Air Pollution Modelling of Potential High Asthma Days in the Boolaroo-Argenton area.

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SUMMARY

Ausplume, a Gaussian dispersion model was used to predict short term sulphur dioxide concentrations for low convective days near a lead-zinc smelter at Boolaroo, NSW. Two events were selected, with major model adjustments for terrain. Results showed 10-minute maxima were greatest downwind of the study area, due primarily to increasing wind strengths over each event. Further adjustments for daily selection criteria will involve mesoscale weather conditions and health data.

INTRODUCTION

Sulphur dioxide (SO_2), a gaseous pollutant produced from fossil fuel burning, has been linked to decreased respiratory function in both normal and asthmatic subjects (Schwartz 1989; Charpin *et al* 1988). High SO_2 emissions have traditionally been controlled through the use of stacks, relying on atmospheric dispersion to dilute emissions to safe concentrations before reaching ground level. Dispersion is largely dependent upon meteorological conditions and the topography of the surrounding area. The influence of meteorology does not guarantee that ground level concentrations will meet existing health criteria (Steer and Heskinen 1993). Optimal meteorological conditions for high SO_2 episodes are typically characterised by fogs, inversions and anticyclonic conditions.

Although asthma research has acknowledged the role of meteorological parameters in influencing pollutant levels, small scale fluctuations are often disregarded to obtain averaging times compatible with other pollutants e.g. daily particulates (Pönkä 1990). Shorter averaging times provide information essential to asthma research, as two-minute exposures as low as $1100 \mu g/m^3$ are known to cause acute symptoms in mild asthmatic subjects (Balmes *et al.* 1987)

This study at Boolaroo-Argenton modelled 10-minute maximum concentrations from a smelter point source. The main aims were to test modelling procedures prior to the release of medical data from the Boolaroo-Argenton section of a regional asthma study. A preliminary attempt was made to construct a spatial dispersion picture and examine exposure levels.

EQUATIONS

Ausplume is a widely accepted Gaussian dispersion model employed Australian regulatory bodies such as the Victorian EPA. Gaussian plume models are based upon the premise that cross sections through a plume from a point source have a Gaussian (normal) distribution. A three dimensional concentration field with a steady source and unbounded airflow (Turner 1994) can be expressed as:

$$\chi = (x,y,z,H) = \frac{Q}{2\pi u \sigma y \sigma z} \exp\left[-\frac{y^2}{2\sigma y^2}\right] \cdot \left\{\exp\left[-\frac{H-z^2}{2\sigma z^2}\right] + \exp\left[-\frac{H+z^2}{2\sigma z^2}\right]\right\}$$

χ	=	concentration at point (x,y,z) averaged over time
x	=	downwind distance from source
y	=	cross wind distance
z	=	height, with the source at z = 0
Q	=	emission rate
H	=	effective height of the plume centre line
u	=	wind speed
$\sigma y \sigma z$	=	dispersion coefficients representing cross wind and vertical spread, which are increasing functions of x and time.

Concentrations for receptors at ground level, can be calculated by reducing the above equation to:

$$\chi = (x,y,0,H) = \frac{Q}{\pi u \sigma y \sigma z} \exp\left[\frac{y^2}{2\sigma y^2}\right] \exp\left[\frac{H^2}{2\sigma z^2}\right]$$

STUDY AREA

The Boolaroo-Argenton area (151°37' E 32° 56' S) is a mixed residential-industrial area, 9 kilometres south west of Newcastle. NSW. The Pasminco Metals-Sulphide plant, located two kilometres north of Lake Macquarie, produces lead, zinc, and sulphuric acid from ore smelting processes. Pasminco's emissions are produced from the sinter and acid plant stacks, with estimated levels at 2.2 and 280 kg/hr respectively (see Table 1). Historically, ten minute SO_2 levels have been high, exceeding NSW EPA health standards[1]. Reduction of these levels has, in recent times improved with recirculation of gases back thorough the sinter plant. An upgrade of the acid plant will see further improvements to air quality by 1997 (Holmes 1994).

NSW EPA 10 minute maxima criteria = $1400 \mu g/m^3$.

Table 1 . A summary of Pasminco stack emissions.

Stack	Height m	Elevation m	Diameter m	Temperature K	Flux m/s	SO2 kg/h
Sinter	67	20	2.3	353	7.9	2.2
Acid	80	25	1.2	323	23.7	280

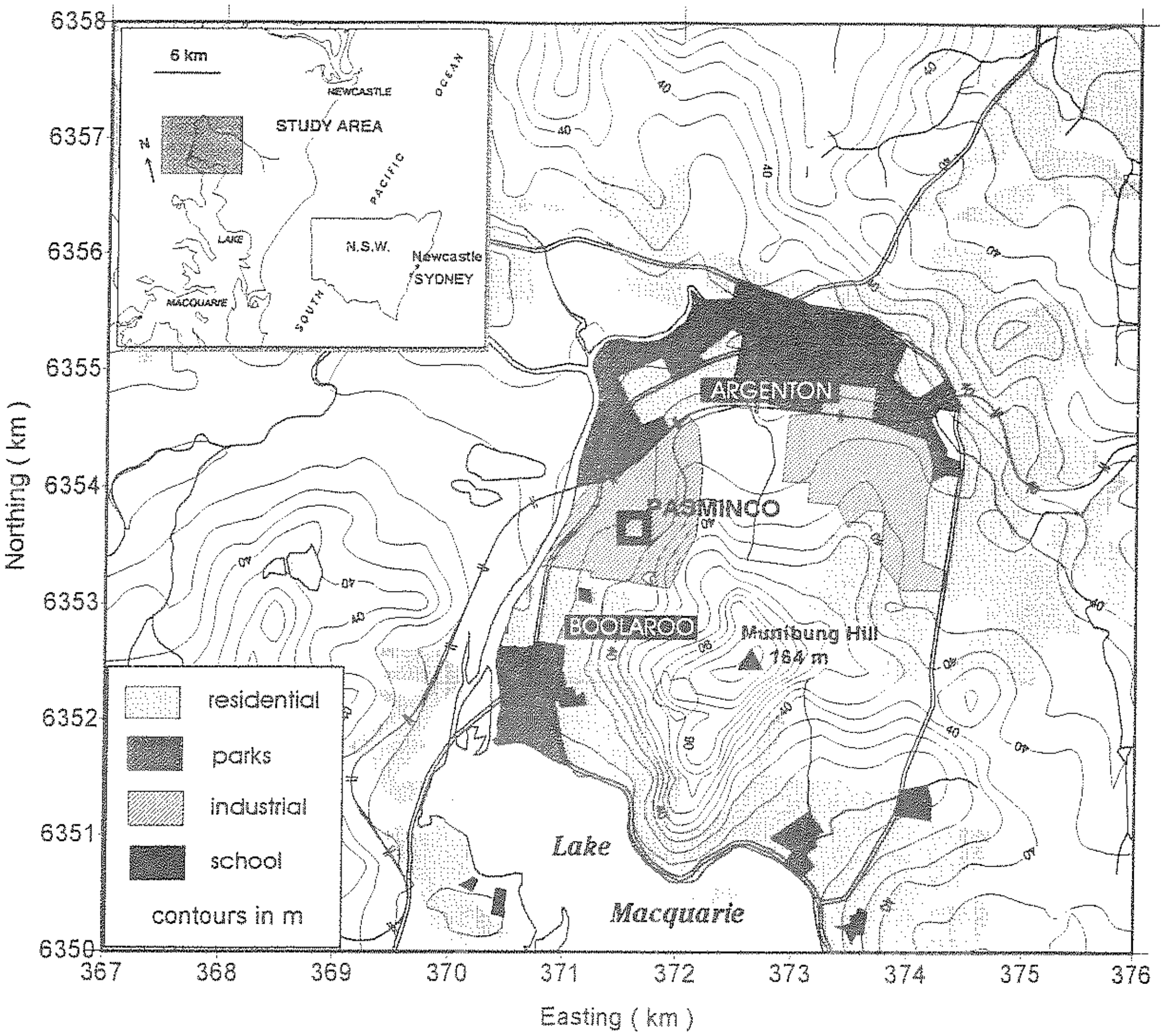

Figure 1. The Boolaroo-Argenton study area.

The predominant topographic feature, Munibung Hill (164m) has a significant influence on air flow and turbulence. During summer months plumes are disrupted from interaction with north easterly seabreezes, while in winter, prevailing westerlies increase uplift and mesoscale instability. The presence of Munibung Hill also buffers suburbs to the east from industrial emissions. Argenton, separated by an adjoining dump and rail line, is relatively flat increasing its susceptibility to emissions. Boolaroo directly adjoins Pasminco's southern boundary making it the most susceptible of all suburbs to local source

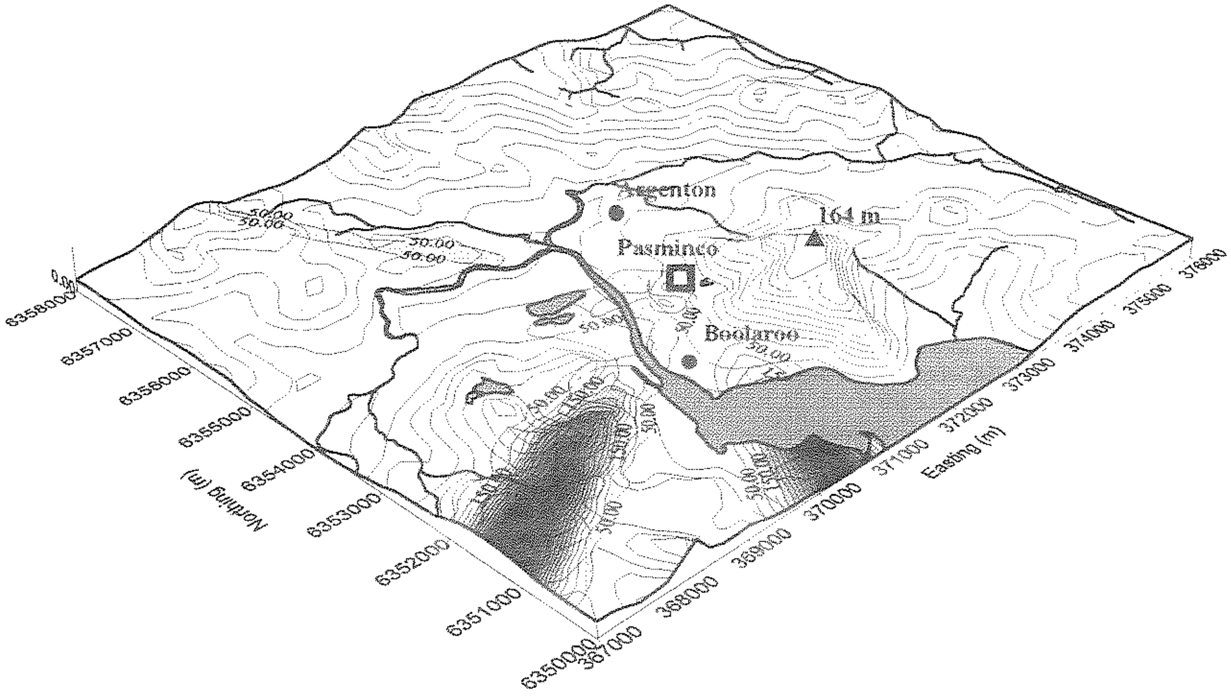

Figure 2. Event 1, characterised by strong dispersion south and west of the study area. Contour values = 50 ug/m3.

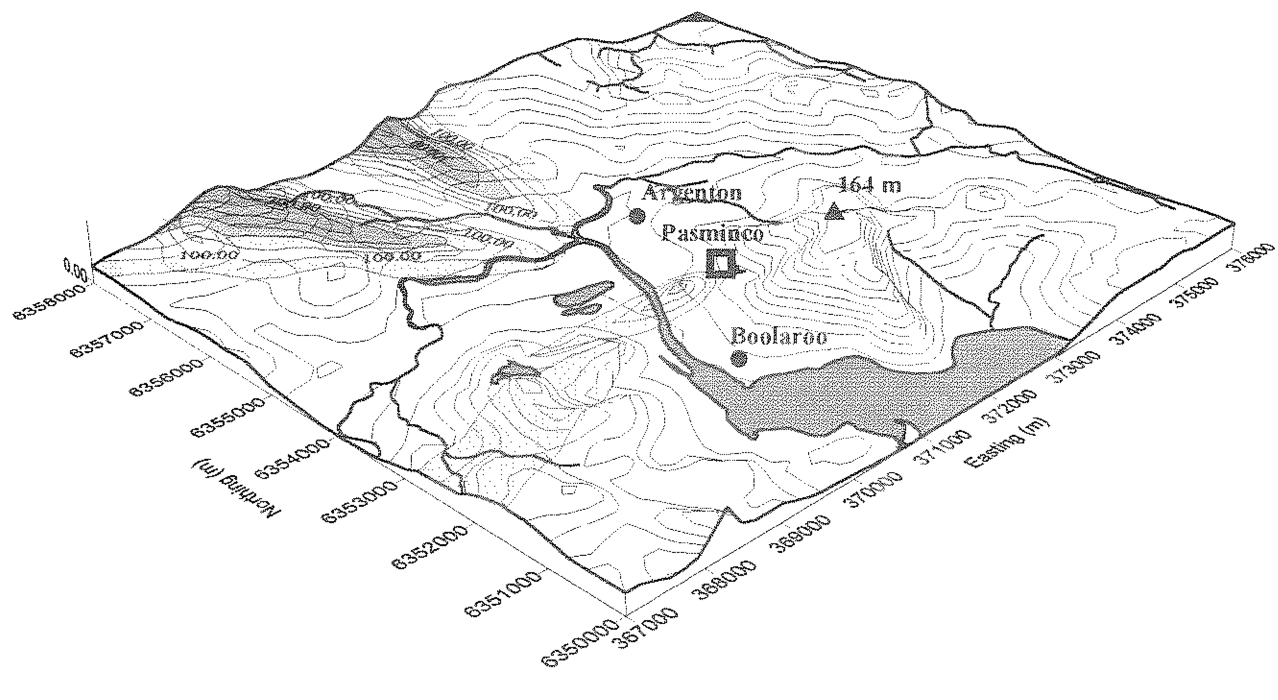

Figure 3. Event 2, characterised by strong northerly dispersion and lower SO2 concentrations. Contour values = 50 ug/m3.

emissions. Recently a 150m buffer zone was created to reduce impacts of pollution on the local community.

MEASUREMENTS AND METHODOLOGY

As these investigations were a pilot prior to the use of health data, an indicator of asthma potential was needed to select days of interest. For this study, a stability index was derived from balloon data at Williamtown, 25 kilometres north-east of Boolaroo. Ranking of the index provided a crude indicator for modelling episodes. Two days of interest were chosen; September 16 (Event 1) and October 14 (Event 2) 1994. In both events, constant rates (g/s) were assumed for acid plant and sinter stack emissions. Meteorological information (temperature, wind parameters and humidity) was obtained from Pasminco's on site weather station. Due to the absence of tower data, initial mixing height depth was estimated from balloon traces adjusted using a time-varying depth calculation. Pasquill stability class was assigned by diurnal pattern, sigma theta and wind speed values (Mitchell 1982). Terrain for the North Lake Macquarie area was converted into a 9 by 8 kilometre grid with 250 metre node spacings, with information upon topography also entered into the model input file. To overcome the effects of Munibung Hill, an Egan value of 0.99 was used for all Pasquill stability classes, which assumed that plumes were extremely close to Munibung Hill upon release. Results of dispersion events were drawn on a grid file using Surfer™ software and key features, such as urban areas and hydrology were drawn using a computer aided design package.

RESULTS AND DISCUSSION

Figures 1 and 2 show the results of dispersion for the selected days. Event 1 was a fine day characterised by dry sunny conditions and light north easterly winds. An elongated high pressure system situated over central Australia, extended across eastern NSW produced stable conditions. Temperatures at Boolaroo ranged from 10-25°C. By 0900, convective warming created strong vertical mixing, with increasing wind strengths in the afternoon. One dispersion area was predicted 1-2 km south-west of the source. Some minor deposition was found near the plant is apparent due to turbulence from Munibung Hill. Highest predicted concentrations (780 $\mu g/m^3$) were over unpopulated quarry and mine sites to the west. Another dispersion area, 2-3 km south of the source was situated over Lake Macquarie and more distant suburban areas (see Figure 2). Both dispersion areas extended off the bounds of the grid, suggesting the impact of increasing afternoon wind stength.

In Event two, a major high pressure system centred directly over the NSW coast, brought fine sunny conditions. South westerly mesoscale winds were gusty, particularly in the morning, ranging from 1.9-3.6 m/s. Temperatures for Boolaroo ranged from 14-20°C. Two major concentrations were predicted 2-4 km north of Argenton, with deposition on distant terrain and elevated suburban areas. Minor concentrations was also found west of the plant. Predicted concentrations were comparatively lower, with maximum values at 380 ug/m^3.

CONCLUSION

A Gaussian plume dispersion model was used to evaluate ten minute maxima for days of high asthma potential, based on an atmospheric stability indicator. This paper, a precursor for an asthma study including the Boolaroo-Argenton area, showed that impacts of SO_2 on the study area were minimal, due to increasing afternoon winds, causing deposition at more distant sites

The selection criteria for days of high asthma will need further refining. Allowances for topographic variation between Boolaroo and Williamtown may be necessary, due to the impacts of Munibung Hill and Lake Macquarie. The use of asthma data and mesoscale weather patterns will be incorporated into future criteria for the selection of modelled events.

Adjustments for Ausplume will be necessary in a number of areas. Modification of Egan values will be needed to accommodate terrain more distant from the source. Although values of 0.99 were suitable for Munibung Hill, downwind dispersion would unlikely result in high levels on distant terrain. Predicted values will need validating against monitored data using single point averaging times. Previous fits of the modelled SO_2 area found that Ausplume consistently under predicted concentrations over one year, suggesting levels much higher than predicted (Holmes 1994). Further accuracy will be obtainable using hourly stack emission rates.

Ausplume itself has a number of limitations. The prediction of channelling around hill slopes cannot be handled, contributing to inaccurate concentrations near hills. Pasquill stability classes, stored in the Ausplume files, do not simulate dispersion rates during sea breeze events. This may be overcome by selecting hourly periods unaffected by sea-breeze conditions.

Predicted levels for this paper are below health criteria for normal subjects, but impacts on the asthmatic population remain to be seen. The effects of complex terrain make it difficult to predict true spatial concentrations, but a more thorough understanding of short term effects will enhance the details of medical information over the study period.

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