northern expressway
environmental report
air quality technical paper

Australian Government

AUSLINK
Building our National Transport Future

Government of South Australia
Department for Transport, Energy and Infrastructure

AIR QUALITY TECHNICAL PAPER

Northern Expressway

Air Quality

Technical Paper

28 February 2007

Prepared by:

Consulting Environmental Engineers

PO Box 201
Richmond Vic 3121

Telephone: + 61 3 9429 4644
Facsimile: + 61 3 9428 0021

Prepared for:

Department for Transport, Energy and Infrastructure

33-37 Warwick Street
Walkerville SA 5081

PO Box 1
Walkerville SA 5081

Telephone: 1300 658 621
Facsimile: + 61 8 8343 2005
Email: northernexpressway@saugov.sa.gov.au

Revision	Date	Comment	Signatures		
			Originated by	Checked by	Authorised by
0	23/12/06	Issues to Client for Review	Lisa Russ	Ian Wallis	
1	28/02/07	Amendments and additional information	Lisa Russ	Ian Wallis	Daniel Leinfelder

Table of Contents

1 Introduction 1

1.1 Background 1

1.2 Legislative and policy requirements 1

1.2.1 South Australian legislation 1

1.2.2 NEPM standards 1

1.2.3 NEPM air quality guidelines 2

2 Existing environment 5

2.1 Description of existing environment 5

2.1.1 Background air quality 5

2.1.2 Comparison of background levels and NEPM 7

2.2 Meteorological conditions 8

2.2.1 Winds at Edinburgh 8

2.2.2 Mixing rates 9

3 Health effects of air pollutants 13

3.1 Nitrogen dioxide (NO_2) 13

3.2 Carbon monoxide (CO) 13

3.3 Particulate matter – PM10 and PM2.5 14

3.4 Benzene 15

3.5 Toluene 15

3.6 Formaldehyde 16

3.7 Polycyclic aromatic hydrocarbons – PAH 17

3.8 Xylenes 17

4 Near road air quality 19

4.1 Air quality assessment methodology 19

4.2 Summary of criteria 20

4.3 Sensitive receptors 20

4.3.1 Northern Expressway 20

4.3.2 Port Wakefield Road 20

4.4 Traffic projections 22

4.5 Traffic fleet composition 23

4.6 Emission factors 23

5 Model predictions 25

5.1 Northern Expressway 25

5.2 Port Wakefield Road 27
5.3 Air quality effects on other roads 29

6 Environmental management 31

6.1 Approach to environmental management 31
6.1.1 Construction impacts 31
6.1.2 Mitigation measures 31

7 Conclusion 33

8 References 35

List of figures

Figure 2.1	Wind rose for Edinburgh airfield – annual (all hours)	10
Figure 2.2	Wind rose for Edinburgh airfield – annual (day hours)	11
Figure 2.3	Wind rose for Edinburgh airfield – annual (night hours)	12
Figure 5.1	Predicted peak 1-hour NO_2 concentrations on Northern Expressway	26
Figure 5.2	Predicted peak 1-hour NO_2 concentrations on Port Wakefield Road	28

List of tables

Table 1.1	National Environment Protection (Ambient Air Quality) Measure – standards and goals	3
Table 1.2	Variation to the National Environment Protection (Ambient Air Quality) Measure for particles as PM2.5 – advisory standards and goals	3
Table 1.3	National Environment Protection (Air Toxics) Measure – monitoring investigation levels	3
Table 2.1	Monitoring results for Elizabeth	5
Table 2.2	Monitoring results for PM2.5 at Northfield	6
Table 2.3	Monitoring results for benzene and toluene	6
Table 2.4	Adopted background levels for the Northern Expressway	7
Table 2.5	Comparison of background levels with NEPM	8
Table 4.1	Summary of National Environment Protection Measure limits	20
Table 4.2	Projected traffic volumes	222
Table 4.3	Traffic composition	23
Table 4.4	Fleet emission rates for 2011 and 2021 for Northern Expressway and Port Wakefield Road	24
Table 5.1	Model predictions at the nearest receptor – Northern Expressway	26
Table 5.2	Model predictions at the nearest receptor – Port Wakefield Road (at 6 m)	27
Table 5.3	Model predictions at the nearest receptor – Port Wakefield Road (at 17 m)	28
Table 5.4	Main North, Angle Vale and Heaslip roads projected daily traffic volumes	29
Table 5.5	Main North, Angle Vale and Heaslip roads proportion of heavy vehicles (percentage of vehicles)	29

List of abbreviations

Air NEPM	National Environment Protection (Ambient Air Quality) Measure
CO	Carbon monoxide
DTEI	Department for Transport, Energy and Infrastructure
EMP	Environmental Management Plan
EPA	Environment Protection Authority
g/km/vehicle	grams per kilometre per vehicle
m/s	metre per second
ng/m^3	nanograms per cubic metre
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O_3	Ozone
PAH (as BaP)	Polycyclic aromatic hydrocarbons (expressed as benzo-(a)-pyrene)
Pb	Lead
PM2.5	Particulate matter. Fine particles less than 2.5 microns in diameter
PM10	Particulate matter. Fine particles less than 10 microns in diameter
ppm	Parts per million
SO_2	Sulphur dioxide
$\mu g/m^3$	micrograms per cubic metre
vpd	vehicles per day

Glossary

Averaging period	The period over which the average is taken (e.g. 1-hour averaging period is the average of all readings over 1 hour).
Sensitive receptors	Residences, schools and other non-commercial places that are permanently occupied by people

1 Introduction

1.1 Background

Motor vehicles emit contaminants such as nitrogen dioxide, carbon monoxide and fine particles to the atmosphere. The effect of the emissions from vehicles depends on the traffic volumes and composition, vehicle emission rates, existing air quality levels, the local meteorological conditions and the distance of sensitive receptors from the roadway.

An air quality assessment was undertaken to determine the effects of the Northern Expressway and Port Wakefield Road on the existing air quality of the study area and to determine if any air quality criteria will be exceeded in the future at any sensitive receptors.

1.2 Legislative and policy requirements

1.2.1 South Australian legislation

The *Environment Protection Act 1993* addresses air quality issues in South Australia. The Act defines two categories of environmental harm caused by pollution including air pollution:

- material environmental harm
- serious environmental harm.

The Act provides for the development of Environment Protection Policies. Air quality is covered by the *Environment Protection (Air Quality) Policy 1994*. This policy provides for the regulation of industrial pollution and associated source monitoring and testing where required. However, the policy does not deal specifically with sources of diffuse pollution, such as motor vehicles.

South Australia has adopted the NEPM (National Environment Protection Measure) guideline limits for air quality through the *Environment Protection Act 1993*, and the *National Environment Protection Council (South Australia) Act 1995*. As a result the NEPM limits apply as Environmental Protection Policies under the *Environment Protection Act 1993 (SA) Section 28A*. Such policies are to be 'taken into account' by the SA Environment Protection Authority (EPA), in assessing air quality concerns and issues.

For carbon monoxide, nitrogen dioxide and fine particles (PM10), the National Environment Protection Council (NEPC) has specified **national environmental protection** standards. For fine particles expressed as PM2.5, the NEPC has specified an **advisory** standard, which does not have a time frame for compliance. For air toxics, NEPC has specified **monitoring investigation levels**, and some further risk assessment should be undertaken if they are exceeded.

1.2.2 NEPM standards

The *National Environment Protection (Ambient Air Quality) Measure* (Air NEPM) was introduced in 1998 to provide a consistent approach to the measurement of air quality around Australia, with the ultimate

aim of providing equivalent protection to all Australians, wherever they live. The Air NEPM established air quality standards for six common pollutants:

1. Carbon monoxide (CO)
2. Nitrogen dioxide (NO_2)
3. Ozone (O_3)
4. Sulfur dioxide (SO_2)
5. Particulate matter less than 10 micrometres (μm) in diameter (PM10)
6. Lead (Pb).

The NEPM Standards are set to provide adequate protection for human health and well-being. The goal of the Air NEPM is to achieve the NEPM Standards, as assessed by EPA monitoring, within 10 years (see National Environment Protection Council, 1998).

In 2003, a variation to the Air NEPM was made to include particulate matter of less than 2.5 μm in diameter (PM2.5).

Also in 2003, the NEPC issued a draft NEPM on air toxics for public consultation. On 16 April 2004, the NEPC, the Council of all State, Territory and Commonwealth environment ministers that promulgates NEPMs, adopted a new *National Environment Protection (Air Toxics) Measure*.

NEPMs are defined in the NEPC Act and promulgated by the NEPC. They are similar to policies and are set to ensure environmental protection. NEPMs can include any combination of goals, standards, protocols and guidelines.

A **goal** means the desired outcome of the NEPM (e.g. protection of human health). A **standard** is a 'measure of environmental quality' (e.g. a pollutant concentration). **Protocol** is the 'procedure to be followed to determine whether a standard or goal is being met' (e.g. guidelines for the location of sites and methods of monitoring and analysis).

An **NEPM site** is a monitoring site that has been nominated by the EPA in the *Ambient Air Quality Monitoring Plan for South Australia* (2001), as one that meets the standards set out by the NEPM with respect to, for example, placement of the site and monitoring methods, and has been approved by the NEPC.

An **exceedence** of the NEPM is characterised by an exceedence of the maximum allowable concentration, for a greater number of times than set out in the goal, at a NEPM designated site.

The NEPM limits are given for two concentration units: ppm (as used in the NEPM reports) and $\mu g/m^3$ (as used in air quality modelling).

1.2.3 NEPM air quality guidelines

Table 1.1 outlines the standards and goals for CO, NO_2 and PM10.

Table 1.1 National Environment Protection (Ambient Air Quality) Measure – standards and goals

Pollutant	Averaging time	Max conc as listed in NEPM*	Max conc as µg/m^3 *
CO	8-hour	9.0 ppm	10,440
NO_2	1-hour	0.12 ppm	228
	1-year**	0.03 ppm	57
Particles as PM10	1-day	50 µg/m^3	50

* *The NEPM limits are given for two concentration units: ppm (as used in the NEPM reports) and µg/m^3 (as used in air quality modelling).*

** *1-year = calendar year average.*

Table 1.2 outlines the NEPM advisory standards and goals for particulate matter with fine particles less than 2.5 microns in diameter (PM2.5). The NEPC has specified this pollutant as a reporting standard that does not have a time frame for compliance.

Table 1.2 Variation to the National Environment Protection (Ambient Air Quality) Measure for particles as PM2.5 – advisory standards and goals

Pollutant	Averaging time	Max conc as listed in NEPM*	Max conc as µg/m^3 *
Particles as PM2.5	1-day	25 ug/m^3	25
	1-year**	8 µg/m^3	8

* *The NEPM limits are given for two concentration units: ppm (as used in the NEPM reports) and ug/m^3 (as used in air quality modelling).*

** *1-year = calendar year average.*

Table 1.3 outlines the NEPM monitoring investigation levels for benzene, polycyclic aromatic hydrocarbons (expressed as benzo-(a)-pyrene) (PAH [as BaP]), formaldehyde, toluene and xylenes. For air toxics, the NEPC has specified monitoring investigation levels, and some further risk assessment should be undertaken if they are exceeded.

Table 1.3 National Environment Protection (Air Toxics) Measure – monitoring investigation levels

Pollutant	Averaging time	Max conc as listed in NEPM*	Max conc as µg/m^3 *
Benzene	Annual**	0.003 ppm	9
PAH (as BaP)	Annual	0.3 ng/m^3	0.0003
Formaldehyde	24-hour	0.04 ppm	49
Toluene	24-hour	1 ppm	3,770
	Annual	0.1 ppm	380
Xylenes	24-hour	0.25 ppm	1,085
	Annual	0.2 ppm	870

* *The NEPM limits are given for two concentration units: ppm (as used in the NEPM reports) and µg/m^3 (as used in air quality modelling).*

** *Annual average concentrations are the arithmetic mean concentrations of 24-hour monitoring results.*

The NEPM limits are designed to protect public health. The NEPM (Air Toxics) states that: 'the monitoring investigation level values are levels of air pollution below which lifetime exposure, or exposure for a given averaging time, does not constitute a significant health risk. If these limits are exceeded in the short term it does not mean that adverse health effects automatically occur' (NEPC 2004).

2 Existing environment

2.1 Description of existing environment

2.1.1 Background air quality

A conservative representation of background air quality was achieved by using the 90 percentile measured values for the area, where available. Background air quality for nitrogen dioxide, carbon monoxide and PM10 is available for the Elizabeth and Gawler monitoring stations. The 90 percentile values are summarised in Table 2.1. Note that ozone and sulphur dioxide also are monitored at Elizabeth, and ozone also was monitored at Gawler. The Gawler monitoring station was closed in October 2004.

The Elizabeth monitoring station is located at Elizabeth Downs Primary School, and is not located near industry or heavy transport corridors. As such, the South Australian EPA considers this monitoring site represents background air quality for the northern suburbs of Adelaide.

The 90 percentile concentration based on recent measurements has been adopted as the background concentration to provide a conservative measure of ambient air quality conditions, while avoiding short peaks which may reflect specific conditions at the monitoring site. The Victorian EPA 'Plume Calculation Procedure' recommends use of the 70 percentile as background, so the use of 90 percentile is more conservative.

Table 2.1 Monitoring results for Elizabeth

Substance	Unit	Averaging period	Elizabeth 90 percentile
Nitrogen dioxide	µg/m^3	1-hour	19.6
	µg/m^3	Annual	8.1*
Carbon monoxide	µg/m^3	8-hour	120
PM10	µg/m^3	24-hour	28.6

** Equals annual value.*

The background values adopted for this study are:

- Nitrogen dioxide (1-hour average) 20 µg/m^3
- Nitrogen dioxide (annual average) 8 µg/m^3
- Carbon monoxide (8-hour average) 120 µg/m^3
- PM10 (24-hour average) 29 µg/m^3.

It is considered that background air quality in the northern suburbs in 2011 will be much the same as in recent years. There is a trend for reduced emissions per kilometre from vehicles, but this is balanced by growth in the number of vehicles travelling through the region, and further residential and commercial development in the region.

During 2005, a study of fine particle composition in four major Australian cities was undertaken to determine the contribution of PM2.5 to overall PM10 concentrations (EPA Victoria et al. 2005). PM10 and PM2.5 data were collected at two suburban sites in Adelaide – Netley and Northfield. Netley is located adjacent to residential and light industrial areas in the western suburbs of Adelaide, close to the Adelaide Airport, about 5 km from the city centre. Northfield is located north-east of Adelaide adjacent to a residential area in the grounds of a hospital and is closer to the Northern Expressway region. Table 2.2 shows a summary of the PM2.5 monitoring results for Northfield.

The study found that the annual median PM2.5 level was 4.9 µg/m^3 at Northfield. The 90 percentile level was 8 µg/m^3 (at Northfield), with the highest measured concentration (in 37 weeks) being 13 µg/m^3 (EPA Victoria et al. 2005).

Table 2.2 Monitoring results for PM2.5 at Northfield

Substance	Unit	Averaging period	Northfield 90 percentile
PM2.5	µg/m^3	24-hour	8.0
	µg/m^3	Annual	4.9

The particle study (EPA Victoria et al. 2005) also found that about one-third of the PM2.5 level recorded at Netley is salt (sodium chloride) and one-quarter was found to be crustal material (i.e. fine dirt).

Background levels for benzene and toluene were taken as the mean of the average and maximum results presented in the paper *Roadside Air Monitoring of Criteria Air Pollutants and Air Toxics in Adelaide* (Morgan and May, presented at the Clean Air Society of Australia and New Zealand (CASANZ) National Clean Air Conference 2003). Table 2.3 summarises the background levels for these parameters for the three studies, known as RAQM1, RAQM2 and RAQM3.

Table 2.3 Monitoring results for benzene and toluene

Substance	Unit	Averaging period	RAQM1	RAQM2	RAQM3
Benzene	µg/m^3	24-hour			
		Average	0.84	0.31	0.37
		Max	1.3	0.41	0.65
		Mean	1.1	0.36	0.51
Toluene	µg/m^3	24-hour			
		Average	6.1	1.9	1.0
		Max	9.5	3.2	1.8
		Mean	7.7	2.6	1.4

The adopted annual background level for benzene is 1 µg/m^3 based on the average of the three RAQM sites rounded upwards to 1 µg/m^3.

The background level adopted for this study for 24-hour toluene is 8 µg/m^3 (rounded from 7.7 µg/m^3). This value is from the highest of the three monitoring sites (RAQM1) and is considered to approximate the 90 percentile background level for the study area.

The adopted annual background level for toluene is 3 µg/m^3 based on the average of the three RAQM sites.

The adopted 24-hour background level for xylenes is 11 µg/m^3 based on the 90 percentile value measured in monitoring on 48 days by VicRoads, at Mitcham, an outer suburb of Melbourne. The adopted annual background level for xylenes is 2 µg/m^3 based on the average of all measurements at Mitcham.

There is limited monitoring data available for formaldehyde. The background level adopted for formaldehyde is 6 µg/m^3 based on the monitoring data for South Australia presented in the *Impact Statement for the National Environment Protection (Air Toxics) Measure* (May 2003).

In the fine particle study (EPA Victoria et al. 2005), an analysis was conducted on the particle phase PAHs at the two sites in Adelaide. Seventeen PAHs were identified in the samples including benzo-(a)-pyrene (BaP). The background BaP for the Northern Expressway was adopted from the mean at the Netley monitoring station as 0.19 ng/m^3 (0.00019 µg/m^3).

Table 2.4 summarises the adopted background levels for the Northern Expressway. These levels are considered conservative as background levels for the study area which is a semi-rural environment on the outskirts of Adelaide.

Table 2.4 Adopted background levels for the Northern Expressway

Substance	Unit	Averaging period	Background level
Nitrogen dioxide	µg/m^3	1-hour	20
	µg/m^3	Annual	8
Carbon monoxide	µg/m^3	8-hour	120
PM10	µg/m^3	24-hour	29
PM2.5	µg/m^3	24-hour	8
	µg/m^3	Annual	4.9
Benzene	µg/m^3	Annual	1
Formaldehyde	µg/m^3	24-hour	6
BaP	µg/m^3	Annual	0.00019
Toluene	µg/m^3	24-hour	8
	µg/m^3	Annual	3
Xylenes	µg/m^3	24-hour	11
	µg/m^3	Annual	2

2.1.2 Comparison of background levels and NEPM

Table 2.5 compares the background levels, developed as described in Section 1.2, with the NEPM standards and investigation levels. It can be seen that for CO, toluene and xylene the background level is less than 3% of the NEPM limit. For NO_2, benzene and formaldehyde, the background level is 9 to 14% of the NEPM limit.

For the 24-hour averaging period, PM10, PM2.5 and BaP background levels are 32 to 63% of the NEPM limit and the annual PM2.5 background level is 61% of the NEPM limit.

Table 2.5 Comparison of background levels with NEPM

Substance	Averaging period	Background level (µg/m^3)	NEPM	Percentage of NEPM (%)
Nitrogen dioxide	1-hour	20	228	9
	Annual	8	57	14
Carbon monoxide	8-hour	120	10,440	1
PM10	24-hour	29	50	58
PM2.5	24-hour	8	25	32
	Annual	4.9	8	61
Benzene	Annual	1	9	12
Formaldehyde	24-hour	6	49	12
BaP	Annual	0.00019	0.00030	63
Toluene	24-hour	8	3,770	< 1
	Annual	3	380	1
Xylenes	24-hour	11	1,085	1
	Annual	2	870	< 1

2.2 Meteorological conditions

Modelling of near-road air quality requires information on wind speed, wind direction, ambient temperature and atmospheric stability class for each hour over a period of one year, to ensure that diurnal and seasonal variations are represented.

Local winds are very important for predicting the dispersion and movement of contaminants. The nearest wind monitoring site to the Northern Expressway is at Edinburgh airfield. The Edinburgh wind data for year 2000 were supplied by the South Australian EPA.

The 10 percentile, median and 90 percentile wind speeds for Edinburgh airfield over the year were 1.5 metres per second (m/s), 4.1 m/s and 8.2 m/s. These represent wind conditions for a site near to, but inland from, the coast, and well south of tropical cyclones.

2.2.1 Winds at Edinburgh

The hourly wind speed and wind direction at Edinburgh were plotted to provide an annual wind rose, as shown in Figure 2.1. In the wind rose, the length of the bars represents the proportion of winds from each sector over the year; thus longer bars denote the more common wind directions. The width of the bars represents the speed range of the winds; thus wider bars indicate stronger winds.

The wind rose for Edinburgh shows that the most frequent winds come from the north-east and the south-west. Low wind speeds come from all directions, as indicated by the fine lines near the centre of Figure 2.1, depicting the proportion of measured wind speeds in the range of 0 to 2 m/s. A higher proportion of low winds come from the north-east and south-west sectors.

Figure 2.2 shows the wind rose for daytime hours (from 7 a.m. to 7 p.m.). South-west winds are the most frequent direction (probably sea breezes) with west-south-west and north-east winds also being common.

Figure 2.3 shows the wind rose for night hours (from 7 p.m. to 7 a.m.). Winds from the north-east are dominant, with east-north-east winds also being common. These probably represent night drainage breezes from the land to the sea.

2.2.2 Mixing rates

Compilation of a meteorological data file in AusRoads format from the Edinburgh airfield wind records was carried out by the Victorian EPA.

The parameters in an AusRoads format meteorological file are:

- wind speed (m/s, with a minimum wind speed of 0.5 m/s)
- wind direction (direction from north)
- ambient temperature (degrees C)
- stability class (Pasquill-Gifford Classes A to F)
- mixing height (maximum of convective and mechanical mixing height)
- sigma theta (60-minute average of sigma theta).

The atmospheric stability classes were calculated from wind speed, cloud cover and time of day using the Turner Workbook approach (Turner 1964). Examination of the wind file reveals that the proportion of stability conditions is as follows:

- Class A < 0.05% of hours
- Class B 6% of hours
- Class C 16% of hours
- Class D 43% of hours
- Class E 20% of hours
- Class F 15% of hours.

The mixing height was determined by using the methodology of Benkley and Schulman (1979). The mixing height uses upper air profiles of temperature and moisture from the nearest observing station, and the extent of turbulence generated by shear as the wind travels over the terrain. Examination of the data file shows that the 10 percentile, 50 percentile and 90 percentile mixing heights are 37 m, 163 m and 307 m. These are consistent with the recorded wind speeds and a semi-rural area.

Figure 2.1 Wind rose for Edinburgh airfield – annual (all hours)

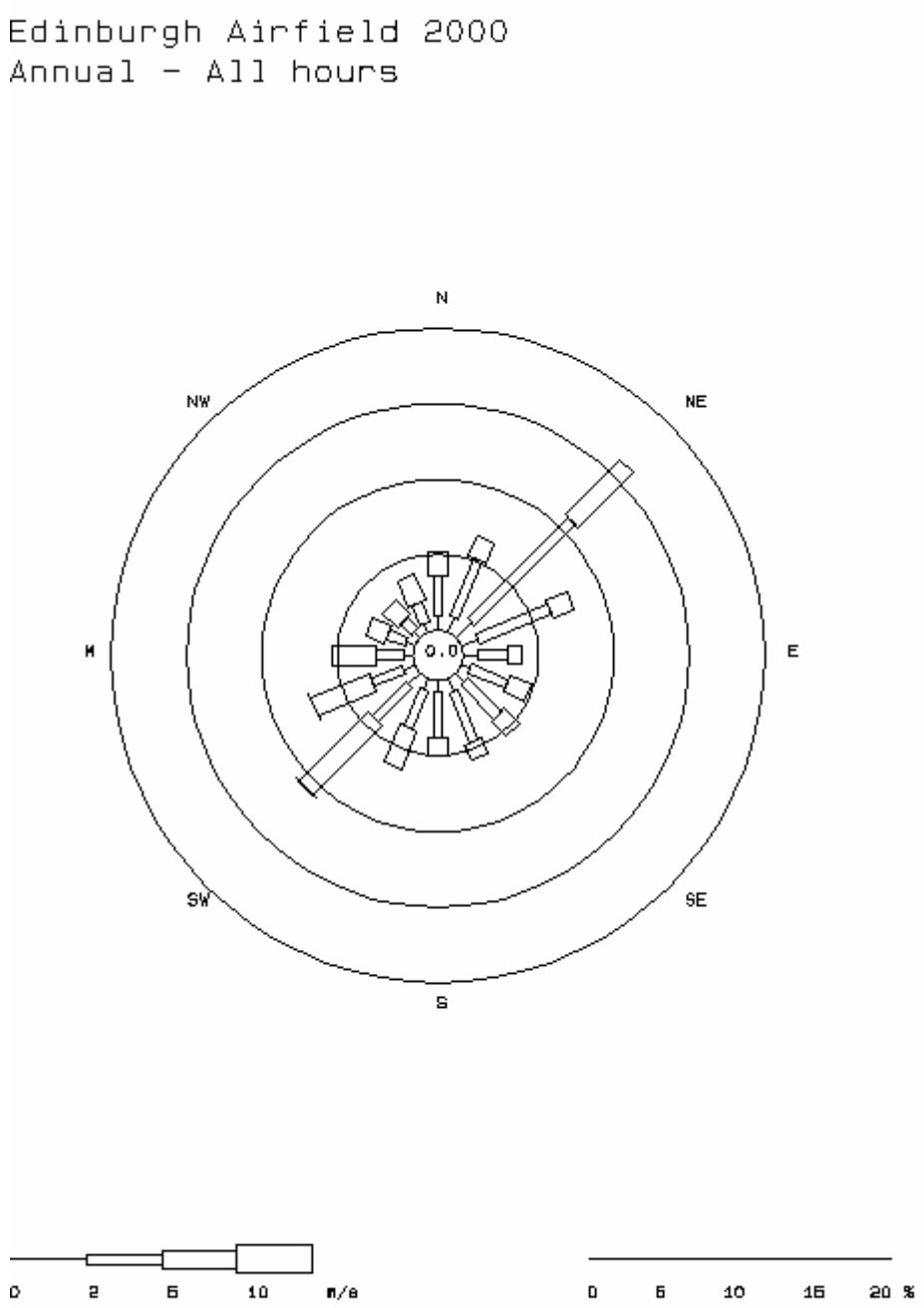


Figure 2.2 Wind rose for Edinburgh airfield – annual (day hours)

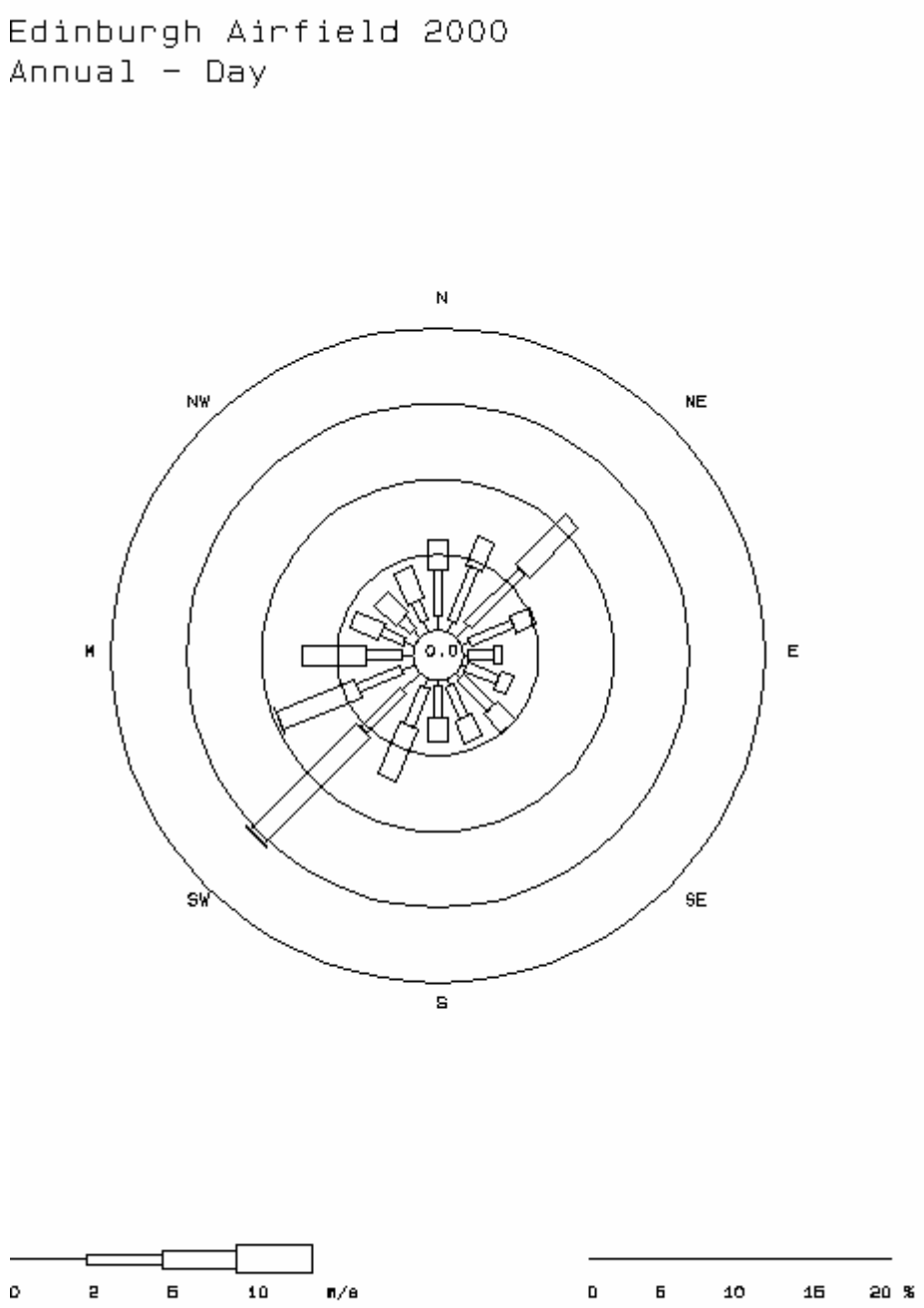
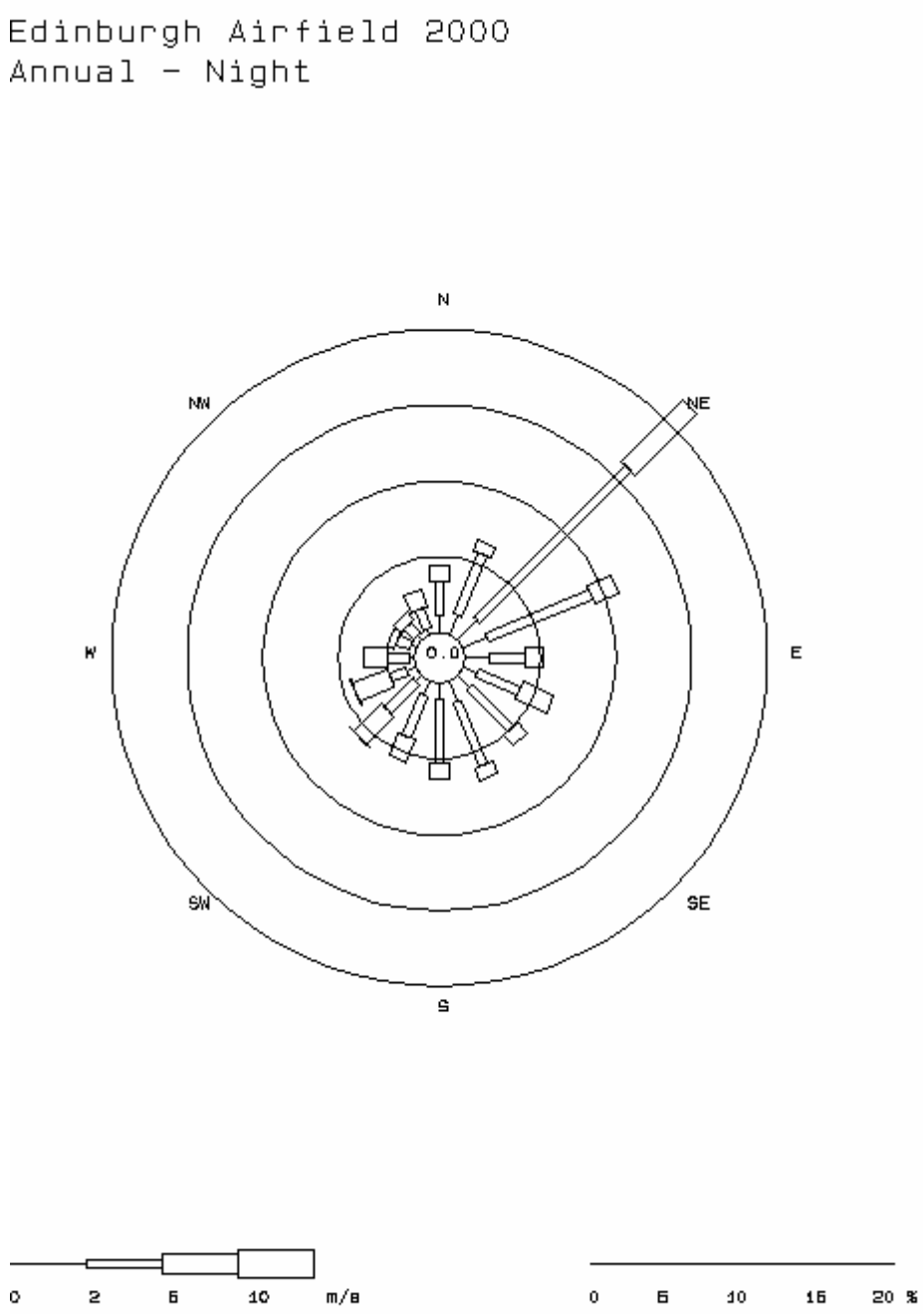


Figure 2.3 Wind rose for Edinburgh airfield – annual (night hours)



3 Health effects of air pollutants

3.1 Nitrogen dioxide (NO_2)

Nitrogen dioxide is a pungent acidic gas which is corrosive and strongly oxidising. It is produced in high temperature combustion of fuels by a reaction with the nitrogen in air. Motor vehicles produce approximately 60 to 70% of the total emissions of nitrogen oxides in urban areas. Other major sources are residential and commercial use of gas, industrial boilers and bushfires. Nitrogen dioxide is formed naturally by lightning and the oxidation of ammonia.

The majority of nitrogen oxides (NO_x) from combustion sources are emitted in the form of nitric oxide (NO), which is converted into nitrogen dioxide (NO_2) in the atmosphere. Nitrogen oxides also are involved in chemical reactions in the atmosphere which lead to the production of ozone and photochemical smog. The major sinks for nitrogen dioxide are absorption by soil, uptake by plants and washout by rain.

A variety of human health effects have been associated with nitrogen dioxide exposure, including decreased lung function and increased respiratory illness, especially in young children. Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of elevated nitrogen dioxide. Nitrogen dioxide at high concentrations also can cause significant damage to plants.

Nitrogen dioxide is one of the primary air contaminants selected by the EPA and NEPC to define ambient air quality.

3.2 Carbon monoxide (CO)

Carbon monoxide is present naturally in the atmosphere in trace quantities, typically at 0.01 to 0.02 ppm (parts per million). It is a colourless, odourless and tasteless gas. The principal source of carbon monoxide is the incomplete combustion of fuels. Motor vehicles are the predominant source of carbon monoxide in urban areas, contributing 80 to 90% of annual total carbon monoxide emissions. Domestic heating, industrial boilers and bushfires are other sources of carbon monoxide. The major sinks for carbon monoxide are chemical transformation to carbon dioxide and uptake by micro-organisms and plants.

When carbon monoxide is inhaled it enters the bloodstream and can disrupt the supply of oxygen to the body. The impact that this reduction in oxygen supply can have on health depends on the degree and duration of the effect. Potential effects on human health include: reduced vigilance, decreased manual dexterity, impaired performance on complex tasks and disturbed sleep.

Elevated levels of carbon monoxide also can reduce the availability of oxygen to the central nervous system, including the brain. There are small amounts of carbon monoxide produced naturally within the body and these can be increased by a factor of five in smokers.

Carbon monoxide is one of the primary air contaminants selected by the EPA and NEPC to define ambient air quality.

3.3 Particulate matter – PM10 and PM2.5

Suspended matter in the atmosphere comprises a wide range of materials including dust, combustion particles, secondary particles (such as nitrates and sulfates) and pollens. The size of the particles affects their significance as air contaminants: particles about one micron or smaller in diameter cause visibility reduction through light scattering; those with diameters between one and ten microns (respirable particles) are most likely to deposit in the small passages of the lung; while most larger particles do not reach the lower, more sensitive parts of the lung, but can cause irritation and aesthetic nuisance.

The health effects of fine particles depends on their size and chemical composition: finer particles appear to be of greatest concern; fine dust (5 to 50 microns) may be less harmful than particles produced from combustion processes (Streeton 1997). Possibly the most harmful fine particles are produced from combustion of fossil fuels, including diesel emissions in particular, or secondary oxidation compounds produced by oxidation processes in the atmosphere (smog-formed particles).

Air quality standards have been established to reflect the health effects of fine particles (less than 10 microns, known as PM10), and very fine particles (less than 2.5 microns known as PM2.5).

The Six Cities Study in the USA (Dockery et al. 1994) established a correlation between total mortality (and morbidity) and average PM10 level. As a result, it is frequently cited that there is a 1% increase in total mortality for each 10 $\mu g/m^3$ increase in PM10 levels (e.g. see NEPC 1997; Streeton 1997). While there are questions about the validity of the correlation (e.g. Lipfert and Wyzga (1997) express doubts) it seems logical that PM10 should be a good surrogate indicator for combustion, oxidation and acid particles, and hence fine particles should correlate with observed chronic and acute health effects.

Vehicles are estimated to contribute about 20% of the annual PM10 load in urban regions in Australia. Diesel trucks are the major source of fine particles from vehicles. Fuel combustion in boilers, heaters and domestic burning are other major sources of PM10. Very high levels of PM10 can occur when there are bushfires.

In June 1998, the Ambient Air Quality NEPM set Australian national air quality standards. The national air quality standard for fine particles is expressed as PM10, as an average over 24 hours. In view of the concern about the potential health implications of fine particles, PM10 is a widely used indicator of air quality.

In May 2003, the NEPM (Ambient Air Quality) added PM2.5 as another indicator for fine particles. PM2.5 comprises the very fine particles in the atmosphere that are smaller than 2.5 microns. A high proportion of these particles are volatile substances including diesel emissions and secondary oxidation particles. The health effects are similar to those for PM10.

Vehicles are estimated to contribute about 20 to 30% of the annual PM2.5 load in urban regions in Australia (not including road dust). The proportion increases to about 40% in summer and reduces to about 15% in winter. Road dust can contribute up to 70% of summer PM2.5 emissions and 50% of winter PM2.5 emissions.

A study of fine particle composition at Northfield and Netley in Adelaide (EPA Victoria et al. 1995) found that the major components of PM2.5 were sodium and chloride (i.e. sea salt constitutes 30% of PM2.5). Other significant (but smaller) components were iron, aluminium and calcium (i.e. 10% crustal sources), black carbon (12% from soot and motor vehicles) and photochemical particles.

3.4 Benzene

Benzene is a volatile reactive hydrocarbon which is contained in exhaust and evaporative emissions from vehicles, particularly from cars with defective catalysts. About 76% of benzene is released in the exhaust gases from petrol vehicles, 22% from evaporation of stored fuel and 2% is released while filling petrol tanks (Hearn 1994). Vehicles are estimated to contribute about 80% of annual benzene emissions in urban regions.

Benzene also forms during the combustion of other aromatic compounds in fuel. Catalysts reduce the quantity of benzene discharged in exhaust gases by about 50 to 70%. Small quantities of benzene may be released indoors by some products (solvents, adhesives and cleaners). Cigarette smoking is a significant source of exposure to benzene.

Benzene in the air comes from emissions in oil and natural gas production, petroleum refining, burning coal and oil, petrol stations, pulp and paper production, coke ovens and motor vehicle exhausts. Benzene is used as a constituent in motor fuels; as a solvent for fats, waxes, resins, oils, inks, paints, plastics, and rubber; in the extraction of oils from seeds and nuts; and in photogravure printing. Benzene also is used in the manufacture of detergents, explosives, pharmaceuticals and dyes.

Benzene is slowly removed from the atmosphere by reactions with hydroxyl radicals and wet deposition. The effect of benzene on human health depends on the concentration of benzene and the duration of exposure. Benzene at prolonged elevated concentrations is a primary carcinogen in humans, causing blood disorders.

The NEPM (Air Toxics) investigation level for annual benzene is 0.003 ppm (9 $\mu g/m^3$).

3.5 Toluene

Toluene (also known as methyl benzene) is produced in petrol refining, chemical manufacturing, the manufacture of paints, lacquers, adhesives and rubber, and some printing and leather tanning processes. Toluene occurs naturally from volcanoes, bushfires and crude oil.

Toluene is released into the atmosphere principally from the evaporation of petroleum fumes and toluene-based solvents and thinners. Motor vehicle exhausts are a source of toluene emissions to the air, and vehicles are estimated to contribute about 50 to 60% of annual toluene emission in urban regions. Tobacco smoke also is a source of toluene.

If toluene is released to the atmosphere it will occur predominantly as a gas which degrades fairly quickly. The concentration of toluene in air varies across sampling locations, with low concentrations being found in rural areas. High concentrations of toluene are found indoors. This is due mostly to the use of household products containing toluene and infiltration of car exhaust emissions.

The most important health issue for humans from exposure to toluene is its harmful effects on the nervous system. These effects depend on both the amount and the length of exposure. Short-term

exposure to moderate amounts of toluene can produce fatigue, confusion, general weakness, actions similar to those when drunk, memory loss, nausea and loss of appetite. Short-term exposure to high concentrations of toluene results first in light-headedness and euphoria followed by dizziness, sleepiness, unconsciousness and in some cases, death by asphyxiation.

Long-term exposure to low and moderate amounts of toluene can cause minor effects on the kidneys in some people. Toluene has not been classified for its carcinogenicity in humans.

The general population is most likely to be exposed in areas with heavy traffic, near hazardous waste sites, near industries where toluene is used or manufactured, or around petrol stations.

The NEPM (Air Toxics) investigation level for 24-hour toluene is 1 ppm (3770 µg/m^3), with an annual limit of 0.1 ppm (380 µg/m^3).

3.6 Formaldehyde

Formaldehyde is a gas which is produced naturally and is also manufactured in large quantities. It is produced by plants and animals and is both made and destroyed by reactions in the air in the presence of sunlight.

It is used to manufacture a wide range of resins, rubber latex for carpet backing, processed wood products, artificial fibres and fabrics, and in the production of some chemicals. Formaldehyde is used as a preservative, a hardening agent in photographic processes, corrosion inhibitor and to disinfect dwellings, ships, stores, clothes and utensils. It is a germicide and pesticide and can be used as an embalming fluid.

Most formaldehyde outdoors comes from combustion, either directly or after the reaction of other combustion products in the presence of sunlight. It also is emitted by industries using or manufacturing formaldehyde. Vehicle exhausts, domestic and industrial processes or bushfires are major sources of formaldehyde. Vehicles are estimated to contribute about 60 to 70% of annual formaldehyde emissions in urban regions. Concentrations in the air change during the day, reaching a maximum in the late afternoon.

Air inside homes or work places may contain formaldehyde, especially if they are poorly ventilated. Cigarette smoke and wood fires are a source of formaldehyde. Formaldehyde can be released to indoor air from resins and latexes used in building materials such as particle board and plywood, and from fabrics and furnishings.

The effect of formaldehyde on human health depends on the amount and duration of exposure. Acute exposure may cause irritation to the eyes, nose and throat. Formaldehyde is a skin sensitising agent inducing an allergic skin disease. Long-term exposure to formaldehyde may be a cause of cancer in the human lung and respiratory tract. Formaldehyde is classified as a probable human carcinogen by the International Agency for Research on Cancer.

The major source of human exposure to formaldehyde is contaminated air. Exposure to harmful levels may occur in poorly ventilated work environments, and homes constructed of building materials which release formaldehyde.

The NEPM (Air Toxics) investigation level for 24-hour formaldehyde is 0.04 ppm (49 µg/m^3).

3.7 Polycyclic aromatic hydrocarbons – PAH

PAH comprise a wide range of organic compounds in vehicle emissions. They also are produced by the incomplete combustion of solid and liquid fuels in a variety of situations including bushfires, barbeques, furnaces, incinerators, heating appliances (including wood stoves and open fires) and smoking. The intake of PAH in food and drink may be higher than the intake by inhalation (foods containing relatively high concentrations of PAH include barbequed meat, burnt toast, and smoked meat and fish).

Vehicles are estimated to contribute about 40% of annual PAH emissions to air in urban regions. PAH are generally associated with fine particles and may be removed from the atmosphere in 1 to 3 hours during rainy periods. However, they can persist for up to 60 hours during prolonged dry periods.

The United Kingdom (UK) Standard for PAH (as BaP) is 0.25 ng/m^3 as an annual average. This was derived from the lowest adverse effect (in a quoted range of 250 to 2,500 ng/m^3) and then applying a safety factor of 10 (to get to the assumed 'no effect' level) and another factor of 10 (to convert from working life to a full 70-year life) and another factor of safety of 10 (to apply to the general population, rather than workers). On this basis, the range of BaP levels for 'no effect' over 70 years on the general population becomes 0.25 to 2.5 ng/m^3, and the lowest value was adopted as the UK Standard.

The NEPM (Air Toxics) investigation level for annual PAH (as BaP) is 0.3 ng/m^3 (0.0003 µg/m^3). The Australian Standard is taken from the New Zealand (NZ) guideline limit of 0.3 ng/m^3. This is based on the World Health Organization (WHO) risk factor for a lifetime risk of lung cancer of 1 in 100,000. However, the WHO risk factor was based on a review of epidemiological data conducted in 1973 and the NZ guideline for PAH is to be re-examined in 2007. The evidence suggests that an annual limit of 0.3 ng/m^3 for BaP is conservative.

3.8 Xylenes

Xylene (of which there are three isomers: m-, o- and p-) also is known as dimethyl benzene. It occurs naturally in petroleum and coal tar and is produced in bushfires, vehicle exhausts and cigarette smoke. It is used as a solvent for paints, coatings, adhesives and rubbers, and in the manufacture of some synthetic materials such as polyester fibres, resins, insecticides, perfumes and pharmaceutical products. It is the basic component for the manufacture of some food containers. Xylene also is used in the leather industry.

The major sources of atmospheric xylene are vehicle exhausts and petroleum refining. Vehicles are estimated to contribute about 50 to 60% of annual xylene emissions in urban regions. Evaporation also occurs during fuel storage, transport and refuelling. In the presence of sunlight, xylenes are rapidly removed by reaction with other chemicals.

Short-term exposure to high levels of xylene can cause respiratory irritation, light-headedness, nausea and headaches. Long-term exposure may cause menstrual disorders in women. Although existing evidence does not suggest that xylene is an animal or human carcinogen, the evidence is not adequate to prove that it is not a carcinogen.

The NEPM (Air Toxics) investigation level for 24-hour xylene is 0.25 ppm (1,085 µg/m^3) and an annual limit is 0.2 ppm (870 µg/m^3).

4 Near road air quality

4.1 Air quality assessment methodology

Tasks undertaken for the air quality impact assessment included:

- inspecting the plans of the project and the route to locate sensitive receptors near the existing and proposed roadways
- analysing traffic information to determine traffic volumes and fleet composition for the years 2011 and 2021
- determining traffic fleet emission rates for the project for years 2011 and 2021
- selecting appropriate wind files for use in modelling air quality
- determining background air quality for the study area
- calculating peak concentrations of the following constituents using the computer model AusRoads, for the averaging times listed below, for comparison with the NEPM limits:
  - Carbon monoxide 8-hour average
  - Nitrogen dioxide 1-hour average and annual average
  - PM10 24-hour average
  - PM2.5 24-hour average and annual average
  - Benzene annual average
  - PAH (BaP) annual average
  - Formaldehyde 1-day average
  - Toluene 1-day average and annual average
  - Xylenes 1-day average and annual average
- assessing the implications and preparing a report on the findings and any necessary mitigation measures.

Near-road air quality modelling for the Northern Expressway and the Port Wakefield Road Upgrade was undertaken for the years 2011 and 2021. The emission factors used in this assessment were based on vehicle emission factors provided by the Victorian EPA (Ng 2005), as emission factors for South Australia are yet to be developed. The emission factors used for this study were the most recent available at the time. Emission factors have been developed for the years 2008, 2011 and 2021, and are not available for years 2016 and 2026. Therefore, the years of 2011 and 2021 were used in this assessment.

4.2 Summary of criteria

As described in Section 1.2, South Australia has adopted the NEPM (National Environment Protection Measure) guideline limits for air quality through the *Environment Protection Act 1993*. The NEPM limits were used for the air quality assessment, and are summarised in Table 4.1.

Table 4.1 Summary of National Environment Protection Measure limits

Pollutant	Averaging time	Max conc as per NEPM*	Max conc as µg/m³*
CO	8-hour	9.0 ppm	10,440
NO2	1-hour	0.12 ppm	228
	1-year**	0.03 ppm	57
Particles as PM10	1-day	50 µg/m³	50
Particles as PM2.5	1-day	25 µg/m3	25
	1-year	8 µg/m3	8
Benzene	Annual	0.003 ppm	9
PAH (as BaP)	Annual	0.3 ng/m3	0.0003
Formaldehyde	24-hour	0.04 ppm	49
Toluene	24-hour	1 ppm	3,770
	Annual	0.1 ppm	380
Xylenes	24-hour	0.25 ppm	1,085
	Annual	0.2 ppm	870

** The NEPM limits are given for two concentration units: ppm (as used in the NEPM reports) and ug/m³ (as used in air quality modelling).*

*** 1-year = calendar year average.*

4.3 Sensitive receptors

The plans of the Northern Expressway and Port Wakefield Road Upgrade were studied to establish the areas where houses were near to the roadway, and site inspections was conducted in November 2006 to identify sensitive receptors close to the roadway. A summary of the sensitive receptors for the Northern Expressway and Port Wakefield Road is provided below.

4.3.1 Northern Expressway

The Northern Expressway runs between the Gawler Bypass (in the east) and Port Wakefield Road (in the west). The Department for Transport, Energy and Infrastructure (DTEI) policy is to establish a 25 m wide buffer zone on either side of the Northern Expressway. Thus there will not be any residences, or other existing receptors, within 25 m of the Northern Expressway.

4.3.2 Port Wakefield Road

A careful inspection of the alignment of the proposed Port Wakefield Road Upgrade was made to identify sensitive receptors close to the roadway. The results are provided below for the four major sections of the proposed upgrade:

- Section 1 Salisbury Highway to Ryans Road
- Section 2 Ryans Road to Bolivar Road
- Section 3 Bolivar Road to Burton Road
- Section 4 Burton Road to Northern Expressway connection.

Section 1: Salisbury Highway to Ryans Road

There are no sensitive receptors close to the roadway between Port Wakefield Road and Globe Derby Park. The land to the west of the road is wetlands or salt crystalliser areas. The land to the east of the road is mostly wetlands apart from the new residential estate of Mawson Lakes. No existing houses in Mawson Lakes are within 200 m of the road and future houses will be at least 100 m from the roadway.

Spectators at Globe Derby Park are more than 300 m from the road and other land to the west of the road is mostly orchards or rural land uses in relatively small blocks. There are five rural houses on small orchards at about 50 to 100 m west of the roadway. The land to the east of the road is all used for commercial purposes with no houses.

In summary, sensitive receptors in this section are

- 50 m to the west
- 100 m to the east.

Section 2: Ryans Road to Bolivar Road

The White Horse Inn, at the junction with Hodgson Drive, has accommodation units with the verandah being 43 m from the roadway.

Most of the land to the east is used for commercial purposes (e.g. truck yards, storage, gardening supplies, caravan sales, etc.). A substantial renewal of the commercial area can be anticipated in the decade following the construction of the Northern Expressway and Port Wakefield Road Upgrade.

There is a small residential zone adjacent to the road between Victoria Drive and Little Para River. The eight houses in Swallow Crescent back on to the eastern side of the road with the fences being only 17 m from the edge of the present roadway. Houses further to the north, in Willowbank Place and Lakeside Drive, are 50 m from the roadway.

In summary, sensitive receptors in this section are:

- 43 m and 60 m to the west
- 17 m and 50 m to the east.

Section 3: Bolivar Road to Burton Road

The land to the west of the road comprises a caravan park and the buffer zone around the Bolivar Sewage Treatment Plant. The caravan park is protected by a 2 m high partly-vegetated berm, with the fence being 24 m west of the roadway. At the intersection of Jobson Road, there is a house with the outer fence being only 15 m from the roadway.

Most of the land to the east is residential. There are long sections of houses adjacent to the eastern side of the road. Eight houses opposite the caravan park, in Henry Street, Bolivia Crescent, General

Drive and Brazil Drive back on to the eastern side of the road with the fences being only 17 m from the edge of the present roadway. Other houses (e.g. Lakeside Drive) are 50 m from the road.

The rest of the land to the east is used for rural or commercial purposes and there are no sensitive receptors within 100 m of the road.

In summary, sensitive receptors in this section are:

- 15 m and 24 m to the west
- 17 m, 50 m and 100 m to the east.

Section 4: Burton Road to Northern Expressway connection

From the Burton Road intersection north to the connection with the Northern Expressway, the land is mostly rural with scattered houses either side of Port Wakefield Road. Unfortunately, several of these houses are very close to the roadway.

To the west, there are houses as close as 6 m (two houses), 6.5 m (one house) and 7 m (one house). To the east there is one house at 6.5 m from the roadway.

In summary, sensitive receptors in this section are:

- 6 m, 6.5 m and 7 m to the west
- 6.5 m to the east.

4.4 Traffic projections

Emission rates are determined from the total number of vehicles per hour, the composition of the vehicle fleet (particularly the proportion of heavy trucks and buses) and the emission rates corresponding to each component of the vehicle fleet.

The traffic volumes used for modelling air quality levels were provided by the DTEI for the years 2011 and 2021, for the Northern Expressway and Port Wakefield Road. The daily traffic volumes (expressed in vehicles per day [vpd]) for the section of the roadways with the nearest sensitive receptors are shown in Table 4.2.

Table 4.2 Projected traffic volumes

Section with nearest sensitive receptors	2011 traffic volume	2021 traffic volume
	Daily (vpd)	Daily (vpd)
Northern Expressway	18,300	26,300
Port Wakefield Road	43,400	57,000

4.5 Traffic fleet composition

Based on information provided by DTEI, the typical composition of traffic using the Northern Expressway and Port Wakefield Road is summarised in Table 4.3.

Table 4.3 Traffic composition

Vehicle type	Northern Expressway (%)	Port Wakefield Road (%)
Cars (petrol)	82	80
Cars (diesel)	2.1	2
Cars (LPG)	2.1	2
Light commercial vehicles (petrol)	2.4	3
Light commercial vehicles (diesel)	2.3	3.5
Light commercial vehicles (LPG)	0.1	0.5
Heavy articulated vehicles (diesel)	6	6
Heavy vehicle (road trains, B-doubles)	3	3
Total	**100**	**100**

4.6 Emission factors

The air quality assessment for the Northern Expressway is based on the vehicle emission factors provided to Consulting Environmental Engineers (CEE) by the Victorian EPA in 2005 (Ng 2005). The South Australian fleet is older than the Victorian fleet. According to the Australian Bureau of Statistics (ABS) Motor Vehicle Census (2005) the average age of vehicles in South Australia is 11.5 years compared to Victoria which has an average vehicle age of 10.4 years. Hence the conservative assumption was made that the fleet emission factors for South Australia were equivalent to the Victorian EPA emission factors after allowing for the two-year gap.

In addition, to allow for day-to-day variations in congestion level, speed, vehicle fleet composition and other variables, a 10% increase has been applied to the calculated hour-by-hour fleet emission factors to provide a conservative estimate of contaminant concentrations near the proposed roadways.

The resulting peak hour emission rates for the South Australian vehicle fleet in 2011 and 2021 are shown in Table 4.4.

Table 4.4 shows that fleet emission factors for Port Wakefield Road in 2011 are slightly higher than for the Northern Expressway. This is due to the greater proportion of light commercial vehicles predicted to use Port Wakefield Road, compared to the Northern Expressway. By 2021, the fleet emission rates on the Northern Expressway are expected to be much the same as on Port Wakefield Road, except for fine particles (PM10 and PM2.5).

From comparison in Table 4.4 of the vehicle emission factors for 2011 with the factors for 2021, it can be seen that a substantial reduction in emissions is predicted for that 10-year period. For example, NO_x emissions from cars are predicted to decrease by about 30% and by about 60% from trucks. The emission rates of most air toxics from cars are predicted to decrease by about 50% and 30% from

trucks. Emissions of PM10 and PM2.5 from trucks also are predicted to be much lower in 2021 compared to 2011 due to more stringent fuel and emission standards.

Table 4.4 Fleet emission rates for 2011 and 2021 for Northern Expressway and Port Wakefield Road

	Northern Expressway Fleet emission factors		Port Wakefield Road Fleet emission factors	
Contaminant	**2011 (g/km/vehicle)**	**2021 (g/km/vehicle)**	**2011 (g/km/vehicle)**	**2021 (g/km/vehicle)**
Nitrogen dioxide	0.25	0.15	0.26	0.15
Carbon monoxide	5.7	3.6	6.0	3.6
PM10	0.11	0.07	0.09	0.05
PM2.5	0.07	0.04	0.06	0.03
Benzene	0.023	0.009	0.024	0.009
Formaldehyde	0.0039	0.0019	0.0041	0.0019
PAH (as BaP)	5.3×10^{-7}	1.2×10^{-7}	5.7×10^{-7}	1.2×10^{-7}
Toluene	0.034	0.014	0.035	0.014
Xylenes	0.021	0.009	0.022	0.008

Note: g/km/vehicle = grams per kilometre per vehicle.

5 Model predictions

The currently approved version of the Victorian EPA regulatory near-road model (AusRoads) was used to predict the impact on air quality of traffic from the proposed Northern Expressway Road and Port Wakefield Road Upgrade.

Modelling to determine the concentrations of the air contaminants near the proposed roadways was carried out using the following procedure:

- AusRoads model (current version 1.0) as issued by the Victorian EPA
- 1-hour, 8-hour, 24-hour and 1-year averaging times as appropriate
- emission rates from traffic numbers and composition
- one-year meteorological file for Edinburgh airfield
- background concentrations as listed above
- surface roughness of 0.4 m
- other model parameters to best suit the area.

The AusRoads model predicts the peak concentrations of each contaminant at various distances from the roadway, including the background level. The resulting concentration pattern has been plotted for various sections along the proposed roadways. The plots show highest concentrations are predicted to occur on the roadways and the concentration decreases with distance from the roadway to approach the background levels at 100 m from the centre of the road. The decline in concentrations is much the same on each side of the road, but is not completely symmetrical because of the different local wind patterns from different directions.

5.1 Northern Expressway

As noted above, the corridor for the Northern Expressway has been defined to include a buffer zone of 25 m on each side of the roadway. Thus the pertinent concentration for assessment of air quality impacts is the peak level of each contaminant at 25 m from the edge of the roadway.

Table 5.1 lists the predicted peak concentrations of each contaminant at 25 m from the Northern Expressway, for the zone with the highest predicted truck and total vehicle numbers. It can be seen in the table that the peak concentrations for all contaminants are lower than the air quality criteria. Thus it is concluded that the Northern Expressway will not cause adverse air quality effects at sensitive receptors near the roadways.

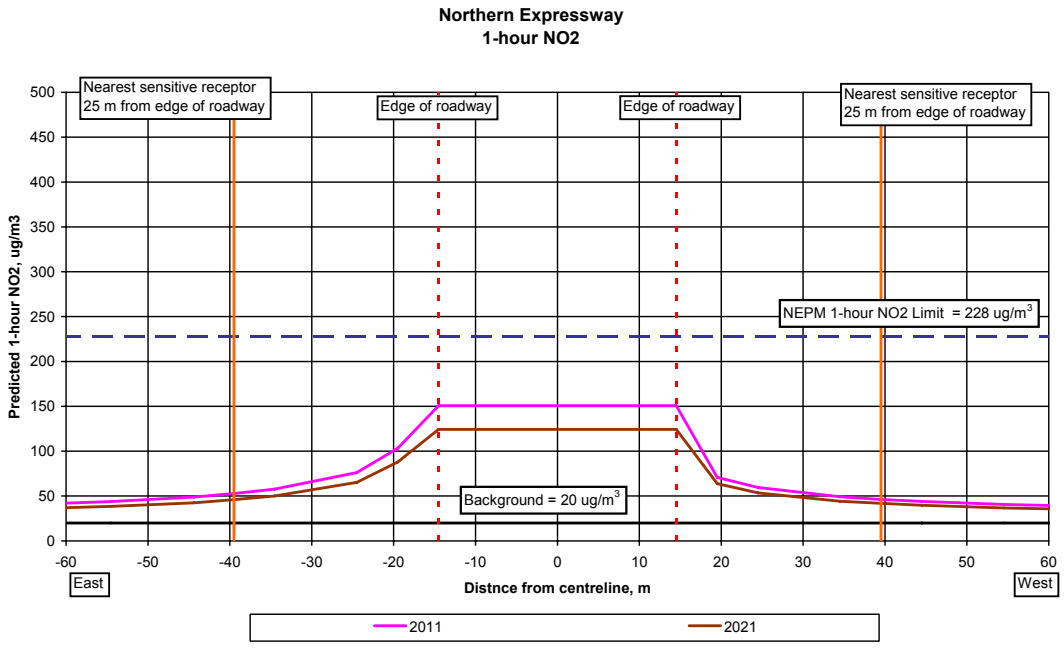
Figure 5.1 shows the predicted peak 1-hour nitrogen dioxide concentration for the Northern Expressway plotted as a cross-section for 2011 (pink line) and 2021 (brown line). The highest concentration of 151 µg/m^3 in the year 2011 occurs on the roadway, and is less than the NEPM 1-hour limit of 228 µg/m^3. The concentration decreases with distance from the roadway, and at 25 m to the west is predicted to be 53 µg/m^3, well below the NEPM 1-hour limit for nitrogen dioxide. At 50 m to the east and west of the roadway, the concentration is predicted to decline to about 40 µg/m^3. For the year 2021, the peak concentration on the roadway is 124 µg/m^3, which is about 20% lower than in 2011.

Similar plots for the other contaminants show similar patterns (CEE 2006), with the peak concentrations predicted to occur on the roadway, decreasing with distance from the roadway. In most cases the predicted concentrations approach background levels within 60 m of the roadway.

Table 5.1 Model predictions at the nearest receptor – Northern Expressway

Substance	Unit	Averaging period	Predicted peak concentration at 25 m		NEPM	Meets NEPM at 25 m
			2011	2021		
NO_2	µg/m^3	1-hour	53	46	228	Yes
	µg/m^3	Annual	9.2	9.0	57	Yes
CO	µg/m^3	8-hour	346	304	10,440	Yes
PM10	µg/m^3	24-hour	30.8	30.2	50	Yes
PM2.5	µg/m^3	24-hour	9.2	8.9	25	Yes
	µg/m^3	Annual	5.2	5.1	8	Yes
Benzene	µg/m^3	Annual	1.10	1.06	9	Yes
Formaldehyde	µg/m^3	24-hour	6.1	6.1	49	Yes
BaP	µg/m^3	Annual	0.00019	0.00019	0.00030	Yes
Toluene	µg/m^3	24-hour	8.7	8.4	3,770	Yes
	µg/m^3	Annual	3.2	3.1	380	Yes
Xylenes	µg/m^3	24-hour	11.4	11.2	1,085	Yes
	µg/m^3	Annual	2.1	2.1	870	Yes

Figure 5.1 Predicted peak 1-hour NO_2 concentrations on Northern Expressway



5.2 Port Wakefield Road

For Port Wakefield Road, there are several sections to be considered in the modelling. For the most northern section, the traffic volume is lowest (36,300 vpd) but the sensitive receptors are very close to the roadway. Table 5.2 lists the predicted peak concentrations of each contaminant at 6 m from the roadway. It can be seen in the table that the peak concentrations for all contaminants are lower than the air quality criteria. It should be noted, however, that a small increase in traffic would potentially cause concerns for PM2.5 (annual average) and, at slightly higher volumes, for nitrogen dioxide.

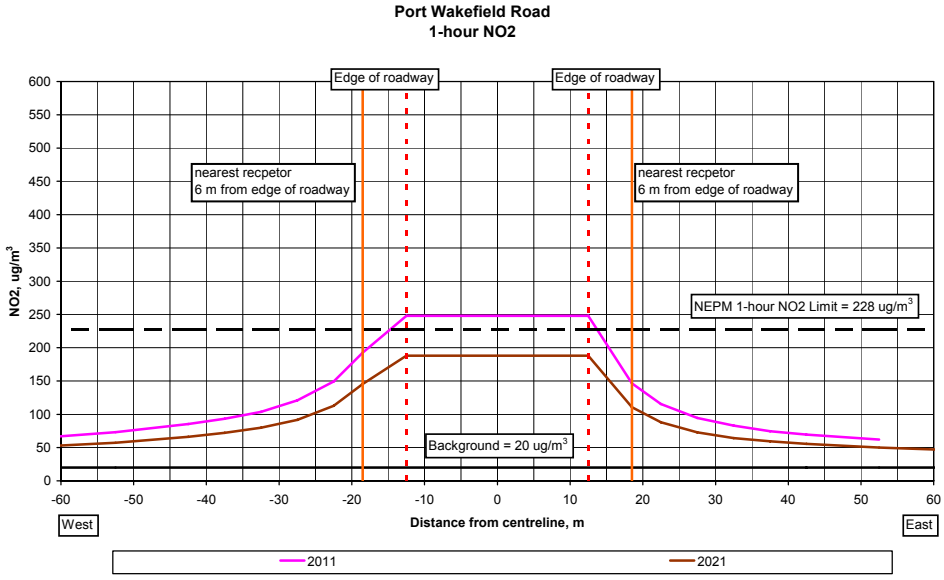
Figure 5.2 shows the predicted peak 1-hour nitrogen dioxide concentration plotted as a cross-section for 2011 (pink line) and 2021 (brown line). The highest concentration of 248 µg/m^3 in the year 2011 occurs on the roadway, and is slightly higher than the NEPM 1-hour limit of 228 µg/m^3. The concentration decreases with distance from the roadway, and at 6 m to the west is predicted to be 193 µg/m^3, slightly lower than the NEPM 1-hour limit for nitrogen dioxide. At 50 m to the east and west of the roadway the concentration is predicted to decline to about 60 µg/m^3. For the year 2021, the peak concentration on the roadway is 190 µg/m^3, which is about 25% lower than in 2011.

Similar plots for the other contaminants show similar patterns (CEE 2006), with the peak concentrations predicted to occur on the roadway, decreasing with distance from the roadway. In most cases, the predicted concentrations approach background levels within 60 m of the roadway.

Table 5.2 Model predictions at the nearest receptor – Port Wakefield Road (at 6 m)

Substance	Unit	Averaging period	Predicted peak concentration at 6 m		NEPM	Meets NEPM at 6 m
			2011	2021		
NO_2	µg/m^3	1-hour	193	145	228	Yes
	µg/m^3	Annual	15.3	13.5	57	Yes
CO	µg/m^3	8-hour	1,308	1,038	10,440	Yes
PM10	µg/m^3	24-hour	36.7	34	50	Yes
PM2.5	µg/m^3	24-hour	13.4	11.5	25	Yes
	µg/m^3	Annual	6.7	6.0	8	Yes
Benzene	µg/m^3	Annual	1.7	1.3	9	Yes
Formaldehyde	µg/m^3	24-hour	6.3	6.2	49	Yes
BaP	µg/m^3	Annual	0.00021	0.00019	0.00030	Yes
Toluene	µg/m^3	24-hour	11.0	9.5	3,770	Yes
	µg/m^3	Annual	4.0	3.5	380	Yes
Xylenes	µg/m^3	24-hour	12.9	12.0	1,085	Yes
	µg/m^3	Annual	2.6	2.3	870	Yes

Figure 5.2 Predicted peak 1-hour NO_2 concentrations on Port Wakefield Road



For the central section of Port Wakefield Road (between Ryans Road and Burton Road), the traffic volume is higher (57,000 vpd) but the sensitive receptors are further from the roadway (17 m). Table 5.3 lists the predicted peak concentrations of each contaminant at 17 m from the roadway. It can be seen in the table that the peak concentrations for all contaminants are lower than the air quality criteria. Thus it is concluded that upgrading Port Wakefield Road (with the predicted future traffic volumes) will not cause adverse air quality effects near the roadways.

Table 5.3 Model predictions at the nearest receptor – Port Wakefield Road (at 17 m)

Substance	Unit	Averaging period	Predicted peak concentration at 17 m		NEPM	Meets NEPM at 17 m
			2011	2021		
NO_2	µg/m³	1-hour	142	107	228	Yes
	µg/m³	Annual	13.8	12.3	57	Yes
CO	µg/m³	8-hour	1,060	829	10,440	Yes
PM10	µg/m³	24-hour	35.1	32.8	50	Yes
PM2.5	µg/m³	24-hour	12.2	10.7	25	Yes
	µg/m³	Annual	6.1	5.6	8	Yes
Benzene	µg/m³	Annual	1.5	1.3	9	Yes
Formaldehyde	µg/m³	24-hour	6.3	6.2	49	Yes
BaP	µg/m³	Annual	0.00020	0.00019	0.00030	Yes
Toluene	µg/m³	24-hour	10.4	9.2	3,770	Yes
	µg/m³	Annual	3.8	3.4	380	Yes
Xylenes	µg/m³	24-hour	12.5	11.8	1,085	Yes
	µg/m³	Annual	2.5	2.3	870	Yes

5.3 Air quality effects on other roads

The Northern Expressway will draw traffic from a number of parallel roads and hence lead to lower traffic volumes on those roads. Table 5.4 sets out the projected changes in traffic volumes on three roads at present and for the year 2011, with and without the Northern Expressway. The three roads are:

1. Main North Road – north of Tiver Road;
2. Angle Vale Road – east of Dalkeith Road; and
3. Heaslip Road – north of Womma Road.

Table 5.4 Main North, Angle Vale and Heaslip roads projected daily traffic volumes

Location	Predicted traffic volumes (vehicles per day)		
	2006	2011 without Northern Expressway	2011 with Northern Expressway
Main North Road north of Tiver Road	29,000	34,300	28,100
Angle Vale Road east of Dalkeith Road	6,100	7,300	2,000
Heaslip Road north of Womma Road	10,400	11,300	5,900

As can be seen in Table 5.4, the reduction in daily traffic volume in 2011 ranges from 18 per cent on Main North Road, to 48 per cent on Heaslip Road to 73 per cent on Angle Vale Road.

Emission rates of air contaminants are determined by the composition of the vehicle fleet (particularly the proportion of heavy vehicles) as well as the number of vehicles. Table 5.5 sets out the proportion of heavy vehicles on the three roads at present and for the year 2011, with and without the Northern Expressway. It can be seen in Table 5.5 that there is a major reduction in the proportion of heavy vehicles on Angle Vale Road and Heaslip Road and a small reduction on Main North Road.

Table 5.5 Main North, Angle Vale and Heaslip roads proportion of heavy vehicles (percentage of vehicles)

Location	Percentage heavy vehicles		
	2006	2011 without Northern Expressway	2011 with Northern Expressway
Main North Road north of Tiver Road	2.5 %	2.5 %	1.5 %
Angle Vale Road east of Dalkeith Road	16 %	16 %	1.6 %
Heaslip Road north of Womma Road	10 %	10 %	1 %

The combined effect of the reduction in vehicles numbers and the reduction in the proportion of heavy vehicles will be to decrease the concentrations of air contaminants at receptors near these roads. For nitrogen dioxide, as an example, the expected reduction in concentrations at 10 to 20 m from the roadway is as follows:

1. Main North Road – 30 per cent reduction
2. Angle Vale Road – 70 per cent reduction
3. Heaslip Road – 60 per cent reduction.

It is apparent that the Northern Expressway will produce a substantial reduction in near-road concentrations of contaminants and hence an improvement in local air quality adjacent to Main North Road, Angle Vale Road and Heaslip Road.

6 Environmental management

6.1 Approach to environmental management

6.1.1 Construction impacts

From an air quality perspective, the main issues during construction are dust and the emission of combustion particles by heavy construction equipment. The latter can be controlled by ensuring the equipment used on the project is fitted with appropriate filters and control systems, and is appropriately maintained.

Dust can be more difficult to control, as the rate of erosion of excavated surfaces, stockpiles of soil and recently placed material depends on weather as well as construction practices. There needs to be a predefined management plan for dust management for all construction activities and stockpiles and any material handling.

It is recommended that a range of 'good practice' procedures is specified for the project to control dust during construction as part of the Environmental Management Plan (EMP) for the project.

In addition, it is recommended that real-time dust monitors be installed each side of major earth-moving operations and used to identify periods with high dust levels, as a basis for controlling dust impacts.

6.1.2 Mitigation measures

The predictions of near-road air quality described above indicate that the peak levels will be within the NEPM limits. Nonetheless, there will be wake effects (i.e. air flow or suction) when road trains pass and variations in wind patterns which could result in concentrations being slightly higher than predicted near the roadway. It would be prudent to aim for no houses within 15 m of the roadway on Port Wakefield Road, as a long-term goal.

Measures to manage dust effects during construction should be specified in the project EMP and include:

- Develop the project schedule so that the area of cleared land is minimised during the drier months of the year when dust generation will be greater.
- Provide gravel surface, a temporary seal or watering on haul roads. The frequency of watering is be determined by weather conditions and the character of the soil. Water areas other than haul roads if they are a source of dust.
- Ensure that smooth soil surfaces are deep-ripped and left rough and cloddy to reduce wind velocity at the soil surface.
- Apply dust suppression measures.
- Construct wind fences as necessary to restrict dust generation at the site.

7 Conclusion

This report provides an assessment of the air quality implications of the near-road air quality effects for the proposed Northern Expressway. The scope of work involved:

- inspecting the plans of the project and the route to locate sensitive receptors near the existing and proposed roadways
- analysing traffic information to determine traffic volumes and fleet composition for the years 2011 and 2021
- determining traffic fleet emission rates for the project for the years 2011 and 2021
- selecting appropriate wind files for use in modelling air quality
- determining background air quality for the study area
- calculating peak concentrations of the following constituents using the computer model (AusRoads), for the averaging times listed below, for comparison with the NEPM limits:
  - Carbon monoxide 8-hour average
  - Nitrogen dioxide 1-hour average and annual average
  - PM10 24-hour average
  - PM2.5 24-hour average and annual average
  - Benzene annual average
  - Toluene 1-day average and annual average
  - Formaldehyde 1-day average
  - PAH (BaP) annual average
  - Xylenes 1-day average and annual average
- assessing the implications and preparing a report on the findings and any necessary mitigation measures.

Land uses on each side of the roadway were identified from aerial photographs and site inspections. Residential areas adjacent to the edge of the road reservation are the most sensitive land uses from an air quality perspective. Along the northern sections of Port Wakefield Road, the nearest house is only 6 m from the roadway.

The air quality assessment for the Northern Expressway and Port Wakefield Road involved:

- the air quality model AusRoads
- project-specific background concentrations for all contaminants
- detailed measurements of property boundaries and building locations from project plans and site inspections
- projected traffic volumes for each hour of a typical day for the years 2011 and 2021
- meteorological file for Edinburgh airfield.

The corridor for the Northern Expressway has been defined to include a buffer zone of 25 m on each side of the roadway. Thus the pertinent concentration for assessment of air quality effects is the peak level of each contaminant at 25 m from the edge of the roadway. The assessment found that the peak concentrations for all contaminants are lower than the air quality criteria. Thus it is concluded that the Northern Expressway will not cause adverse air quality effects near the roadways.

For Port Wakefield Road, there are several sections to be considered in the modelling. For the most northern section, the traffic volume is lowest (36,300 vpd) but the sensitive receptors are very close to the roadway. The predicted peak concentrations of each contaminant, even, at 6 m from the roadway, are within the air quality criteria. It should be noted, however, that a small increase in traffic would potentially cause concerns for PM2.5 (annual average) and, at slightly higher volumes, for nitrogen dioxide.

For the central section of Port Wakefield Road (between Ryans Road and Burton Road), the traffic volume is higher (57,000 vpd) but the sensitive receptors are further from the roadway (17 m). The predicted peak concentrations for all contaminants are lower than the air quality criteria. Thus it is concluded that upgrading Port Wakefield Road (with the predicted future traffic volumes) will not cause adverse air quality effects near the roadways.

The combined effect of the reduction in vehicles numbers and the reduction in the proportion of heavy vehicles using Main North, Angle Vale and Heaslip roads will be to decrease the concentrations of air contaminants at receptors near these roads. It is apparent that with the operation of the Northern Expressway it will produce a substantial reduction in near-road concentrations of contaminants and hence an improvement in local air quality adjacent to Main North Road, Angle Vale Road and Heaslip Road.

DTEI generally has responsibility for construction of major transport corridors, as well as planning and operations. The key issues in construction with respect to air quality are to manage dust.

Measures to manage dust effects during construction should be specified in the project EMP and include:

- Develop the project schedule to minimise the area of cleared land during the drier months of the year when dust generation will be greater.
- Provide a temporary gravel surface, a temporary seal or watering on haul road. The frequency of watering should be determined by weather conditions and the character of the soil.
- Water areas other than haul roads if they are a source of dust.
- Ensure that smooth soil surfaces are deep-ripped and left rough and cloddy to reduce wind velocity at the soil surface.
- Apply dust suppression measures **whenever needed**.
- Construct wind fences as necessary to restrict dust generation at the site.

8 References

Benkley CW and Schulman LL. 1979. *Estimating Hourly Mixing Depths from Historical Data.* J Appl. Met., **18**, 772-780.

Consulting Environmental Engineers. 2006. *Assessment of Air Quality Impacts for the Northern Expressway (Gawler to Port Wakefield Road)*.

Consulting Environmental Engineers. 2006. *Assessment of Air Quality Impacts for the Northern Expressway (Port Wakefield Road)*.

Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay MA, Ferris BG and Speizer FR. 1994. *An Association Between Air Pollution and Mortality in Six US Cities,* New England Journal of Medicine, **329**, 1753-9.

Hearn. 1994. *Motor Vehicle Emissions in Melbourne and their Environmental Impact*, Publication 392.

Lipfert FW and Wyzga RE. 1997. *Air Pollution and Mortality: The Implications of Uncertainties in Regression Modelling and Exposure Measurement*, J Air and Waste Management Association, **47**, 517-23, April.

Morgan P and May R. 2003. *Roadside Air Monitoring of Criteria Air Pollutants and Air Toxics in Adelaide*. Presented as Clean Air Conference, Newcastle, 23–27 November 2003.

NEPC. 1997. *Towards a National Environment Protection Measure on Ambient Air Quality*. June 1997.

NEPC. 1998. *National Environment Protection Measure for Ambient Air Quality*. 26 June 1998.

NEPC. 1998. *Final Impact Statement for the Ambient Air Quality National Environment Protection Measure*. 26 June 1998.

NEPC. 2001. *Checklist for Monitoring Plans (Ambient Air Quality)*.

NEPC. 2001. *The Need for a PM2.5 Standard in Australia*.

NEPC. 2003. *Impact Statement for the National Environment Protection (Air Toxics) Measure*.

NEPC. 2003. *Variation to the National Environment Protection Measure for Ambient Air Quality (PM2.5)*.

NEPC. 2004. *National Environment Protection (Air Toxics) Measure*.

Ng Y. 2005. *Development of an Australian Motor Vehicle Emission Factor System (AUSVEH).*

Streeton. 1997. *A Review of Existing Health Data on Six Pollutants*. NEPC Report.

Turner DB. 1964. *Workbook of Atmospheric Dispersion Estimates*, USEPA, North Carolina.

Victoria EPA, Griffith University, University of the Sunshine Coast, Australian Nuclear Science and Technology Organisation and Queensland Health and Scientific Services. 2005. *Particle Composition in Four Major Australian Cities,* A consultancy funded by the National Heritage Trust.