Airport Link

Phase 2 – Detailed Feasibility

CHAPTER 9

AIR QUALITY AND GREENHOUSE GASES

- October 2006

Contents

9. Air Quality and Greenhouse Gases

This chapter addresses Section 5.4 of the Terms of Reference. The chapter discusses the local and Brisbane-wide climatic conditions and prevailing meteorology and presents a review of air quality monitoring data from the Brisbane region of relevance to the project. It deals with construction and operational air quality effects and an assessment of public health from the point of view of air quality issues.

The impacts of the proposal on air quality are assessed using:

- *For construction – an assessment of dust and odour emissions on sensitive receivers near work compounds and construction sites; and*
- *For operation – computer dispersion modelling of emissions from ventilation outlets and from roads subject to significant changes in traffic volumes. Changes in emissions are also assessed in the context of the Brisbane airshed.*

The potential impacts on ambient air quality are assessed against criteria set by the Queensland Government and the National Environment Protection Council. Processes for managing construction impacts and mitigation measures for the operation of the tunnel are outlined.

Two Technical Reports provide the basis for much of the work within this chapter. Technical Report No 5A – Air Quality by Holmes Air Sciences deals with the impacts on ambient air quality. Technical Report No 5B – Health Risk Assessment by Dr Tim O'Meara addresses the effects of changes of the concentrations of pollutants on public health.

Amongst the considered mitigation measures for tunnel operation are the effectiveness, benefits, operational costs, as well as suitability and availability of air filtration technologies. Trends in filtration technology are also reviewed.

In-tunnel air quality conditions are described and their compliance with PIARC standards and comparable standards for in-tunnel air quality from other countries are described.

Health risk assessment techniques are used to assess any changes in public health due to the emissions from motor vehicles.

The energy consumption during construction and operation of the tunnel is described, and the implications of this for greenhouse gas emissions assessed. The compliance with the project under both State and Council Greenhouse Policies is provided.

9.1 Description of the Existing Environment

9.1.1 Background on Dispersion Meteorology and Modelling

The air quality assessment for the operation of the Airport Link Project is based on the use of computer-based dispersion modelling to predict air pollutant concentrations in the study area. The assessment considers air pollutants arising from motor vehicles using the tunnel and regional surface roads and predicts concentrations at key locations by modelling the means by which those pollutants are dispersed. The study area for this assessment extends over an area of about 200 km^2, centred on the study corridor.

To undertake the dispersion modelling, a knowledge of the meteorology in the study area is required. The meteorology is influenced by several factors including the local terrain and land use. On a relatively small scale, winds would be largely affected by the local topography. At larger scales, winds are affected by synoptic scale winds, which are modified by sea breezes in the daytime in summer (also to a certain extent in the winter) and also by a complex pattern of regional drainage flows that develop overnight.

Given the relatively diverse terrain and landuse in the study area, differences in wind patterns at different locations in the study area would be expected. These varying wind patterns would arise as a result of the interaction of the air flow with the surrounding topography and the differential heating of the land and water.

In a built-up urban environment like central Brisbane, wind dispersion patterns will be complicated by the turbulence induced by buildings. Wind data collected in 2004 in the study area and reviewed for the purposes of this study are from the Bureau of Meteorology sites at Brisbane Airport, at Bowen Hills and at Eagle Farm. The site established in January 2006 at Kedron was not operational in 2004. The meteorological data collected from the sites include hourly records of temperature, wind speed and wind direction.

Bowen Hills

On an annual basis the winds are predominantly from the south-western quadrant, although there are some winds observed from the north-north-east and south-east. The cooler months, autumn and winter, show that winds from the south-west and south-south-west are the most common, while in spring the winds come mainly from the north-north-east. Summer shows slightly different trends to any other season with relatively similar proportions of winds from the north clockwise through to the south-east. The only areas showing very little wind flow are the west and west-north-western sectors.

Annually, the Bowen Hills site has recorded 17% calm periods – that is, when the wind speed was less than or equal to 0.5 m/s. Mean wind speed for the 2004/2005 period was 1.9 m/s.

Brisbane Airport

Annually, the most common winds at this site are from the north to north-north-east, south-west to south-south-west and east-south-east to south-east. The pattern of winds is similar to the Bowen Hills site, with slightly stronger winds. At the Brisbane airport site, large areas of cleared land with unobstructed wind flows, result in higher than average local wind speeds compared to the surrounding residential and industrial areas.

In summer, winds at the airport are predominantly from the north which is a typical result of the sea breeze. The sea breeze usually commences in the late morning and is well established in the afternoon. Spring exhibits a similar pattern to summer. In contrast to summer and spring, the most common winds in autumn and winter are from the south-west and south-south-west.

The average wind speed in 2004 at the airport was 4.4 m/s with a maximum hourly average wind speed of 13.3 m/s. The frequency of calm conditions was 2.2%.

Eagle Farm

The distribution of winds for Eagle Farm on an annual and seasonal basis is similar to that at both Bowen Hills and Brisbane Airport. This would be expected given the relatively close proximity of the Eagle Farm site to the other sites – less than approximately five kilometres.

Eagle Farm typically has lower wind speeds than the Airport with a maximum hourly average wind speed of 7.3 m/s and an annual average of 2.0 m/s. The percentage of calms is 8.4%. The lower speed winds at the Bowen Hills and Eagle Farm sites are consistent with their location within residential and industrial areas, where buildings and terrain provide some shielding from the prevailing winds, compared with the more exposed Airport site.

The similarities in the wind data for Eagle Farm and Bowen Hills may be expected given that there are not many significant terrain features between the two sites.

For the purposes of this study Brisbane Airport and Eagle Farm data were considered to provide the most suitable data sets to establish wind patterns over the entire study area. The proximity of these sites to the area of interest ensures that they would contain data that are representative of the dispersion conditions in the study corridor.

9.1.2 Air Monitoring Results

This section discusses the concept of background air pollution as it applies to this study and presents a review of air quality monitoring data that can be used to estimate background pollution levels.

Data from three air quality monitoring sites have been assessed for the purposes of this study – Eagle Farm, Bowen Hills and Kedron. Located around the proposed tunnel route, these sites are considered to be representative of the existing air quality environment.

The monitoring sites are summarised as follows:

- Eagle Farm, operated by the EPA but now decommissioned, included measurements of NO_x, O_3, SO_2 and PM_{10};
- Bowen Hills, operated by Simtars but now decommissioned, included measurements of CO, NO_x, PM_{10} and $PM_{2.5}$; and
- Kedron, currently monitoring and operated by Simtars. Measurements include CO, NO_x, PM_{10} and $PM_{2.5}$.

The Eagle Farm site was located in a light industrial area at the DPI Quarantine Centre and was decommissioned in mid 2005. A site at Pinkenba commenced operation in 2001 and has essentially replaced the Eagle Farm site.

The Bowen Hills site was located to the north of Campbell Street in the vicinity of the proposed southern connection. This station was decommissioned in November 2005 and moved to its current position at Kedron. Monitoring commenced at Kedron in mid January 2006. These data will be reviewed as the information becomes available.

Table 9-1 summarises each of the air pollutants and compares these data with the relevant air quality goal. From the table, the pollutants which recorded levels above their respective air quality goals included 24-hour average PM_{10}, 24-hour and annual average $PM_{2.5}$. There were no other measurements of pollutants above air quality goals. Exceedances of the particulate matter air quality goals (PM_{10} and $PM_{2.5}$) are usually attributed to widespread events such as dust storms or bushfires.

The location of the Bowen Hills and Eagle Farm sites ensures that the data collected may be most representative of air quality in suburban and residential areas of Brisbane, removed from very busy streets. Time series of the hourly averages are presented in **Figure 9-1** and **Figure 9-2**.

Table 9-1 Summary of Air Quality Monitoring Data for the Area

Parameter	Bowen Hills (Jul 2004 to Jun 2005)	Eagle Farm (2003 and 2004)	Kedron Brook (Jan 2006 to May 2006)	Goal
CO, 8-hour maximum (mg/m^3)	2.5	-	2.2	10
NO_2, 1-hour maximum (μg/m^3)	129	125	83	246
NO_2, Annual average (μg/m^3)	51	25	20	62
PM_{10}, 24-hour* maximum (μg/m^3)	63	85	34	50
PM_{10}, Average (μg/m^3)	18	21	14	30
$PM_{2.5}$, 24-hour* maximum (μg/m^3)	35	-	13	25#
$PM_{2.5}$, Average (μg/m^3)	9	-	6	8#
SO_2, 1-hour maximum (μg/m^3)	-	114	-	570
SO_2, 24-hour maximum (μg/m^3)	-	29	-	225
SO_2, Annual average (μg/m^3)	-	6	-	60
O_3, 1-hour maximum (μg/m^3)	-	193	-	210
O_3, 4-hour maximum (μg/m^3)	-	150	-	170

Table Notes:
* 24-hour clock average
# The $PM_{2.5}$ goals are referred to as Advisory Reporting Standards and are set for the purpose of gathering data to facilitate a review of these standards as part of the development of the $PM_{2.5}$ NEPM. The goals are not applied on a project-specific basis.

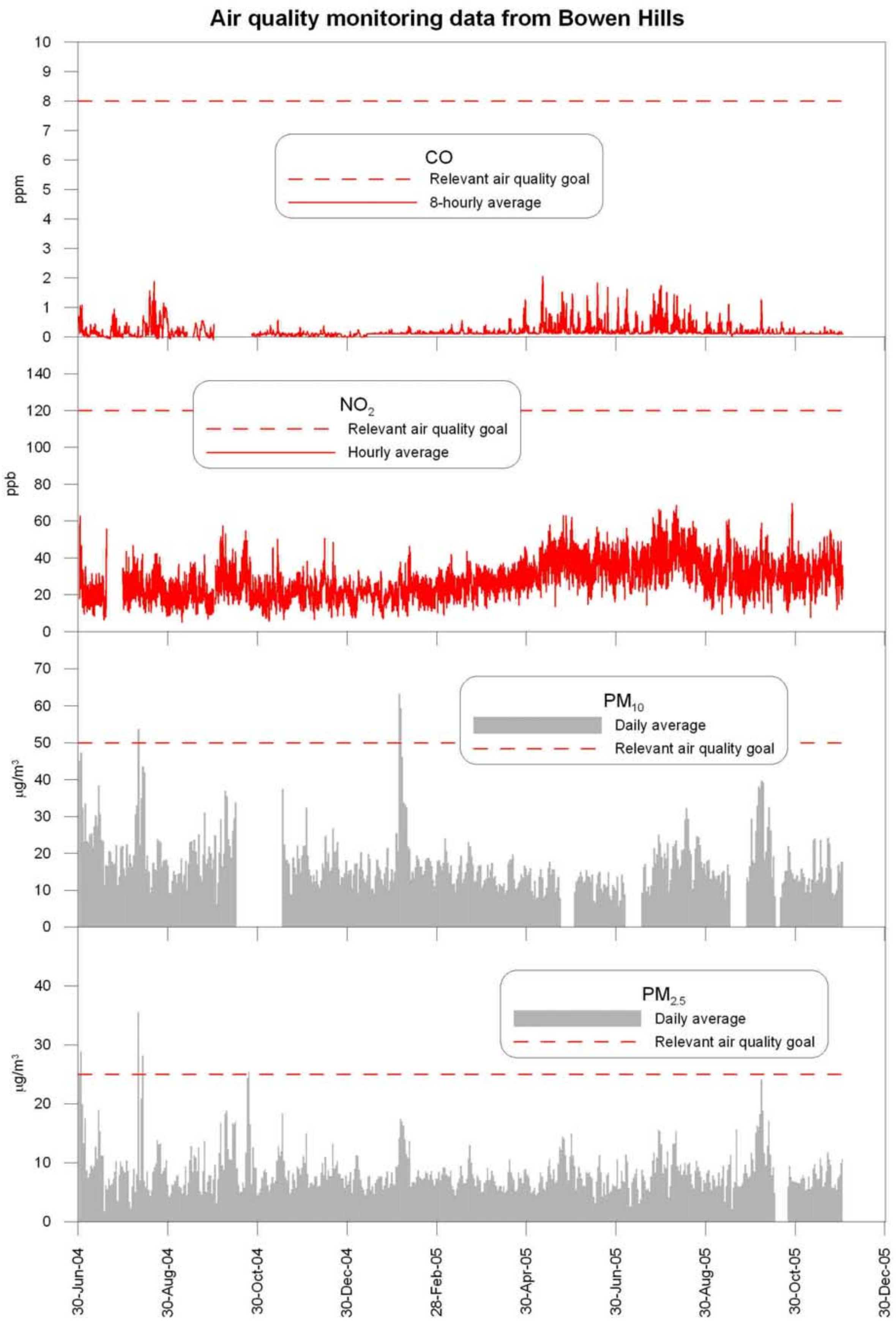
Bowen Hills

Measured CO concentrations at Bowen Hills over the monitoring period were well below the ambient air quality goal of 10 mg/m^3. The maximum 8-hour average CO concentration was 2.5 mg/m^3.

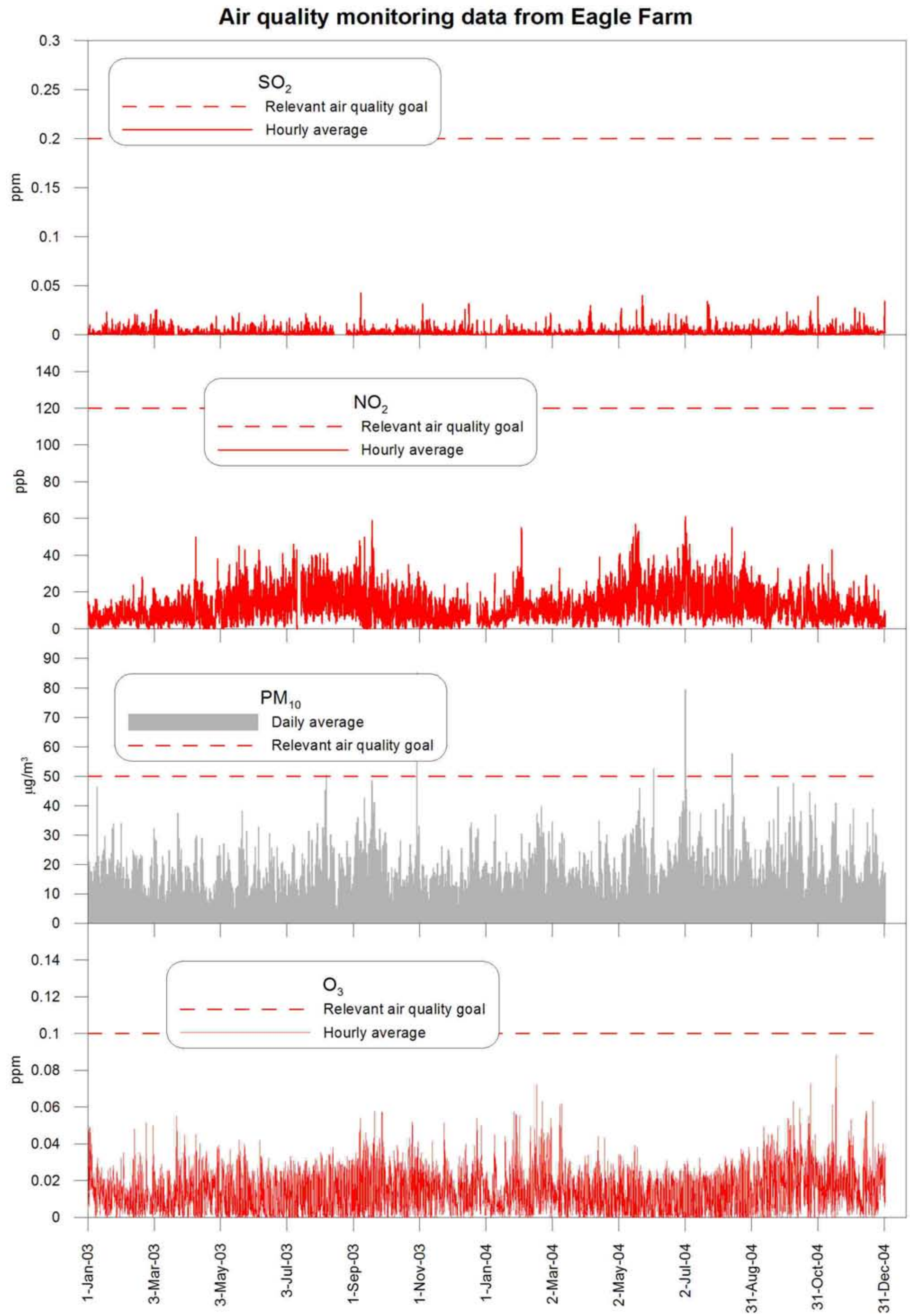
It can be seen from **Figure 9-1** that slightly higher CO levels occurred in the winter months. This trend is also evident in the monitoring data presented in the NSBT EIS and is attributable to the more stable conditions that apply during busy morning and evening peak traffic periods in winter.

Measured NO_2 concentrations over the monitoring period were below the ambient air quality goal of 246 μg/m^3 with the maximum hourly average NO_2 concentration at 129 μg/m^3. This value is in the same range of maxima recorded at the five EPA monitoring sites in the NSBT EIS. The average NO_2 concentration at the Bowen Hills site was 51 μg/m^3.

Measurements of particulate matter (PM_{10} and $PM_{2.5}$) at the Bowen Hills site showed that there were occasional exceedances of the 24-hour average air quality goals. It should be noted, however, that the $PM_{2.5}$ goals are referred to as Advisory Reporting Standards and are set for the purpose of gathering data to facilitate a review of these standards as part of the development of the $PM_{2.5}$ NEPM. Exceedances of the 24-hour PM_{10} goal were also recorded in the EPA air quality monitoring data, presented in the NSBT EIS. Average PM_{10} concentrations at Bowen Hills (18 μg/m^3) were similar to those reported in the NSBT EIS (between 17 and 28 μg/m^3) and below the 30 μg/m^3 air quality goal.



Airport Link Figure 9-1



AIRPORT LINK - Figure 9-2

Air Quality Monitoring Data

Eagle Farm

Figure 9-2 shows the time series of monitoring data from Eagle Farm. Measured SO_2 levels were well below 570 μg/m^3 goal. There are some infrequent spikes in the hourly data which reach about a quarter of the goal. There are no significant seasonal trends evident in these data.

Concentrations of NO_2 have been below the 246 μg/m^3 goal – the maximum hourly average for 2003 and 2004 was 125 μg/m^3. The one hourly average ozone goal was almost reached late in 2004 with a measurement of 193 μg/m^3 compared with the goal of 210 μg/m^3.

Measurements of PM_{10} at Eagle Farm have indicated four exceedances of the 50 μg/m^3 goal for 24-hour averages over the 2003 and 2004 period. Historical EPA data, as presented in the NSBT EIS, have shown that many EPA sites in the Brisbane region record occasional exceedances of the 24-hour PM_{10} goal each year.

The measured concentrations of each pollutant are determined by all sources that at some stage have been upwind of the monitoring station. Carbon monoxide and oxides of nitrogen would have predominantly originated from motor vehicle emissions in this area. In the case of particulate matter (PM_{10}), a number of different types of sources would have contributed to the PM_{10} measurements. These sources may have included emissions from the combustion of wood from domestic heating, from bushfires, from industry, motor vehicles, wind blown dust from nearby and remote areas, fragments of pollens, moulds, sea-salts and so on.

Graphs of PM_{10} (**Figure 9-1** and **Figure 9-2**) highlight the occasions when 24-hour concentrations were above their respective air quality goals. Bowen Hills is the only site to concurrently measure PM_{10} and $PM_{2.5}$. It can be seen from the graphs that exceedances of both the PM_{10} and $PM_{2.5}$ goals were recorded on the same days, signifying the relationship between the two particulate matter classifications. The high PM_{10} levels around August 2004 (54 μg/m^3 on 10 August 2004) suggest that the exceedance is from a combustion source where the percentage of $PM_{2.5}$ would be relatively high. On 3 February 2005 the 24-hour average PM_{10} was 63 μg/m^3 and the fraction of $PM_{2.5}$ was much lower than the previous event. A major dust storm in Brisbane was reported by the Bureau of Meteorology on 3 Feb 2005.

9.1.3 Construction Issues and Air Quality

Overview

The main community air quality concerns in relation to construction of road and tunnel works typically relate to dust generation from excavation and material handling, potential odour emissions from excavated material, and exhaust emissions from diesel powered equipment.

As outlined in Chapter 4 of the EIS, construction of the Airport Link Project is expected to commence in 2008 and will occur for approximately 4 years, until commissioning in 2012. Given the extended duration of construction activities the management of dust emissions will be an important component of the reference project. A discussion of the likely sources of dust generation and the potential construction air quality impacts on nearby sensitive receivers is provided.

Construction Activities and Sources of Air Emissions

The sources of dust generation associated with the tunnel construction activities are likely to include:

- Demolition activities at the worksites (existing buildings, road pavements);
- Earthmoving and excavation works;
- Tunnelling (driven and cut-and-cover) and emissions of tunnel ventilation air;

- Possibly some drilling and blasting;
- Stockpiling, handling and transport of excavated material (including loading of spoil into trucks);
- Surface road and bridge construction works;
- Dust from vehicles moving around unpaved areas at the construction sites; and
- Operation of diesel powered equipment.

Potential odour generation from the excavation of contaminated material at the north-western worksite is also a possible issue for concern.

Location of Works and Nearest Receivers

The reference project involves five worksites in the three main surface connection areas. There would be one worksite at the southern connection, three worksites at the north-western connection and one worksite at the north-eastern connection respectively.

A full description of the project and the typical construction activities associated with tunnel and surface works is provided in Chapter 4, as are the project worksite locations and proposed spoil transport routes.

The nearest potentially affected sensitive receivers to the reference project sites include:

- Residential and commercial areas adjacent to portal and surface worksites at the southern end of the tunnel, including the Royal Brisbane Hospital;
- Residential and commercial areas adjacent to the two portals, cut-and-cover tunnels, surface road works sites, and overhead bridge structures at the primary worksite at Kedron, including Department of Emergency Services Complex and Kedron Brook corrdior, Kedron State High School and Wooloowin Primary School;
- Residential, commercial, and recreational areas adjacent to the portal, surface road works sites, and overhead bridge structures at the eastern end of the tunnel, including Kalinga Park;
- Residential, commercial and industrial areas adjacent to the spoil transport routes; and
- Public spaces and industrial areas adjacent to the spoil placement sites.

As stated in Section 9.1.1, on an annual basis the winds over the study area are predominantly from the south-western quadrant, although there are some winds also from the north-east and south-east quadrants. Winds in summer are generally from either the north-north-east or east-south-east. The cooler months, autumn and winter, show that winds from the south-west are the most common, while in spring, winds are either from the north-north-east or south-west. The only direction from which there are few winds over the year is the west-north-western quadrant.

Construction works have the greatest potential to cause dust impacts at receivers located to the north-west, anticlockwise, to the south-west, and to the north-east in cooler months, of construction work sites.

9.2 Potential Construction Impacts and Mitigation Measures

9.2.1 Construction Impacts Methodology and Criteria

Methodology

A construction air quality impact assessment was undertaken, comprising:

- A discussion of the likely construction air quality issues associated with the reference project;
- Identification of nearest potentially affected sensitive receivers to construction worksite areas;
- Discussion of potential nuisance dust and odour impacts resulting from construction activities;
- Assessment by air dispersion modelling of potential air quality impacts due to placement of excavated material; and
- The development of in-principle construction air quality management and mitigation measures appropriate for the works.

Assessment Criteria – Air Quality Guidelines

Air quality guidelines are specified by the EPA in the Queensland Environment Protection Policy EPP (Air) 1997. These goals are based largely upon the National Guidelines published by the Australian and New Zealand Environment and Conservation Council (ANZECC).

The current goals for criteria pollutants considered relevant to the assessment of air quality impacts during construction of the Airport Link Project, as shown in Schedule 1 of the EPP (Air), are as follows:

- PM_{10} maximum 24-hourly average, 150 µg/m^3;
- PM_{10} annual average, 50 µg/m^3; and
- TSP annual average, 90 µg/m^3.

The National Environment Protection Measure (NEPM) for Air Quality was released by the National Environment Protection Council (NEPC) in 1998. The relevant standard for PM_{10} in the NEPM is:

- PM_{10} maximum 24-hourly average, 50 µg/m^3 (with 5 allowable exceedances per year).

The application of the NEPM is intended to provide a representative measure of regional air quality, rather than a project specific target. Although the NEPM is not considered strictly applicable to construction projects it is recognised that projects should work towards achieving the NEPM goals.

The design ground level concentrations for industrial developments specified in the BCC Air Quality Planning Scheme Policy for TSP and PM_{10} are generally as outlined in the EPP (Air). In addition to the EPP goals, the following levels are specified for sensitive receiving environments:

- PM_{10} 24-hour average, 50 µg/m^3; and
- $PM_{2.5}$ 24-hour average, 25 µg/m^3.

The policy is designed for consideration when citing industrial developments and is not necessarily relevant to the assessment of construction impacts associated with the proposed tunnel. However, given the expected duration of the construction works and the residential nature of the immediate area surrounding the proposed worksites, it would be prudent to adopt these goals as part of the environmental performance criteria for the project.

Air Quality Criteria - Dustfall

Deposited dust, if present at sufficiently high levels, can reduce the amenity of an area. No formal criteria for dust deposition exist within Queensland, although an informal draft guideline of 120 mg/m^2/day was introduced some years ago by the then Department of Environment and Heritage (now the EPA) applicable at nearby sensitive residential places. Dustfall monitoring has historically been undertaken as part of mining and large scale construction projects to assist with the monitoring of satisfactory performance. The EPA (2003) recommended this guideline for preparing environmental management plans for non-standard mining projects. The informal guidelines are consistent with the NSW Department of Environment and Conservation (2005) guidelines for deposited dust, which limit the maximum dust deposition rate to 4 g/m^2/month.

A dust deposition guideline of 120 mg/m^2/day is therefore considered appropriate for the construction of the reference project.

9.2.2 Construction Air Quality Impacts

Overview

As outlined above, construction activities being undertaken within the tunnel sections and at the surface worksites may generate dust and impact on the amenity of adjacent residential, commercial and industrial receivers.

Discussion of Potential Impacts

Diesel Powered Vehicles and Plant

The potential for air quality impacts from construction vehicle fleet exhaust emissions would depend on the size and type of vehicle fleet, the hours of operation and the type of controls adopted by the Construction Contractor. The main sources of exhaust emissions from diesel powered equipment are likely to include:

- Vehicles working at the surface construction site, such as excavators, front-end loaders, scrapers, rollers, backhoes, concrete trucks, delivery trucks, truck-mounted cranes, rock hammers etc;
- Trucks queuing adjacent to sensitive receivers located near the surface worksites;
- Fully-laden trucks exiting the main tunnel excavation worksites and commencing their journey to spoil placement areas;
- Stationary plant emissions (mobile generators, dewatering pumps, concrete pumps etc); and
- Vehicles and equipment operating within the underground excavation area or within the enclosed workshed, including front end loaders, trucks, and mobile diesel generators.

The main potential for impacts from diesel emissions is likely to result from trucks queuing adjacent to residents located near to the surface worksites and operation of diesel equipment within the underground excavation area. The exhaust emissions would contribute to volumes of particulates, carbon monoxide, carbon dioxide, hydrocarbons and nitrogen oxides in the atmosphere. The level of air quality impact on surface receivers adjacent to the construction site would be subject to the location of the tunnel ventilation exit point, the loading of these pollutants within the tunnel air, the local dispersion meteorology and the controls (including particulate removal) incorporated as part of the tunnel construction ventilation systems.

The management measures in Section 9.2.3 will assist in minimising impacts on adjacent receivers.

Site Establishment and Demolition Activities

Open excavations and areas where spoil is handled (stockpiled, loaded into trucks etc) are recognised as key risks in relation to potential nuisance dust and possible odour impacts on nearby sensitive places. Excavation works would be required for the establishment of the reference project offices and portal worksites and would involve typical construction methods, including excavators, graders, and cranes.

The greatest potential for dust impacts arising from these activities is likely to include:

- Graders working unpaved areas and dozers moving material;
- Pavement and curb ripping;
- Wind erosion from exposed surfaces;
- Wheel generated dust from vehicles travelling along unpaved or dirty paved surfaces; and
- The handling and transport of spoil.

The extent of likely impacts is expected to be minimal, provided appropriate pro-active management measures are implemented throughout the excavation period. Measures for the management and control of potentially odorous or harmful substances (particulate and gaseous) are outlined in Section 9.2.3.

Tunnelling and Underground Works

As outlined in Chapter 4 of the EIS, the tunnelling involves the use of up to four roadheaders and one TBM. The roadheader driven tunnels comprise the north-south tunnels that connect the southern and north-western connections and their associated portals. The roadheaders would excavate the tunnels (two roadheaders heading north and two heading south), meeting near the midpoint where breakthrough would occur. The east-west tunnel would most likely be constructed using a specialised TBM known as an Earth Pressure Balance (EPB) machine. All of the tunnel support would be provided from the Kedron site, including removal of spoil.

The main sources of potential air quality impact associated with these activities is the stockpiling of spoil material, loading of spoil into trucks and the off-site transport and placement of spoil.

To control dust emissions from the tunnelling, stockpiling and truck loading works Tunnel Portal Cover Sheds (TPCSs) would be constructed at each of the portals as part of the initial site establishment works.

During excavation of the tunnel, spoil would be stockpiled in the bottom of the access chamber (at the worksite) during nights and then lifted to the surface and loaded into trucks. All stockpiling and truck loading activities would be undertaken entirely within the worksite sheds or within the tunnel excavation area.

In order to maintain adequate air quality within the underground working environment, ventilation fans will need to be located within the tunnels. At each of the tunnel portal worksites, ventilation air from the tunnelling works would leave the work shed after passing through dust extraction equipment to remove particles from the ventilation air. Details on the dust extraction equipment would be provided during the detailed design stage of the project construction works, when tunnel ventilation and air extraction rates are determined. The performance of the extraction equipment would be detailed during the detailed design stage of the works but would be designed to satisfy the EPP (Air) requirements and be sufficient to minimise nuisance dust impacts on adjacent sensitive places.

Dust impacts from the tunnel excavation, spoil stockpiling and truck loading operations at off-site sensitive places adjacent to the tunnel portal worksites are therefore expected to be minimal, provided dust mitigation and management measures such as those described above and in the mitigation section below are implemented and managed.

A discussion of the potential dust impacts associated with the management and transport of spoil excavated from the tunnel is provided in the following sections.

Cut-and-cover Tunnelling Works

Cut-and-cover construction involves excavating and installing supports (bored piles) prior to covering the excavation with precast deck units. The greatest potential for dust impacts arising from these activities is likely to include:

- Graders working in unpaved areas and dozers moving material;
- Wind erosion from exposed surfaces;
- Wheel generated dust from vehicles travelling along unpaved or dirty paved surfaces; and
- The handling and transport of spoil.

Dust control and mitigation measures would be required throughout the project in order to minimise the potential for impacts from these activities. Spoil generated from cut-and-cover tunnelling would be stockpiled within the worksite sheds, before being removed from the worksite in covered trucks. The effect of wind erosion on exposed areas can be reduced by minimising the length of time between excavating a section of tunnel and covering it with a precast deck unit.

The sources of dust generation associated with these activities are expected to be similar to those outlined earlier and impacts from these activities can be managed in accordance with the measures outlined in Section 9.2.3.

Spoil Management and Transport

About 2.4 million m^3 (loose) would be generated by the Airport Link Project and sent from the three worksite areas. Two general areas have been considered for the disposal of the excavated material, namely areas on or near the Brisbane Airport (Viola Place recycling site, GUP on the Old Airport Site) and at the Port of Brisbane (Clunies Flat and Fisherman Islands).

An estimate of the number of trucks required is shown in **Table 9-2**. This has been determined from the material volumes estimated and the usage of trucks able to carry about 22 m^3 of (loose) material during the haulage times.

Table 9-2 Spoil Removal by Trucks (Approximate Numbers)

Connection	Truckloads (one way)	Average Truckloads per day
Southern connection	32,000	50
North-western Connection	68,000	115
North-eastern connection	15,000	40
Total	115,000	

The spoil would be transported to the Airport and Port sites using trucks. The haul route from the north-western and southern sites would follow Lutwyche Road onto Kingsford Smith Drive via O'Connell Terrace, Hamilton Place, Campbell Street, Montpelier Road and Breakfast Creek Road. The haul route from the north-eastern site would be along the East-West Arterial.

Given the estimated quantity of spoil to be transported to the spoil placement sites the potential exists for dust impacts adjacent to the loading and unloading sites and adjacent to the transport routes. As outlined above, the loading of spoil would be undertaken within the site work sheds and truck operators would cover their loads prior to leaving the work sheds.

The contractor would be required to prevent the transport of dust, mud and loose material from the construction worksites onto the adjacent local paved road network (wheel washing stations and truck washing stations erected at each spoil removal worksite and covering loads before they leave the spoil loading sheds would be one set of options to achieve this requirement).

Dust generation during the dumping of spoil at the placement sites has the potential to cause nuisance impacts to the public and adjacent commercial receivers. The management of dust emissions during spoil unloading and storage at the placement sites would be in accordance with the Construction Contractor’s site environmental management plan. Mitigation measures for these activities are outlined in Section 9.3.4 below.

Surface Road and Bridge Works

A range of new road works would be performed as part of the project, predominantly at the north-western worksite at Kedron. Proposed works include intersection upgrades to Lutwyche Road/Kedron Park Road, and elevated turning lanes for tunnel access to both Gympie Road and Stafford Road. The elevated turning lanes would be a combination of fill embankments and bridge structures. Fill required would be obtained from the ongoing tunnel excavations. Traditional road construction methods, including excavators, graders, compaction equipment and pavement placing equipment would be utilised for these works.

Works to be undertaken at the southern worksite include tunnel on and off-ramps and connections with the Inner City Bypass and North-South Bypass Tunnel. Works to be undertaken at the eastern worksite include intersection upgrade of Sandgate Road/East-West Arterial.

The surface works at each of the worksites would involve some acquisition of properties and demolition of buildings, kerb, roadway pavements, fencing and relocation of existing utilities. The sources of dust generation associated with these activities are expected to be similar to those outlined earlier and impacts from these activities can be managed in accordance with the measures outlined in Section 9.2.3 below.

9.2.3 Mitigation Measures for Construction Impacts

The following sections outline construction mitigation measures which may be implemented to minimise the potential for nuisance dust impacts during the tunnel construction works.

Measures for Avoiding Nuisance Dust and Odour Impacts

The most effective way of avoiding nuisance from construction activities is to have in place a system that addresses the following:

- Effective management of dust and odour generation;
- Effective monitoring of impacts;
- Effective communications with the local community on issues associated with the construction activities;
- A clearly identified point of contact should the community have comments or complaints;
- A well defined process to ensure that any issues are dealt with promptly and to a satisfactory level; and
- A well defined system of recording any incidents or complaints.

The contractor responsible for construction will implement a system which incorporates those elements for the duration of the tunnels and surface construction works. Further detail on the requirements for a comprehensive dust and odour management and communications system will be included as part of a Construction Dust and Odour Environmental Management Plan for the Airport Link Project. The requirements for monitoring of particulate levels within areas adjacent to the main worksites will also be included as part of this plan.

Management Measures for Diesel Exhaust Emissions

The effects of diesel exhaust emissions can be minimised by the following measures:

- Avoiding queuing of the construction traffic vehicle fleet in the streets adjacent to the sites which will in turn minimise the amount of exhaust emissions generated during the construction works;
- Where possible, exhaust emissions from mobile and stationary plant would be directed away from the ground and sensitive receivers; and
- Vehicles and machinery would be fitted with appropriate emission control equipment and be maintained sufficiently to enable to design specifications to be met.

Management Measures for Odour Impacts

During the first disturbances of potentially odorous soils, work management measures would include:

- Proceeding slowly during excavation of potentially odorous sites to determine whether odour impacts at off-site sensitive receivers will be likely;
- In the event that is seems odour impacts will be likely, disturbances would only take place if the wind direction is not incident on sensitive receptors; and
- If excavated soil is potentially odorous and stockpiled on-site, it would be covered with a tarpaulin to prevent odour release prior to treatment or transport to appropriate disposal site.

Management Measures for Nuisance Dust Mitigation

Components of the dust and odour management and mitigation strategy to be considered during the construction works are expected to include:

- Surface excavation works would incorporate consideration of prevailing meteorological conditions (wind speed and direction), if high winds are blowing in the direction of sensitive receivers;
- Demolition activities (buildings on acquired land, kerbs and road pavements etc) would be performed using appropriate dust controls such as consideration of meteorological conditions, use of water sprays, and covering loads of material transported from the sites;
- Excavation at the tunnel portals would be performed within enclosed work sheds. The sheds would be constructed prior to the commencement of underground works and will totally cover the excavated areas at the tunnel portals;
- Work sheds would need to be large enough to allow stockpiling of the excavated tunnel material, access and egress of trucks and truck loading operations;
- Truck and wheel wash stations at the worksites, at locations where trucks would be moving from unsealed areas of pavement to sealed roads;
- The tunnel would be ventilated during excavation works. Ventilation air would be treated, by passing through a particulate filter, prior to exit from the work sheds. The particle filter would be regularly maintained and the performance of the particulate removal technology will meet required standards. Dust collected from the filtration system would be disposed of appropriately;

- Spoil loads being transported from spoil loading sheds to placement sites being covered would prevent wind blown dust during transport;
- Regular monitoring of TSP, PM_{10} and dust deposition levels at nearest sensitive places adjacent to the worksites, and locations representative of the work space, would provide a basis for compliance with appropriate criteria;
- Water sprays will be used on newly established stockpiles at the placement sites. Water sprays on newly established stockpiles could be activated when wind speed is above a certain threshold, say 5-8 m/s, and would be switched on more regularly during drier periods and times of higher winds;
- On un-sealed trafficked areas at the spoil placement locations the surface would be kept damp using a water truck, to prevent excess wheel generated dust emissions; and
- The sealed access roads to the worksite sheds will be kept relatively dust free by regular sweeping and washing if needed. At certain times of the year, natural rainfall should keep this surface washed.

9.3 Potential Operational Impacts and Mitigation Measures

9.3.1 Ambient Air Quality Criteria

In assessing any project with significant air emissions, it is necessary to compare the impacts of the project with relevant air quality goals. Air quality standards or goals are used to assess the potential for ambient air quality to give rise to adverse health or nuisance effects.

The Queensland Government Environment Protection Agency (EPA) has set air quality goals as part of the *Environmental Protection (Air) Policy 1997*. The policy was developed to meet air quality objectives for Queensland's air environment as outlined in the *Environmental Protection Act 1994*.

In addition, the National Environment Protection Council of Australia (NEPC) has determined a set of air quality goals for adoption at a national level, which are part of the National Environment Protection Measures (NEPM). For the purposes of this project the EPA has proposed to adopt the NEPM air quality standards and goals either where there is no set EPA criteria or where the NEPM criteria are more stringent than the set EPA criteria.

It is important to note that the standards established as part of the NEPM are designed to be measured to give an 'average' representation of general air quality. That is, the NEPM monitoring protocol was not designed to apply to monitoring peak concentrations from major emission sources.

Table 9-3 lists the air quality goals for criteria pollutants noted by the EPA and NEPM that are relevant for this study. Also included in this table are air quality goals for air toxics developed by NEPC and part of their National Environment Protection (Air Toxics) Measure. At this stage values for air toxics are termed "investigation levels" rather than goals which are applied on a project basis. The basis of these air quality goals and, where relevant, the safety margins that they provide are discussed in detail in Technical Report No 5A – Air Quality in Volume 3 of the EIS.

The primary air quality objective of most projects is to ensure that the air quality goals listed in **Table 9-3** are not exceeded at any location where there is possibility of human exposure for the time period relevant to the goal.

Queensland does not have a long-term goal for PM_{10} that is consistent with the 24 hour NEPM goal. The NSW Department of Environment and Conservation (DEC) long-term goal has been included to provide a benchmark for comparison with the 24-hour NEPM goal.

Table 9-3 Air Quality Goals Relevant to this Project

Pollutant	Goal	Averaging Period	Agency
Carbon monoxide (CO)	8 ppm or 10 mg/m^3 9 ppm or 11 mg/m^3	8-hour maximum 8-hour maximum	EPA NEPM[1]
Nitrogen dioxide (NO_2)	0.16 ppm or 320 μg/m^3 0.12 ppm or 246 μg/m^3 0.03 ppm or 62 μg/m^3	1-hour maximum 1-hour maximum[1] Annual mean	EPA NEPM NEPM
Particulate matter less than 10 μm (PM_{10})	150 μg/m^3 50 μg/m^3 50 μg/m^3 (30 μg/m^3)	24-hour maximum 24-hour maximum Annual mean (Annual mean)	EPA NEPM[2] EPA (NSW DEC)
Particulate matter less than 2.5 μm ($PM_{2.5}$)	25 μg/m^3 8 μg/m^3	24-hour maximum Annual average	NEPM NEPM
Total Suspended Particulate Matter (TSP)	90 μg/m^3	Annual average	EPA
Sulfur Dioxide (SO_2)	0.25 ppm or 700 μg/m^3 0.20 ppm or 570 μg/m^3 0.08 ppm or 225 μg/m^3 0.02 ppm or 60 μg/m^3	10-minute maximum 1-hour maximum 24-hour maximum Annual average	EPA NEPM[1], EPA NEPM[1] NEPM, EPA
Ozone (O_3)	0.10 ppm or 210 μg/m^3 0.08 ppm or 170 μg/m^3	1-hour maximum 4-hour maximum	NEPM[1], EPA NEPM[1], EPA
Lead (Pb)	1.5 μg/m^3 0.5 μg/m^3	90-day average Annual average	EPA NEPM
Air Toxics (investigation levels only and not project-specific goals)			
Benzene	0.003 ppm	Annual average	NEPM (Air Toxics)
Benzo(a)pyrene	0.3 ng/m^3	Annual average	NEPM (Air Toxics)
Formaldehyde	0.04 ppm	24-hour maximum	NEPM (Air Toxics)
Toluene	2 ppm or 8 mg/m^3 1 ppm or 4 mg/m^3 0.1 ppm or 0.4 mg/m^3	24-hour maximum 24-hour maximum Annual average	EPA NEPM (Air Toxics) NEPM (Air Toxics)
Xylene	0.25 ppm 0.2 ppm	24-hour maximum Annual average	NEPM (Air Toxics) NEPM (Air Toxics)

Table Notes:
[1] One day per year maximum allowable exceedances
[2] Five days per year maximum allowable exceedances

9.3.2 Air Quality Issues Associated with Roadway Projects

One objective for roadway projects is to improve air quality or to minimise air quality impacts and it is important to review the change in air quality that is likely to occur with the project. Assessing the change in air quality should take into account any reduction or increase in emissions in the study area due to the project. Decreases or increases in emissions will arise as a result of a change in the traffic along a particular corridor.

Emissions from vehicles vary depending on a number of factors. A major factor in emissions from vehicles is the increasing standard being applied to engine emissions and improvements to the fuels allowed to be sold in Australia, which results in decreasing emissions from newer vehicles as the transport fleet on Australian roads is replaced over time. In general, a congested road with numerous intersections will generate higher emissions than a free flowing road with no intersections. Steeper road gradients generate higher emissions due to the higher engine loads, and roads with a higher percentage of heavy vehicles typically generate higher emissions.

In terms of emissions from vehicles and resultant pollutant concentrations the difference between surface roads and tunnels lies at the point of emission. Emissions from surface roads are released at ground-level where a greater proportion of the population reside. The surface road relies solely on atmospheric dispersion to reduce the pollutant concentrations between the roadway and the sensitive receptor. In contrast, tunnel emissions are generally vented via a ventilation outlet(s) assuming that the ventilation system is operated to avoid portal emissions. The point of emission from the tunnel is therefore above ground-level (at the outlet height) and the reduction of the pollutant concentrations from the outlet to the sensitive receptor combines the initial distance of the release point with the dispersive capacity of the atmosphere. An elevated point source is therefore more effective than a line source with the same emission.

9.3.3 Approach to Assessment

As noted in Section 9.1 dispersion models are used as the primary tool to assess air quality impacts arising from the project. The approach is to show not only the pollutant concentrations resulting from individual road sections and tunnel ventilation outlets, but also the net effect of the project within the study area. The aim is to assess any change to air quality that may arise with the project.

The most significant emissions produced from motor vehicles are CO, NO_x, hydrocarbons and PM_{10}. Estimated emissions of these pollutants are required as input to computer-based dispersion models in order to predict pollutant concentrations in the area of interest and to compare these concentrations with associated air quality goals. The primary factors which influence emissions from vehicles include the mode of travel, the grade of the road and the mix or type of vehicles on the road. Sources of emission factors which have been referenced for the purposes of this project include:

- World Road Association, referred to as PIARC (formerly the Permanent International Association of Road Congresses); and
- The South-East Queensland Region Air Emissions Inventory.

Traffic data used for the purposes of the air quality study included the following:

- Annual Average Daily Traffic (AADT) for years 2004 (existing), 2012, 2016 and 2026;
- Modelled existing (2004) AADT for selected surface roads;
- Modelled 2012, 2016 and 2012 AADT without Airport Link (do minimal) for selected surface roads;
- Modelled 2012, 2016 and 2026 AADT with Airport Link (do something) for the tunnel and selected surface roads;
- Indicative flow profiles for light and heavy vehicles by hour of day for each section of tunnel; and
- Indicative flow profiles for light and heavy vehicles by hour of day for surface roads.

Pollutant emissions were estimated for each tunnel ventilation outlet and for relevant surface roads. No potential future improvements in vehicle technology or fuel standards have been included in the PIARC emission estimates. This would result in some overestimation of emission rates for future years. Assumed reductions in the proportion of older vehicles in the fleet has, however, simulated some improvement to vehicle emissions in future years.

In order to determine emissions from a ventilation outlet, the source of air which leads into the outlet has been considered (refer to **Figure 4-4** in Chapter 4 for a schematic of air movements in the tunnel). The air in the outlet comes from sections of tunnel which have a traffic volume, traffic mix, traffic speed and road grade. These data are included in the process to generate pollutant emissions for each hour of the day for each outlet. Road gradient information for every section of the tunnel is included in the modelling.

Traffic speed within the tunnel has been set to 80 km/h outside peak-hour periods. During peak-hour periods a speed of 20 km/h has been used. For this study peak-hour periods in the tunnel have been defined as hours ending 7, 8, 9, 16, 17, 18 and 19 for both directions in the tunnel. The peak-hour or "congested" periods are consistent with the hours selected for the Cross City Tunnel EIS in Sydney. A speed of 80 km/h has been assumed for vehicles on the motorways while 50 km/h has been assumed for all other surface roads.

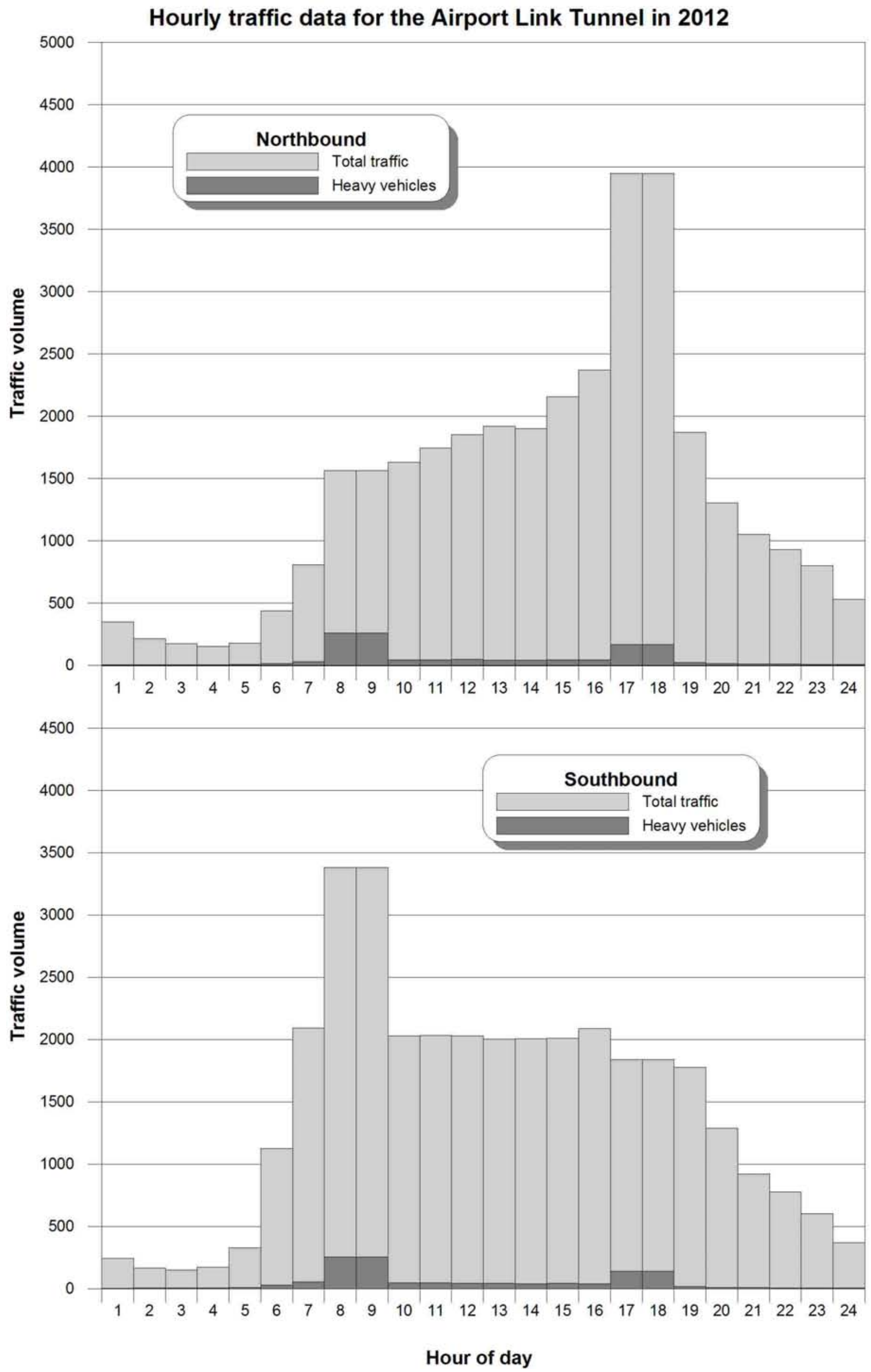
Figure 9-3 shows the estimated traffic and **Figure 9-4** the pollutant emissions (CO, NO_x and PM_{10}) for each hour of the day for 2012 with and without the Airport Link. The profile of emission rates closely follows the traffic profile, although the emission rates are also influenced by other factors such as the grade in the tunnel, speed of traffic and the proportion of heavy vehicles in the traffic mix.

Emissions data for selected surface roads in 2012 are provided in **Table 9-4**. With the introduction of the Airport Link into the traffic network there would be some re-distribution of traffic and therefore of emissions. The locations of these roadway samples are shown on Figure 19 in the Technical Report No. 5 Air Quality and Health in Volume 3 of the EIS. Note that the Lutwyche Road/Gympie Road modelling site includes the north-western connection to reflect changes in traffic flows both on Lutwyche Road at the surface and entering or leaving the Airport Link tunnels. Similarly the increases in Gympie Road and Stafford Road reflect increased traffic heading for the Airport Link. The Lutwyche Road modelling area, north of Maygar Street, reflects the change in vehicle emissions on Lutwyche Road remote from the tunnel portals. The primary purpose of the table is to establish emission levels at certain places on the road network for input to the modelling study.

- **Table 9-4 Estimated Emissions from Selected Surface Roads**

Road Section	Section Length (km)	2004 (kg/km/d)			2012 Without AL (kg/km/d)			2012 With AL (kg/km/d)		
		CO	NO_x	PM_{10}	CO	NO_x	PM_{10}	CO	NO_x	PM_{10}
Bowen Bridge Road	1.41	315	114	6	349	106	5	267	83	4
Lutwyche/Gympie Road	0.85	276	88	5	340	95	4	482	134	6
Gympie Road	2.29	296	92	5	384	105	5	486	129	6
Sandgate Road South	2.14	173	55	3	229	64	3	160	46	2
Sandgate Road North	2.07	263	88	5	308	92	4	268	80	4
Stafford Road East Webster	1.66	104	30	2	132	37	2	192	51	2
Newmarket Road	2.36	128	36	2	202	49	2	154	36	2
Gateway Motorway North Arterial	1.51	265	135	6	168	73	3	180	79	3
East-West Arterial	1.70	189	80	4	293	103	5	373	116	6
Airport Drive East Motorway	1.15	322	76	4	372	82	3	382	84	4
Lutwyche Road North Maygar	2.17	315	114	6	349	106	5	267	83	4

In addition to emissions from the Airport Link tunnel ventilation outlets and major surface roads in the area, the dispersion modelling also considered emissions from the northern ventilation outlet of the NSBT.



AIRPORT LINK - Figure 9-3

Hourly Traffic Data - 2012

Airport Link

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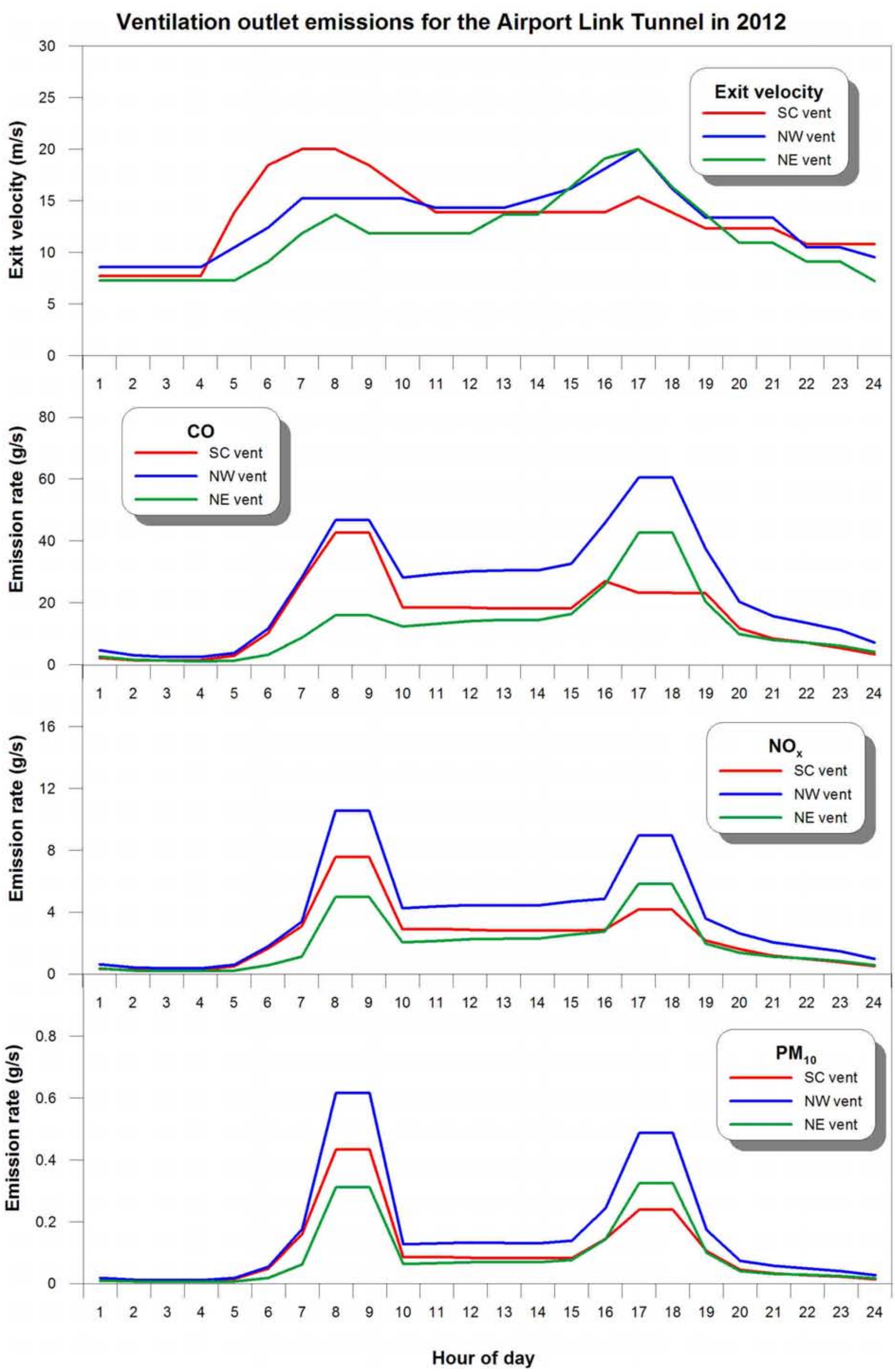


AIRPORT LINK - Figure 9-4

Ventilation Outlet Emissions - 2012

9.3.4 Assessment of Operational Air Quality

This section provides an assessment of the air quality impacts associated with the project.

Regional Effects

Carbon Monoxide

The simulations of carbon monoxide (CO) concentrations in the study area include surface road sources and tunnel ventilation outlets where appropriate. Background CO concentrations are also included in these predictions.

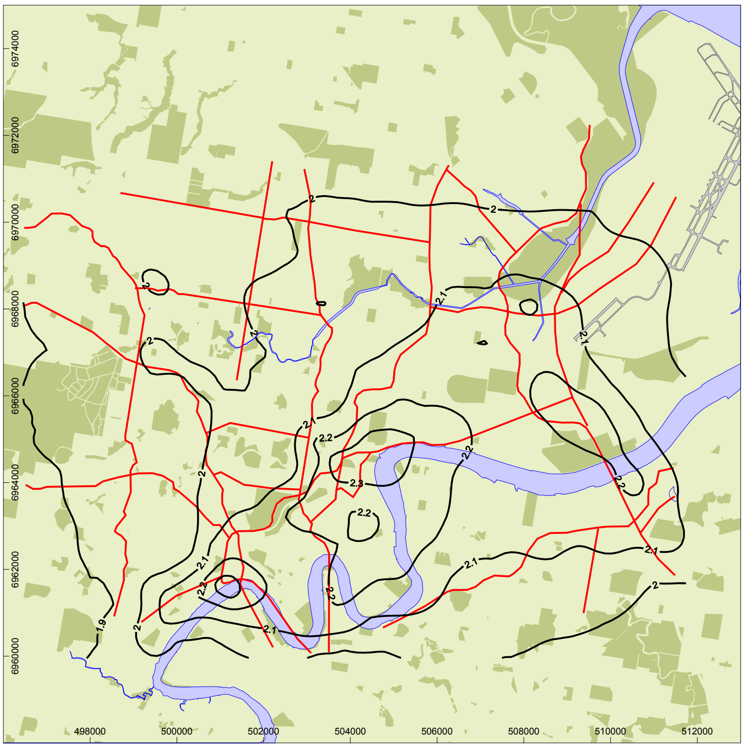
The following observations were made from the review of the CO model predictions:

- Predictions for the existing case (2004) show that maximum 8-hour average CO concentrations are below the 8-hour maximum air quality goal of 10 mg/m^3 (**Figure 9-5a**). The air quality monitoring data also shows that existing maximum 8-hour average CO concentrations are below 10 mg/m^3;
- CO concentrations in future years (2012+) are predicted to be very similar to existing (2004) concentrations (**Figure 9-5b** and **Figure 9-5c)**. The likely improvements to vehicle emissions appear to offset projected increases in traffic in the study area. However, the emission estimates have not considered any further tightening of emission standards so the future projections are considered to be conservatively high;
- As expected, higher CO concentrations are predicted near roads carrying more traffic (for example, the Gateway Motorway);
- Predictions for the future (2012+) 'with Airport Link' and 'without Airport Link' scenarios are very similar; and
- The contribution to ground-level concentrations due to tunnel ventilation outlets (with Airport Link case) appear to be overwhelmed by contributions from the major surface roads.

Nitrogen Dioxide

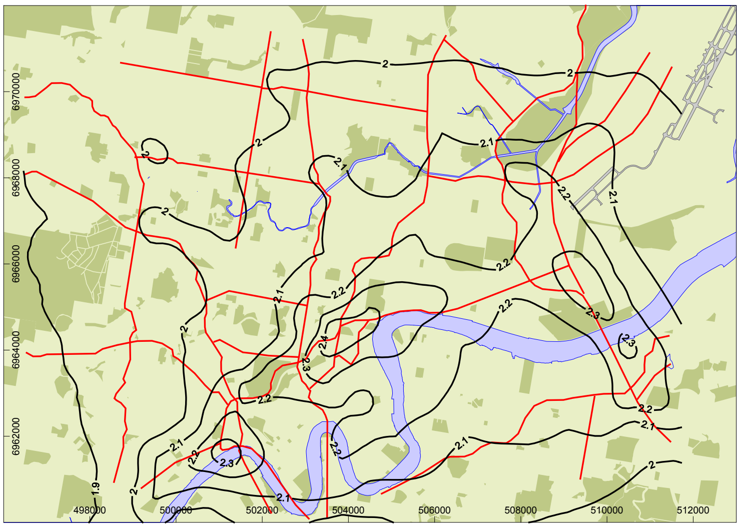
Predictions of NO_2 concentrations in the study area for existing and future years present a similar story to the CO predictions. These results also include background NO_2 concentrations. The following observations were made from the review of the NO_2 model predictions:

- Predictions for the existing case (2004) show that maximum 1-hour average NO_2 concentrations are up to around 200 µg/m^3 near the busy roads in the CBD (**Figure 9-6a**). These levels are below the 246 µg/m^3 air quality goal. Monitoring data from the sites examined for this study (that is, Bowen Hills, Eagle Farm and Kedron) show that existing maximum 1-hour average NO_2 concentrations are below the goal;
- Predictions for the existing case (2004) show that annual average NO_2 concentrations are below the annual air quality goal of 62 µg/m^3. The air quality monitoring data also shows that existing annual average NO_2 concentrations are below 62 µg/m^3;
- NO_2 concentrations in future years (2012+) are predicted to be very similar to existing (2004) concentrations (**Figure 9-6b** and **Figure 9-6c**). The likely improvements to vehicle emissions appear to offset projected increases in traffic in the study area. However, the emission estimates have not considered any further tightening of emission standards so the future projections are considered to be conservative;
- As expected, higher NO_2 concentrations are predicted near roads carrying more traffic (for example, in the CBD);
- Predictions for the future (2012+) build and no-build cases are very similar; and
- The contribution to ground-level concentrations due to tunnel ventilation outlets (with Airport Link case) appear to be overwhelmed by contributions from the major surface roads.

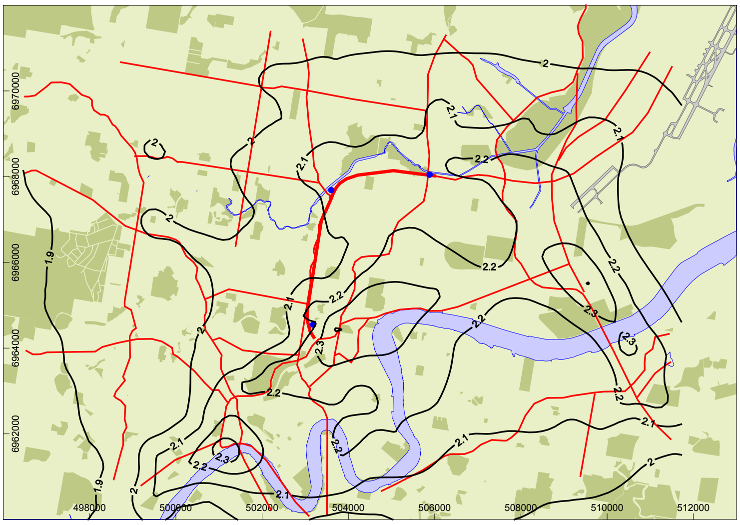


Existing

Predicted maximum 8-hour average CO concentrations in 2004 (mg/m^3)



Without Airport Link



With Airport Link

Predicted maximum 8-hour average CO concentrations in 2012 (mg/m^3)

AIRPORT LINK - Figure 9-5

Predicted Average CO Concentrations

Airport Link

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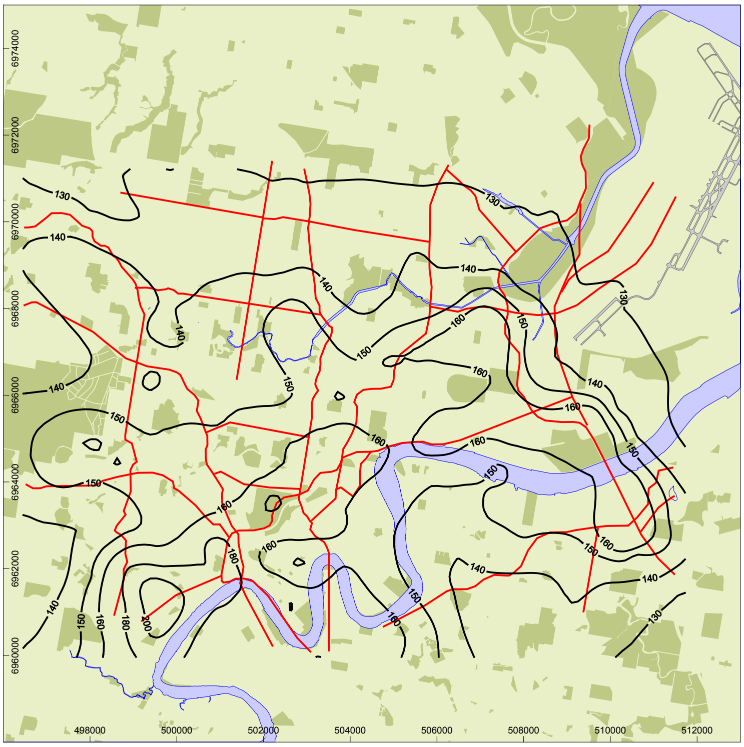
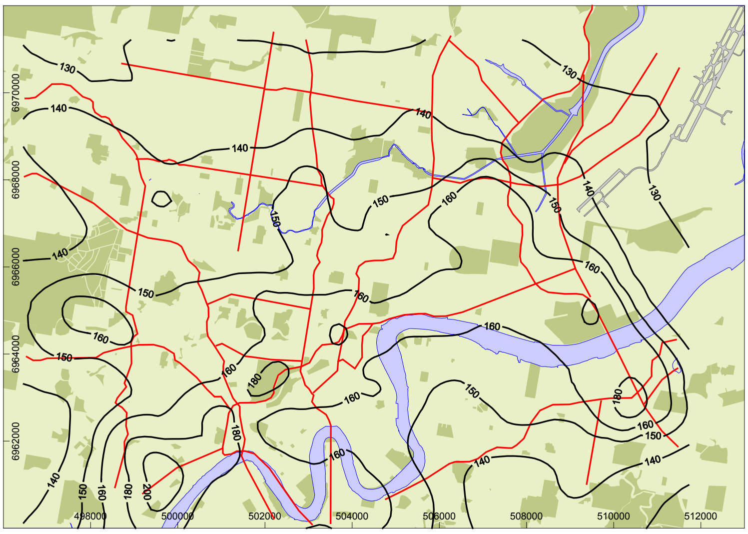
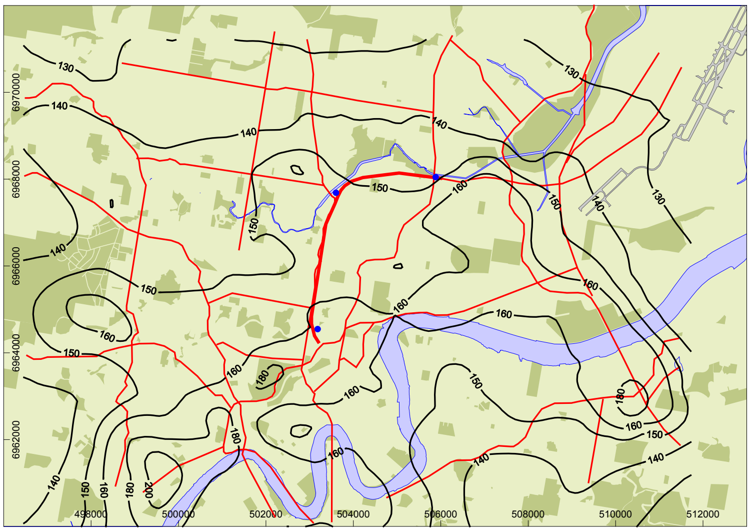


Existing

Predicted maximum 1-hour average NO_2 concentrations in 2004 ($\mu g/m^3$)



Without Airport Link



With Airport Link

Predicted maximum 1-hour average NO_2 concentrations in 2012 ($\mu g/m^3$)

AIRPORT LINK - Figure 9-6

Predicted Average NO_2 Concentrations

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Particulates

The regional dispersion modelling results for PM_{10} showed that existing maximum 24-hour background PM_{10} levels can be above the goal of 50 μg/m^3 (up to 85 μg/m^3) and the major sources contributing to these levels are most likely bushfires and dust storms. For this reason the concentrations include only the modelled surface roads and ventilation outlet sources.

As for CO and NO_2, there are some common patterns of high and low concentrations predicted in the study area resulting from the modelled sources. The dispersion model predictions for PM_{10} are summarised below:

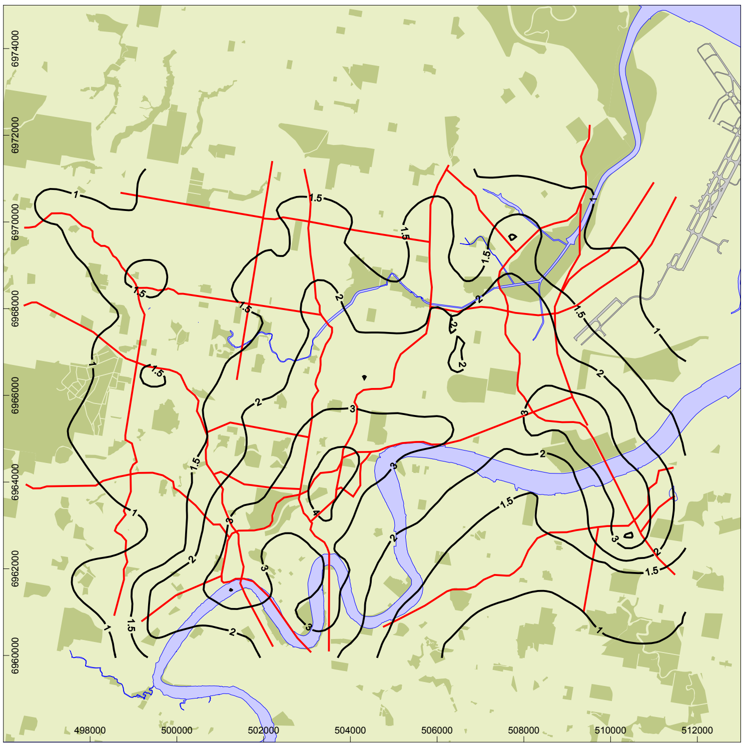
- Predictions for the existing case (2004) show that PM_{10} concentrations are below the maximum 24-hour (**Figure 9-7a**) and annual average air quality goals (50 and 30 μg/m^3). However, these predictions are due only to the modelled sources and not events such as bushfires;
- PM_{10} concentrations in future years (2012+) are predicted to be very similar to existing (2004) concentrations (**Figure 9-7b** and **Figure 9-7c**). The likely improvements to vehicle emissions appear to offset projected increases in traffic in the study area. Again, the emission estimates have not considered any further tightening of emission standards so the future projections are considered to be conservatively high;
- Higher PM_{10} concentrations are predicted near roads carrying more traffic (for example, the CBD);
- Predictions for the future (2012+) build and no-build cases are very similar;
- The contribution to ground-level concentrations due to tunnel ventilation outlets (with Airport Link case) appear to be overwhelmed by contributions from the major surface roads.

There is a generally held view that most of the PM_{10} in urban areas is $PM_{2.5}$ derived from motor vehicles. The proportion of $PM_{2.5}$ at the monitoring site at Bowen Hills comprised 50%, whereas monitoring in tunnel outlets in Sydney and Melbourne show results varying between 35 and 70%. Air quality standards or goals are used to assess the potential for ambient air quality to give rise to adverse health or nuisance effects and it is now generally considered that finer particles (those less than 2.5 μm in equivalent aerodynamic diameter or $<PM_{2.5}$) are more likely to have health consequences than larger particles. An air quality goal has been is provided for $PM_{2.5}$ (described in **Table 9-3**), although it should be noted that this is an advisory rather than a project specific goal.

To assess the implications of $PM_{2.5}$ concentrations in the regional context, the data has been remodelled (Technical Report No 5A – Air Quality of the EIS) assuming that most (96%) of the particulate matter was $PM_{2.5}$. The data show that the changes in $PM_{2.5}$ between “with tunnel” and ‘without tunnel’ are relatively minor. As with PM_{10}, the existing background levels already exceeded the NEPM goal (described in **Table 9-3**).

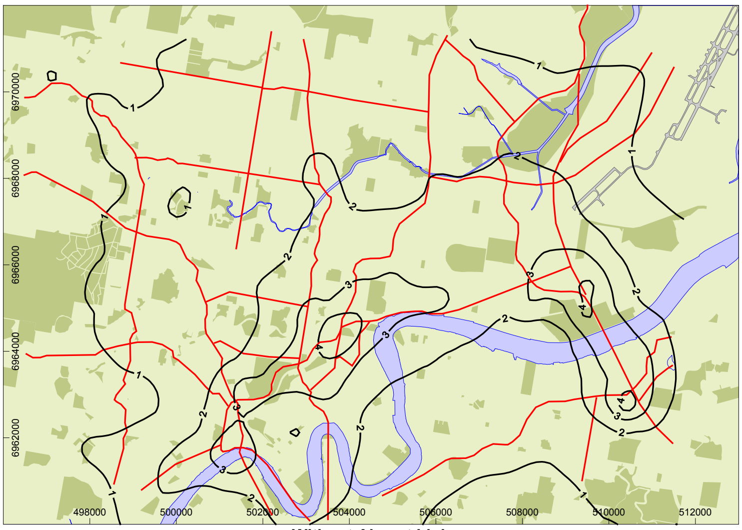
Ultrafine particles are defined as those smaller than 0.1 μm in diameter. While ultrafine particles make a small contribution to total particle mass, they make a very large contribution to particle number. Particles in this size range are generally formed from combustion, gas to particle conversion, nucleation and photochemical processes. Some are emitted as primary particles and others are secondary in nature formed from precursor molecules.

While an association between health effects and concentrations of fine particles (those less than 2.5 μm in equivalent aerodynamic diameter) is well established, the role played by the ultrafine particles is less clear. There are plausible mechanisms to suggest that ultrafine particles may indeed be a dominant factor in the health effects of particulate matter. At this stage, however, the evidence is too limited to develop exposure standards. In addition, methodologies for measuring ultrafine particles are still being developed and there is no widely agreed technique for measuring both ultrafine particle mass and number.

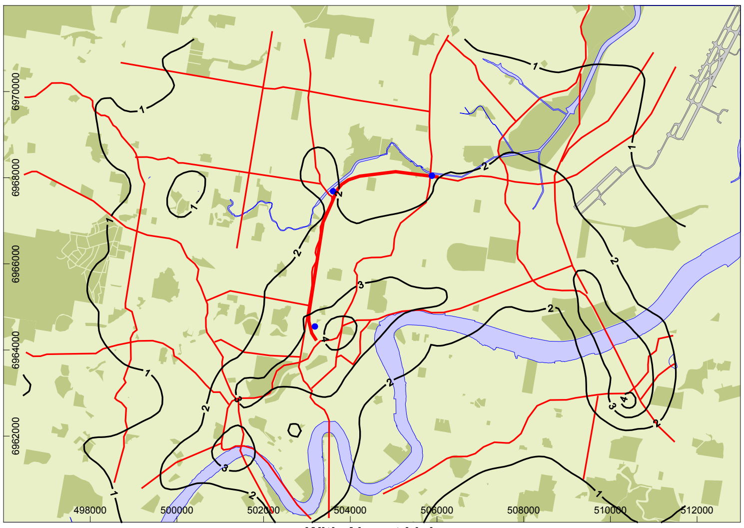


Existing

Predicted maximum 24-hour average PM_{10} concentrations in 2004 ($\mu g/m^3$)



Without Airport Link



With Airport Link

Predicted maximum 24-hour average PM_{10} concentrations in 2012 ($\mu g/m^3$)

AIRPORT LINK - Figure 9-7

Predicted Average PM_{10} Concentrations

Airport Link

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Comparison of Modelled Results with Monitored Results

Table 9-5 presents the dispersion model results specifically for the city-based air quality monitoring locations for each of the criteria pollutants. From these results it is possible to assess the performance of the model, that is, by comparing the 2004 predictions with the 2004 monitoring data. Spatial variation (between the different sites) can also be assessed as well as differences between build and no-build cases and existing and future cases.

Table 9-5 Predicted Concentrations at Air Quality Monitoring Locations

Site	2004	2012		2016		2026		Goal
	DM	DM	DS	DM	DS	DM	DS	
Bowen Hills								
Maximum 8-hour average CO (mg/m^3)	2.2	2.3	2.3	2.4	2.3	2.4	2.4	10
Maximum 1-hour average NO_2 (µg/m^3)	169	174	168	174	168	174	167	246
Annual average NO_2 (ug/m^3)	34	35	34	35	34	35	34	62
Maximum 24-hour average PM_{10} (µg/m^3)*	4.2	4.2	3.9	4.0	3.6	3.7	3.3	50
Annual average PM_{10} (µg/m^3)*	1.1	1.1	1.0	1.0	0.9	0.9	0.8	30
Kedron								
Maximum 8-hour average CO (mg/m^3)	2.1	2.1	2.1	2.1	2.1	2.1	2.2	10
Maximum 1-hour average NO_2 (µg/m^3)	146	150	156	151	158	153	162	246
Annual average NO_2 (ug/m^3)	30	30	31	30	31	30	31	62
Maximum 24-hour average PM_{10} (µg/m^3)*	2.3	2.2	2.1	2.1	2.0	1.8	1.8	50
Annual average PM_{10} (µg/m^3)*	0.4	0.4	0.5	0.4	0.5	0.3	0.4	30

Table Note: *Predictions due to modelled roads and outlets only.

For the Bowen Hills and Kedron monitoring sites, the dispersion modelling indicates that pollutant concentrations in future years (2012+) would be very similar to existing (2004) concentrations. This is true for all monitoring sites in both the 'with' and 'without' tunnel cases. At both sites, there are no pollutants where future concentrations are substantially different from existing concentrations.

Spatially, the 2004 model predictions show that CO concentrations at the two sites are similar. Bowen Hills, however, is simulated to experience slightly higher NO_2 concentrations. This is generally consistent with the spatial variation observed in the most recent air quality monitoring data, although Kedron has only been collecting data since January 2006.

Table 9-5 also shows that all pollutant concentrations are below air quality goals at each of the monitoring locations for all future year cases. The predictions for the with-tunnel (DS) and without-tunnel (DM) cases are very similar and the difference in concentrations between these two cases would be considered difficult to detect by current measurement techniques.

Ventilation Outlets

This section examines pollutant concentrations due only to emissions from the tunnel ventilation outlets. **Table 9-6** shows the highest ground-level pollutant concentrations that are predicted in the study area due only to the emissions from the tunnel ventilation outlets. Note that these are the highest concentrations predicted in the study area and that in most areas the concentrations due to ventilation outlets will be much lower than these numbers.

It can be seen from **Table 9-6** that the highest ground-level concentrations due to all ventilation outlet emissions are well below the associated air quality goals. Of all the pollutants modelled, the maximum 1-hour average

NO_2 is predicted to consume the greatest fraction of the air quality goal at less than 8%. These predictions suggest that the ventilation outlets would not be the cause of exceedances of air quality goals.

- **Table 9-6 Highest Ground-Level Concentrations due to Ventilation Outlet Emissions**

Pollutant and Averaging Time	2012	2016	2026	Relevant Air Quality Goal
Maximum 8-hour average CO (mg/m^3)	0.1	0.1	0.2	10
Maximum 1-hour average NO_2 (µg/m^3)	15	16	18	246
Annual average NO_2 (µg/m^3)	0.5	0.7	0.9	62
Maximum 24-hour average PM_{10} (µg/m^3)	0.5	0.6	0.7	50
Annual average PM_{10} (µg/m^3)	0.1	0.1	0.1	30

Pollutant concentrations at locations above ground level have also been assessed as part of this project. The predicted maximum 8-hour average CO concentrations above ground level in 2012 due to emissions from all tunnel ventilation outlets are less than 1 mg/m^3 at all locations both 30 and 50 m above ground level. This level of impact demonstrates compliance with the 10 mg/m^3 air quality goal at elevated locations even when considering background levels of 2.5 mg/m^3.

The predicted maximum 1-hour and annual average NO_2 concentrations at elevated locations due to emissions from tunnel ventilation outlets are of up to 60 µg/m^3 at 50 m above ground-level and close to vent outlets. This level of impact demonstrates compliance with the 246 µg/m^3 air quality goal at all elevated locations even when considering background levels of 129 µg/m^3. Similarly, for annual average NO_2 concentrations, the highest concentrations are of the order of 5 µg/m^3 – close to the ventilation outlets and at 50 m above ground level. Compliance with the 62 µg/m^3 should be comfortably achieved at all elevated locations even when considering annual average NO_2 concentrations (in 2004/2005 Bowen Hills reported an annual average NO_2 concentration of 51 µg/m^3).

Predicted maximum 24-hour average PM_{10} concentrations at elevated locations are up to about 5 µg/m^3. Again, this level is predicted at 50 m above ground level and close to the vent outlets. This is well below the 50 µg/m^3 goal and unlikely to be the cause of exceedances at elevated locations. Annual average PM_{10} concentrations are predicted to be less than 1 µg/m^3 at 30 and 50 m above ground level at all locations – well below the 30 µg/m^3 goal and compliance at elevated locations would be anticipated.

Surface Roads

This section examines pollutant concentrations very close to selected surface roads. Results presented show the effect of emissions from the selected surface road only and do not include contributions from other sources. An objective of this section was to compare existing near roadside pollutant concentrations with future scenarios.

From examination of the model results, the highest pollutant concentrations for 2004 are predicted in the vicinity of the Gateway Motorway. This may be expected, given the very high traffic volumes experienced on this road. Predicted pollutant concentrations are highest at the kerb and decrease with distance from the kerb for all road sections. This shows the dispersion effect of distance from the source.

In assessing the magnitude of the predicted pollutant concentrations, an appropriate distance from the kerb should be selected based on the distance to the nearest residences. For example, the separation distance between the kerb and the nearest residences is greater for the Gateway Motorway than for many of the other selected roads. The most relevant distances from the Gateway Motorway section would be about 30 m while for most other sections, 10 m from the kerb would be the appropriate distance for the nearest residences.

The following observations were made from the surface road dispersion model predictions:

- Predicted pollutant concentrations are highest at the kerb for each road section;
- Predicted pollutant concentrations for 2004 are highest near the Gateway Motorway;
- Road sections where the with tunnel case is predicted to be lower than the without tunnel case include Bowen Bridge Road, Lutwyche Road, Sandgate Road and Newmarket Road;
- Road sections where the with tunnel case is predicted to be higher than the without tunnel case include Gympie Road, Stafford Road and East-West Arterial;
- Road sections where the differences between the with tunnel case and without tunnel cases are considered negligible include Gateway Motorway and Airport Drive;
- Improvements in local air quality are observed with reductions in surface traffic that occurs as a result of diverting traffic to the tunnel;
- Concentrations near the Gateway Motorway are predicted to decrease significantly from 2004 to future scenarios. This is due to reduced traffic on this section as a result of the Gateway duplication project; and
- At distances appropriate for the nearest residences, the model predictions for all sections and future years are below the associated air quality goals.

A useful comparison can also be made between predicted maximum pollutant concentrations due only to ventilation outlets and maximum pollutant concentrations near surface roads. It is important not to underestimate the pollutant concentrations near surface roads as they are likely to be significantly higher than maximum levels expected as a result of emissions from tunnel ventilation outlets. Also, there would be a higher frequency of the elevated pollutant concentrations near surface roads than for the elevated pollutant concentrations due to ventilation outlets.

Cumulative Effects of Northern Busway

As noted, the Northern Busway may proceed at the same time as the Airport Link Project. This section assesses the potential cumulative impacts of the project with the Northern Busway.

The cumulative impacts of the project with the Northern Busway were assessed by examining the differences in the traffic forecasting for the Airport Link with and without the Northern Busway operating. The AADT on major roads were calculated for the two options and the results showed that most road sections were predicted to experience very little change in traffic volume as a result of the busway, and as a consequence, little change in air quality.

9.3.5 Conclusions and Mitigation Measures

Dispersion modelling has been used as the primary tool to quantitatively assess pollutant concentrations in the study area. The conclusions of the modelling show that:

- Pollutant concentrations in the study area in future years (2012+) arising from motor vehicles would be expected to be similar to existing (2004) concentrations. This is the case both with and without the project;
- Model results for future years are considered to be conservatively high since no further improvements to vehicle emissions have been taken into account;
- Particulate matter concentrations arising from non-motor vehicle sources, such as bushfires, may continue to result in elevated levels on occasions;
- At ground level the with and without tunnel cases are predicted to be very similar. That is, regional air quality with the Project may be expected to be similar to air quality without the project;

- At ground-level the highest concentrations due to emissions from ventilation outlets are predicted to be much less than concentrations near busy surface roads;
- Pollutant concentrations at elevated locations due to ventilation outlet emissions would be expected to be below relevant air quality goals; and
- Air quality impacts arising from the project with the proposed Northern Busway would be expected to be very similar to the project without the Northern Busway.

It is concluded, from the operational (ambient) air quality study, that there would be no adverse air quality impacts as a direct result of the project. No detailed mitigation measures are proposed, although the ambient air quality will continue to be monitored at the existing monitoring sites. Consideration will be given to establishing three extra monitoring locations, each at a sensitive location near a ventilation outlet, to assess whether any impacts can be demonstrated from the ventilation outlet dispersion. These sites would be established to complement the existing EPA network and be operational for at least 12 months before and at least two years after the tunnel operations commence. Confirmation of modelling predictions is an important mitigation measure. Provision will be made for filtration in the future if a subsequent decision is made to provide for air treatment. This is discussed in Section 9.5.

9.4 Assessment of In-Tunnel Air Quality

The design of the tunnel ventilation system was described in Chapter 4, where it was specified that in-tunnel air quality would conform with guidelines issued by the World Road Association, also known as the Permanent International Association of Road Congresses (PIARC). PIARC is a European-based non-political and non-profit making association which was founded to promote international cooperation in issues related to roads and road transport. Its members comprise national and regional governments, as well as collective and individual members in over 130 countries. Amongst other things, it identifies, develops and disseminates best practice information on road transport matters. It has established a series of technical committees from which “best practice” advice on design and management of tunnels and ventilation systems is derived.

9.4.1 In-Tunnel Guidelines

The motor vehicle generated air emissions which are considered in ventilation design for tunnels are CO (carbon monoxide), particulates and various oxides of nitrogen, termed NOx. PIARC (1995; 2000; 2003) has recommended limits on the concentrations of these emissions within a tunnel as follows:

- A peak of 70 ppm (parts per million) of CO, with a peak of up to 90 ppm during extreme congestion;
- An average (in the tunnel) of 1 ppm of NO_2; and
- Visibility limit of $0.005m^{-1}$.

The allowable levels of carbon monoxide and visibility specified are standard requirements in European tunnel designs and have changed little in recent years. Visibility requirements have not changed since 1991, and CO levels have decreased, mainly to allow CO to continue to be the determining pollutant for ventilation control systems and not necessarily because lower CO levels were desirable in themselves. It should be noted, however, that the approval conditions for new tunnels in NSW (Cross City Tunnel and Lane Cove Tunnel) require a peak CO level of 50 ppm. This is based on the WHO guideline for CO of 50 ppm for a 30 minute exposure. The basis of this condition relates to potential problems associated with prolonged periods of exposure within the tunnel (for example, car speeds of less than 10 kph or a breakdown in the tunnel and the delays associated with car passengers waiting for emergency vehicles while other traffic is still moving within the tunnel).

Oxides of nitrogen are the pollutants being given attention due to the emergence of data on potential physiological effects of NO_2. The PIARC guideline on NO_2 argues that for healthy people, an average value of the order of 1 ppm that is not exceeded 98% of the time is acceptable (Mott McDonald, 2004).

The national NO_2 standards of various European countries are shown in **Table 9-7** below.

France is implementing its stringent requirements in stages to align with the expected reduction in vehicle emissions resulting from better performing engines. The limits will be achieved by replacing the air in the tunnels at extract/intake shafts along the length of the tunnel. Belgium achieves its limits by the use of short tunnels, while Sweden appears to achieve its pollution limits by fresh air dilution. The standards for both Belgium and Sweden are averages over time, not absolute limits that must never be exceeded.

- **Table 9-7 In-Tunnel NO_2 Standards**

Country	Value (Average)
United Kingdom	4 ppm if < 500 m (tunnel length) 3 ppm if < 1,000 m 1.5 ppm if < 2,500 m
France	0.8 ppm from 2003 0.6 ppm from 2005 0.5 ppm from 2007 0.4 ppm from 2010
Belgium	0.5 ppm, 20 minute mean 0.2 ppm, one hour mean
Norway	1.5 ppm
Sweden	0.2 ppm, one hour mean

Table Note: Source: Mott McDonald, 2004.

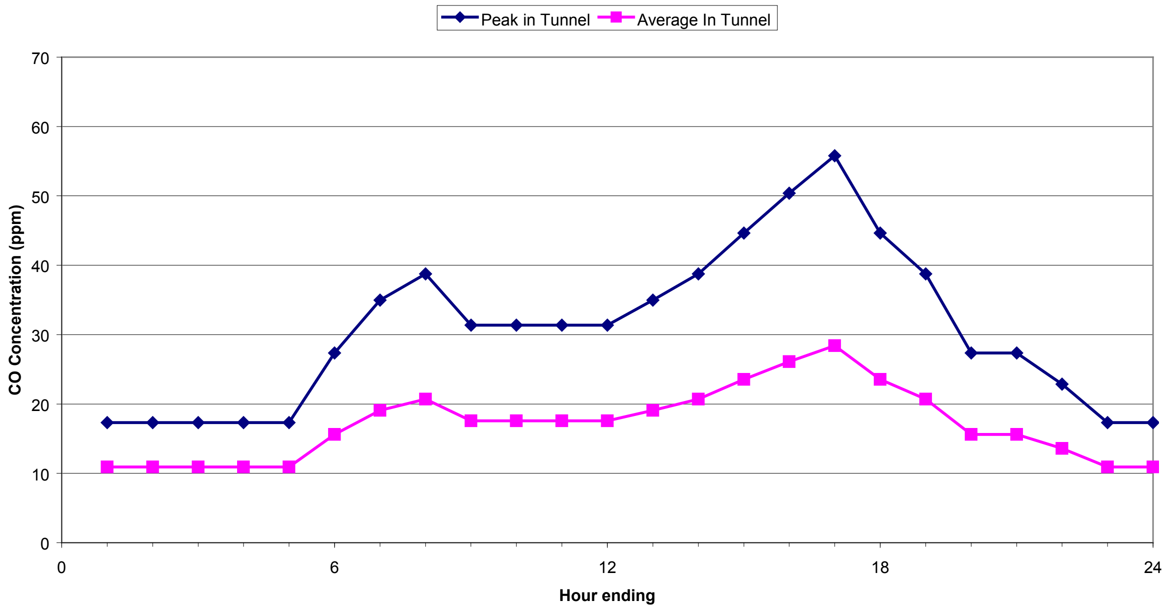
In-tunnel guidelines for particulate matter are not offered by PIARC or most regulatory agencies, except as a visibility measure (extinction value). There are currently no plans to tighten the allowable levels of CO or visibility in tunnels in Europe. Although national standards have now considered very low levels of NO_2, no long European tunnels have been built that dilute emissions to very low levels of NO_2 and at the same time prevent emissions from the tunnel portals.

The in-tunnel requirements for air quality in Japan are outlined in RTA (2004). The specified limit for CO is 100 ppm, whilst visibility limits for road tunnels in Japan are comparable to PIARC standards. There are no limits specified for NO_2.

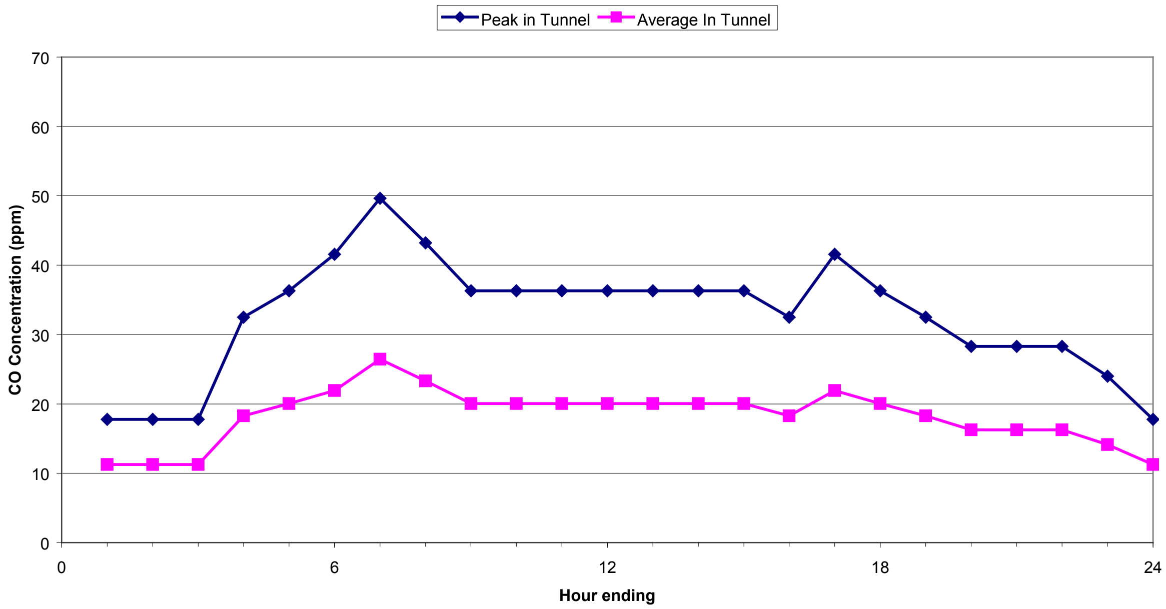
9.4.2 In-Tunnel Concentrations

Daily traffic profiles were modelled in the development of the tunnel design to show daily profiles of the pollutant concentrations within the tunnel. The concentrations for CO are shown in **Figure 9-8** and for NO_2 in **Figure 9-9**.

Typical CO Concentration North/Eastbound



Typical CO Concentration West/Southbound

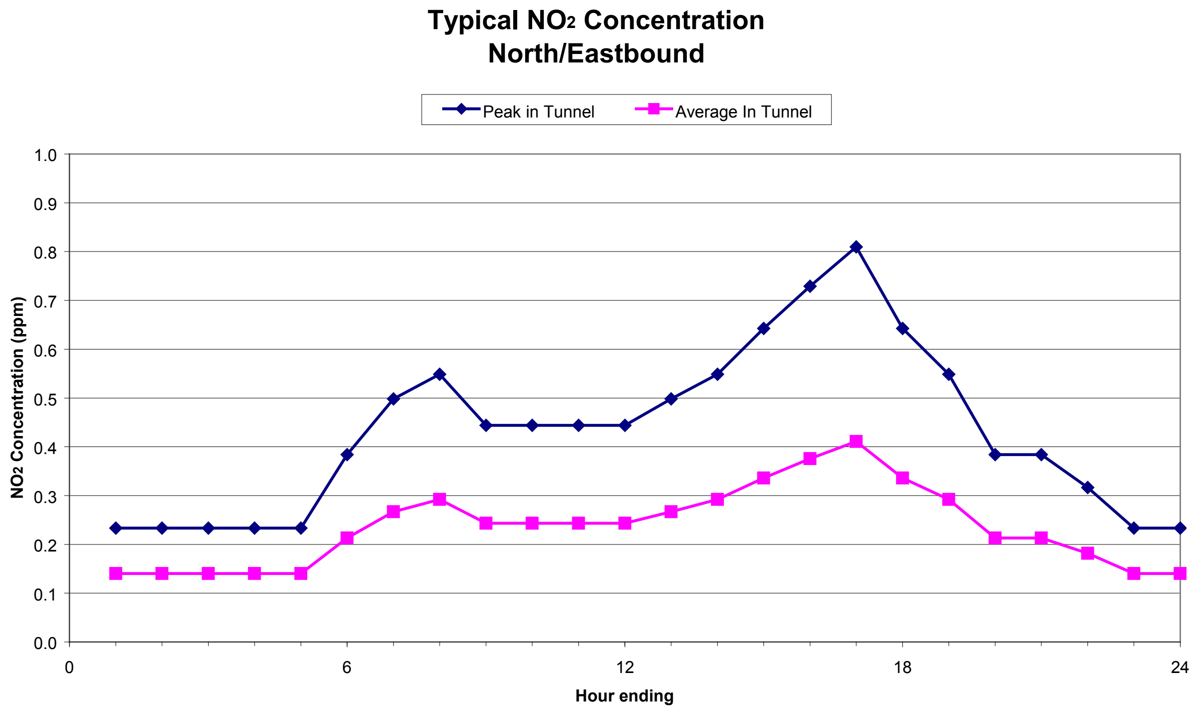


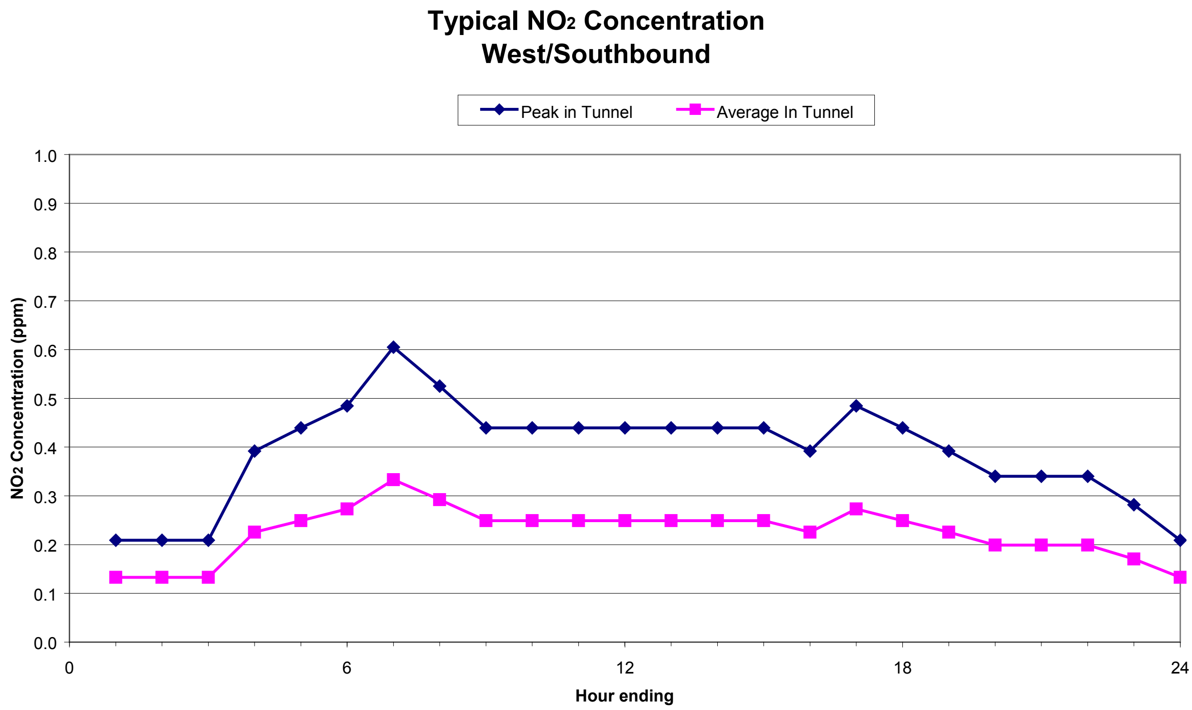
AIRPORT LINK - Figure 9-8

Carbon Monoxide In-tunnel Concentrations

Airport Link

SKM Connell Wagner JOINT VENTURE





AIRPORT LINK - Figure 9-9

Nitrogen Dioxide In-tunnel Concentrations

Airport Link

SKM Connell Wagner JOINT VENTURE

Figure 9-8 shows that peak level of CO in the north/east bound tunnel is about 57 ppm (which is below the PIARC criterion of 70 ppm on all occasions) and is at or higher than the 50 ppm level only during the pm peak. The averages in the tunnel, although not directly relevant to the goal, indicate that the peak values are not uniform throughout the tunnel. The concentrations in the west/south bound tunnel would remain below the PIARC guideline and only achieve the 50 ppm value in the am peak.

The NO_2 criterion for in-tunnel concentrations is an average of 1ppm. The daily profiles in **Figure 9-9** show that the tunnel design will allow for a peak of less than 1ppm, with the average at any given time not exceeding 0.4 ppm. This indicates that the tunnel NO_2 levels will be well within PIARC and European agency standards, including the stricter French standards. Comparison with the Belgian and Swedish standards is not possible, as the numbers provided in those standards are rolling averages over time, whereas the modelled results are averaged in the tunnel at any given time.

9.5 Air Filtration Technologies

9.5.1 Review of Technologies

A review of air treatment technologies was undertaken for the NSW Roads and Traffic Authority by Child & Associates (2004). The two “established” filtration technologies are:

- Electrostatic precipitators (ESPs) which remove particulates (i.e. suspended particles) by applying an electric charge to them as they pass through an electric field and then collecting them on a series of oppositely charged metallic plates. The plates are cleaned regularly either by a dry process (e.g. shaking the plates) or by a wet process (e.g. washing the plates). In both cleaning processes, the particles are collected and disposed of to an appropriate site. The wet process requires an intermediate water filtration process to form a cake, while the water is either discharged or recycled; and
- Denitrification which removes nitrogen dioxide and other oxides of nitrogen by means of either chemical absorption or catalytic conversion to a more benign gas. Typically, a denitrification process requires prior particulate removal so it is often used in conjunction with a bank of ESPs.

Child & Associates (2004), RTA (2001, 2004) and Arnold Dix (2004, 2006) reviewed these technologies in terms of their state of development and actual application to road tunnels. From these reviews it is clear that:

- Only two countries - Japan and Norway - have more than basic operational experience with air treatment, and this treatment is based on ESP technology - about 50 tunnels in Japan and about 7 in Norway. In these countries, in-tunnel air quality issues are associated with visibility problems caused by heavy diesel truck traffic (in Japan) and tyre debris (especially Norway);
- In Norway this technology was installed in only one tunnel to maintain in-tunnel air quality (due to the tunnel length and absence of ventilation stacks and fresh air intakes). Another tunnel in Norway has ESP technology installed for treatment of air vented externally, but the filtration technology is not used;
- In about 7 tunnels in Japan ESP technology was installed prior to external discharge to address community or regulatory concerns. The major issue is to attempt to meet external air quality goals. No data are available on usage and performance of the technology;
- Only one tunnel has full scale NO_2 removal technology installed. This tunnel is in Norway and there has been no need for the system to be used; and
- Japan and Spain are committed to the installation of full scale, fully operational ESP and NO_2 removal technology, Japan on the Tokyo Ring Road system and Spain on the Madrid M30. Italy is committed to full

scale ESP technology in the Cessena Tunnel. These systems will all become operational over the next few years.

In NSW the RTA has announced (www.rta.nsw.gov.au) its intention to proceed with the filtration trial first announced in April 2004. The trial will test PM_{10} and NO_2 technology and will be applied to the M5 East as part of a package to improve in-tunnel air quality in that tunnel.

Capital and operating costs for tunnel filtration of the Airport Link were estimated with an airflow through the mainline tunnel systems of approximately 2,350m^3/s. The estimated capital cost of filtration equipment incorporating both electrostatic precipitation for particle removal and scrubbing for removal of NO_2, is likely to be up to or in excess of $200 million in $2006 terms. This estimate, which makes an allowance of about $50 million for civil works required to support such equipment, would need to be subject to detailed design and construction costing. Operational costs (energy consumption by the ESP filters estimated as about 3 GWh per year) would be expected to be about $250,000 per year (assuming 8 cents per kWh).

In summary, only electrostatic precipitator technology can be considered as "proven" in road tunnel applications, with operational experience being limited primarily to two countries which have particular issues not associated with the Airport Link Project. Even within these countries, verifiable operational data on actual filtration performance are not available.

9.5.2 Modelled Results from Use of Filtration

An analysis of the effect on local air quality due to the Airport Link fitted with some form of emission treatment has been carried out. Child (2004) has reviewed various emission treatment technologies and systems for road tunnels and provided information on pollutant removal efficiencies. Typical claimed performance results are as follows:

- 80 to 95% removal efficiency for total suspended particulates; and
- 60% removal efficiency for total oxides of nitrogen.

These performance results were claimed in relation to trials conducted in Germany. The quoted figures were among the highest of the total suspended particulates and oxides of nitrogen removal efficiencies presented in the review.

Dispersion modelling has assisted with the analysis of the effects on ambient air quality arising from the Airport Link both with and without some form of emission treatment. For the analysis it has been assumed that the emission treatment would remove 60% of the NO_x and 90% of the PM_{10} from ventilation outlets emissions.

Dispersion modelling results were obtained which compare ground-level pollutant concentrations for the Airport Link without and with emission treatment. Plots for maximum 1-hour and annual average NO_2 and maximum 24-hour and annual average PM_{10} concentration predictions for 2012 show the effect of vehicle emissions from surface roads and from the tunnel's proposed ventilation outlets.

The ground-level pollutant concentrations both without and with tunnel filtration were found to be very similar. Differences to ambient air quality arising solely from emission treatment for the tunnel would be difficult to detect. The model predictions suggest that pollutant concentrations in the study area are dominated by emissions from motor vehicles on the surface roads and that emissions treatment for each of the six kilometres (approximately) of tunnels associated with the project would result in very similar ambient air quality implications to the project without emissions treatment.

9.5.3 Rationale for Approach to Ventilation and Air Treatment

The system of mechanical ventilation proposed for the project would be achieved by longitudinal air flow in each tunnel tube. That is, air would be drawn in at the entry portal, carried along the tunnel in the direction of traffic, and drawn out just prior to the exit portal to the ventilation station located nearby on the surface. A series of roof mounted jet fans would draw air into and convey it along each tube. Between the draw off point and the exit portal, the jet fans will be reverse mounted so as to draw air into the tunnel to the draw-off point, thereby mitigating portal discharge at the exit. Unlike recent road tunnels in Sydney (M5 East), there will be no recirculation of air from one tube to the other.

It is proposed that this project would have three separate ventilation stations. Each ventilation station would have an elevated outlet structure, about 30 m high (the height used in dispersion modelling), to achieve adequate dispersion of the in-tunnel air. The quality of the in-tunnel air, the appropriate terrain and the ability to disperse the air via the ventilation outlets means that filtration at the ventilation station is not required.

An alternative or supplementary approach to the control of air pollution levels in the tunnel and ultimately in the wider airshed following discharge is to place filtration systems within the tunnel itself. This could be achieved by installing bypass tunnels which draw a percentage of air from the traffic tunnel into a separate return tunnel that contains the treatment system (e.g. ESPs). The treated air is then returned to the main tunnel and mixes with the untreated air to lower overall concentrations within the tunnel and ultimately at the discharge vent or portal. A similar effect can be achieved with roof mounted systems, installed in niches above the roadway. This type of facility is generally limited to very long tunnels (e.g. 10 km in length or more) where intermediate air intakes or off-takes are not available (e.g. below mountain ranges) and in-tunnel filtration is needed to maintain in-tunnel air quality. It has never been used as a method to control the quality of air emissions being discharged into the wider airshed, although it is likely that the quality of air emitted from the vent outlet would benefit from the in-tunnel treatment. The length of the Airport Link tunnels is such that in-tunnel air quality goals can be achieved without the need for intermediate treatment.

The rationale behind this proposed ventilation arrangement is that:

- It achieves a more equitable spread of motor vehicle emissions through three widely separated outlets rather than concentrating all emissions at a single point and having to raise the height of that outlet significantly;
- It provides an operationally more efficient ventilation system with lower power consumption and associated greenhouse gas emissions (i.e. there are fewer “corners” for the air to turn through);
- It provides more redundancy (i.e. backup) in the event of any operational difficulties or incidents (e.g. fire); and
- The placing of ventilation stations on the surface (rather than in the tunnel) provides space and flexibility to accommodate any air treatment technology that may be considered for the project in the future.

9.6 Effects on Public Health

9.6.1 In-Tunnel Air Quality

Consideration of potential effects on the health of tunnel users is discussed in this section. The criteria for CO and NO_2 discussed in Section 9.4.2 are health based criteria and generally relate to the degree (time) of exposure to the pollutants. There are no in-tunnel criteria for particulate matter, other than those prescribed for the maintenance of visibility.

Carbon Monoxide

As noted previously, the design guideline for CO for this project is 70 ppm peak within the tunnel. Section 9.4 above noted that the peak of 70 ppm would not be reached under normal conditions within the tunnel. Health criteria for CO exposure (average of 87 ppm for a 15 minute exposure and of 50 ppm for a 30 minute exposure) are well established (WHO, 2000) and the modelled results indicate there would not be any threat to the health of motorists using the tunnel under normal operating conditions.

A study undertaken by NSW Health (2003) and also reported in Sheppeard et al (2003) measured CO concentrations in motor vehicles passing through the M5 East tunnel in Sydney. The in-tunnel CO criterion in that tunnel is 87 ppm, yet the surveys undertaken showed that concentrations of CO within the motor vehicles passing through the tunnel ranged from 0 to 35 ppm, with the lowest results for CO achieved when the windows of the motor vehicles were closed (average 4.8 ppm) compared with an average of 21.7ppm when the windows were open. External concentrations (i.e. on the vehicle) ranged up to 38.7 ppm, with an average of 20.6 ppm. This indicates that the tunnel design is conservative in that, when the ventilation system is operated correctly, it is unlikely the criterion set would be approached. As noted, the NSW Government has adopted the 30 minute exposure criterion (50 ppm) to provide a margin of safety for motorists held within the tunnel for a period of 30 minutes. That is, the peak concentration in the tunnel should not exceed 50 ppm. A more appropriate response, adopted for this project, was to ensure safe conditions by operating the tunnel efficiently, thus keeping the concentration well below the criterion of 70 ppm and, in the event of possible delays within the tunnel (i.e. motorists being in the tunnel for 15-30 minutes), providing traffic management measures to ensure motorists are not subject to criterion exposures over those time frames.

Nitrogen Dioxide

The recognised ambient health criterion for NO_2 (identified by NEPM and outlined in **Table 9-3** above) is 245 ug/m3 or 0.12 ppm maximum averaged over 1 hour exposure. This is significantly lower in absolute terms than the criterion set for exposure in the tunnel. There is no NO_2 criterion for shorter time exposures than one hour. WHO (2000) notes that 0.2 to 0.3 ppm is the clear lowest-observed-effect level for asthmatics and patients with chronic obstructive pulmonary disease. The application of a 50% margin for safety was applied, resulting in the NEPM criterion of 0.12 ppm (one hour maximum). For acute exposures, WHO indicates only very high concentrations (>1 ppm) may affect healthy people.

The surveys undertaken by NSW Health (2003) and Sheppeard et al (2003) have indicated that NO_2 levels in or on motor vehicles travelling in the M5 East tunnel reach the ambient guideline levels. Concentrations in the cabin ranged from 0.03 to 0.25 ppm, with the lowest level being achieved when the windows are closed (average 0.06 ppm) compared with an average of 0.20 ppm when windows are open. External (to the vehicle), NO_2 ranged up to 0.48 ppm, with an average of 0.21 ppm. These in-tunnel results are consistent with the predicted results from the modelling described in Section 9.4.2.

NSW Health (2003) concluded that, while none of the transits undertaken measured an exposure likely to be associated with an acute health effect, peak levels of NO_2 were such that should they be present during prolonged transits (15 – 30 minutes), exposures previously reported to be associated with increased inflammatory response to allergens in asthmatics may be encountered if the vehicle cabin is not closed.

It is therefore concluded that, for this project, traffic management programs will be required to be implemented to ensure that prolonged exposure (> 15 minutes) is not experienced by any motorist. In the event that those circumstances are not possible, then motorists who may be susceptible to asthmatic symptoms should be advised, via the tunnel communication system, to close their car windows while they wait.

Particulate Matter

Ambient concentrations and health impacts for particulate matter have usually been assessed in terms of particles less than 10 microns (PM_{10}), although there has been an approach towards assessing in terms of fine particles ($PM_{2.5}$). The ambient air quality standard (NEPM) for PM10 is 50 ug/m^3 maximum averaged over 24 hours, while there is a NEPM advisory of 25 ug/m^3 for $PM_{2.5}$.

There is no in-tunnel guideline (i.e. short-term exposure) in terms of particulate matter and the health impacts associated with it. NSW Health (2003) references work done in Sweden where asthmatic volunteers were exposed to tunnel air for 30 minutes ($PM_{2.5}$ levels averaged 95ug/m^3, range from 60-262 ug/m^3) and were subsequently assessed for lung function for 18 hours. Adverse respiratory effects to $PM_{2.5}$ exposure appeared mild compared with nitrogen dioxide. Subjects with exposure in excess of 100 ug/m^3 had a slightly greater early reaction to allergen challenge.

NSW Health (2003) notes that, while some investigators have suggested that adverse health effects of fine particles may occur in response to short-term (less than one hour) exposures, fine particle standards are based on well-established 24-hour exposure dose-response effects. Individuals with pre-existing heart or lung diseases are most susceptible to the effects of fine particles and effects of increased levels have also been demonstrated on asthmatic children.

Mitigation Measures

Mitigation measures proposed to manage in-tunnel air quality comprise:

- Visibility, air speed and gas monitors (for CO and NO/NO_2) will be installed in the tunnel. Automated control systems will respond to data collected by these air quality monitors, switching individual jet fans and axial fans on and off to regulate the overall air flow;
- In-tunnel air and traffic management procedures to ensure motorists within the tunnel are not subject to CO concentration levels approaching ambient guidelines defined by time exposures, i.e. 50 ppm for 30 minutes or 87 ppm for 15 minutes; and
- In-tunnel air and traffic management procedures to ensure motorists within the tunnel are not subject to extended periods of exposure to NO_2 (15 to 30 minutes). In the unlikely event of prolonged times in the tunnel, motorists with susceptibility to inflammatory responses to NO_2 will be advised to close their vehicle windows.

9.6.2 Ambient Air Quality and Health Risk

Ambient air quality in urban areas and any changes which may result from the proposed tunnel were expressed as issues of major community concern. A health risk assessment was undertaken to determine the possible impacts on public health from regional changes to ambient air pollutants from the Airport Link. The air pollutants considered were benzene, carbon monoxide (CO), formaldehyde, nitrogen dioxide (NO_2), PM_{10}, $PM_{2.5}$, toluene and xylene. As changes in traffic volume would occur on roads adjacent to the proposed Airport Link, health effects due to those traffic volumes were also considered.

The health risk assessment is presented in full in Technical Report No 5B – Health Impacts of the Proposed Airport Link, by Dr Tim O’Meara, Environmental Health Consultant.

Health Risk Assessment for Regional Air Pollution

A conservative approach was used to model the health impacts of ambient regional air pollutants from the proposed Airport Link. Holmes Air Sciences (HAS) (Technical Report No 5A - Air Quality in Volume 3 of the EIS) provided predicted ground level concentrations for the criteria pollutants - CO, NO_2, PM_{10} and $PM_{2.5}$ at four specific sites and four time periods (2004, 2012, 2016 and 2026). For the air toxics, benzene, formaldehyde, toluene and xylene data were provided for 2004 and 2012 at three sites. The worst case increases in air pollutants were used for assessing the potential worst case health impact. Where improvements in air quality were forecast in Technical Report No 5A in Volume 3 of the EIS, they were not used to offset the worst case estimates of adverse health effects.

The models used for estimating the health effects were based on published epidemiological studies in Brisbane, other Australian cities or overseas cities, long term studies of mortality and lung function growth from the United States challenge chamber studies and panel studies. These are reviewed in detail in Technical Report No 5B in Volume 3 of the EIS. Where more than one health effect estimate was available the most conservative estimate, that is, the one that gave the largest adverse health impact, was used.

The health effects resulting from predicted worst case increases in ambient air pollutants were examined. The pollutants considered were benzene, CO, formaldehyde, NO_2, PM_{10}, $PM_{2.5}$, toluene and xylene. Four sites were considered for the criteria pollutants and three for air toxics. The sites included Albert Bishop Park, Bowen Hills, Eagle Farm, Kalinga Park and Kedron. The health effects were modelled for the worst affected sites.

Both acute and long term health effects were examined. The acute health effects examined were:

- Mortality and hospital admission; and
- Lung function, symptoms and GP visits.

The long term effects considered were:

- Mortality;
- Cancer incidence; and
- Lung function growth in children.

For the health effect modelling, the worst case forecast increases in emissions across the 4 sites were:

- Annual average benzene: 0.03 $\mu g/m^3$;
- 8 hour carbon monoxide (CO): 0.1 mg/m^3;
- Annual average formaldehyde: 0.0093 $\mu g/m^3$;
- 1 hour maximum nitrogen dioxide (NO_2): 9 $\mu g/m^3$;
- Annual average NO_2: 1.0 $\mu g/m^3$;
- 24 hour PM_{10} $\mu g/m^3$: 0.1 $\mu g/m^3$;
- Annual average PM_{10}: 0.1 $\mu g/m^3$;
- 24 hour toluene: 0.04 $\mu g/m^3$;
- Annual average toluene: 0.047 $\mu g/m^3$;
- 24 hour xylene: 0.027 $\mu g/m^3$; and
- Annual average xylene: 0.035 $\mu g/m^3$.

In all cases the forecast increases in ambient air pollutants were small (0.001% to 3.7%), relative to the current air quality goals (shown in **Table 9-3**). The results are summarised below.

Benzene

Based on the worst case scenario, the maximum forecast increases in cancer risk as a result of the proposed Airport Link is 0.24 additional leukaemia cases per 1 million people over 70 years, i.e. 1 additional leukaemia case per 4.2 million people exposed to the worst case increase in ambient annual average benzene over a 70 year period. This is a negligible increase in health risk.

Carbon Monoxide

Based on the worst case scenario, the maximum forecast increases in cardiovascular hospital admissions as a result of the proposed Airport Link is 0.005 persons/100,000, i.e. 1 additional cardiovascular admission per 20 million people exposed to the worst case increase in ambient 8 hour CO. This is a negligible increase in health risk.

Formaldehyde

The forecast worst case contribution of the proposed Airport Link to ambient 24 hour formaldehyde is not expected to have an impact on health. The forecast increase of 0.03 $\mu g/m^3$ represents 3% of the unit risk factor for formaldehyde as a carcinogen which equates to an additional risk of cancer equivalent to 0.39 additional cancer cases per 1 million people exposed to this increase over a 70 year period and therefore no increase in cancer risk.

Nitrogen Dioxide

The worst case increases in acute adverse health events resulting from increases to ambient NO_2 from the proposed Airport Link are forecast to be very small. For every 5 million people exposed to the worst case increase in NO_2 on that day, one additional cardiovascular hospital admission is forecast. For every 10 million people exposed to the worst case increase in NO_2 on that day, one additional death is forecast. These are negligible increases in health risk.

The worst case increase in long term health effects is likely to be negligible, since the forecast increase in ambient annual average NO_2 is equivalent to 1.4% of the levels reported to have an adverse impact on lung function growth in children.

PM_{10}

Small increases in the risk for mortality, hospital admission and respiratory symptoms are forecast. The increased mortality risk is 1 additional death per 287 million people exposed to the worst case PM_{10} increase, while the most adverse increase in hospital admission is equivalent to 1 cardiovascular admission per 192 million people exposed to the worst case PM_{10} increase.

The long term effects of the increase in annual average PM_{10} as a result of emissions from the proposed Airport Link are forecast to be extremely small.

$PM_{2.5}$

A small increase in cardiovascular admissions is forecast, which is equivalent to 1 additional hospital admission per 92 million people exposed to the worst case increase in $PM_{2.5}$. Negligible increases in hospital admission for asthma, and all respiratory conditions are also forecast.

Toluene

The forecast worst case contribution of the proposed Airport Link to ambient 24 hour and annual average toluene are not expected to have an impact on health. The forecast worst case increases of 0.04 $\mu g/m^3$ and 0.047 $\mu g/m^3$ in 24 hour and annual average toluene, respectively, represent increases equivalent to 0.001% and 0.01%

of the AAQ NEPM Monitoring Investigational Levels, which were set in consideration of no adverse health effects.

Xylene

The forecast worst case contribution of the proposed Airport Link to ambient 24 hour and annual average xylene are not expected to have an impact on health. The forecast increases of 0.0027 and 0.0035 $\mu g/m^3$ in 24-hour and annual average xylene, respectively, represent increases equivalent to 0.0025% and 0.004% of the AAQ NEPM Monitoring Investigational Levels, which were set in consideration of no adverse health impacts.

Health Risk Assessment for Roadside Air Pollution

The health effects resulting from changes in roadside pollutants are likely to affect fewer people than the regional changes in pollutants. However, the changes in roadside pollutants, since they are next to major roads, are often higher than regional changes in pollutants. To estimate the likely impact the proximity of child care centres, schools, aged care facilities and hospitals form the major roads are also considered. Both acute and long term health effects are examined, using the same methodology as regional health effect modelling.

The forecast worst case contribution of the proposed Airport Link to near road CO levels is not expected to have an impact on health. The maximum forecast increase in near road CO is 0.21 mg/m^3 at a distance of 10m from Gympie Road and is forecast to result in extremely small increases in hospital admissions for asthma, all respiratory diseases, cardiovascular diseases and mortality. The size of the increases ranged from 0.01-0.003 persons per 100,000 people exposed to the forecast worst case increase in CO. Given the relatively localised increase in the roadside pollutants, this increase is extremely unlikely to have measurable impact on community health.

The forecast worst case contribution of the proposed Airport Link to near road 1-hour maximum NO_2 levels is very low and not expected to have a significant impact on health. The worst case maximum increase in roadside annual NO_2 is more obvious, resulting in 5.80 $\mu g/m^3$ at a distance of 10m from Gympie Road. Previous studies on the growth of lung function in adolescents living in different communities in southern California have found that a 71.5 $\mu g/m^3$ increase in annual average NO_2, over an eight year period, resulted in a 6% increase in the number of 18 year olds who had a clinically significant lower lung function. Based on the forecast annual average level of NO_2 forecast in this study and the published Californian studies, the increase from the proposed Airport Link is around 1.4 % of the value reported in the Californian study and is therefore not likely to have a significant impact on lung function growth of adolescents.

The forecast worst case contribution of the proposed Airport Link to near road 24-hour maximum or annual average PM_{10} levels is not expected to have a significant impact on health. The predicted maximum increase in near road 24-hour PM_{10} is 1.72 $\mu g/m^3$ at a distance of 10 m from Gympie Road. Hospital admissions for all respiratory diseases, cardiovascular diseases and mortality are predicted to increase, although the magnitude of the increases is extremely small and ranged from 0.004-0.009 person per 100,000 people exposed to the forecast worst case increase in PM_{10}. The forecast impact on acute symptoms in adults and children with asthma was also negligible. The worst case increase in annual average PM_{10} is 0.72 $\mu g/m^3$ at a distance of 10 m from Gympie Road. This is not likely to have a significant impact on lung growth or mortality, since it represents a small increase in comparison to levels known to have a long term impact on health.

The forecast worst case contribution of the proposed Airport Link to near road 24-hour maximum or annual average $PM_{2.5}$ levels is not expected to have a significant impact on health. $PM_{2.5}$ is not modelled, although it is assumed conservatively that all of the near-road PM_{10} is $PM_{2.5}$, therefore the size and location of forecast increases was as per PM_{10}. The magnitude of increases in hospital admission for asthma, other respiratory diseases and cardiovascular diseases as result of the worst case increase in $PM_{2.5}$ is very small. Increases of between 0.009-0.02 persons per 100,000 people exposed to the worst case increase are forecast. The long term increase in $PM_{2.5}$ impact is also forecast to be negligible.

Conclusions and Mitigation Measures

The health risk study undertaken in Technical Report No 5B in Volume 3 of the EIS shows that regional air pollution as a result of the proposed Airport Link is not expected to have an impact on community health. As noted above, the worst case changes in regional ambient benzene, carbon monoxide, formaldehyde, nitrogen dioxide, coarse and fine particulate matter, toluene and xylene, as a result of the proposed Airport Link, are forecast to be very small. These worst case increases are used to predict the acute and chronic health impacts based on a range of known published relationships between air pollutants and health. The increased risk of acute adverse health events, such as hospital admissions or mortalityare correspondingly small, in the order of 1 in 5 million to 1 in 300 million on the day and at the location where the forecast worst case occurs. The forecast impact on symptoms of asthmatic children, a sensitive subgroup within the community, is also found to be small, representing a worst case acute effect of a 0.008% increase in lower respiratory tract symptoms. Long term health effects on cancer, mortality and lung function growth in children are also forecast to be negligible.

No mitigation measures to manage regional health effects are required.

9.7 Greenhouse Gases

9.7.1 Introduction

Increasing concentrations of greenhouse gases in the atmosphere have the potential to cause climate change. Brisbane City Council (2001) developed the Sustainable Energy and Greenhouse Action Plan as a framework to assist in managing sustainable energy and reducing greenhouse gas emissions in line with State and National commitments. The plan sets targets for Council, as follows:

- A 20% reduction in 1990 levels of greenhouse gas emissions from Council activities by 2003, leading to a 45% reduction by 2010;
- Stabilisation of greenhouse gas emissions for the community of Brisbane at 2000 levels by 2010; and
- An increase in renewable energy generation and usage within Council to 10 MW by 2010.

BCC is committed to achieving these targets by using renewable energy sources, reducing greenhouse gases, supporting sustainable development and being energy efficient. Specific programs undertaken and planned by BCC include:

- Capturing and flaring landfill gas;
- Introducing energy-efficiency standards for residential and commercial buildings;
- Implementing the Efficient Brisbane incentive and awareness campaign;
- Generating renewable energy from sewage methane at Luggage Point;
- Improving public transport, bikeways and pedestrian facilities;
- Pioneering the introduction of water-saving dual-flush toilets;
- Utilising alternative fuels and vehicle technologies in its fleet; and
- Promoting and facilitating composting and recycling of wastes.

More broadly, the key objectives of the Queensland Government's Queensland Greenhouse Strategy (EPA, 2004) are to:

- Foster increased knowledge and understanding of greenhouse issues and climate change impacts;
- Reduce greenhouse gas emissions; and
- Lay the foundation for adaptation to climate change.

AGO (2005b) has calculated that in 2002 Queensland emitted 145.1 Mt CO_2-e (almost 27% of Australia's total greenhouse gas emissions). Queensland's emissions consisted of 44.1 Mt CO_2-e from electricity generation, 16.8 Mt CO_2-e from the transport sources, and 4.4 Mt CO_2-e from industrial processes, with the remainder attributed primarily to agriculture, landuse, landuse change and forestry.

The Queensland Government's strategies to reduce the rates of increase of greenhouse gases from the transport sector include:

- Improving the energy efficiency of the urban vehicle fleet through "road transport smoothing" programs;
- Improving in-service emission levels of light and heavy vehicles with on-road vehicle emission testing for cars and Smoky Vehicle reporting in south-east Queensland, encouraging the development and uptake of non-fossil-fuelled or lower greenhouse-gas-producing vehicles (e.g. those that may use compressed or natural gas) and informing the national agenda on more stringent national vehicle and fuel emission standards; and
- Reducing emissions from the freight sector through integrated transport planning to minimise the need for freight movement and optimise urban freight logistics, and examining options to reduce congestion and "stop-start" traffic, thereby reducing emissions from each freight vehicle.

The Greenhouse Gas implications of the Airport Link Project have been discussed in the context of the broader Queensland Government and BCC greenhouse strategies.

9.7.2 Methodology

A greenhouse gas inventory has been prepared for the construction and operation of the reference project, to provide an indication of the relative benefits and impacts of the project.

The potential change in vehicle contributions to greenhouse gas emissions between the Do Minimum scenario and the delivery of the Airport Link Project has been investigated. The AGO Factors and Methods Workbook (AGO, 2005a) were used in the preparation of the greenhouse gas inventory for the Airport Link Project. The relevant emission factors are summarised in **Table 9-8**.

- **Table 9-8 Emission Factors for Greenhouse Gases**

Source	Emission Factor
Electricity end use (Qld)	1.058 kg CO_2-e/kWh
Automotive Diesel Oil (Diesel)	2.7 t CO_2-e/kL
Automotive Gasoline (Petrol)	2.5 t CO_2-e/kL

Table Note: Source: AGO (2005a)

9.7.3 Construction

Diesel and electrical power consumption estimates during the 4 years of construction of the reference project are summarised in **Table 9-9**. These estimates are based on preliminary design information relating to the works and are based on typical diesel consumption rates in the construction vehicle fleet, electricity consumption from tunnel excavation and ventilation equipment, site services. The corresponding greenhouse gas emission estimates resulting from construction of the reference project are also included in **Table 9-9**. Construction of the reference project is estimated to result in approximately 0.31 Mt CO_2-e of greenhouse gases.

The emissions estimated over the 4 year construction period represent a small fraction of Queensland's annual greenhouse gas emissions. Mitigation options would be considered as part of further design refinements and implemented during the construction works to minimise energy consumption and greenhouse gas emissions.

- **Table 9-9 Diesel and Electricity Consumption and Greenhouse Gas Emissions during Construction**

Construction Activity	Diesel Consumption	Electricity Consumption	Greenhouse Gas Emissions
Excavation equipment	90 ML	32 million kWh	0.28 Mt CO_2-e
Ventilation and other services		30 million kWh	0.03 Mt CO_2-e

9.7.4 Operation

The estimated energy consumption during operation of the reference project is 32 GWhr per year, comprising mainly tunnel ventilation. This energy consumption represents about 0.034 Mt CO_2-e per year of greenhouse gases, based on current emission factors for black coal-fired power generation in Queensland.

The delivery of the Airport Link Project may affect road network performance and therefore greenhouse gas emissions from Brisbane's vehicle fleet. Aside from engine fuel efficiency modifications, greenhouse gas emissions reductions could arise by either reducing vehicle kilometres travelled (VKT) for the network or improving the flow of traffic, which improves the fuel efficiency of vehicles.

For the purposes of this assessment, the efficiency of the road network was assumed to be reflected in a comparison of projected VKT with and without the reference project. This is considered a conservative assumption as it does not account for any improvements in traffic flow or potential future improvements in energy efficiency from alternative fuels. The projected VKT on the Brisbane road network with and without the reference project is shown in **Table 9-10**. These data show an overall increase in VKT on the Brisbane metropolitan road network, based on population growth and changes in background traffic, network reliability and the like.

Further detail on the traffic projections for the reference project is provided in Chapter 5 of the EIS. In summary, the reference project is expected to result in a small increase in VKT (approximately 0.1%) across the Brisbane road network.

Table 9-10 Total VKT Data for Brisbane

Year	Do Minimum Scenario (AWDT)	Airport Link Scenario (AWDT)	Difference in VKT
2012 VKT	55,754,160	55,832,875	+78,715 AWDT +25,976,065 Annual
2016 VKT	60,289,829	60,357,082	+67,253 AWDT +22,193,337 Annual
2022 VKT	66,742,050	66,793,487	+51,436 AWDT +16,974,032 Annual
2026 VKT	71,269,228	71,316,778	+47,550 AWDT +15,691,523 Annual

Table Notes:
AWDT = average weekday travelled
Annual = AWDT x 330

The greenhouse gas emissions from vehicles are determined using the following assumptions:

- The vehicle fleet consists of 95% passenger cars, and 5% heavy vehicles (4% medium (or rigid) trucks, 1% heavy (articulated) trucks);
- Fuel consumption rates per kilometre are derived from AGO (2005a) (refer to **Table 9-11**); and
- All heavy vehicles use diesel and all small vehicles use petrol.

Table 9-11Fuel Consumption Rates by Vehicle Type

Source	Fuel	Fuel Consumption
Passenger Cars	Petrol	0.107 L/km
Medium Trucks	Diesel	0.283 L/km
Heavy Trucks	Diesel	0.542 L/km

Table Note: Source: AGO (2005a)

The difference in greenhouse gases emissions as a result of changed network performance on the Brisbane road network due to the implementation of the reference project is shown in **Table 9-12**.

Table 9-12 Difference in Greenhouse Gas Emissions from Network Performance

Year	Difference in VKT from Project implementation (km/yr)	Difference in Greenhouse Gas Emissions (t CO_2-e/yr)
2012	+ 25,976,065	+ 7,775
2016	+22,193,337	+ 6,643
2022	+ 16,974,032	+ 5,081
2026	+ 15,691,523	+ 4,697

The greenhouse inventory for the implementation of the reference project indicates that there will be a small increase in greenhouse gas emissions due to an increase in VKT. However, the calculation methodology is considered conservative as it does not account for any improvements as a result of reduced road congestion that is likely to result along Lutwyche Road, Sandgate Road, Kedron Park Road, and Albion Road as a result of delivering the reference project. Fuel consumption per vehicle under congested traffic conditions is approximately twice that under free-flow conditions (BTE, 2000).

As outlined in Chapter 5 of the EIS, significant traffic congestion is forecast along Lutwyche Road as part of the Do Minimum project, if the Northern Busway and Airport Link Projects are not delivered. The combined projects will reduce surface congestion and generate capacity for free flowing, reliable and effective busway services to the northern suburbs of Brisbane. Motorists using Airport Link will avoid 16 sets of traffic lights between Bowen Hills and Kedron and 14 sets between Bowen Hills and Toombul.

It is therefore likely that the implementation of the Airport Link (and Northern Busway) Project would result in improved energy efficiency within Brisbane's vehicle fleet, compared with the no project case.

9.7.5 Conclusion and Mitigation Measures

In order to minimise greenhouse gas emissions due to construction of the project a variety of mitigation and management measures are available, including:

- Designing a construction works program to minimise haul distances from construction sites to spoil placement locations;
- Maintaining construction equipment and haul trucks in good working order so fuel efficiency of equipment is maximised;
- Using of appropriately sized equipment for construction activities;
- Minimising waste from construction;
- Substituting high energy intensity building materials, where possible, for materials that have a lower energy intensity; and
- Using low intensity lighting throughout the length of the tunnel; more powerful lighting is used at the portals for safety reasons.

In order to minimise greenhouse gas emissions during operation of the reference project a variety of mitigation and management measures are available, including:

- Automatic control of light intensity in the portal region as varying with ambient light conditions on the surface; and
- Design of ventilation system which utilises the piston effect of traffic movement through the tunnels and utilises demand management of the ventilation system based on in-tunnel concentrations of air pollutants or in the event of fire or emergency situations.

Further design refinements will consider measures to minimise energy consumption and greenhouse gas generation. Although the traffic modelling shows the implementation of the reference project would result in an overall increase in VKT on the Brisbane road network, and therefore an increase in greenhouse gas emissions compared with a lesser amount of traffic travelling at the same speed, the improvements in energy efficiency within Brisbane's vehicle fleet (from reduced congestion) is likely to result in a small reduction in greenhouse gas emissions per passenger kilometre travelled compared with the Do Minimum scenario. Easing congestion on surface streets will provide opportunities to improve public transport network, such as the implementation of Northern Busway Stage 2. Improving public transport is also likely to result in improvements to Brisbane's transport related greenhouse gas emissions.

BCC is committed to achieving the targets for its greenhouse gas production by using renewable energy sources, reducing greenhouse gases, supporting sustainable development and being energy efficient. In parallel to this project, BCC and the Queensland government are managing greenhouse emissions across the community through the provision of better public transport alternatives, travel demand management measures and promoting cycling and walking as important transport modes.