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PROTECTING NZ'S CLEAN AIR

Evaluation of Baseline PM10 Levels for Industrial Resource Consent Applications

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REPORT

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Table of Contents

TABLES

FIGURES

APPENDICES

GLOSSARY OF TERMS AND ABBREVIATIONS

Baseline PM_{10}	The level of PM_{10} that would occur if the source under consideration were absent. The PM_{10} arising due to all other sources, e.g., industry, domestic fires, motor vehicles, dust or sea salt
Airshed	(1) Area officially defined by TLAs for the purposes of air quality management, in which air quality is monitored for compliance with the NES. (2) Area over which localized emissions to air are contained physically, either by the source extent or meteorological or geographical factors
Air dispersion model	A computational model which simulates the dispersion and predicts the downwind concentrations of air pollutants. Examples mentioned in this report are CALPUFF and ISC3 Prime
Urban airshed model	A computational model which predicts urban air quality impacts from all source sectors, including industry, motor vehicles, domestic heating and biogenic emissions
Straight-line path	A straight line drawn by TLAs between a measure of current urban air quality in 2004 to a state of compliance with the NES in 2013, which the airshed is not permitted to exceed in the interim
AEE	Assessment of Effects on the Environment
CAU	Census area unit (population up to 5,000)
EW	Environment Waikato
GLC	Ground-level concentration
DGLC	Design ground-level concentration (air quality target)
Golder	Golder Associates (NZ) Limited
GPG	Good-practice guide
MCR	Maximum Continuous Rating (related to coal-fired boilers)
MfE	NZ Ministry for the Environment
NES	National Environmental Standard(s) (for air quality – see MfE, 2005)
NO_x	Mono-nitrogen oxides, NO and NO_2, produced during combustion
ORC	Otago Regional Council
PM_{10}	Particulate Matter suspended in air; particles have aerodynamic diameter less than 10µm
SO_2	Sulphur dioxide
SLiP	Straight-line path (see above)
TLA	Territorial local authority, such as a regional or district council
VOC	Volatile Organic Compound
µg/m³	Micrograms per cubic metre
m/s	Metres per second

1.0 INTRODUCTION

1.1 Background

Assessments of air discharges from industrial stacks need to account for cumulative effects of stack discharge on baseline air quality. That is, predictions of air pollutant concentrations from industry need, in some way, to be added to the concentrations which arise in the absence of the specific industrial source.

Several ways of combining modelled stack concentrations with baseline concentrations are available; the choice of method depends principally on the amount of information available, and the amount of detail or accuracy required of the assessment. Regarding the latter, a simple conservative approach may indicate a breach of air quality targets, necessitating the application of a more physically realistic, and less conservative, approach.

This report draws on a selection of industrial AEEs which have included discharges of PM_{10} into the atmosphere, and have required examination of the baseline PM_{10}. Several methods are described herein, and the aim is to give guidance to the reader on which may be used in given circumstances. The focus here is on PM_{10}, for several reasons. Firstly, it is a criterion pollutant of the NES (MfE, 2005). Secondly, baseline levels can be high, due to urban and natural components, or both. Third, having a 24-hour average target for PM_{10} leads to challenges in assessing baseline levels and relating them to other factors such as the meteorology.

The focus in this report is on the industrial sector, and the air pollutant PM_{10}, but the ideas presented can apply to any sector where a new (or changed) discharge is planned in an area that has degraded air quality. The report is based on modelling and analysis carried out in recent years by Golder in the course of preparing AEEs and applications for resource consent. These have been independently reviewed, and where necessary have been through hearings, with evidence presented by Golder as an independent contractor. Those AEEs are now publicly available information, and their numerical results are used here without change. However, some supplementary analysis has been carried out for the purposes of this report (contained in Sections 2.2.1, 3.2.1 and 4.1).

1.2 Why Consider Baseline PM_{10}? – NES Regulations

The total PM_{10} at any location arises from several sources, and many studies have been carried out in which the PM_{10} is apportioned among sources. Considering the assessment of effects of PM_{10} from a localised industrial source, the baseline PM_{10} is that due to everything else, such as neighbouring industries, urban sources such as domestic heating and motor vehicles, or natural components such as wind-blown soil, crustal material, pollens or sea spray.

There has always been a need to assess cumulative effects of industrial discharges upon ambient contaminant levels (air pollution), combining levels of air pollution from the source in question with the existing air quality in its absence. Since the advent of the NES, guidelines (MfE, 2002) have become regulations (MfE, 2005), the regulations apply to the total PM_{10} from all sources, and there is a larger onus on the applicant to demonstrate minor environmental effects. If air quality is too degraded in the airshed, by breaching the NES, by being above the defined straight-line path, or being made to breach the straight-line path by the presence of new industry, an application for consent to discharge into the air may be declined. There is also the possibility that TLAs will have more stringent targets than the NES.

The NES limit for PM_{10} is a 24-hour-average concentration of 50 $\mu g/m^3$, to be exceeded no more than once per year. Many urban airsheds are currently close to, or in breach of this limit, due to motor vehicles or domestic fires in winter. There can also be a significant natural level of ambient PM_{10}, and the NES target for PM_{10} includes this component.

In the absence of more detailed information, some ‘default’ baseline concentration examples are given in the MfE good-practice guide for assessing industrial discharges (MfE, 2008a), and those for PM_{10} are summarized in Table 1. These apply to screening studies, and are shown here to provide an indication of likely concentrations. (Different levels of assessment are discussed further in Section 1.3). The baseline concentrations range from above 100 $\mu g/m^3$ in urban areas in breach of the NES, down to 15 $\mu g/m^3$ in rural areas. Even inland, there can be a component of sea spray of a few $\mu g/m^3$.

Table 1: Examples baseline 24-hour PM_{10} concentrations for screening assessments (based on Table 7.1 of MfE (2008a)).

Type of Area	Concentration	Justification
Urban – significant wood- or coal-burning	100 µg/m^3	Observed in larger urban areas, such as Christchurch, Nelson, Masterton
Urban – vehicle dominated	70 µg/m^3	Observed at Khyber Pass, Auckland
Smaller urban centres – less solid fuel burning and fewer vehicles	40 µg/m^3	Observed in residential neighbourhoods
Rural	15 µg/m^3	Wind-blown PM_{10} in the absence of obvious upwind sources

Often TLAs specify an annual-average PM_{10} limit of 20 µg/m^3, as this has historically been a guideline concentration. This is easier to attain than the 24-hour average, and is not considered further in this report.

1.3 Current Good-Practice Guidance

Several GPGs have been developed by air-quality scientists in New Zealand, and published by the MfE. These include GPGs for atmospheric dispersion modelling (MfE, 2004), and for assessing discharges to air from industry (MfE, 2008a) and land transport (MfE, 2008b).

The GPG for industrial discharges describes several levels of assessment which may be required, as a succession of Tiers, numbered 1 to 3. The basic Tier definitions are quoted below:

- Tier 1 – a preliminary assessment to identify whether there are likely to be significant air quality effects;
- Tier 2 – a largely qualitative assessment with screening-level modelling only;
- Tier 3 – a largely quantitative assessment with increased complexity in the modelling and reliance on site-specific data.

The GPG states that "a Tier 2 screening dispersion modelling study provides conservative estimates of likely air quality impacts", and should take only a few days' work. The study's conservatism stems from the use of maximum emission rates and worst-case meteorological conditions, and would employ a steady-state dispersion model. For baseline PM_{10}, the GPG suggests the following, in order of preference:

- Find the maximum-observed PM_{10} concentration from a nearby site for each of five years of data, and use the average of those five concentrations as the baseline;
- Carry out the same calculation on data from an alternative, but similar, site;
- Use reasonable default values chosen from a table in the GPG (some of which are shown in Table 1).

If the airshed breaches the NES, a fuller assessment would be required, including the use of more sophisticated dispersion models, to produce more realistic (rather than conservative) results. This is referred to as Tier 3, and may include exposure estimates and a health risk assessment.

The GPG states that for Tier 3, hourly ambient air quality data would ideally available for the same period that has been modelled, so that the baseline PM_{10} may be simply added to the modelled PM_{10} from the industrial discharge. Aside from acknowledging that this situation is rare, the GPG does not offer further guidance on this aspect.

If *P* is defined as the highest PM_{10} concentration resulting from the industrial discharge, *Q* as the highest observed concentration, and *A* as the (annual-)mean observed concentration. A Tier 2 assessment

indicates that the cumulative PM_{10} concentration should be *P* + *Q*, which may unrealistically indicate a breach of the NES. Under a Tier 3 assessment, the industrial and modelling GPGs mention *P* + *A* or *P* + *2A* as candidates for the cumulative PM_{10}. However, the former of these may be unrealistically low, and the latter somewhat arbitrary. In other words, neither the observed peak nor mean concentrations are necessarily good candidates for the baseline PM_{10} in a full assessment. Usually, a more sophisticated approach would be required. Baseline PM_{10} levels and impacts from industrial discharges vary significantly both temporarily and spatially, and their times and locations of maximum impact are usually different.

1.4 Challenges to Determining Baseline PM_{10}

1.4.1 Conservative results from summing two maximum concentrations

As mentioned above, simply adding the maximum modelled concentration from an industrial air discharge to the maximum baseline level may conservatively predict a higher cumulative total than that allowed by the NES. If this is not the case, then a more detailed analysis may not be needed. However, as the NES PM_{10} limit is quite stringent, and it is often likely that the sum of the two contributions is too high, a more rigorous examination is needed. This should start by establishing whether the highest industrial and baseline concentrations occur at the same location or the same time. This is often related to the meteorological conditions under which different sources lead to peak impacts.

For example, industrial discharges may have their largest impacts at ground level during summer, when pollutants are mixed from tall stacks to the surface. At this time, the baseline urban air quality may be much better than its worst-case level. If urban air quality is poor during the winter, due to trapping of pollutants from domestic fires in shallow inversion layers, the industrial discharge may remain in the residual layer above the inversion and have little impact at the surface. In this case, adding together the worst-case modelled impact from the industrial stack and worst-case measured PM_{10} would overstate the true cumulative ambient concentrations.

1.4.2 Availability of ambient PM_{10} and meteorological data

There are several situations which might be found when attempting to quantify the baseline PM_{10} for an industrial assessment. They may be broadly described as follows (starting with least ideal):

1) There are no local ambient PM_{10} data;
2) They are 1-in-6 day 24-hour averages of PM_{10};
3) Daily 24-hour averages are available;
4) Hourly PM_{10} are available from nearby ambient monitoring.

Since the advent of the NES, any areas designated as airsheds should have continuous ambient PM_{10} monitoring in progress at one or more locations. Also, airsheds should be designated around industry, so that situation (1) should not arise except in some small urban areas. However, the dispersion modelling assessment may be carried out based on meteorological modelling and source activity for a different time period to that of the PM_{10} measurements. It is unlikely there will be a case where all of the data are simultaneously available, and therefore unlikely that the cumulative PM_{10} may be simply evaluated by adding the hour-by-hour observations to hourly modelled concentrations. Therefore a statistical analysis of ambient monitoring data would usually be required, and this type of analysis can be effective at determining typical baseline levels of PM_{10} as a function of season and weather conditions.

If the industrial assessment is for a resource-consent renewal, such that the industry is already in production, the ambient PM_{10} observations contain a contribution from the industry in question as well as the baseline contribution. The extent of this contribution must be established to avoid double counting of the industry's contributions during the cumulative assessment of PM_{10} concentrations. To achieve this, the ambient data can be filtered, with ambient data only retained under conditions when there is no contribution from the

industry to the ambient PM_{10}. The easiest way would be to discount wind directions under which the ambient monitoring site is downwind of the PM_{10} sources. However, standard analysis of variance methods can also be used to more rigorously establish the industrial contribution to ambient data.

1.4.3 Spatial distribution of ambient PM_{10} – the need for airshed modelling

Ambient PM_{10} measurements may not be representative of the industrial site if, for instance, the industrial area is at the edge of an urban area and PM_{10} is measured in the centre of the urban area. In this case, the spatial distribution of the ambient PM_{10} can be examined using airshed modelling to ascertain ambient PM_{10} levels near the industrial site.

Airshed models produce an hourly three-dimensional picture of pollution dispersion from all sources in the urban area. A realistic spatial and temporal distribution of emissions can produce a realistic spatial and temporal distribution of concentrations. For this an inventory of emissions is needed for the airshed, and most of the larger urban areas in New Zealand now have these. If they do not, then estimates may be made based on emissions in 'similar' areas. It is only in recent times that inventories for large urban areas have highly resolved temporal and spatial air emissions from different sectors.

As ambient PM_{10} data are usually available, airshed model predictions can potentially be validated, and an assessment of airshed model performance should be carried out.

1.5 Methods for Determining Baseline PM_{10}

The GPGs give guidance on air discharge assessments as whole, with some detail on each stage. It is the aim of this work to expand on the details for establishing baseline air quality. Despite the usual complexities and the uniqueness of each case, Golder's experience with AEEs has found that there are essentially three general situations in which the practitioner finds themselves when needing to establish the baseline PM_{10}. Therefore there are three general approaches or methods which can be used to accommodate these situations. The situations are as follows:

1) Minimal ambient data except for dispersion modelling results for stack emissions. In these cases there are no ambient PM_{10} data, or they are not frequent enough, and the baseline level on any given day is estimated according to the weather conditions of that day. Baseline and stack-discharge PM_{10} are combined for days when the worst-case baseline PM_{10} is expected to occur. This is described in Section 2.0.
2) Reasonable quantity of ambient PM_{10} and associated meteorological data. In these cases, the ambient PM_{10} is filtered not just according to the general conditions, but more specifically according to wind direction, to exclude contributions from the industrial plant. The modelling results for the stack discharge of PM_{10} may or may not be filtered according to the meteorological detail. This depends on the details of the analysis of PM_{10} *versus* weather conditions. Often the peak baseline PM_{10} is simply ascertained for specific seasons. This is described in Section 3.0.
3) An emissions inventory is available and ambient monitoring data are available for the urban area. In these cases, the spatial and temporal distribution of the baseline PM_{10} in areas surrounding the site can be determined using airshed modelling. Ambient measurements may not be representative of the industrial area, but the area modelled includes the monitoring and the observations are used to evaluate the airshed model predictions. This is described in Section 4.0.

In the end, the analysis carried out may combine these methods. Also, the methods may be combined with a statistical approach or probabilistic assessment. In general, a more sophisticated approach is required when a simpler approach is too conservative, but it then follows that the sophisticated approach has to be shown to be robust and realistic.

1.6 Structure of the Report

Sections 2.0, 3.0 and 4.0 present examples of the use of the methods outlined above (numbered items (1), (2) and (3), respectively). Each section contains two examples. Section 5.0 provides a summary of the work, with some recommendations.

This report is provided subject to the limitations in Appendix A.

2.0 USE OF METEOROLOGY TO ESTIMATE THE BASELINE PM_{10}

2.1 Dunedin Tannery

This example concerns a fellmonger and tanning site in Dunedin. The site operates coal-fired boilers which provide the thermal energy for wool drying and hot water used in the fellmongery process. The assessment concerned, *inter alia*, the effects of discharges of PM_{10} from those boilers. Dispersion modelling of the boiler discharges was carried out for the year 2001 using the CALMET/CALPUFF modelling system (Scire *et al.*, 2000a, b). The results for the maximum PM_{10} GLCs over the year, for three coal-fired boilers running at 65% MCR, are shown as a contour plot in Figure 1, with numerical values extracted from peak locations shown in Table 2.

Table 2: Dispersion Modelling Results for Dunedin Tannery.

	ORC DGLC* ($\mu g/m^3$)	PM_{10} Predictions ($\mu g/m^3$)		
		Onsite	**Offsite Industrial**	**Offsite Residential**
24 hour Average	37.5	24	32	22

(* Design Ground Level Concentration in the Otago Regional Air Plan)

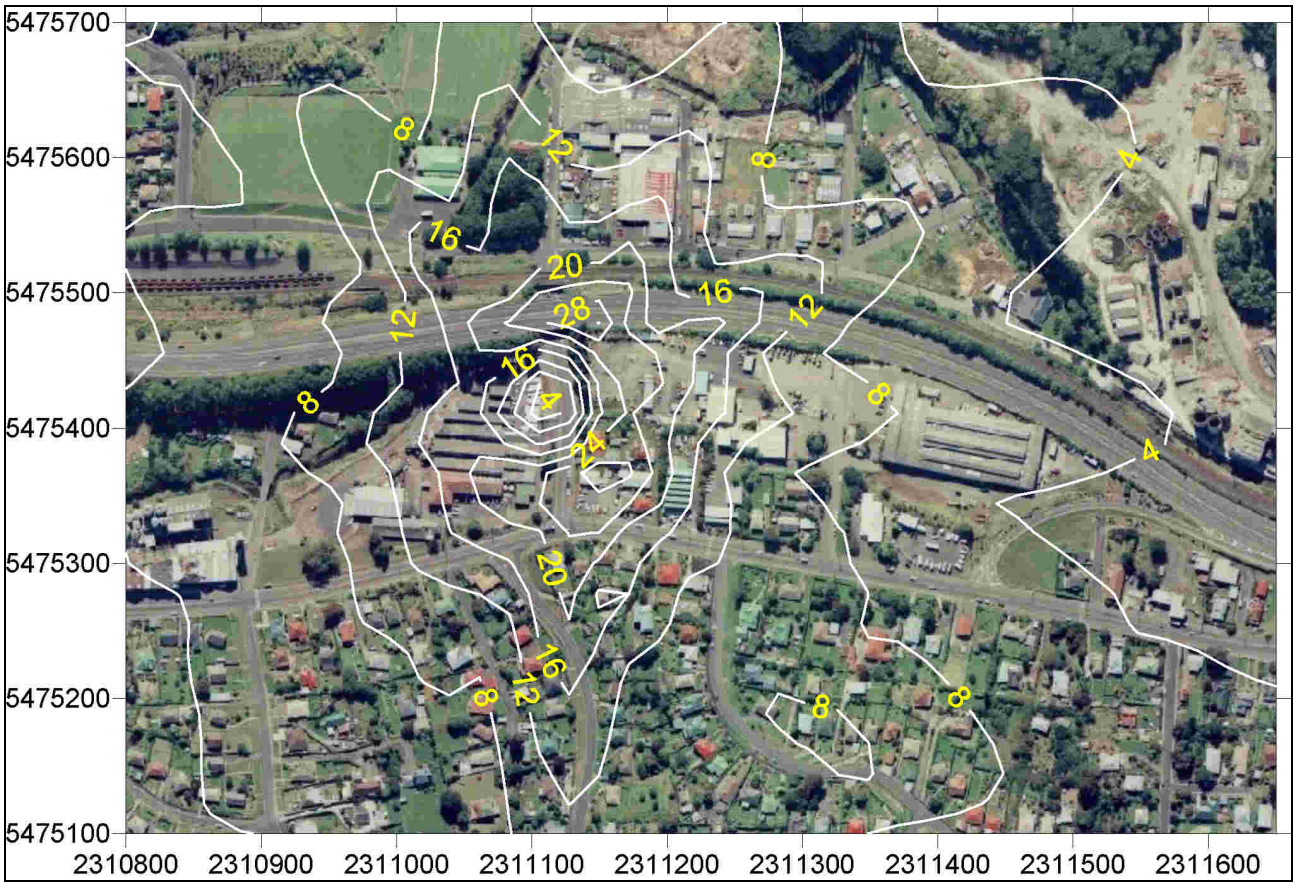


Figure 1: Maximum modelled PM_{10} from coal-fired boilers at Dunedin Tannery.

The maximum GLC in the offsite residential area was 22 μg/m³, less than the DGLC of 37.5 μg/m³. As the peak was to the southeast of the plant, the maximum impact was expected to occur on days when northwesterly wind conditions are prevalent.

Monitoring of the 24-hour-average PM_{10} at a site 200 m east of the plant had been in progress between 1997 and 2002, with measurements once every six days. The breakdown of PM_{10} measurements was as follows:

- 6 occasions (10%) >50 μg/m^3
- 13 occasions (21%) >40 μg/m^3
- 24 occasions (38%) >30 μg/m^3
- 46 occasions (73%) >20 μg/m^3

Therefore, the local airshed did not comply with the NES, and a conservative estimate of cumulative effects would have added another 22 μg/m³ to this, if the concentrations could simply be summed together. However, for this site the highest baseline PM_{10} (on cold, still days) is not likely to coincide with the highest PM_{10} GLC off-site due to the stack-discharge (which occurs in northwesterly winds). The former would occur under cold, calm conditions, due to releases close to the surface (from residences and motor vehicles, for example). Optimal meteorological conditions for worst-case 24-hour average GLCs from the 17.7 m boiler would be very different.

To examine the contribution to cumulative PM_{10} from the plant under conditions of high baseline PM_{10}, the 2001 model results were filtered for days assumed to be worst-case baseline pollution events and these were selected according to the following criteria being satisfied concurrently:

- The daily-average temperature was less than 5°C, to identify cold days;
- The temperature range (maximum minus minimum) was greater than 5°C, to identify clear skies, rapid cooling, and still, stable conditions.

Having selected the relevant days from the 2001 model results, the modelled stack-discharge PM_{10} was examined at a set of discrete receptors along the road next to the plant's southern boundary and to the north of the plant. For three coal-fired boilers running at 75% MCR, the highest contribution to the total PM_{10} was 8 μg/m³ at the receptor closest to the plant. Moreover, as the plant already included two boilers, the option of a third boiler was predicted to add less than 3 μg/m³ of PM_{10} to existing levels. This amount was considered an insignificant addition to the total PM_{10} under conditions of worst-case baseline PM_{10}, even though those worst-case conditions constituted a breach of the NES. The addition of the highest modelled PM_{10} GLC from the boiler stacks to PM10 concentrations during cold, calm conditions is clearly not a realistic scenario, and grossly overstates the potential cumulative PM_{10} GLC.

2.2 Christchurch Tomato Grower

This example concerns a tomato growing operation on the western peri-urban outskirts of Christchurch. The site operates coal-fired boilers for the indirect heating of glass houses. Dispersion modelling of the boiler discharges was carried out for the period 1997-1998 using the ISC3-Prime model, based on meteorology from Christchurch airport. The modelling for the recommended scenario of one 2,000 kW boiler discharging through an existing 16 m stack, and 1,500 kW and 750 kW boilers ducted together and discharging through a common 16 m stack, is discussed here. A two-dimensional plot of the results for the maximum PM_{10} over the modelling period is shown in Figure 2.

It can be seen from Figure 2 that at the peak location, the maximum PM_{10} from stack discharges was 26 μg/m³. At the onsite house (receptor number 7), the maximum concentration was 23.4 μg/m³, and the maximum concentration at any sensitive receptor offsite was 15 μg/m³ (houses numbered 5 and 6). The concentration was less than 5 μg/m³ at distances more than 300 m from the site. As in the previous example (Section 2.1), the highest PM_{10} concentration due to the site was not expected to occur under conditions of worst-case baseline PM_{10}, and Table 3 shows that the highest modelled concentrations occurred under neutral stability (Class D), moderate wind speeds, and diurnal temperature ranges between 3°C and 9°C. These are not generally conditions of worst-case urban air quality in Christchurch.

A similar procedure to the previous example was followed, to filter the modelled PM_{10} GLCs according to the meteorological surrogate for worst-case urban air quality. Over the 17 worst-case days in the 1997-1998 period, the maximum-modelled PM_{10} GLC was 8.2 μg/m³. This occurred at receptor number 6, with a maximum concentration under these meteorological conditions around half of that occurring over the full period. Although the Christchurch airshed is not compliant with the NES, the effect of the tomato growing operation under worst-case conditions of ambient air quality was considered to be minor.

This example is similar to that presented in Section 2.1, but with the added examination of the meteorological conditions under the predicted worst-case PM_{10} GLCs due to the coal-fired boiler emissions.

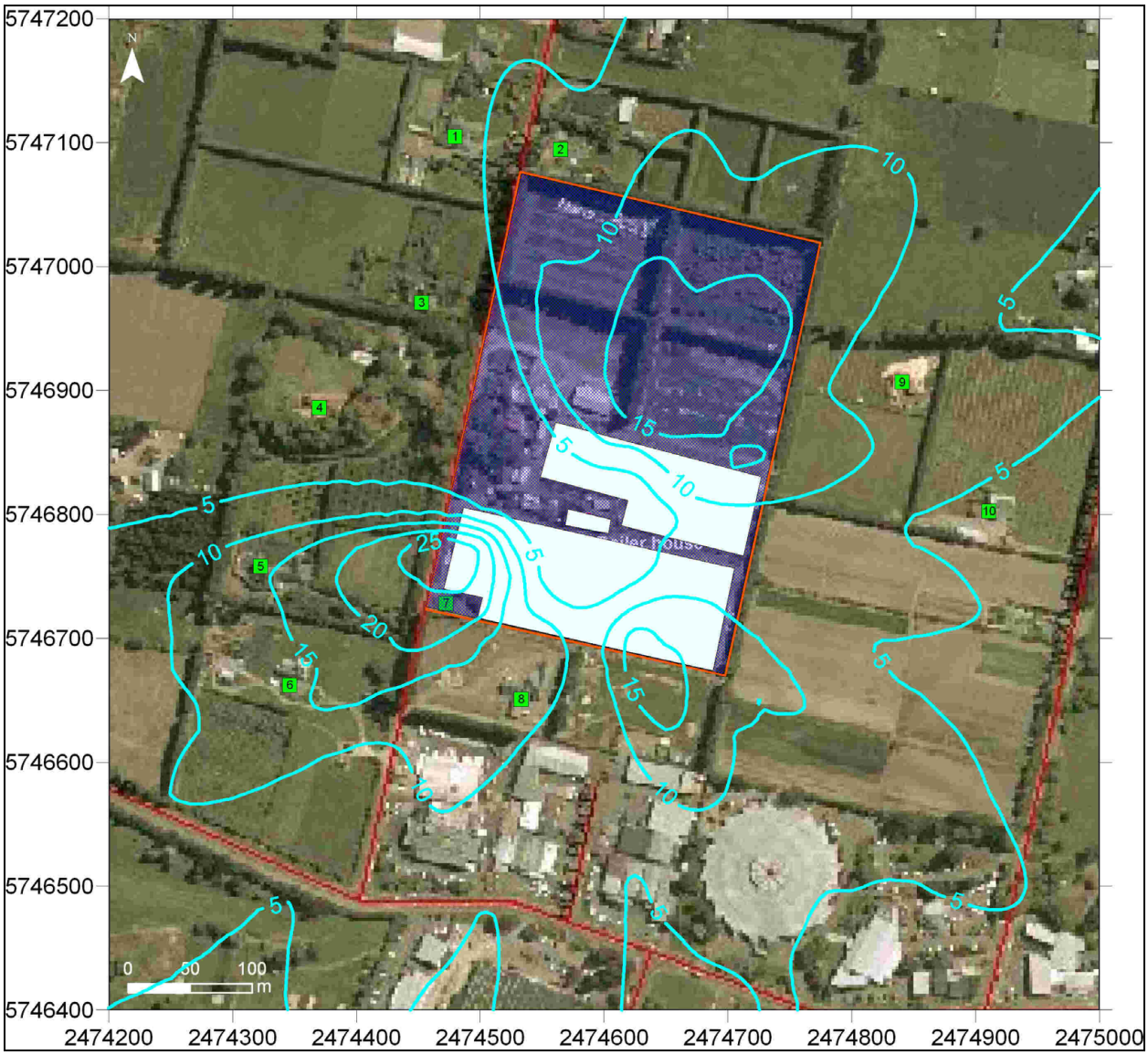


Figure 2: Maximum modelled PM_{10} from coal-fired boilers at Christchurch Tomato Grower. The numbered receptors are residential dwellings

Table 3: Meteorological conditions during worst-case PM_{10} concentrations due to stack discharges.

Date	Predicted concentration (µg/m³)	Stability	Daily average wind speed (m/s)	Daily temperature range
7 May	23.4	Class D all day	6.0	from 11°C to 13°C
21 May	19.2	Mainly class D	3.5	from 4°C to 11°C
22 May	20.9	Class D all day	4.9	from 11°C to 14°C
25 Jun	19.2	Class D all day	4.6	from 9°C to 18°C
21 Jul	18.5	Class C and D through the day 5 hours of Class F in the evening	3.6	from 9°C to 16°C
22 Jul	16.4	Mainly class D	4.2	from 10°C to 18°C

2.2.1 Further Analysis

An examination of the ambient PM_{10} at Burnside in 2004 has been carried out as a check on the meteorological criteria for worst-case baseline PM_{10}. Figure 3 shows the daily PM_{10} GLCs through 2004, with worst-case days highlighted according to the temperature criteria used above. The highlighted days include the highest six concentrations and most of the days above 40 µg/m³.

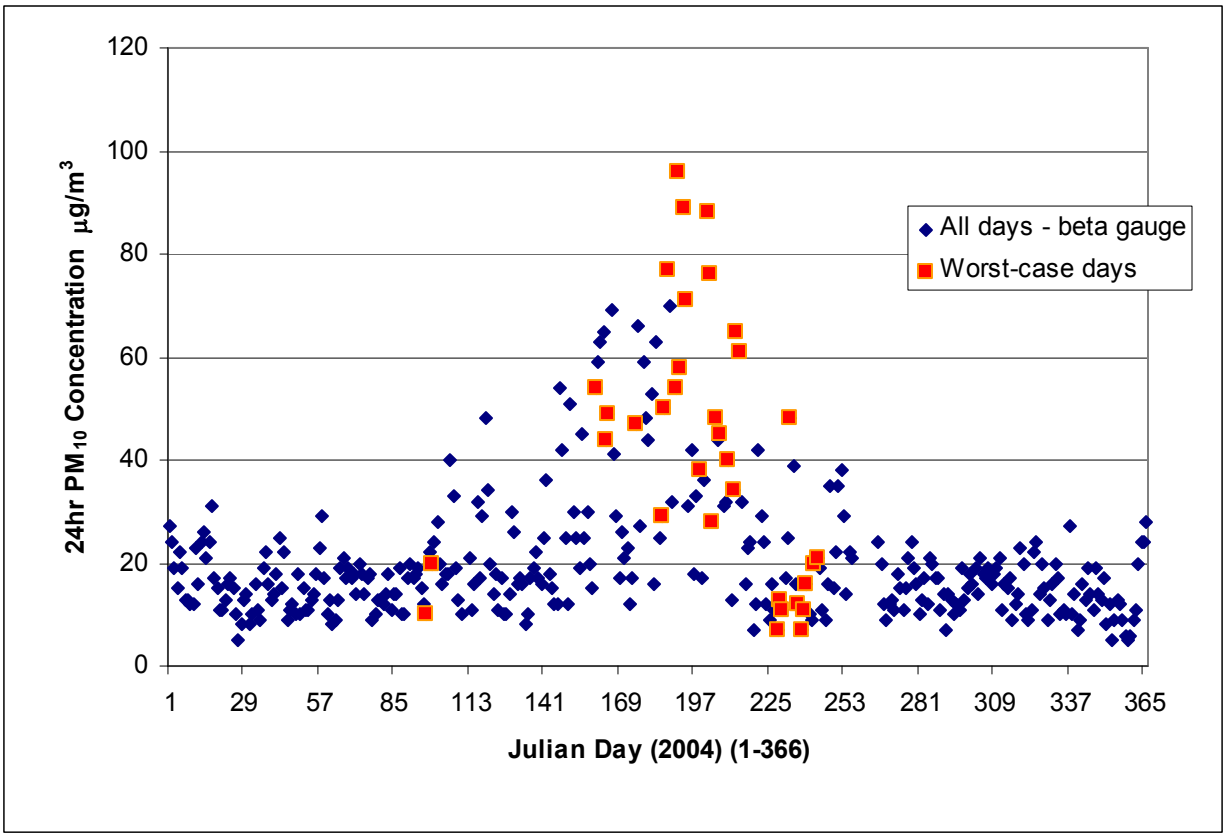


Figure 3: PM_{10} observations at Burnside. Worst-case days identified when average temperature below 5 deg.C and diurnal temperature range above 5 deg.C.

The highest 40 PM_{10} concentrations occur when the diurnal temperature range is greater than 10°C, and there is also a distinct decrease of PM_{10} with increasing daily scalar-average wind speed. The highest three PM_{10} concentrations occur when the wind speed is between 0.5 and 1.5 m/s. Revising the criteria to temperature range greater than 10°C, mean temperature below 5°C and wind speed below 3 m/s (all of these must be satisfied), leads to the set of worst-case days shown in Figure 4. These criteria retain the cases over 40 µg/m³, but omit a cluster below 20 µg/m³. In both examples there are some cases around Julian day 169, with PM_{10} concentrations over 60 µg/m³, that do not satisfy the meteorological criteria. These are days of mean temperature between 6°C and 8°C. Changing the criterion mean temperature to include these cases would bring in other days with low PM_{10}.

Note that the use of the altered criteria on meteorological parameters would have lead to fewer case-days in the AEE, and a lower predicted PM_{10} from the coal-fired boiler discharges.

Note also that the step of relating ambient PM_{10} to criteria on the meteorological conditions was necessary, as the meteorology used for the AEE was from a different year. This is usually the situation when modelling stack emissions.

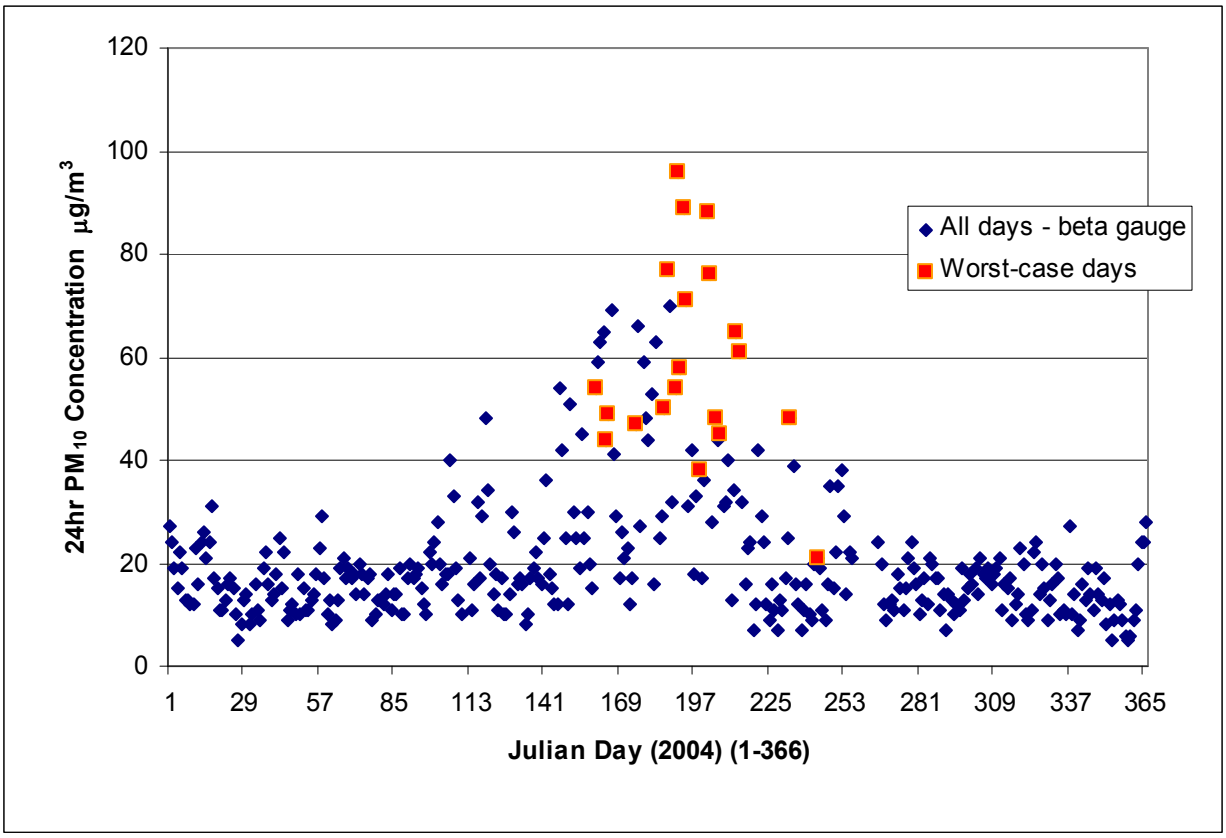


Figure 4: PM_{10} observations at Burnside. Worst-case days identified when average temperature below 5 deg.C and diurnal temperature range above 10 deg.C and scalar-average wind speed below 3 m/s.

3.0 USE OF AMBIENT PM_{10} DATA – ESTABLISHING RELATIONSHIPS WITH METEOROLOGY

Section 2.0 was concerned with filtering the modelled PM_{10} results due to stack emissions according to meteorological conditions that are assumed to be associated with high baseline ambient PM_{10} levels. It also contains an examination of the ambient PM_{10} themselves as a check on the meteorological criteria used (and applied to different years). This section also examines the ambient PM_{10}, but shows how ambient concentrations may be used as baseline PM_{10} levels, where there is a substantive and representative set of monitoring data near to the site. There is not usually a single appropriate concentration value – the baseline PM_{10} GLC (i.e. a 24-hour average) depends on the prevalent meteorological conditions of the day, which can indicate the likely contributor to the measured value.

3.1 Southland Milk Processing Plant

This example concerns a milk processing plant at Edendale, Southland. An assessment was carried out in 2001 on the effects of discharges of PM_{10} from a new coal-fired boiler through a new stack. Dispersion modelling was carried out using the ISC3-Prime model. An ambient air quality monitoring site had been located in the township, about 300m from the plant, measuring 24-hour PM_{10} one day in six with a high-volume sampler during the milk processing season (Spring-Summer and Autumn). The observed PM_{10} concentrations are shown in Table 4, with comments on the meteorological conditions for each day included. Table 4 shows the highest levels (40 – 56 $\mu g/m^3$) occurring under strong northwesterly conditions, indicating wind blown dust. Unless winds were light, the baseline PM_{10} was around 15 $\mu g/m^3$. There were no

observations taken in winter, when there would be a contribution from domestic fires. However the plant does not operate during this season, therefore baseline data during this period, while likely to be the highest, was not as important to the assessment as data from the process season.

Table 4: Ambient 24-hour PM_{10} at Edendale, 1998-2000.

Date	Measured PM_{10} ($\mu g/m^3$)	Weather conditions
25/09/98	46	Wind not from site for whole day
01/10/98	36	Wind from site after 7:00 pm that day
26/10/98	40	North west all day
15/09/98	33	Wind from site for small part of the day
17/09/00	27	Light northerly followed by moderate southwest winds
19/09/00	56	Moderate to strong northwesterly winds for most of the day
23/09/00	22	Moderate northwest in morning and evening, westerly during the day.
27/09/00	14	Light west-northwest in the morning then light west-southwest all day
3/10/00	23	Light northerly, south-easterlies, southwest through to westerly wind
5/10/00	6	Moderate to strong west northwest wind all day
7/10/00	15	Light to moderate northwest through to west southeast
11/10/00	24	Light to moderate northwest wind throughout the day
17/10/00	12	Moderate westerly all day before becoming northwest in the evening
19/10/00	13	Light west northwest wind that turns west to southwest at mid day
23/10/00	18	Light northerly, westerly and southwesterly breezes all day
25/10/00	4	Light northeast through to light northwest breezes
31/10/00	9	Light northerly to northwest followed by moderate southeast wind at mid day
2/11/00	15	Light to moderate northwest to westerly winds, turning to southerly in evening
6/11/00	13	Light highly variable winds all day, northerly, westerly, southwest to southeast
8/11/00	11	Light to southwesterly and moderate westerly winds
12/11/00	10	Light southerly to southwest winds all day
16/11/00	8	Light to moderate south west to west southwest winds all day
18/11/00	15	Moderate west southwest winds all day
22/11/00	6	Moderate west southwest and westerly winds all day
26/11/00	8	Moderate west southwest and westerly winds all day
30/11/00	8	Calm day with very light breeze
4/12/00	13	Light west southwest breeze all day
6/12/00	38	Light northerly and southerly breezes
12/12/00	33	Light southerly, south west, westerly and northwest breezes
16/12/00	18	Very light northerly and moderate southerly winds

Given the range of observed concentrations occurring under the same conditions, a careful choice must be made of a 'typical' baseline PM_{10} for those conditions. The milk processing plant is northwest of the township. In the assessment, account was also taken of the direction of the sensitive receptors (township and school) from the milk processing plant, and baseline PM_{10} levels chosen for several locations. These are shown in Table 5, and were added to the modelled GLCs from the plant.

Table 5: Estimated 24-hour baseline PM_{10} concentrations around Edendale, Southland.

Location	Baseline PM_{10} ($\mu g/m^3$)	Weather Conditions
Edendale Township, South East of plant	**30**	Strong to moderate dry NW wind blowing for long periods
Edendale Township, South East of plant	**20**	Light to moderate NW winds
Edendale Township, South East of plant	**40**	Light southerly and northerly breezes on cold days, where plant emissions are not directed towards the township
Edendale School South West of plant	**15**	North-easterly winds for much of the day and for all ambient conditions
Rural area North East of plant	**15**	South-westerly winds for much of the day and for all ambient conditions

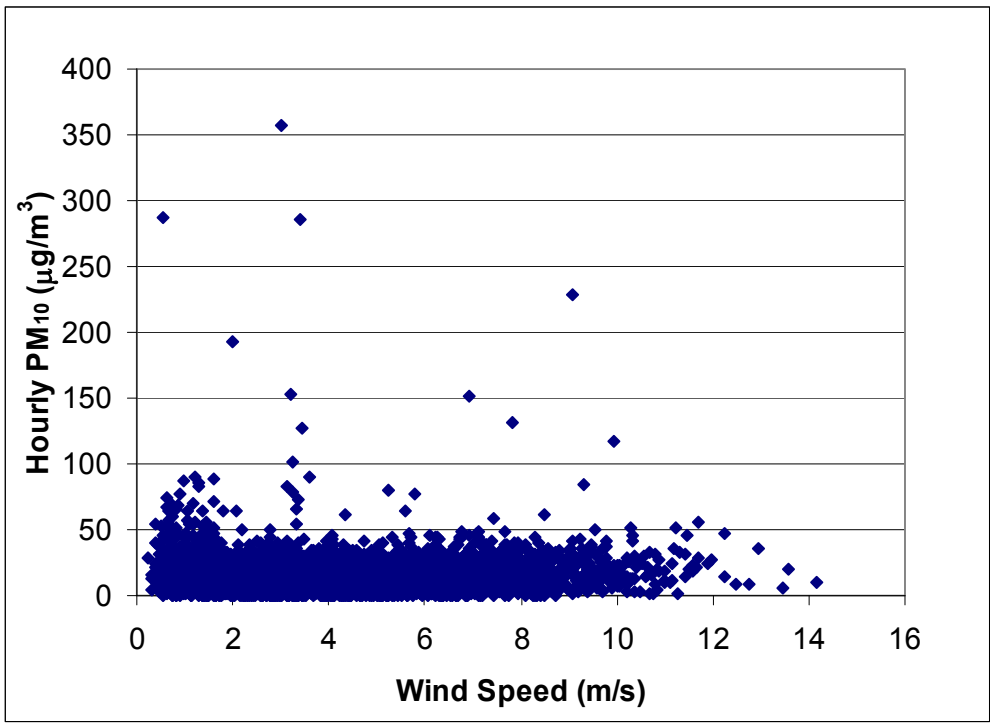
3.2 Waikato Milk Processing Plant

This example concerns a milk processing plant at Te Awamutu, south of Hamilton. An assessment was carried out in 2008 on the effects of discharges of PM_{10} from milk powder processing and a re-configured energy centre. Dispersion modelling was carried out using the CALMET/CALPUFF modelling system. Ambient monitoring of PM_{10} and SO_2 was carried out at a location near to the plant (roughly 200m to the east of the Energy Centre). The continuous hourly monitoring of PM_{10} enabled the distinction between different kinds of pollutant 'events' (due to different sources) which produce similar 24-hour average PM_{10} levels. It also enabled the determination of a suitable baseline level of PM_{10} to combine with modelled stack-discharge GLCs, and detection of a contribution within the ambient data, if any, due to PM_{10} discharges from the plant. The following discussion is taken from an examination of PM_{10} and meteorological observations contained in the 2008 AEE.

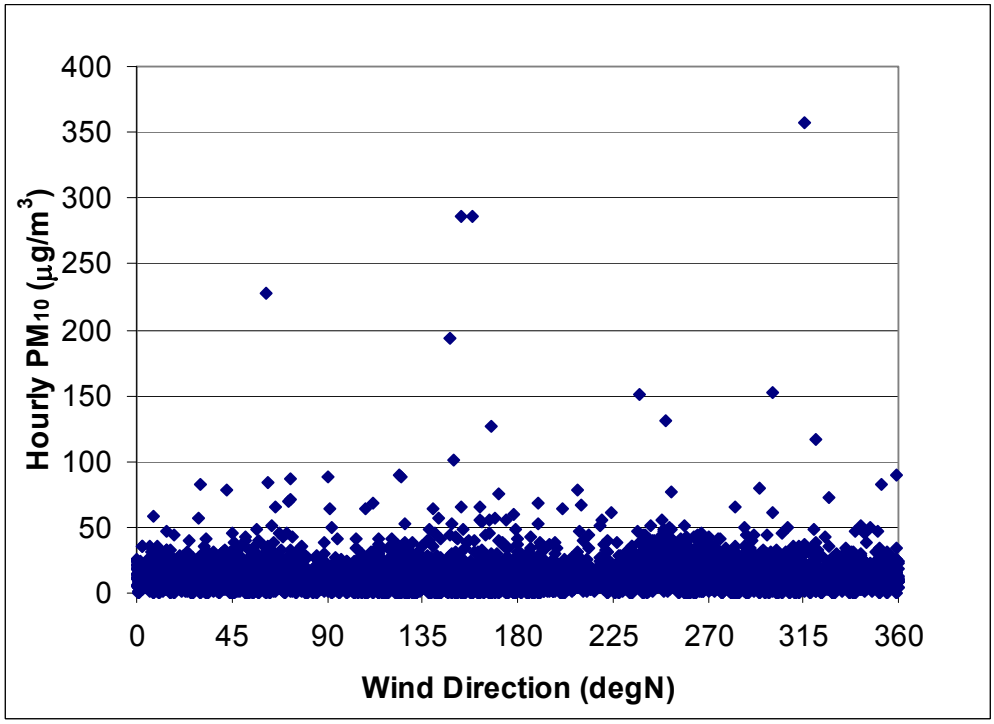
Hourly PM_{10} concentrations are plotted against wind speed and direction in Figure 5. The concentration was generally below 50 $\mu g/m^3$, with a slight increase in the bulk of the concentrations at low wind speed. This is not direction-dependent, and indicated local ground-level sources, such as natural windborne aged particulate, domestic fires and motor vehicles, raising the PM_{10} above a natural background level. Some isolated higher values were measured, occurring at any wind speed or direction. The Te Awamutu plant is upwind of the monitoring site if the wind direction is between 270°N and 315°N, but there was no consistent appearance of elevated PM_{10} when the wind direction was in this range.

An examination of the hourly distribution of PM_{10} and meteorology for days when 24-hour average PM_{10} concentrations were above 30 $\mu g/m^3$ reveals two basic types of elevated PM_{10} events. These included (i) a winter's day hourly urban air quality profile with peaks due to domestic heating and motor vehicles, and (ii) a natural wind-blown dust day (occurring in any season). An example of a winter urban-airshed PM_{10} event is shown in Figure 6(a), from 19 June 2007. The wind speed was mostly less than 2 m/s, from the south, and the 24-hour-average PM_{10} was 42 $\mu g/m^3$. The diurnal pattern of PM_{10} is typical of an urban airshed under these conditions, where the night-time peak due to domestic fires and the morning peak due to both domestic fires and motor vehicles are evident. On 25 October, a different pattern is seen (Figure 6(b)), in which the PM_{10} was continuously elevated. The wind was from the southwest, with speed up to around

7 m/s. The 24-hour-average PM_{10} was 31µg/m^3. This indicates wind-blown dust as a likely source. Other examples of this type had a westerly wind, and the PM_{10} may have a contribution from the milk powder plants, with the wind producing downwash in the lee of the buildings.

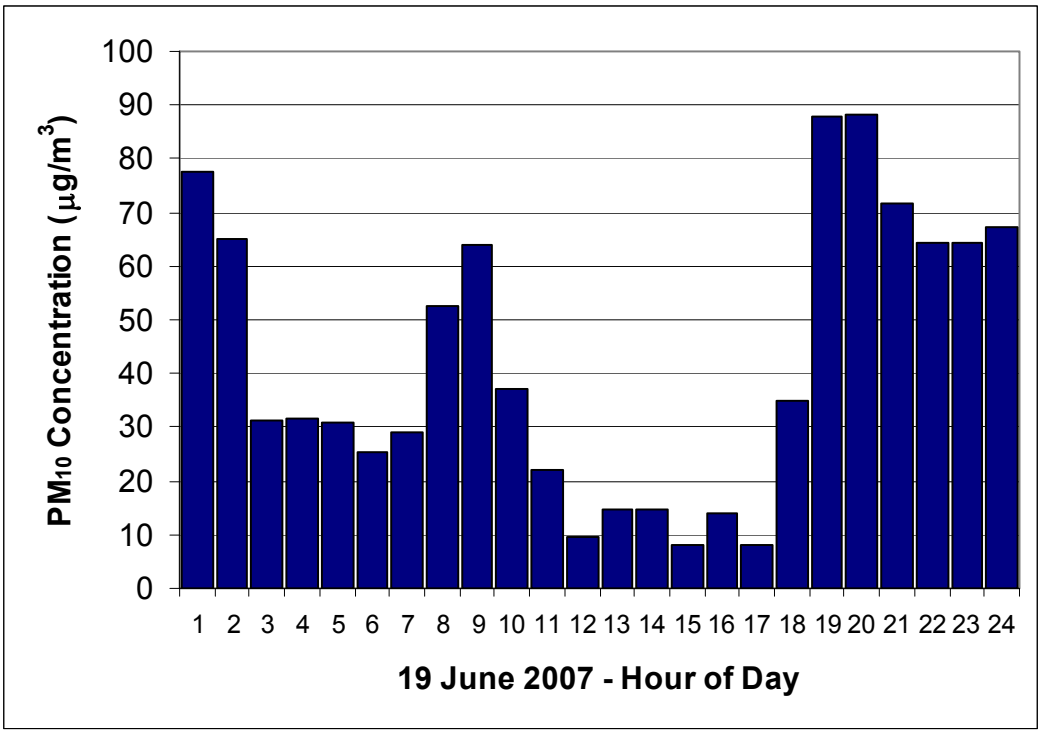


(a)

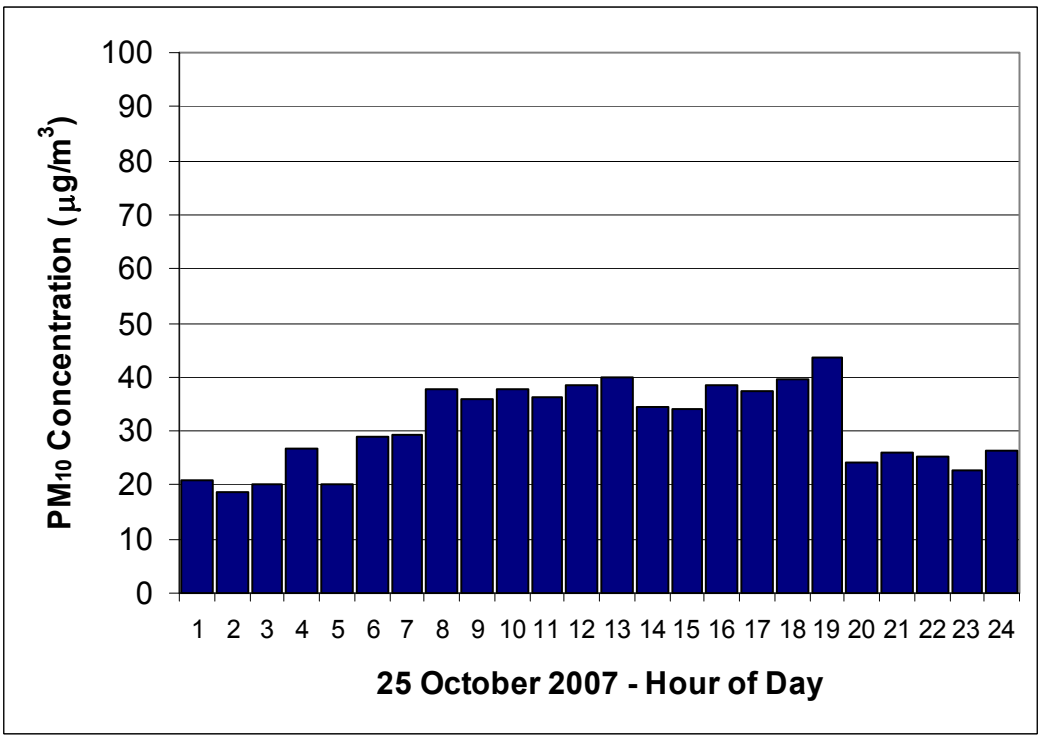


(b)

Figure 5: Scatter-plots of Hourly PM_{10} against (a) Wind Speed and (b) Wind Direction.



(a)



(b)

Figure 6: Hourly PM_{10}: (a) Winter's day domestic fires and vehicles, (b) Windblown dust (spring).

The examples of diurnal PM_{10} profiles presented here show different hourly patterns of PM_{10}, which are explainable in terms of urban air quality processes or natural events. It was not possible to discern a signature of the milk powder plant in the PM_{10} observations, which implies that the contributions of the plant were small. The dispersion modelling showed a maximum PM_{10} of just under 10 $\mu g/m^3$ at the monitoring site, which would be a conservative prediction. The modelling was carried out using constant maximum emission rates, where in practice actual emissions are much lower.

A time-series of 24-hour average PM_{10} GLCs from ambient monitoring is shown in Figure 7. A low level of PM_{10} can be seen, and the concentration was below 25 $\mu g/m^3$ for 95% of the time. The mean concentration over this period was 14 $\mu g/m^3$ and the NES concentration of 50 $\mu g/m^3$ was exceeded on one occasion, reaching 52 $\mu g/m^3$. The analysis of meteorology during days of peak PM_{10} (see above) indicated that on days when site emissions may contribute to measured values (i.e., prevalent westerly winds) that 24-hr PM_{10} GLCs are approximately 30 $\mu g/m^3$. Most of this impact is likely to be a result of the baseline level of ambient PM_{10}, therefore the assumption of the 95% percentile value of 25 $\mu g/m^3$ is considered to provide a reliable estimate of the peak background ambient concentrations that could add to 24-hr PM_{10} GLCs that the modelling predicts to be caused by site discharges alone. Therefore, cumulative PM_{10} concentrations were calculated from modelled PM_{10} due to stack discharges by adding 25 $\mu g/m^3$ to the model results.

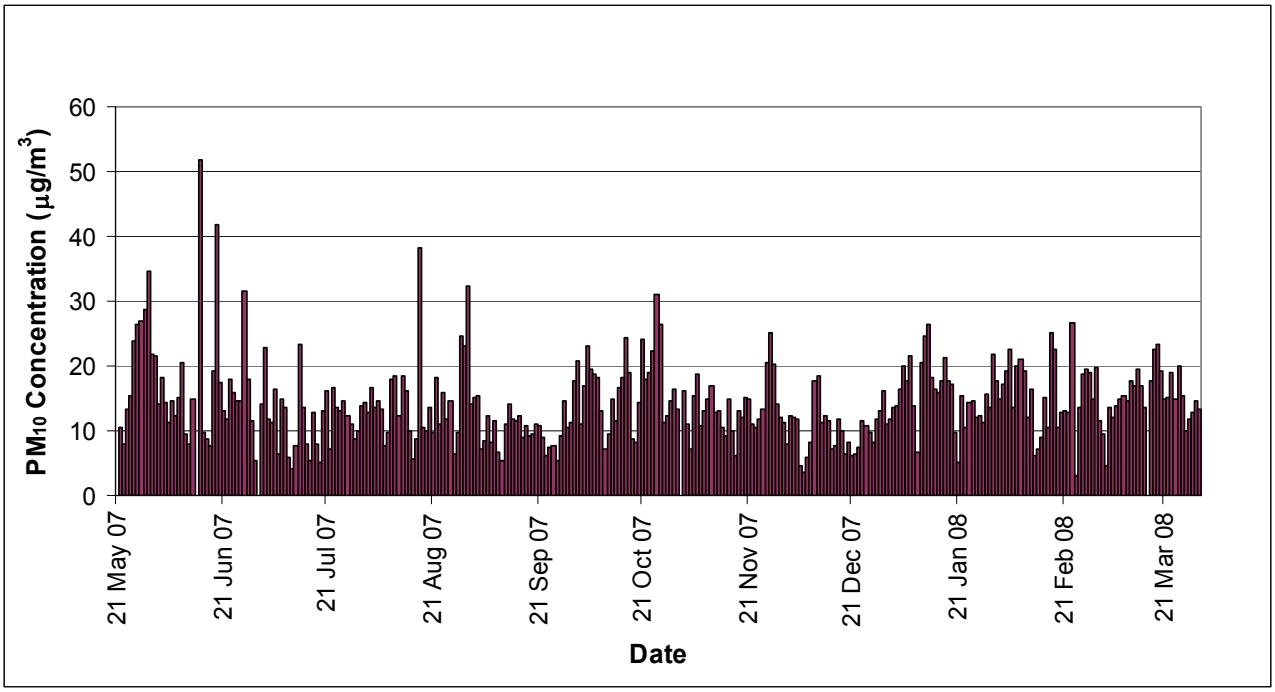


Figure 7: Time series of 24-hour average PM_{10} over the monitoring period.

3.2.1 Further Analysis

A refinement to the above is possible, as the monitoring and modelling were carried out for the same period, and therefore under the same meteorological conditions day by day. For the location of peak modelled PM_{10} from the stack, the modelled and monitored concentrations are plotted together in Figure 8, as bars with the modelled concentration superposed on the baseline PM_{10}.

A visual inspection shows that the highest baseline values do not have substantial PM_{10} contributions from the stack discharge, and that the highest stack discharge concentrations occur under more moderate baseline levels. This is partly due to the peak PM_{10} occurring under northerly wind conditions (as the

location of the maximum is south of the plant), but the highest baseline PM_{10} occurs under westerly or northwesterly conditions. These findings are consistent with what was expected to occur.

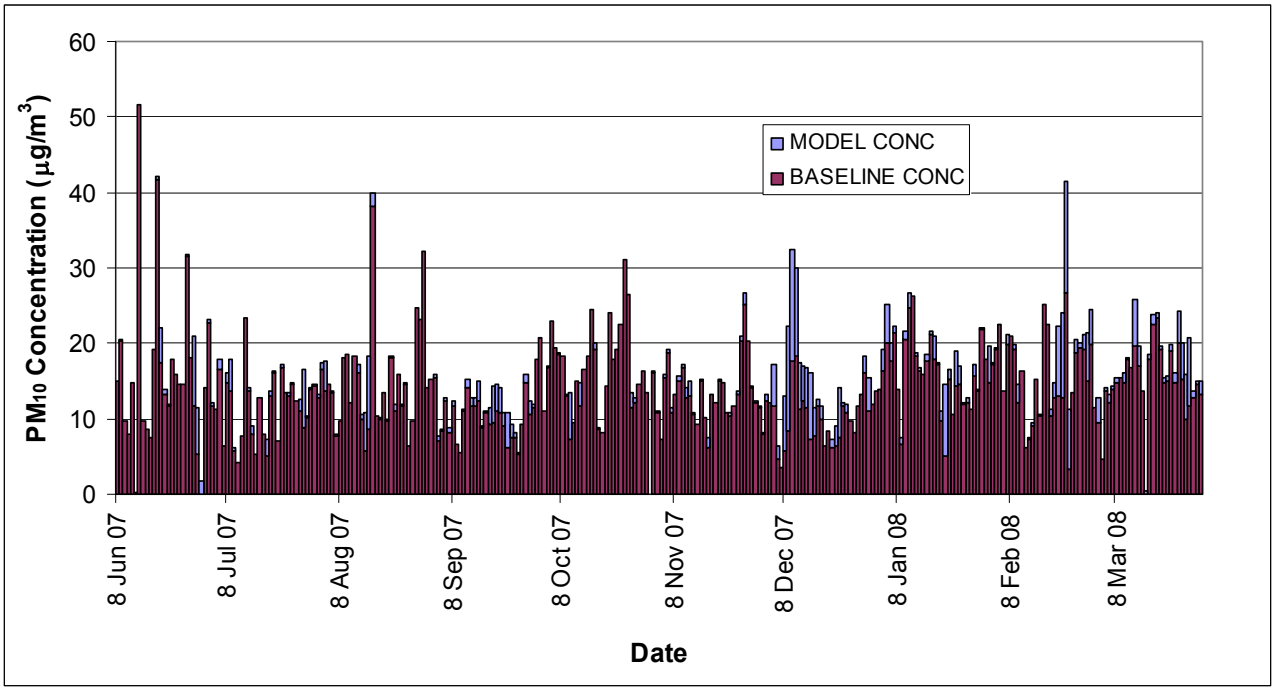


Figure 8: Time series of 24-hour-average PM_{10} for the monitoring/modelling overlap period.

The maximum baseline and modelled concentrations were 52 µg/m^3 and 15 µg/m^3, respectively, but they did not occur together. The former occurred in early June 2007, and the latter occurred (in the model) in mid-February 2008 (see Figure 8). Under worst-case baseline PM_{10} conditions – cases where the baseline PM_{10} is above 30 µg/m^3 – the maximum stack-discharge PM_{10} is 2 µg/m^3. This strengthens the argument presented in the AEE that the appropriate baseline level for the modelled PM_{10} is 25 µg/m^3. Above this level, impacts from stack discharges are small. Under conditions of largest impacts from stack discharges, the cumulative concentration would be around 40 µg/m^3 (25 µg/m^3 baseline plus 15 µg/m^3 from the stack).

4.0 URBAN AIRSHED MODELLING

As outlined in Section 1.4.3, in the absence of near-site data, it may be appropriate to carry out airshed modelling to determine the baseline PM_{10}. The airshed model simulates the dispersion of air contaminants from urban sources such as domestic fires and motor vehicles, producing three-dimensional pollution concentration distributions at (typically) hourly time steps. For this to produce realistic results, the input meteorology and emissions need to be spatially and temporally defined. In the absence of PM_{10} data, there would likely be an absence of emissions data and estimates would need to be made. If PM_{10} *is* monitored in the urban area under consideration, there may also be an inventory of emissions from domestic heating and motor vehicles.

Traditionally, urban airshed models have been developed to simulate atmospheric chemistry, specifically the photochemical reactions between NO_x and VOCs leading to ozone production. In New Zealand, they have often been used to simulate of the wintertime dispersion of PM_{10} in urban areas. The following examples use CALPUFF as the dispersion model. Whilst not an airshed model in the usual sense, it is capable of

simulating the dispersion of inert pollutants from arbitrarily-shaped area sources, and has been used to simulate the dispersion of PM_{10} from suburban sources.

In the example of Section 4.1, there were no PM_{10} data available at the time; in the example of Section 4.2, the industrial area is outside the urban area (though still in the same defined airshed).

4.1 Waikato Milk Processing Plant

This example concerns the industrial site mentioned in Section 3.2. Urban airshed modelling was carried out before the establishment of the air quality monitoring site in Te Awamutu, to ascertain the baseline PM_{10} and assess the cumulative impacts of the industry. For the purposes of the example presented here, the following should be noted:

- The airshed modelling was not included in the final AEE (in 2008) – ambient PM_{10} data had become available, and the modelling was appropriate for winter only, outside the milk processing season;
- The final AEE contained new source-configuration options. Options presented in a previous version of the AEE (from 2006) no longer apply, though airshed-model results from that time are presented here by way of example;
- Model-configuration options have been changed slightly for this report, so that the concentration contour-plots presented in this section are slightly different to those presented in the previous 2006 AEE.

The four CAUs comprising Te Awamutu were used to define six polygonal area sources in CALPUFF, as shown in Figure 9. Emissions inventory data were obtained from Environment Waikato to represent a typical winter's emissions, of PM_{10} in kg per day, for each CAU. The divided CAUs were assigned PM_{10} emissions according to size (area of each part). Daily emissions were disaggregated into hourly emissions, using monitored PM_{10} from Hamilton as a guide. Hourly three-dimensional meteorological fields were supplied by CALMET.

The modelling was carried out with separate CALPUFF runs for the urban airshed (area sources) and stack discharges (point sources). This is because settings in CALPUFF may need to be different in each. Cumulative PM_{10} concentrations were calculated as a post-processing step.

Figure 10 shows the baseline PM_{10}, due to urban sources such as domestic heating and motor vehicles. The model predicts maximum concentrations in the centre of the Te Awamutu urban area which are greater than the NES limit of 50 $\mu g/m^3$, and the highest concentration is 65 $\mu g/m^3$. Note that the airshed model does not include a natural component of the PM_{10}, and this could be a further 15 $\mu g/m^3$. Note also that recent observations of PM_{10} in Te Awamutu have a maximum measurement of only 51.7 $\mu g/m^3$, and this an outlier. Thus there are strong indications that the model was overstating the baseline PM_{10}. (If airshed modelling had been presented as part of the AEE, this would have been investigated further).

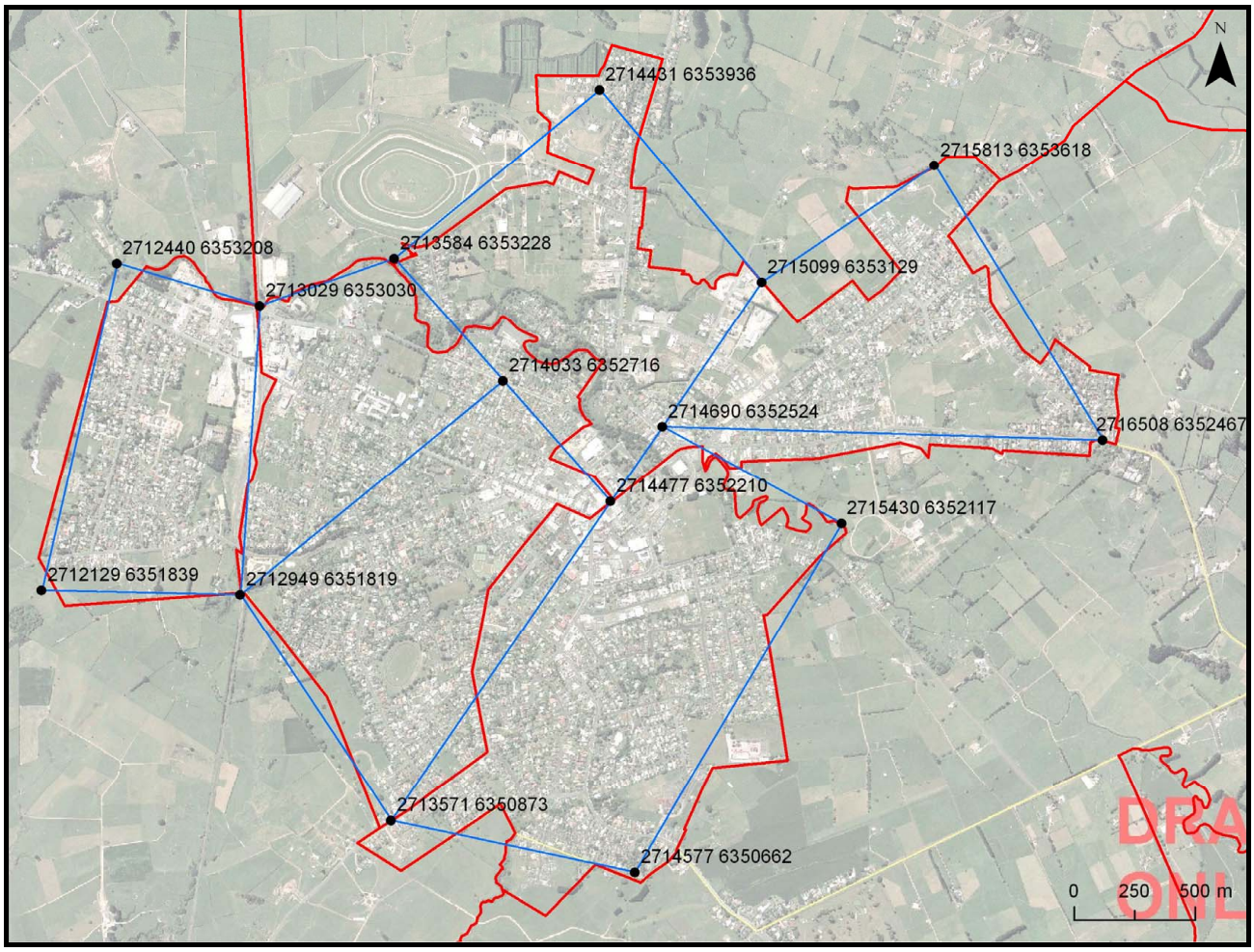


Figure 9: Division of Te Awamutu into CAU boundaries (red) and polygonal area sources for CALPUFF (blue).

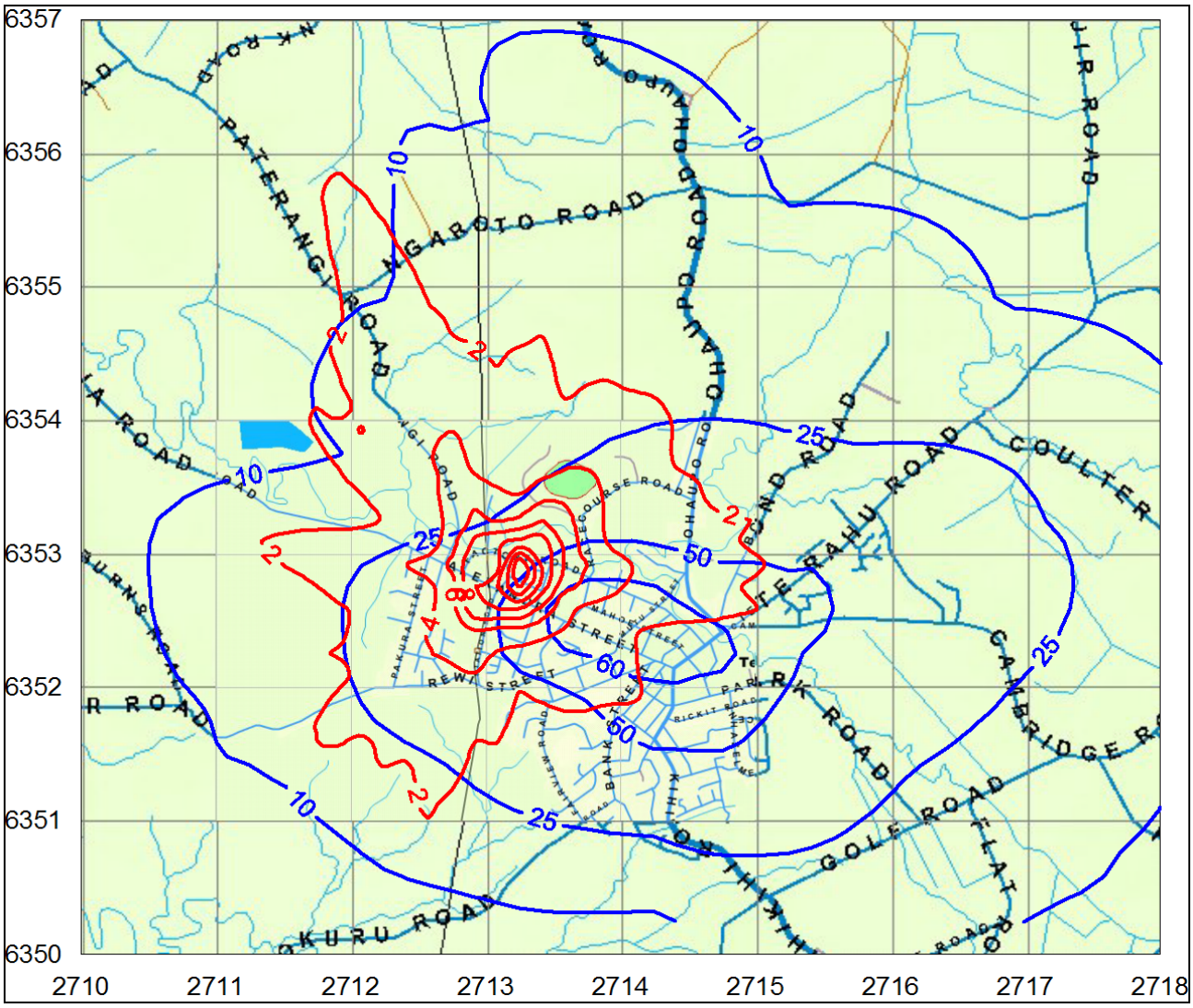


Figure 10: Contour plots of baseline PM_{10} (blue) and maximum PM_{10} from the milk processing plant (red).

Figure 10 also shows the maximum PM_{10} likely to arise from stack discharges (modelled separately, shown in red). This component reaches 18 µg/m^3, coinciding with the 50 µg/m^3 urban PM_{10} contour. However, this does not necessarily mean that the cumulative PM_{10} could reach the sum of these GLCs, namely 68 µg/m^3. The two-dimensional plots are a composite, in that at each point the maximum PM_{10} over the winter is plotted. At neighbouring points, this may have occurred on a different day. Moreover, the maximum PM_{10} from the industrial site (18 µg/m^3) may have occurred on a different day to that on which the baseline PM_{10} was a maximum at that location (50 µg/m^3). Accounting for both components together, the maximum cumulative PM_{10} at that location would be a GLC ≤ 50 µg/m^3, plus a GLC ≤ 18 µg/m^3. This is demonstrated in the following.

Figure 11 also shows the baseline PM_{10} (in blue), and the cumulative PM_{10} (in red). The cumulative PM_{10} is the maximum PM_{10} at each location arising from the combination of urban sources and industrial discharges. The cumulative PM_{10} is everywhere at least as high as the baseline PM_{10}, with the largest difference around the industrial site. At that location, where Alexandra Street intersects the 50 µg/m^3 baseline PM_{10} contour (in blue), the cumulative PM_{10} is 60 µg/m^3 (the red contour). The cumulative PM_{10} is less than the sum of the baseline PM_{10} and the stack discharge PM_{10}, and the airshed modelling provides a more seamless spatially and temporally varying account of the interaction between baseline PM_{10} and impacts due to industrial discharges.

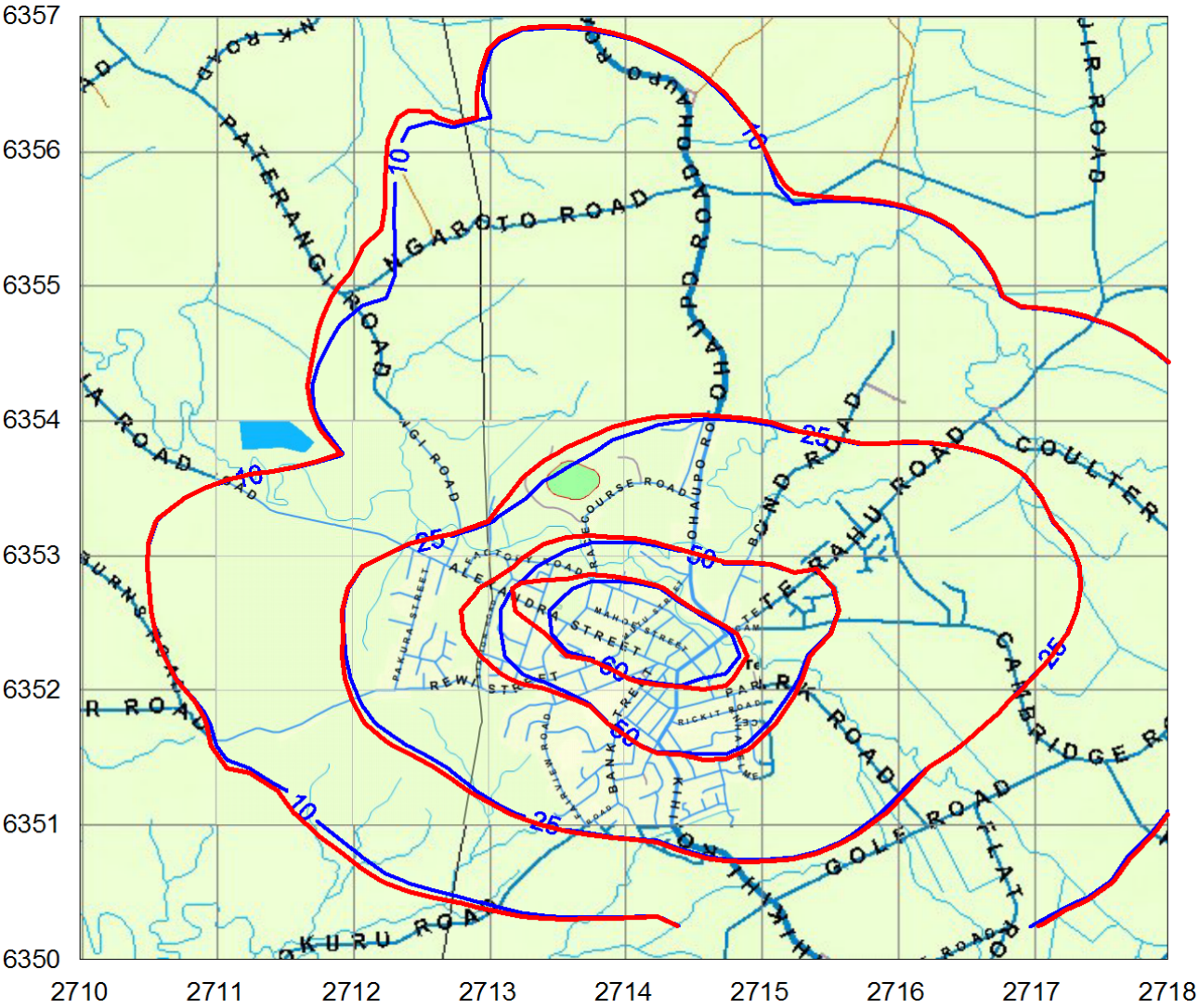


Figure 11: Contour plot of baseline PM_{10} (blue) and cumulative PM_{10} (red).

Airshed modelling was undertaken to evaluate wintertime urban levels of PM_{10} and their spatial variation. The industrial site was found not to lie in the more impacted part of Te Awamutu, but away from the centre of the urban PM_{10} plume, and the spatial influence of the site was shown be very localised. Airshed modelling was not used to derive a robust estimate of baseline PM_{10} as at the time there were no ambient PM_{10} with which to compare airshed model results. Although ambient PM_{10} measurements have been carried out since, an evaluation of model performance was not undertaken, as the airshed modelling was not used in the final AEE. However, the comparison of model results with ambient PM_{10} data should be considered an integral part of an airshed modelling exercise

The discussion of airshed model results is presented in this section by way of an example of the technique in use. As the milk processing season does not include winter, an examination of the wintertime baseline PM_{10} is not relevant. As shown in Section 3.2.1, similar baseline PM_{10} levels occur at other times of the year, which appear to be due to windblown soil dust.

The example presented in this section shows that the maximum PM_{10} likely to occur in the absence of the industrial site in question is a valid representation of baseline air quality, but can give conservative cumulative impacts. This still useful if no NES exceedence is indicated by the presence of the industrial site,

and a map of the blue contours in Figure 11 may be used as a baseline in the assessment of wintertime PM_{10} for any industry in the area without further airshed modelling being necessary.

Airshed modelling is useful as a supplement to ambient monitoring data, in providing a detailed spatial and temporal picture of baseline urban air quality. Without ambient monitoring data in the area against which to evaluate the model results, there is a higher level of uncertainty in them. A high quality inventory of emissions is required, with good spatial and temporal resolution (by suburb, CAU, hour of day, and season). Given this, and a good representation of meteorological conditions, airshed models can provide a realistic, reliable baseline PM_{10}.

4.2 Taupo Wood Pellet Manufacturer

4.2.1 Introduction

This example concerns a wood pellet manufacturer in Taupo. An air discharge permit was needed for the expansion of site operations. This included the drying of fresh sawdust in order to produce pellets, and that process and the use of wood-fired boilers were considered to the main discharges of PM_{10} to air. The industry is some distance away from built-up residential areas where ambient monitoring data has been collected. Therefore airshed modelling for this project was used to indicate the extent to which elevated wintertime PM_{10} levels within the residential areas would interact with the industrial zone and therefore cause cumulative impacts with the industrial emissions. Previously, assessments of industrial discharges had simply derived baseline PM_{10} data from residential ambient monitoring results. These overstated the potential for cumulative impacts as the baseline PM_{10} due to the residential area should decrease with distance from the town.

The assessment of PM_{10} effects was complex for the following reasons:

- Exceedences of the NES target had been observed in Taupo's residential area;
- The industrial area, containing the site in question, is 5 km northeast of the town centre. The industrial area and urban areas are geographically separated, though in the same designated airshed;
- Other industries are in close proximity to the site in question;
- There is a natural, wind-blown component of PM_{10} which is relatively high during summer months;
- Sensitive receptors (residential dwellings) are located outside the defined airshed, but near to the industrial area. The edge of the town is 3 km away.

From a regulatory point of view, Taupo is a non-compliant airshed, so that new industry would not be allowed to take urban air quality above the SLiP. New industry would need to show insignificant effects on PM_{10} in the airshed, and in practice this is taken to mean that the maximum GLC due to the new industry should be less than 1 $\mu g/m^3$ in the urban area. (This is the application of Regulation 17 of the NES) Outside the airshed, where there are no exceedences, Regulation 18 of the NES applies, whereby a resource consent is needed for new activity and the activity must not lead to an exceedence of the NES target.

As pointed out earlier in this report, the targets refer to cumulative effects, so all sources of PM_{10} need to be accounted for. Components of the observed PM_{10} were distinguished according to season and meteorological conditions, as levels measured during calm winter periods would be due to urban sources, and events at other times of the year in windier conditions due to natural wind-blown dust.

The natural component could be treated as spatially uniform throughout the area, and observations from central Taupo considered relevant at the pellet plant. This is not true if the PM_{10} were due to urban sources, where concentrations at the edge of the urban area would be much lower than those in its centre. To address this, the spatial distribution of the PM_{10} from urban sources had to be modelled.

Discharges from the pellet manufacturer and neighbouring industries were modelled as collections of point sources. Emissions from the urban airshed were treated as area sources, in the same way as described in Section 4.1.

Cumulative effects calculated by simply adding the maximum concentrations due to all sources of PM_{10} give conservative levels, which, if well below the NES target, would be sufficient to demonstrate statutory compliance. However, at some locations, and under some meteorological conditions, the conservative estimate was above the NES target, and a more detailed examination of the interaction of the components of PM_{10} was required. This is described in the following sections.

4.2.2 Individual components of PM_{10}

4.2.2.1 PM_{10} concentrations around the pellet plant

A contour plot of the predicted maximum 24-hour PM_{10} due to discharges from the pellet plant is shown in Figure 12, with the maximum off-site concentration about 40 µg/m³. This level of PM_{10} occurs locally over industrial or rural land. At the nearest house, the concentration maximum is less than 5 µg/m³, and over the Taupo residential area (off the south western corner of the figure) it is less than 1 µg/m³.

Figure 12: Predicted maximum 24-hour average PM_{10} GLCs due to the proposed pellet plant (20 t/hr dryers).

4.2.2.2 Monitoring results from central Taupo

Environment Waikato (EW) currently monitors ambient PM_{10} concentrations at six urban sites in the Waikato region. A monitoring site is situated at the Gillies Avenue Reserve in central Taupo and has been operational since November 2000. Monitoring of 24-hour average PM_{10} with a Partisol ambient monitor was undertaken with a 1-in-6 day frequency until July 2002, and thereafter once every third day. Peak 24-hour PM_{10} ground level concentrations exceed 50 $\mu g/m^3$ during the winter of most years and in June 2006 there were two events greater than 80 $\mu g/m^3$. On three occasions there have been exceedences of the NES in late autumn – these occurred under winter-like conditions of low wind speed and low temperature.

The Waikato Regional Plan (EW, 2007) categorizes air quality as "degraded", "acceptable", or "high". The air quality is considered "degraded" if PM_{10} levels exceed 66% of the NES. This happens on around one in four days during the winter, and on occasions in the other seasons.

The Gillies Avenue 24-hour average PM_{10} data set has been examined, and GLCs plotted against wind speed (Figure 13) and temperature (Figure 14) for each season. It can be seen that the peak PM_{10} concentrations occur mostly on days with average wind speed less than 2 m/s, and average temperature less than 10 degrees Celsius. These levels are considered to be primarily due to the influence of home heating emissions. However, elevated PM_{10} concentrations (> 30 $\mu g/m^3$) also occur under more moderate wind speeds (and any season, temperature range or wind direction). Elevated PM_{10} concentrations can be associated with dry and windy conditions resulting in region wide high PM_{10} concentrations. This PM_{10} may originate from either anthropogenic sources or non-anthropogenic sources such as surface dust.

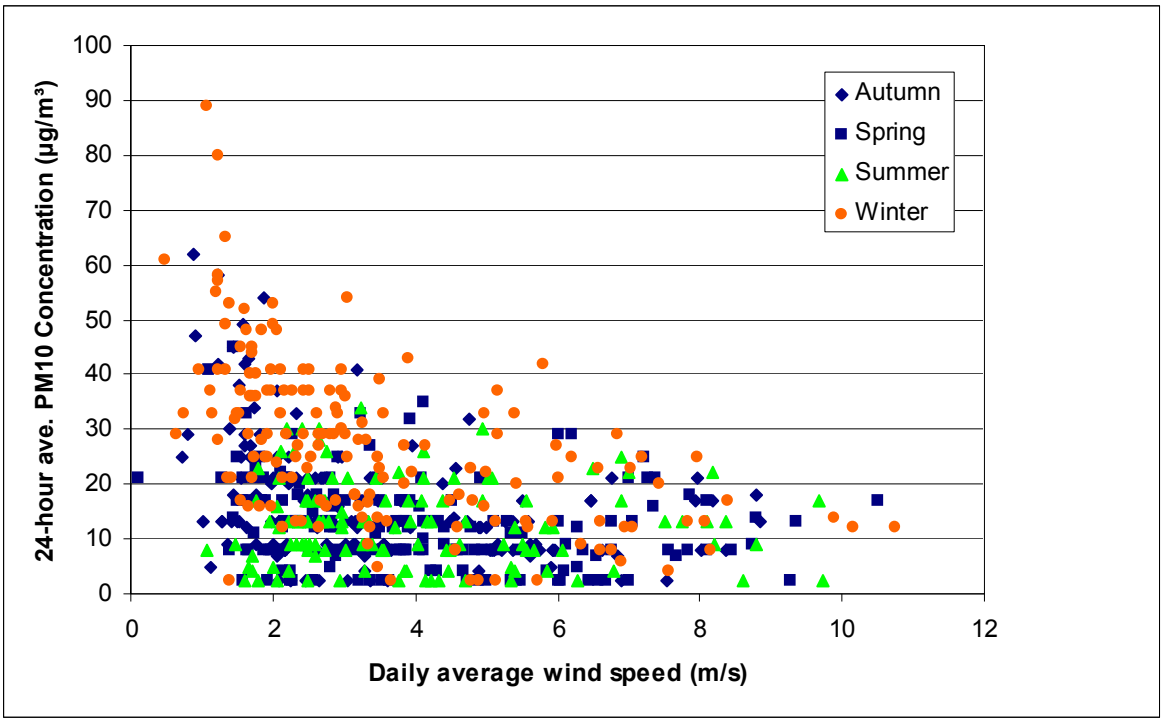


Figure 13: 24-hour PM_{10} monitoring Gillies Avenue, Taupo (data source: Environment Waikato) versus daily average wind speed (Taupo AWS).

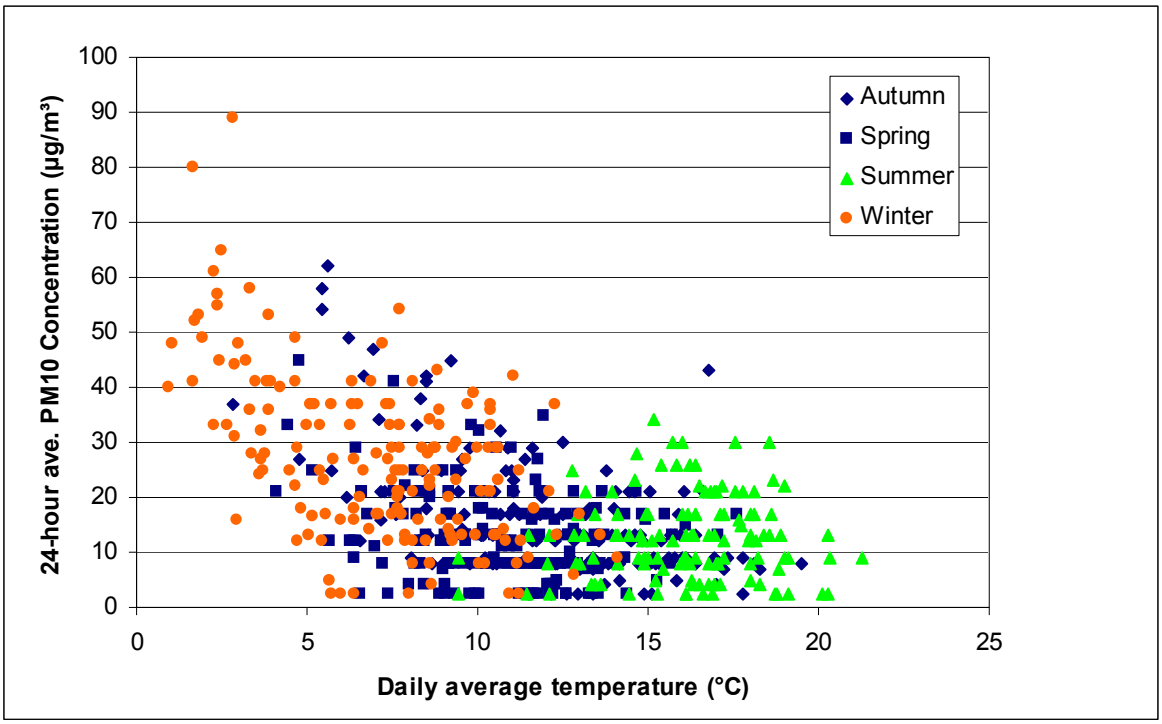


Figure 14: 24-hour PM_{10} monitoring Gillies Avenue, Taupo (data source: Environment Waikato) versus daily average temperature (Taupo AWS).

4.2.2.3 Urban airshed modelling

There is evidence in the ambient PM_{10} data of local urban combustion sources, namely, the occurrence of higher concentrations during calm and cold conditions. Airshed modelling (using CALPUFF) was necessary to determine the spatial extent of elevated PM_{10} and estimate PM_{10} levels at the pellet plant due to urban-area emissions during winter. The modelling was based on the same meteorological outputs from CALMET as used to model dispersion from the pellet plant, but for the winter period only (May to August, 2003). Information from an inventory of emissions compiled for Taupo by Environment Waikato (EW, 2004) was used as input to the dispersion model. The inventory quantifies discharges from domestic heating, motor vehicles, outdoor burning and industry, over several sub-areas of Taupo, for four several-hour time periods of a winter's day. The information was represented in the model as seven area sources, with emissions at a constant rate through each sub-day period.

The maximum ground-level PM_{10} is plotted in Figure 15. This peaks in central Taupo at 190 µg/m^3, rapidly decreasing outside the urban area, to levels around the pellet plant site to the northeast of around 12 µg/m^3. GLCs are somewhat smaller over the lake than over the land at comparable distances. This is due to the difference in stability between land and water on winter nights. The night-time temperature inversion is not so strong over water, as the water would be less cold than the land.

The observed PM_{10} in Taupo has never been above 89 µg/m^3, meaning that airshed model overstates worst-case concentrations in the centre of the city by a factor of at least two. This could be due to conservative emission assumptions or a tendency of the airshed model itself to produce conservative results. Model predictions should be evaluated wherever possible by comparison with observations, to assess these possibilities. It may be that at greater distances from the source (for example, in the industrial areas) the model does not over-state GLCs to the same extent. For this example, the concentrations in the industrial area were taken to be as given by the model.

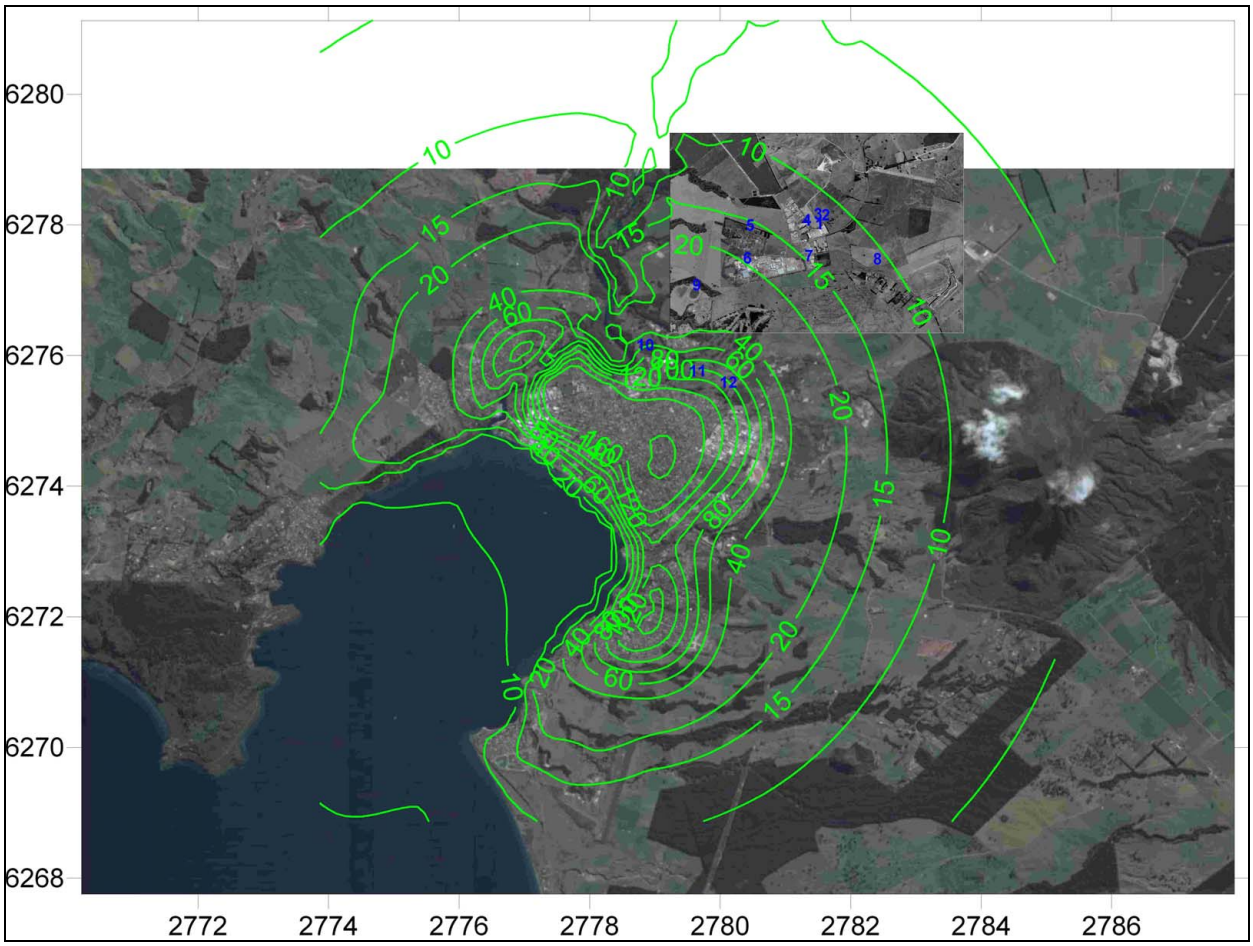


Figure 15: Maximum 24-hour PM_{10} concentrations ($\mu g/m^3$) due to emission from the Taupo residential area.

4.2.2.4 Maximum observed and modelled PM_{10} levels

The maximum PM_{10} concentrations for the source components considered separately, at specific receptor locations, are summarized in Table 6. The main sources identified by observed PM_{10} in the table are those likely to dominate under conditions of elevated PM_{10}, though other sources would have some impact.

Table 6: Summary of maximum GLCs of PM_{10} from individual sources, at selected locations.

Line	Main source(s)	Location	Maximum 24-hour PM_{10}
1	Pellet Plant (modelled PM_{10})	Plant fence-line	~ 40 µg/m³
2	Pellet Plant (modelled PM_{10})	Nearest house to plant	~ 5 µg/m³
3	Pellet Plant (modelled PM_{10})	Taupo urban area	< 1 µg/m³
4	Urban sources (winter, observed PM_{10})	Taupo urban area	89 µg/m³
5	Urban sources (winter, modelled PM_{10})	Pellet plant and surrounds	~ 12 µg/m³
6	Wind-blown dust (other seasons, observed)	Everywhere	~ 40 µg/m³

It is possible to calculate cumulative PM_{10} concentrations by simply summing the component GLCs given in Table 6. This would lead to a maximum concentration at the nearest house of 17 µg/m³ during winter and 45 µg/m³ in the other seasons. At the fence-line, the maximum GLC would be 62 µg/m³ during winter and 80 µg/m³ in the other seasons. (Also, those sums using the modelled urban baseline PM_{10} should also have a natural winter component added – 15 µg/m³ is recommended in Table 1).

Noting that the maximum PM_{10} from the pellet plant occurs under conditions of moderate wind speed (4 - 7 m/s), the baseline peak PM_{10} levels may be refined by filtering out concentrations occurring under low wind speed. This, coupled with the low expected baseline PM_{10} at the pellet-plant site during winter – as determined by the airshed model – effectively rules out calm and cold meteorological conditions as conditions of concern.

On the other hand, the higher concentrations of PM_{10} due to the pellet plant occur under similar meteorological conditions to the higher baseline concentrations (moderate wind speed, any season), and a simple summation could still lead to a cumulative concentration of 80 µg/m³ at the plant fence-line (this is the summation of lines 1 and 6 of Table 6). Possible cumulative PM_{10} levels – arrived at by summation of GLCs from Table 6 – are summarized in Table 7.

Table 7: Cumulative PM_{10} GLCs arrived at by simple summation.

Season / Meteorology	Location	GLC due to Pellet Plant (µg/m³)	Baseline GLC (µg/m³)	Summed GLC (µg/m³)
Winter / Cold, Calm	Plant fence-line	<< 40	12	< 52
	Nearest house	<< 5	12	< 17
	Taupo urban area	<< 1	89	89
All / Moderate wind	**Plant fence-line**	**40**	**40**	**80**
	Nearest house	5	40	45
	Taupo urban area	1	40	41

The modelled cumulative PM_{10} concentration at the plant fence-line may still be greater, at 80 µg/m³, than the NES limit (the case is in bold blue type in Table 7). This may occur under moderate-wind conditions when there could a significant amount PM_{10} occurring naturally (other conditions are not cause for concern). Although the highest-possible cumulative GLC is around 80 µg/m³, it still remains to be seen how likely such a concentration is to occur. This requires a statistical approach, based on modelled dispersion PM_{10} from the pellet plant, and ambient PM_{10} and meteorological data, which is described in the following section.

4.2.2.5 Statistical analysis of ambient PM_{10} data and model results

The statistical approach uses the distributions of PM_{10} concentration at specific receptors due to the pellet plant (modelled PM_{10}) and the baseline (the ambient observations of PM_{10}), combining them together to give a distribution of the sum of the two PM_{10} contributions. This distribution allows the probability of the total PM_{10} being above 50 µg/m³ to be determined.

In the statistical approach the data can be partitioned according to meteorological conditions, the distributions determined for each meteorological type, and the results re-combined. In the pellet plant case, the meteorology was divided into categories of temperature and wind speed. This allowed a better representation of the cumulative PM_{10} distribution, as higher concentrations due to the plant occurred when the wind speed was greater than 6 m/s, and higher baseline concentrations occurred between 2 m/s and 6 m/s. The wind speed category below 2 m/s was partitioned according to whether the temperature was above or below 10°C, as this distinguished different baseline PM_{10} distributions in winter and the other seasons.

As the approach uses distributions of PM_{10}, calculated from model results or observations, the data streams need not be from the same period. Industrial assessments are usually carried out using historical meteorological data, generating modelled PM_{10} for that year. Ambient PM_{10} data for an urban area may not be available for that same year, and monitoring may be commissioned by the industry concerned at a later time (as a resource-consent condition). There is the implicit assumption that the concentration distributions would be similar every year, and the calculated combined probability of an NES exceedence then applies for any year. (Even if the data streams were from the same period, a statistical approach should be followed, as results of a day by day analysis of baseline and industrial PM_{10} would only apply to that specific year).

For the pellet-plant assessment a comprehensive PM_{10} data set was available from the Taupo urban area, along with meteorological monitoring over all seasons. The approach followed here was not applied to wintertime conditions, as these had been addressed using airshed modelling. Consequently, the PM_{10} and meteorological data could be considered applicable to the nearby industrial site. The data were analysed to categorise baseline levels as a function of wind speed and temperature. The modelled ambient levels of PM_{10} due to the industrial discharge at the most impacted off-site locations and the ambient observations from the urban area were categorized according to wind speed and temperature. For each meteorological category, the frequency distributions of observed baseline PM_{10} and modelled industrial PM_{10} at specific receptors were calculated in a small number of discrete concentration intervals, so that the probability of cumulative impacts of PM_{10} greater than 50 µg/m³ could be calculated. The procedure is outlined in the following:

Table 8 shows the frequency distributions for baseline PM_{10} (several years of data) and ambient PM_{10} at an off-site receptor (2003 modelling), when the daily-average wind speed was between 2 and 6 m/s.

Table 8: Probability distribution for baseline PM_{10} GLCs based on the Gillies Ave. monitoring data and modelled PM_{10} at an off-site receptor. Wind speed between 2 and 6 m/s.

PM_{10} concentration (µg/m³)	Gillies Avenue (baseline)	Off-site receptor (modelled)
Greater than 40 µg/m³	3%	0%
30 to 40 µg/m³	7%	2%
25 to 30 µg/m³	8%	1%
20 to 25 µg/m³	11%	5%
10 to 20 µg/m³	36%	26%
0 to 10 µg/m³	35%	66%

Immediately it can be seen that there is only a small chance of the cumulative concentration exceeding 80 µg/m³ in this range of wind speeds. The two frequency distributions can be treated as statistically independent and combined together by multiplying the frequencies in pairs, one from each column. This leads to the combined frequency distribution shown in Table 9.

The column sums in Table 9 are the values for the off-site receptor column in Table 8; the row sums in Table 9 are the values for the Gillies Avenue column in Table 8. The percentages total to 100%. The probability that the cumulative PM_{10} is greater than 50 µg/m³ is the sum of percentages in the upper-right half of Table 9, marked in bold type. Therefore, when the wind speed is between 2 and 6 m/s, the probability of a cumulative concentration above 50 µg/m³ at the specific receptor is 2.0%.

For wind speeds above 6 m/s, similar calculations shown the probability of a cumulative concentration above 50 µg/m³ at the receptor is 1.9%. For wind speed below 2 m/s and daily average temperature above 10°C, the probability is 0.3%. The case wind speed below 2 m/s and daily average temperature below 10°C has been examined using airshed modelling, and the probability of exceeding 50 µg/m³ is zero. The proportion of time spent in each of the meteorological categories is shown in Table 10, along with the probability of the cumulative PM_{10} exceeding 50 µg/m³ in that category.

Table 9: Combined frequency of ranges of observed concentrations at Gillies Ave. and modelled concentrations at the off-site receptor.

Columns of Plant PM_{10} range ($\mu g/m^3$) => =>	*0-10*	*10-20*	*20-25*	*25-30*	*30-40*	*>40*
Rows of Observed PM_{10} concentration range ($\mu g/m^3$)						
≥40	2.0%	**0.8%**	**0.2%**	**0.0%**	**0.1%**	**0.0%**
30-40	4.6%	1.8%	**0.4%**	**0.1%**	**0.1%**	**0.0%**
25-30	5.3%	2.1%	0.4%	**0.1%**	**0.2%**	**0.0%**
20-25	7.3%	2.9%	0.6%	0.1%	**0.2%**	**0.0%**
10-20	23.8%	9.4%	1.8%	0.4%	0.7%	**0.0%**
0-10	23.1%	9.1%	1.8%	0.4%	0.7%	0.0%

Table 10: Wind speed and temperature statistics for Taupo AWS, and cumulative PM_{10} probabilities.

Wind Speed	Temperature	Percentage of time in range	Probability of cumulative PM_{10} above 50 $\mu g/m^3$
Less than 2 m/s	Less than 10°C	11%	0.0%
Less than 2 m/s	Greater than 10°C	10%	0.3%
Between 2 and 6 m/s	Any	67%	2.0%
Greater than 6 m/s	Any	12%	1.9%

The meteorology-dependent cumulative PM_{10} probability can be weighted according to frequency of occurrence of different meteorological conditions, to give the probability of the cumulative PM_{10} being above 50 $\mu g/m^3$ under any conditions. Percentages in the rows of Table 10 are multiplied and the products summed over the columns. Then the probability is 1.6%, which can be thought of as six daily occurrences per year. This analysis was applied to several receptors, and the results presented here show the highest number of exceedences. Hence the likelihood of six daily occurrences is the maximum at any location, and, moreover, applies in a small area close to the plant fence line. Elsewhere, there is no likelihood of the total PM_{10} being greater than 50 $\mu g/m^3$.

The statistical analysis has shown that whilst there is a potential for the cumulative PM_{10} to be up to 80 $\mu g/m^3$, the cumulative PM_{10} is only likely to be above 50 $\mu g/m^3$ at most six times per year.

5.0 SUMMARY AND RECOMMENDATIONS

This report provides examples of how baseline PM_{10} has been established for a number of industrial resource assessments. They have been grouped together as three general approaches, depending essentially on the abundance of available, applicable data. Data streams include ambient PM_{10} measurements, meteorological observations, or derived data such as inventories of emissions. The three approaches are reprised as follows:

1) **Filtering of dispersion modelling results according to local meteorology.** This uses a bare minimum of information, in which the meteorological measurements are used as a surrogate for high and low baseline PM_{10} levels. Modelling results of dispersion from stack emissions can be filtered for days of worst-case baseline PM_{10} and low-level baseline PM_{10}. For urban areas where the baseline PM_{10} is dominated by home heating sources and the industrial emissions dominated by stack discharges, the conditions for worst-case PM_{10} do not coincide, and a more realistic (and less conservative) assessment of cumulative PM_{10} is achievable. The approach thus involves an analysis of the meteorological conditions associated with high concentrations arising from the industrial site and the inference of baseline PM_{10} in terms of the meteorological conditions. The latter step is a weakness of the approach, as it does not give a quantitative picture of the baseline PM_{10}, which can have several components under different meteorological situations (for example, high PM_{10} from domestic heating under calm, cold conditions, and high PM_{10} from natural wind-blown sources at more moderate wind speeds). The approach should only be used if there is no substantial amount of ambient PM10 data nearby.
2) **Detailed analysis of representative ambient PM_{10} and meteorological data.** Where concurrent PM_{10} and ambient meteorological data are available, a more sophisticated analysis can be performed, to establish the meteorological conditions under which baseline PM_{10} levels may be elevated, possibly inferring its likely sources and likely cumulative effects. This approach can give better results if hourly, rather than 24-hourly PM_{10} are available. Within this general approach, there are varying levels of analytical complexity possible, and examples of these are provided in this report[1]. The level of complexity required is driven by not only by the amount of data available *per se*, but by the adequacy or otherwise of the results from a simpler analysis. For example, had the simple summation of PM_{10} components in Table 7 resulted in a maximum cumulative concentration of less than 50 µg/m³, the statistical analysis of Section 4.2.2.5 would have been unnecessary.
3) **Airshed modelling.** Airshed modelling is ideally a complementary approach to the use of ambient PM_{10} data, which would be followed when the ambient monitoring site is not located appropriately to measure baseline PM_{10} near to the industrial site. The airshed model would be used to provide a picture of the spatial distribution of the baseline PM_{10}, giving levels appropriate to the vicinity of the site. Ideally, there should be measurements of PM_{10} in the urban airshed which may be used to assess the airshed model's performance. A limiting factor on airshed-model performance is the quality of emissions inventory data. Comparison of results with ambient PM_{10} measurements is an important component, and uncertainties in the results should be acknowledged if there are no PM_{10} data available and/or emissions have be estimated.

The examples in this report have arisen under differing general situations, and applicable methods to follow in each have been presented. The necessary approaches followed logically in the above cases, though in some a more involved analysis was eventually required. Although new cases will be different in the details, the examples and methods presented in this report should provide a scientific basis for the assessment of baseline PM_{10} in industrial resource consent applications. As pointed out in the introductory sections of this report, the work presented here has been extensively reviewed, examined by regulators and tested at

[1] Two case-study examples of approach (2) are described in Section 3.0. A third is contained in Section 4.2.2.5 (being part of a case-study under the theme of urban airshed modelling).

hearings. It should be useful to consultants carrying out industrial air quality assessments, allowing them to expedite the technical aspects and reduce the cost to industry of the consenting process.

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Otago Regional Council – ambient PM_{10} from Dunedin,

Environment Canterbury – ambient PM_{10} from Burnside, Christchurch,

Environment Waikato – ambient PM_{10} from Taupo, Taupo emissions inventory.

National Climate Database – meteorological data.

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APPENDIX A

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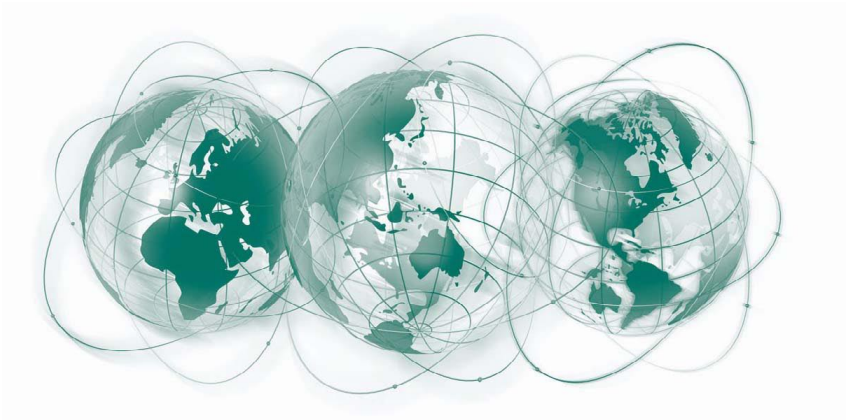

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