sampling site for the 2001-2003 programme shown by the red arrow. Westland Milk Products Ltd (WMP) ran a continuous PM_{10} monitoring site from November 2002 to January 2003 as part of their requirements of their resource consent for discharge to air

Like Westport, Hokitika is on a small coastal plain some distance from higher ground further inland. Its meteorology is likely to be similar to that of Westport, with the prevailing relatively light winds being land breezes during the late afternoon and overnight. These are likely to be approximately south-easterly winds. If this is the situation, the monitoring site at Westland High School is about half the distance between the south eastern edge of the town and its north-western edge, the maximum wind travel over built-up areas from which emissions can be accumulated. It would then be possible that higher concentrations might be measured west of State Highway 6.

The passive sampling data shows that concentrations of sulphur dioxide, which are similar to those in Greymouth, are unlikely to be of concern.

The two predominant uncertainties in relation to assessing likely PM_{10} concentrations are the fuel mix burned in the town and the effect of the further distance of air travel over built-up area from the Westland High School to the western end of the town during (presumed) prevailing land breezes during cold, calm periods, such as overnight. If the fuel mix, including the ratio of wood to coal burned is similar to that in Greymouth, and the sulphur content of the coal is similar to or higher than that in Greymouth, the PM_{10} concentrations at the High School should be similar to those in Greymouth in 2001, although the single relatively high sulphur dioxide concentrations in August 2001 suggests that there might be, on occasion, significantly higher concentrations. On the other hand, if the predominant fuel is wood, the PM_{10} concentrations in Hokitika are quite uncertain based on the present information. The data in Table 13 suggests that there is more wood burned in Hokitika than in other West Coast towns, with 53% of households stating that they burn coal and 70% stating that they burn wood, whereas in most other towns the percentages or households burning coal and wood are about the same, typically in the range 70%-90%.

Figure 17. Hokitika and environs.

Local information is probably the best guide at this stage. It is a common occurrence on cold calm mornings and evenings to see visible particulates hazes (Richard Cotton, *pers comm.*) As discussed in Section 5.2.3, it appears that the PM_{10} concentrations may well be intermediate between those measured at Greymouth and Westport, and possibly closer to those in Westport, but this is quite uncertain.

6. HEALTH RISK ASSESSMENT

6.1 SULPHUR DIOXIDE.

It is generally considered that concentrations of sulphur dioxide below a threshold related to the period of exposure do not result in adverse health effects. The MfE Ambient Air Guidelines are set at levels based on these thresholds, so that no adverse health effects are expected if the concentrations of sulphur dioxide meet the guidelines.

The maximum concentrations found by the present monitoring programme are well below the MfE Ambient Air Guidelines. The maximum 1-hour average concentration of sulphur dioxide in Reefton was 167 $\mu g/m^3$, 48% of the MfE ambient air guideline of 350 $\mu g/m^3$. The maximum 24-hour average concentrations of sulphur dioxide in Reefton was 87 $\mu g/m^3$, 73% of the MfE ambient air guideline of 120 $\mu g/m^3$. The concentrations of sulphur dioxide found in Greymouth were much smaller than those found in Reefton.

Accordingly, no adverse health effects are expected to result from the present concentrations of sulphur dioxide in these towns.

As discussed in Section 5.3.1, there is a possibility that higher concentrations of sulphur dioxide than those measured in Reefton might occur in Westport, in areas near the northern end of the town during years when the meteorology is unfavourable. It is possible that there might be a occasional, infrequent exceedances of the 24-hour average MfE ambient air guideline under these conditions, or less likely, the 1-hour average MfE ambient air guideline. While these infrequent exceedances would be of concern, significant adverse health effects are unlikely, because the degree of exceedance would be minor. Any possible adverse effects are likely to be very much smaller than those associated with PM_{10}, and measures required to control the levels of PM_{10} pollution would also reduce the concentrations of sulphur dioxide.

The passive sampling data for sulphur dioxide for Hokitika and Runanga indicates that relatively low concentrations of sulphur dioxide are typical in these towns, so that adverse health effects from this pollutant are not anticipated.

6.2 BENZENE.

The predominant health concern in relation to benzene is the fact that it is carcinogenic, causing leukemia. The World Health Organisation has recommended a unit risk factor for benzene of $6x10^{-6}/\mu g/m^3$. This means that for every 1 million people exposed over their lifetime to an average concentration of 1 $\mu g/m^3$ of benzene, 6 people would be expected to develop cancer.

The highest benzene concentrations were measured in Reefton, where the winter average concentrations during both 2002 and 2003 were 2.9 $\mu g/m^3$. This winter average concentration will be substantially higher than the annual average concentration, which is that

most relevant to assessing cancer risks. Cancer risk estimates are based on long-term average concentrations. However, if the extreme worst case is considered, by assuming that the winter average concentration applies throughout the year, and that all of the residents in Reefton, Westport, Greymouth, Runanga and Hokitika (a total of about 16,400) are exposed to this level of benzene throughout their lives, the rate of increased cancer among the population would be 0.28 additional cancer deaths per lifetime of the population. This amounts to approximately one additional cancer death in 250 years!

Clearly, benzene exposures at the concentrations found in West Coast towns present negligible cancer risks. This is particularly so compared with the much larger mortality risks resulting from exposures to PM_{10}.

6.3 PM_{10}

The approached used in this analysis is based upon the methodology developed by Künzli et al. (1999) to evaluate mortality and morbidity rates in Austria, France, and Switzerland associated with traffic related air pollution. This method has subsequently been used by a Ministry of Transport-funded evaluation of potential health impact of vehicle emissions in New Zealand (Fisher et al., 2002). The estimates are based on the long-term effect of ambient average annual PM_{10} concentrations on mortality rates in the adult population. The estimated impact includes several processes covering acute as well as cumulative chronic effects.

Background information and further detail on the calculation are presented in Appendix 8, and only an overview of the calculation and results is presented in this section.

Epidemiological studies of the increases in death rates associated with long-term exposure to be PM_{10} provide estimates of the relative increase in death rates (relative risks) per 10 $\mu g/m^3$ increase in annual average concentrations of PM_{10}. Application of these relative risks to a particular situation, such as the West Coast towns, involves the following steps:

1. Estimation of annual average PM_{10} concentrations;
2. Estimation of the baseline mortality rate for the population, in the absence of exposure to PM_{10};
3. Estimation of the mortality rate including the effect of exposures to 10 $\mu g/m^3$ PM_{10} by multiplying the baseline mortality rate by the relative risk per 10 $\mu g/m^3$ PM_{10} from the epidemiological studies;
4. Estimation of the mortality per thousand people attributable to exposure to 10 $\mu g/m^3$ by subtracting 2. from 3.
5. Estimation of the annual numbers of deaths per million people attributable to exposure to the estimated actual PM_{10} concentrations by multiplying 4. by the estimated annual average concentration of PM_{10} from 1., and dividing by 10 $\mu g/m^3$.

6. Estimation of the number of deaths attributable to PM_{10} exposures in the West Coast towns by multiplying the annual number of deaths per million people from 5. by the actual population of the towns, divided by 1,000,000.

6.3.1 Estimation of annual average PM_{10} concentrations

The West Coast 2001-2003 air pollution sampling programming monitored PM_{10} levels in Greymouth, Reefton and Westport during the three winter months of June to August when the highest pollution level are likely to occur as a consequence of domestic heating emissions. The average PM_{10} level recorded at each of the townships were respectively 21µg/m^3, 31µg/m^3 and 27µg/m3. Based on of the similarity in the measured concentrations of sulphur dioxide and benzene and the proximity of Runanga to Greymouth, it has been assumed that PM_{10} concentrations are similar in both areas. As discussed in Section 5.2.3 the PM_{10} concentrations in Hokitika are likely to be intermediate between those found in Greymouth and Westport, and possibly closer to those in Westport, but this is quite uncertain. Accordingly two estimates of annual average PM_{10} concentrations have been made for Hokitika, one using the Greymouth PM_{10} concentration and, to cover the widest likely range, the other using the Reefton concentration, which is slightly higher than that for Westport.

Only limited data are available for PM_{10} concentrations in West Coast towns other than during the winter months (Table 4).

There may also be a significant sea salt contribution to the higher PM_{10} concentrations measured during late March and early April, but these samples show increasing PM_{10} concentrations as is expected for progression through autumn and the increasing use of domestic heating appliances. Such an increase is consistent with the method used to estimate annual average concentrations in Section (Estimation of annual average PM_{10} concentrations)

The PM_{10} monitoring in Greymouth during February and March 2004 (Table 4) showed an average PM_{10} concentration of 8.7 µg/m^3. Analyses of the PM_{10} samples for chloride suggest that the concentrations of PM_{10} during summer from sources other than sea salt are very low, at least in Greymouth.

The PM_{10} concentrations measured by NIWA at the Hokitika Holiday park, at the south eastern edge of the town from November 2002 until mid-February 2003 indicate substantially higher summer PM_{10} concentrations than the monitoring in Greymouth, with the average concentration over the monitoring period being 19 µg/m^3 (Sinclair Knight Merz, 2003). In light of the predominance of sea salt found in the samples showing higher PM_{10} concentrations at Greymouth, it appears likely that sea salt may also be an important contributor to the total PM_{10} concentrations in Hokitika during summer.

PM_{10} concentrations have been monitored at several 'smaller' New Zealand urban centres over an entire year, including Napier (HBRC), Tauranga (EBOP), Whakatane (EBOP), Upper Hutt (WRC), Wainuiomata (WRC), and Masterton (WRC). The average concentrations recorded during the nine 'non-winter' months are between 8.6µg/m^3 and 15µg/m^3. All these urban centres have larger populations than any West Coast townships. Therefore, it is likely that traffic densities in these areas are higher than those on the Coast West and consequently

the contribution from motor vehicle emissions to recorded PM_{10} levels greater than generally found in the West Coast urban areas. Meteorological factors and positioning of monitoring station with respect to emission sources would also influence recorded levels.

The proportion of the total PM_{10} concentration that is sea salt is almost certainly important in considering likely health effects. It is unlikely that inhaled sea salt, which would quickly dissolve in the lungs and become an indistinguishable part of the blood plasma, would have the same adverse health effects as combustion particulates. This salt component of the inhaled particulates may well have no adverse health effect.

Taking account of the very small concentrations of the non-sea salt PM_{10} measured in summer at Greymouth, the concentrations of PM_{10} measured in towns and small cities away from the West Coast, and the concentrations measured in Hokitika, there is a wide range of uncertainty about the PM_{10} concentrations during the non-winter months. These could range from near zero to 19 $\mu g/m^3$. A range of annual average PM_{10} concentrations has therefore been estimated, to provide a range of annual mortality attributable to PM_{10} concentrations in the West Coast towns

The low end of the range of PM_{10} concentrations is based on the concentrations of PM_{10} likely to have health effects being very small during summer, with the predominant contributor to measured PM_{10} concentrations being sea salt. This, non-sea salt PM_{10} concentration during summer is taken as 2 $\mu g/m^3$. It is then considered that during spring and autumn, the average concentrations of PM_{10} producing health effects are midway between the measured winter PM_{10} concentrations and 2 $\mu g/m^3$. The annual average concentration is then calculated from these estimates of the summer, spring and autumn average concentrations, and the measured winter PM_{10} concentrations.

The high end of the range of PM_{10} concentrations assumes that the average concentrations of 19 $\mu g/m^3$ measured in Hokitika over the summer 2002/3 consists entirely of PM_{10}, and that this concentration is representative for all of the West Coast towns. It is the PM_{10} from combustion sources that has the potential to cause adverse health effects. The spring and autumn concentrations are calculated as midway between the measured winter PM_{10} concentrations and 19 $\mu g/m^3$. The annual average concentration is then calculated in the same way as for the low end estimate.

Table 14 sets out these estimates of the annual average concentrations of PM_{10} for the West Coast towns. The non-winter average concentrations calculated assuming a summer concentration of 2 $\mu g/m^3$ are similar to those measured for the non-winter months in other small cities and towns in New Zealand, whereas those calculated assuming a summer concentrations of 19 $\mu g/m^3$ are 30-250% higher than those measured elsewhere. Accordingly, the low range annual average estimates appear more likely to be close to the true situation, and may still overestimate the PM_{10} concentrations that would actually have health effects, because some of the winter PM_{10} concentration were almost certainly be sea salt.

Table 14. Estimated annual average concentrations of PM_{10}

Area	Winter Jun - Aug µg/m³	Summer Dec-Feb µg/m³	Spring/Autum µg/m³	Non-Winter (9 month avg) µg/m³	Annual µg/m³
Low range estimates					
Greymouth	21	2	12	8	12
Runanga	21	2	12	8	12
Westport	27	2	15	10	15
Reefton	31	2	17	12	17
Hokitika	21 to 31	2	12 to 17	8 to 12	12 to 17
High range estimates					
Greymouth	21	19	20	20	20
Runanga	21	19	20	20	20
Westport	27	19	23	22	23
Reefton	31	19	25	23	25
Hokitika	21 to 31	19	20 to 25	20 to 23	20 to 25

6.3.2 Baseline mortality rates in the absence of PM_{10} exposures

Appendix 8 estimates baseline mortality rates, excluding the effect of PM_{10} exposures, for both the West Coast population and for the New Zealand population in general, excluding in both cases sudden (typically accidental) deaths.

In these estimates, and in the estimated annual numbers of deaths attributable to exposure to the estimated actual PM_{10} concentrations, a threshold concentration of PM_{10} is subtracted from the measured or total estimated PM_{10} concentrations. This threshold concentration is defined as the PM_{10} concentration below which PM_{10} is assumed to not increase the risk of mortalities. It might be considered, for example, to correspond to the natural background concentrations of PM_{10}, excluding man-made pollution. There is considerable uncertainty about the most appropriate threshold concentration, and a range of threshold concentrations is commonly considered.

An average urban New Zealand non-sudden death mortality rate of 12.1 deaths per 1000 people was calculated for residents aged over 30 years. The corresponding baseline mortality rates for non-air pollutant-related deaths was then estimated to be 11.5 deaths per 1000 people assuming a threshold effect concentration of 7.5µg/m^3.

An average non-sudden death rate of 13.8 per 1000 was estimated for over-30-year-olds in West Coast towns. At the selected threshold concentration of 7.5µg/m^3 and average relative risk of 1.043, 13.0-13.4 deaths per year per 1000 residents over 30 years old in West Coast urban areas are estimated to be not PM_{10}-related.

Observed mortality rates are higher for older age groups, and since the age distribution on the West Coast includes a higher proportion of older people, higher observed mortality rates are expected for the West Coast than for the New Zealand population as a whole.

6.3.3 Estimated PM_{10}-related mortalities in West Coast towns

Table 15 shows the predicted West Coast mortalities using the derived West Coast regional urban mortality rate and annual average ambient PM_{10} levels calculated from low range and high range summer PM_{10} concentrations as in Table 14. This table also shows the range of estimated mortalities for Hokitika, based on the range of estimates for the winter PM_{10} concentrations there, and the total for all West Coast towns included in the study using the low (Total low) and high (Total high) estimates for the winter PM_{10} concentrations in Hokitika. The effect of varying the threshold concentration, below which PM_{10} concentrations are assumed to have no effect on mortality rates, from 0µg/m^3 to 10µg/m^3 is also presented in Table 15.

Table 15. Predicted annual mortalities from PM_{10} exposures

Urban Areas	**Threshold PM_{10} Concentration (B)**							
	7.5 µg/m^3		**0 µg/m^3**		**5.0 µg/m^3**		**10 µg/m^3**	
Summer PM_{10} estimate	Low	High	Low	High	Low	High	Low	High
Greymouth/Runanga	1.2	3.5	3.2	5.4	1.9	4.1	0.4	2.8
Westport	1.1	2.3	2.1	3.3	1.4	2.6	0.7	1.9
Reefton	0.3	0.6	0.6	0.9	0.4	0.7	0.2	0.5
Hokitika low	0.5	1.5	1.4	2.4	0.8	1.8	0.2	1.2
Hokitika high	1.1	2.1	2.0	2.9	1.4	2.4	0.8	1.8
Total low	3.1	7.9	7.3	11.9	4.5	9.2	1.6	6.5
Total high	3.7	8.5	8.0	12.5	5.1	9.8	2.2	7.1

The range of relative risks from the epidemiological studies also contribute to the range of possible annual mortalities that could be estimated. Use of the upper and lower limits of the Relative Risk 95% confidence interval (1.026 and 1.061) would decrease or increase the mortality estimates by approximately 40% of the estimates given in the tables. The uncertainty in the non-winter PM_{10} concentrations (low and high summer PM_{10} estimates) and in the appropriate threshold concentration have substantially larger effects on the estimated mortalities than the uncertainties in these relative risks.

The most likely combinations of threshold values and low or high summer PM_{10} estimates are low summer PM_{10} estimates with low threshold concentrations and high summer PM_{10} estimates with high threshold concentrations.

If the summer (non-winter) PM_{10} concentrations are low, this implies that the background "natural" concentrations are low and therefore particulates such as combustion particulates that affect health are likely to have an effect from low concentrations. Also, at the very low non-sea salt PM_{10} concentrations indicated by the Greymouth summer sampling, substantial threshold concentrations are not realistic, since they would imply negative net PM_{10} concentrations after subtracting the threshold.

Similarly, if summer PM_{10} concentrations are high, (when contributions from combustion particulates that are likely to be low) there is likely to be a substantial "natural" background

concentration (which may well be sea salt), that would be appropriately adjusted for by using a relatively high threshold concentration.

Based on these considerations, the best estimates of annual mortality in the West Coast towns included in the study appear to be in the range 5-8 deaths per year attributable to exposures to PM_{10} concentrations, based on the regional baseline mortality data.

Table 15 shows that the greatest number of PM_{10} related mortalities are expected to occur in the Greymouth/Runanga urban areas. This is because the largest population is in these areas.

A summary of predicted PM_{10}-related annual mortality rates (deaths per thousand residents per year) is shown in Table 16 for the different summer PM_{10} concentration and threshold concentration assumptions. The highest PM_{10}-related mortality rates are estimated for Reefton because the highest annual average PM_{10} concentration over the winter (31µg/m3) was recorded there. The lowest mortality rates are estimated for Greymouth/Runanga, because the lowest winter average PM_{10} concentrations were measured there.

Table 16. Estimated PM_{10} mortality rates per year per 1000 residents over 30 years old

	Threshold PM_{10} Concentration							
	7.5 µg/m³		**0 µg/m³**		**5.0 µg/m³**		**10 µg/m³**	
Summer PM_{10} estimate	Low	High	Low	High	Low	High	Low	High
Greymouth/Runanga	0.23	0.70	0.64	1.08	0.37	0.83	0.09	0.56
Westport	0.41	0.86	0.81	1.24	0.54	0.99	0.26	0.73
Reefton	0.52	0.98	0.93	1.35	0.66	1.10	0.38	0.85
Hokitika low	0.23	0.70	0.64	1.08	0.37	0.83	0.09	0.56
Hokitika high	0.52	0.98	0.93	1.35	0.66	1.10	0.38	0.85
WC urban average low	0.29	0.76	0.70	1.14	0.43	0.89	0.15	0.62
WC urban average high	0.35	0.81	0.76	1.20	0.49	0.94	0.21	0.68

Estimates similar to those presented in Table 15 and Table 16, but using baseline mortality rates based on national, rather than West Coast, data are given in Appendix 8. These do not differ greatly from the figures presented here.

6.3.4 Uncertainties in the estimates

One of the larger sources of uncertainty in these estimates of mortality is the representativeness of the PM_{10} concentrations used for the resident populations in the West Coast towns. PM_{10} measurements have been made only in one year, during the winter months. The annual average concentrations have had to be estimated on the basis of limited summer monitoring in Greymouth and Hokitika, and assumed similarity to non-winter PM_{10} concentrations measured in other urban areas away from the West Coast. Also, PM_{10} concentrations will vary from year to year. The relationship of the estimated annual average PM_{10} concentrations to the long-term (multi-year) average PM_{10} concentrations, which are those most appropriate for use in conjunction with the relative risk factors from the published

epidemiological studies, is unknown. However, it seems unlikely that the true long-term average PM_{10} concentrations would be outside the range of about 50% higher or lower than the estimated annual average PM_{10} concentrations used here.

It may also be that the size of the West Coast towns means that the measured winter PM_{10} concentrations and the estimated annual average concentrations derived from them may not represent the exposures for the general population in the towns in the same way that the PM_{10} concentrations used in the epidemiological studies represents exposures for the general population of the cities included in those studies. The smallest of these (Topeka, Kansas) has a population almost 10 times the total population of all of the West Coast towns considered here. In the larger urban areas, air pollution levels change more slowly with changing location than they do in small towns. A much higher proportion of the population in small towns resides immediately adjacent to open areas with no emissions and are likely to be subject to lower levels of pollution than people living near the centre of town, or at the downwind edge in the prevailing wind direction. This situation is likely to mean that the estimates of mortality made here overestimate the true mortality impact of the concentrations measured at sites chosen to be likely to give the highest concentrations of urban pollutants. Many people move around during the day, for example to their place of work, where they may be exposed to higher or lower concentrations than at home. However, the highest concentrations of sulphur dioxide, and therefore probably PM_{10}, occur in the West Coast towns in the evenings and mornings, when most people are likely to be at home.

The methodology assumes that typical levels of personal exposure relative to measured ambient air concentrations in the West Coast urban areas are comparable to those experienced by participants included in the ACS and Harvard Six Cities studies (Dockery et al, 1993; Pope et al, 1995). It is possible that different life styles and work patterns of the may influence this relationship. Similarly the method assumes that the relationship between indoor and outdoor air pollutant levels is maintained. Variations in design, proximity to emission sources and ventilation rates may influence exposure.

The methodology also assumes that variations in the frequency or time of exposure are unimportant. The same long-term average PM_{10} concentration might result from either short periods of very high concentrations followed by periods of low concentrations, or from more-or-less for continuous concentrations at about the average level. The methodology assumes that both of these situations produce the same result. In fact, neither extreme is likely, because of the dominant effect of meteorology on pollutant concentrations, but there will be some variation towards the extremes between different towns and cities. The range of cities included in the ACS study is likely to have included a wide range of temporal patterns of exposure, and accordingly such effects are likely to have been incorporated within the estimates of the 95% confidence limits for the relative risks.

It could be questioned whether the nature of the PM_{10} in the cities included in the American long-term epidemiological studies differs significantly from the PM_{10} in West Coast towns, for example in relation to particle size distributions and particle toxicity. However, the nature of the particulate material in cities in the American studies varies substantially, ranging from predominantly motor vehicle emission particulates to predominantly industrial emissions including those from coal combustion. Further, short-term studies in Christchurch, where the

pollution is predominantly from domestic fires, have shown effects at the levels that would be expected from similar overseas studies in a wide range of cities that include a range of contributing sources to PM_{10} concentrations. The long-term American studies note consistency between the short term and long-term effects of PM_{10} and other fine particulates. Accordingly, it is most probable that the relationships between PM_{10} concentrations and mortality are applicable to the situation in West Coast towns.

Although there are uncertainties, the predicted mortalities are based upon the best available evidence. This suggests that PM_{10} does have a public health impact in the West Coast towns. The exact magnitude of this impact is less clear, and may possibly be overestimated by the estimates presented here.

6.3.5 Summary

The best estimates from health risk assessment calculations of mortalities attributed to ambient levels of PM_{10} in the West Coast's urban areas is 5 to 8 mortalities per year.

However, the true mortalities attributable to PM_{10} concentrations may be lower than these estimates because of the small size of West Coast towns and the indications that a significant fraction of the measured PM_{10} concentrations is likely to be sea salt.

The small size of the West Coast towns may mean that only a modest proportion of the population in them would be subject to PM_{10} concentrations as high as those measured at sites selected to give near-maximum concentrations within the town. Those living near the edge of the town are likely to have significantly better air quality than those living near the centre. This effect will be greater in small towns than in cities, where a much smaller proportion of the population lives adjacent to open areas where there are negligible pollutant emissions.

The sea salt component of PM_{10} is unlikely to have the same adverse health effects as combustion particulates, which are likely to be the predominant contributors to the PM_{10} concentrations measured in the epidemiological studies on which the health risk calculations are based.

7. DISCUSSION IN RELATION TO REGIONAL AIR QUALITY PLAN.

The Plan notes that high concentrations of smoke particulates and sulphur dioxide may be a contributing factor in the Region's high incidence of hospitalisation due to respiratory disease and states that research needs to be done on the possible health effects of air pollution in the Region. The monitoring covered by the present report is part of the assessment of possible effects of air pollution, and Section 6 presents a health risk assessment based on the data obtained. This is in accordance with the *Objective 8.3.1 - The protection of human health and the environment from the adverse effects of discharges of products of combustion.*

The Regional Air Quality Plan adopts the 1994 MfE Ambient Air Guidelines, which include a guideline of 120 µg/m^3 for the 24-hour average concentration of PM_{10}. The Ambient Air Quality Guidelines issued in May 2002 replace this guideline with a guideline of 50 µg/m^3. The Regional Council is now working to the more recent Guideline.

The predominant source of PM_{10} emissions producing the relatively high ambient air concentrations is almost certainly domestic heating emissions. The Plan explicitly provides no rules for controlling discharges from inside domestic fires or outside domestic fires. In accordance with a directive from the Ministry of Health, outside domestic fires should be controlled by territorial authorities under the Health Act 1956, relying particularly on Sections 29-35 of the Act, relating to nuisances.

Inside domestic fires are the predominant contributors to high 24-hour average PM_{10} concentrations over the winter period. The following Policy 8.4.3 is particularly relevant to this situation.

> **8.4.3 To promote, or where appropriate and practicable, require measures to avoid, remedy or mitigate the adverse effects of discharges to air from outside domestic fires and inside domestic fires.**
>
> **Explanation**
> *This policy recognises that because of the number of individual sources of discharge and their low individual effect, region-wide control of all sources through regulation is not appropriate, and other non-regulatory means are more appropriate in achieving the objective. However the policy also provides for the consideration of other methods that require adverse effects to be avoided, remedied or mitigated, if significant sources of contamination or cumulative effects arise. The gathering of monitoring information will be an important part of any such action.*

The Council will implement this policy particularly through the following Methods:

8.5.2
The Council will promote the use and correct operation of cleaner burning solid fuel heaters in place of less efficient forms of heating. Appropriate types of fuel for domestic heating purposes will also be promoted.

8.5.3
In conjunction with Crown Public Health and other agencies, the Council may carry out research to determine whether there is any link between lung disease and the incidence of winter urban air pollution.

The Plan notes that when further monitoring is undertaken, other measures in addition to promotion and education may be adopted where necessary. The Council considers that, in many cases, reduction in discharges to air from products of combustion can be promoted by the use of non-regulatory methods. These include information dissemination about good management practices and alternatives to burning, and promotion of appropriate Codes of Practice. It is expected that there will be a slow gradual incremental improvement in ambient air quality as replacement solid fuel burners are replaced with new burners that have substantially lower emissions. This is likely to occur without regulation.

Publication of this report is part of the promotion and education process, by making information available about present air quality conditions and the adverse effects, assessed in terms of increased mortality. It is anticipated that this will contribute to the following anticipated environmental results:

8.6.2
Increased promotion amongst the community of methods for preventing or minimising cumulative adverse effects arising from discharges from domestic fires and home heating appliances.

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APPENDIX 1. QUALITY ASSURANCE

8.1 PM_{10}

Quality assurance data are provided in the reports from K2 Environmental in Appendix 2.

8.2 SULPHUR DIOXIDE.

A sulphur dioxide fluorescent analyser (API 100A), the use of a calibrator (API 700) to generate known concentrations of gas, and cylinders of zero grade air and sulphur dioxide gas, were provided to the West Coast Regional Council by Environment Canterbury for this work. All previous maintenance and operating procedures for the sulphur dioxide analyser had been conducted by Environment Canterbury, and were therefore outside the control or knowledge of AES.

A three-point calibration was performed on the analyser at the time of installation at the monitoring site, and the instrument span and zero set accordingly. For the duration of the program, the analyser was calibrated at approximately one-month intervals by Environment Canterbury staff, and prior to the analyser being removed upon completion of the programme.

Checks on the operation of the analyser were carried out using telephone link to the analyser by AES, usually on a daily basis. Data was transferred on a daily basis using the telephone link, and the data checked.

In addition to the normal quality assurance measures applied to the instrumental sulphur dioxide monitoring, the monitoring programme included assessment of the reproducibility of the sulphur dioxide measurements using passive samplers, and assessment of the accuracy of the results by comparison of the instrumental period average concentrations for the passive sampling periods with the passive sampling results. The quality assurance data obtained is set out in Table 17.

Five replicate passive samples were collected in Greymouth in June 2001. These showed very good reproducibility, with the relative standard deviation being 7%. The several sets of duplicate passive sampling results in Table 17 indicate that, while reproducibility remained good for each of the monitoring periods, it was not consistently as good as indicated by the June 2001 relative standard deviation, with the relative deviation between the two measurements in each duplicate set being in the range 0-25%. A maximum relative deviation 25% is acceptable, particularly noting the relatively low concentrations found, even at the sites showing the highest concentrations.

The replicates and duplicate sampling was carried out at the same location as the instrumental monitoring in 2001 and 2003. This allowed direct comparison of the passive sampling results with the average concentrations from the instrumental monitoring over the same periods as the passive samplers were exposed. The difference between the concentration from the instrumental monitoring and from the passive samplers was in the range 1.1-4.5 $\mu g/m^3$, with the instrumental concentrations being higher than the passive sampling results. This

difference in concentrations is at about the best level of accuracy that can be expected for instrumental monitoring. In other words if two instrumental monitors were operating at the same location, consistent agreement within 1-5 µg/m^3 sulphur dioxide would be regarded as excellent performance.

Table 17. Quality assurance results for sulphur dioxide

	Sulphur dioxide µg/m3				
	Greymouth		Westport	Reefton	
	2001 Instrument	2001 Passive	2002 Passive	2003 Instrument	2003 Passive
June	4.5	3.6	19.0	24.2	24.8
		3.7	18.7		19.2
		4.0			
		3.4			
		4.0			
Relative standard deviation		7%			
Relative difference			2%		25%
Instrument - passive		-0.7			-2.2
July	5.8	4.6	30.6	33.5	29.3
		3.9	29.0		29.3
Relative difference		17%	5%		0%
Instrument - passive		-1.5			-4.2
August	4.4	3.1		22.2	18.6
		3.1			18.0
Relative difference		0%			3%
Instrument - passive		-1.3			-1.3

Furthermore, the instrumental and passive sampling methods for sulphur dioxide are based on entirely different chemical and physical principles and therefore provide entirely independent measures of the concentrations. Agreement between results using independent analytical methods is one of the best methods of demonstrating the accuracy of the measurements from both methods. Accordingly, the agreement between the instrumental and passive sampling results gives an excellent assurance of the accuracy of the data.

8.3 BENZENE, TOLUENE, ETHYL BENZENE, AND XYLENES

Quality assurance for the BTEX passive samplers took the form of an "additivity" trial in which 3 samplers were exposed over consecutive 1 month periods, and a 4th was exposed continuously over the full 3 month period covered by the individual month samplers. The concentration from the sampler exposed continuously over the three-month period should be the same as the average of the one-month average concentrations from the other three samplers.

This additivity check is a more stringent quality assurance check than duplicate sampling, because good agreement between single three-month sampler results, and the average of the three 1 month sampler results, cannot be obtained unless there is good reproducibility. The additivity check also covers possible variability arising from different handling of the samplers at different times, and variability in the accuracy of the laboratory analyses at different times. A satisfactory result in this check also indicates the reliability of the passive samplers for the three-month sampling period.

The results from the quality assurance trials are set out in Table 18.

Table 18. Quality assurance results for benzene toluene and xylenes

	Benzene	Toluene	m+p Xylenes
	µg/m3		
Westport 2002			
June	2.4		2.3
July	2.4		2.5
August	2.2		2.4
Average of monthly samples	2.3		2.4
June-August sample	2.2		2.3
Reefton 2003			
June	2.5	3.5	1.9
July	2.9	4.3	2.0
August	2.2	3.6	1.7
Average of monthly samples	2.5	3.8	1.9
June-August sample	2.4	3.3	1.8

The additivity checks for benzene agree within 5-6%, indicating excellent reliability of the passive sampling technique. The additivity checks for m+p xylenes are in the range 2.5-4.5%, and the single check for toluene gives a 12.6% difference between the concentration from the sampler exposed continuously over the three-month period and the average of the one-month average concentrations from the other three samplers

The passive samplers for the 2002 additivity checks showed unusually high toluene concentrations and had evidently been exposed to toluene at some time between sample collection and analysis. However, the very satisfactory additivity check for benzene and xylenes shows that these compounds were not affected by the contamination.

The 2001 passive sampling for benzene used a different type of passive sampler. There were various difficulties in operation of the additivity trial, including sampler changes that were not as specified. However, examination of the results cast doubt on the reliability of the samplers themselves, and we are not prepared to place any reliance on the results, other than as approximate indications of the lowest likely benzene concentrations. These unsatisfactory results led to reverting to the 3M Organic Vapour Monitors, that had previously performed very well, and this performance was again confirmed by the quality assurance checks presented here.

APPENDIX 2. K2 ENVIRONMENTAL REPORTS FOR PM_{10}

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Air and Environmental Sciences Ltd.

Ambient PM10 for West Coast Regional Council

May-Aug 2001

Stuart Keer-Keer

Issue 3: February, 04

1. INTRODUCTION

Ambient Particulate (PM10) samples have been gathered by the West Coast Regional Council. Samples were delivered to K2 Environmental Ltd and the particulate concentration was determined as per K2 Environmental Ltd TM 4.3 weighing of PM10 filters.

Nine filters were sent on 5 September 2001. With this batch of samples 2 lab blanks were analysed. One of the nine filters was a field blank. The sample forms contained all the required information.

2. SAMPLING RESULTS

2.1 Particulate (PM10) Results

Dates		Weight			Gas Meter			Flow Rate	Conc
Start	End	Initial	Final	Diff	Start	End	Diff	m^3/min	µg/m^3
30-May		4.4525	4.4635	0.0110	1873	3745	1872		6
2-Jun		4.4247	4.5109	0.0862	3719	5592	1873	1.3007	46
6-Jun	7-Jun	4.4441	4.4807	0.0366	5592	7465	1872		20
9-Jun	10-Jun	4.4570	4.4946	0.0376	7465	9337	1872	1.3000	20
12-Jun	14-Jun	4.4110	4.4696	0.0586	9337	11209	1872	1.3000	31
16-Jun		4.4285	4.4521	0.0236	11209	13081	1872		13
20-Jun		4.4405	4.4973	0.0568	13081	14953	1872		30
24-Jun		4.4198	4.4635	0.0437	14953	16825	1872		23
30-Jun	2-Jul	4.4486	4.4776	0.0290	16825	18695	3745		16
5-Jul	6-Jul	4.4342	4.4766	0.0424	18699	20572	1873	1.3007	23
8-Jul	9-Jul	4.4756	4.5116	0.0360	20572	22440	1868	1.2972	19
10-Jul	11-Jul	4.5061	4.5494	0.0433	22446	24321	1875	1.3021	23
12-Jul	13-Jul	4.5039	4.5346	0.0307	24321	26194	1873	1.3007	16
16-Jul	17-Jul	4.4701	4.4791	0.0090	26194	28068	1874	1.3014	5
19-Jul	20-Jul	4.5301	4.6052	0.0751	28068	29942	1874	1.3014	40
22-Jul	23-Jul	4.4981	4.5099	0.0118	29942	31816	1874	1.3014	6
25-Jul	26-Jul	4.4738	4.5252	0.0514	31816	33690	1874	1.3014	27
28-Jul	29-Jul	4.4440	4.4705	0.0265	33690	35563	1873	1.3007	14
31-Jul	1-Aug	4.4793	4.524	0.0447	35563	37436	1873	1.3007	24

Dates		Gas Meter			Gas Meter			Flow Rate	Conc
Start	End	Initial	Final	Diff	Start	End	Diff	m^3/min	µg/m^3
3-Aug	4-Aug	4.5046	4.5568	0.0522	37436	39309	1873	1.3007	28
6-Aug	6-Aug	4.4967	4.5112	0.0145	39309	41183	1874	1.3014	8
11-Aug	12-Aug	4.4554	4.4924	0.0370	41226	43092	1866	1.2958	20
13-Aug	14-Aug	4.4631	4.5026	0.0395	43092	44959	1867	1.2965	21
16-Aug	18-Aug	4.468	4.5034	0.0354	44959	46827	1868	1.2972	19
17-Aug	18-Aug	4.5125	4.5123	-0.0002	Field Blank				
19-Aug	20-Aug	4.4829	4.5124	0.0295	46827	48694	1867	1.2965	16
21-Aug	22-Aug	4.4897	4.5329	0.0432	48694	50561	1867	1.2965	23
25-Aug	26-Aug	4.5145	4.5549	0.0404	50561	52428	1867	1.2965	22
28-Aug	29-Aug	4.5151	4.5494	0.0343	52428	54295	1867	1.2965	18
31-Aug	01-Sep	4.5346	4.5548	0.0202	54295	56161	1866	1.2958	11

All particulate samples reported were for a twenty four hour period.

2.2 Control Sample Results

Date	7171881	7171867
	4.4568	4.5152
18 July 2001	4.4590	4.5151
25 July 2001	4.4560	4.5124
16 –August 2001	4.4563	4.5118
13-Sept-2001	4.4575	4.5125

2.3 Number of Samples

In this project for this year 30 samples were analysed (including one field blank). Ten lab blanks were analysed

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Air and Environmental Sciences Ltd.

Ambient PM10 for West Coast Regional Council

May - September 2002

Stuart Keer-Keer

Issue 2: February, 04

1. INTRODUCTION

Ambient Particulate (PM10) samples have been gathered by the West Coast Regional Council. Samples were delivered to K2 Environmental Ltd and the particulate concentration was determined as per K2 Environmental Ltd TM 4.3 weighing of PM10 filters. The balance used has been calibrated by an IANZ accredited supplier.

For the period of 21 June- 25 July 2002, the start and finish gas meter readings were not gathered so a standard volume of 1814 m^3 was used. The assumptions made in using this figure are

- the samplers are running at the same rate throughout.
- for each day the sample was run for 24 hours.
- The sample rate for the sampler was 1.26 standard cubed meters minute (scmm)

The 1.26 was derived from information supplied by the West Coast Regional council from calibrations they have made. This information is appended.

1.1. Changes from Previous Report

The volumes used in the previous report were based on the time sampled as reported. These times varied significantly. We have subsequently been informed that all sample times were for 24 hours. The sample volumes have been adjusted accordingly. This affects the final reported results.

2. SAMPLING RESULTS

2.1 Particulate (PM10) Results

Sample Date	Weight			Volume Sampled [a]			Concentration	
	Initial	Final	Gain	Start	End	Total		
	Grams			m^3			$\mu g/m^3$	$\mu g/m^3$ ° C
31-May-02	4.488	4.5638	0.0758			1868	41	42
03-Jun-02	4.4787	4.5491	0.0704			1868	38	39
06-Jun-02	4.4812	4.5820	0.1008			1868	54	56
09-Jun-02	4.4829	4.5742	0.0913			1868	49	51
12-Jun-02	4.4835	4.5771	0.0936			1868	50	52
15-Jun-02	4.4713	5.9690	1.4977			1868	b	b
18-Jun-02	4.4583	4.6500	0.1917			1868	b	b
21-Jun-02	4.4774	4.5109	0.0335			1814	18	19
24-Jun-02	4.3814	4.4369	0.0555			1814	31	32
27-Jun-02	4.3887	4.4246	0.0359			1814	20	21
30-Jun-02	4.4131	4.4550	0.0419			1814	23	24
03-Jul-02	4.4018	4.454	0.0522			1814	29	30
06-Jul-02	4.4967	4.561	0.0643			1814	35	37
09-Jul-02	4.4928	4.5743	0.0815			1814	45	46
11-Jul-02	4.4882	4.5129	0.0247			1814	14	14
14-Jul-02	4.495	4.5457	0.0507			1814	28	29
16-Jul-02	4.4407	4.5047	0.0640			1814	35	36
19-Jul-02	4.5063	4.5772	0.0709			1814	39	41
22-Jul-02	4.4477	4.4738	0.0261		96570	1814	14	14
25-Jul-02	4.4474	4.4706	0.0232	96570	98438	1868	12	12
28-Jul-02	4.4614	4.4985	0.0371	98438	100302	1864	20	20
31-Jul-02	4.4386	4.4962	0.0576	100302	102171	1869	31	32
04-Aug-02	4.4548	4.4698	0.0150	102171	104035	1864	8	8
07-Aug-02	4.449	4.4766	0.0276	104035	105901	1866	15	15
09-Aug-02	4.4387	4.5154	0.0767	105901	107765	1864	41	43
12-Aug-02	4.4718	4.4956	0.0238	107765	109628	1863	13	13
15-Aug-02	4.3792	4.4024	0.0232	109628	111442	1814	13	13
18-Aug-02	4.3934	4.4322	0.0388	111442	113354	1912	20	21
22-Aug-02	4.4414	4.4637	0.0223	113354	115216	1862	12	12
25-Aug-02	4.5837	4.6182	0.0345	115216	117080	1864	19	19
27-Aug-02	4.3413	4.3772	0.0359	117080	118945	1865	19	20
31-Aug-02	4.4349	4.4503	0.0154	118945	120810	1865	8	9
03-Sep-02	4.4442	4.4979	0.0537	120810	122674	1864	29	30

a Where the gas meter readings were not available the volume has been calculated on the basis of 24 hour sample time and a flow rate of 1.26 (SCMM)

b Two samples were lost in the analysis process. K2 Environmental has moved locations and in the transit the filters were damaged. These results have not been reported, they relate to 15 and 18 of June 2002.

Two samples were lost in the analysis process. K2 Environmental has moved locations and in the transit the filters were damaged. These results have not been reported, they relate to 15 and 18 of June 2002.

2.2 Control Sample Results

Date	7230016	7230017	717863
10 May			
17 July			
22 July			4.5100
25 July			4.5096
29 July			4.5132
2 Aug			4.5127
13 Aug			4.5123
14 Aug	4.4700		4.5127
15 Aug	4.4696	4.4376	4.512
19 Aug	4.4696	4.437	4.5106
23 Aug	4.4706	4.4352	4.5112
13 Sept	4.469	4.4346	4.5075
16 Sept	4.4695	4.4362	4.5071
18 Sept	4.4692	4.436	4.5065

Control filters are weighed at the same time as the sample filters.

Calibrations at Westport (Funeral Directors site) – 2002 Winter
(Units in SCMM)

DATE	PM10 SAMPLER (DIGITAL READINGS	CALIBRATION EQUIPMENT (ANALOGUE READINGS)
15/05	1.235 –1.285*	1.27-1.35*
29/06	1.25-1.26	1.35-1.36
31/7	1.25-1.27	1.255-1.256
5/9	1.26	1.26

* Large variation could be caused by poor sealing of the calibrator on the unit.

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Air and Environmental Sciences Ltd.

Ambient PM10 for West Coast Regional Council

May - September 2003

Stuart Keer-Keer

Issue 2: October, 03

1. INTRODUCTION

Ambient Particulate (PM10) samples have been gathered by the West Coast Regional Council. Samples were delivered to K2 Environmental Ltd and the particulate concentration was determined as per K2 Environmental Ltd TM 4.3 weighing of PM10 filters. The balance used has been calibrated by an IANZ accredited supplier.

A maximum and minimum temperature has been supplied. The average of the minimum and maximum has been used in the calculations. All filters have been weighed three times and the average of these three weights was used in the calculations.

2. SAMPLING RESULTS

2.1 Particulate (PM10) Results

Sample Date	Weight			Volume Sampled			Concentration	
	Initial	Final	Gain	Start	End	Total		
	Grams			m^3			$\mu g/m^3$	$\mu g/m^3$ ° C
***23-May-03**	4.4668	4.5178	0.0509	128284	128308	24	2122	2204
26-May-03	4.5123	4.5736	0.0612	128308	130166	1858	33	34
29-May-03	4.4878	4.5570	0.0692	130166	132026	1860	37	38
01-Jun-03	4.5770	4.6652	0.0881	132026	133886	1860	47	49
04-Jun-03	4.4678	4.5334	0.0657	133886	135745	1859	35	37
07-Jun-03	4.4516	4.5201	0.0685	135745	137605	1860	37	38
10-Jun-03	4.5020	4.5447	0.0428	137605	139465	1860	23	23
13-Jun-03	4.4950	4.5886	0.0935	139465	141323	1858	50	51
16-Jun-03	4.4684	4.5189	0.0505	141323	143183	1860	27	28
18-Jun-03	4.4775	4.5717	0.0942	143183	145037	1854	51	52
22-Jun-03	4.3762	4.4399	0.0638	145037	146892	1855	34	36
25-Jun-03	4.3880	4.4380	0.0500	146892	148748	1856	27	27
28-Jun-03	4.4034	4.4604	0.0570	148748	150605	1857	31	31
****01-Jul-03**	4.3867	4.4058	0.0190	150605	151054	449	42	
10-Jul-03	4.4845	4.5212	0.0367	151054	152910	1856	20	20
13-Jul-03	4.4453	4.5251	0.0798	152910	154621	1711	47	48
16-Jul-03	4.4427	4.4701	0.0274	154621	156289	1668	16	17
19-Jul-03	4.4729	4.5324	0.0595	156289	157957	1668	36	36
22-Jul-03	4.4713	4.5622	0.0909	157957	159628	1671	54	55
25-Jul-03	4.4798	4.5514	0.0716	159628	161299	1671	43	43
28-Jul-03	4.3732	4.3973	0.0241	161299	162966	1667	14	15
31-Jul-03	4.4774	4.5651	0.0877	162966	164639	1673	52	54
03-Aug-03	4.3593	4.3975	0.0382	164639	166315	1676	23	23
06-Aug-03	4.4651	4.5074	0.0423	166315	167987	1672	25	26
09-Aug-03	4.4595	4.5006	0.0411	167987	169657	1670	25	25
12-Aug-03	4.4808	4.5288	0.0480	169657	171327	1670	29	29
15-Aug-03	4.4967	4.5195	0.0228	171327	172993	1666	14	14
18-Aug-03	4.3683	4.3910	0.0227	172993	174660	1667	14	14
21-Aug-03	4.4755	4.5230	0.0475	174660	176327	1667	28	29
24-Aug-03	4.4525	4.4897	0.0373	176327	177997	1670	22	23
27-Aug-03	4.4591	4.4819	0.0228	177997	179663	1666	14	14
30-Aug-03	4.4576	4.4747	0.0171	179663	181331	1668	10	11
02-Sept-03	4.4818	4.5051	0.0233	181331	183004	1673	14	14
05-Sept-03	4.4729	4.4874	0.0145	183004	184672	1668	9	9
08- Sept-03	4.5015	4.5228	0.0213	184672	186340	1668	13	13
11-Sept-03	4.3909	4.4060	0.0151	186340	188005	1665	9	9
14-Sept-03	4.4972	4.5135	0.0163	188005	189671	1666	10	10

* 23-May-03 start meter reading seems to be high

** 01-Jul-03 motor broke down only run for 6 hours – no temperature readings taken

N.B. Flow rate was turned down to 1.134 SCMM at 4pm on the 11 July 2003 and the calibration was within range (as per email from Trevor James)

2.2 Control Sample Results

Date	7230068	7230016	7230017	717863
10 June 03	4.5148	4.4668		4.5060
11 June 03	4.5119	4.4667	4.4362	4.5062
12 June 03	4.5154	4.4667	4.4362	4.5053
2 July 03	4.5107	4.4651	4.4346	4.5025
3 July 03	4.5127	4.4653	4.434	4.5131
4 July 03	4.5113	4.4654	4.434	4.5025
1 Aug 03	4.5187	4.4660	4.4364	4.5152
4 Aug 03	4.5124	4.4648	4.4361	4.5139
6 Aug 03	4.5140	4.4673	4.4384	4.5145
8 Aug 03	4.5133	4.4677	4.4368	4.5141
11 Aug 03	4.5128	4.4662	4.4358	4.5133
12 Aug 03	4.5127	4.4666	4.4363	4.5121
18 Aug 03	4.5094	4.4644	4.4330	4.5117
20 Aug 03	4.5039	4.4634	4.4332	4.5106
21 Aug 03	4.5075	4.4631	4.4331	4.5109
27 Aug 03	4.5097	4.4641	4.4323	4.5123
28 Aug 03	4.5102	4.4638	4.4332	4.5119
29 Aug 03	4.5030	4.4624	4.4321	4.5094
18 Sept 03	4.5031	4.4607	4.4317	4.5071
19 Sept 03	4.4987	4.4591	4.4295	4.5053
2 Oct 03	4.5005	4.4591	4.4295	4.5078
6 Oct 03	4.4947	4.4581	4.4286	4.5058
9 Oct 03	4.4954	4.4580	4.4289	4.5052

Control filters are weighed at the same time as the sample filters

2.3 Travel Blank Results

Date	Filter ID	Initial Weight	Final Weight
18-Jul-03	7230014	4.4641	4.4610
21- Jul- 03	7363692	4.3488	4.3509
18-Sept-03	7363695	4.3596	4.3642
2-Oct-03	7363694	4.3456	4.3421

APPENDIX 3. MONITORING AND METEOROLOGICAL DATA FOR GREYMOUTH FOR 2001

Figure 18. Monitoring and meteorological data for Greymouth for 2001

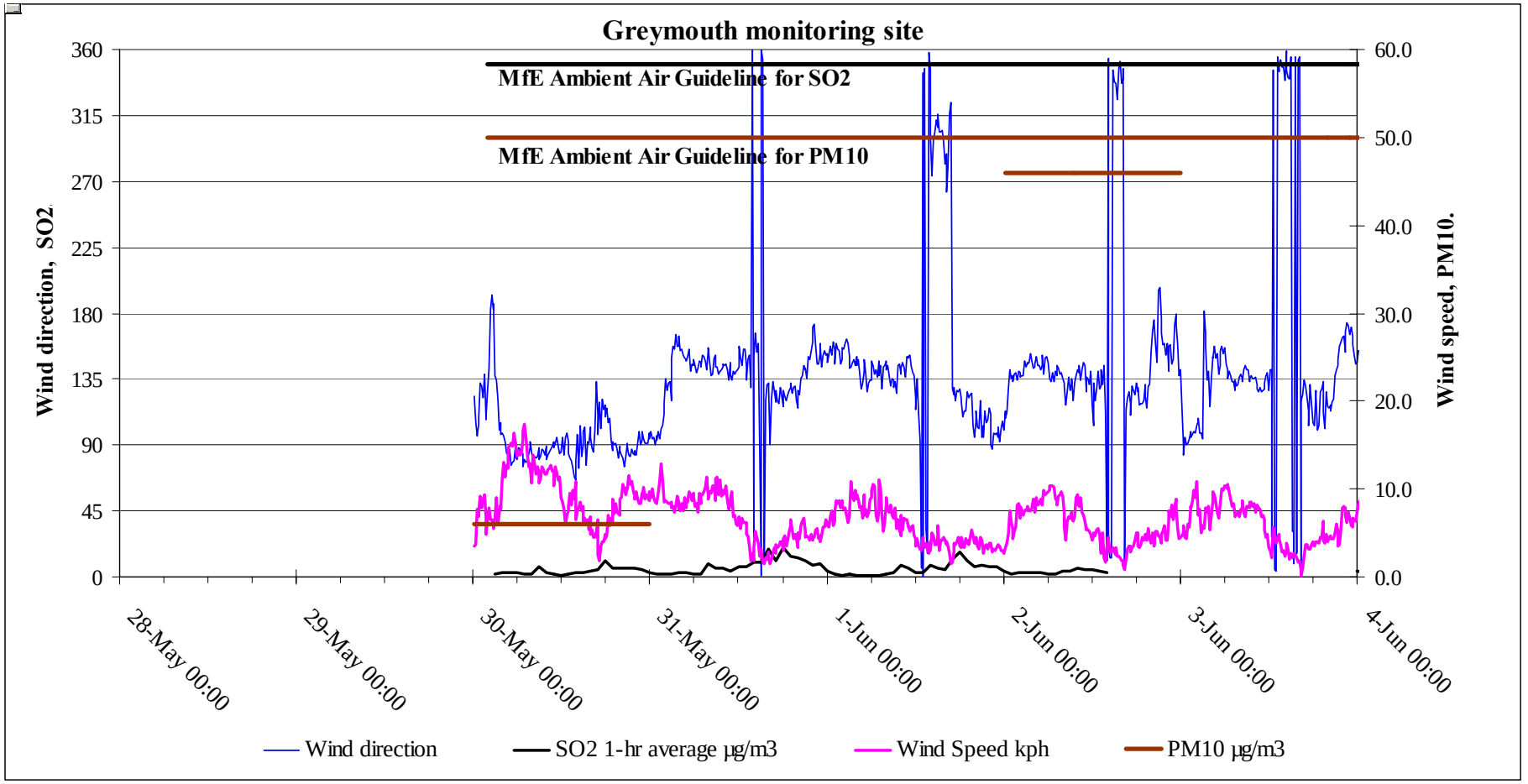


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

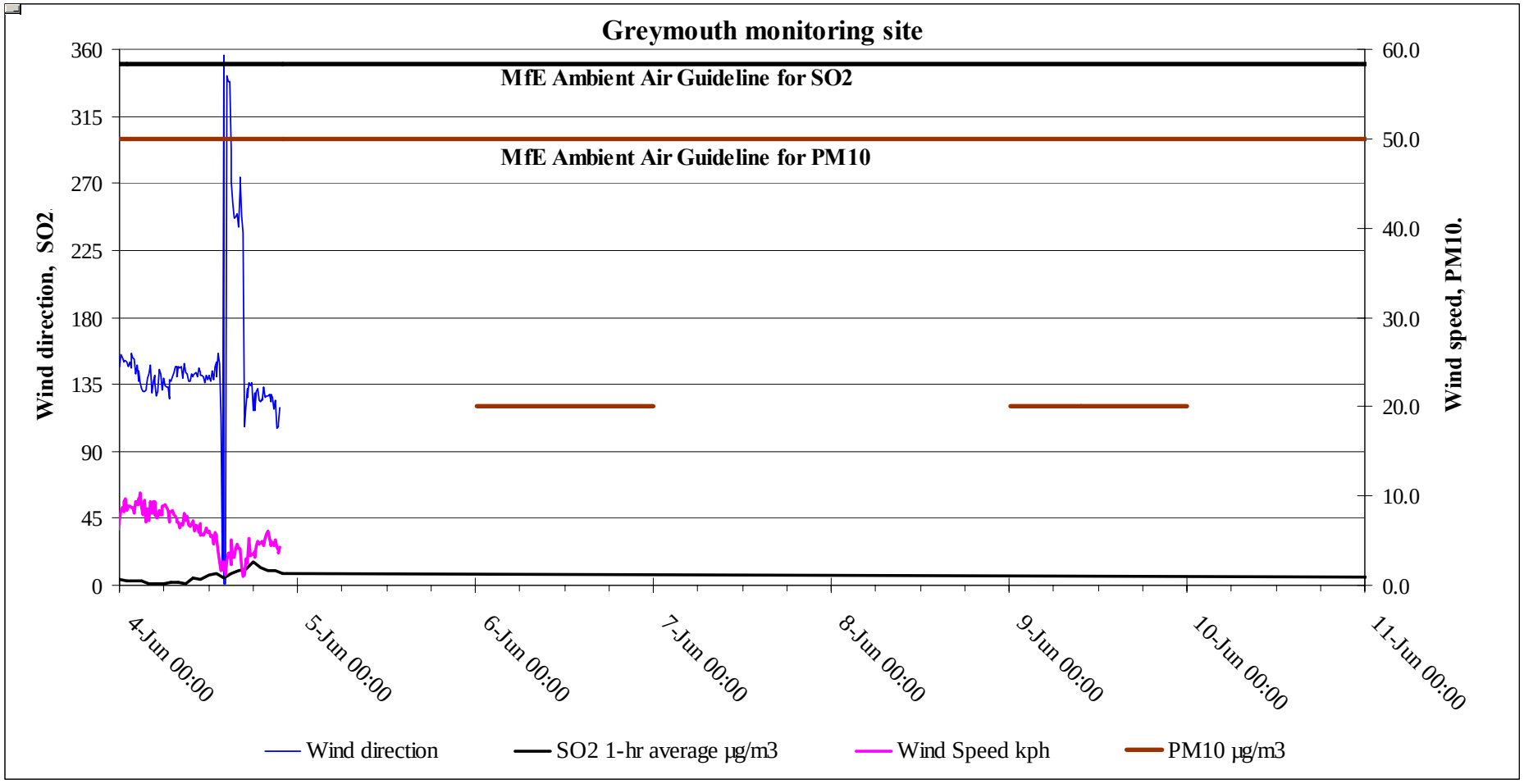


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

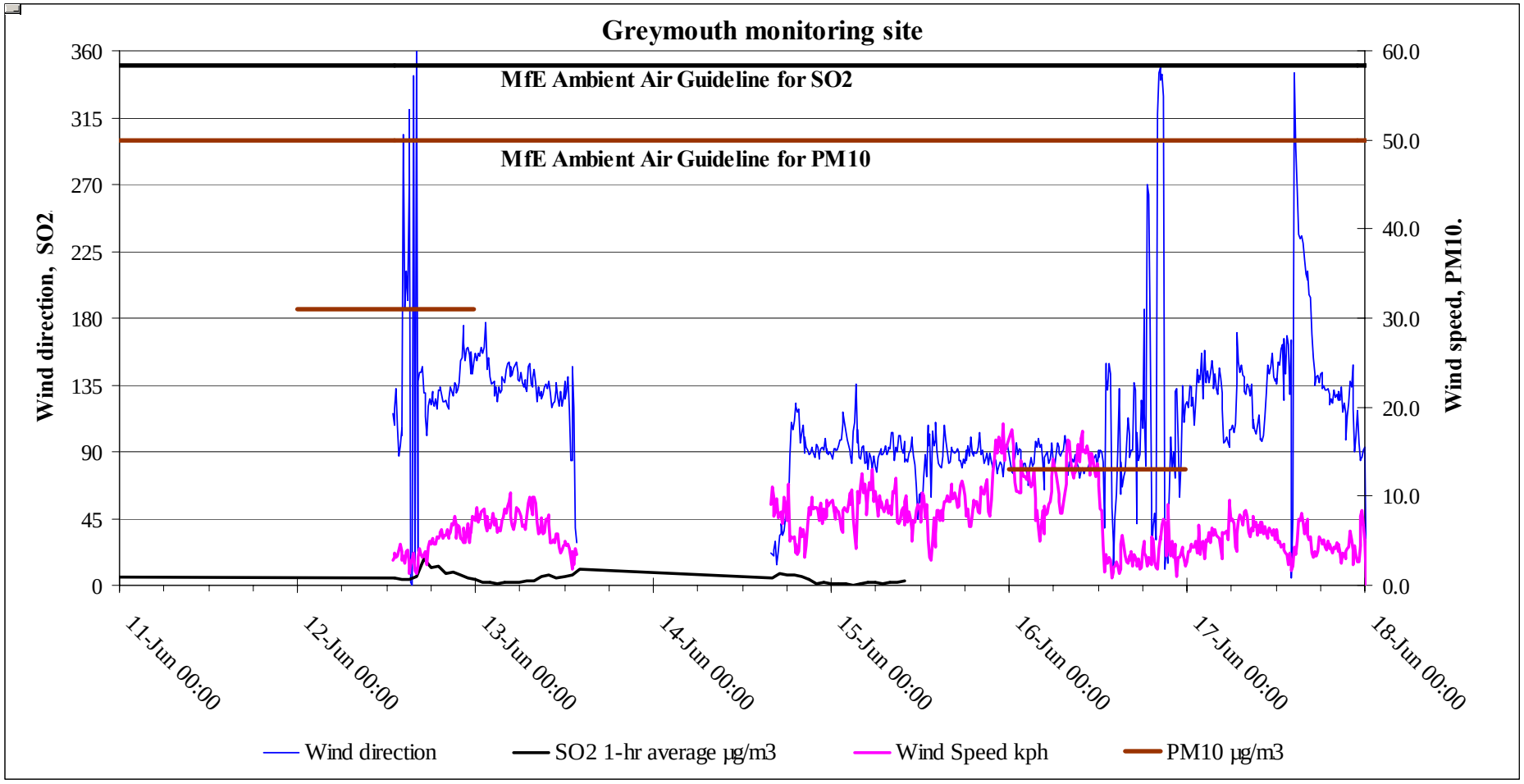


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

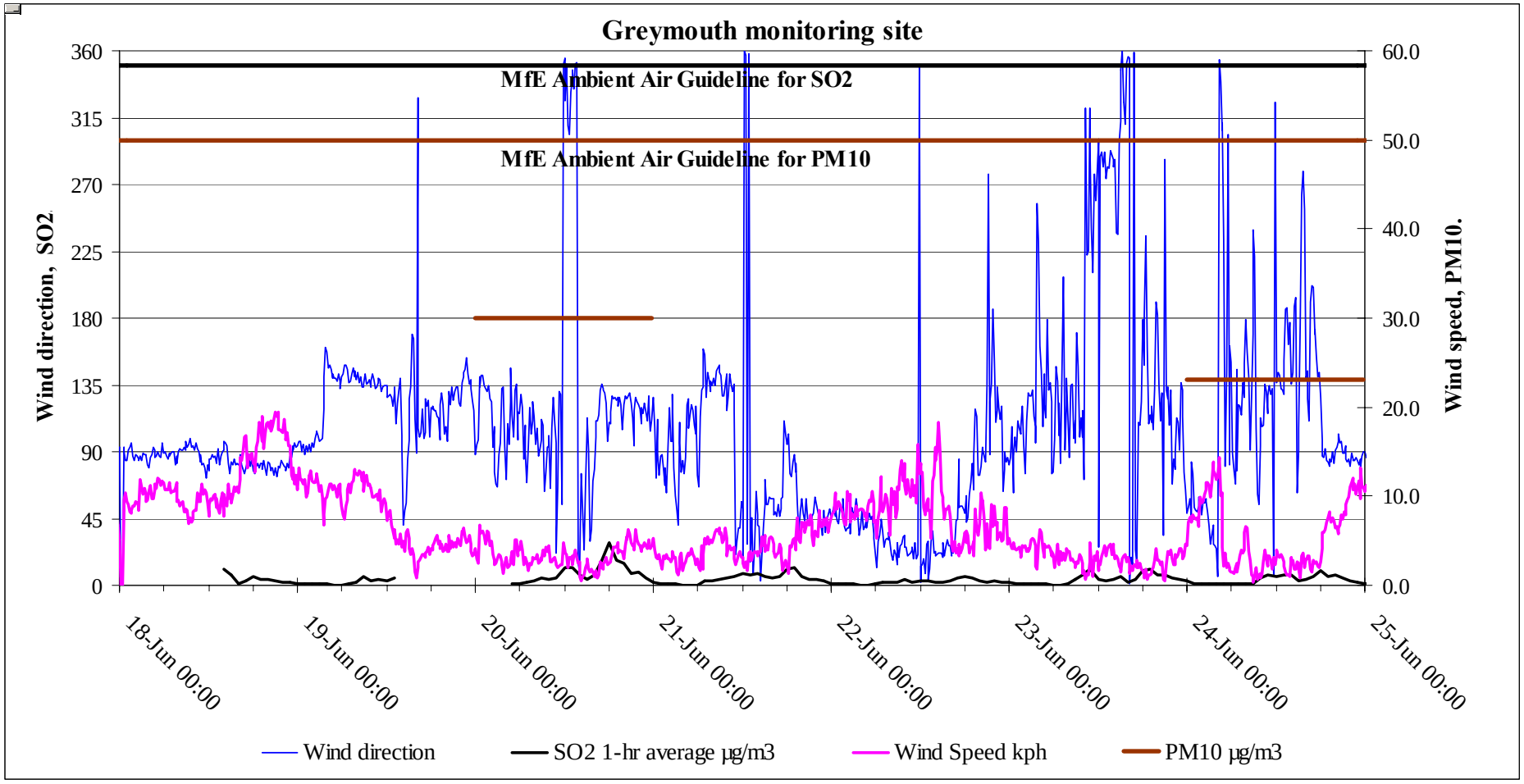


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

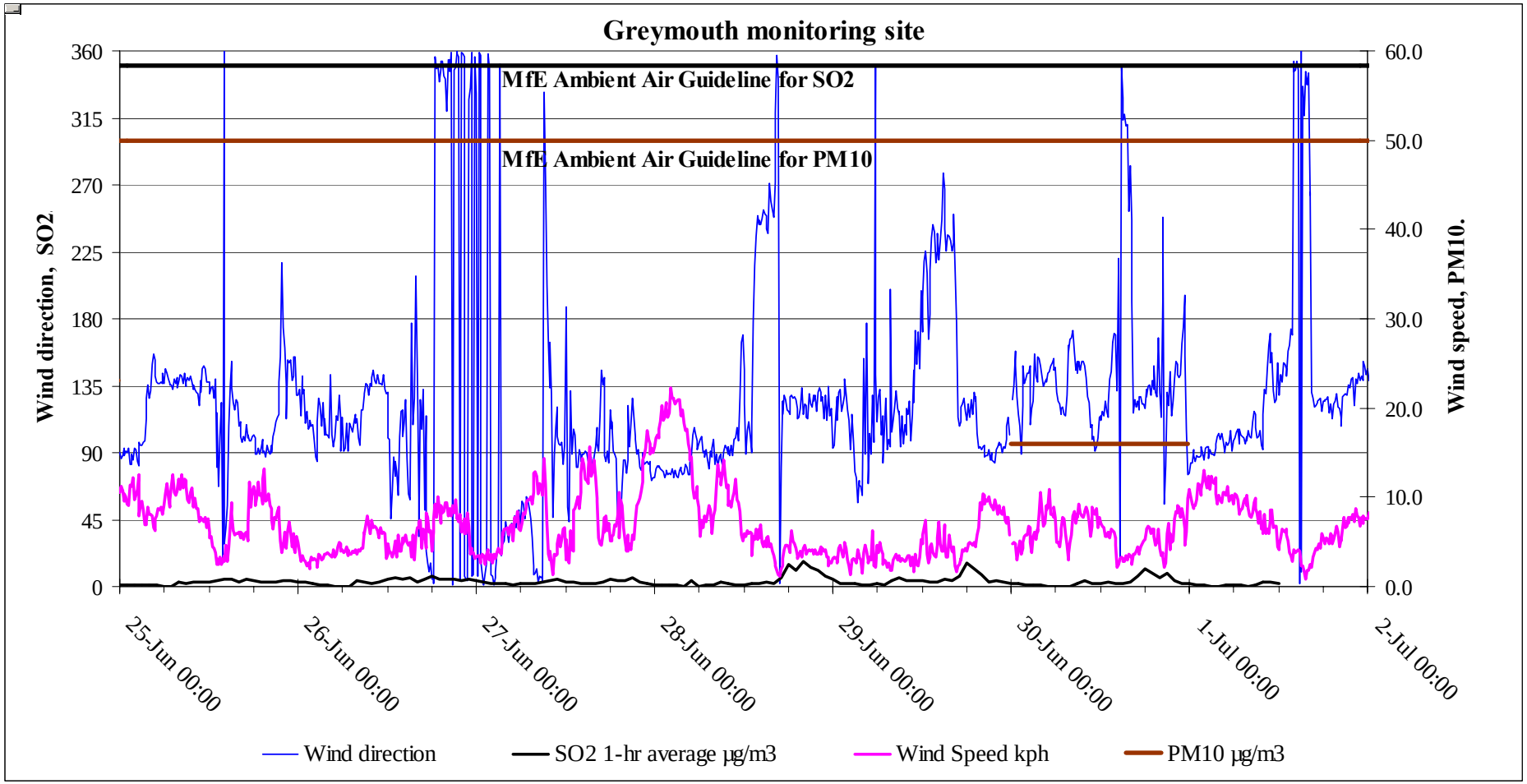


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

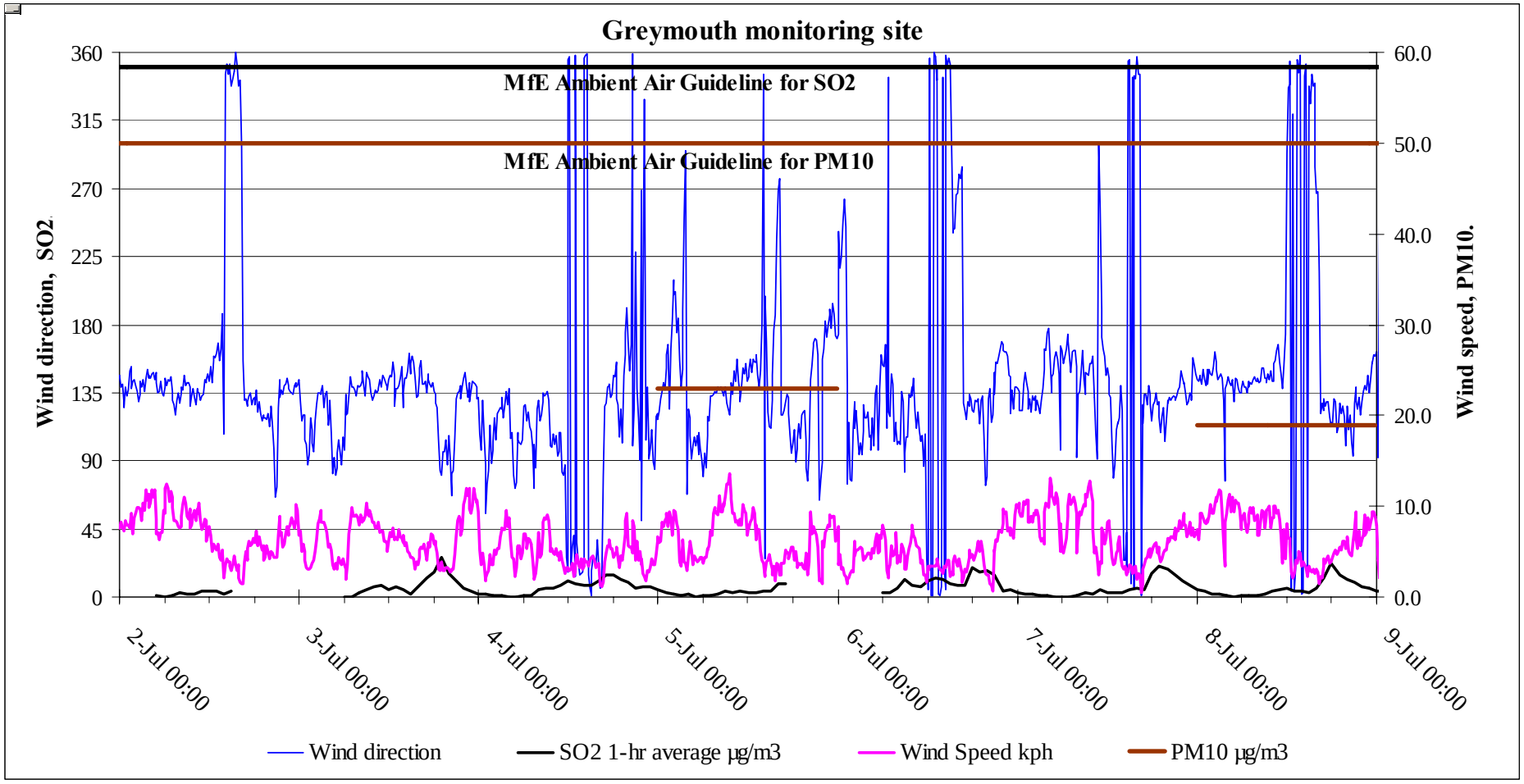


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

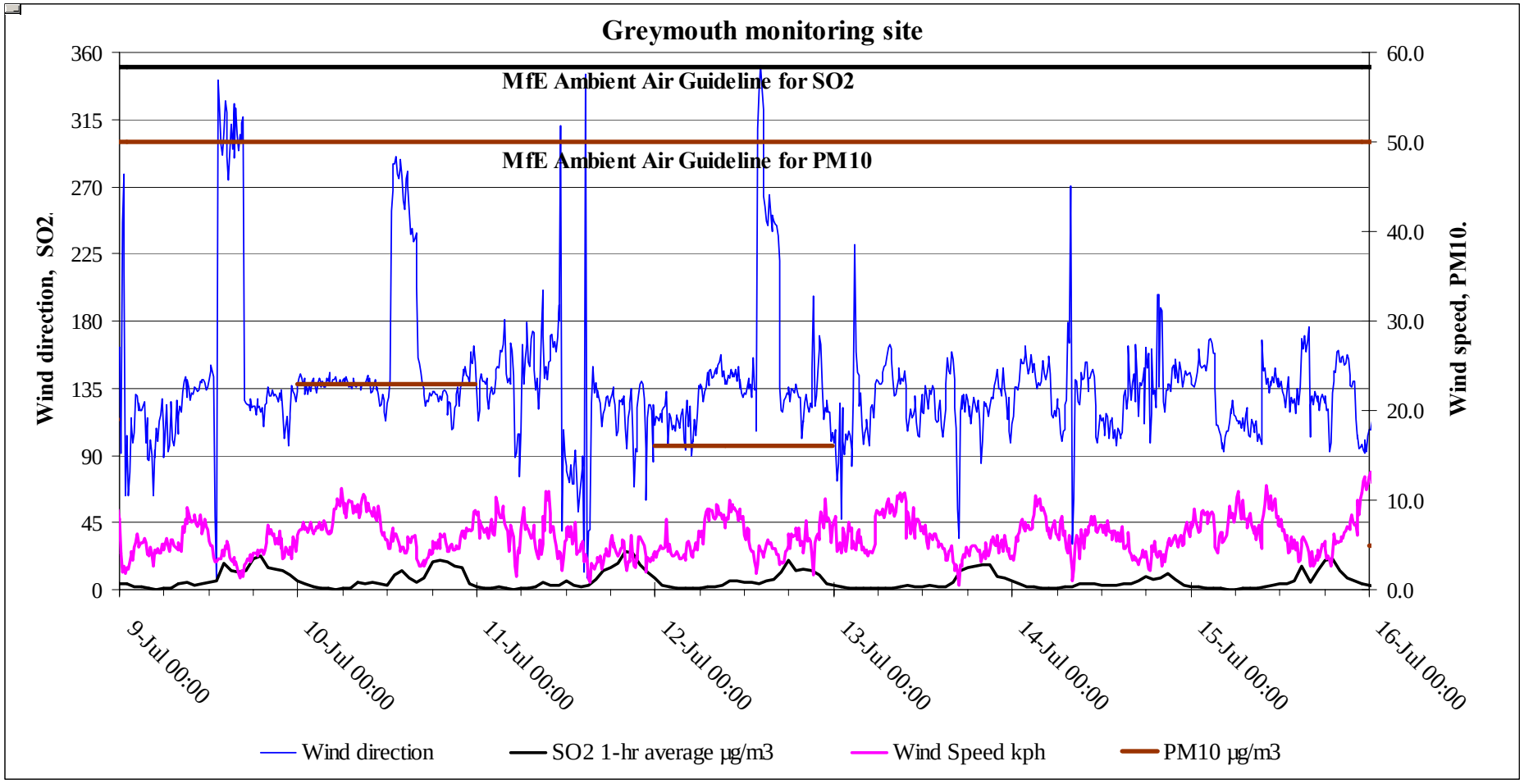


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

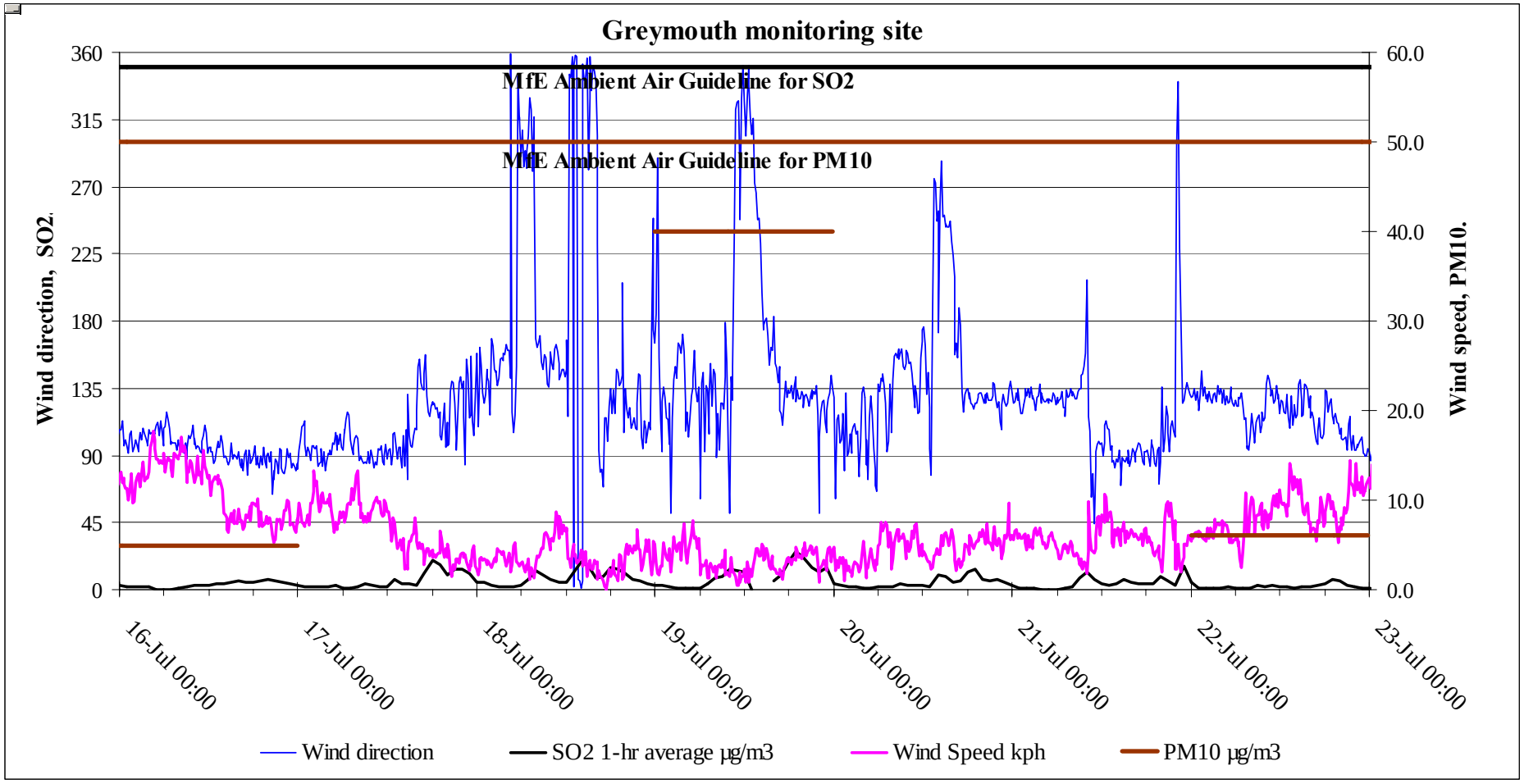


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

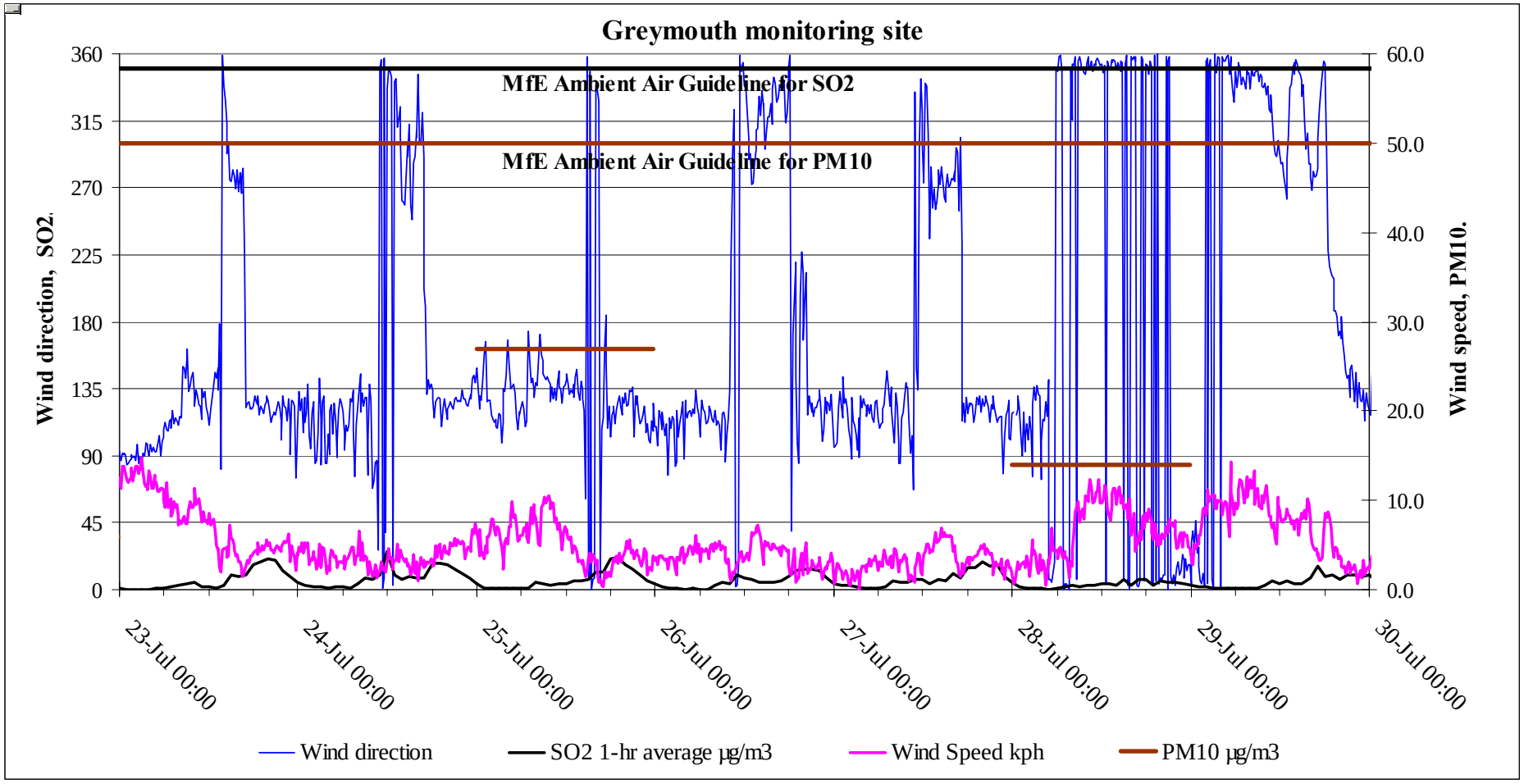


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

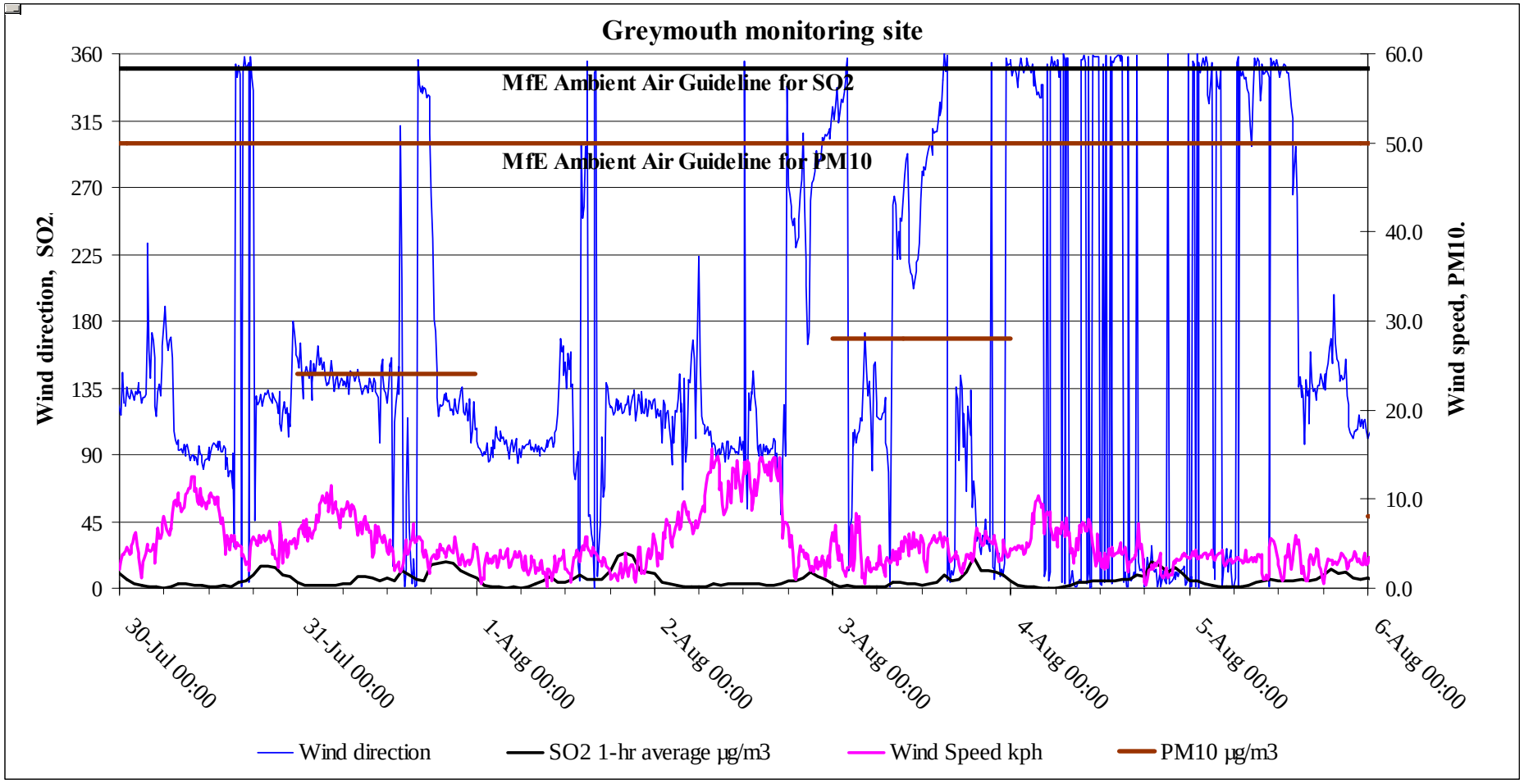


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

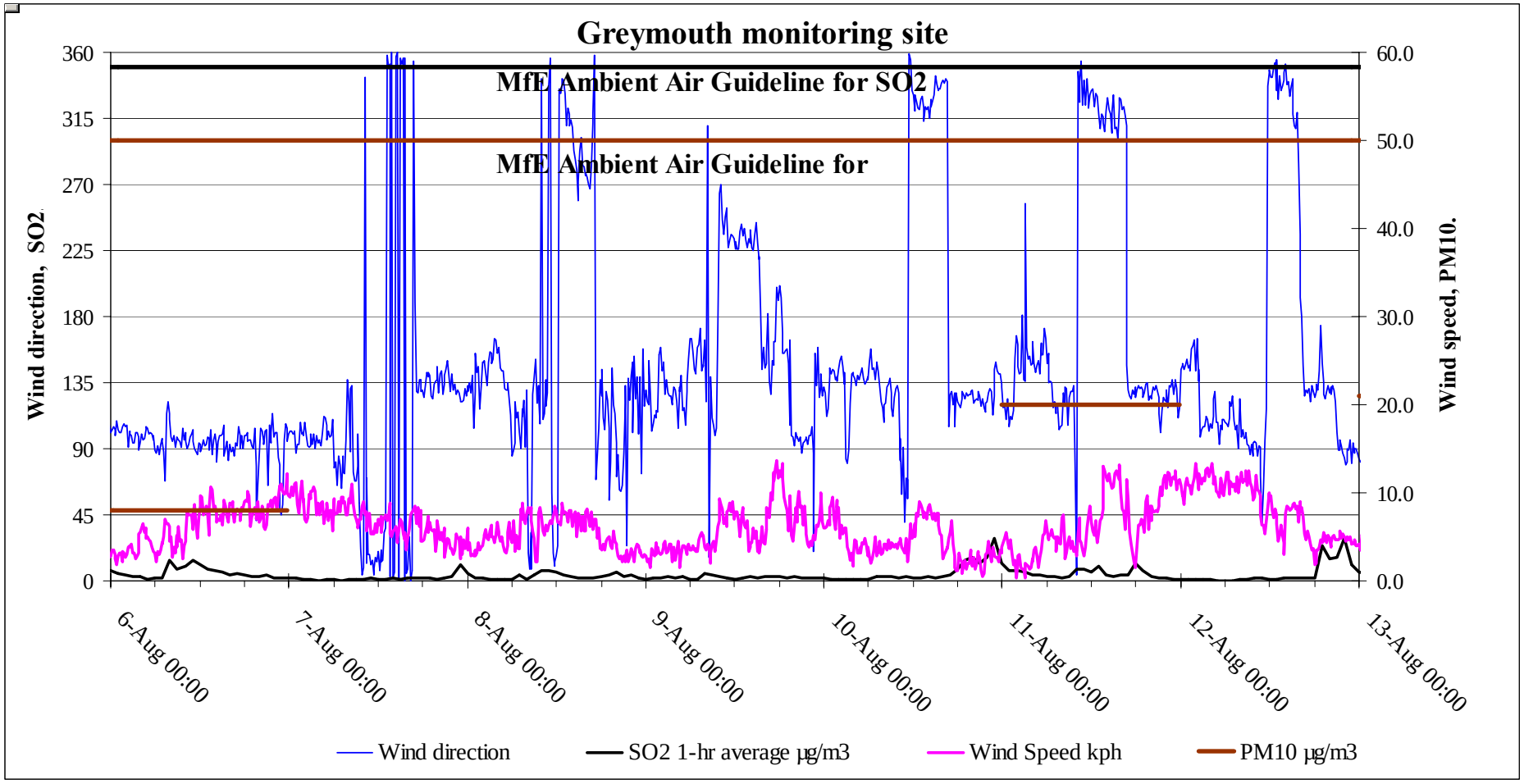


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

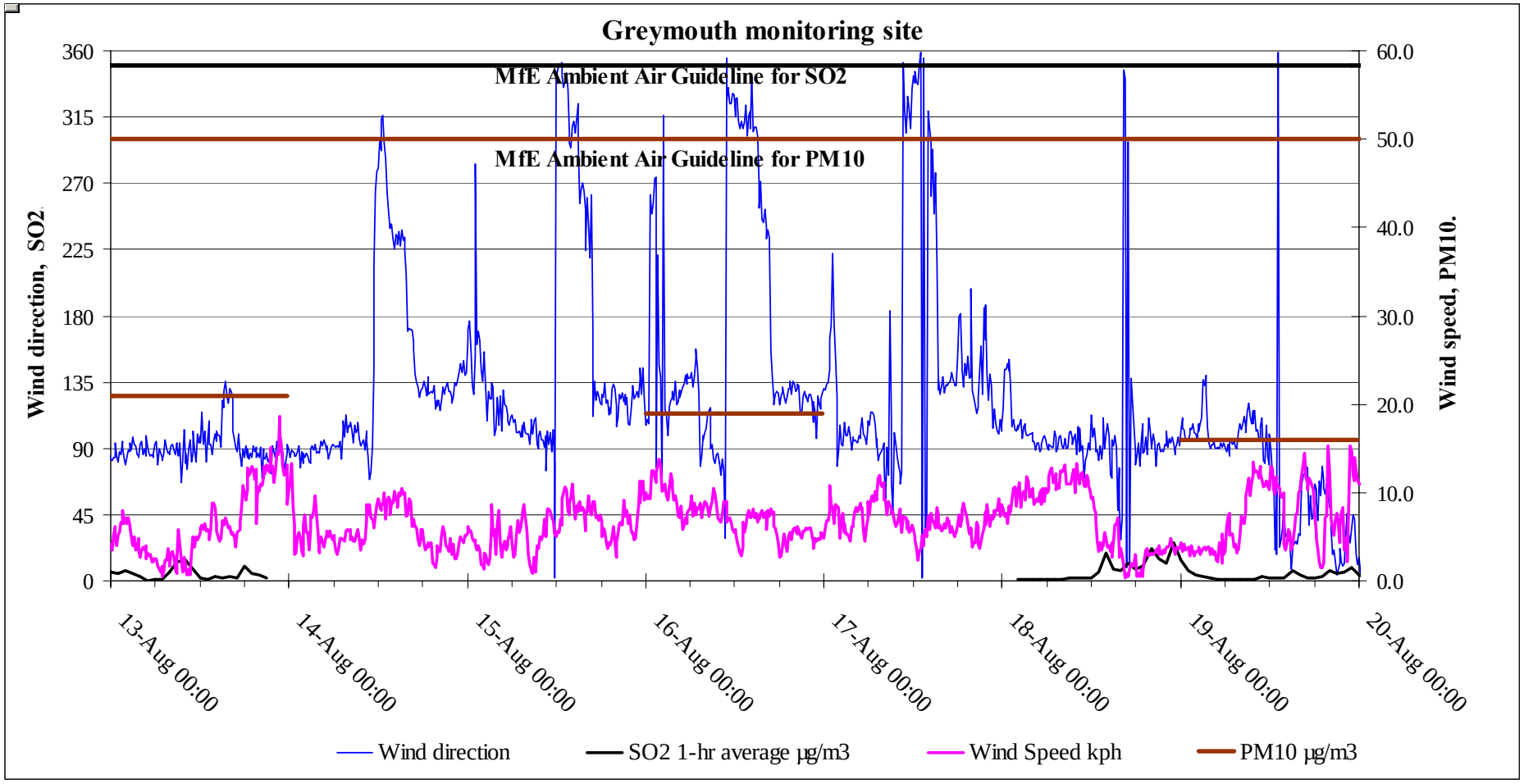


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

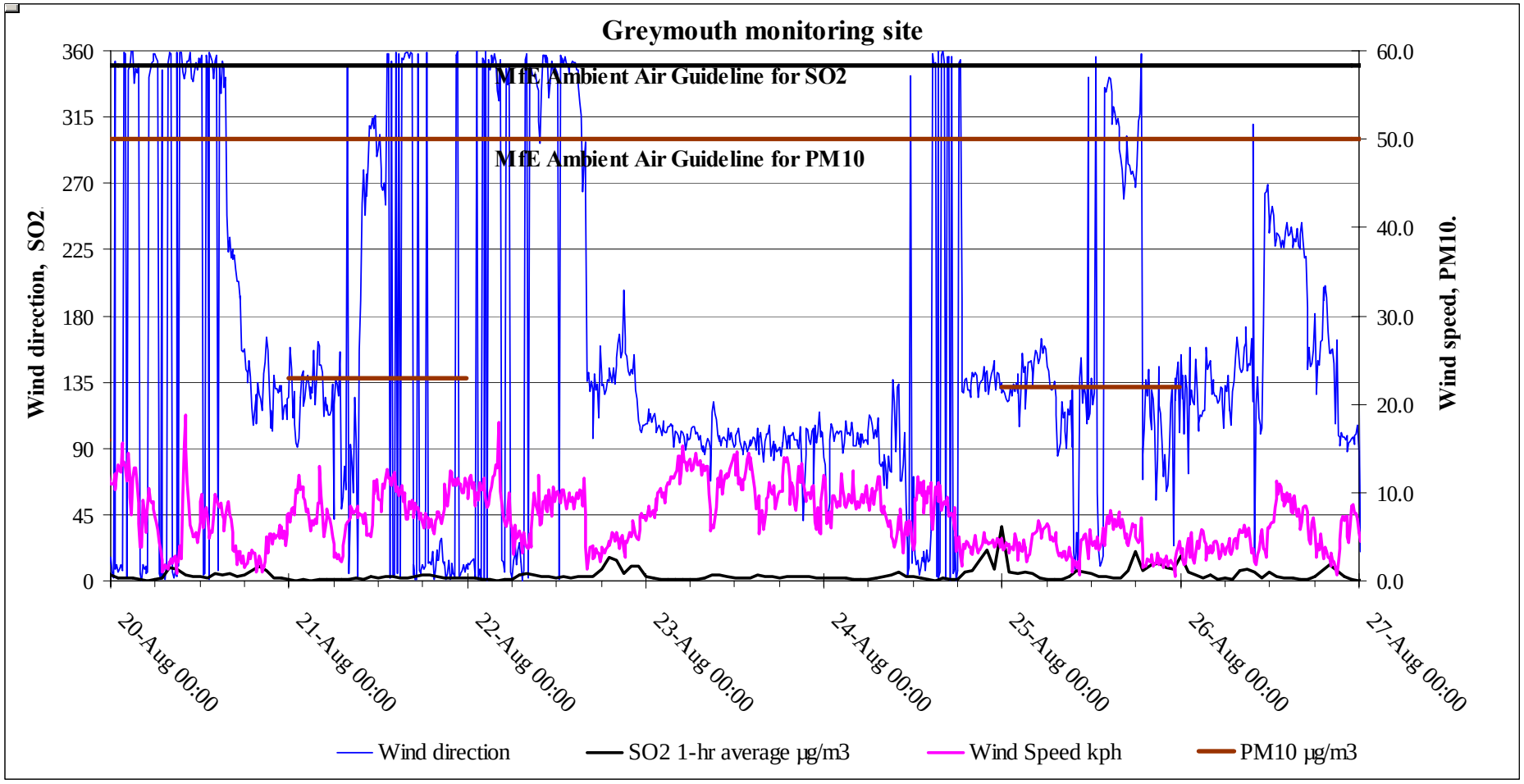


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

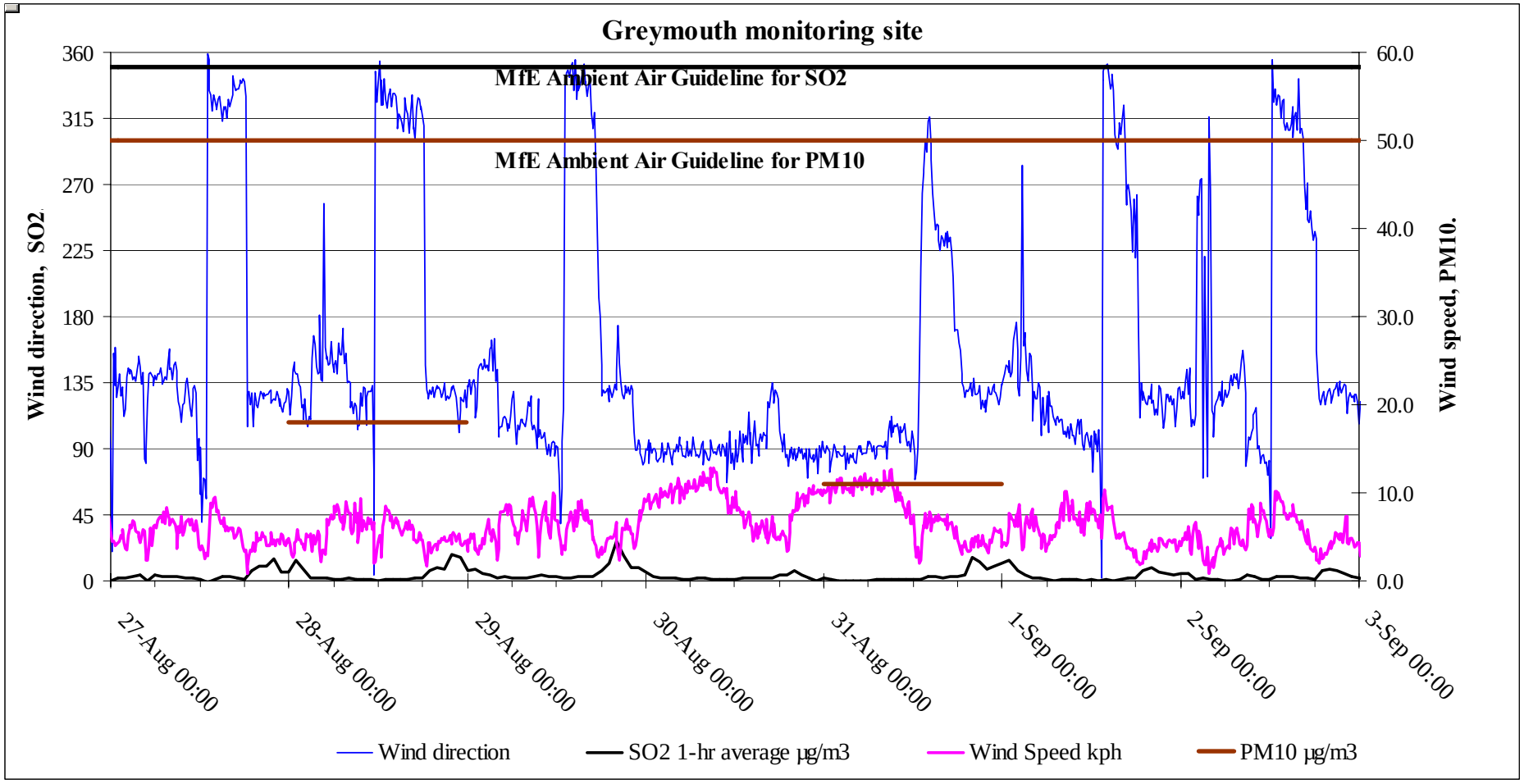


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001

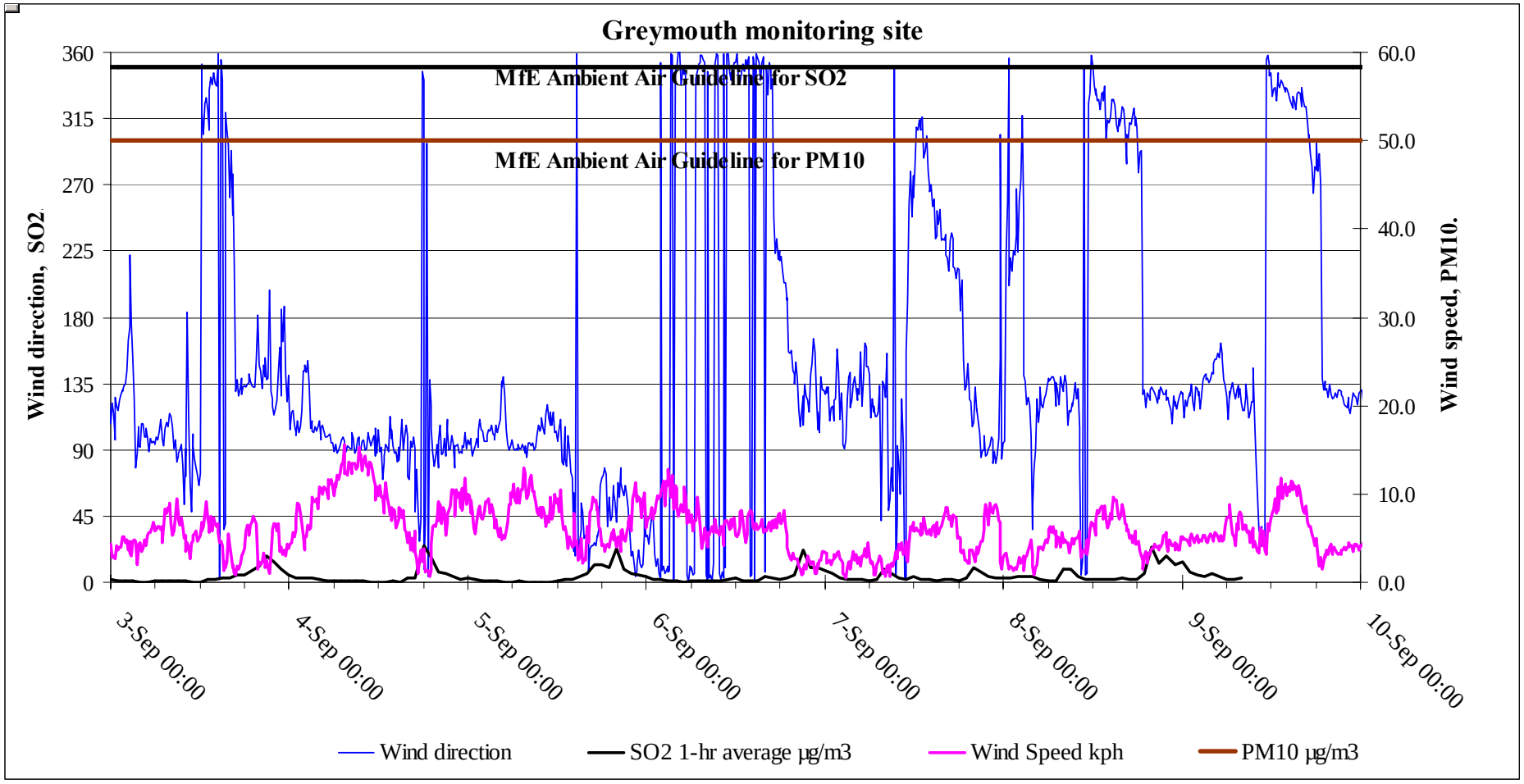
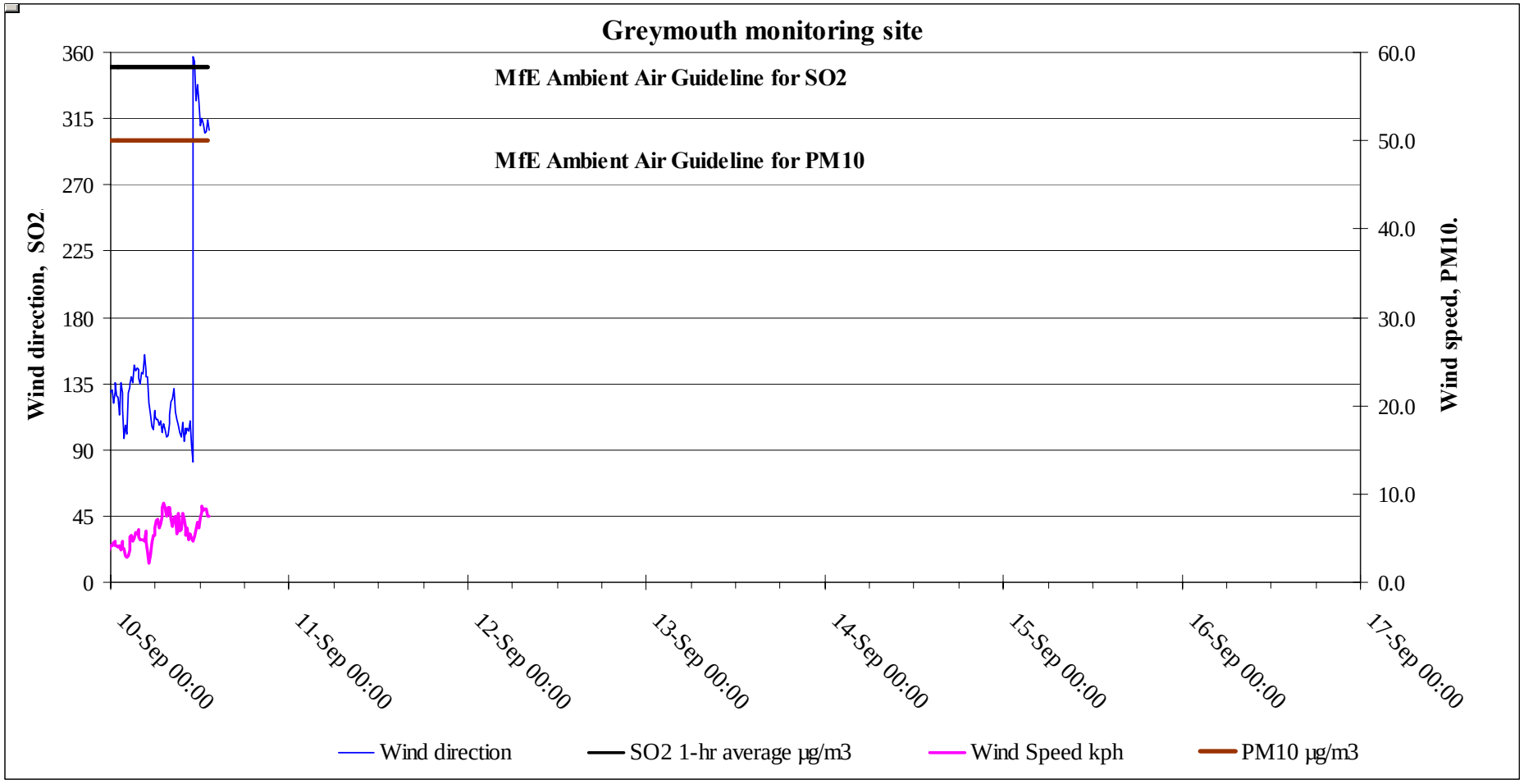


Figure 18. Cont'd. Monitoring and meteorological data for Greymouth for 2001



APPENDIX 4. MONITORING AND METEOROLOGICAL DATA FOR WESTPORT FOR 2002

Figure 19. Monitoring and meteorological data for Westport for 2002

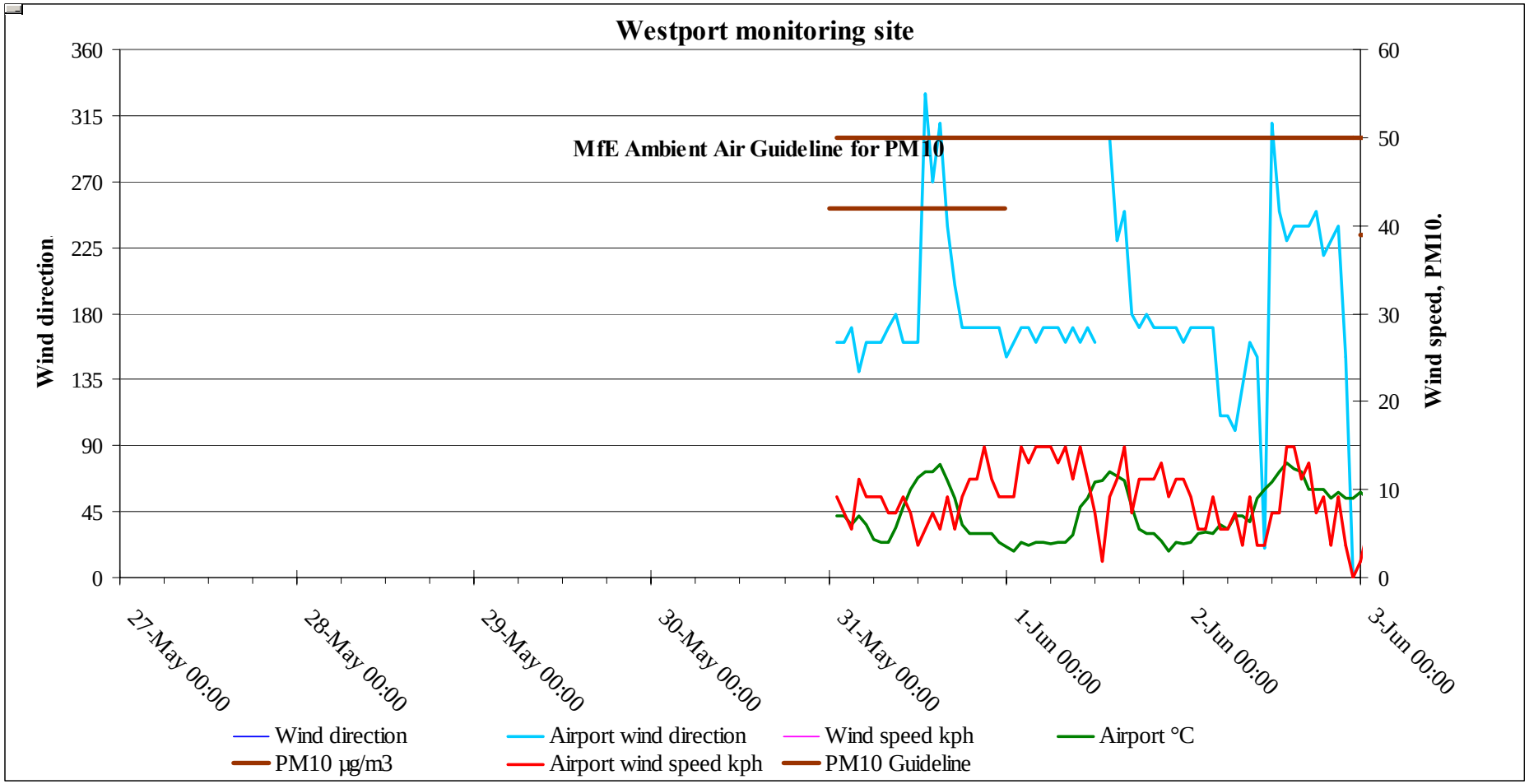


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

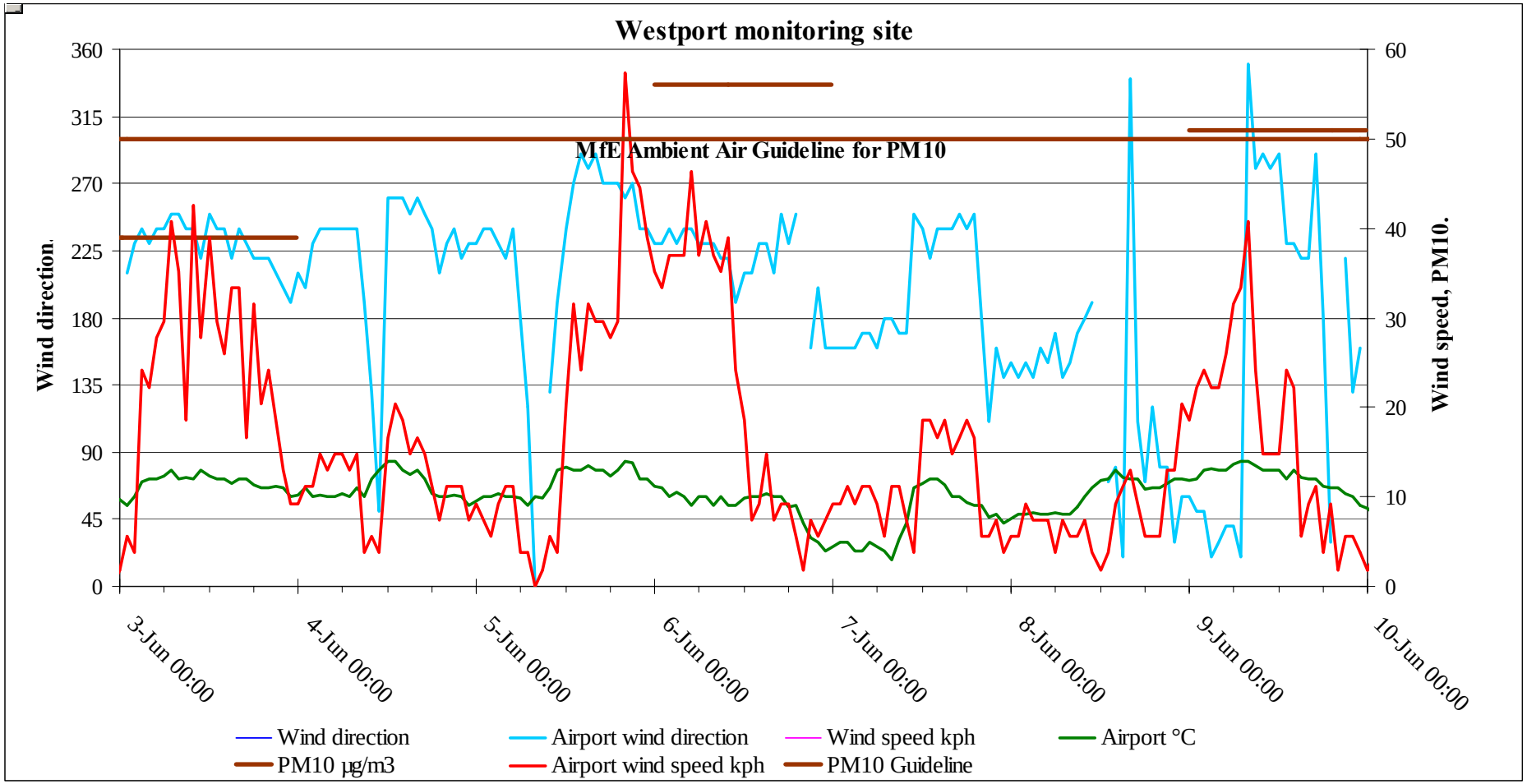


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

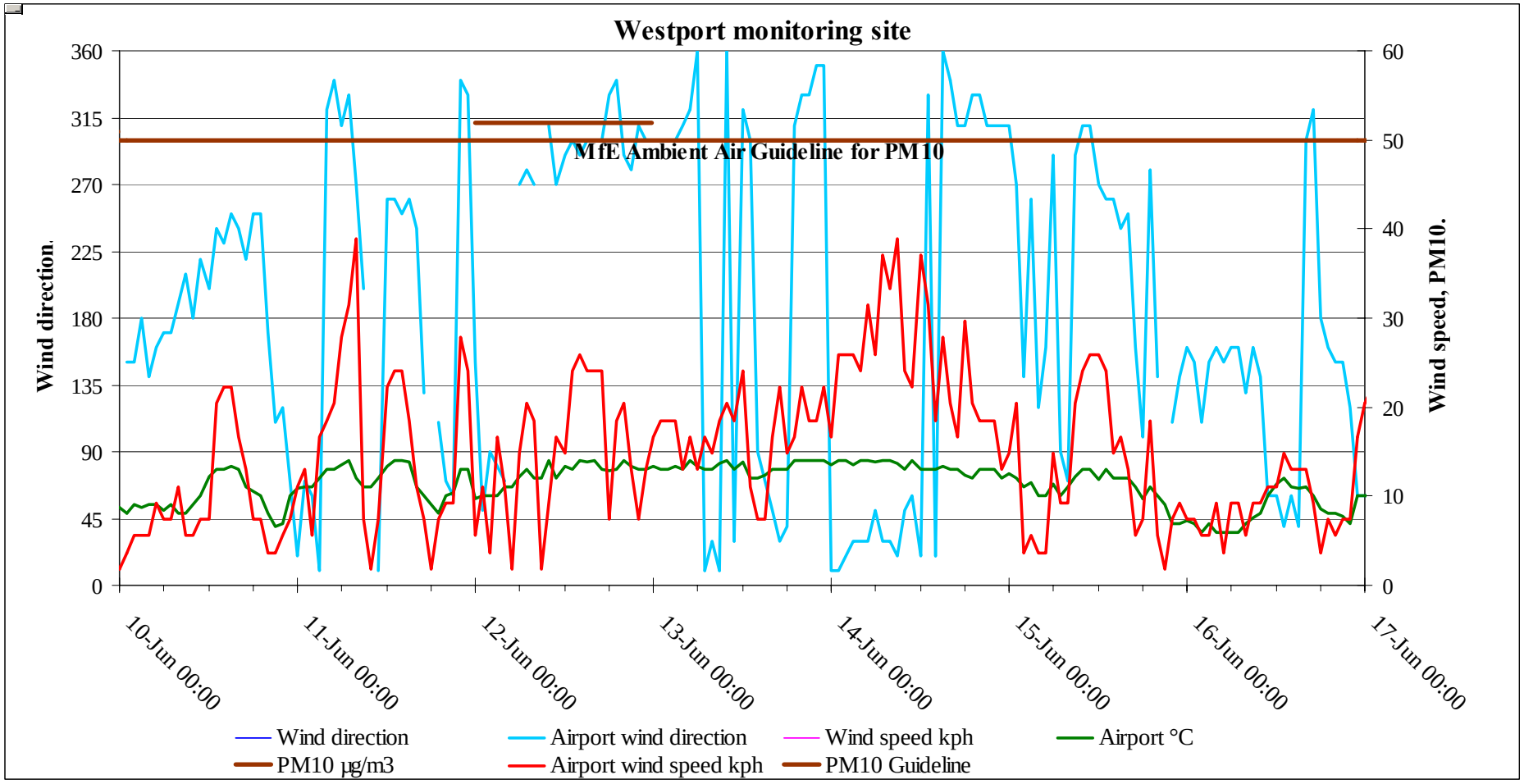


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

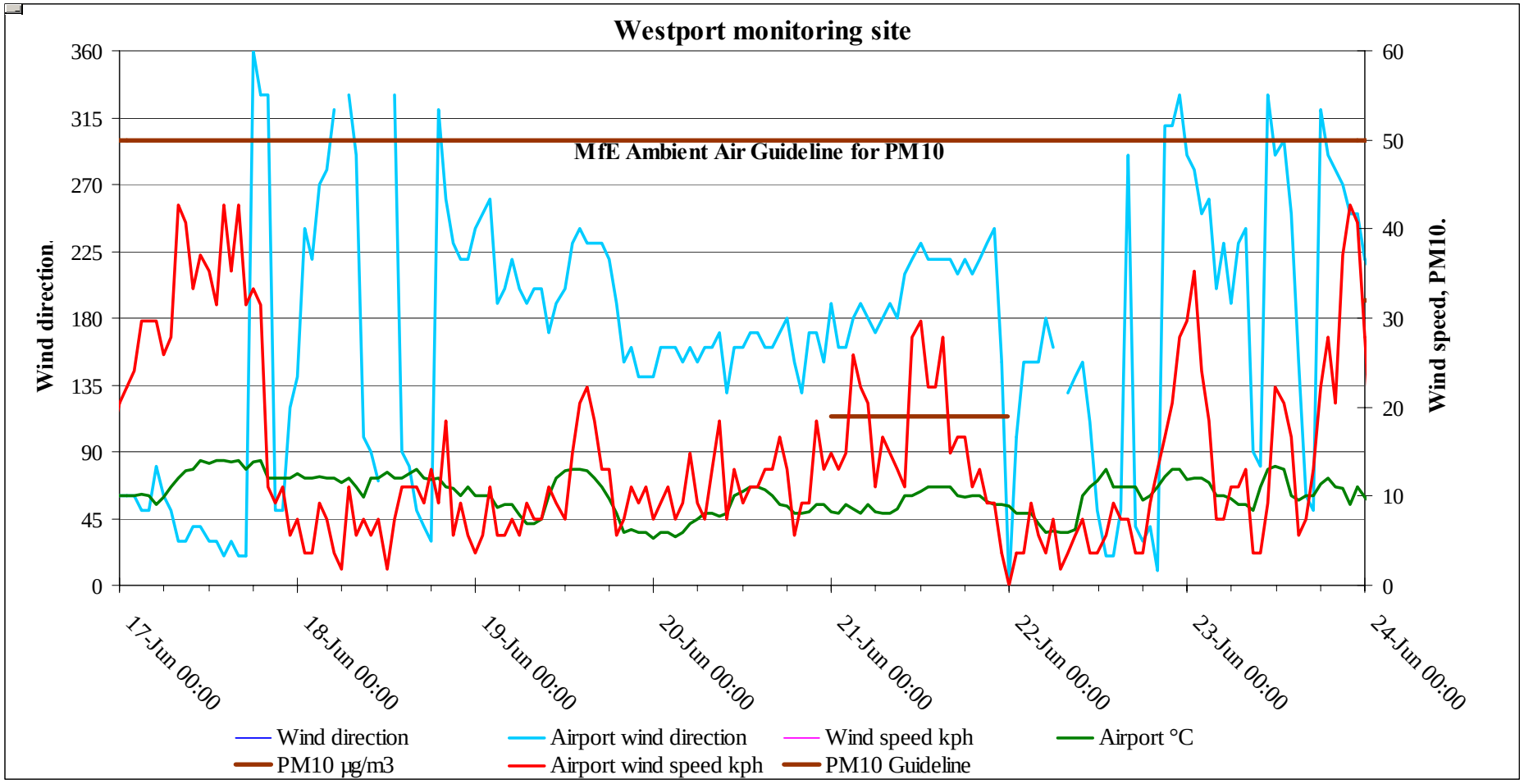


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

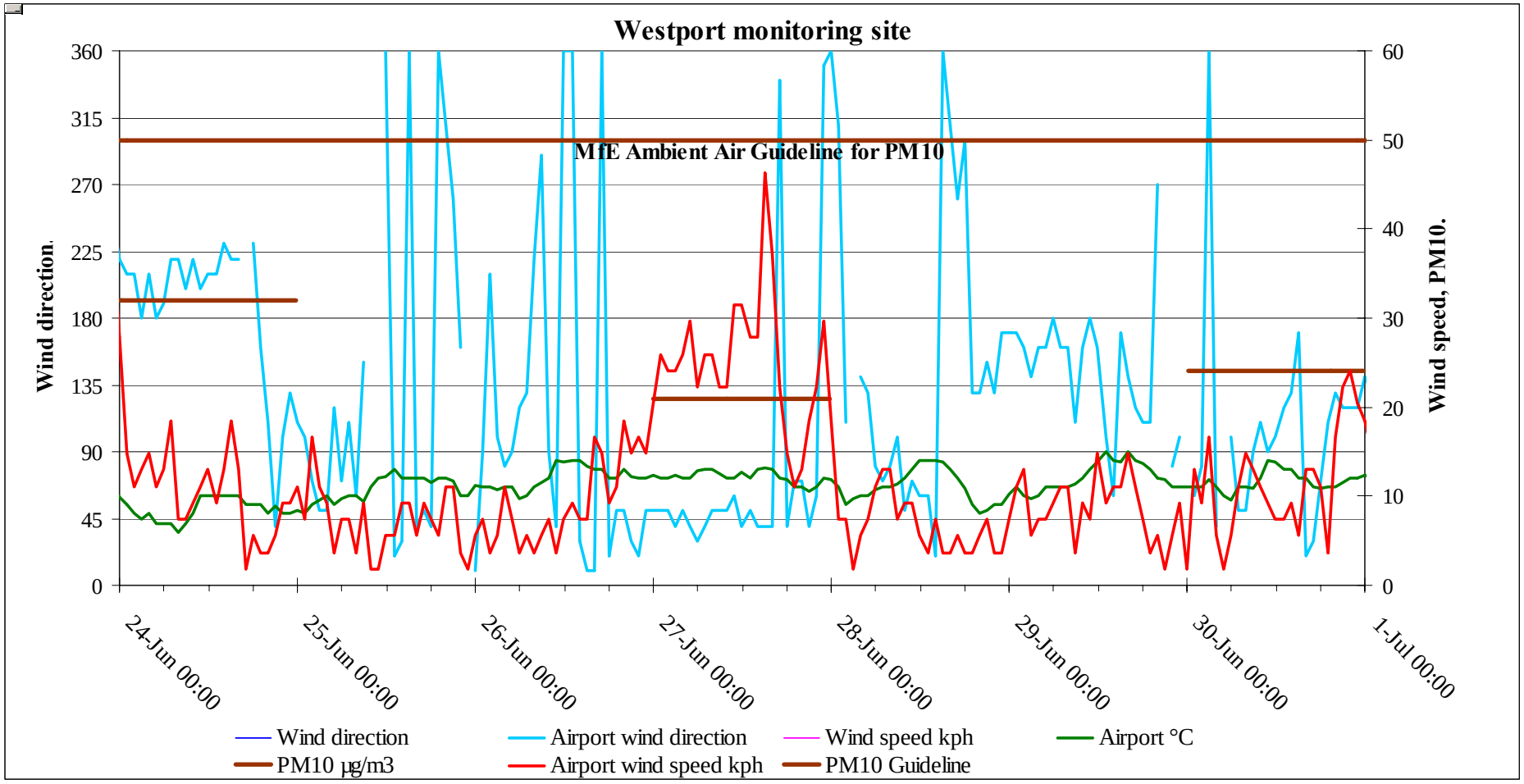


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

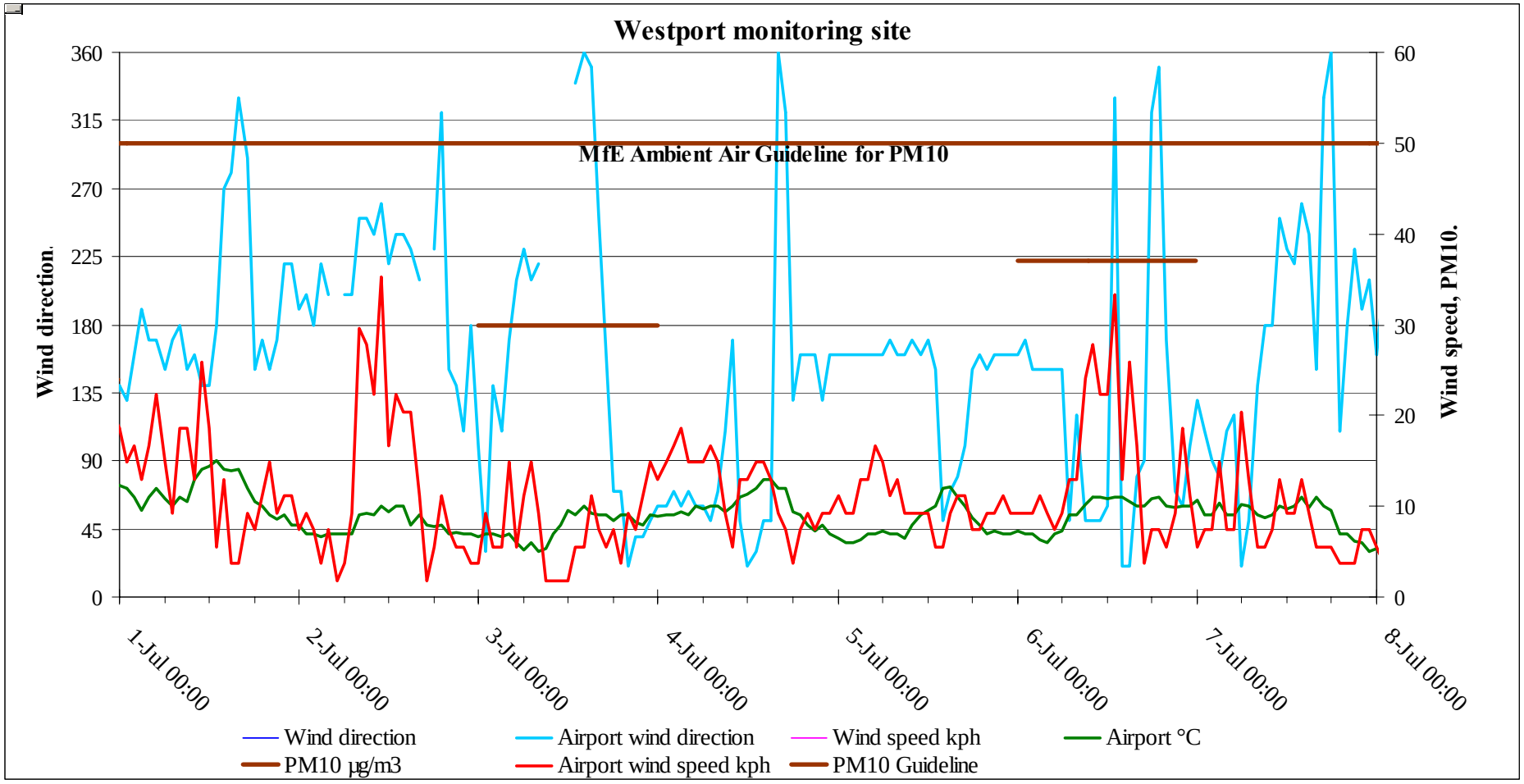


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

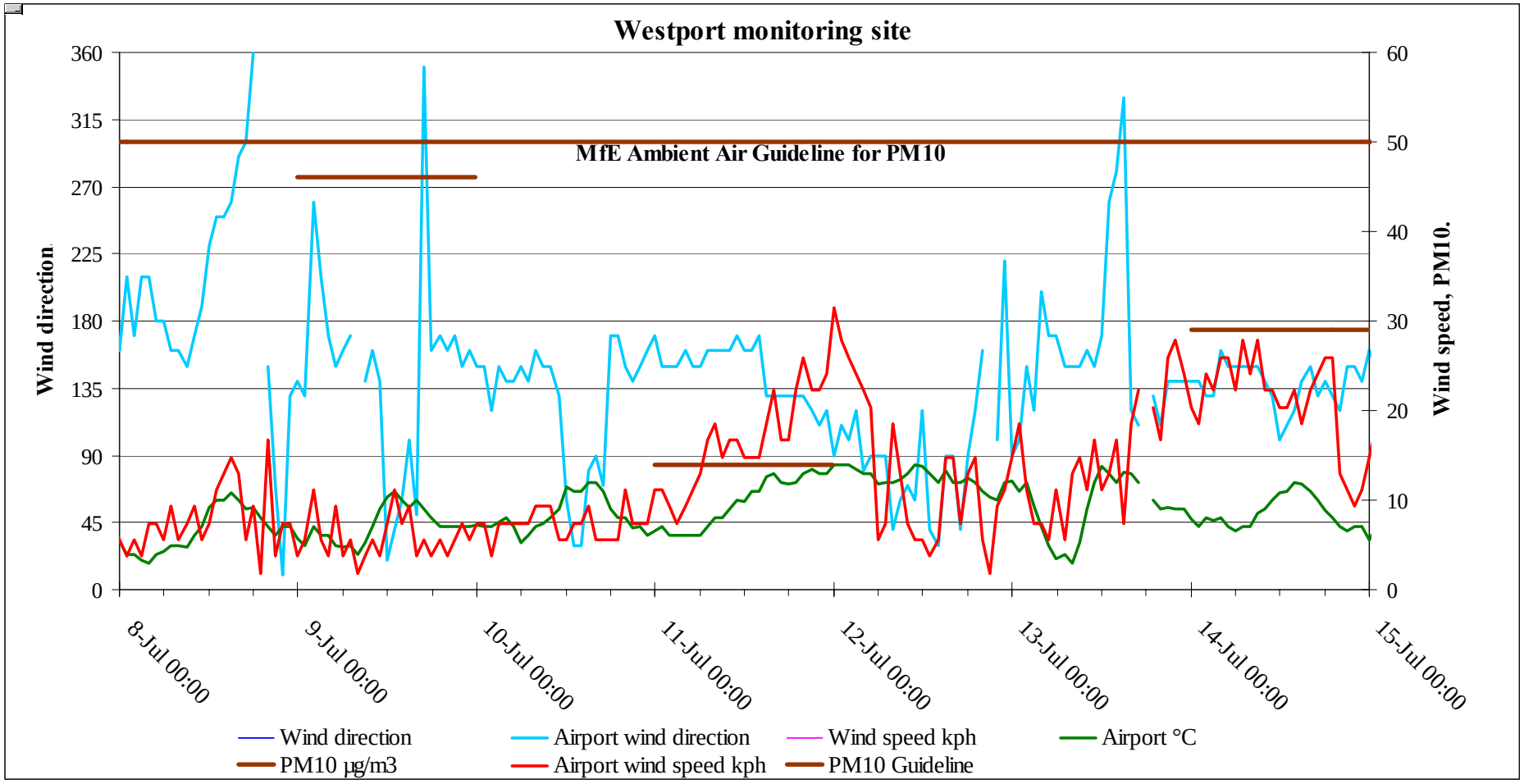


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

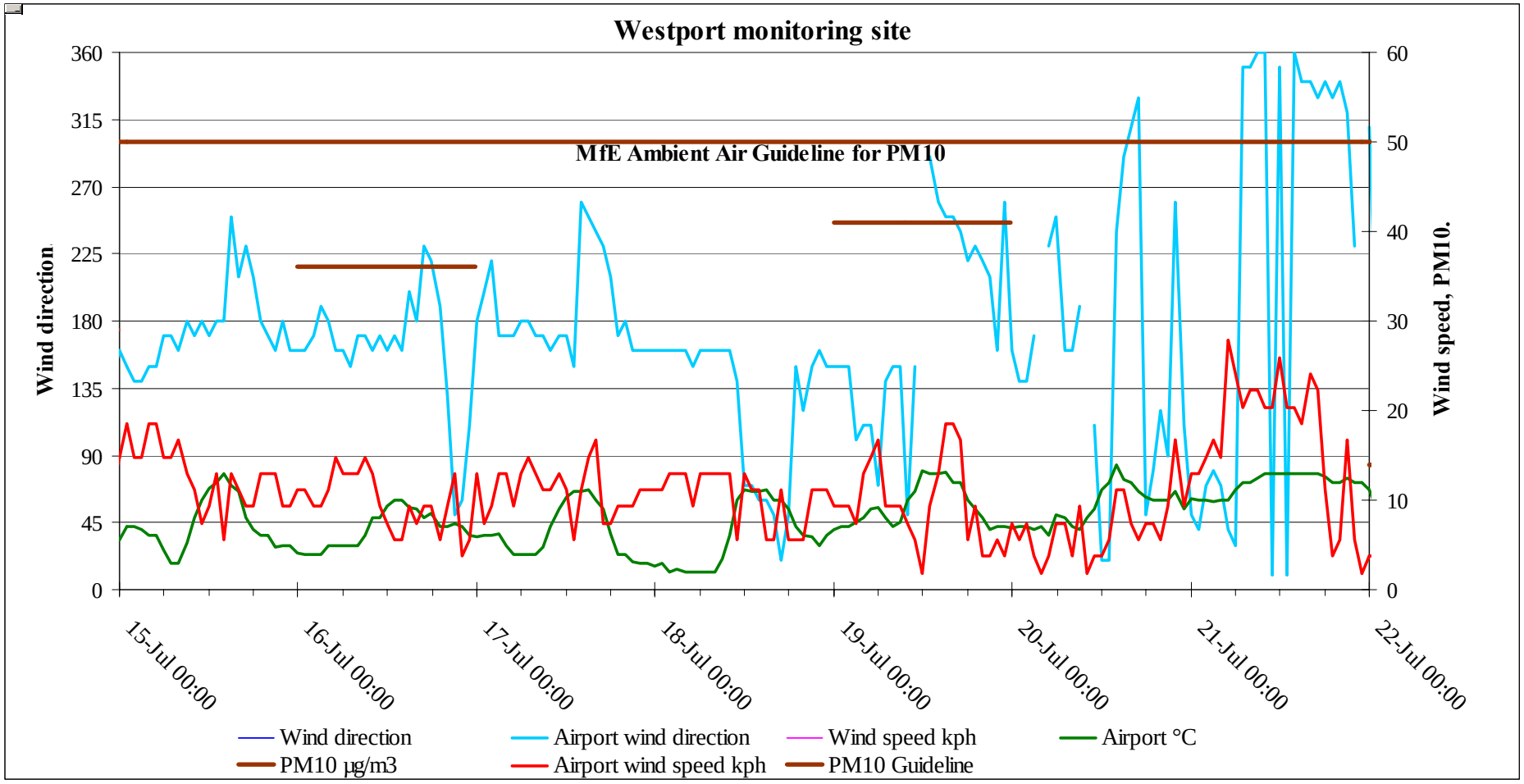


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

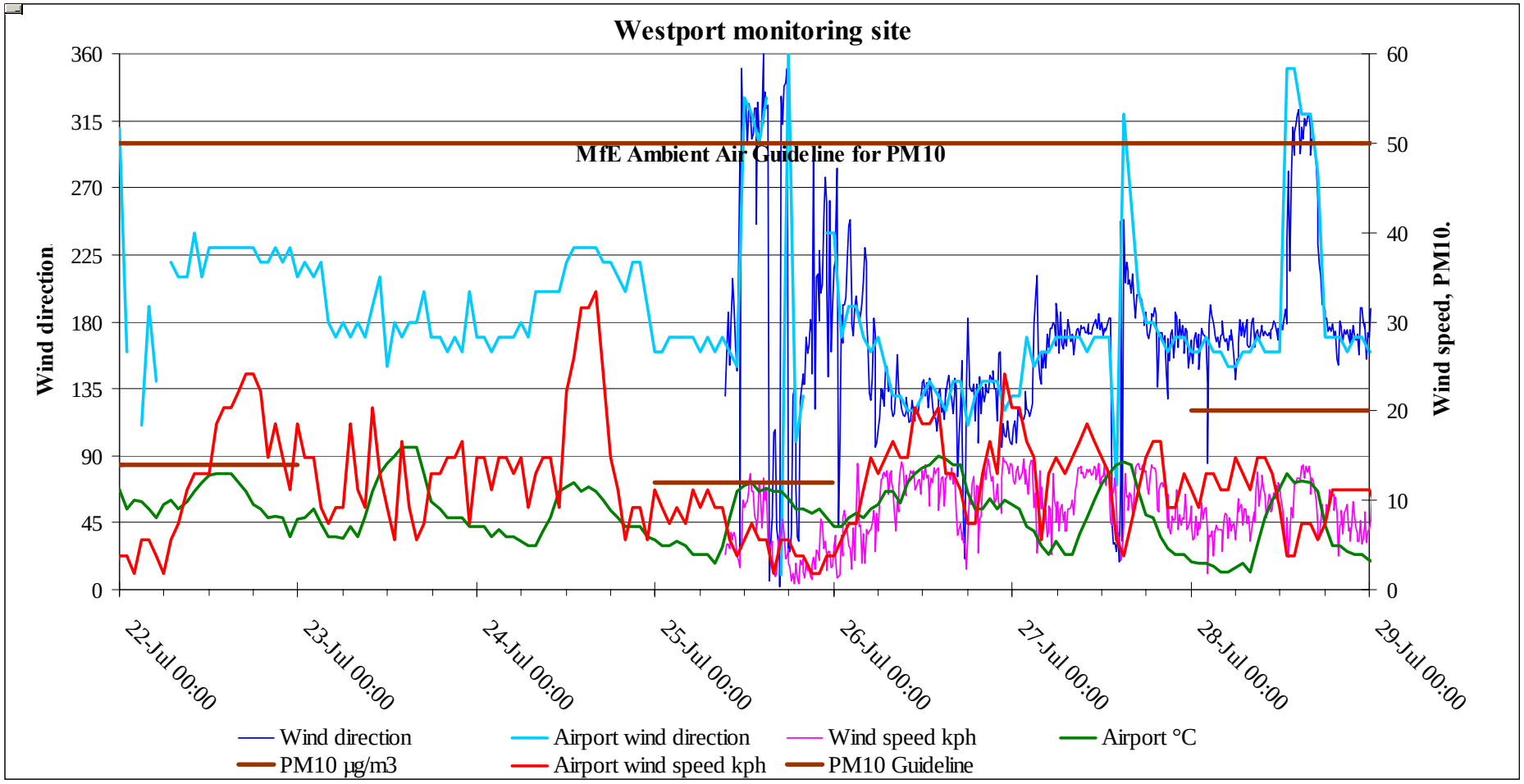


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

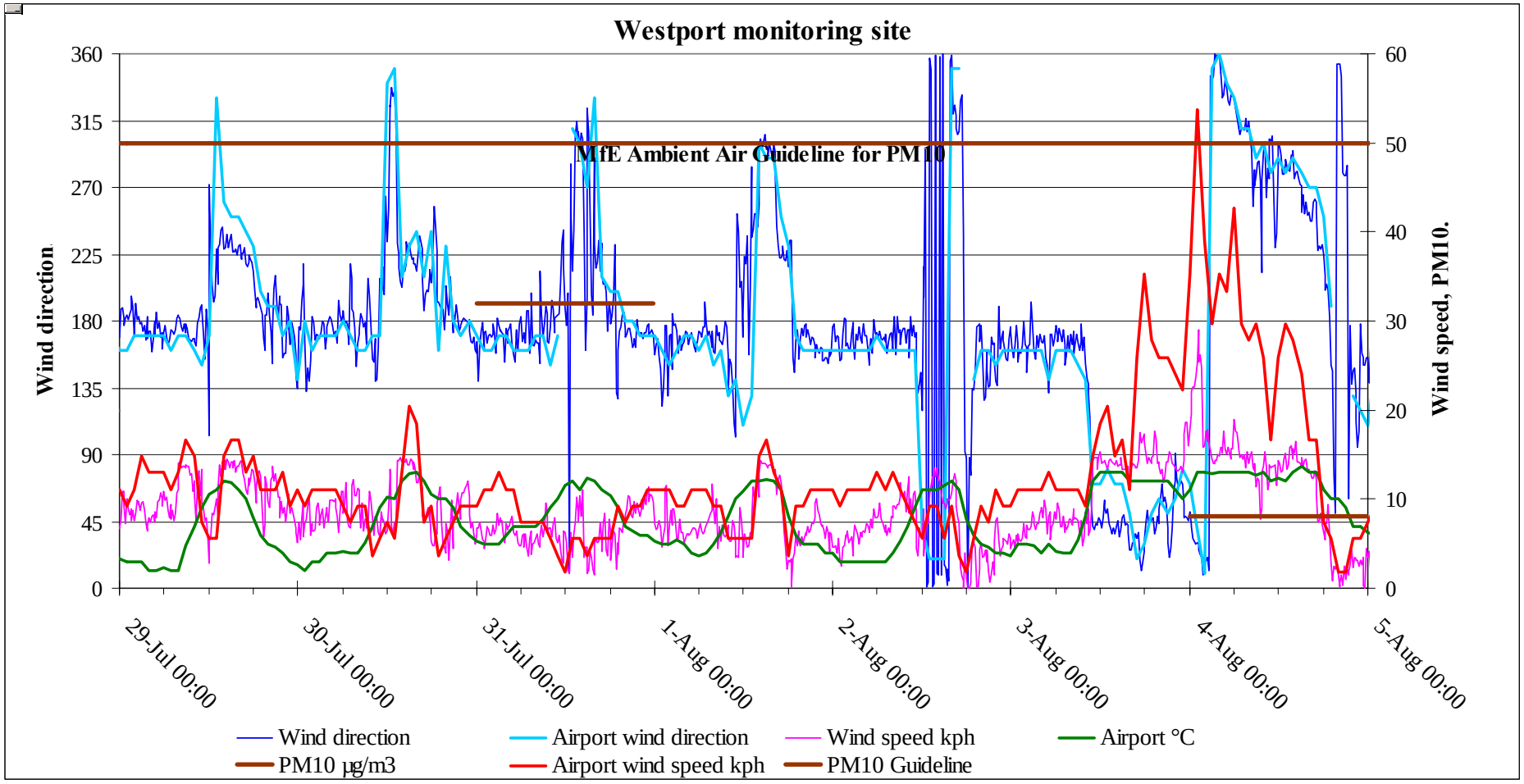


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

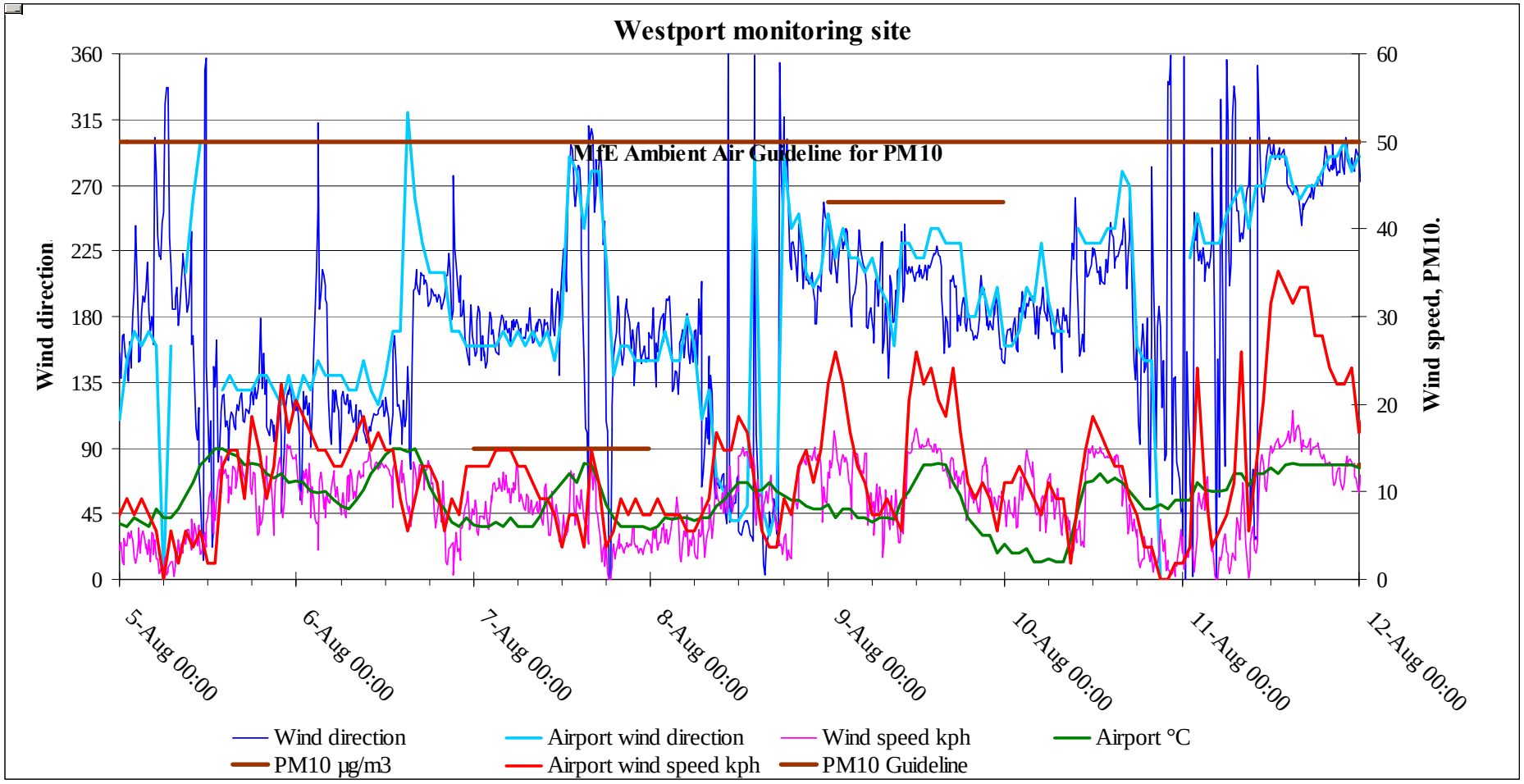


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

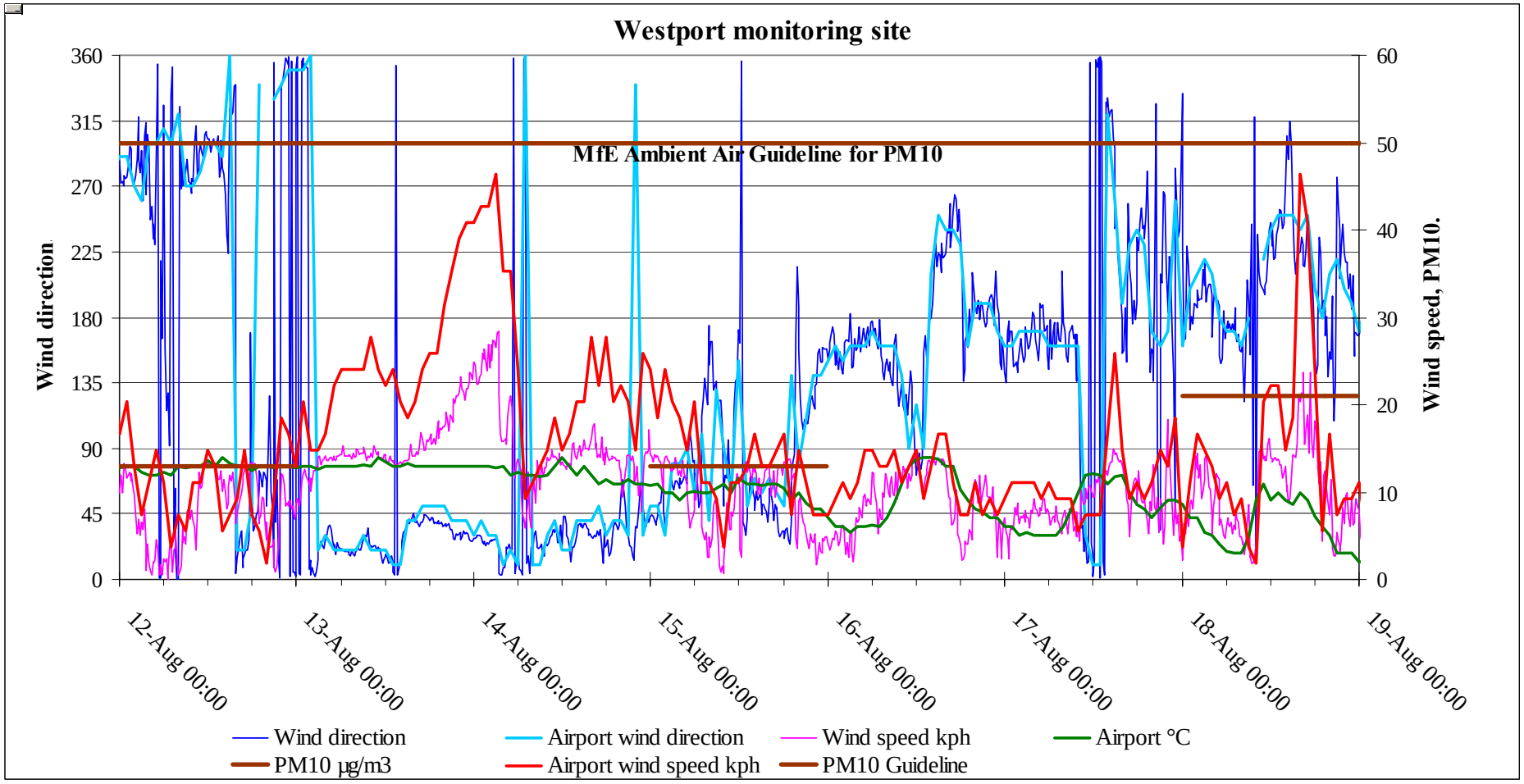


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

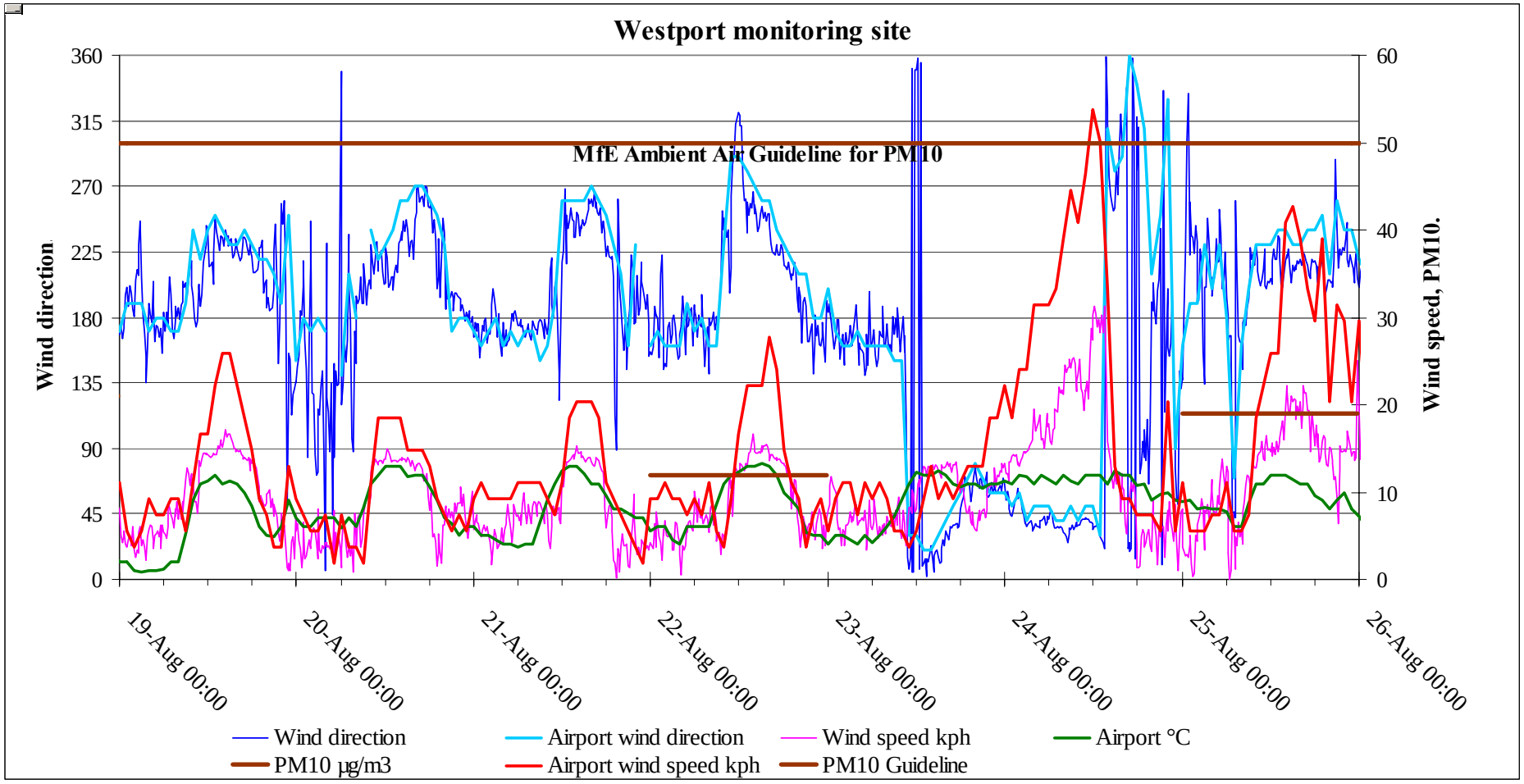


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002

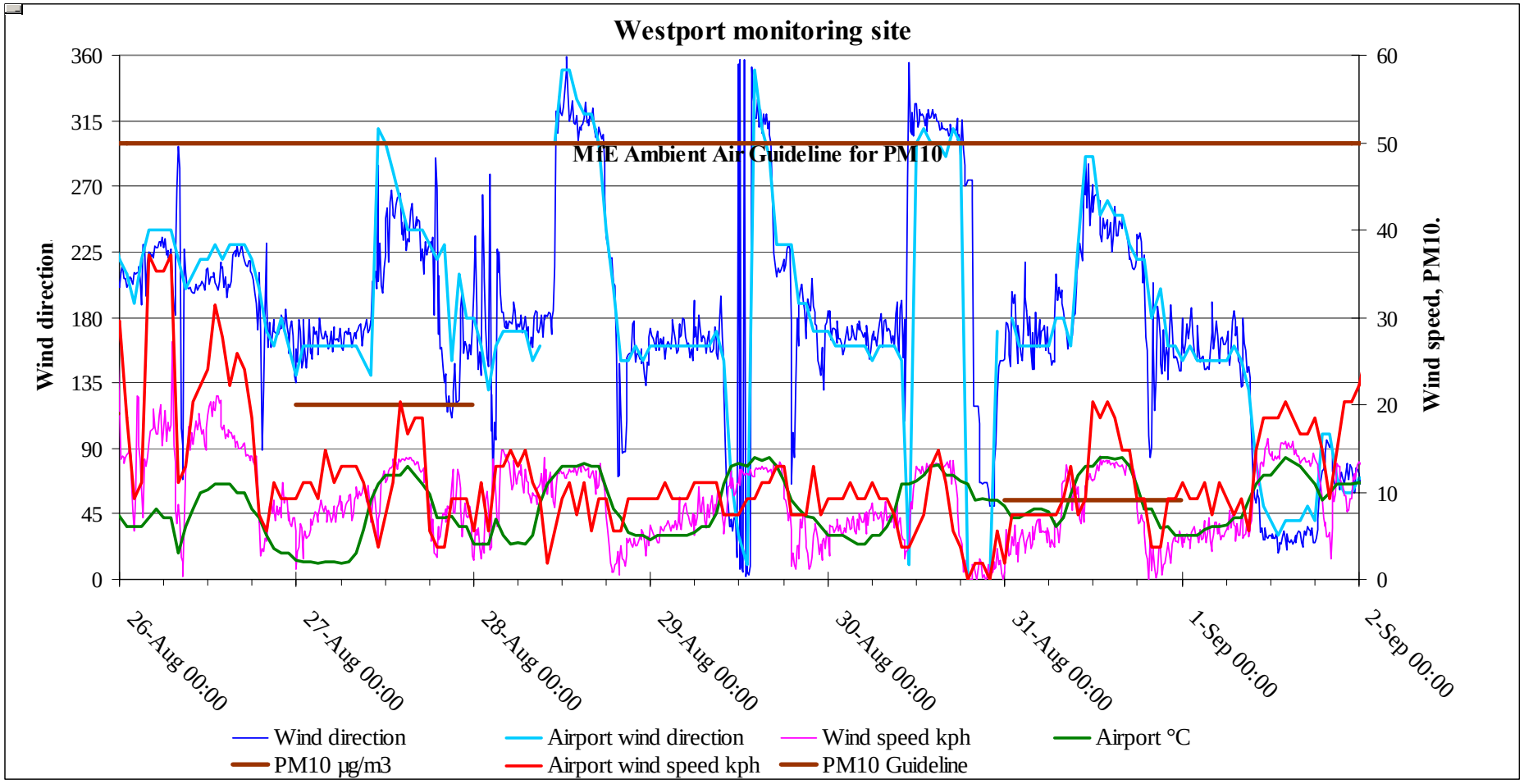
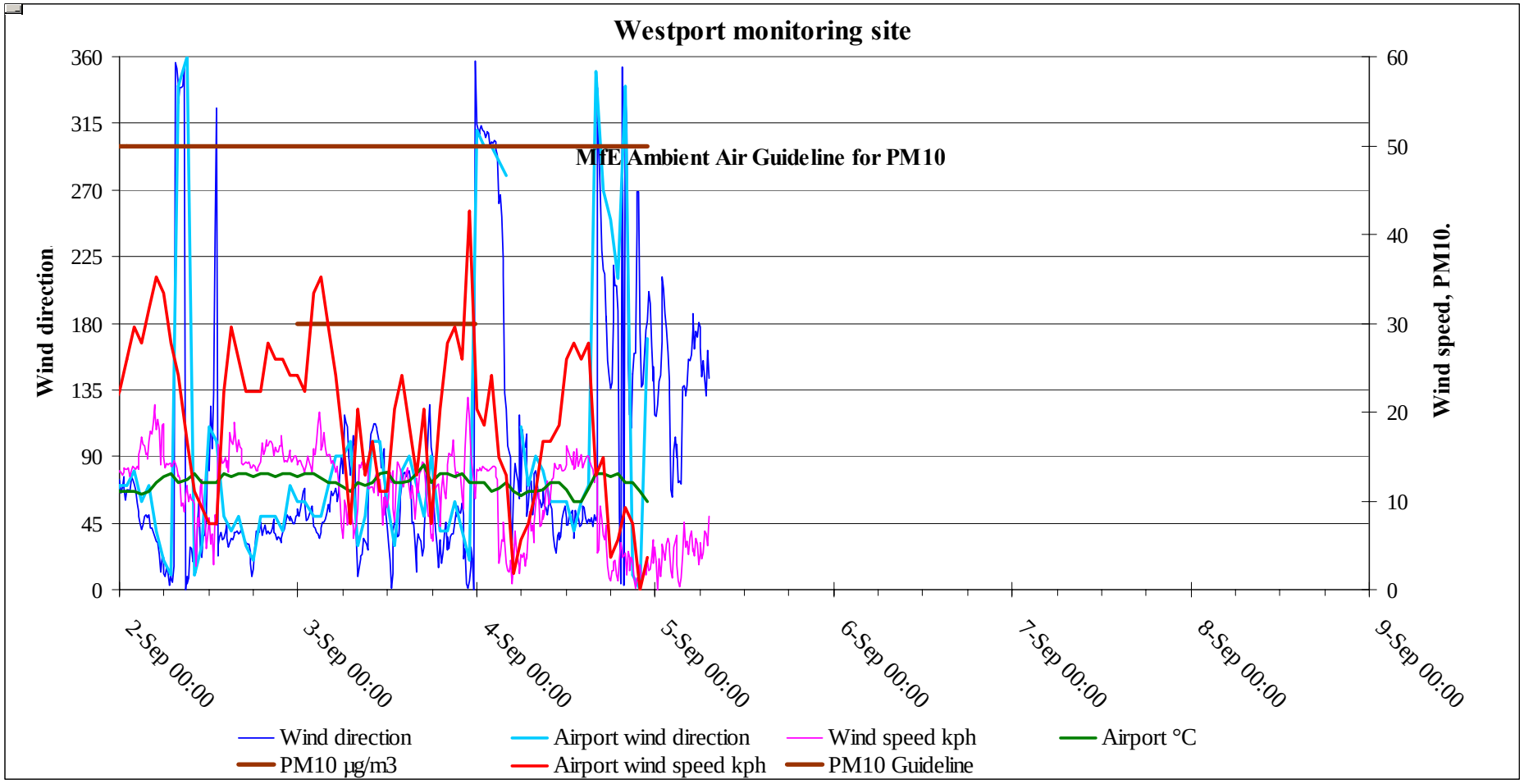
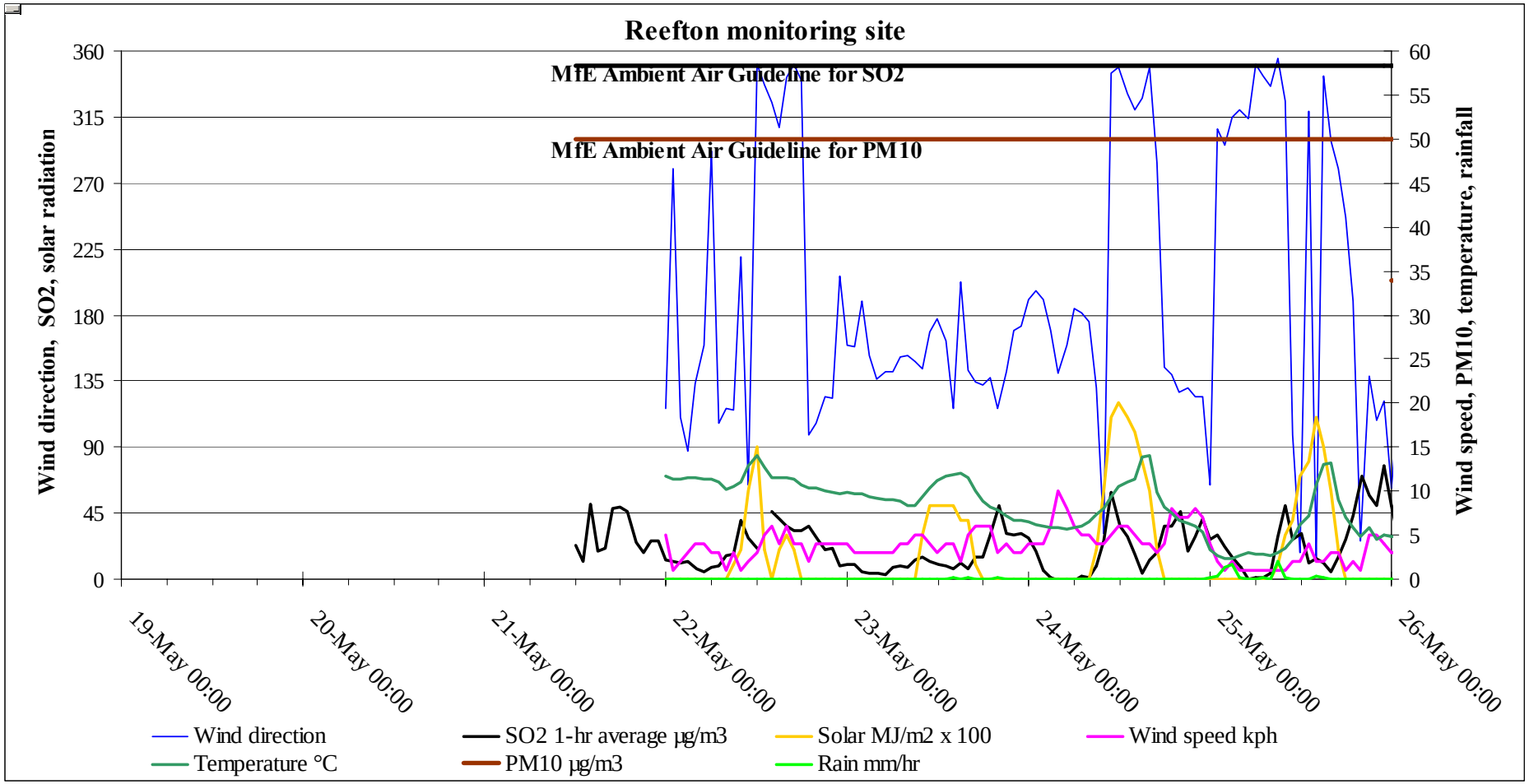


Figure 19 Cont'd. Monitoring and meteorological data for Westport for 2002



APPENDIX 5. MONITORING AND METEOROLOGICAL DATA FOR REEFTON FOR 2003

Figure 20. Monitoring and meteorological data for Reefton for 2003



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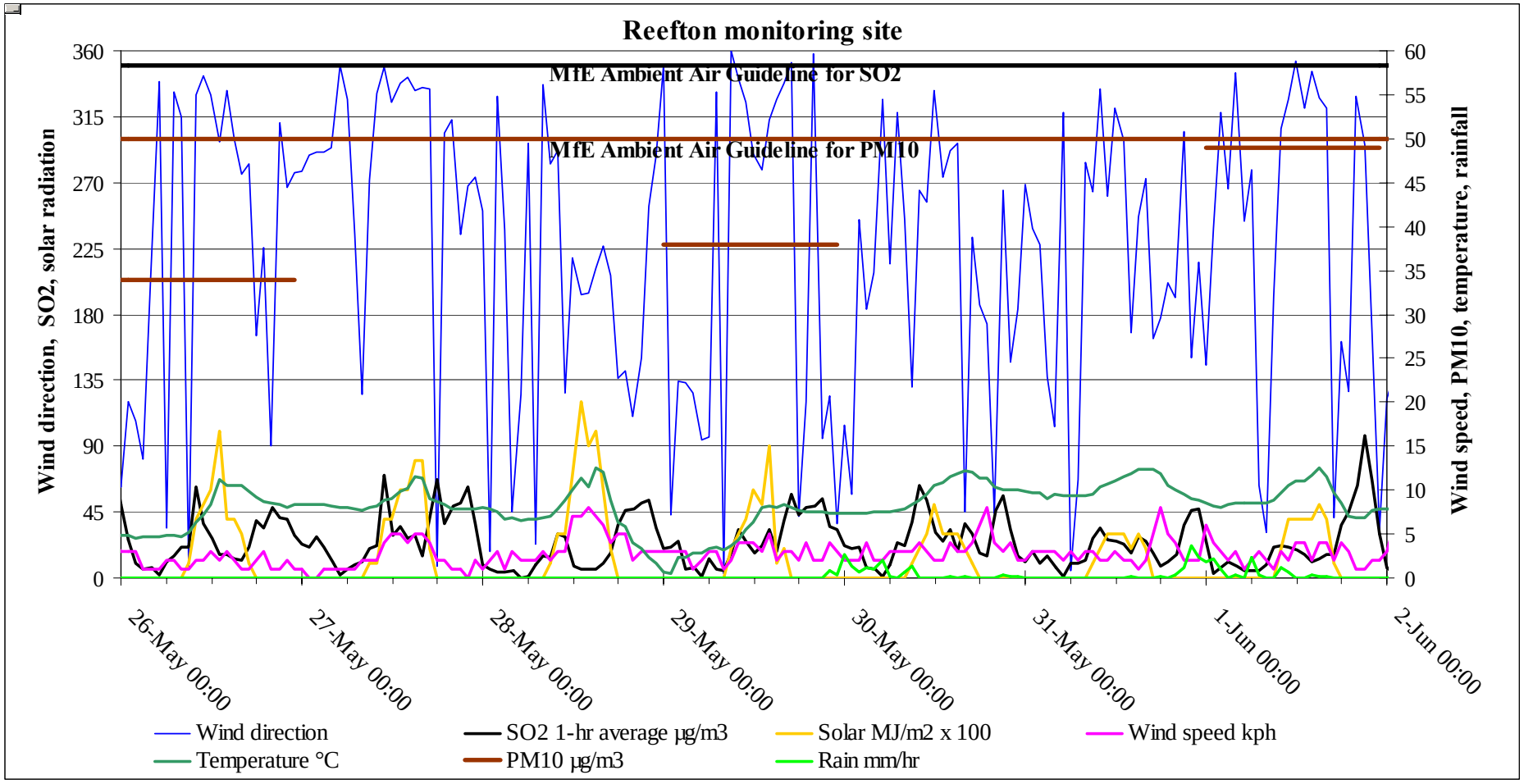

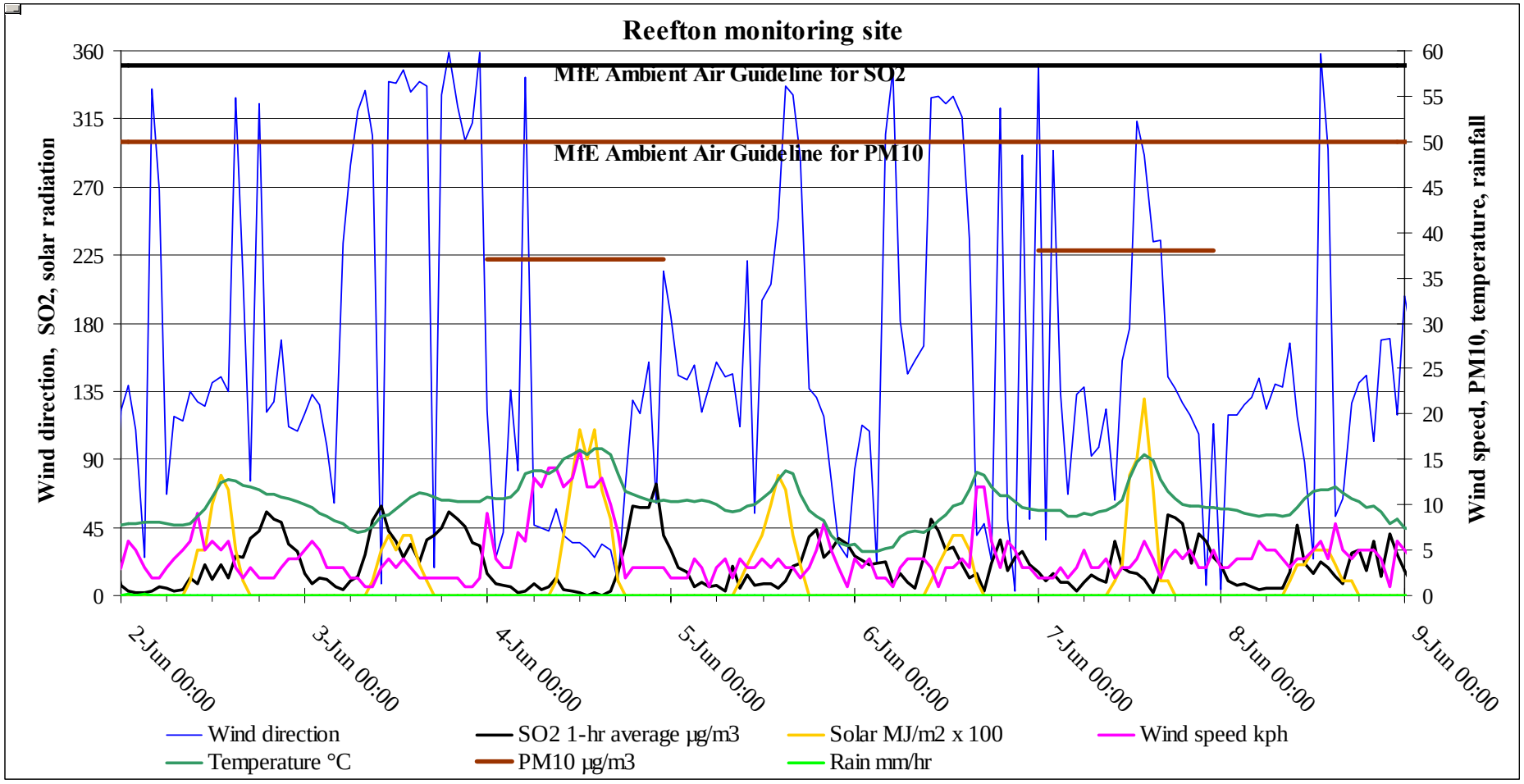
Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
360
315
270
225
180
135
90
45
0
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55
50
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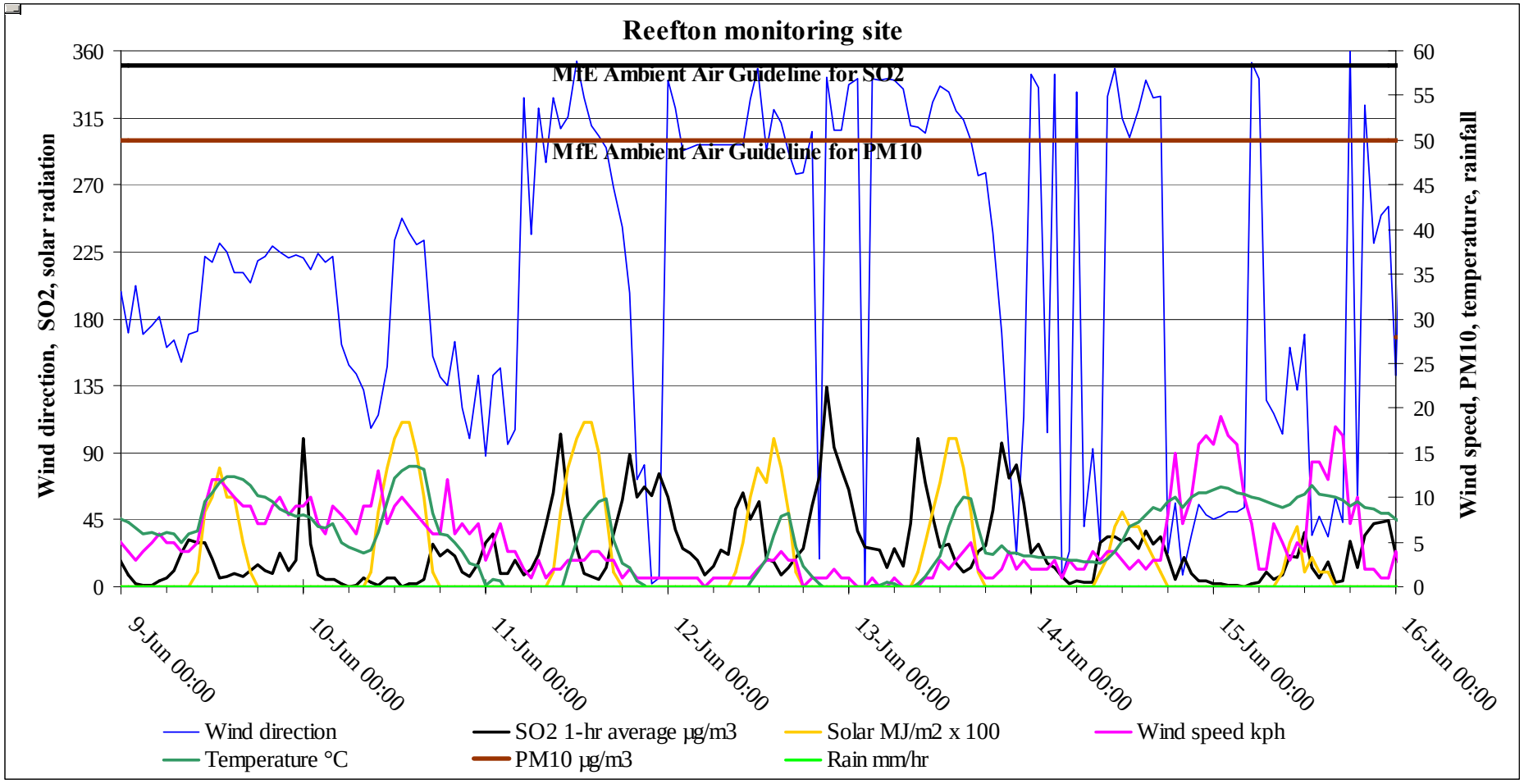
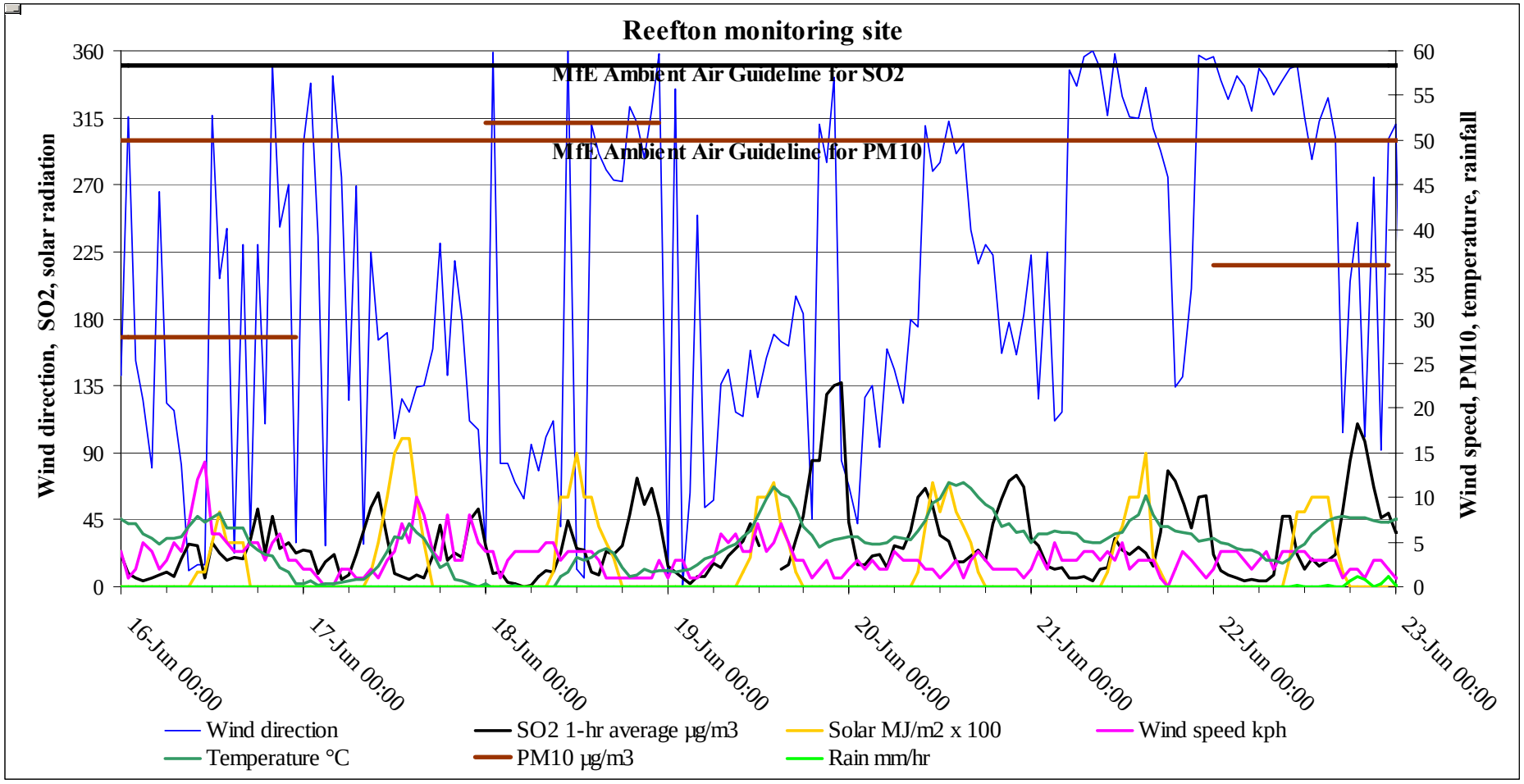
40
35
30
25
20
15
10
5
0
2-Jun 00:00
3-Jun 00:00
4-Jun 00:00
5-Jun 00:00
6-Jun 00:00
7-Jun 00:00
8-Jun 00:00
9-Jun 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr

Error! Reference source not found.. Cont'd. Monitoring and meteorological data for Reefton for 2003




Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
360
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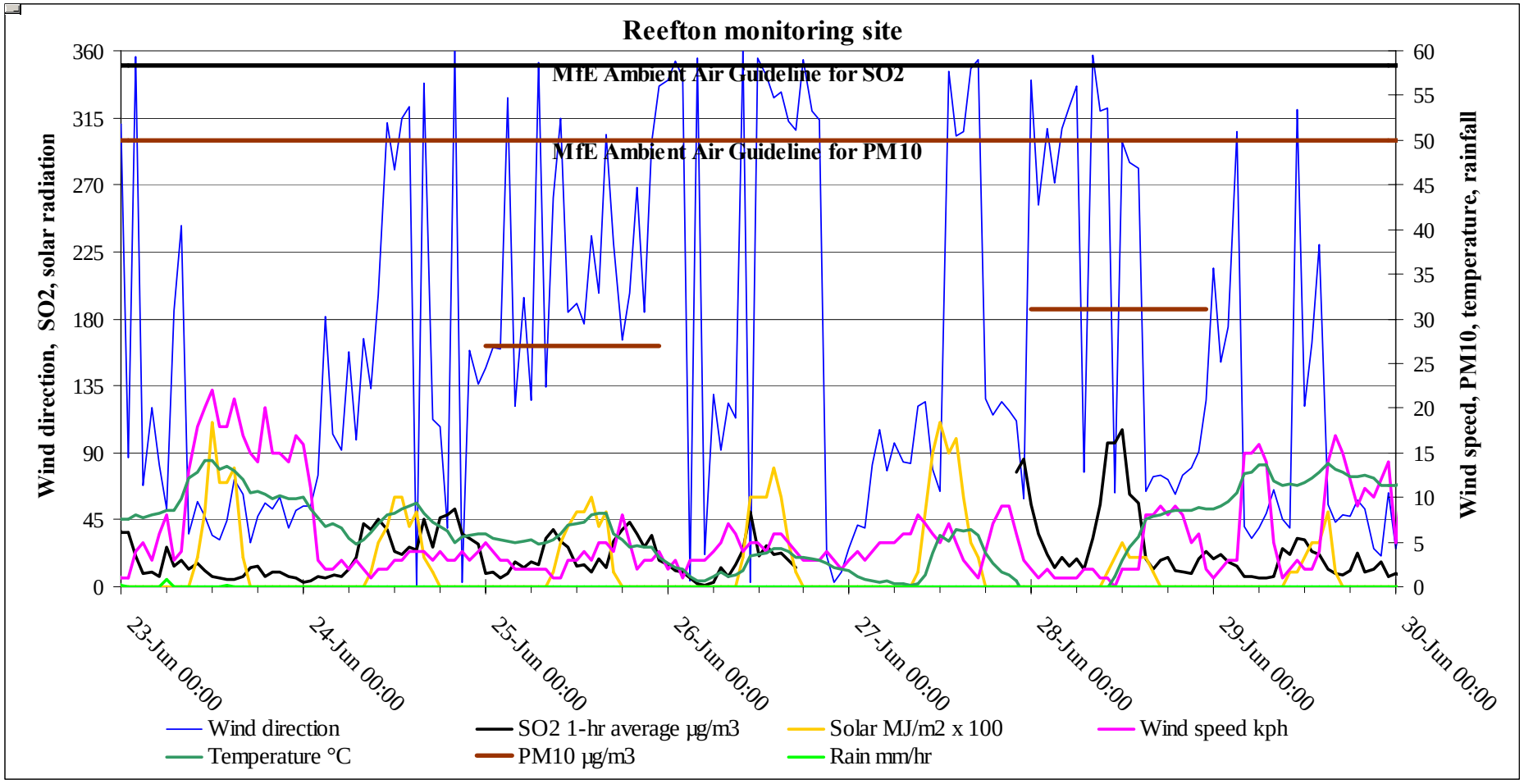
16-Jun 00:00
17-Jun 00:00
18-Jun 00:00
19-Jun 00:00
20-Jun 00:00
21-Jun 00:00
22-Jun 00:00
23-Jun 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
360
315
270
225
180
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35
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25
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15
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5
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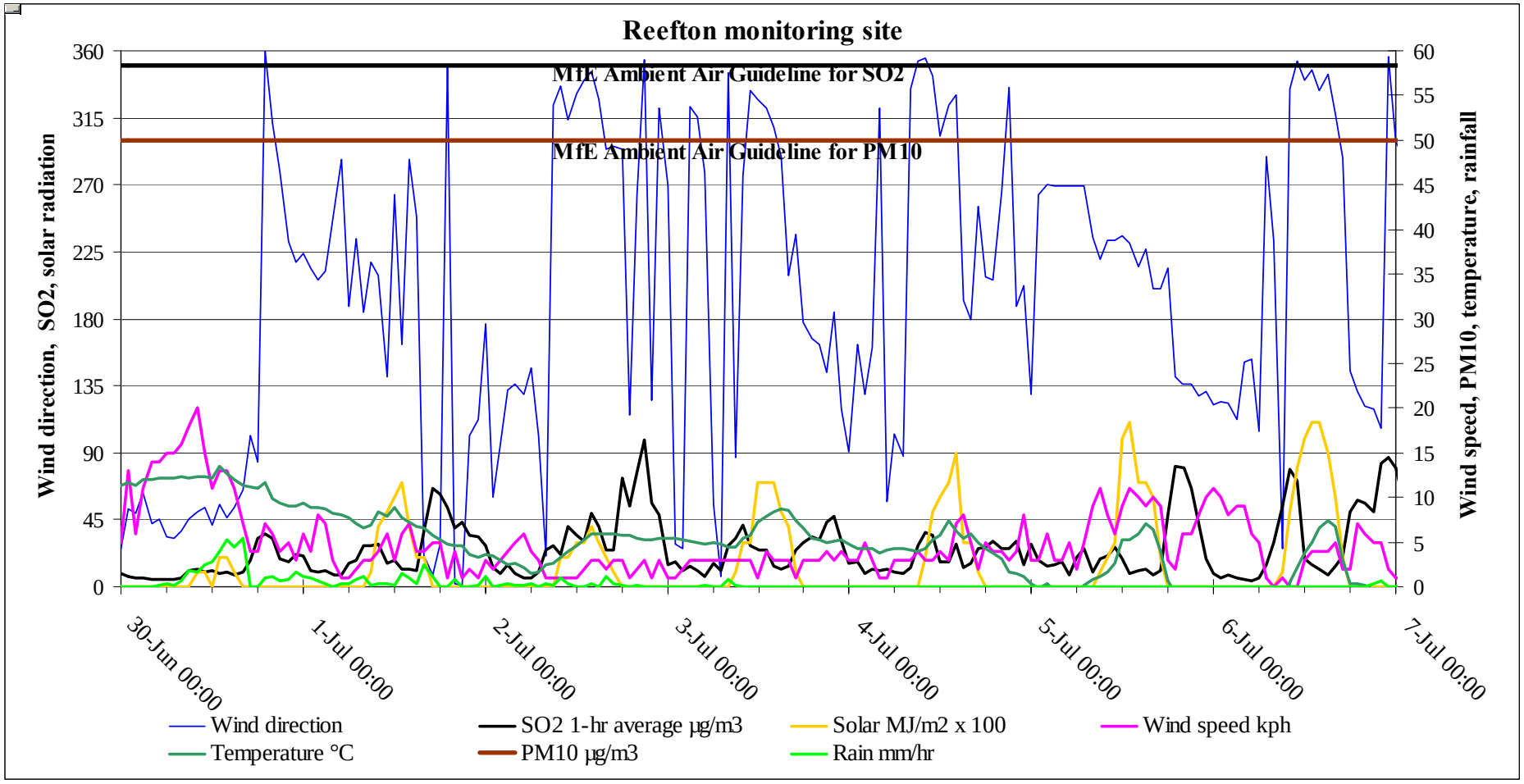
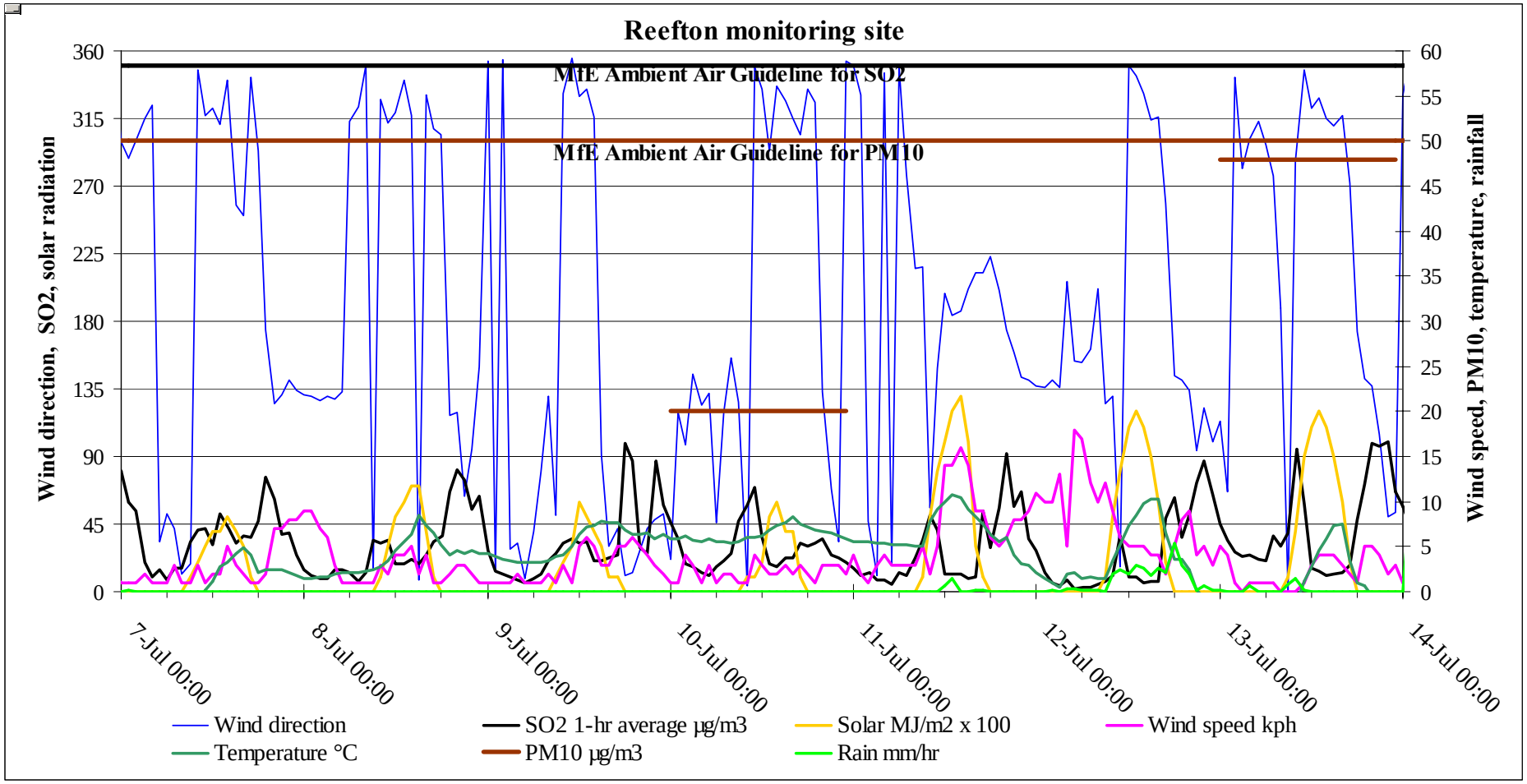
23-Jun 00:00
24-Jun 00:00
25-Jun 00:00
26-Jun 00:00
27-Jun 00:00
28-Jun 00:00
29-Jun 00:00
30-Jun 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr

Error! Reference source not found.. Cont'd. Monitoring and meteorological data for Reefton for 2003




Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
360
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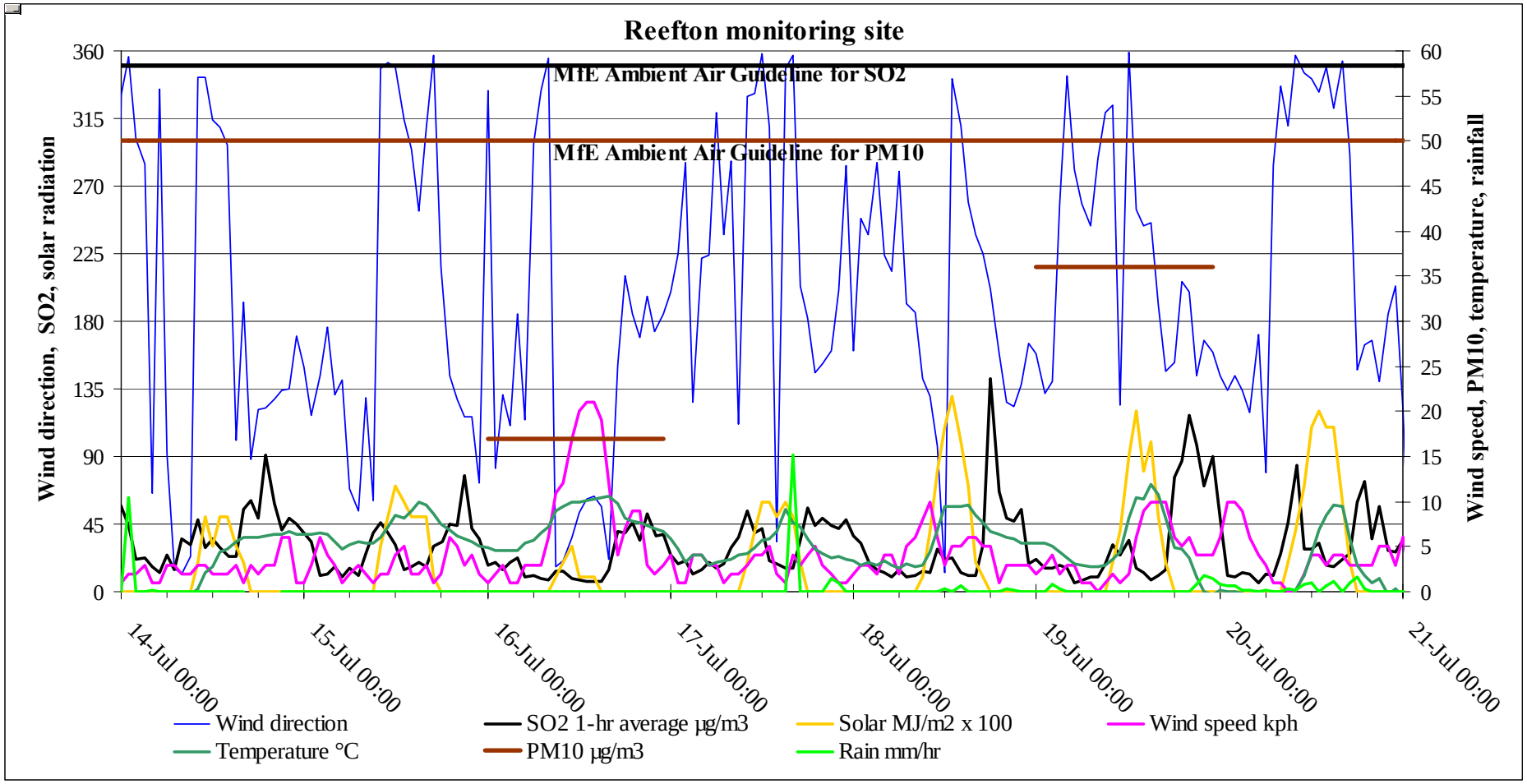
7-Jul 00:00
8-Jul 00:00
9-Jul 00:00
10-Jul 00:00
11-Jul 00:00
12-Jul 00:00
13-Jul 00:00
14-Jul 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
360
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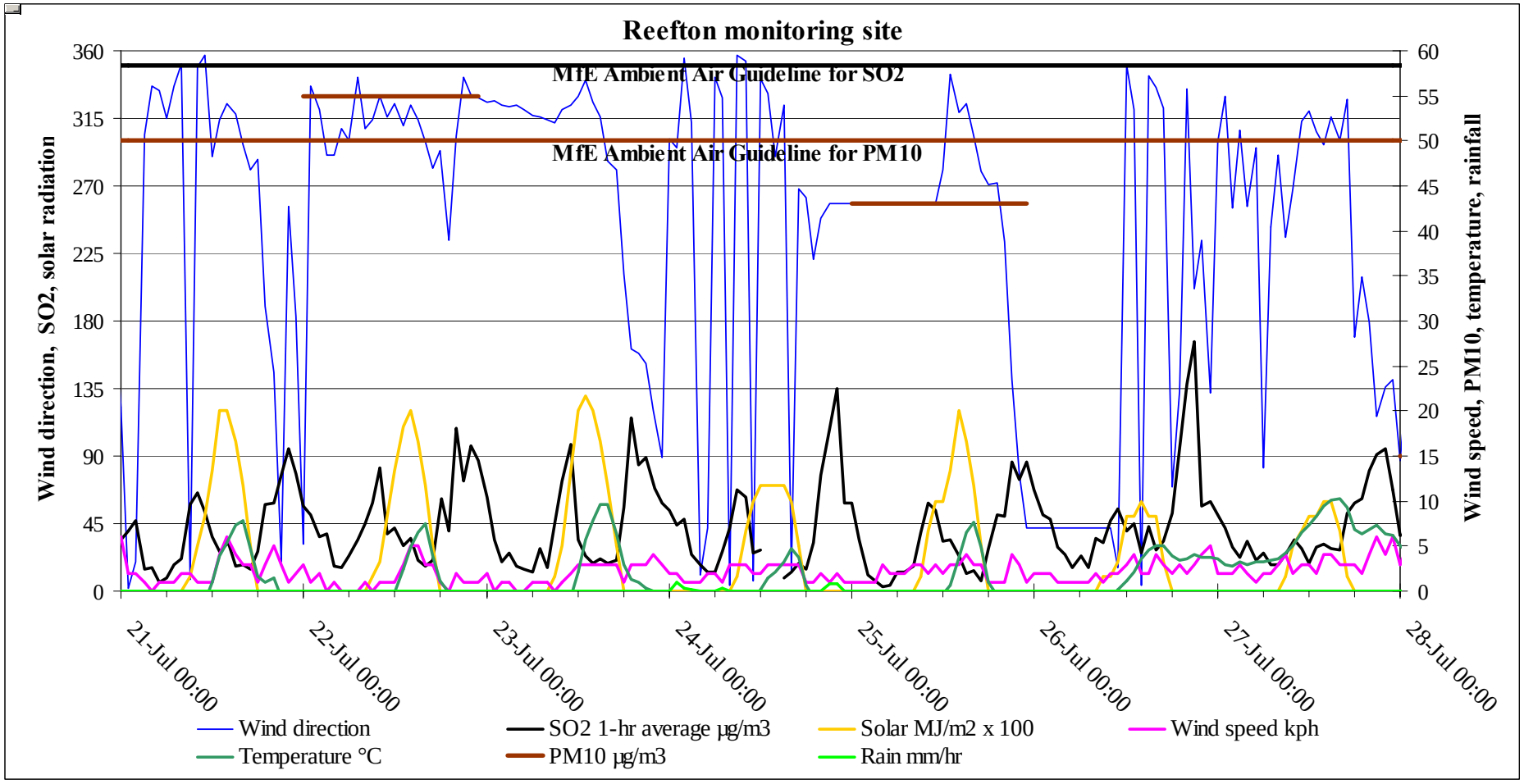
14-Jul 00:00
15-Jul 00:00
16-Jul 00:00
17-Jul 00:00
18-Jul 00:00
19-Jul 00:00
20-Jul 00:00
21-Jul 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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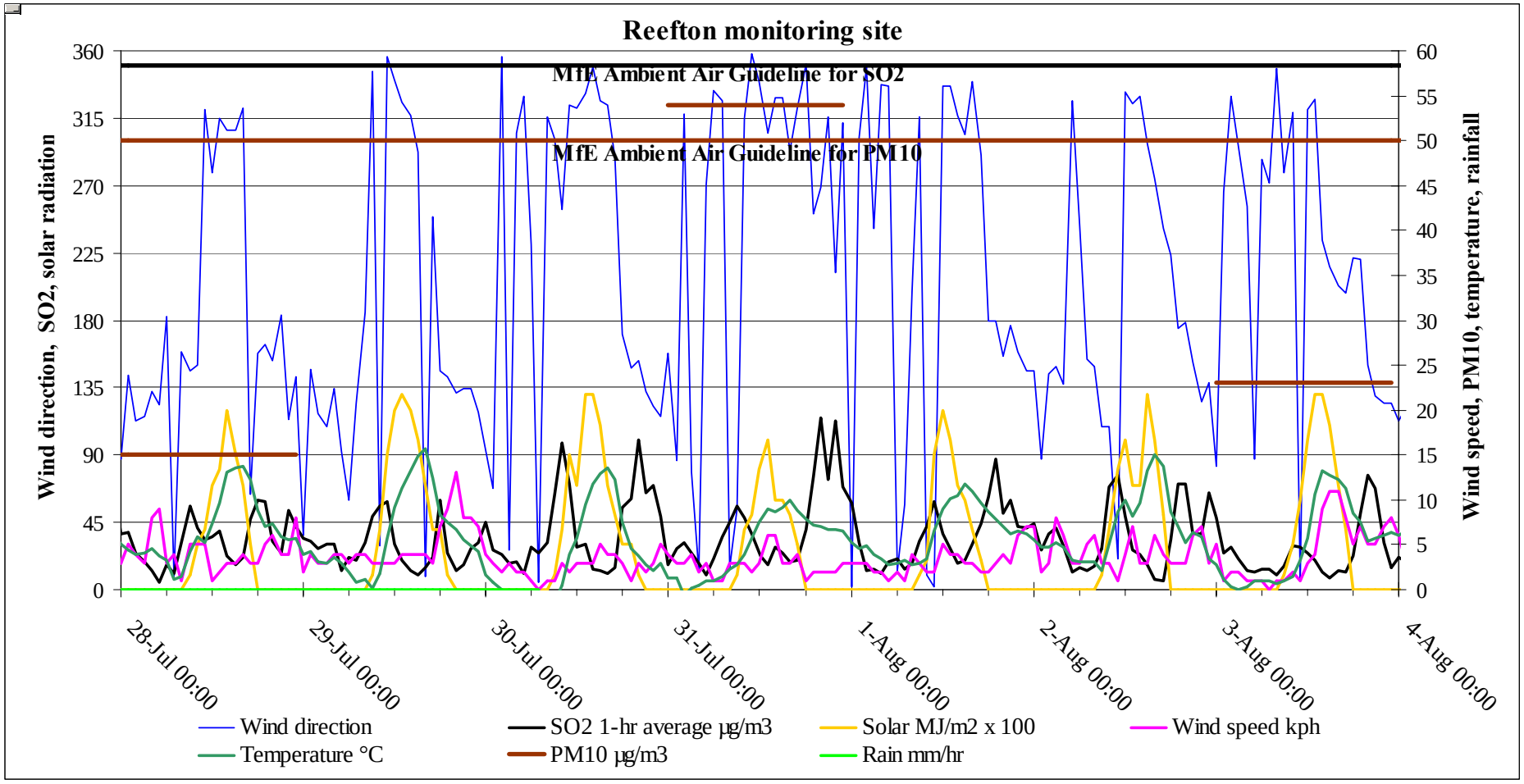
22-Jul 00:00
23-Jul 00:00
24-Jul 00:00
25-Jul 00:00
26-Jul 00:00
27-Jul 00:00
28-Jul 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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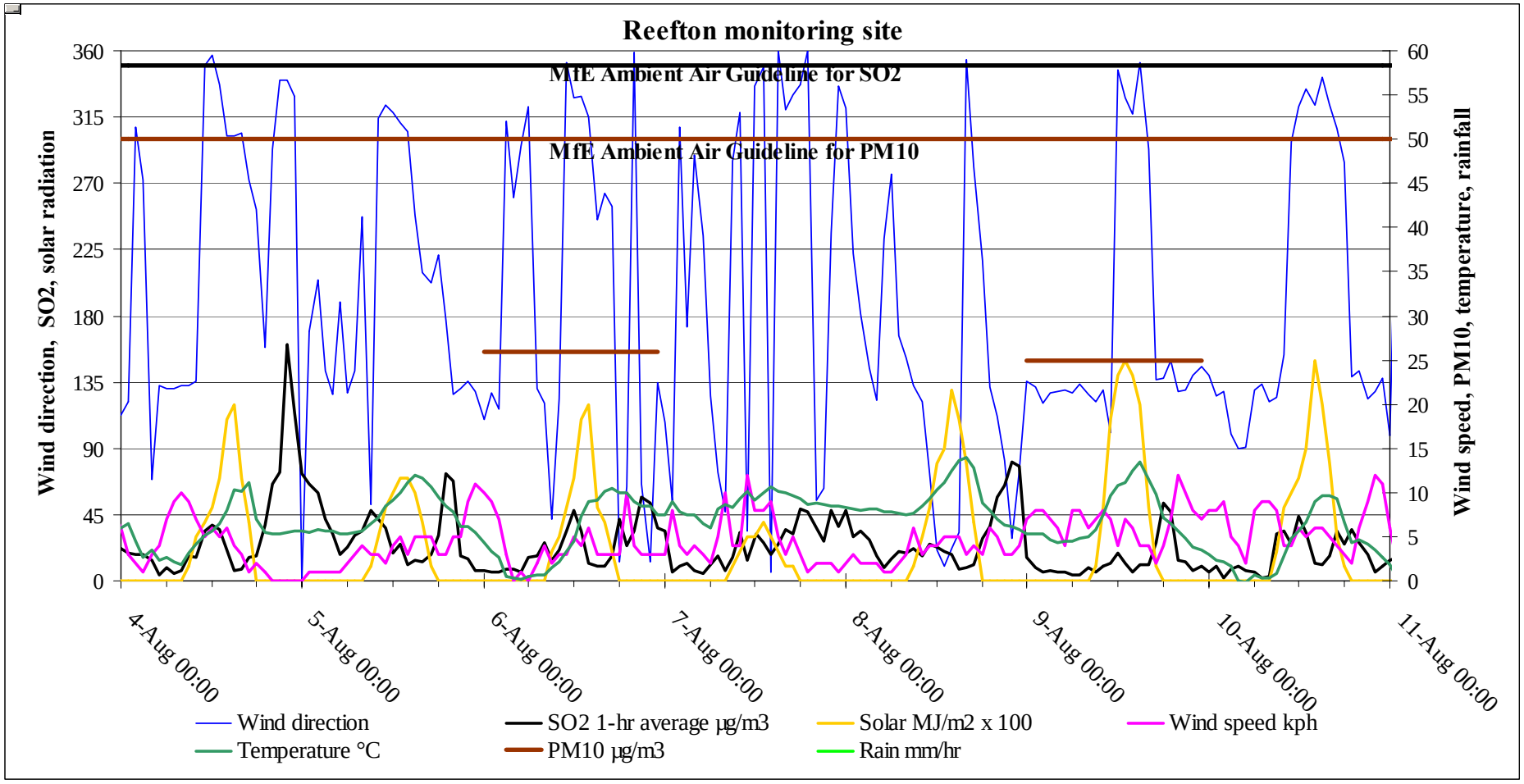
29-Jul 00:00
30-Jul 00:00
31-Jul 00:00
1-Aug 00:00
2-Aug 00:00
3-Aug 00:00
4-Aug 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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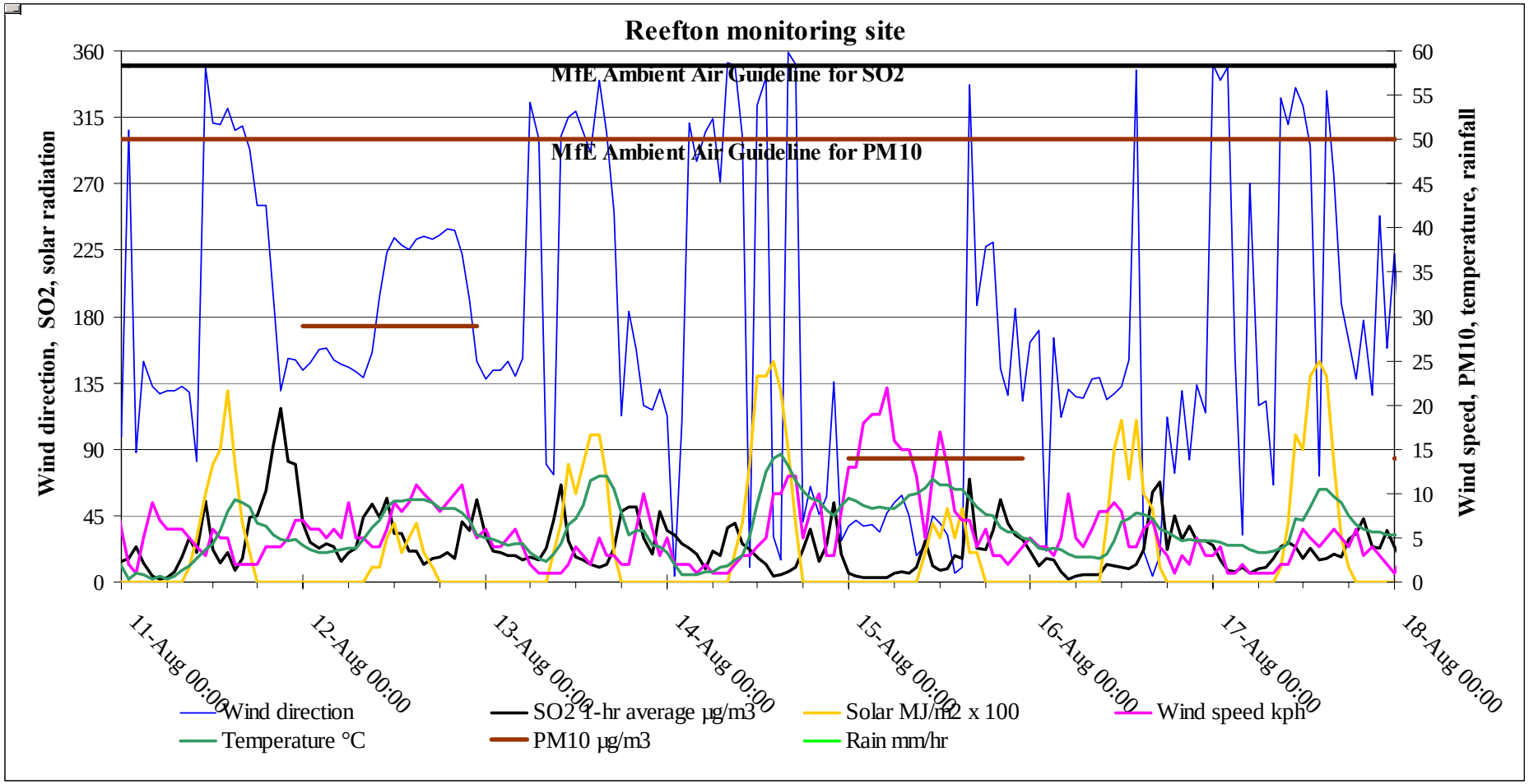
7-Aug 00:00
8-Aug 00:00
9-Aug 00:00
10-Aug 00:00
11-Aug 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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12-Aug 00:00
13-Aug 00:00
14-Aug 00:00
15-Aug 00:00
16-Aug 00:00
17-Aug 00:00
18-Aug 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr

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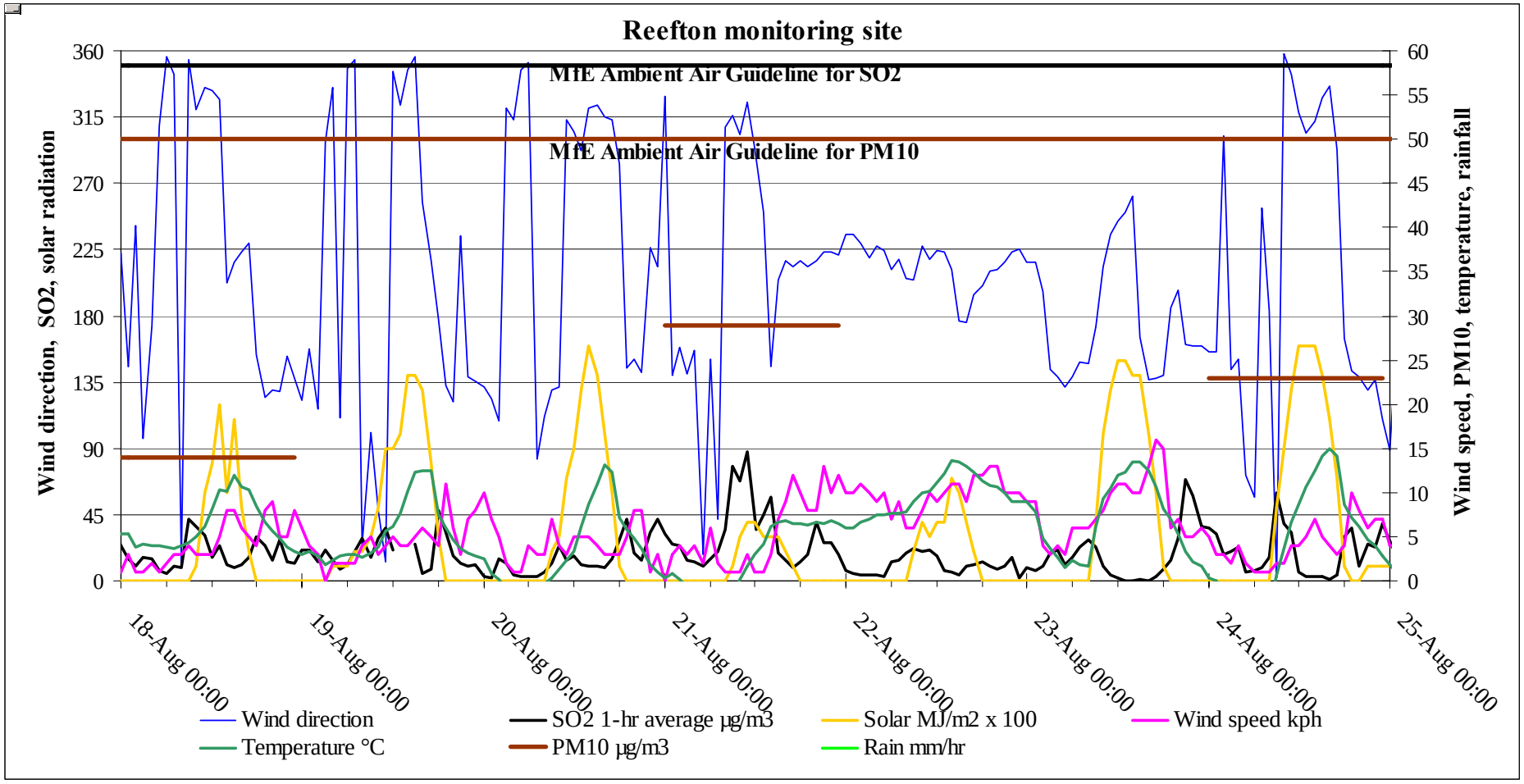

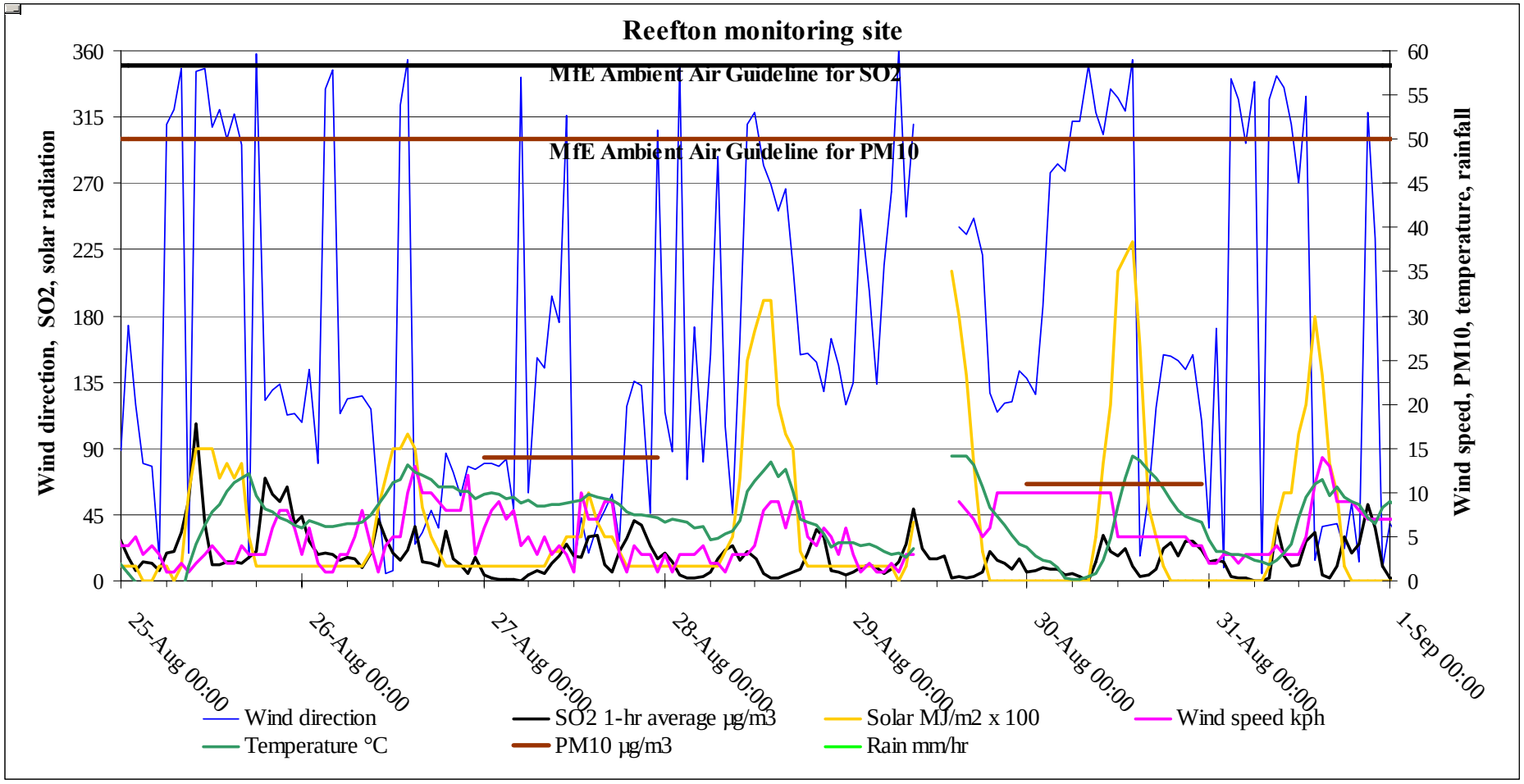
Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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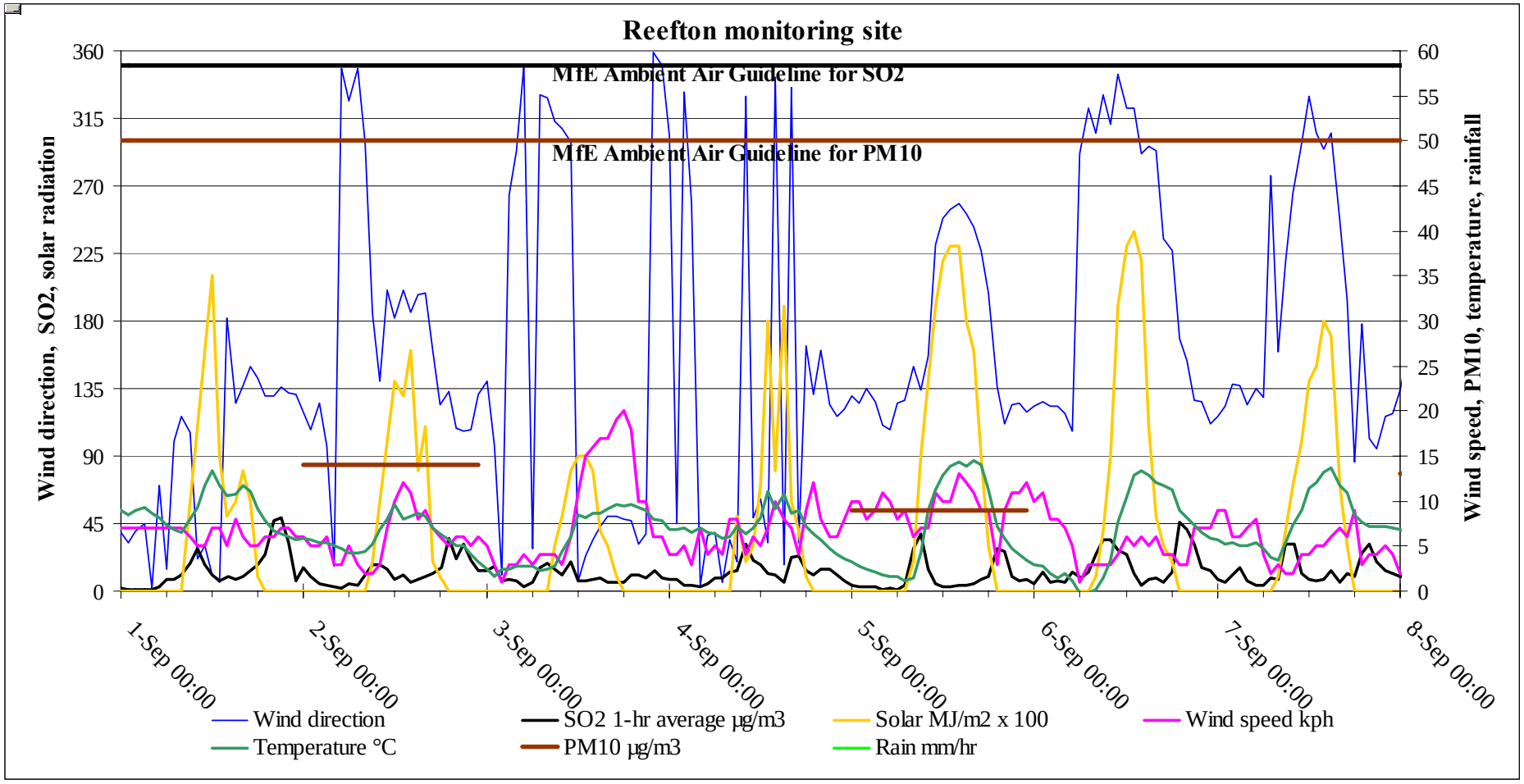
26-Aug 00:00
27-Aug 00:00
28-Aug 00:00
29-Aug 00:00
30-Aug 00:00
31-Aug 00:00
1-Sep 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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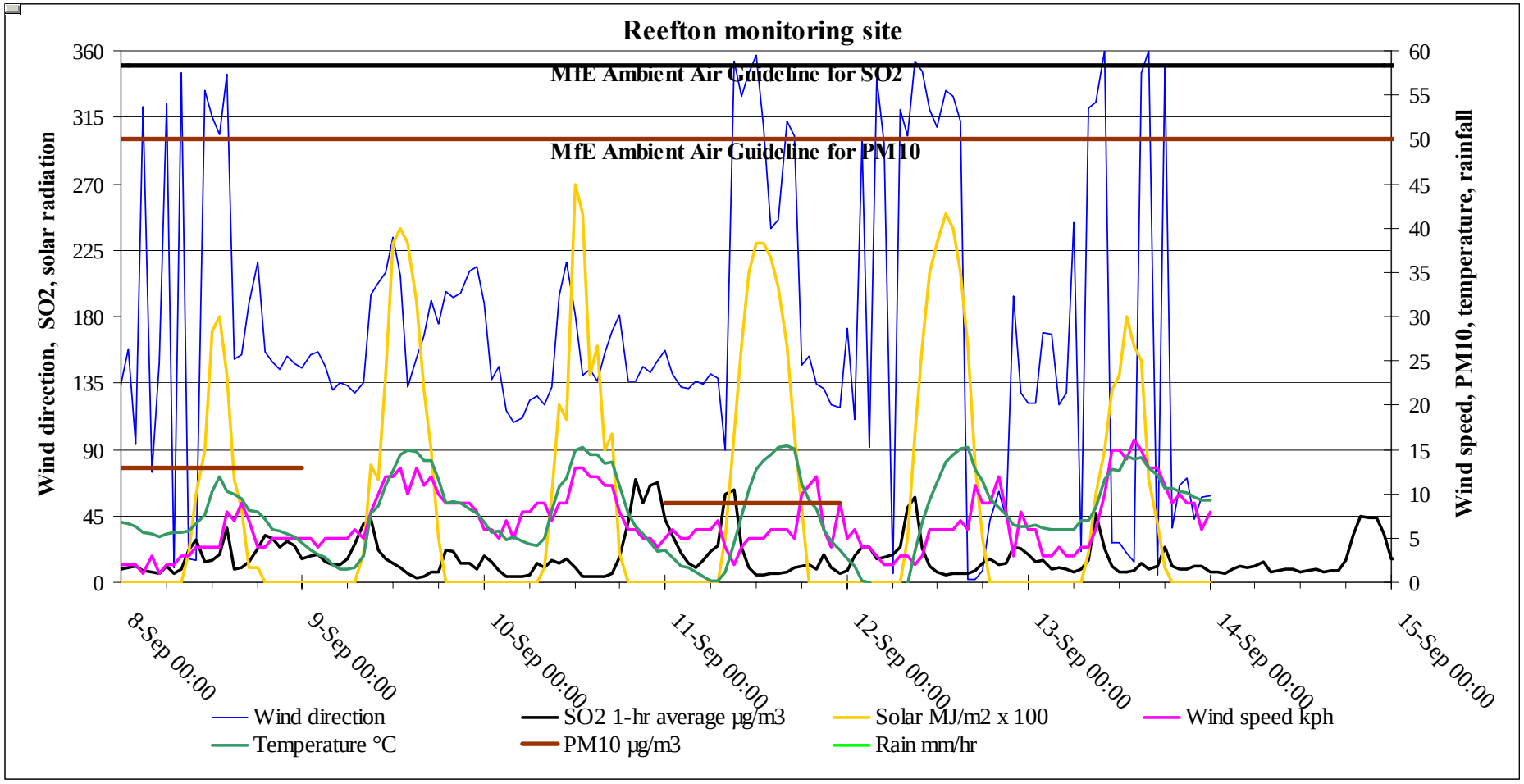
2-Sep 00:00
3-Sep 00:00
4-Sep 00:00
5-Sep 00:00
6-Sep 00:00
7-Sep 00:00
8-Sep 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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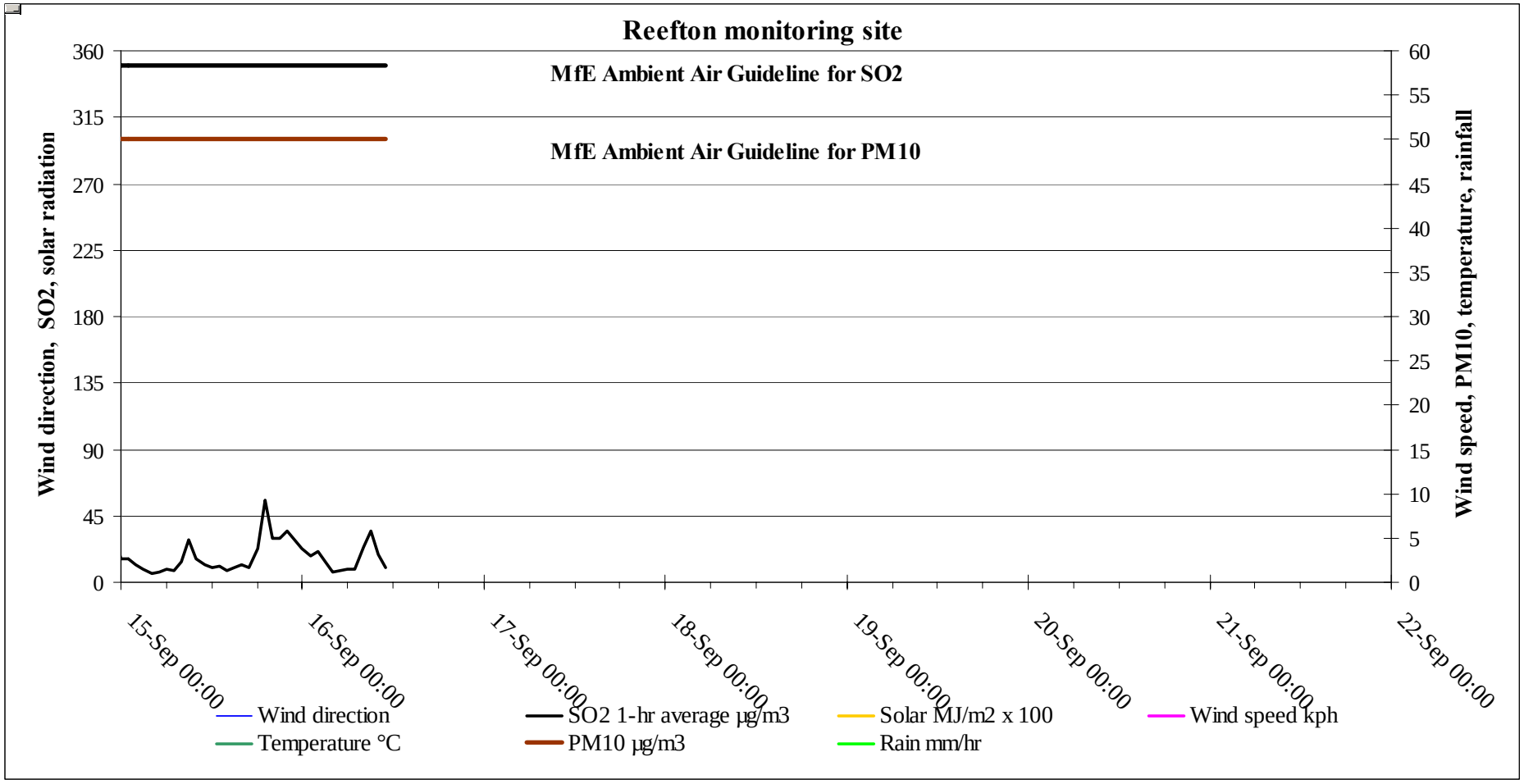
8-Sep 00:00
9-Sep 00:00
10-Sep 00:00
11-Sep 00:00
12-Sep 00:00
13-Sep 00:00
14-Sep 00:00
15-Sep 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr


Reefton monitoring site
MfE Ambient Air Guideline for SO2
MfE Ambient Air Guideline for PM10
Wind direction, SO2, solar radiation
Wind speed, PM10, temperature, rainfall
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15-Sep 00:00
16-Sep 00:00
17-Sep 00:00
18-Sep 00:00
19-Sep 00:00
20-Sep 00:00
21-Sep 00:00
22-Sep 00:00
Wind direction
SO2 1-hr average µg/m3
Solar MJ/m2 x 100
Wind speed kph
Temperature °C
PM10 µg/m3
Rain mm/hr

APPENDIX 6. PASSIVE SAMPLING DATA FOR BENZENE, TOLUENE, ETHYLBENZENE AND XYLENES

	Westport Derby St				Westport Council depot	Hokitika Westland High	Reefton Primary School	Reefton Bowling Club	Greymouth Palmerston St	Runanga Council Pool
From	31/05/2002	29/06/2002	31/05/2002	1/08/2002	29/05/2002	15/07/2002	31/05/2002	30/05/2002	30/05/2002	30/05/2002
To	29/06/2002	31/07/2002	3/09/2002	3/09/2002	3/09/2002	4/09/2002	30/08/2002	3/09/2002	3/09/2002	3/09/2002
Benzene	2.4	2.4	2.1	2.2	2	2.5	1.6	2.9	1.9	1.7
Toluene	4.5	5.5	*	*	*	*	*	*	*	*
Ethylbenzene	<2	<2	0.6	<2	<1	<1	<1	0.7	<1	<1
m+p-Xylene	2.3	2.5	2.3	2.4	1.3	1.9	1.3	2.5	1.5	1.1
o-Xylene	<2	<2	0.7	<2	<1	<1	<1	0.7	<1	<1
Xylenes	3.1	3.4	3.0	3.2	1.7	2.5	1.7	3.2	2.0	1.5

* All samplers removed at the end of August/beginning of September were contaminated by toluene in transit.

	Reefton Primary School				Reefton Bowling Club	Greymouth Palmerston St	Greymouth Bowling Club	Westport Derby St	Hokitika Westland High	Runanga Council Pool
From	30/05/2003	1/07/2003	30/07/2003	30/05/2003	30/05/2003	30/05/2003	30/05/2003	30/05/2003	31/05/2003	30/05/2003
To	1/07/2003	30/07/2003	31/08/2003	31/08/2003	31/08/2003	30/08/2003	30/08/2003	29/08/2003	29/08/2003	30/08/2003
Benzene	2.5	2.9	2.2	2.4	1.9	1.6	2.2	2.1	2.1	0 1.5
Toluene	3.5	4.3	3.6	3.3	2.4	2.2	4.1	4.4	2.7	0 1.8
Ethylbenzene	< 1.7	< 1.8	< 1.6	< 0.6	< 0.6	< 0.6	0.7	0.6	< 0.6	< 0.6
m+p-Xylene	1.9	2.0	1.7	1.8	1.4	1.0	2.5	2.4	1.4	0 1.0
o-Xylene	< 1.6	< 1.8	< 1.6	0.6	< 0.6	< 0.6	0.9	0.8	< 0.6	< 0.6
Xylenes	2.5	2.6	2.3	2.4	1.9	1.3	3.3	3.2	1.9	0 1.3

APPENDIX 7. PASSIVE SAMPLING RESULTS FOR SULPHUR DIOXIDE

Sulfure dioxide (SO2) - Measurement by Diffusive Samplers

West Coast Regional Council analytical method: ion chromatography SP10

Greymouth sampling method: diffusive sampler

Site	start		end		exposure	concentration SO2 [			**mean**	rel. SD
Code	date	time	date	time	time	code	value 1	value 2	ug/m³	%
Hokitika	29/05/2001	15:00	10/07/2001	12:55	1005.92	27	1.7		**1.7**	
Greymouth	29/05/2001	10:30	10/07/2001	17:30	1015.00	28	3.6		**3.6**	
Greymouth	29/05/2001	10:30	10/07/2001	17:30	1015.00	21	3.7		**3.7**	
Greymouth	29/05/2001	10:30	10/07/2001	17:30	1015.00	26	4.0		**4.0**	
Greymouth	29/05/2001	10:30	10/07/2001	17:30	1015.00	23	3.4		**3.4**	
Greymouth	29/05/2001	10:30	10/07/2001	17:30	1015.00	40	4.0		**4.0**	
Cobden	29/05/2001	11:00	11/07/2001	14:55	1035.92	22	3.6		**3.6**	
Rununga	29/05/2001	11:30	11/07/2001	13:20	1033.83	19	9.3		**9.3**	
Reefton	30/05/2001	13:20	13/07/2001	16:10	1058.83	32	28.9		**28.9**	
Hokitika	10/07/2001	13:00	16/08/2001	17:00	892.00	37	1.9		**1.9**	
Greymouth	10/07/2001	17:40	17/08/2001	08:40	903.00	34	4.6	3.9	**4.2**	11.9
Cobden	13/07/2001	17:00	17/08/2001	10:30	833.50	24	2.5		**2.5**	
Rununga	13/07/2001	15:20	17/08/2001	10:55	835.58	31	2.5		**2.5**	
Reefton	13/07/2001	16:15	17/08/2001	15:15	839.00	17	18.7		**18.7**	
Westport	13/07/2001	13:40	17/08/2001	13:15	839.58	36	29.6		**29.6**	
Hokitika	16/08/2001	17:05	20/09/2001	09:45	832.67	42	11.1		**11.1**	
Greymouth	17/08/2001	08:50	18/09/2001	08:45	767.92	20	3.1	3.1	**3.1**	0.2
Cobden	17/08/2001	10:30	18/09/2001	12:20	769.83	41	1.0		**1.0**	
Rununga	17/08/2001	11:00	18/09/2001	12:35	769.58	39	1.7		**1.7**	
Reefton	17/08/2001	15:15	18/09/2001	15:45	768.50	29	11.6		**11.6**	
Westport	17/08/2001	13:20	18/09/2001	14:05	768.75	18	18.3		**18.3**	

Arrival date: 7/10/2001 detection limit 0.7 µg/m3 14 days

Date of analysis: 17/10/2001 blank 0.26 µg/m3

sampling rate 16.5 ml/min Uncertainty on request

Period 29/05/2001 til 18/09/2001

The values are representativ for the immediate measuring site only. Conclusions to remote points with reservation.

These data are part of a long-term measuring series and it is not allowed to publish partly without permission of Passam Ltd.

Sulfure dioxide (SO2) - Measurement by Diffusive Samplers

sampling method: diffusive sampler analytical method: ion chromatography SP10

K2 Environmental Ltd

Christchurch Date of analysis: 23/09/2002 sampling rate 16.5 ml/min

Site	start		end		exposure	concentration SO2 [ug/m³]				**mean**	rel. SD
Code NZ	date	time	date	time	time	code	value 1	value 2	value 3	ug/m³	%
Greymouth Site	30/05/2002	14:45	1/07/2002	16:40	769.92	DO37 111	1.3			**1.3**	
Reefton Site 1	30/05/2002	13:00	1/07/2002	11:00	766.00	-96	8.3			**8.3**	
Reefton Site 2	30/05/2002	13:30	1/07/2002	11:20	765.83	-93	22.5			**22.5**	
Runanga Site	30/05/2002	16:12	1/07/2002	15:50	767.63	-110	1.6			**1.6**	
Westport Site 1	31/05/2002	08:00	29/06/2002	12:15	700.25	-105	19.0	18.7		**18.8**	1.0
Westport Site 2	31/05/2002	07:45	29/06/2002	11:25	699.67	-98	17.1			**17.1**	
Greymouth Site	1/07/2002	16:40	1/08/2002	14:20	741.67	-90	3.2			**3.2**	
Reefton Site 1	1/07/2002	11:00	31/07/2002	10:00	719.00	-97	24.1			**24.1**	
Reefton Site 2	1/07/2002	11:20	31/07/2002	10:40	719.33	-94	22.4			**22.4**	
Runanga Site	1/07/2002	15:50	1/08/2002	12:50	741.00	-109	2.3			**2.3**	
Westport Site 1	29/06/2002	12:15	31/07/2002	12:00	767.75	-101	30.6	29.0		**29.8**	3.8
Westport Site 2	30/06/2002	12:00	31/07/2002	12:00	744.00	-103	22.8			**22.8**	
Hokitika Site	3/07/2002	07:25	1/08/2002	17:45	706.33	-92	4.0			**4.0**	
Greymouth Site	1/08/2002	14:20	3/09/2002	12:00	789.67	-113	4.1			**4.1**	
Reefton Site 1	31/07/2002	10:00	30/08/2002	09:45	719.75	-99	17.5			**17.5**	
Reefton Site 2	31/07/2002	10:40	30/08/2002	10:00	719.33	-95	13.3			**13.3**	
Runanga Site	1/08/2002	12:50	3/09/2002	11:45	790.92	-108	1.9			**1.9**	
Westport Site 1	1/08/2002	09:50	3/09/2002	08:30	790.67	-107	13.8			**13.8**	
Westport Site 1	31/05/2002	08:00	3/09/2002	08:30	2280.50	-106	10.5			**10.5**	
Westport Site 2	1/08/2002	10:30	3/09/2002	08:45	790.25	-104	23.1			**23.1**	
Hokitika Site	1/08/2002	17:45	4/09/2002	07:23	805.63	-112	1.1			**1.1**	

Arrival date: 19.09.02 detection limit 0.7 ug/m3 14 days

Uncertainty on request

The values are representativ for the immediate measuring site only. Conclusions to remote points with reservation.

These data are part of a long-term measuring serie and it is not allowed to publish partly without permission of passam Ltd.

Sulfure dioxide (SO2) - Measurement by Diffusive Samplers

sampling method: diffusive sampler analytical method: ion chromatography SP10

West Coast Regional Council Ambient **period**

Date of analysis: 30/09/2003 sampling rate 11.9 ml/min 20°

Site	start		end		exposure	concentration SO2 [ug/m³]				**mean**	rel. SD
Code NDZ	date	time	date	time	time	code	value 1	value 2	value 3	ug/m³	%
Greymouth 1	30/05/2003	16:00	2/07/2003	11:30	787.50	69	2.5			**2.5**	
Greymouth 1	2/07/2003	11:30	30/07/2003	16:30	677.00	59	3.7			**3.7**	
Greymouth 1	30/07/2003	16:30	30/08/2003	15:35	743.08	62	3.1			**3.1**	
Greymouth 2	30/05/2003	15:45	2/07/2003	11:50	788.08	66	2.0			**2.0**	
Greymouth 2	2/07/2003	11:50	30/07/2003	16:20	676.50	56	2.5			**2.5**	
Greymouth 2	30/07/2003	16:20	30/08/2003	15:31	743.18	61	0.6			**0.6**	
Reefton 1	30/05/2003	10:00	1/07/2003	09:30	767.50	71	24.8	19.2		**22.0**	17.9
Reefton 1	1/07/2003	09:30	30/07/2003	12:30	699.00	77	29.3	29.3		**29.3**	0.1
Reefton 1	30/07/2003	12:30	31/08/2003	16:30	772.00	73	18.6	18.0		**18.3**	2.4
Reefton 2	30/05/2003	10:30	1/07/2003	10:00	767.50	78	19.7			**19.7**	
Reefton 2	1/07/2003	10:00	30/07/2003	12:30	698.50	79	24.5			**24.5**	
Reefton 2	30/07/2003	12:30	31/08/2003	16:45	772.25	74	16.8			**16.8**	
Hokitika	31/05/2003	13:05	27/06/2003	17:00	651.92	63	1.1			**1.1**	
Hokitika	27/06/2003	17:00	26/07/2003	13:05	692.08	57	1.4			**1.4**	
Hokitika	26/07/2003	13:55	29/08/2003	17:30	819.58	58	1.6			**1.6**	
Westport	30/05/2003	13:30	30/06/2003	15:30	746.00	55	27.9			**27.9**	
Westport	30/06/2003	15:30	30/07/2003	15:30	720.00	60	36.3			**36.3**	
Westport	30/07/2003	15:30	29/08/2003	15:30	720.00	65	30.6			**30.6**	
Runanga	30/05/2003	15:10	2/07/2003	12:00	788.83	67	1.8			**1.8**	
Runanga	30/07/2003	16:40	30/08/2003	17:00	744.33	64	2.3			**2.3**	
Runanga	2/07/2003	12:00	30/07/2003	16:40	676.67	68	2.2			**2.2**	
		Travelblank 100403									

Arrival date: 25.09.03 detection limit 0.4 ug/m³ 14 days

uncertainty www.passam.ch/products.htm

The values are representativ for the immediate measuring site only. Conclusions to remote points with reservation.

APPENDIX 8 BACKGROUND INFORMATION AND CALCULATION DETAILS FOR THE RISK ASSESSMENT FOR PM_{10}.

The approached used in this analysis is based upon the methodology developed by Künzli et al. (1999) to evaluate mortality and morbidity rates in Austria, France, and Switzerland associated with traffic related air pollution. This method has subsequently been used by a Ministry of Transport-funded evaluation of potential health impact of vehicle emissions in New Zealand (Fisher et al., 2002).

8.4 BACKGROUND INFORMATION

Most of evidence of health effect of air pollutants has come from epidemiological studies. The association of airborne suspended particle concentration with reported morbidly and mortality rates has been increasingly well documented in American and too a lesser extent European cities. Generally such epidemiological studies can be classified as either short-term time-series studies or long term cohort studies. Short term studies associated measured daily air pollutant concentrations against daily health end points. For particulates, common end points are daily rates of hospitalisation, emergency room visits, mortality associated with exacerbations of cardiac or respiratory diseases, increased respiratory symptoms, and reductions in levels of pulmonary function (HEI, 2001).

Although, these studies have generally indicated a potential causal relation between urban air pollutant levels and increases in mortality, a number of methodological weaknesses have been associated with the approach. Time series studies also do not provide a complete assessment of the extent to which particulate material may impact upon health of the public as they cannot determine the degree of life span reduction. For instance, if the increases in mortality are mainly among the old and frail, shortening their life span by a few days, then it is possible to argue that the public health impact is not that large. If on the other hand increases in mortality reflect larger reductions in life expectancy throughout the community then the public health impact is more significant (HEI, 2001).

Cohort studies, in which large populations are followed for years, can provide the most complete estimates of both numbers of deaths and average reductions in lifespan attributable to air pollution. Such studies include not only those whose deaths were advanced by recent exposure to air pollution, but also those who died from chronic disease caused by long-term exposure (WHO, 2000).

Two recent prospective cohort studies, the Harvard Six Cities Study (as reported in Dockery et al. 1993) and the American Cancer Society (ACS) Study (as reported in Pope et al. 1995) provided some of the most robust quantitative evidence of the increase in average mortality rates associated with an increase in the ambient concentrations of fine and inhalable particles.

The Harvard Six Cities followed groups of 8,111 adult subjects in northwest and mid west American cities for 14-16 years. The larger American Cancer Society 552,138 adult subjects in 154 US cities beginning in 1982 and ending in 1989. In both studies higher concentrations of particles were found to be associated with increased mortality. The ACS study observed an average 6.9% increase in overall mortality rates with every $10\mu g/m^3$ increase in fine

particles ($PM_{2.5}$) (95% confidence interval of 3.7% to 10.6%). The results from the smaller Six City Study were comparable although, on average, higher. The average increase in mortality per 10µg/m^3 of $PM_{2.5}$ was estimated to be 14.0% (95% confidence interval of 4.3% to 25.3%). Both studies controlled for confounding factors such as social and smoking status (Dockery et al, 1993; Pope et al, 1995).

The results of these studies have under gone intense scrutiny since the US EPA used them to support new Ambient Air Quality Standards for fine particles (particles less than 2.5µm in median aerodynamic diameter ($PM_{2.5}$)) and to maintain the standards for particles less than 10µm in median aerodynamic diameter (PM_{10}) already in effect. To address the public controversy an independent reanalysis of the results was commission by Harvard University and the ACS.

The comprehensive reanalysis of the results by Health Effects Institute (HEI), an independent research organisation funded by the USEPA and industry, confirmed the results as the original studies. Relatively robust associations of mortality with fine particles, sulfate, and sulphur dioxide were maintained even when these relationships were tested using a variety of statistical techniques and other confounding variables considered. The further reanalysis of the data also suggested a possible linkage of mortality with education, location, and ambient sulphur dioxide concentrations. The HEI re-analysis team concluded that increased relative risk of "mortality may be attributed to more than one component of the complex mix of ambient air pollutants in urban areas in the United States".

Künzli et al. (2000) used the results from both the ACS and Harvard Six Cities studies to estimate mortality rates associated with ambient PM_{10} levels in Austria, France, and Switzerland. Based upon the studies Künzli et al. estimated a 4.3% increase in total mortality with every 10µg/m^3 increment in PM_{10} for adults over the age of 30 (with a 95% confidence interval of 2.6% to 6.1%). The joint estimate of relative increases in mortality per 10µg/m3 PM_{10} increment was dominated by the large cohort of the American Cancer Society (ACS) (Pope et al, 1995). It should be noted that Pope et al. (1995) used PM2.5 as an indicator of particulate levels and not PM_{10}. When estimating risk ratios it would appear than Künzli et al. (1999) converted $PM_{2.5}$ concentration to PM_{10} by dividing the concentration by a factor of 0.6, however the documentation in unclear in this respect.

In addition to estimating relative risks for total mortalities, Künzli et al. (2000) estimated the relative risk[1] of other air pollutant-related health outcomes based on a meta-analysis of published epidemiology studies. These relative risks are present in Table 19.

[1] The Relative Risk (RR) is a common measure of effect used to report results in epidemiologic studies. The RR is the ratio of the risk to experience some health outcome among an exposed population divided by the risk for the same outcome among unexposed. If the exposed and unexposed have the same risk for a particular health outcome (i.e., the exposure has no health impact), the RR equals one (RR = 1).

Table 19. Künzli et al. (2000) effect relative risk per 10µg/m³ PM_{10} Health outcomes

Health outcome	Effect estimate relative risk (95% CI)
Total mortality (adults >30 years, excluding violent death)	1·043 (1·026-1·061)
Respiratory hospital admission (all ages)	1·013 (1·001-1·025)
Cardiovascular hospital admission (all ages)	1·013 (1·007-1·019)
Chronic-bronchitis incidence (adults ≥25 years)	1·098 (1·009-1·194)
Bronchitis episodes (children <15 years)	1·306 (1·135-1·502)
Restricted activity days (adults ≥20 year)*	1·094 (1·079-1·502)
Asthma attacks t	1·044 (1·027-1·062)
Asthma attacks (adults ≥t)	1·039 (1·019-1·059)

*Total person-days per year. t Total person-days per year with asthma attacks.

Due to the variety of compounds and sizes that the PM_{10} classification incorporates, increasing attention is now being placed on further characterising the public health risk of airborne particles with respect to composition and distribution, and potential synergistic health effect with other air pollutions (MfE, 2003).

8.5 ASSESSMENT METHODOLOGY.

The West Coast health impact assessment has been based on the long-term effect of ambient average annual PM_{10} concentrations on mortality rates in the adult population. The estimated impact includes several processes covering acute as well as cumulative chronic effects.

The methodology used by Künzli et al. (2000) to assess health outcomes in Austria, France, and Switzerland has been used in this assessment to estimate total mortality rates associated with PM_{10} levels in the West Coast urban centres of Greymouth (including Runanaga), Hokitika, Reefton and Westport. A similar methodological approached has also been applied by Fisher et al. (2002) to estimate the overall mortality rates in New Zealand associated with motor vehicle emissions.

In the analysis, mortality rates have been calculated for the 2001 base year since this is the most recent year for which national census data is available, and it coincides with the West Coast ambient air monitoring programme.

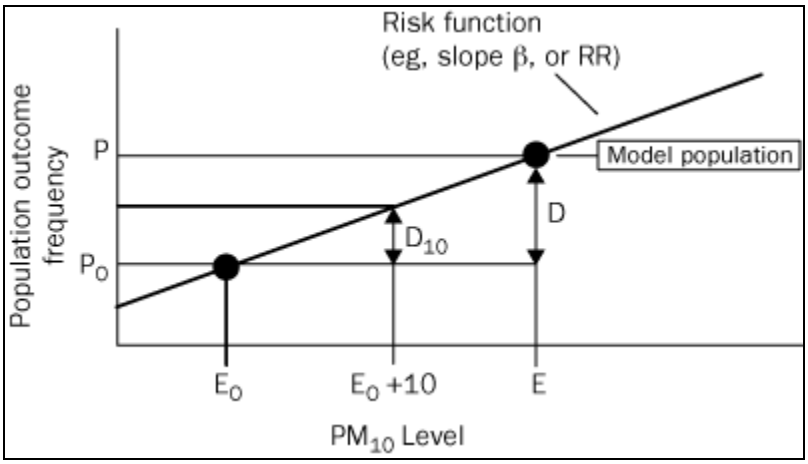
Künzli et al. methodology is based on a dose-response function, based on the epidemiological studies, that can is used to predict health outcomes (in this instance total mortality) with increasing pollutant exposure levels. Total mortality rates are assumed to increase linearly with increasing annual average concentration above a threshold. A 4.3% increase in mortality per 10µg/m^3 PM_{10} has been used in the analysis, based on Künzli et al. (2000) meta-analysis. This figure was also used by Fisher et al. when assessing national mortality rates resulting from motor vehicle emissions.

The dose-response function assumes a threshold PM_{10} concentration below which no mortalities are attributed to ambient PM_{10} levels. Künzli et al. selected a threshold concentration of 7.5µg/m^3 based on 'lowest assessed level' that they in found in the epidemiological literature. At the time of the study the long-term impact of particulates at annual average concentrations below 5µg/m^3 to 10µg/m^3 had not been evaluated. Künzli et al. (1999) adopted an 'at least' approach throughout their analysis, consistently selecting methodological assumptions such that predicted impacts can be taken to be the minimum attributable to air pollution.

Künzli et al. did note that predicted health outcomes were highly sensitive to the selected threshold value, however. Varying the assumed threshold concentration between 0µg/m^3 and 15µg/m^3 respectively (corresponding to Swiss public-health exposure levels over 15µg/m^3) increased and decreased predicted mortality rates by 54%. Fisher et al. also provided an initial evaluation of the sensitivity of the predicted traffic mortality rates in New Zealand by considering threshold concentrations of 0µg/m^3, 5µg/m^3 and 10µg/m^3 in addition to the selected 7.5µg/m^3. The same sensitivity of predicted mortality rates to the selected threshold concentration has also been considered in this analysis.

The Künzli et al. (1999) dose-exposure function used to estimate air pollutant related mortalities is shown in Figure 21. In the figure 'E_0' is the threshold concentration, 'E' is the concentration to which the population is exposed, 'P_0' is the frequency of mortalities at threshold concentration not attributable to air pollutant levels, 'P' is the total frequency of mortalities attributable to ambient PM_{10} concentrations ('E') and those that would have occurred in a the absence of air pollutants. 'D' represents the incremental increase in mortality rates associated with PM_{10} levels. The slope of the function is the Relative Risk (RR) of PM_{10}-attributed mortalities in the population, in this instance 1.043 per 10µg/m^3.

Figure 21. Dose response function (Künzli et al. 199)



The analysis considers only PM_{10}-related mortalities in Greymouth, Hokitika Reefton and Westport. A reliable indication of air pollution level during winter is available for Greymouth, Reefton and Westport from the present monitoring programme and a range of estimates has been used for Hokitika. Potential health risks associated with long-term expose to PM_{10} is also likely to be greatest in these townships due to the expected higher typical

ambient air pollutant levels and population density than elsewhere on the West Coast. Combined, these towns represent 56% of the West Coast population age over 30 (Statistics NZ 2001 Census).

8.6 CALCULATION PROCEDURE

Estimation of the PM_{10}-related mortalities in West Coast towns incorporated the calculation steps outlined in Section 6.3. However, because some of the steps outlined in Section 6.3 are combined in the actual calculation, it is not convenient to describe the calculation precisely in terms of those steps. The calculation procedure is conveniently considered in terms of three steps here:

- Estimation of annual average PM_{10} concentrations;
- Estimation of baseline mortality rates and the mortality per 1000 people attributable to 10 $\mu g/m^3$ PM_{10}
- Estimation of the annual number of deaths attributable to PM_{10} exposure in the West Coast towns, based on their populations and the measured or estimated PM_{10} levels.

8.6.1 Estimation of annual average PM_{10} concentrations.

Section 6.3.1 in the main report presents the estimation of PM_{10} concentrations for the West Coast towns.

Typical national annual PM_{10} exposure levels have been based on the Fisher et al. (2002) estimation of typical air pollutant levels for 62 New Zealand urban areas. Typical average PM_{10} concentrations for each of the areas were estimated using a combination of;

- Ambient air PM_{10} monitoring data (used in preference to other methods)
- Results from PM_{10} air shed modelling conducted for Auckland, Christchurch and Hamilton
- Derived exposure limits based upon population density and motor vehicle use.

The boundaries of each of the urban areas and usual residential population within them were derived using the Statistic New Zealand 2001 Census data. Based on the compilation of air quality and population data, the typical PM_{10} exposure for the population over 30 years old is estimated to be 19$\mu g/m^3$ in urban New Zealand.

8.6.2 Calculation of Baseline Mortality Rates.

The baseline mortality is an estimate of the total number of non-sudden death (eg accidental) mortalities in the population aged over 30 years that is not attributable to PM_{10} level.

This step calculates the frequency of mortalities in the community that are not caused by air pollution – the baseline mortality rate (Po). The expression used to calculate calculation is presented below.

$$Po = \frac{Pe}{1 + \left[(RR - 1)(E - B) / 10 \right]}$$

Where:

Po = The baseline frequency of non-accidental or sudden death mortalities not associated with PM_{10} levels for individuals aged over 30 years

Pe = The observed frequency of non-accidental or sudden death mortalities in the community for individuals aged over 30 years

RR = Relative Risk of an increase in mortality rates with each 10µg/m^3 increment in PM_{10} levels. In this instance a value of 1.043 (1.026, 1.062) is used in the analysis

E = Estimated level of PM_{10} exposure that the population over 30 years is typically exposed to.

B = Threshold annual average PM_{10} concentrations below which PM_{10} is assumed to not increase the risk of mortalities

The corresponding increase in mortality with each 10 µg/m3 incremental increase in PM_{10} levels per million people is calculated using the following formula.

$$D_{10} = 1'000'000 * F_p * P_0 * (RR-1)$$

Where:

D_{10} = Estimated Incremental increase in mortalities per 1,000,000 people associated with each 10µg/m^3 increment in average annual PM_{10} concentrations

F_p = Fraction of the population exposed. In this instance it is F_p is assumed to be 1.

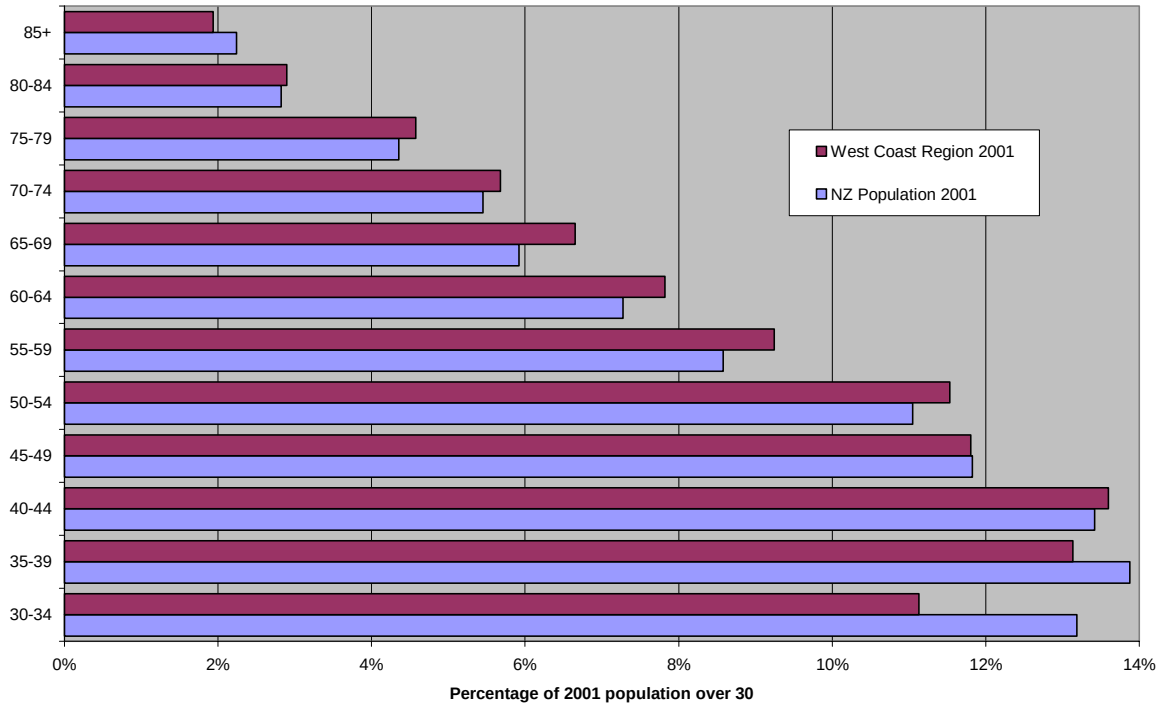
The calculation of the baseline mortality rates requires the choice of populations for which observed mortality rates (Pe) and typical PM_{10} exposure values could be obtained or derived. The chosen areas also need to be representative of the population within the West Coast townships considered.

Neither of the epidemiological studies examining long-term effects of particulate air pollution (Dockery et al. (1993), Pope et al, (1995)) examined how the mortality rates attributable to PM_{10} exposure vary between age groups. The importance of choosing the appropriate population for which the observed mortality rates are used arises because the calculation of PM_{10}-related mortality, in simple terms, multiplies the baseline mortality by the relative risk factor. Higher observed mortality rates give higher baseline mortality rates and therefore higher mortality attributable to PM_{10}. Observed mortality rates are higher for older age groups, and since the age distribution on the West Coast includes a higher proportion of older people (see Figure 22), higher observed mortality rates are expected for the West Coast than for the New Zealand population as a whole.

Although calculations based on the West Coast population should, within the uncertainties inherent in these estimates, give the more reliable estimates, it was decided to construct two

baseline mortalities rates, $Po_{national}$ and $Po_{regional}$, using available or derived national or regional data. In part, because the estimates based on national data are simpler, it is helpful for understanding to present these estimates before moving on to calculating the regionally based estimates. Also, for both the national and region mortalities rates it was necessary to make a number of assumptions. Since each assumption introduces an additional degree of uncertainty into the estimates, the use of two estimates provides an initial assessment of the sensitivity of the predicted mortalities.

Figure 22. Age distribution of New Zealand and West Coast population over 30 in 2001



8.6.3 Nationally based Baseline Mortality($Po_{national}$)

The national baseline mortality frequency ($Po_{national}$) has been calculated based on observed non-sudden death mortality rates for the New Zealand population aged over 30 years old for the year 2001 and estimated average level of PM_{10} exposure for the population living in urban areas in New Zealand.

The observed mortality for over-30-year-olds in urban New Zealand was based on national mortality statistics collected for the year 2001. Currently only mortalities for census age groups are available for the entire New Zealand population, with no distinction between urban and rural areas. Therefore over-30-year-old urban area mortality rates were estimated based on the 2001 urban area population age distribution and the national mortality rates for the age group. Since over 73% of the over-30-year-olds in New Zealand are estimated to reside in the defined urban areas, national, age-dependent mortality rates are likely to be representative for urban areas. Urban area mortality rates were estimated separately for males and females.

A further correction to the 2001 mortality estimates was made to account for deaths that were either accidental or sudden, that cannot be attributed to air pollutant health impacts, for example deaths due to traffic accidents. Although, the Ministry of Health has compiled detailed mortally statistics for the years 1999, 1998 and 1997 a breakdown of causes of death with respect to age was not available for the year 2001. However, a review of the 1999, 1998 and 1997 data indicates that the proportion of deaths in each age grouping, listed as 'External causes of injury and poisoning' (using the ICD chapter headings), remained relatively consistent for all the three years considered. Consequently, it has been assumed that the average percentage of deaths per age group for 2001 that are associated with 'External causes of injury and poisoning' is the average of years 1999, 1998 and 1997. A summary of the average, maximum and minimum percentage of total deaths in New Zealand that are not attributable to external causes of injury and poisoning is presented in Table 20.

Table 20. Summary of the percentage of non sudden death mortalities for 1999, 1998 and 1997

Age Group	Percentage of Non Sudden Death		
	Average	Maximum	Minimum
0-4	85.80%	87.50%	83.80%
5-9	52.50%	54.00%	50.90%
10-14	46.60%	54.10%	40.30%
15-19	21.70%	26.50%	18.40%
20-24	25.70%	30.50%	21.20%
25-29	31.10%	35.10%	25.80%
30-34	50.30%	53.20%	48.80%
35-39	62.80%	64.20%	60.90%
40-44	75.50%	76.00%	75.00%
45-49	85.50%	87.30%	84.30%
50-54	92.20%	93.10%	91.50%
55-59	94.20%	95.00%	93.20%
60-64	96.50%	96.60%	96.30%
65-69	97.50%	97.90%	97.20%
70-74	98.00%	98.30%	97.80%
75-79	98.10%	98.40%	97.50%
80-84	97.90%	98.60%	97.00%
85+	98.40%	99.20%	97.90%

Age-dependent New Zealand mortality rates, urban population and predicted urban mortality rates are presented in Table 21. The 2001 'Urban Population' is considered to be that in all areas defined by Statistics New Zealand as either main or secondary urban areas.

Table 21. Estimation of mortality rates in 2001 for urban New Zealand areas

Age Group	Average 2001 NZ Mortality (deaths/1000)		2001 NZ Resident Urban population			
			Population		Estimated Mortalities	
	Male	Female	Male	Female	Total	Non Sudden
0-4	1.47	1.2	106,965	101,967	275	236
5-9	0.15	0.2	110,313	104,139	35	18
10-14	0.24	0.2	111,030	106,326	46	22
15-19	0.93	0.4	106,047	105,453	144	31
20-24	1.24	0.4	99,312	103,896	163	42
25-29	1.09	0.5	96,225	106,290	153	48
30-34	1.31	0.6	105,216	117,267	202	102
35-39	1.3	0.7	109,983	119,739	227	143
40-44	1.84	1.1	104,151	112,554	316	238
45-49	2.42	1.9	92,037	98,232	405	346
50-54	4.15	3.1	86,751	90,234	642	592
55-59	6.76	4.6	65,832	68,787	762	718
60-64	11.76	8.3	54,732	58,506	1127	1088
65-69	19.91	12.5	44,802	49,605	1512	1474
70-74	34.6	19.0	41,421	48,447	2356	2308
75-79	52.4	33.0	31,164	43,374	3066	3008
80-84	87.2	60.8	17,913	31,569	3482	3408
85+	186.16	147.1	11,649	28,614	6377	6277
		Total	1,395,543	1,494,999	21,292	20,099
		Total 30+	765,651	866,928	20,475	19,702

Based on these assumptions, an average urban New Zealand non-sudden death mortality rate of 12.1 deaths per 1000 people was calculated for residents aged over 30 years. The corresponding baseline mortality rates for non-air pollutant-related deaths was then estimated to be 11.5 deaths per 1000 people assuming a threshold effect concentration of 7.5µg/m^3. In other words approximately 0.6 deaths per 1000 people over 30 years in urban New Zealand are attributable to exposure to PM_{10}. A summary of predicted $Po_{national}$ and $D_{10\text{-}national}$ when relative risk and threshold concentration assumptions are varied is shown in Table 22. The range of relative risks in the table corresponds to the 95% confidence interval calculated by Künzli et al. (1999). The values in bold are the average $Po_{national}$ and $D_{10\text{-}national}$ based on the assumed average threshold PM_{10} concentration of 7.5µg/m^3.

Table 22. Estimated $Po_{national}$ (deaths per 1000 people) and $D_{10\text{-}national}$ (incremental death per 10µg/m^3 increase in PM_{10} per 1,000,000)

Relative Risk		Threshold PM_{10} Concentration			
		7.5µg/m^3	0µg/m^3	5µg/m^3	10µg/m^3
1.043	Po	**11.5**	11.2	11.4	11.6
	D_{10}	**494**	480	489	500
1.026	Po	11.7	11.5	11.6	11.8
	D_{10}	305	299	303	307
1.062	Po	11.3	10.8	11.1	11.4
	D_{10}	688	660	678	698

8.6.4 West Coast based Baseline Mortality ($Po_{regional}$)

West Coast regional baseline mortalities ($Po_{regional}$) and incremental increases in mortality ($D_{10\text{-}regional}$) have also been calculated using the above formula. As statistical data detailing the mortality rates in the West Coast towns is not available, total mortality rates for the region were taken to be representative those in the towns. Since approximately 56% of the region's population over 30 are located in the towns considered, this approximation is likely to reasonable.

In 2001, a total of 277 deaths where recorded for the West Coast region. In determining the mortality rates for over 30 year olds in the region, it was assumed that West Coast mortality rates per census age grouping in 2001 were approximately equal to national trends (see Table 21). Consequently the number deaths in the region for each age group has been estimated based on national 2001 gender-weighted, age-dependent mortality rates and the proportion of 2001 West Coast population represented by each age grouping. These, predictions were further corrected to take into account the estimated percentage of mortalities that were likely to be sudden death-related (see Table 20). A summary of predicted regional mortalities is present in Table 23. From the data, an average non-sudden death rate of 13.8 per 1000 was estimated for over-30-year-olds in West Coast towns.

Table 23. Estimated non-sudden deaths in the West Coast region in 2001

Age Group	2001 West Coast population			
	Population		Estimated Mortalities	
	Male	Female	Total	Non Sudden
0-4	990	951	3.0	2.6
5-9	1,251	1,221	0.5	0.2
10-14	1,209	1,188	0.6	0.3
15-19	945	786	1.4	0.3
20-24	690	684	1.3	0.3
25-29	771	852	1.5	0.5
30-34	996	1,092	2.3	1.1
35-39	1,230	1,236	2.9	1.8
40-44	1,317	1,236	4.5	3.4
45-49	1,170	1,044	5.6	4.8
50-54	1,140	1,026	9.4	8.6
55-59	879	855	11.7	11.0
60-64	753	717	17.5	16.8
65-69	675	573	24.3	23.7
70-74	516	549	33.4	32.8
75-79	405	453	42.7	41.9
80-84	210	333	45.5	44.6
85+	114	252	68.8	67.8
Total	15,261	15,048	277	263
Total 30+	9,405	9,366	269	258

It should be noted that a higher or lower regional mortality rate would influence the subsequent calculation of PM_{10}-related mortalities. The mortality rates for 2001 were selected to be consistent with the available demographic census data. However, as the average number of reported mortalities in the West Coast between 1998 and 2002 was 276 per year, although varying annually between 320 and 227, the use of 2001 mortality rate of 277 is generally representative of typical West Coast rates.

Estimation of West Coast PM_{10} concentrations required in the calculation of baseline mortality rate ($Po_{regional}$) is described in Section 6.3.1, with low range and high range estimates given in Table 14.

A summary of $Po_{regional}$ and D_{10}-$_{regional}$ values calculated for urban areas in the West Coast is presented in Table 24. At the selected threshold concentration (B) of 7.5µg/m^3 and average relative risk of 1.043, 13.0-13.4 deaths per year per 1000 residents over 30 years old in West Coast urban areas are estimated to be not PM_{10}-related, depending on the concentration of PM_{10} used for the non-winter months in the calculation. If this value is subtracted from overall urban area death rate of 13.8 per year per 1000, then an estimated 0.35 to 0.81 deaths per year per 1000 residents are attributable to ambient PM_{10} levels, the mortality rate depending upon the PM_{10} concentrations taken for the non-winter months. These rates are 72% to 164% the PM_{10}-related mortality rate calculated for New Zealand urban areas as a whole (see Table 22). Because of the generally older population on the West Coast, the incremental death rate per 1,000,000 population, per 10 µg/m^3 PM_{10} (D_{10}), is about 17% higher than for New Zealand as a whole.

Table 24. Estimated $Po_{regional}$ (deaths per 1000 people per year) and $D_{10\text{-}regional}$ (incremental death per 10µg/m^3 increase in PM_{10} per 1,000,000 per year)

		Threshold PM_{10} concentration							
		7.5 µg/m^3		0 µg/m^3		5.0 µg/m^3		10 µg/m^3	
Summer PM10 estimate Relative risk		Low	High	Low	High	Low	High	Low	High
1.043	P_0	13.4	13.0	13.0	12.6	13.3	12.8	13.6	13.1
	D_{10}	577	557	560	541	571	552	583	563
1.026	P_0	13.6	13.3	13.3	13.0	13.5	13.2	13.6	13.4
	D_{10}	353	345	346	339	350	343	355	347
1.062	P_0	13.3	12.7	12.7	12.1	13.1	12.5	13.5	12.8
	D_{10}	810	772	776	741	798	761	822	783

8.6.5 Calculation of West Coast Township PM_{10}-related Mortality Rates

The estimated number of PM_{10}-related mortalities in each of the West Coast towns considered has been estimated individually using the following expression.

$$N_c = D_{10} * P_c / 1'000'000 * [(x_c - B) / 10]$$

Where:

D_{10} = Estimated Incremental increase in mortalities per 1,000,000 people associated with

each 10µg/m^3 increment in average annual PM_{10} concentrations

P_c = The population over thirty exposed

x_c = The average annual PM_{10} concentration (µg/m^3)

B = Threshold annual average PM_{10} concentrations below which PM_{10} is assumed to not increase the risk of mortalities (µg/m^3)

N_c = The number of mortalities in the township associated with ambient PM_{10} levels

Mortality rates for each West Coast town have been estimated using values calculated from both national and region urban estimates of D_{10}. Average annual ambient air PM_{10} concentrations and residential population for each urban area is presented in Table 13 and Table 14.

Table 25 shows the predicted West Coast mortalities when the D_{10} values are calculated using the derived West Coast regional urban mortality rate and annual average ambient PM_{10} levels calculated from low range and high range summer PM_{10} concentrations as in Table 14. This table also shows the range of estimated mortalities for Hokitika, based on the range of estimates for the winter PM_{10} concentrations there, and the total for all West Coast towns included in the study using the low (Total low) and high (Total high) estimates for the winter PM_{10} concentrations in Hokitika. The effect of varying the threshold concentration, below which PM_{10} concentrations are assumed to have no effect on mortality rates, from 0µg/m^3 to 10µg/m^3 is also presented in Table 25 and Table 26.

Table 25. Predicted annual mortalities from PM_{10} exposures, based on $D_{10\text{-regional}}$ values

Urban Areas	Threshold PM_{10} Concentration (B)							
	7.5 µg/m^3		0 µg/m^3		5.0 µg/m^3		10 µg/m^3	
Summer PM_{10} estimate	Low	High	Low	High	Low	High	Low	High
Greymouth/Runanga	1.2	3.5	3.2	5.4	1.9	4.1	0.4	2.8
Westport	1.1	2.3	2.1	3.3	1.4	2.6	0.7	1.9
Reefton	0.3	0.6	0.6	0.9	0.4	0.7	0.2	0.5
Hokitika low	0.5	1.5	1.4	2.4	0.8	1.8	0.2	1.2
Hokitika high	1.1	2.1	2.0	2.9	1.4	2.4	0.8	1.8
Total low	3.1	7.9	7.3	11.9	4.5	9.2	1.6	6.5
Total high	3.7	8.5	8.0	12.5	5.1	9.8	2.2	7.1

Table 26 presents the estimated mortalities in Greymouth, Westport, Reefton and Hokitika associated with ambient PM_{10} levels when the D_{10} values are derived from the national urban mortality rate and ambient PM_{10} concentration, for comparison.

Table 26. Predicted annual mortalities from PM_{10} exposures, based on $D_{10\text{-national}}$ values

Urban Areas	Threshold PM_{10} Concentration (B)							
	7.5 µg/m^3		0 µg/m^3		5.0 µg/m^3		10 µg/m^3	
Summer PM_{10} estimate	Low	High	Low	High	Low	High	Low	High
Greymouth/Runanga	1.0	3.1	2.8	4.8	1.6	3.7	0.4	2.5
Westport	0.9	2.0	1.8	2.9	1.2	2.3	0.6	1.7
Reefton	0.3	0.6	0.5	0.8	0.4	0.6	0.2	0.5
Hokitika low	0.4	1.3	1.2	2.1	0.7	1.6	0.2	1.1
Hokitika high	1.0	1.9	1.7	2.6	1.2	2.1	0.7	1.6
Total low	2.6	7.0	6.3	10.5	3.9	8.2	1.3	5.8
Total high	3.2	7.5	6.8	11.1	4.4	8.7	1.9	6.3

The range of relative risks from the epidemiological studies also contribute to the range of possible annual mortalities that could be estimated. Use of the upper and lower limits of the Relative Risk 95% confidence interval (1.026 and 1.061) would decrease or increase the mortality estimates by approximately 40% of the estimates given in the tables. The

uncertainty in the non-winter PM_{10} concentrations (low and high summer PM_{10} estimates) and in the appropriate threshold concentration have substantially larger effects on the estimated mortalities than the uncertainties in these relative risks.

The most likely combinations of threshold values and low or high summer PM_{10} estimates are low summer PM_{10} estimates with low threshold concentrations and high summer PM_{10} estimates with high threshold concentrations.

If the summer (non-winter) PM_{10} concentrations are low, this implies that the background "natural" concentrations are low and therefore particulates such as combustion particulates that affect health are likely to have an effect from low concentrations. Also, at the very low non-sea salt PM_{10} concentrations indicated by the Greymouth summer sampling, substantial threshold concentrations are not realistic, since they would imply negative net PM_{10} concentrations after subtracting the threshold.

Similarly, if summer PM_{10} concentrations are high, (when contributions from combustion particulates that are likely to be low) there is likely to be a substantial "natural" background concentration (which may well be sea salt), that would be appropriately adjusted for by using a relatively high threshold concentration.

Based on these considerations, the best estimates of annual mortality in the West Coast towns included in the study appear to be in the range 5-8 deaths per year attributable to exposures to PM_{10} concentrations, based on the regional baseline mortality data. The estimates based on the national mortality data are similar, being in the range 4-7 for the low-low combination of summer PM_{10} concentration estimates and threshold concentrations, and in the range 6-8 for the high-high combinations.

Table 25 and Table 26 show that the greatest number of PM_{10} related mortalities are expected to occur in the Greymouth/Runanga urban areas. This is because the largest population is in these areas.

A summary of predicted PM_{10}-related annual mortality rates (deaths per thousand residents per year) is shown in Table 27 and Table 28 for the different summer PM_{10} concentration and threshold concentration assumptions, and for nationally and regionally derived D_{10} values. The highest estimated PM_{10}-related mortality rates are estimated for Reefton because the highest average PM_{10} concentration over the winter (31µg/m3) was recorded there. The lowest mortality rates are estimated for Greymouth/Runanga, because the lowest winter average PM_{10} concentrations were measured there.

Table 27. Estimated PM_{10} mortality rates per year per 1000 residents over 30 years old based on $D_{10\text{-regional}}$ values

	Threshold PM_{10} Concentration							
	7.5 µg/m³		**0 µg/m³**		**5.0 µg/m³**		**10 µg/m³**	
Summer PM_{10} estimate	Low	High	Low	High	Low	High	Low	High
Greymouth/Runanga	0.23	0.70	0.64	1.08	0.37	0.83	0.09	0.56
Westport	0.41	0.86	0.81	1.24	0.54	0.99	0.26	0.73
Reefton	0.52	0.98	0.93	1.35	0.66	1.10	0.38	0.85
Hokitika low	0.23	0.70	0.64	1.08	0.37	0.83	0.09	0.56
Hokitika high	0.52	0.98	0.93	1.35	0.66	1.10	0.38	0.85
WC urban average low	0.29	0.76	0.70	1.14	0.43	0.89	0.15	0.62
WC urban average high	0.35	0.81	0.76	1.20	0.49	0.94	0.21	0.68

Table 28. Estimated PM_{10} mortality rates per year per 1000 residents over 30 years old based on $D_{10\text{-national}}$ values

	Threshold PM_{10} Concentration							
	7.5 µg/m³		**0 µg/m³**		**5.0 µg/m³**		**10 µg/m³**	
Summer PM_{10} estimate	Low	High	Low	High	Low	High	Low	High
Greymouth/Runanga	0.20	0.62	0.55	0.96	0.32	0.73	0.08	0.50
Westport	0.35	0.77	0.70	1.10	0.47	0.88	0.23	0.65
Reefton	0.45	0.87	0.79	1.20	0.56	0.98	0.33	0.75
Hokitika low	0.20	0.62	0.55	0.96	0.32	0.73	0.08	0.50
Hokitika high	0.45	0.87	0.79	1.20	0.56	0.98	0.33	0.75
WC urban average low	0.25	0.67	0.60	1.01	0.37	0.79	0.13	0.55
WC urban average high	0.30	0.72	0.65	1.06	0.42	0.84	0.18	0.61