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Spatial Variation of Particulate Air Pollution in Hamilton and Taupo During Winter 2008

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Spatial variation of particulate air pollution in Hamilton and Taupo during winter 2008

Photo by Jeff Smith

NIWA Client Report: CHC2008-177
December 2008

NIWA Project: EVW09502

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Executive Summary

The Air Quality National Environmental Standards (AQNES) include a requirement for Regional Councils to monitor PM_{10} in airsheds where the ambient standard for PM_{10} is likely to be exceeded. Regulation 15 of the AQNES also specifies that monitoring within airsheds must be conducted at locations where PM_{10} concentrations are likely to be greatest, or exceeded the greatest number of times. It is therefore important to understand the spatial variability of PM_{10} concentrations within particular airsheds.

A vehicle-based mobile monitoring system is available for measuring spatial patterns of PM_{10} and was used to assess spatial variation of pollution within the Hamilton and Taupo airsheds in the Waikato region. One objective was to evaluate the appropriateness of the locations of current air quality monitoring stations in these airsheds, in terms of complying with AQNES Regulation 15.

In Hamilton, monitoring included two relatively high pollution nights. The highest PM_{10} concentrations (~80 $\mu g/m^3$) were consistently observed by mobile monitoring in neighbourhoods of Fairfield, Frankton, Hamilton East and Melville. Average PM_{10} concentrations were higher in these locations than at the Peachgrove Road monitoring site. This suggests that it would be valuable to install PM_{10} monitoring in some or all of these parts of the Hamilton airshed.

Data from two high pollution nights in Taupo showed that observations recorded at Gillies Ave were not representative of the maximum PM_{10} concentrations experienced in the Taupo airshed on those nights. The highest PM_{10} concentrations in Taupo (~350 $\mu g/m^3$) were consistently observed by mobile monitoring in the central residential area of Taupo, northwest of the Gillies Ave monitoring site. This suggests that, along with the monitoring site at Gillies Ave, it would be valuable to install PM_{10} monitoring in the central residential region of the Taupo airshed.

Daily survey monitoring is recommended in these Hamilton and Taupo suburbs for at least one winter as a minimum.

1. Introduction

1.1. Regulation and sources of particulate matter in New Zealand

The Air Quality National Environmental Standards (AQNES) of New Zealand took effect in October 2004 and include a threshold of 50 $\mu g/m^3$ for 24-hour average concentrations of respirable particulate matter (PM_{10}). The AQNES specifies that resource consents for discharge of PM_{10} to air will be restricted or prohibited if ambient concentrations exceed the threshold of 50 $\mu g/m^3$ for more than one 24-hour period in a year. Exceedances of the AQNES for PM_{10} have been observed at around 30 urban areas within New Zealand (MfE, 2008) and home heating emissions have been identified as the main cause of air pollution in the Waikato region, including the Hamilton and Taupo airsheds (Wilton 2007).

The AQNES also includes a requirement for Regional Councils to monitor PM_{10} in airsheds where the ambient standard for PM_{10} is likely to be exceeded. Regulation 15 of the AQNES specifies that monitoring must be conducted at a location where PM_{10} concentrations are likely to be greatest, or exceeded the most number of times, within the airshed. Due to these monitoring requirements defined within the AQNES, it is important to understand the spatial variability of PM_{10} concentrations within a particular airshed.

Throughout the Waikato region, PM_{10} is generally monitored continuously at only one location within each gazetted airshed. This limited number of monitoring sites is insufficient to provide a comprehensive spatial assessment of PM_{10} concentrations throughout the airsheds. Permanent PM_{10} monitoring stations are expensive to install and operate so that invariably, a comprehensive spatial coverage of permanent stations is neither practical nor realistic. The most common approach is to use other means to identify the area where PM_{10} concentrations are likely to be greatest, before installing a permanent monitoring station.

1.2. Spatial variation of particulate matter within airsheds

PM_{10} concentrations may vary within airsheds due to spatial variability of emissions (e.g. Wilton 2005, Iremonger & Graham 2007), along with topographical or meteorological influences (Aberkane 2000, Iremonger & Graham 2007). Techniques for assessing spatial variation of PM_{10} concentrations within airsheds traditionally include airshed dispersion modelling and survey monitoring. The latter approach was used by Hamilton et al. (2004) to evaluate particulate concentrations at two urban areas near Christchurch. Hamilton et al. (2004) used a handheld Dustrak portable laser

photometer to record data related to PM_{10} concentrations at 20 sites in Rangiora and Kaiapoi. In addition, a Kestrel handheld instrument was used to obtain manual observations of wind speed, air temperature and humidity. Due to the "stop and go" nature of the sampling, two hours were required to traverse the 20 sites at both towns.

From sampling over five nights, Hamilton et al. (2004) constructed contour plots based on the 10 measurements taken in each town. The survey identified that highest concentrations were recorded in residential neighbourhoods, which was attributed to burning of solid fuel on domestic heating appliances in those areas.

In another published study of spatial variability in New Zealand, Conway et al. (2007) used the same instruments and technique at ten sites in Invercargill. While highest concentrations were observed in the southern residential suburbs, a complex meteorological environment was reported. Only a limited number of observations are possible when using this technique and this may have been inadequate to identify the spatial pattern at a sufficiently high enough resolution.

For both of these studies, numerical modelling of air pollution concentrations and meteorology was undertaken using The Air Pollution Model (TAPM), which provided useful information about the distribution of pollution under various topographical and meteorological scenarios. However, the model performance was compromised due to the coarse spatial resolution of the gridded emission data.

Airshed particulate modelling has been conducted for some New Zealand urban areas, including Christchurch (Zawar-Reza et al. 2005), Hastings (Gimson 2006) and Rotorua (Fisher et al. 2007). These models demonstrate the variable nature of particulate concentrations throughout airsheds in New Zealand, depending on factors including the spatial distribution of emissions, topography and meteorological characteristics.

Mobile measurements, using instruments mounted in a vehicle, offer a complimentary means of validating or reinforcing conclusions drawn from modelling, or may be used as an alternative means of assessing spatial variation in airsheds where no modelling has been undertaken. Advances in miniaturisation have made it possible for air quality instrumentation to be deployed on mobile platforms and to be operated whilst on the move. Although relatively labour intensive, this method maximises the utility of single instruments and provides information about the spatial variability of pollutant concentrations.

While the temporal variability at greater than weekly timescales is difficult to capture with these kinds of measurements, there are several advantages of mobile monitoring. Recent developments in air quality monitoring technology mean that it now possible to build a relatively low cost mobile monitoring system that provides good quality, real time data at high spatial resolution. Such a mobile measurement system can provide data to allow the assessment of the variation of contaminant concentrations across an airshed for the purposes of identifying hot spots for monitoring sites, validating airshed dispersion models, or for input to the development or improvement of air quality management strategies.

Olivares et al. (2008a) developed a system for measuring spatial patterns of particulate matter, including PM_{10}, and other associated variables from a moving vehicle. This technique was successfully trialled during winter 2007 at Alexandra, Christchurch and Auckland. The system is ideally suited to provide data for assessment of spatial variation of pollution within airsheds in the Waikato region.

1.3. Project objective

The objective of this report is to detail the spatial variation of PM_{10} concentrations within the Hamilton and Taupo airsheds. By presenting these results, the report aims to assess the location of the Hamilton and Taupo air quality monitoring stations in terms of complying with AQNES Regulation 15.

2. Methodology

2.1. Instrumentation and configuration

Instruments were located both inside the vehicle and in a rooftop enclosure (Figure 2-1). A purpose-built conduit was used to bring cables and sample tubes through the vehicle rear passenger window, to and from the rooftop enclosure.

2.1.1. Aethalometer

A Magee Scientific (Berkeley, California) AE22 aethalometer was housed in the vehicle with a sample tube passing through the window conduit into the rooftop enclosure, upon which the air intake was located. The aethalometer measures the optical absorption of particles on a filter through which an air stream is drawn. The optical absorption provides an index of mass concentration of 'Black' or Elemental Carbon (BC) particles that in urban environments are generally associated with coal or

diesel combustion. The aethalometer used in this study uses two wavelengths: 880 nm (near-IR) to quantify BC and 370 nm (UV) that provides a qualitative measure of aromatic organic compounds. The dual wavelength measurement may be used for identification of different sources; for example, vehicle emissions vs. wood smoke from home heating or biomass combustion. Near real time measurements are possible with a time resolution from five seconds to one hour

Figure 2-1: Mobile monitoring vehicle and (inset) rooftop enclosure. Rooftop instrumentation (including Airmar and temperature + relative humidity sensor) and air intake is shown.

2.1.2. GRIMM particulate sampler

A GRIMM Model 107 Dust Monitor (Grimm Aerosol Technik GmbH & Co. KG, Germany) was housed in the rooftop enclosure, with power and data cabling via the window conduit. The GRIMM monitor is a low-volume sampler that uses a light

scattering technique to continuously measure particle concentration and size distribution in an air stream. The GRIMM is well suited to this mobile application due to the fast response time with near-continuous (six second time resolution), simultaneous measurements of PM_{10}, $PM_{2.5}$ and PM_1 mass values.

Particulate mass concentrations ($\mu g/m^3$) are calculated internally by the instrument, after making some assumptions about particle density and optical properties. Because particle density information is generally unavailable, it is recommended to calibrate the GRIMM by comparing results with those obtained by another measurement technique (Maletto et al. 2003).

In a separate study, an equivalent GRIMM Model 107 Dust Monitor was collocated at an Environment Canterbury permanent monitoring station in Woolston, Christchurch, to identify measurement differences between the GRIMM PM_{10} sampler and AQNES compliant monitors (Olivares et al. 2008b). Hourly average concentrations from the Woolston FDMS versus GRIMM are plotted in Figure 2-2. The linear regression line (r^2=0.89) in Figure 2-2 suggests that PM_{10} data from the collocated GRIMM are around 15% less than FDMS results, at PM_{10} concentrations of 150 $\mu g/m^3$.

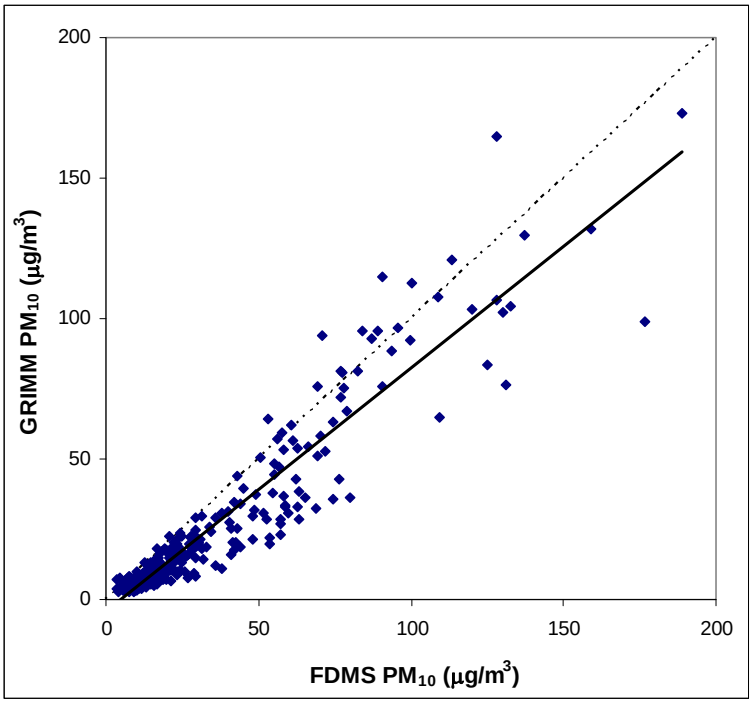

Figure 2-2 **Scatterplot of hourly average PM_{10} data obtained from an FDMS permanently installed at Woolston, Christchurch, and a GRIMM instrument, collocated between 6 August and 20 August 2008 (from Olivares et al. 2008b). Linear regression line (solid line) has equation *y=0.9x–4* (r^2=0.89) and 1-1 line is plotted for comparison (dotted line). FDMS data were provided by Environment Canterbury.**

Because the main objective of this system is to investigate relative concentrations throughout airsheds, a full calibration of the GRIMM is considered to be unnecessary. Furthermore, there is sufficient agreement between GRIMM data and FDMS results (Figure 2-2) to show that the GRIMM Model 107 Dust Monitor is well suited for mobile monitoring to evaluate PM_{10} monitoring sites for NES compliance.

2.1.3. AirMar PB100 Ultrasonic weather station

A PB100 (AIRMAR Technology Corporation, MILFORD, New Hampshire) ultrasonic weather station was mounted on the system's rooftop enclosure (Figure 2-1). The weather station also provides measurements of wind speed and wind direction (both absolute and relative to the vehicle movement), air temperature, relative humidity and barometric pressure.

2.1.4. Data acquisition and accessory equipment

A GPS (Garmin GPS76CSX) was used throughout the campaign to provide longitude and latitude coordinates, plus altitude with accuracy 3m and resolution of 300mm. Instruments were interfaced to a computer via a serial-USB adapter (Quatech ESU2-100). A LabVIEW (National Instruments) application was developed with functions for system control and data acquisition, such that data were updated and stored every second.

The LabVIEW application also provided an on-screen display of instantaneous data in real time. All instruments and equipment were ultimately powered from a dedicated 12VDC lead-acid battery power supply, with a 12VDC-240VAC inverter used to power the aethalometer and DC-DC converters as required for other applications.

2.2. System configuration and operation

The intake was designed and built by NIWA with a convex top-piece (Figure 2-3) intended to direct air and particulate matter into the intake tube. Air was drawn through the system intake using a pump (Charles Austen Pumps – model CAPEX V2-SE) capable of 17L/min maximum flow. Sample air was then drawn from the main intake into the GRIMM and aethelometer using the dedicated pumps of these instruments.

This arrangement was developed in an effort to overcome loss of particulate that was previously observed when the system was operated at moderate vehicle speeds with

the regular GRIMM intake (Olivares et al. 2008a). The purpose-built intake and installation of the separate pump successfully overcame this issue, as demonstrated by Olivares et al. (2008b).

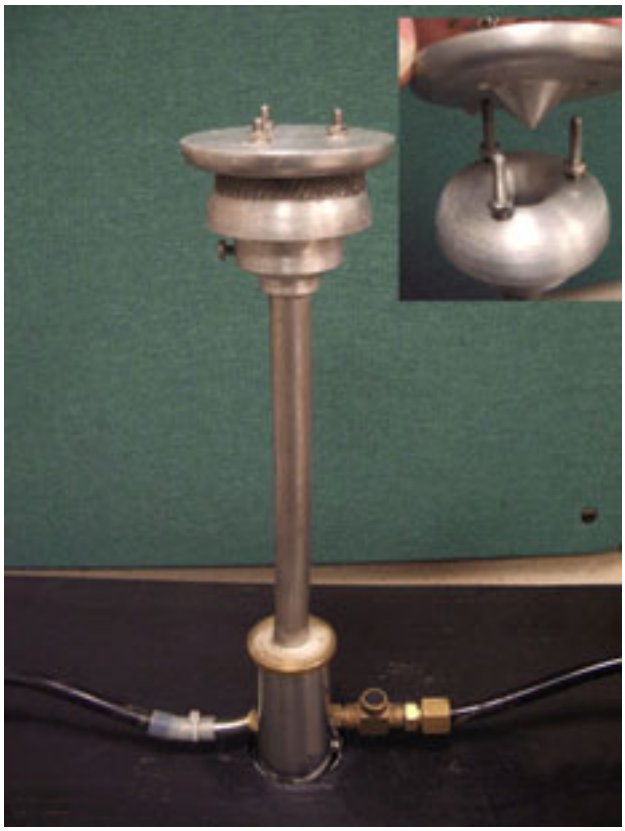

Figure 2-3: Sample tube intake, showing (inset) convex top-piece designed to direct flow into the tube.

Inside the vehicle, the Aethalometer enclosure along with the GPS, serial-USB interface and power converters, were positioned on the rear seat, directly behind the driver. The system was operated by two people. One person was driving while the second assessed the performance of the instruments, assisted with navigation and notified the driver when it was necessary to stop for maintenance.

2.2.1. Experimental trials – winter 2007

The mobile system was trialled during winter 2007 at Alexandra, Christchurch and Auckland (Olivares et al. 2008a). Results of the trial showed that the mobile monitoring system may be applied to: evaluation of variability of PM concentrations both within and between airsheds; identification of potential locations for new monitoring sites within airsheds to ensure compliance with AQNES Regulation 15; and assessment of the representativeness of data collected by existing monitoring sites.

2.3. Locations of Waikato monitoring campaigns – winter 2008

During winter 2008, mobile monitoring of airborne particulate was undertaken in Hamilton and Taupo (Figure 2-4).

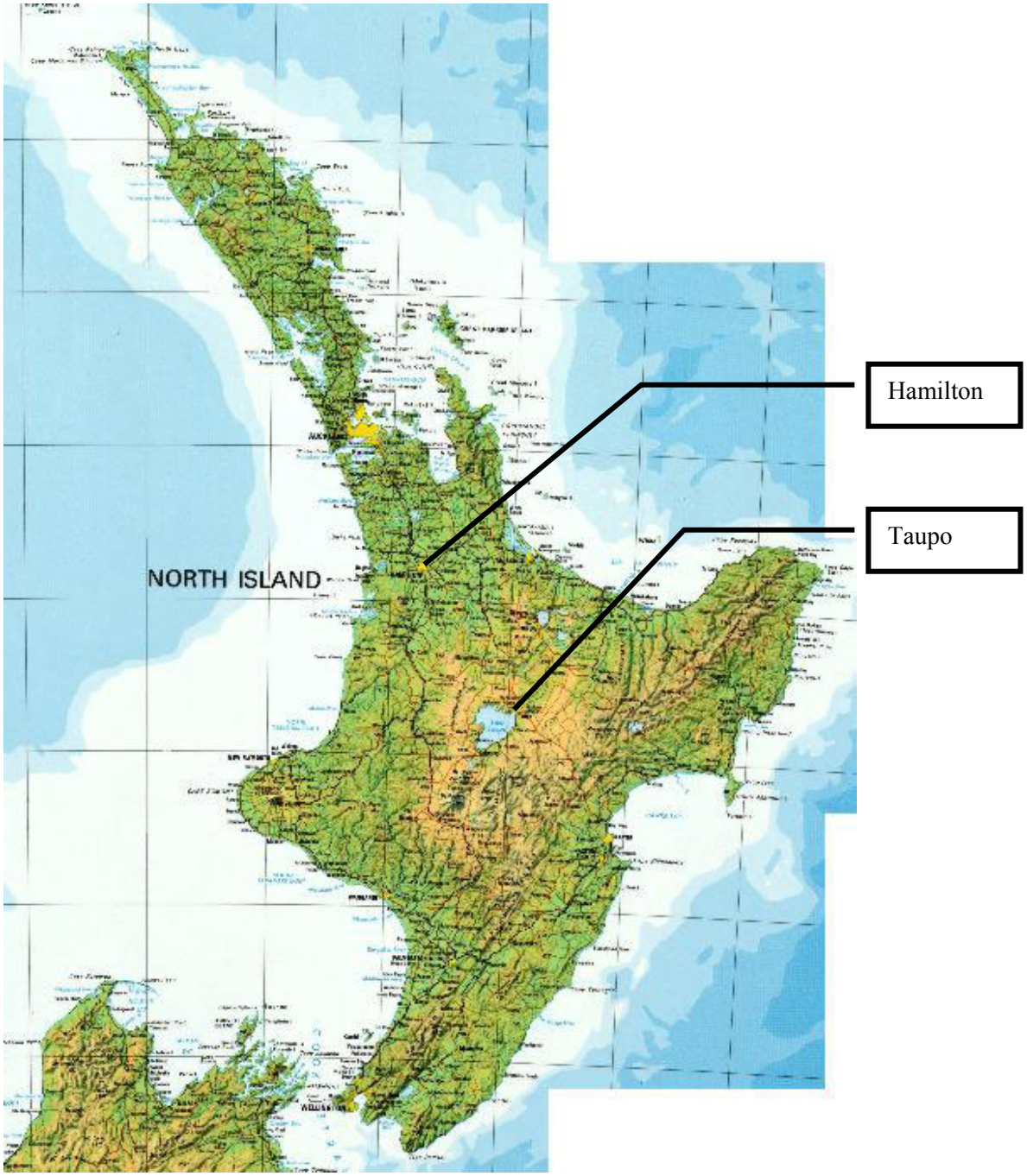

Figure 2-4: Map of the North Island of New Zealand, showing locations of Hamilton and Taupo

Table 2-1 shows the campaign dates along with the number of nights when measurements were obtained. Monitoring was usually completed for a 4-5 hour period between 1900hr and 0100hr. While monitoring was undertaken during four nights in Taupo, there were problems with the GPS system on the first night (7 July) and coordinate data are spurious. Moreover, weather conditions on 7 July were not conducive to high PM_{10} concentrations, so data from that night have been ignored from analyses.

Table 2-1: Measurement dates of the mobile monitoring undertaken at Hamilton and Taupo during winter 2008.

	Measurement dates	Number of nights
Hamilton	30 June – 03 July	4
Taupo	07 July – 10 July	4

Continuous monitoring of PM_{10} has been conducted by Environment Waikato using a Tapered Element Oscillating Microbalance (TEOM) at Peachgrove Road in Hamilton since 2000. Figure 2-5 shows the location of the Peachgrove Road monitoring station in Hamilton. The highest 24 hour average PM_{10} concentration observed at Peachgrove Road is 67 $\mu g/m^3$ and the maximum number of exceedances in a year was three, recorded during 2001 (Wilton & Baynes 2008).

Figure 2-5 Location of Peachgrove Road site in Hamilton, where Environment Waikato monitors PM_{10} concentrations on a permanent basis.

At Taupo, continuous monitoring of PM_{10} has been undertaken at the Environment Waikato Gillies Avenue monitoring site using a beta attenuation monitor (BAM) since March 2007. Prior to this, gravimetric monitoring was undertaken on a 1-day-in-3 basis at the same site since 2000. The location of the Gillies Ave monitoring site is shown in Figure 2-6. The maximum 24 hour average PM_{10} concentration observed at Gillies Ave is 72 $\mu g/m^3$ recorded in 2007. The number of PM_{10} exceedances observed from the continuous monitoring data in 2007 was six. The maximum number of annual PM_{10} exceedances determined by extrapolation of gravimetric results is 14, estimated during 2001.

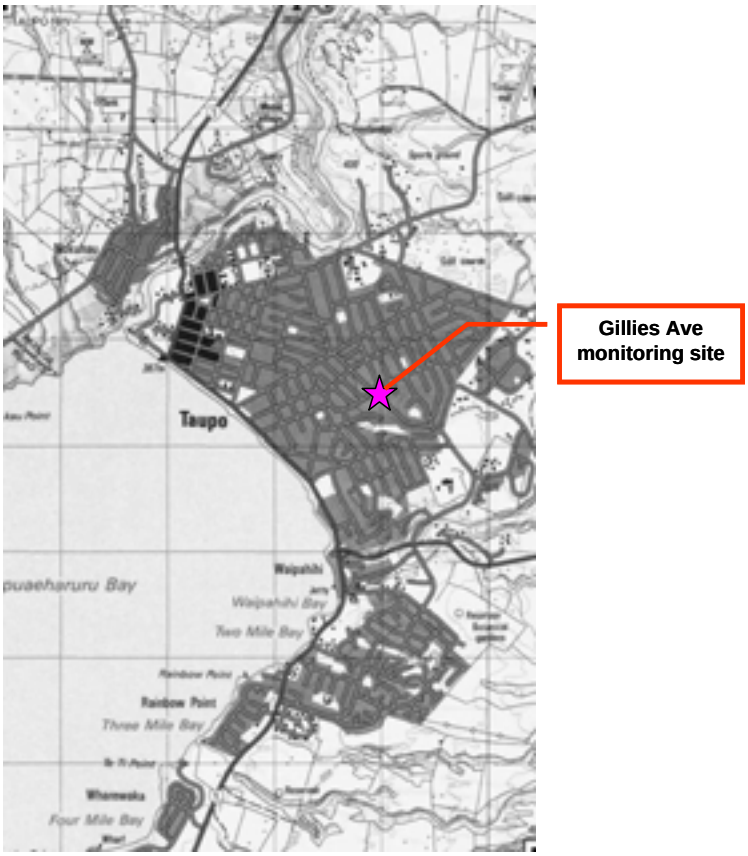

Figure 2-6: Location of the Gillies Avenue site in Taupo, where Environment Waikato monitors PM_{10} concentrations on a permanent basis.

2.3.1. Measurement routes

For the mobile campaigns in Hamilton, different routes were monitored each night, with an aim to achieve the most comprehensive spatial coverage in the total time available. Taupo is a smaller urban area and the routes were approximately the same each night. Monitoring included most of the urban neighbourhoods in Taupo.

3. Results and discussion

3.1. Monitoring in Hamilton

Data from the entire Hamilton campaign were combined and plotted in Figure 3-1. The combined plot provides a general description of where highest concentrations were observed during the Hamilton campaign, although some caution is required when interpreting these results.

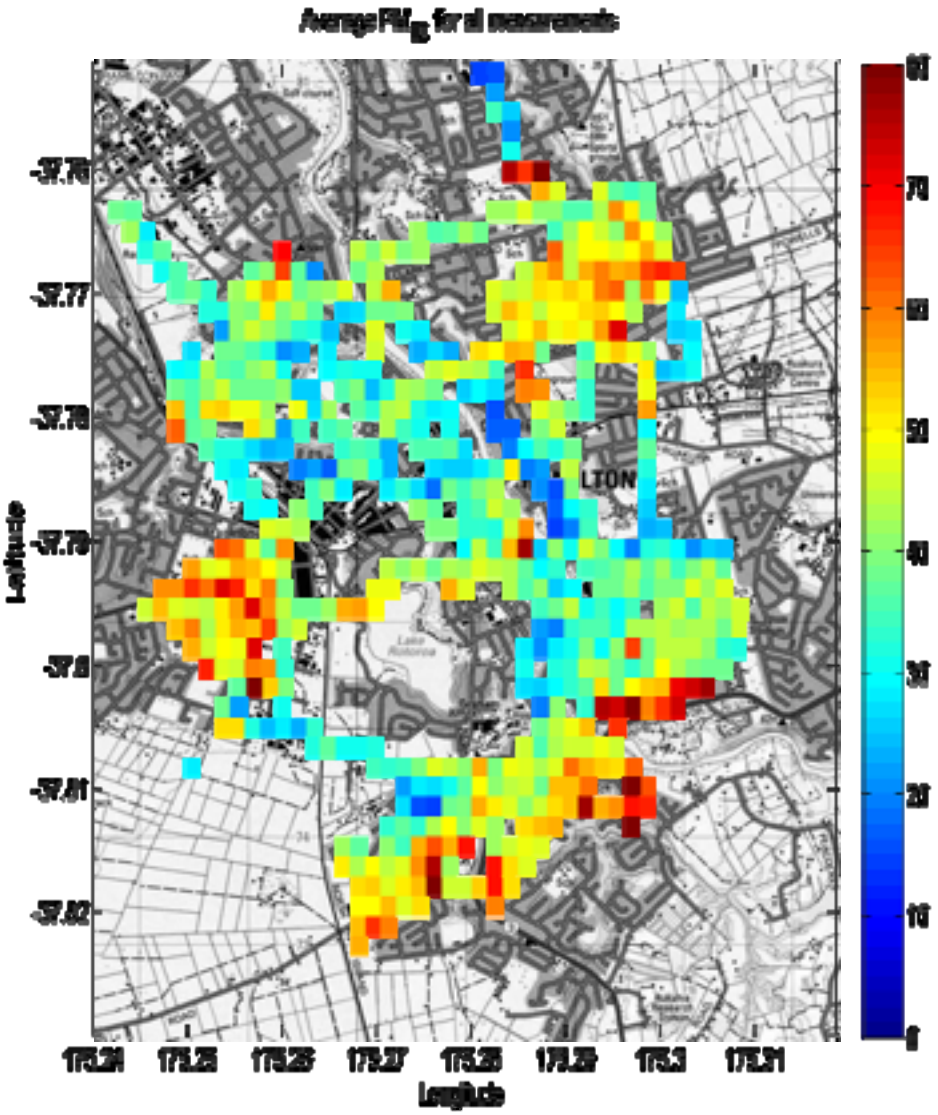

Figure 3-1: **PM_{10} concentrations averaged over 400m^2 grids, during four nights (30 June – 03 July, 2008) when the mobile system was active within the Hamilton airshed. Colour scale is PM_{10} concentration (µg/m^3).**

The first reason for caution is that runs were undertaken over different nights when meteorological conditions may have differed. The spatial variation of concentrations plotted in Figure 3-1 will therefore be confounded to some extent by temporal variability. Another reason for caution is that some locations were visited more than others, which would bias results toward the locations that were monitored for a longer period. However, the combined results do provide a general indication of spatial variability of PM_{10} concentrations.

A plot of isopleths showing areas of equal PM_{10} concentrations is shown in Figure 3-2 and was constructed by interpolation of data points from Figure 3-1. The isopleths are valuable for showing the general pattern of PM_{10} concentrations during the Hamilton campaign. However, some further caution may be required with Figure 3-2 because, due to limitations of time and resources, the entire city area was not monitored during the campaign. It can be seen in Figure 3-1 that data were not collected in some of the northern suburbs in particular, although these are relatively new subdivisions and houses are less likely to burn solid fuel for heating in those suburbs. Therefore due caution needs to be given to the isopleths of lower concentrations (<40 μgm^{-3}) displayed in Figure 3-2. However, the isopleths of higher concentrations (>40 μgm^{-3}) displayed in Figure 3-2 are likely to be representative of reality on the nights when monitoring was undertaken.

Notwithstanding these cautionary remarks, Figure 3-1 and Figure 3-2 show that PM_{10} concentrations were relatively low in the CBD area of Hamilton during the nights when monitoring was undertaken. The highest average PM_{10} concentrations observed in Hamilton during the mobile monitoring campaign were around 80 $\mu g/m^3$ (Figure 3-1). Particularly high PM_{10} concentrations occurred at neighbourhood scales, rather than being widespread across whole suburbs. Generally though, higher PM_{10} concentrations tended to occur in the western suburb of Frankton, along with southern parts of Hamilton East and in Melville to the south. There were also areas with reasonably high PM_{10} concentrations in the eastern suburb of Fairfield.

PM_{10} concentrations on 30 June and 01 July 2008 were relatively higher than other nights during the Hamilton campaign and TEOM data collected by Environment Waikato during these two days are plotted in Figure 3-3. The hourly average PM_{10} data in Figure 3-3 are adjusted for gravimetric equivalency as described by Wilton & Baynes (2008). Because the data represent only two nights from the entire winter of 2008, they are something of a snapshot rather than a definitive assessment of the location of highest 24 hour average PM_{10} concentrations within Hamilton.

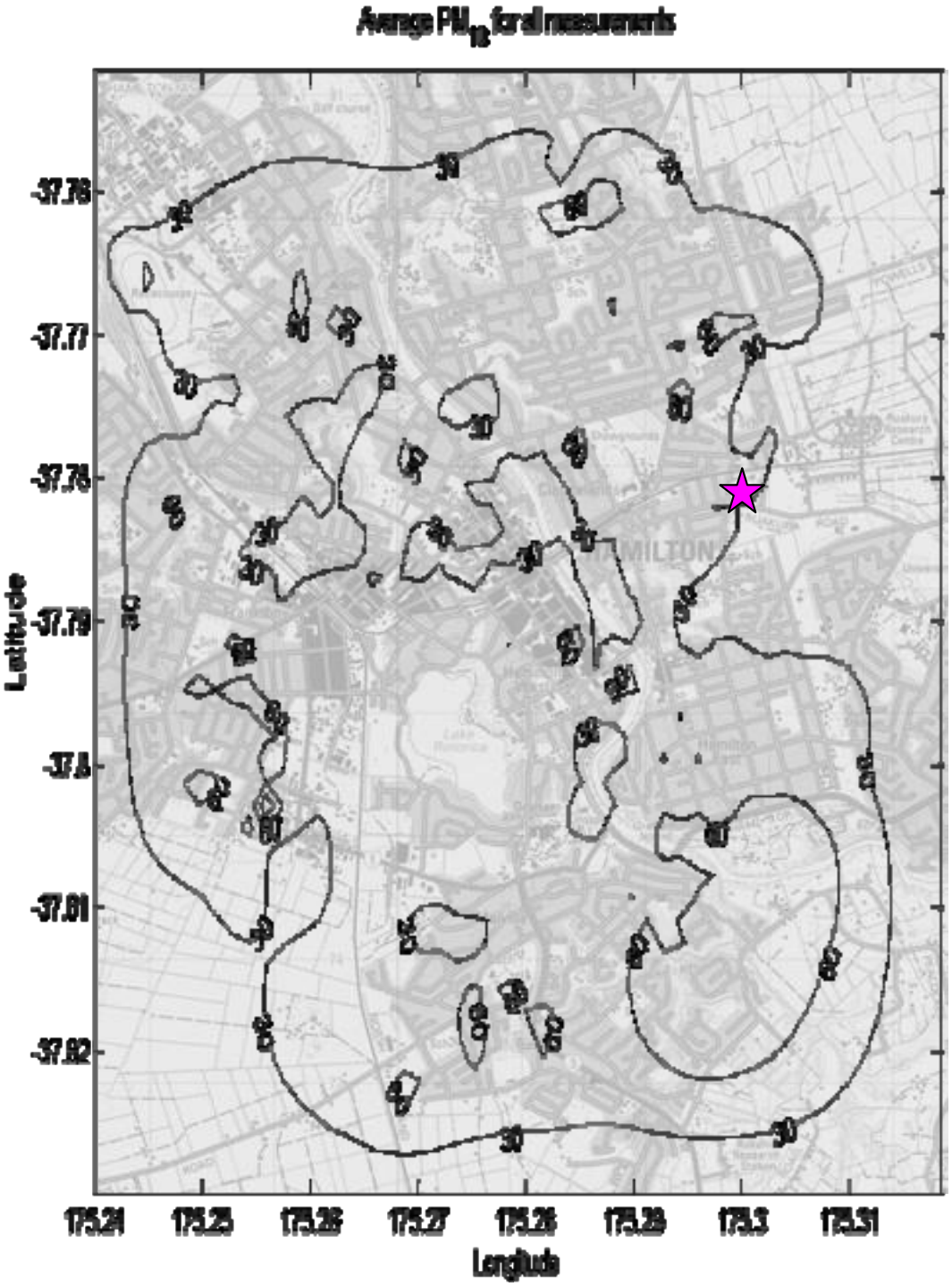

Figure 3-2: **Isopleths of PM_{10} concentrations (µg/m^3) averaged over four nights (30 June – 03 July, 2008) when the mobile system was active within the Hamilton airshed. Pink star indicates the location of Environment Waikato's Peachgrove Road monitoring site.**

Nonetheless, PM_{10} concentrations were relatively high during the two nights, with peak hourly average concentrations of 46 µg/m^3 and 61 µg/m^3 during the nights of 30 June and 01 July respectively (Figure 3-3). During the mobile monitoring period on the night of 30 June, wind was from the westerly quarter and wind speed decreased from 2 m/s at 1900hr to less than 1 m/s by 2100hr (Figure 3-4). On 01 July 2008, light winds less than 0.5 m/s would also have been conducive to higher PM_{10} concentrations due to retarded dispersion of emissions. Therefore, these two nights may be regarded as reasonably high pollution events and this analysis provides a valuable assessment of the location of the Peachgrove Road monitoring site in Hamilton.

More detailed analyses of mobile monitoring data from 30 June and 01 July 2008 are reported below.

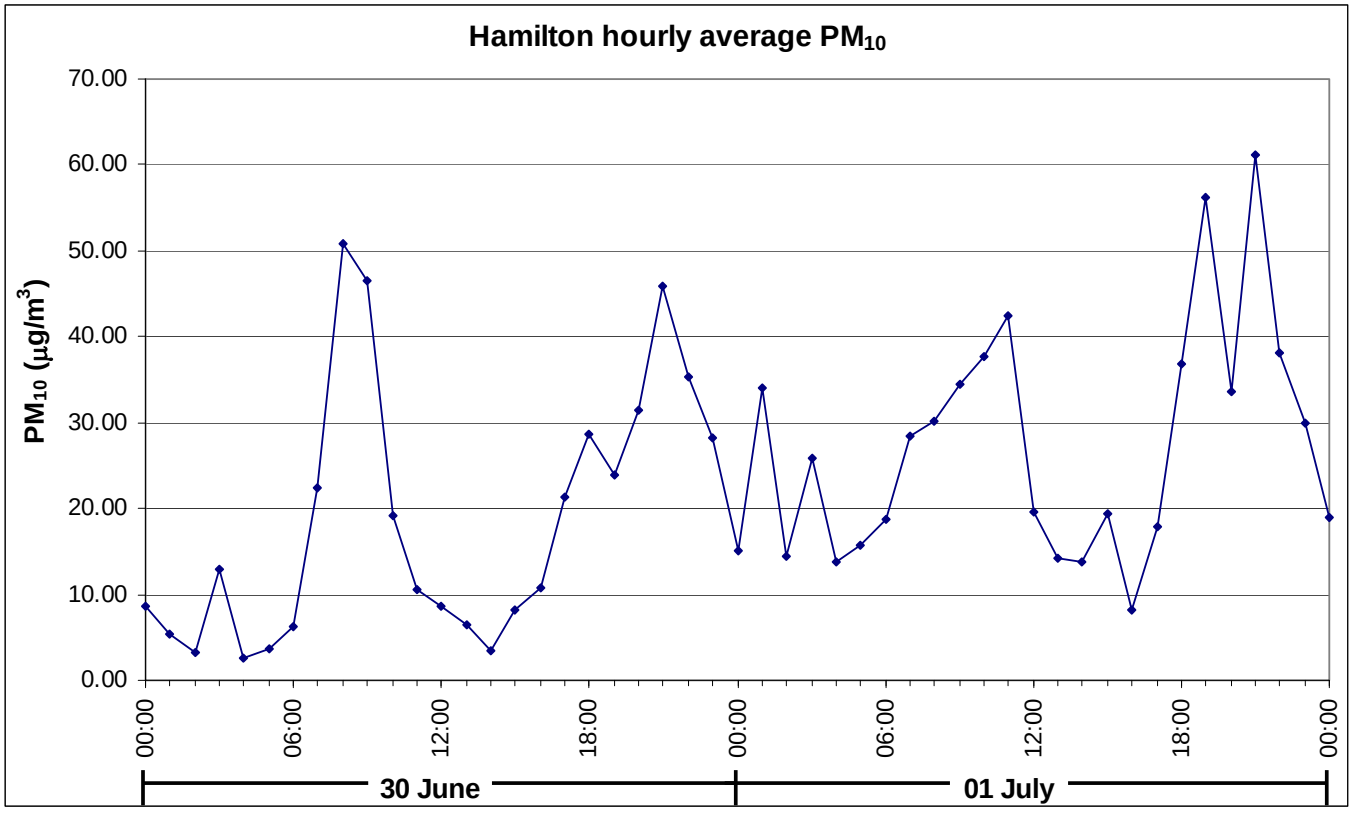

Figure 3-3: Hourly average PM_{10} concentrations (µg/m^3) observed at Peachgrove Road, Hamilton during 30 June and 01 July 2008. Data are provided by Environment Waikato and corrected for gravimetric equivalency as described by Wilton and Baynes (2008).

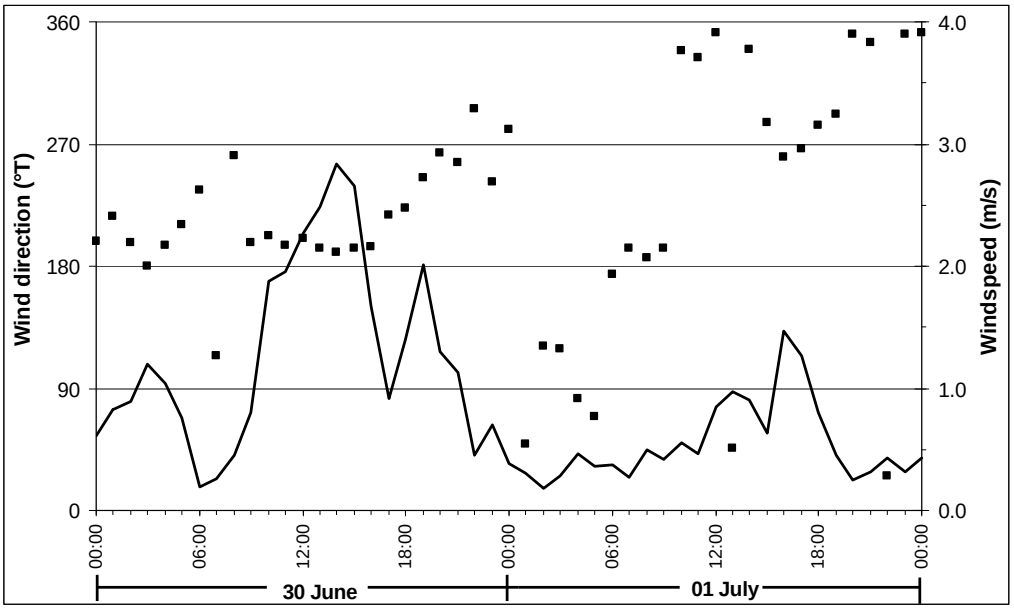

Figure 3-4 : Hourly average windspeed (solid line) and wind direction (black squares) recorded by Environment Waikato at the Peachgrove Road (Hamilton) air quality monitoring station, 30 June - 01 July, 2008.

3.1.1. Mobile monitoring in Hamilton – 30 June 2008

PM_{10} concentrations from the monitoring on 30 June 2008 were averaged over 400m × 400m grids and are plotted in Figure 3-5. PM_{10} concentrations observed at Peachgrove Road during the mobile monitoring on 30 June averaged around 50 µg/m^3. The maximum PM_{10} concentrations, averaging 80 µg/m^3 or more, were observed in Fairfield, Frankton and the southern areas of Hamilton East and Melville/Fitzroy (Figure 3-5). These data show that on the night of 30 June 2008, observations from Peachgrove Road were not representative of the greatest PM_{10} concentrations in the Hamilton airshed

It should be noted for completeness that while the average PM_{10} concentration of around 50 µg/m^3 reported from mobile observations at Peachgrove Road is reasonably consistent with the peak PM_{10} concentration from Environment Waikato monitoring records (Figure 3-3), the averaging periods for these measurements are different. The Environment Waikato data are hourly averages, whereas the mobile data are averages from total time spent monitoring within each 400m^2 grid, which is generally around two or three minutes (e.g. Figure 3-6). Longer periods of monitoring with the mobile system did occasionally occur when the vehicle was parked up. The most common reasons for parking the vehicle were to allow the aethalometer tape to advance (~5min), when briefly collocated next to Environment Waikato monitoring sites (usually ~10min), or for refreshment stops (up to 20min).

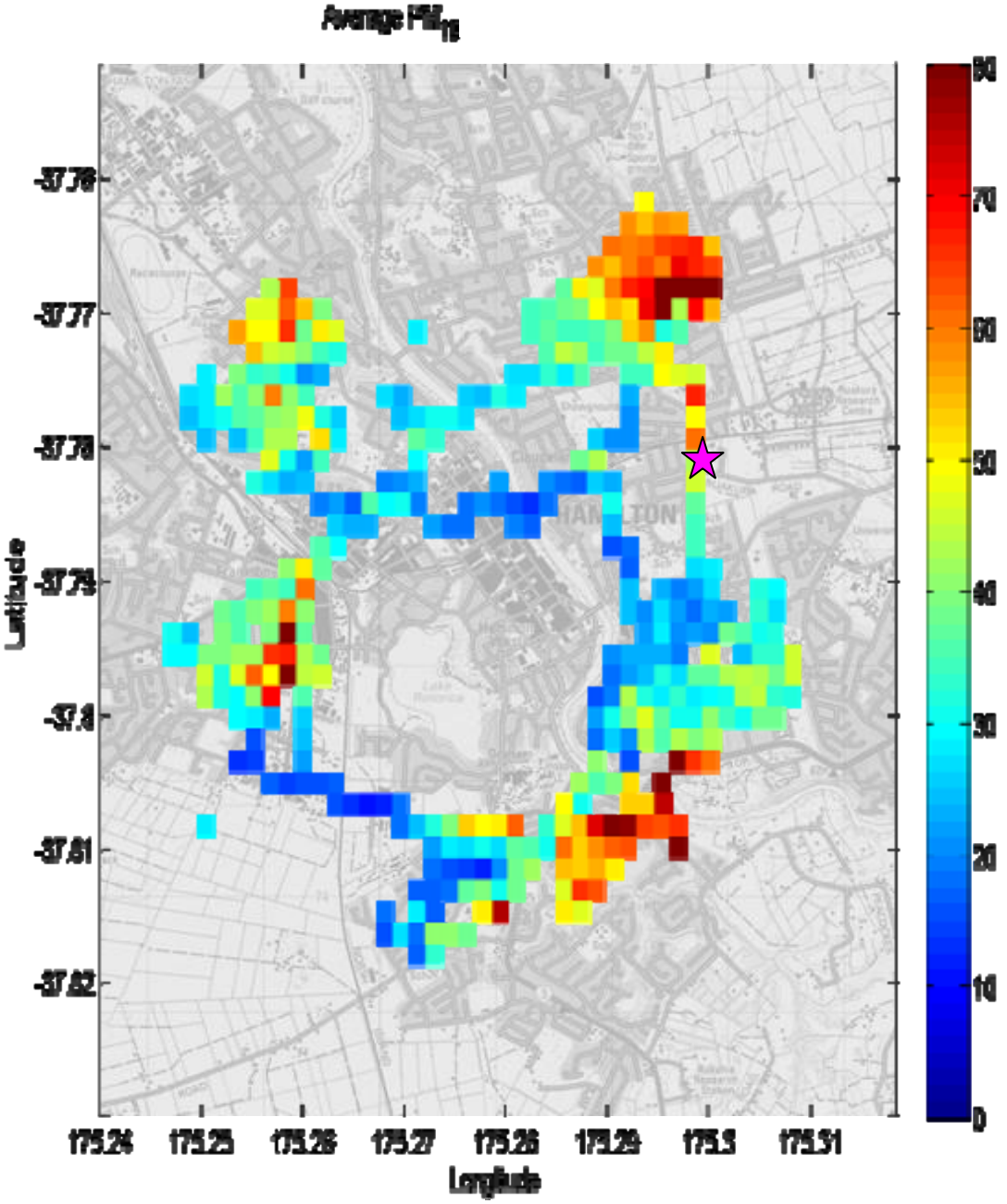

Figure 3-5 **PM_{10} concentrations averaged over 400m^2 grids, in Hamilton during the night of 30 June, 2008. Colour scale is PM_{10} concentration (µg/m^3) and the Peachgrove Road monitoring site is indicated by a pink star.**

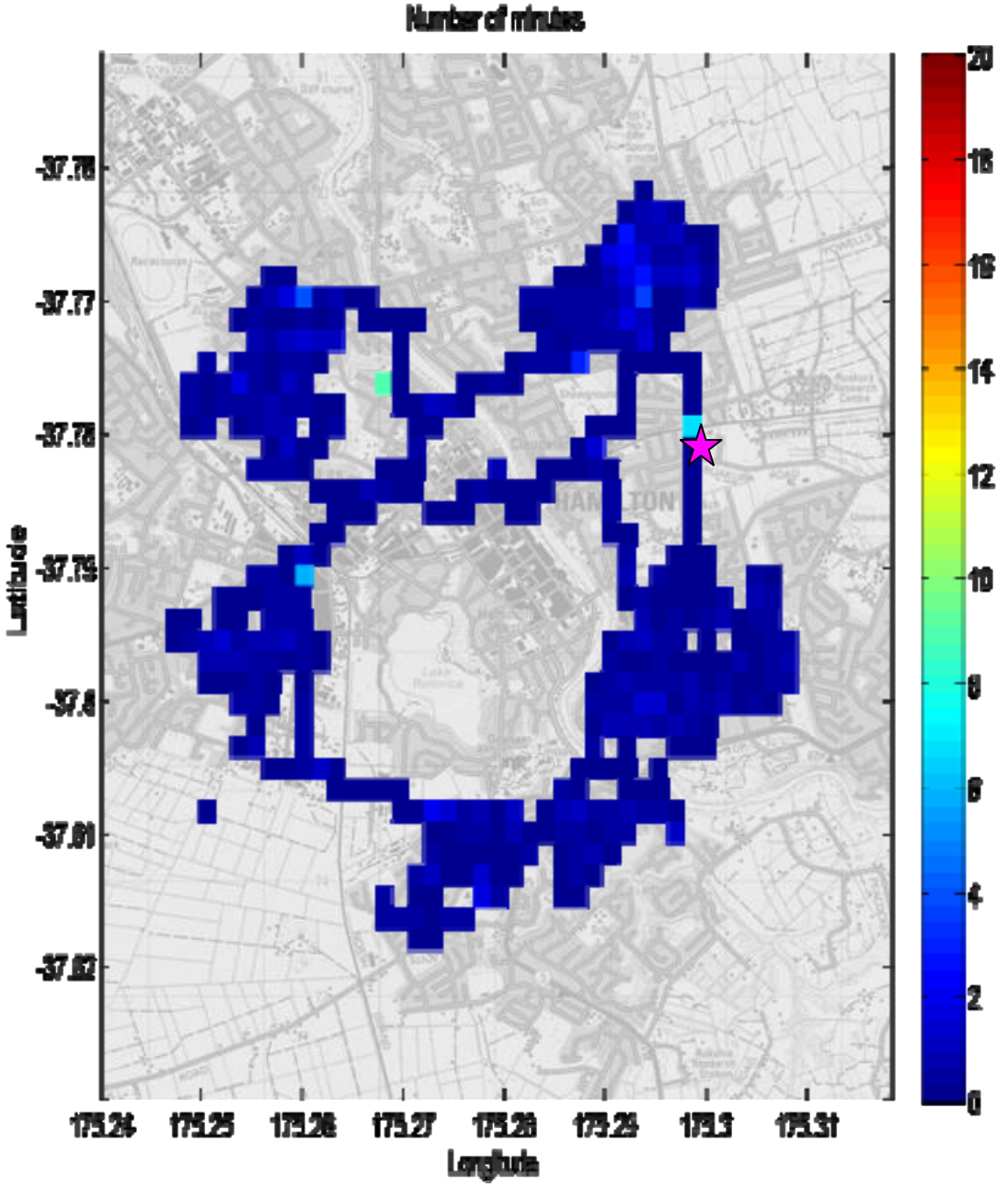

Figure 3-6: **Averaging times for monitoring undertaken within 400m^2 grids during the night of 30 June, 2008. Colour scale represents the total number of minutes spent monitoring within a 400m^2 grid.**

3.1.2. Mobile monitoring in Hamilton – 01 July 2008

PM_{10} concentrations from the monitoring on 01 July 2008 are plotted in Figure 3-7. During the mobile monitoring period on the night of 01 July, wind was from the north and was very light at around 0.5 m/s (Figure 3-4). PM_{10} concentrations observed at Peachgrove Road during the mobile monitoring on 01 July averaged around 50 µg/m^3. On this night, a deviation was made to the northern outer suburb of Pukete. PM_{10} concentrations were relatively low on the northern deviation and, for the sake of maximising spatial resolution, data from the Pukete section were excluded from the combined plot in Figure 3-1.

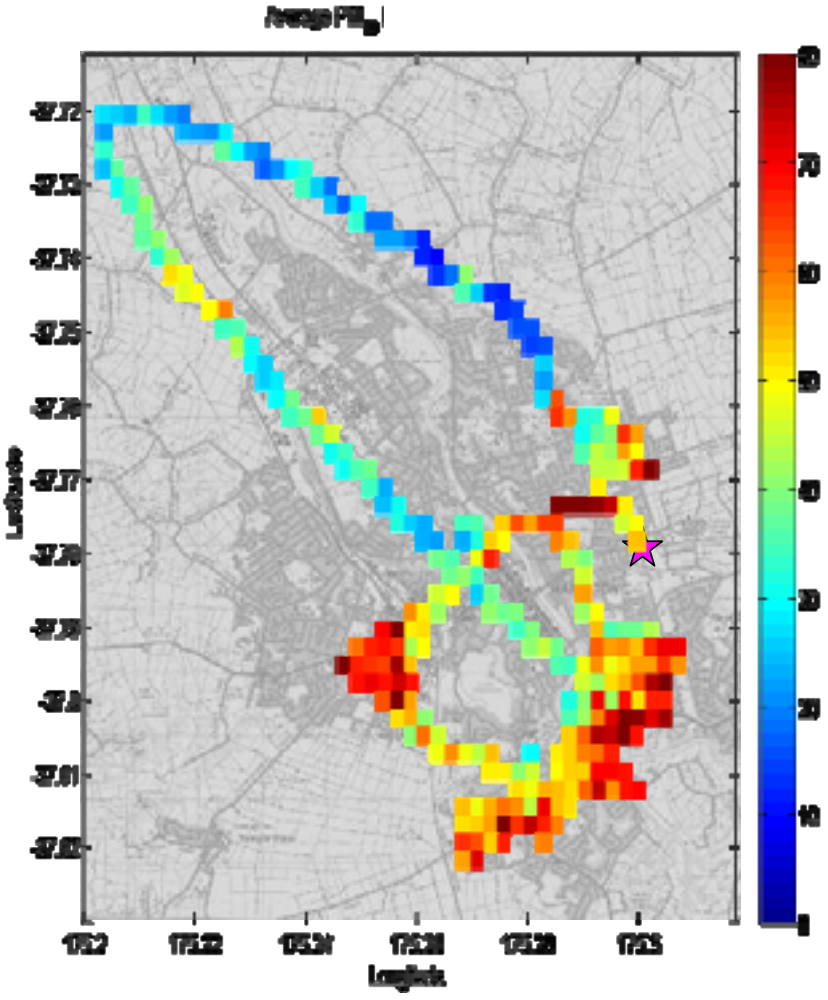

Figure 3-7: **PM_{10} concentrations averaged over 400m^2 grids, in Hamilton during the night of 01 July, 2008. Colour scale is PM_{10} concentration (µg/m^3) and the Peachgrove Road monitoring site is indicated by a pink star. Note the spatial extent of this map is larger than that of Figure 3-5, to accommodate the Pukete deviation in the northwest.**

The maximum PM_{10} concentrations, averaging 80 $\mu g/m^3$ or more, were observed in Fairfield, Frankton and the southern parts of Hamilton East and Melville (Figure 3-7). These data show that on the night of 01 July 2008, observations from Peachgrove Road were not representative of maximum PM_{10} concentrations in the Hamilton airshed. This is entirely consistent with the observations made on 30 June 2008 (Figure 3-5).

3.1.3. Summary of mobile monitoring in Hamilton

Notwithstanding cautionary remarks made earlier, on two relatively high pollution nights, the highest PM_{10} concentrations (up to around 80 $\mu g/m^3$) were consistently observed by mobile monitoring in neighbourhoods of Fairfield, Frankton, Hamilton East and Melville (Figure 3-5 and Figure 3-7). This suggests that, along with the monitoring site at Peachgrove Road, it would be valuable to install PM_{10} monitoring in some or all of these parts of the Hamilton airshed. As a minimum, survey monitoring is recommended in these suburbs for at least one winter.

3.2. Monitoring in Taupo

All Taupo mobile monitoring data were combined and plotted in Figure 3-1, which provides a general description of where highest concentrations were observed during the Taupo campaign. Note that the maximum PM_{10} concentration on the colour scale is 350 $\mu g/m^3$ which is larger than that used in the Hamilton analyses, because PM_{10} concentrations were much greater during the Taupo campaign.

As with the interpretation of Hamilton data, some caution is required when interpreting these results because: 1) runs were undertaken over different nights when meteorological conditions may have differed; and 2) there will be some bias of results toward the locations that were monitored for longer periods. However, the combined results do provide a general indication of spatial variability of PM_{10} concentrations.

A plot of isopleths showing areas of equal PM_{10} concentrations is shown in Figure 3-9 and was constructed by interpolation of data points from Figure 3-8. The isopleths are valuable for showing the general pattern of PM_{10} concentrations during the Taupo campaign.

Notwithstanding the cautionary remarks above, Figure 3-8 and Figure 3-9 show that maximum PM_{10} concentrations were observed in the central residential area of Taupo during the nights when monitoring was undertaken. The maximum PM_{10}

concentrations at Taupo, when spatially averaged over 400m x 400m grids for the entire mobile monitoring campaign, were at least 350 µg/m^3 (Figure 3-8).

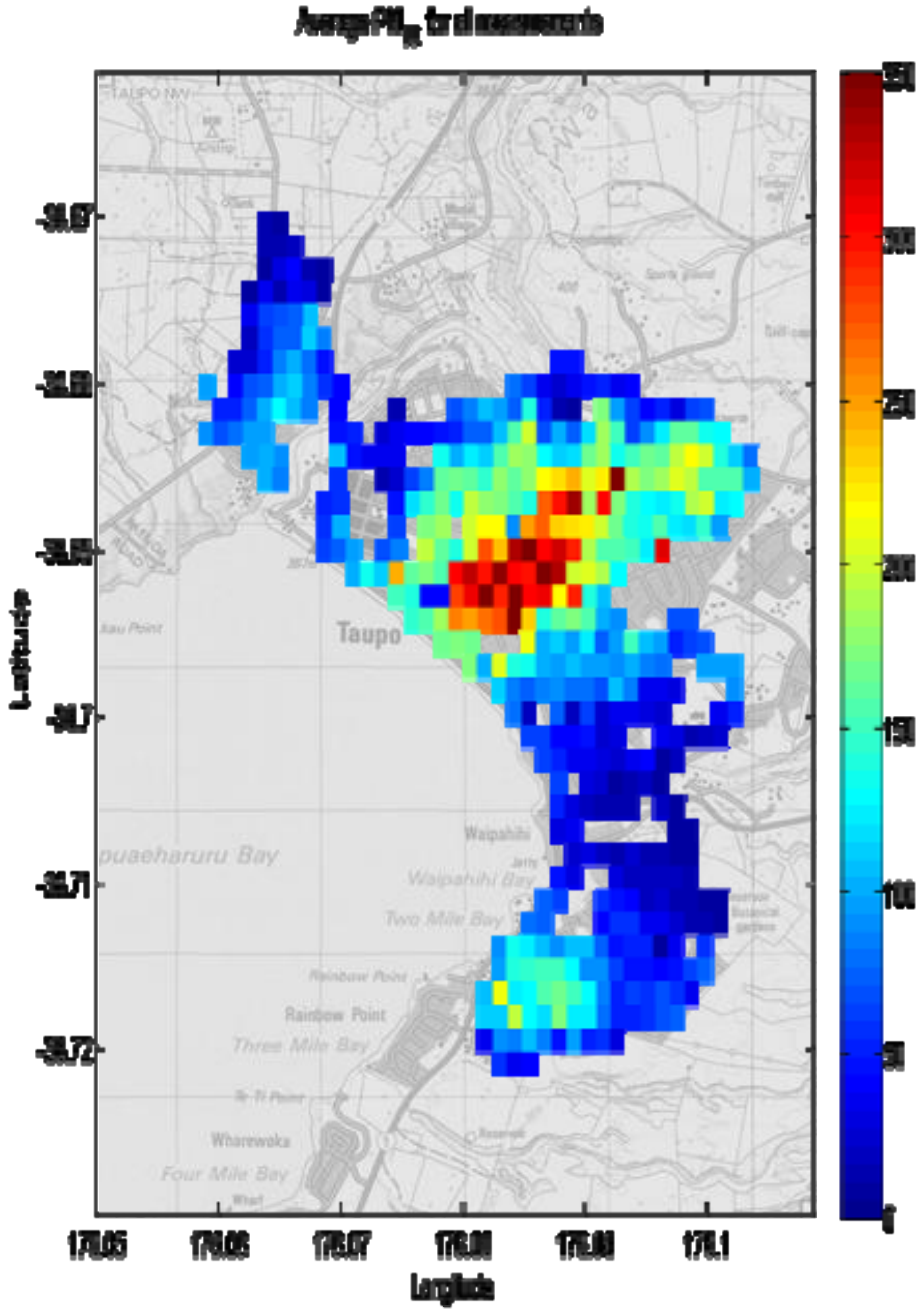

Figure 3-8: **PM_{10} concentrations averaged over 400m^2 grids, during three nights between 08–10 July, 2008 when the mobile system was active within the Taupo airshed. Colour scale is PM_{10} concentration (µg/m^3).**

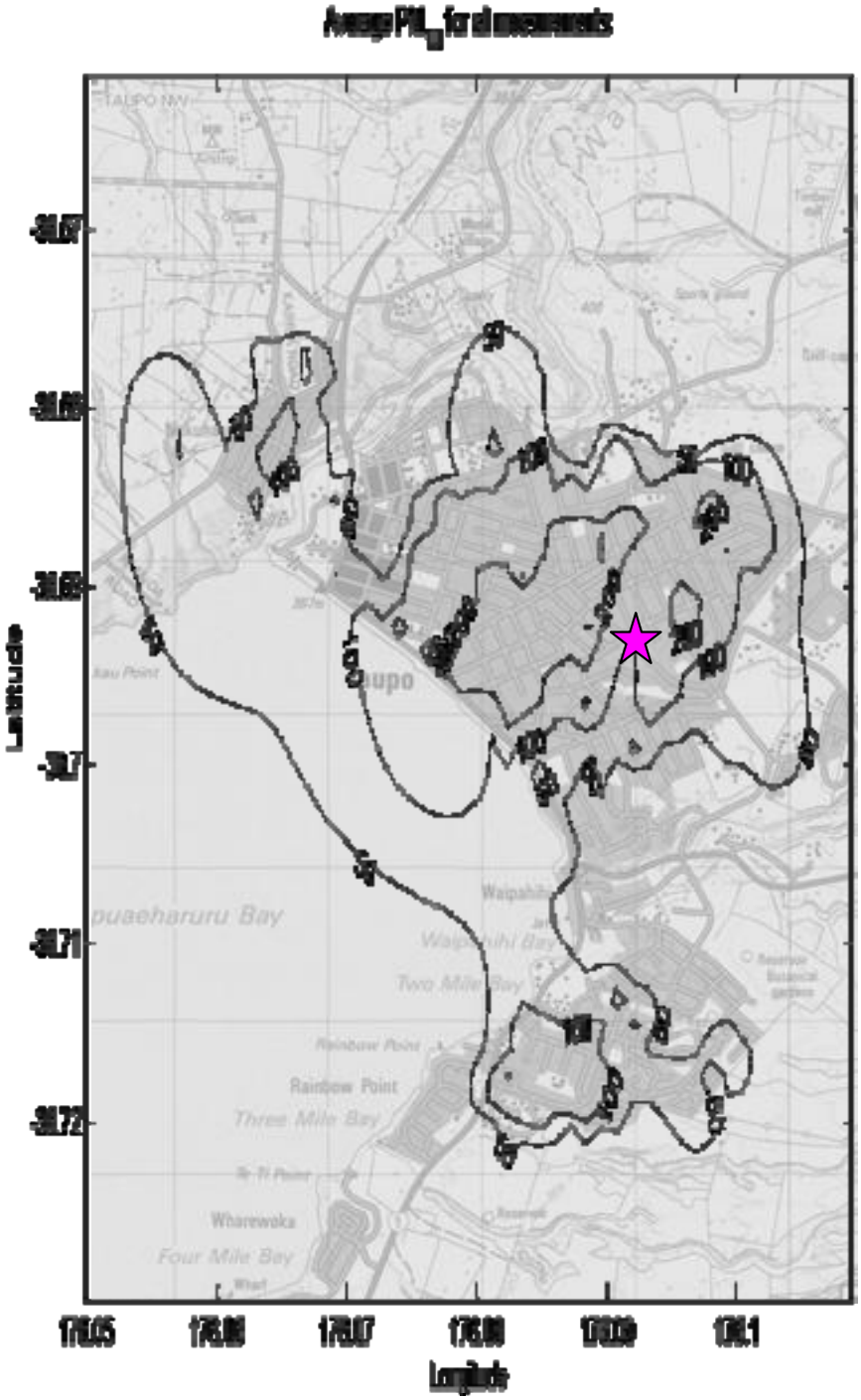

Figure 3-9: **Isopleths of PM_{10} concentrations (µg/m^3) averaged over three nights (08 July – 10 July, 2008) when the mobile system was active within the Taupo airshed. Pink star indicates the location of Environment Waikato's Gillies Ave monitoring site.**

The highest PM_{10} concentrations observed in Taupo during the campaign occurred on 08 July and 09 July 2008 and BAM data collected by Environment Waikato during these two days are plotted in Figure 3-10. The hourly average BAM PM_{10} data in Figure 3-10 are adjusted for gravimetric equivalency as described by Wilton & Baynes (2008). The maximum hourly average PM_{10} concentrations during the nights of 08 July and 09 July were 192 $\mu g/m^3$ and 117 $\mu g/m^3$ respectively and these two nights may be regarded as high pollution events. Therefore, analysis of data from these two nights will provide a valuable assessment of the location of the Gillies Ave monitoring site in Taupo.

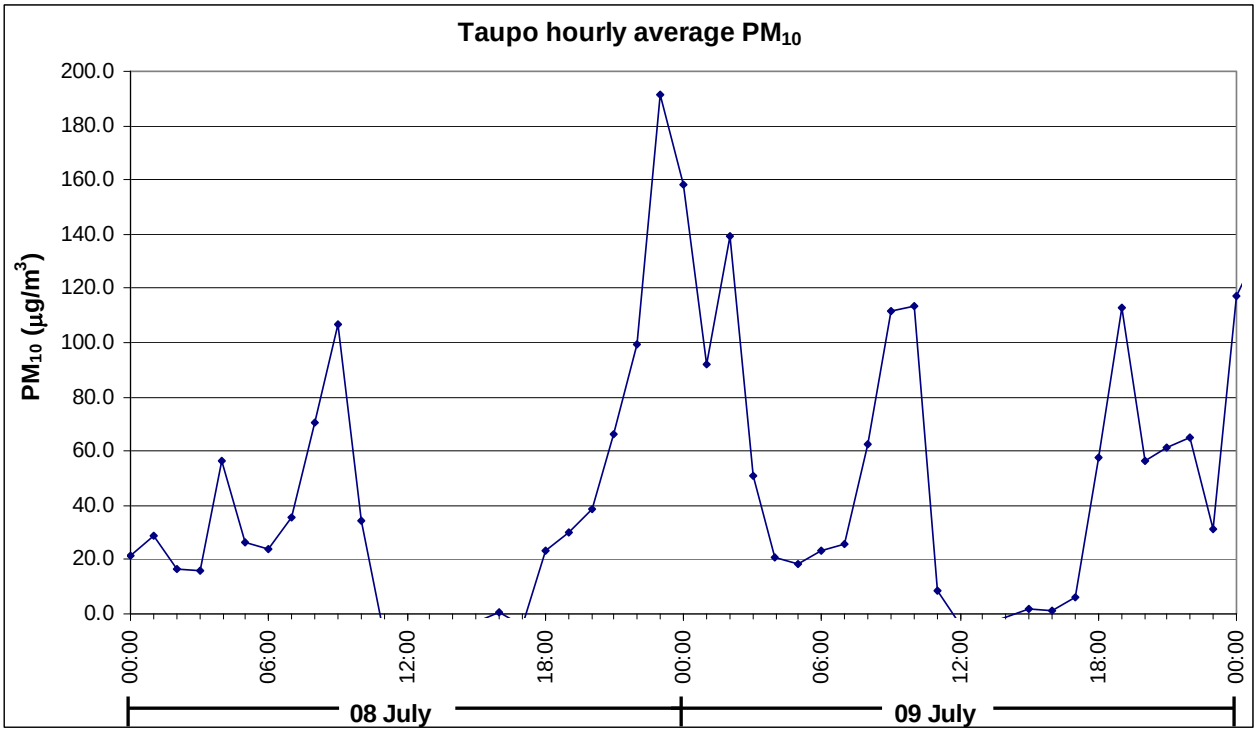

Figure 3-10: Hourly average PM_{10} concentrations ($\mu g/m^3$) observed at Gillies Ave, Taupo during 08 July and 09 July 2008. Data are provided by Environment Waikato and corrected for gravimetric equivalency as described by Wilton and Baynes (2008).

During the periods of mobile monitoring on both nights 08 July and 09 July 2008, wind at the Gillies Ave monitoring station was predominantly from the southerly direction and being consistently less than 1 m/s, was very light (Figure 3-11). These wind conditions would have been conducive to high PM_{10} concentrations, due to retarded dispersion of emissions.

Mobile monitoring data from these two nights are investigated separately below.

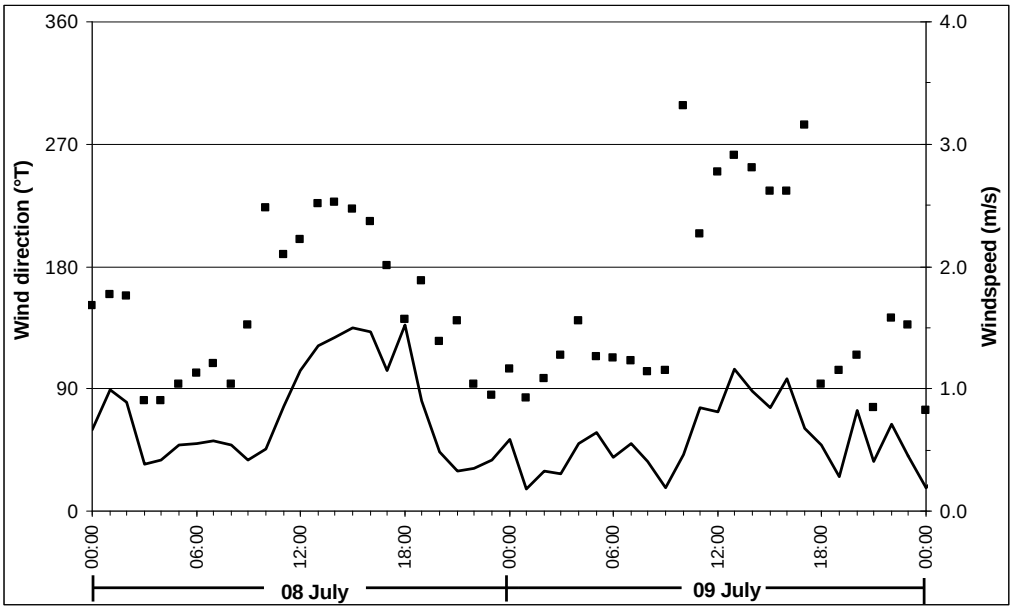

Figure 3-11: Hourly average windspeed (solid line) and wind direction (black squares) recorded by Environment Waikato at the Gillies Ave (Taupo) air quality monitoring station, 08 July - 09 July, 2008.

3.2.1. Mobile monitoring in Taupo – 08 July 2008

PM_{10} concentrations from the monitoring on 08 July 2008 were averaged over 400m × 400m grids for the entire monitoring period and are plotted in Figure 3-12. The closest mobile monitoring PM_{10} observations to the Gillies Ave site on 08 July averaged around 200 µg/m^3 (Figure 3-12). This is consistent with the PM_{10} concentrations recorded at Environment Waikato's Gillies Ave station (Figure 3-10) although, as discussed in Section **Error! Reference source not found.**, some caution is required because the averaging periods for these measurements are different.

The maximum PM_{10} concentrations on 08 July averaged 350 µg/m^3 or more, and were observed in the central residential area, northwest of the Gillies Ave site (Figure 3-12). These data show that on the night of 08 July 2008, observations from Gillies Ave were not representative of the maximum PM_{10} concentrations in the Taupo airshed.

3.2.2. Mobile monitoring in Taupo – 09 July 2008-12-23

PM_{10} concentrations from the monitoring on 09 July 2008 are plotted in Figure 3-13. During the mobile monitoring period on the night of 09 July, wind was from the south and was very light at around 0.5 m/s (Figure 3-11). The mobile monitoring PM_{10} observations undertaken at the Gillies Ave site on 09 July averaged around 150 µg/m^3

(Figure 3-12). This is consistent with the PM_{10} concentrations recorded at Environment Waikato's Gillies Ave station (Figure 3-10) although, as discussed in Section **Error! Reference source not found.**, some caution is required because the averaging periods for these measurements are different.

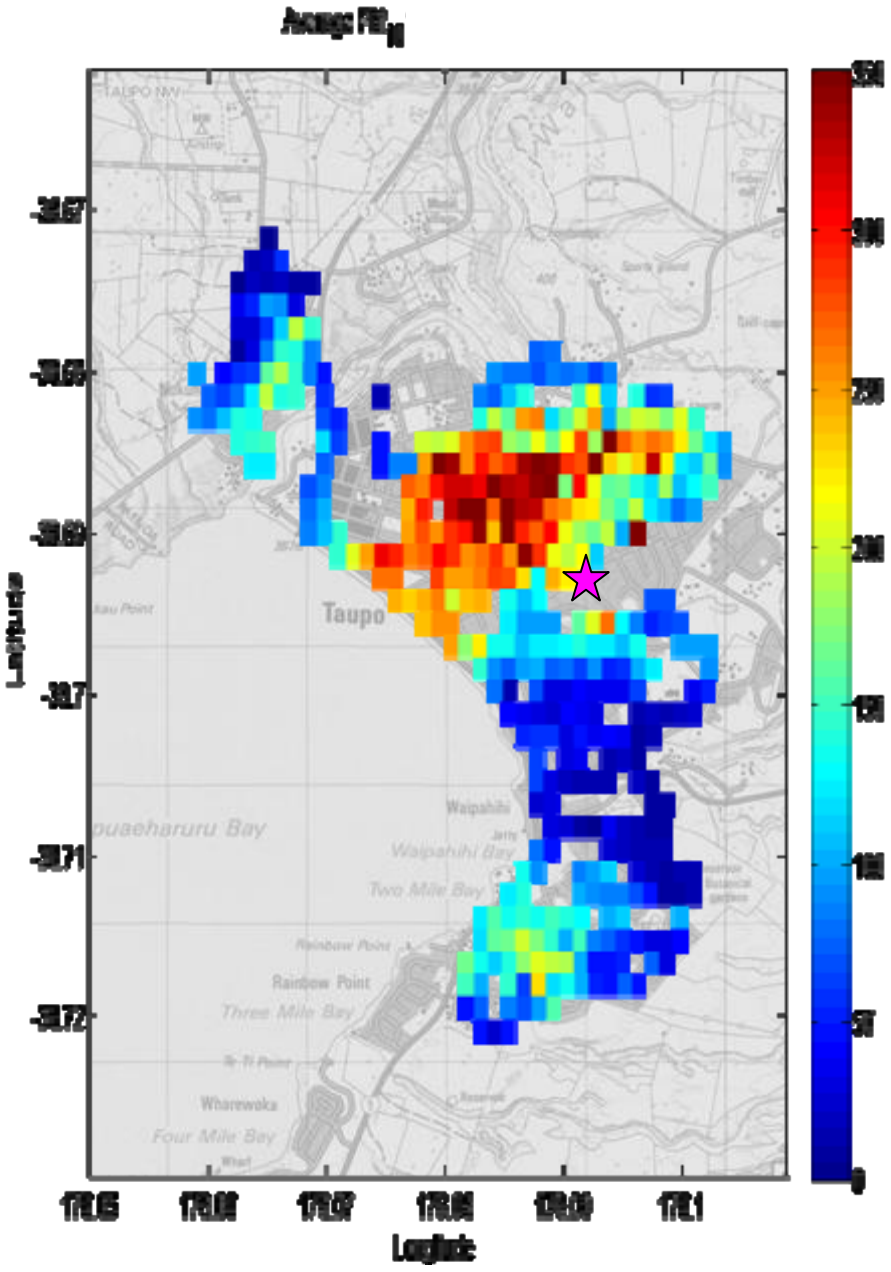

Figure 3-12: PM_{10} concentrations averaged over 400m^2 grids in Taupo during the night of 08 July, 2008. Colour scale is PM_{10} concentration (µg/m^3) and the Gillies Ave monitoring site is indicated by a pink star.

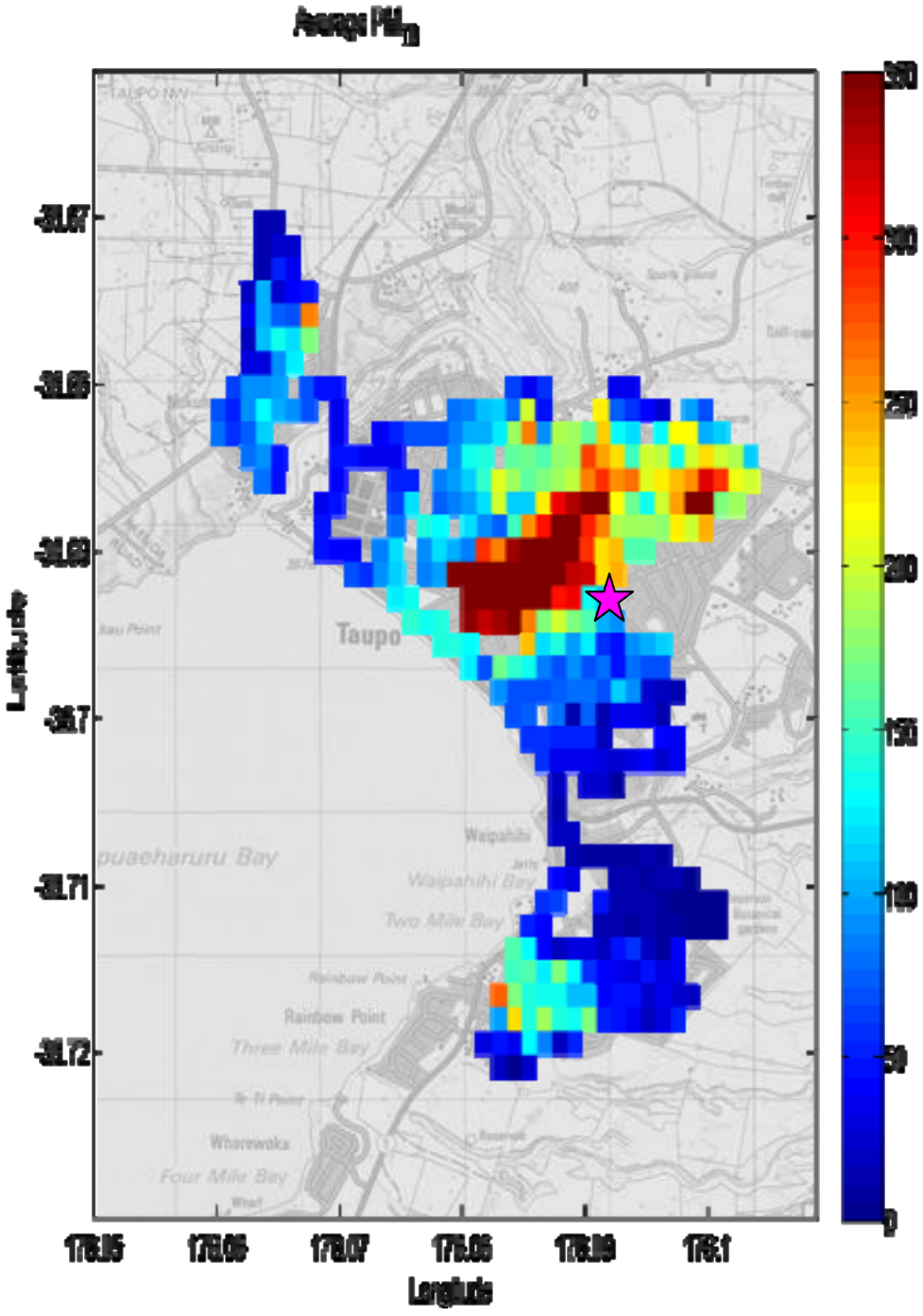

Figure 3-13: **PM_{10} concentrations averaged over 400m^2 grids in Taupo during the night of 09 July, 2008. Colour scale is PM_{10} concentration (µg/m^3) and the Gillies Ave monitoring site is indicated by a pink star.**

The maximum PM_{10} concentrations on 08 July averaged 350 µg/m^3 or more, and were observed in a widespread and clearly distinguishable region of the central residential area, northwest of the Gillies Ave site (Figure 3-13). These data show that on the night of 09 July 2008, observations from Gillies Ave were not representative of the maximum PM_{10} concentrations in the Taupo airshed. This is entirely consistent with the observations made on 08 July 2008 (Figure 3-12).

3.2.3. Summary of mobile monitoring in Taupo

Notwithstanding cautionary remarks made earlier, on two high pollution nights, the highest PM_{10} concentrations (at least 350 µg/m^3) were consistently observed by mobile monitoring in central residential area of Taupo, northwest of the Gillies Ave monitoring site (Figure 3-12 and Figure 3-13). This suggests that, along with the monitoring site at Gillies Ave, it would be valuable to install PM_{10} monitoring in the central residential region of the Taupo airshed. As a minimum, survey monitoring is recommended in the additional location for at least one winter.

4. Conclusions

In Hamilton, mobile monitoring captured data on two relatively high pollution nights. The highest PM_{10} concentrations (around 80 $\mu g/m^3$) were consistently observed by mobile monitoring in neighbourhoods of Fairfield, Frankton, Hamilton East and Melville. Average PM_{10} concentrations were higher in these locations than at the Peachgrove Road monitoring site. This suggests that it would be valuable to install PM_{10} monitoring in some or all of these parts of the Hamilton airshed.

Data from two particularly high pollution nights also demonstrated that observations from Gillies Ave were not representative of the maximum PM_{10} concentrations in the Taupo airshed on those nights. The highest PM_{10} concentrations in Taupo (at least 350 $\mu g/m^3$) were consistently observed by mobile monitoring in the central residential area of Taupo, northwest of the Gillies Ave monitoring site. This suggests that, along with the monitoring site at Gillies Ave, it would be valuable to install PM_{10} monitoring in the central residential region of the Taupo airshed.

Daily survey monitoring is recommended in these Hamilton and Taupo suburbs for at least one winter as a minimum.

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