- vehicles and vehicle travel up 37% for Latrobe Valley and 51% for Melbourne

I believe that the Latrobe Valley Airshed Study has been exemplary in many ways. It has shown that with goodwill and clearly defined roles, different agencies with differing skills, styles and methods of operation can combine well in a common well-targeted cause. It has fostered the acquisition of the most up-to-date knowledge and skills, and provided a professional stimulus to all involved. And, finally, it has produced a comprehensive application of modern meteorological and air quality knowledge to a practical problem of great relevance to the State of Victoria. I am proud to have been associated with it.

METEOROLOGY AND AIR QUALITY OF THE LATROBE VALLEY

Peter Manins

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INTRODUCTION

First impressions of the Latrobe Valley are frequently unfavourable: a foggy morning or hazy day, enormous open-cut mines and machinery for winning brown coal, one or more very visible plumes due to moisture condensation or excess particles from the 20+stacks, occasional dirty layers in the air, and all too often a pervasive smell. While it is an industrial valley, being the centre of electricity generation for Victoria and supporting several other industries including paper manufacturing, it is also a tourist and agricultural centre with beautiful bushlands close at hand and large dairying, beef and sheep enterprises.

This paper concentrates on the **measured** air quality and its controls through the meteorology of the Latrobe region. A report (Manins, 1986) describing most of the findings and accomplishments of the Latrobe Valley Air Shed Study has been published.

The primary indicators of air quality are defined for us by the Environment Protection Authority of Victoria (EPA) in the State Environment Protection Policy (the Air Environment): the so-called 'SEPP' (Parliament of Victoria, 1981). The SEPP lists them as the Class 1 indicators and sets out the 'acceptable' and 'detrimental' levels for each indicator for various averaging times (Table 1). The SEPP also sets 'objectives' for compliance stating that the acceptable levels may be breached no more than three times per year for all indicators (except lead and 1-h ozone which may be breached no more than once per year).

The acceptable levels are intended to offer protection to most individuals and are readily defensible. With pollutant concentrations at or above the detrimental level a substantial number of individuals may be affected adversely or significant changes are likely to be caused to some segments of the environment.

The 8-hour objective for ozone is designed to protect vegetation, while the objective for Local Visual Distance (LVD) is an aesthetic one for social amenity: it also acts as a surrogate for a health-based objective for inhalable particles which is not yet in place. LVD is determined by a heated nephelometer and its interpretation by the public as an indicator of visual range causes much confusion.

Airborne pollutants such as lead (of minor concern according to results of EPA monitoring), toxic chemical releases (from processes, accidents, etc) and odours (a persistent public nuisance in the Latrobe Valley) have not been considered by the Latrobe Valley Air-Shed Study.

MONITORING

While air quality in the Latrobe Valley had been monitored for many years, comprehensive measurements only began with establishment of the network of 16 multi-parameter air quality stations and five meteorological towers in the period 1979-1982 – the Latrobe Valley Air Monitoring Network (LVAMN) – as part of the Latrobe Valley AirShed Study. The LVAMN is shown in Fig.1. The priority pollutants monitored by the LVAMN include NO_x, NO, NO_2 (by subtraction, $= NO_x\text{-}NO$), SO_2, O_3, LVD and, anticipating an inhalable particles objective in the SEPP, PM10 (particle mass for particles of size less than 10 μm effective aerodynamic diameter). Some of the township air quality stations also report CO, some stations measure total solar radiation and ultra-violet radiation, and all stations also report wind speed and direction, and wet- and dry-bulb temperatures. A calibration check on all gas-monitoring instruments is performed around midnight. Quality control is exceptionally high (Kitwood et al., 1988). Experience with different instruments is discussed by Allan (1988).

The towers were instrumented at four levels from 10 m to 110 m above the ground for temperatures and vector velocity. At ground level rainfall, solar radiation, net radiation, soil heat flux and soil temperature are monitored and reported to a central computer (as are all data from the air quality stations) every minute, 24 hours a day as explained by Hellyer and Patching (1988).

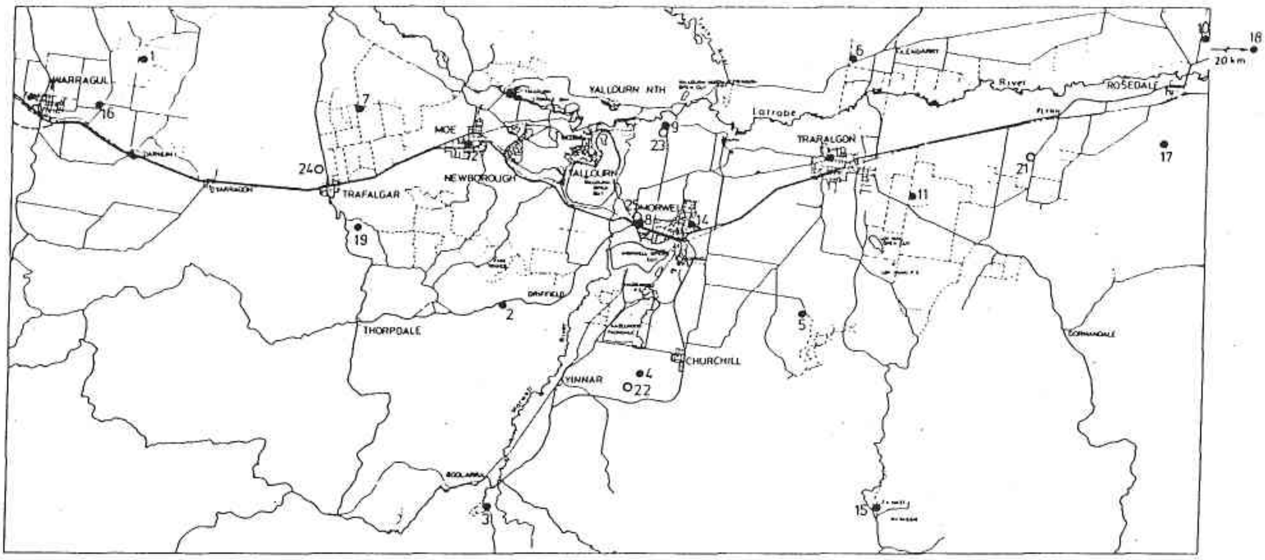
The network has undergone review and revision over the past few years. There are now only seven core air quality stations and a number of investigative stations which have been installed for limited times to address

Table 1: Prescribed levels for Class 1 indicators of air quality as defined by the SEPP (Parliament of Victoria, 1981).

Pollutant		Averaging time (hours)	SEPP[1] 'Acceptable' level	'Detrimental' level
SO_2	(ppb)	1	170	340
NO_2	(ppb)	1	150	250
O_3	(ppb)	1	120	150
		8	50	80
CO	(ppm)	1	30	60
LVD	(km)	1	20	-
Lead	(μ g/m^3)	3mo	1.5	

ppb = parts per billion (10^9), ppm = parts per million (10^6)
(volume/volume) (volume/volume)

[1] There are also Objectives based on 24-hour averaging times.



o— METEOROLOGICAL TOWER SITES
•— AIR QUALITY MONITORING STATION SITES

1 • DARNUM NORTH (DN)	8 • MORWELL WEST (MW)	15 • Mt TASSIE (MT)	21 o FLYNN (FLM)
2 • DRIFFIELD (DR)	9 • THOMS BRIDGE (TB)	16 • NILMA (NI)	22 o YINNAR (YIM)
3 • BOOLARRA (BO)	10 • ROSEDALE NORTH (RN)	17 • ROSEDALE SOUTH (RS)	23 o THOMS BRIDGE (TBM)
4 • HAZELWOOD ESTATE (HE)	11 • MINNIEDALE ROAD (MR)	18 • SALE SOUTH (SS)	24 o TRAFALGAR (TFM)
5 • CLARKES ROAD (CR)	12 • MOE (MO)	19 • TRAFALGAR SOUTH (TS)	25 o MORWELL WEST (MWM)
6 • GLENGARRY (GL)	13 • TRARALGON (TR)		
7 • TRAFALGAR NORTH (TN)	14 • MORWELL EAST (ME)		

LATROBE VALLEY AIR SHED
(Location of meteorological towers and air quality stations)

FIGURE 1. The Latrobe Valley Air Monitoring Network

particular research questions. There is only one core tower, at Flynn, and now a Doppler acoustic sounder for monitoring vector velocity and turbulence to heights of at least 500 m at Thoms Bridge (Fig.1).

We now have comprehensive monitoring data spanning over eight years, enabling an accurate characterization of the ground-level air quality and wind and thermal stability conditions. This has been supplemented by several specialized studies including:

- Slope wind studies by Manins and Sawford (1979) motivated by the possibility of recirculation of pollutants impacting on hills; a study of stagnating or 'blocking' flows (Manins and Sawford, 1982) inspired by Moriarty's (1981) work showing evidence of blocking in the Latrobe Valley; sea breeze studies by Physick (1983) which led to an appreciation of the complex sea-breeze interactions in the Valley and their possible pollution consequences (See Abbs and Physick 1988).
- A major plume tracking experiment which studied power station plumes and associated air quality and meteorological conditions in detail via aircraft, pibal and radiosonde ascents, and stack tests. This experiment is discussed by Carras and Williams (1988), Lorimer et al. (1988), Manins et al. (1988), and Smith and Ross (1988).
- Several years of routine morning radiosonde ascents which characterized the frequency of temperature structures and the predominantly westerly but often strongly sheared winds to 2 km or more. This work built on the success of Spillane and Wren (1978) in collaboration with the SECV in the mid 1970s. The data have been of immense value for all the modelling work, particularly case studies where data on atmospheric inversions are essential and are otherwise unobtainable.
- In situ measurements of speciated non-methanic hydrocarbons (Weeks et al., 1988; Galbally et al., 1988) in support of ozone studies; of fine particles (Ayers et al., 1988; Gras et al., 1988) to characterize airborne particles in the Valley; and sampling of halocarbons (Almog et al., 1988) to test for a metropolitan origin of polluted air.
- An aircraft study which included in-plane and ground-level ozone and NOx monitoring and grab samples for analyses for hydrocarbons (Carras et al., 1988; Ahmet, 1988). This study focussed on the possible interaction of Melbourne and Latrobe Valley regional air masses.

REGIONAL AIR QUALITY

Maps have been drawn for the eight-year period ending May 1988 showing where concentrations averaged over an hour were greater than certain values for less than 0.1% of the time (that is about 9 hours per year - the interpretation of 'three days' used by modellers to compare with the SEPP objectives). Expressed another way, the pollutant concentrations were less than the value corresponding to each marked area on the maps 99.9% of the time. No map for carbon monoxide is shown since the values are so low. Further, the estimates for the Haunted Hills in the western part of the region are based on very limited data, since monitoring at Trafalgar South only commenced in January 1988. The maps are drawn by eye using the measured data and in some instances in the more remote areas, results from air quality modelling.

Sulfur dioxide Practically all SO_2 is emitted from the power stations and other major industry (Marsiglio, 1988). So Fig. 2, a map of the top 0.1% of readings of concentrations of SO_2, shows the direct influence of the tall

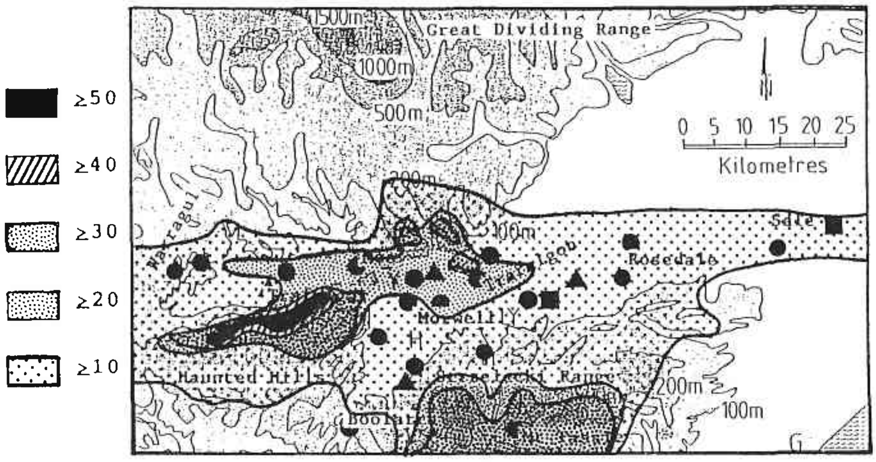


FIGURE 2. Top 0.1% contours for SO_2

stack emissions on the local air quality, practically uncomplicated by ground-level sources. The impact extends along the Valley floor due to the prevailing westerly and easterly winds. Traralgon and Morwell are most affected: concentrations have reached in excess of 30 ppb SO_2 for up to 9 hours a year. They are influenced by the power stations and Maryvale Mill.

Morwell is the closest township to the power stations. This proximity has led to Morwell suffering the highest level of SO_2 recorded by the LVAMN: 85 ppb in the afternoon on 29 October 1987. This appears to have been a case where convection caused by strong solar heating below a shallow capping inversion lid brought the plumes from Hazelwood or Morwell power stations rapidly to ground. Such conditions are not very common in the Latrobe Valley. More usual was the cause of the second highest reading for SO_2 of 72 ppb which was recorded on the morning of 20 June 1986 in Traralgon. Strong westerly winds forced the stack plume of Maryvale Mill (or Yallourn power station) to the ground with strong impact on the township. These values should be compared with the SEPP acceptable level of 170 ppb and show a large margin of safety.

Plume strikes on the southern hills are very evident in the SO_2 results in Fig.2. They practically all occur on calm clear nights. The highest readings recorded anywhere in the Network were short impacts during nights in January and February this year at Trafalgar South (260 m above the Valley floor). Concentrations averaged over one hour reached 129 and 146 ppb of SO_2 respectively. Occurring at the same time as the peak NO_X and NO_2 readings there, they are due to the stacks of Yallourn power station or Maryvale paper mill to the east.

Values of 132 and 91 ppb SO_2 have recently been measured in the middle of the night at Mt Tassie due to the Loy Yang power station. Plume strikes there should become more frequent with Loy Yang B also operating, and the levels should be higher too.

We are fairly confident of the attribution of sources due to past studies on source reconciliation. As is shown by Hoy (1984), the monitored ratio of concentrations of SO_2 to NO_X is a good distinguishing feature for the type of source responsible. If the ratio is about unity (0.3 to 3) then it is a coal-combusting source such as a power station; low values indicate sources such as motor vehicles, fires, etc. We also utilize information about how much of the NOx has been oxidised by ambient ozone from NO to NO_2 to say how fresh (close) the source is. The reaction takes time and a high ratio of NO to NO_X (say 0.5 or more) indicates close proximity.

The plumes from tall stacks such as at Loy Yang should have their most frequent impact in strong winds far to the east. So it is worth remarking that over its 14 months of operation, the air quality station at Sale South (42 km from Loy Yang) has recorded a maximum SO_2 value of only 24 ppb and a 99.9 percentile value of 12 ppb. With Loy Yang B operating these extreme values might double but would still be exceedingly low.

The effectiveness of discharging SO_2 through tall stacks in the Latrobe Valley was assessed in a sulfur budget study for 1984 by Mainwaring and Lau (1987). They concluded that of the total emissions of SO_2 only 30% was discharged into the mixing layer. It was estimated that only 4% of the total emissions of SO_2 went into the nocturnal mixing layer compared with 57% during the day. These figures would be enhanced by rainfall and by morning fumigation. Approximately 80% of all emissions were transported out of the region on an annual basis.

A corollary for these conclusions is illustrated by measured annual average SO_2 concentrations. In the townships, where minor emissions of sulfur are centred, the annual average concentrations are around 1 to 3 ppb, whereas at the rural stations average values are 2 ppb or less. These figures may be compared with measurements in Melbourne: for each of the past three years for all reporting stations the arithmetic means were between 0 and 3 ppb. Such low concentrations are barely above the noise level of the analyser.

Nitrogen dioxide The map in Fig.3 shows contours of the top 0.1% of 1-hour average values for nitrogen dioxide. While superficially similar to the distribution for SO_2, the NO_2 field has some important differences and causes. The emissions inventory (Marsiglio, 1988; Duffy et al., 1988) shows that most NO_X is emitted by the power stations high into the air but that near-ground level sources are significant and include motor vehicles, gas heat-

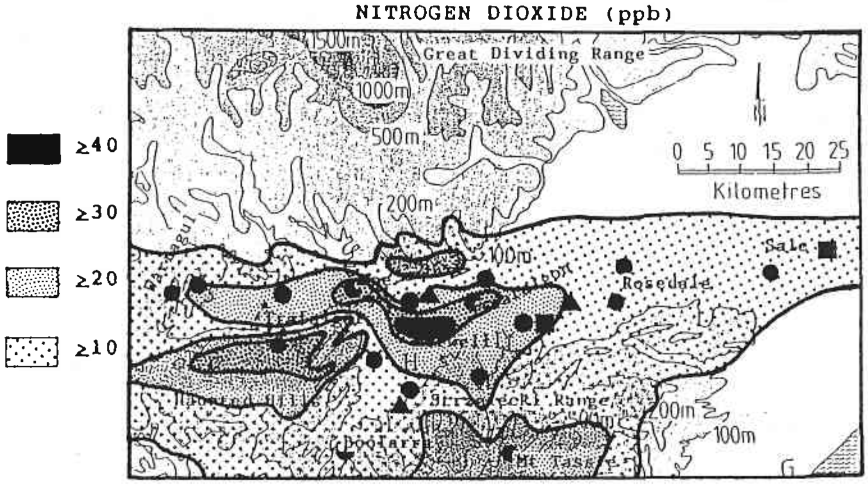


FIGURE 3. Top 0.1% contours for NO_2

ing, biogenic (soil) emissions, etc.

On the Valley floor, the pollution map shows that Morwell and Traralgon have reached in excess of 44 ppb and 35 ppb NO_2 respectively, for up to 9 hours a year. However the extreme measured in the Valley was at Morwell in 1981 when a level of 90 ppb was recorded. This occurred, as do most instances of higher levels of nitrogen dioxide in the Latrobe Valley townships, during an extended period of cold, calm winter weather. Such conditions result in a build up of local urban emissions. This value must be compared with the 'acceptable level' of 150 ppb.

Moriarty (1981) developed this interpretation further. He came to the conclusion that compared with Melbourne, the Latrobe Valley has three times as many days when the mid-afternoon ventilation rate (product of mixing height and wind speed) is low. There is also a much greater tendency for such days to succeed one another - i.e. the Valley is more prone to 'episodes'. This is seen in the winter. In the townships then, NO_2 pollution due to local emissions often occurs on several days in succession. There is the opposite consequence for emissions from tall stacks - they contribute less to ground level concentrations due to their discharge above the capping inversion.

In rural areas, the highest levels of NO_2 may be due to adjacent townships, power station plumes coming to ground, or local burning off. Concentrations have reached 40 ppb at Trafalgar North and 50 ppb at Thoms Bridge - both stations are under the influence of the Yallourn power stations and Maryvale Paper Mill.

The annual average NO_2 level is up to 10 ppb in Traralgon and even lower at 1 to 4 ppb at rural stations.

During the brief periods of plume strike on the Strzelecki Range, levels up to 25 ppb NO_2 have been recorded at Mt Tassie (on 15 November 1987 at 0300 h: SO_2/NO_X = 82/78). A similar finding comes from the monitoring on the hills south of Trafalgar. There, plume strikes from Yallourn and Maryvale Mill sometimes impact, leading to levels even higher than observed on Mt Tassie.

Ozone Figure 4 shows the top 0.1% of 1-hour readings. The reasons for the obvious channelling along the river valleys to the west and south is discussed by Ahmet (1988), and Cope et al., (1988): it depends on the origin of the constituents of the ozone. Of course ozone is the main component of photochemical smog and requires for its formation a mix of nitrogen oxides and non-methanic hydrocarbons to be subjected to strong sunlight in warm conditions.

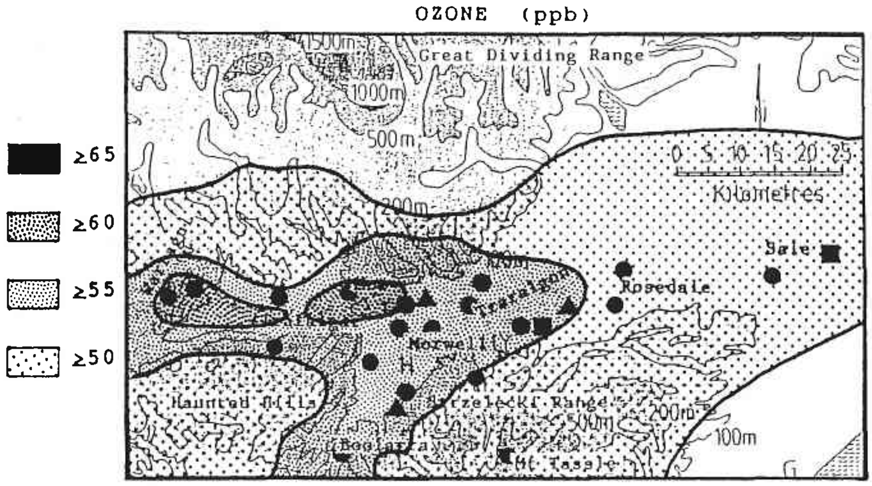


FIGURE 4. Top 0.1% contours for O_3

It is not immediately obvious whether and how the Latrobe Valley power stations and other existing industry contribute to photochemical ozone pollution, since they emit virtually no hydrocarbons but a lot of NO_X. Further, the high frequency of atmospheric inversions below final plume heights for the emissions from the tall stacks means that the NO_X from these sources rarely contributes to the photochemical mix.

Vehicles and natural biological processes are the two dominant sources of hydrocarbons and NO_X for ozone production (Duffy, et al., 1988; Marsiglio, 1988). Other notable sources are a petrochemical plant at Longford, near Sale and transport of emissions from Melbourne. These sources are discussed by Cope et al., (1988).

The highest 1-hour value of ozone recorded by the LVAMN was 100 ppb on the afternoon of 2 February 1987 and extended throughout the Latrobe Valley. This is approaching an exceedence of the SEPP acceptable level of 120 ppb and is of concern. However, the frequency of occurrence of values above 90 ppb is extremely low: only two days in eight years!

The highest 8-hour ozone concentrations usually exceed the acceptable level of 50 ppb once or twice a year in the Latrobe Valley but have not yet reached the detrimental level of 80 ppb.

Local Visual Distance There is little to say about the distribution of the extreme 0.1% of values of LVD shown in Fig.5 except that it appears to be characteristic of a valley in which trapping of low-level smoke occurs, and of rural areas where burning off is practised. There is no clear effect on LVD due to the industrial stacks. These and other interpretations are discussed by Gras et al., (1988) and Joynt (1988). The SEPP acceptable level for LVD is 20 km and this is occasionally breached at every LVAMN station in the region, with the frequency in the townships being about as high as for suburban areas elsewhere: 5 - 10% of days each year.

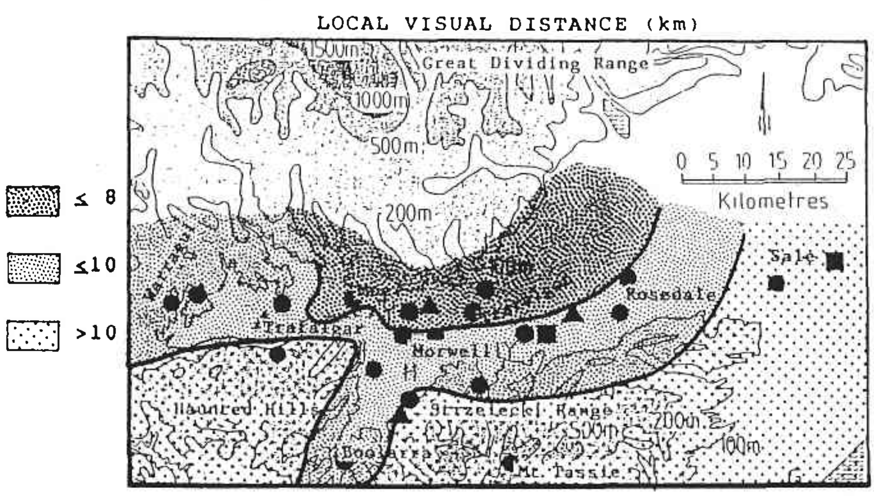


FIGURE 5. Top 0.1% contours for LVD

Note that industrial emissions do have a demonstrable impact on visual range (or, 'visibility'), as distinct from LVD.

Inhalable particles Based on the two years of data now available for most LVAMN stations, Fig.6 is a contour map of annual average PM10 for the region. As would be expected of the largest township, Traralgon has the highest level: 17 $\mu g/m^3$. This may be compared with readings around Melbourne where the level is about 33 $\mu g/m^3$; and the new USEPA standard of 50 $\mu g/m^3$ annual average.

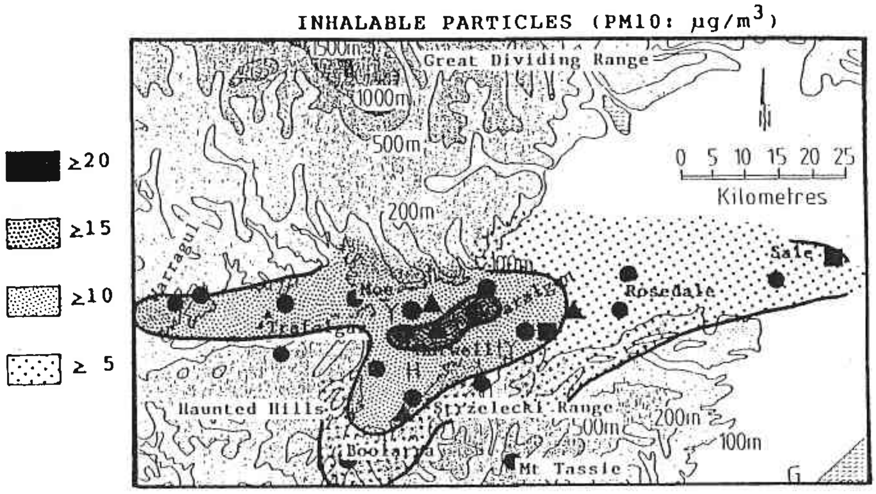


FIGURE 6. Contours of PM10

DISCUSSION

Is the Latrobe Valley polluted?

Referring to Table 2 we may note that:

- The health-based objectives laid down by the SEPP are well met for all indicators except 1-hour ozone. Extremes of 1-hour average ozone have come close to exceeding the acceptable level.
- There is cause for concern about the rare high 8-hour levels of ozone and their possible effect on vegetation in the region.
- No discernable trend over the eight years of measurements is evident even though there has been an increase of more than 25% in coal combustion and urban activity: the region's air quality is dominated by the seasonal meteorology of southern Australia.

By comparison with Melbourne (Table 3. See Morgan, 1988):

- The extremes of nitrogen dioxide are some three times lower in the Latrobe Valley.
- Extremes of sulfur dioxide are closely similar and well below the acceptable level except for brief periods at night on the hills when plume strikes occur.
- Extremes of 1-hour and 8-hour average ozone are about half those in Melbourne and occur far less frequently.
- Only about half the number of breaches of the acceptable LVD level occur in the Valley as compared with Melbourne.

By comparison with abroad (Table 3):

- To quote Morgan (1988) '... Melbourne's air quality can only be [compared] with respect to photochemical smog, because the levels of all other Class 1 indicators, particularly SO_2, are well below the levels experienced elsewhere in the world...'. See Bennett et al. (1985). The same is of course true for the Latrobe Valley, only more so.
- For ozone, Melbourne's extreme 1-hour values of up to 280 ppb are comparable with the worst in the world. However, they are much rarer: in 1986 in Melbourne there were 4 days > 120 ppb. This compares with parts of southern California which in 1986 exceeded 120 ppb on 147 days, and reached as high as 350 ppb. Ozone levels in Tokyo peaked at 210 ppb in 1985 and exceeded 120 ppb on 107 occasions in that year (Melbourne: 13 days). By comparison the extreme of 100 ppb which has been reached only twice since 1980 for the Latrobe Valley, is of little moment.
- To illustrate Morgan's (1988) point with regard to other air quality indicators, some truly random examples will serve: Zib (1980) quotes 12 month average SO_2 values from around Pretoria in 1977. The range is from 6 to 11 ppb.
- Meszaros et al. (1987) quote the 11-year average SO_2 and NO_2 concentrations for central Hungary as about 13 ppb and 5 ppb respectively. An event in January 1985 gave readings up to 210 ppb 1-hour SO_2 concentration.
- Simpson et al. (1987) quote SO_2 concentrations in West Germany during January 1985 up to 350 ppb. In December/January 1981/82 maximum 1-hour concentrations were sustained in the UK Midlands, peaking at SO_2 = 326 ppb, NO_2 = 540 ppb and CO = 7 ppm.

Perhaps the Latrobe Valley has an acid rain problem?

- Fitzgerald (1987) reports that measurements of acidity in precipitation at Minniedale Road since March 1983 indicate that the rain is sometimes acidified well above natural levels. Annual average pH levels have been between 4.9 and 5.2, and about 25% of samples had a pH of less than 4.8 and 10% less than 4.2. Some were as low as 3.7.

Table 2: Extreme values of indicator concentrations measured in the Latrobe Valley. Percentages of Acceptable Levels.

%		1981	1982	1983	1984	1985	1986	1987
NO_2	(1h)	67	47	33	47	33	33	27
SO_2	(1h)	29	35	29	29	24	42	24
CO	(1h)	13	N/A	17	27	27	20	33
LVD	(1h)	500	400	500	500	500	330	500
O_3	(1h)	67	75	83	67	67	58	75
O_3	(8h)	120	120	140	100	120	120	120

Table 3: Comparisons with elsewhere

		Latrobe Valley Extremes floor	Latrobe Valley Extremes hills	Latrobe Valley Average 12mo	Melbourne Extreme metro	Melbourne Average 12mo	WHO's GEMS Ave 95 sites '79-'80	Hungary 11y ave	UK Midlands 4y ave	UK Midlands Extreme
SO_2	ppb	85	146	≤3	124	≤3	40	13	23	326
NO_2	ppb	90	36	≤10	240	≤33	-	5	-	540
O_3	ppb	104	62	~20	280	-				160
PM10*		17	-	~11	33	30	~40	-	~30	
CO	ppm	10		≤1	23	≤3				

*PM10 $\mu g/m^3$ average over 12 months.

- The observed levels of acidity are not particularly high by world standards and are up to a quarter of the levels found in the eastern United States of America.
- Almost no acidification at sites outside the Latrobe Valley have been found and it is believed that the acid found in Latrobe Valley rain comes from local sources. Further investigation is warranted.

CONCLUSIONS

Power station plumes sometimes have a significant visual impact due to start-up or failure conditions. But the emissions rarely reach the ground in the region due to the favourable combination of tall stacks and the local meteorology.

Plume impact on hills, while understood moderately well, and considered in the past, appears to be re-emerging as an issue. Measurements of strikes at Mt Tassie and Trafalgar South indicate that levels of sulfur dioxide on occasion can reach values much higher than hitherto observed. Further, there is an indication that a related problem of acidic deposition is occurring in the Latrobe Valley: this warrants investigation.

Overall, the measured air quality in the Latrobe Valley is:

- good with respect to health-based air quality indicators;
- rarely, questionable with respect to impact on vegetation;
- on occasion poor with respect to aesthetic objectives.

The work required to determine this with full confidence has been a major part of the LVASS activity.

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* *LVASS End of Study Symposium. 20-21 June, Chisholm Institute of Technology. Caulfield, Victoria. 1988.*

DATA PROCESSING AND COMMUNICATIONS IN THE SECV AND EPAV MONITORING NETWORKS

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INTRODUCTION

The Environment Protection Authority of Victoria (EPAV) and the State Electricity Commission of Victoria (SECV) have been involved in monitoring air quality in the Melbourne and Latrobe Valley Airsheds respectively. Data have been collected over periods of several years and can be used for air pollution episode assessment, trend analysis, dispersion modelling, and to ascertain the capacity of the respective airsheds to cope with future industrial and commercial expansion.

The monitoring systems are unique to Victoria and they were independently designed with the aim of capturing and processing data from the networks to provide reliable "real-time" and historical air quality databases. The EPAV and SECV monitoring networks are shown in Figure 1.

THE EPAV - AMBIENT AIR MONITORING NETWORKS.

The EPAV has had two networks since