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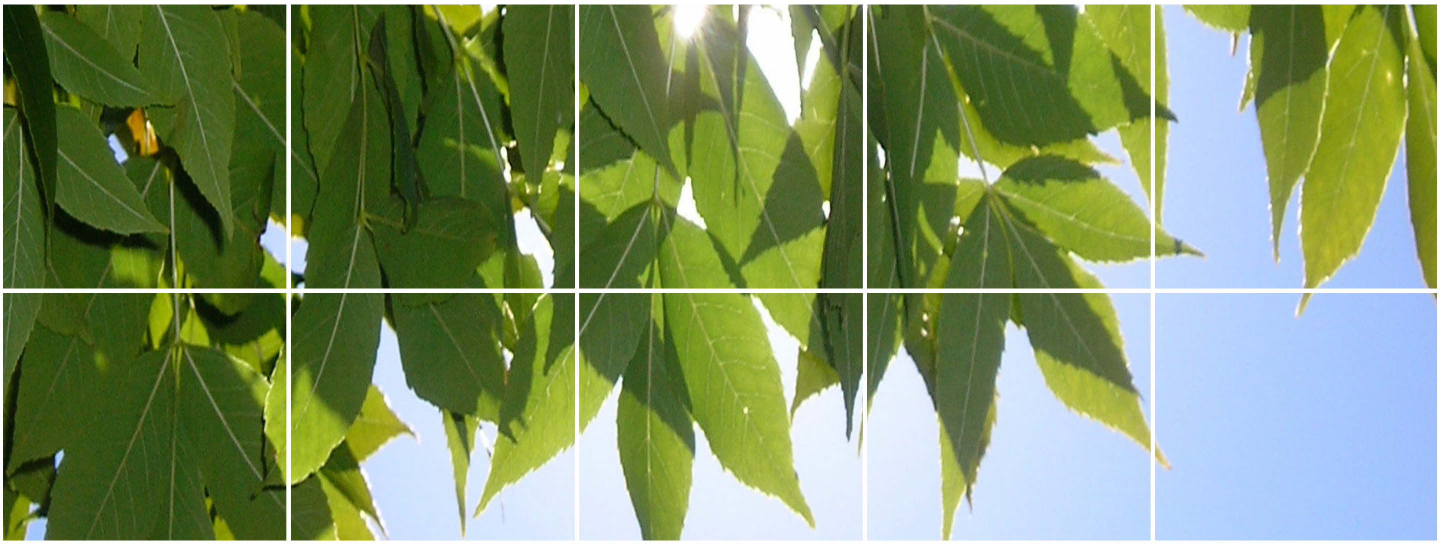

Air Quality Review and Assessment – Detailed Assessment for Southampton

Southampton City Council

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Executive summary

The UK Government published its strategic policy framework for air quality management in 1995 establishing national strategies and policies on air quality, which culminated in the Environment Act, 1995. The Air Quality Strategy provides a framework for air quality control through air quality management and air quality standards. These and other air quality standards[1] and their objectives[2] have been enacted through the Air Quality Regulations in 1997 and 2000, the Air Quality (Amendment) Regulations 2002 and the Air Quality Strategy 2007. The Environment Act 1995 requires Local Authorities to undertake an air quality review. In areas where the air quality objective is not anticipated to be met, Local Authorities are required to establish Air Quality Management Areas to improve air quality.

The intention is that local authorities should only undertake a level of assessment that is proportionate to the risk of air quality objectives being exceeded. The first step in the second round of review and assessment is an Updating and Screening Assessment (USA), which is to be undertaken by all authorities. Where the USA has identified a risk that an air quality objective will be exceeded, the authority is required to undertake a detailed assessment.

Southampton City Council completed a Detailed Assessment which concluded that they needed to declare air quality management areas (AQMAs) for NO_2 at 6 locations in the city. These AQMAs had since been declared and Southampton City Council has completed a Further Assessment to confirm the conclusions of the Detailed Assessment in 2006.

Summary of the 2006 Further Assessment

The 2006 Further Assessment has predicted exceedences of the UK objective for annual mean NO_2 in 2005 in Southampton at the following locations:

- AQMA 1: Bevois Valley - An area along Onslow road from Bevois Hill down to (and encompassing) the Charlotte Place Roundabout
- AQMA 4: Town Quay - An area along the A33 Town Quay between West Quay Road Roundabout and Terminus Terrace (including Terminus Terrace between Platform Road and Bernard Street)
- AQMA 5: Redbridge Road - An area encompassing the Redbridge Road Flyover and Roundabout and sections of the approaching roads

Exceedences were also indicated by diffusion tubes and/or modelling in 2005 at the following areas outside the declared AQMAs:

- 5 Commercial Road (Site 21)
- Hill Lane (Site 22)
- The Avenue (Site 11)
- Near A33 in Millbrook Road at Aukland Road(Site 3)
- Regents Park Junction (Site 4)
- Waterhouse Lane (Site 26).

Modelling of nitrogen dioxide concentrations in 2010 has indicated that a decline in nitrogen dioxide concentrations is expected when compared with 2005, with exceedences of the $40\mu g/m^3$ annual mean objective only in AQMA 1 and AQMA 4.

[1] Refers to standards recommended by the Expert Panel on Air Quality Standards. Recommended standards are set purely with regard to scientific and medical evidence on the effects of the particular pollutants on health, at levels at which risks to public health, including vulnerable groups, are very small or regarded as negligible.
[2] Refers to objectives in the Strategy for each of the eight pollutants. The objectives provide policy targets by outlining what should be achieved in the light of the air quality standards and other relevant factors and are expressed as a given ambient concentration to be achieved within a given timescale.

This Further Assessment has made following recommendations:

- Southampton City Council should consider declaring an AQMA at the junction between Commercial Road and Cumberland Place.
- AQMA 1 may need to be expanded slightly at the junction between St Mary's Road and Graham Road to cover the building facades with predicted annual mean NO_2 concentration above the objective. Council should also consider additional diffusion tubes at the northern and southern ends of this AQMA.
- AQMA 2: revoke.
- AQMA 3: move Sites 11 & 22 to facades of the nearest receptors and initiate a new monitoring site at the junction between Winchester Road and Bassett Avenue. If monitoring shows no exceedence, then revoke.
- Southampton City Council should consider extending AQMA 4 to include B3039 in Canute Road and in Royal Crescent Road, and locate monitors at the facades of the properties close to the ferry pier.
- AQMA5 may need to be expanded to include the building with predicted annual mean NO_2 concentration above the objective, if the building represents relevant exposure, and place additional monitoring sites at the nearest relevant receptors to the road.
- AQMA 6: collect and analyse data from the newly established diffusion tube site at 148 Romsey Road (established in March 2006). If monitoring shows no exceedence, then revoke.
- Diffusion tube site in Waterhouse Lane should be moved to the façade of the nearest relevant receptor. If monitoring shows exceedences, an air quality management area may need to be declared near the diffusion tube site.

Summary of the results of this Detailed Assessment

Following the completion of the 2006 Further Assessment, Southampton City Council commissioned **AEA Energy & Environment** to review the diffusion data for 2006 and to undertake a Detailed Assessment for three additional areas that have not been included in the 2006 Further Assessments. The three areas are:

- PM_{10} for the area between Redbridge roundabout and Millbrook roundabout
- Nitrogen dioxide (NO_2) for Mount Pleasant Level Crossing in Bevois Valley Area
- Nitrogen dioxide (NO_2) for the junction between Bursledon Road and Kathleen Road

This report therefore constitutes a Detailed Assessment for Southampton City Council for these three additional areas. The assessment has investigated the nitrogen dioxide levels in 2005 and 2010 through modelling exercises and by reference to the latest monitored air quality data for Mount Pleasant Crossing and Bursledon Road, and PM_{10} levels in 2005, 2010 and 2012 for the area between Redbridge roundabout and Millbrook roundabout.

Modelling results for NO_2 in Mount Pleasant Road/Crossing

Both diffusion tube and model indicate no exceedence of the annual mean and the hourly mean objectives for NO_2 in this area in 2005.

No exceedence is predicted in 2010.

Modelling results for NO_2 in the Bursledon/Kathleen Road area

Exceedences of the annual mean objective were indicated by a diffusion tube in this area, but not by the model. It was estimated that the annual mean objective for NO_2 has been exceeded at the nearest building facade to the diffusion tube at the junction between Bursledon Road and Kathleen Road in 2005 using the adjustment factors from the helpdesk FAQ (i.e. www.uwe.ac.uk/aqm/review)

No exceedence is predicted in this area in 2010.

Modelling results for PM_{10} between Redbridge Roundabout and Millbrook Roundabout

The model predicts that the objectives of annual mean of 40µg/m^3 and the 24-hour mean of 50µg/m^3 not to be exceeded more 35 times per year have not been exceeded in the area in 2005.

Despite the forecast of a fast growth of traffic volume to Gate 20 of Southampton Port, no exceedence of the annual mean objective for PM_{10} is predicted in the area in 2010 and 2012, and the 24-hour mean objective for PM_{10} will not be exceeded more than 35 times in these future years.

Recommendations

- Southampton City Council should continue the monitoring by diffusion tube at Mount Pleasant Crossing to confirm the predicted trend. The diffusion tube site at Mount Pleasant Road can be removed.
- Southampton City Council could either introduce a diffusion tube at the nearest building facade to diffusion tube Sites 31 in Bursledon Road for 12 months and declare an AQMA for NO_2 if exceedences are indicated at the new site or declare an AQMA including the nearest property to site 31 now.
- Because of exceedences indicated by diffusion tubes in 2005 & 2006 and by model (results were presented in the 2006 Further Assessment), Southampton City Council should consider declaring an AQMA for NO_2 in Commercial Road including an area as indicated in the 2006 Further Assessment.
- Because of exceedences indicated by diffusion tubes in 2005 & 2006, Southampton City Council should consider declaring an AQMA for NO_2 at 305 Millbrook Road West (previously named as Waterhouse Lane).

Maps reproduced within this document

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Appendices

Acronyms and definitions used in this report

AADTF	Annual Average Daily Traffic Flow
ADMS	an atmospheric dispersion model
AQDD	an EU directive (part of EU law) - Common Position on Air Quality Daughter Directives, commonly referred to as the Air Quality Daughter Directive
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
AURN	Automatic Urban and Rural Network (Defra funded network)
base case	In the context of this report, the emissions or concentrations predicted at the date of the relevant air quality objective (2005 for nitrogen dioxide)
CO	Carbon monoxide
d.f.	degrees of freedom (in statistical analysis of data)
DETR	Department of the Environment Transport and the Regions (now Defra)
Defra	Department of the Environment, Food and Rural Affairs
DMRB	Design Manual for Roads and Bridges
EA	Environment Agency
EPA	Environmental Protection Act
EPAQS	Expert Panel on Air Quality Standards (UK panel)
EU	European Union
GIS	Geographical Information System
HDV	All commercial vehicles, including HGV , buses and coaches
HGV	Vehicles > 7.5T
kerbside	0 to 1 m from the kerb
LGV	Vehicles 3.5 –7.5 T
Limit Value	An EU definition for an air quality standard of a pollutant listed in the air quality directives
NAEI	National Atmospheric Emission Inventory
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NRTF	National Road Traffic Forecast
ppb	parts per billion (1 ppb is 1 volume of pollutant in 10^9 volumes of air
PSG	All buses and coaches
r	the correlation coefficient (between two variables)
receptor	In the context of this study, the relevant location where air quality is assessed or predicted (for example, houses, hospitals and schools)
roadside	1 to 5 m from the kerb
SD	standard deviation (of a range of data)
SEPA	Scottish Environment Protection Agency
SO_2	Sulphur dioxide
TEA	Triethanolamine
TEMPRO	A piece of software produced by the Defra used to forecast traffic flow increases
TEOM	Tapered Element Oscillating Microbalance
TEOM (Grav.)	TEOM Measurements expressed as the equivalent value from a gravimetric monitor
V/V	Volume ratio

1 Introduction

1.1 Purpose of the study

Southampton City Council have completed a Detailed Assessment which concluded that they needed to declare air quality management areas (AQMAs) for NO_2 at the following 6 locations in the city as:

- AQMA 1: Bevois Valley - An area along Onslow road from Bevois Hill down to (and encompassing) the Charlotte Place Roundabout
- AQMA 2: Bitterne Road West - An area along Bitterne Road West from the junction with Hawkeswood Road/Quayside Road to the junction with Maybray King Way and Little Lance's Hill
- AQMA 3: Winchester Road - An area along Winchester Road, between and including the junctions with Hill Lane and Bassett Avenue
- AQMA 4: Town Quay - An area along the A33 Town Quay between West Quay Road Roundabout and Terminus Terrace (including Terminus Terrace between Platform Road and Bernard Street)
- AQMA 5: Redbridge Road - An area encompassing the Redbridge Road Flyover and Roundabout and sections of the approaching roads
- AQMA 6: Romsey Road - An area encompassing part of Romsey Road and its junction with Winchester Road

These AQMAs have since been declared and Southampton City Council has completed a Further Assessment for NO_2 in these AQMAs to confirm the conclusions of the Detailed Assessment, and to assess potential measures which could be considered in the City's Action Plan. In addition, the following areas were also included in the Further Assessment:

- St Andrews Road (extension to AQMA 1)
- Redbridge Causeway, west of flyover by Test Lane (extension to AQMA 5)
- West Quay Road, Platform Road, Terminus Terrace and Orchard Place (extensions to AQMA 4)
- Victoria Road
- Bullar Road, Cobbett Road and Athelstan Road (extension to AQMA 2)
- Britannia Road

Following the completion of the 2006 Further Assessment, Southampton City Council had commissioned **AEA Energy & Environment** to review the diffusion data for 2006 and to undertake a Detailed Assessment for three additional areas which haven't included in the Further Assessment. The three additional areas are:

- PM10 for the area between Redbridge R/B and Millbrook R/B
- Nitrogen dioxide (NO_2) for Mount Pleasant Level Crossing in Bevois Valley Area
- Nitrogen dioxide (NO_2) for the junction between Bursledon Road and Kathleen Road

1.2 General approach taken

The approach taken in this study was to:

- Collect and interpret additional data to that already used in previous assessments, in order to support this Detailed Assessment, including more detailed traffic flow data around the areas of concern;
- Utilise the monitoring data from the Council's monitoring campaign to assess the ambient concentrations resulting from road traffic emissions, and to validate the output of the modelling studies;
- Model the concentrations of PM_{10} and NO_2 around the areas outlined above in 2005 and 2010 concentrating on the locations (receptors) where people might be exposed over the relevant averaging times of the air quality objectives;
- Present the concentrations as contour plots and assess the uncertainty in the predicted concentrations.

1.3 Version of the Pollutant Specific Guidance used in this assessment

This report has used the latest guidance in LAQM.TG(03), published in February 2003.

1.4 Numbering of figures and tables

The numbering scheme is not sequential, and the figures and tables are numbered according to the chapter and section that they relate to.

1.5 Units of concentration

The units throughout this report are presented in $\mu g\ m^{-3}$ (which is consistent with the presentation of the new AQS objectives), unless otherwise noted.

1.6 Structure of the report

This document is a detailed air quality review for Southampton City Council for nitrogen dioxide and PM_{10}.

Chapter 1 has summarised the need for the work and the approach to complete the study.

Chapter 2 of the report describes developments in the UK's Air Quality Strategy (AQS). In addition, it discusses when implementation of an AQMA is required.

Chapter 3 contains details of the information used to conduct this Detailed Assessment.

Chapter 4 introduces the latest standards and objectives for nitrogen dioxide, summarises and reviews the monitoring of NO_2 in the areas of concern in 2005 and 2006, and further model validation using the monitoring data.

Chapter 5 describes the NO_2 results of the modelling assessment and discusses whether the nitrogen dioxide objectives will be exceeded in 2005 (the base year) and in 2010. The results of the analysis are displayed as contour plots.

Chapter 6 introduces the latest standards and objectives for PM_{10}, summarises the monitoring data in the areas of concern and model validation against monitoring data.

Chapter 7 describes the PM_{10} results of the modelling assessment and discusses whether the PM_{10} objectives will be exceeded in 2005 (the base year) and in 2010 and 2012 in the area between Redbridge roundabout and Millbrook Roundabout. The results of the analysis are displayed as contour plots.

Chapter 8 summarises the recommendations from this study.

1.7 GIS data used

Southampton City Council provided the Ordnance Survey landline data for use in this project.

1.8 Explanation of the modelling output

The contour maps generated in the modelling for this report are an indication of the predicted pollutant concentrations around the area modelled. They are not lines of absolute values and should not be considered as such. Care should also be taken, in cases where contours join up as enclosed loops. This is common, for example along a section of road. The contours may appear to circle a section of the road, rather than extend all the way along it. This is due to the input area over which the model was run being only a section of the road in question. No assumptions of pollutant concentrations can be made on locations outside of the area being modelled.

2 The updated Air Quality Strategy

2.1 The need for an Air Quality Strategy

The Government published its proposals for review of the National Air Quality Strategy in early 1999 (DETR, 1999). These proposals included revised objectives for many of the regulated pollutants. A key factor in the proposals to revise the objectives was the agreement in June 1998 at the European Union Environment Council of a Common Position on Air Quality Daughter Directives (AQDD).

Following consultation on the Review of the National Air Quality Strategy, the Government prepared the Air Quality Strategy for England, Scotland, Wales and Northern Ireland for consultation in August 1999. It was published in January 2000 (DETR, 2000). This Air Quality strategy established the framework for achieving improvement in ambient air quality in the UK to 2003 and beyond and it was followed by an Addendum in February 2003 which tightened several of the objectives and introduced a new one. A formal consultation and review of the 2000 Air Quality Strategy took place in 2006 and a new Air Quality Strategy for England, Scotland, Wales and Northern Ireland was published in 2007.

The Environment Act (1995) provides the legal framework for requiring LA's to review air quality and for implementation of an AQMA. The main constituents of this Act are summarised in Table 2.1 below.

Table 2.1 Major elements of the Environment Act 1995

Part IV Air Quality	Commentary
Section 80	Obliges the Secretary of State (SoS) to publish a National Air Quality Strategy as soon as possible.
Section 81	Obliges the Environment Agency to take account of the strategy.
Section 82	Requires local authorities, any unitary or Borough, to review air quality and to assess whether the air quality standards and objectives are being achieved. Areas where standards fall short must be identified.
Section 83	Requires a local authority, for any area where air quality standards are not being met, to issue an order designating it an air quality management area (AQMA).
Section 84	Imposes duties on a local authority with respect to AQMAs. The local authority must carry out further assessments and draw up an action plan specifying the measures to be carried out and the timescale to bring air quality in the area back within limits.
Section 85	Gives reserve powers to cause assessments to be made in any area and to give instructions to a local authority to take specified actions. Authorities have a duty to comply with these instructions.
Section 86	Provides for the role of County Councils to make recommendations to a district on the carrying out of an air quality assessment and the preparation of an action plan.
Section 87	Provides the SoS with wide ranging powers to make regulations concerning air quality. These include standards and objectives, the conferring of powers and duties, the prohibition and restriction of certain activities or vehicles, the obtaining of information, the levying of fines and penalties, the hearing of appeals and other criteria. The regulations must be approved by affirmative resolution of both Houses of Parliament.
Section 88	Provides powers to make guidance which local authorities must have regard to.

2.2 Overview of the principles and main elements of the National Air Quality Strategy

The main elements of the AQS can be summarised as follows:

- The use of a health effects based approach using national air quality standards and objectives.
- The use of policies by which the objectives can be achieved and which include the input of important factors such as industry, transportation bodies and local authorities.
- The predetermination of timescales with target dates of 2003, 2004, 2005, 2008 and 2010 for the achievement of objectives and a commitment to review the Strategy every three years.

It is intended that the AQS will provide a framework for the improvement of air quality that is both clear and workable. In order to achieve this, the Strategy is based on several principles which include:

- the provision of a statement of the Government's general aims regarding air quality;
- clear and measurable targets;
- a balance between local and national action and
- a transparent and flexible framework.

Co-operation and participation by different economic and governmental sectors is also encouraged within the context of existing and potential future international policy commitments.

National Air Quality Standards
At the centre of the AQS is the use of national air quality standards to enable air quality to be measured and assessed. These also provide the means by which objectives and timescales for the achievement of objectives can be set. Most of the proposed standards have been based on the available information concerning the health effects resulting from different ambient concentrations of selected pollutants and are the consensus view of medical experts on the Expert Panel on Air Quality Standards (EPAQS). These standards and associated specific objectives to be achieved between 2003 and 2010 are shown in Table 2.2. The table shows the standards in ppb and $\mu g\ m^{-3}$ with the number of exceedences that are permitted (where applicable) and the equivalent percentile.

Specific objectives relate either to achieving the full standard or, where use has been made of a short averaging period, objectives are sometimes expressed in terms of percentile compliance. The use of percentiles means that a limited number of exceedences of the air quality standard over a particular timescale, usually a year, are permitted. This is to account for unusual meteorological conditions or particular events such as November 5th. For example, if an objective is to be complied with at the 99.9th percentile, then 99.9% of measurements at each location must be at or below the level specified.

Table 2.2 Air Quality Objectives in the Air Quality Regulations (2000) and (Amendment) Regulations 2002 for the purpose of Local Air Quality Management in England.

Pollutant	Concentration limits		Averaging period	Objective [number of permitted exceedences a year and equivalent percentile]	
	($\mu g\ m^{-3}$)	(ppb)		($\mu g\ m^{-3}$)	date for objective
Benzene	16.25	5	**running annual** mean	**16.25**	by 31.12.2003
	5	1.5	**Annual mean**	**5**	by 31.12.2010
1,3-butadiene	2.25	1	**running annual** mean	**2.25**	by 31.12.2003
Carbon monoxide	10,000	8,600	**running 8-hour** mean	**10,000**	by 31.12.2003
Lead	0.5	-	**annual** mean	**0.5**	by 31.12.2004
	0.25	-	**annual** mean	**0.25**	by 31.12.2008
NO_2 (see note)	200	105	**1 hour** mean	**200** [maximum of 18 exceedences a year or equivalent to the 99.8th percentile]	by 31.12.2005
	40	21	**annual** mean	**40**	by 31.12.2005
PM_{10} gravimetric (see note)	50	-	**24-hour** mean	**50** [maximum of 35 exceedences a year or ~ equivalent to the 90th percentile]	by 31.12.2004
	40	-	**annual** mean	**40**	by 31.12.2004
	The indicative 2001 objectives for PM_{10} have been replaced by an exposure reduction approach for $PM_{2.5}$ (except in Scotland) in the 2007 Air Quality Strategy as an annual mean objective of 25 μgm^{-3} for $PM_{2.5}$ to be met by 2020 in UK (except Scotland) and a target of 15% reduction in $PM_{2.5}$ concentration at urban background for UK urban areas				
Sulphur dioxide	266	100	**15 minute** mean	**266** [maximum of 35 exceedences a year or equivalent to the 99.9th percentile]	by 31.12.2005
	350	132	**1 hour** mean	**350** [maximum of 24 exceedences a year or equivalent to the 99.7th percentile]	by 31.12.2004
	125	47	**24 hour** mean	**125** [maximum of 3 exceedences a year or equivalent to the 99th percentile]	by 31.12.2004

Notes

1. Conversions of ppb and ppm to ($\mu g\ m^{-3}$) correct at 20°C and 1013 mb.
2. PM_{10} measured using the European gravimetric transfer standard or equivalent.

2.3 Air Quality Reviews

A range of Technical Guidance has been issued to enable air quality to be monitored, modelled, reviewed and assessed in an appropriate and consistent fashion. This includes LAQM.TG(03), on 'Local Air Quality Management: Technical Guidance, February 2003. This review and assessment has considered the procedures set out in the guidance.

The primary objective of undertaking a review of air quality is to identify any areas that are unlikely to meet national air quality objectives and ensure that air quality is considered in local authority decision making processes. The complexity and detail required in a review depends on the risk of failing to achieve air quality objectives and it has been proposed in the second round that reviews should be carried out in two stages. Every authority is expected to undertake at least a first stage Updating and screening Assessment (USA) of air quality in their authority area. Where the USA has identified a risk that an air quality objective will be exceeded at a location with relevant public exposure, the authority will be required to undertake a Further assessment. The Stages are briefly described in the following table, Table 2.3.

Table 2.3: The phased approach to review and assessment.

Level of assessment	Objective	Approach
Updating and screening assessment (USA)	To identify those matters that have changed since the last review and assessment, which might lead to a risk of the air quality objective being exceeded.	Use a check list to identify significant changes that require further consideration. Where such changes are identified, apply simple screening tools to decide whether there is sufficient risk of an exceedence of an objective to justify a Further assessment
Detailed assessment	To provide an accurate assessment of the likelihood of an air quality objective being exceeded at locations with relevant exposure. This should be sufficient to recommend designation or amendment or any necessary AQMAs.	Use quality-assured monitoring and validated modelling methods to determine current and future pollutant concentrations in areas where there is a significant risk of exceeding an air quality objective.
Further assessment	Confirm boundaries of identified areas of exceedence using the latest and most detailed input information available. Provide source apportionment information to identify primary emissions sources contributing to exceedences so that action planning measures can be targeted. Test out the likely impact of potential action planning scenarios if possible.	Use quality-assured monitoring and validated modelling methods to determine current and future pollutant concentrations in areas where there is a significant risk of exceeding an air quality objective.

2.4 Locations that the review and assessment must concentrate on

For the purpose of review and assessment, the authority should focus their work on locations where members of the public are likely to be exposed over the averaging period of the objective. Table 2.4 summarises the locations where the objectives should and should not apply.

Table 2.4 Typical locations where the objectives should and should not apply

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
Annual mean	• 1,3 Butadiene • Benzene • Lead • Nitrogen dioxide • Particulate Matter (PM_{10})	• All background locations where members of the public might be regularly exposed.	• Building façades of offices or other places of work where members of the public do not have regular access.
		• Building façades of residential properties, schools, hospitals, libraries etc.	• Gardens of residential properties.
			• Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term
24 hour mean and 8-hour mean	• Carbon monoxide • Particulate Matter (PM_{10}) • Sulphur dioxide	• All locations where the annual mean objective would apply.	• Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
		• Gardens of residential properties.	

Table 2.4 (contd.) Typical locations where the objectives should and should not apply (England only)

Averaging Period	Pollutants	Objectives should apply at …	Objectives should generally not apply at …
1 hour mean	• Nitrogen dioxide • Sulphur dioxide	• All locations where the annual mean and 24 and 8-hour mean objectives apply.	• Kerbside sites where the public would not be expected to have regular access.
		• Kerbside sites (e.g. pavements of busy shopping streets).	
		• Those parts of car parks and railway stations etc. which are not fully enclosed.	
		• Any outdoor locations to which the public might reasonably expected to have access.	
15 minute mean	• Sulphur dioxide	• All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

It is unnecessary to consider exceedences of the objectives at any location where public exposure over the relevant averaging period would be unrealistic, and the locations should represent non-occupational exposure.

Key Points

- The Environment Act 1995 has required the development of a National Air Quality Strategy for the control of air quality.
- A central element in the Strategy is the use of air quality standards and associated objectives based on human health effects that have been included in the Air Quality Regulations.
- The Strategy uses a local air quality management approach in addition to existing national and international legislation. It promotes an integrated approach to air quality control by the various factors and agencies involved.
- Air quality objectives, with the exception of ozone, are to be achieved by specified dates up to the end of 2010.

3 Information used to support this assessment

This chapter summarises the information used to support this review and assessment. The assessment model developed for the 2006 Further assessment was extended for this Detailed Assessment. This assessment model was developed for a large area including all AQMAs. Information and input data, such as traffic data on main roads in the large area and the shipping data, were described in the report for the 2006 Further Assessment and have not been repeated in full here. Only new data and data which are specific for the areas subject to this Detailed Assessment are presented here.

3.1 Maps

Southampton City Council provided OS Landline data of the areas in the city, which needed to be modelled. This enabled accurate road widths and the distances to be determined. Figure 3.1 below shows the AQMAs declared in Southampton, locations of the areas subject to this detailed assessment and the road links included in the assessment model. Figures 3.2 & 3.4 show the assessed areas in details and the diffusion tube sites within the areas.

3.2 Road traffic data

AADT flow, hourly fluctuations in flow, speed and fraction of HDVs.

Road traffic data for Southampton in 2005 were summarised in Appendix 1 of the 2006 Further Assessment. In additional to these data, COUNT ON US carried out detailed traffic survey at the roundabout of Millbrook Flyover and in First Avenue on 29th March 2007 and the results are summarised in Tables A1.1 – A1.3 in Appendix 1 of this report. The traffic data at Mount Pleasant Road and Bursledon Road are given in Table A1.4 of Appendix 1.

Traffic flows in 2010 and 2012 were estimated using traffic growth factors derived from the NRTF and the TEMPRO v4 model. Growth factors used in the assessment to predict traffic flows in Southampton in future years are given in Table A1.5 of Appendix 1.

To determine the hourly fluctuations in traffic flow, the DETR's diurnal traffic variation default figures were used (DETR, 2002).

3.3 Shipping data

Shipping data used for this assessment are the same as those used for the 2006 Further Assessment. Detailed description of the data can be found in the report for the 2006 Further Assessment.

Shipping data were obtained from Associated British Ports (ABP) and Marine Environmental Research Ltd. From these sources and from discussion with ABP and Red Funnel, estimates were made of ship tonnage; engine and fuel specification; time spent and average speed of cruising, manovering and hotelling. Emissions estimates were then made of total annual emissions in port during cruising, manovering and hotelling, and in berth. The total emissions were estimated to be approximately 3671 tonnes NO_x per year in 2005. This figure is within 5% of the figure of 3872 tonnes/year cited for existing Port of Southampton facilities in 2011 *Dibden terminal combined sources impact assessment* (Laxen and Wilson (2002)) and is therefore likely to represent a good estimate of port emissions in 2005. The number of ferry movements is not anticipated to increase significantly between 2005 and 2010, and ABP advised that emissions from increases in container and cruise shipping movements might be offset by improvements in technology, in particular as increased tonnage would be accommodated in part by larger, newer ships. The assumption has therefore been made that Port of Southampton emissions will not increase significantly between 2005 and 2010, even with increased container and Ro-Ro tonnage.

3.4 Train emission Data

Measured emission factors for current in-service diesel trains are fairly limited. For NOx, the emission factor used for this assessment was taken from the DfT Rail Model, which is being developed by AEA Energy & Environment for DfT. In the DfT Rail Model, measured data for different classes of trains from a few data sources were grouped into engine size ranges or train classes matching those used in the European Commission's amendments to the Non-Road Mobile Machinery (NRMM) Directive 97/68/EC, for Stage IIIA and Stage IIIB engines. Emission factors for Diesel Multiple Units (DMUs) are provided for representative classes of DMUs for which data were available.

Trains passing the Mount Pleasant Crossing are mainly Class 66 Diesel trains and the emission factors used in this assessment are given in Table A1.6 of Appendix 1.

3.5 Meteorological data used in the dispersion modelling

Hourly sequential meteorological data for the nearest suitable meteorological station with adequate data capture was obtained from Southampton Weather Center for 2005. The meteorological data provided information on wind speed and direction and the extent of cloud cover for each hour of the year.

3.6 Ambient monitoring

Nitrogen dioxide concentrations are monitored:

- By continuous monitors at four sites in Southampton as:
    - The Defra Automatic Urban Network station at Brintons Road by the Six Dials junction, established in 1994.
    - A permanent station at Redbridge Community School, established in April 1999.
    - A roadside station opposite 3 Onslow Road, established in July 2005.
    - A mobile unit currently sited at Bitterne Road opposite Mays Carpets.

  The monitoring results are given in Appendix 2.

- By diffusion tubes. Diffusion tube results are available for 37 roadside locations within the city of Southampton. The tubes are supplied and analysed by Gradko. The raw monthly diffusion tube data and their average concentrations in 2005 can be found in Appendix 2 of the 2006 Further Assessment.

Collocation studies were undertaken at three sites in Southampton, i.e. the automatic monitoring station in Brintons Road, the permanent station at Redbridge Community School and the mobile monitoring unit in Bitterne Road.

The regional background NO_2 concentrations were taken from the nearest rural AURN site at Harwell (OS co-ordinates 446772 116020).

3.7 Computer modelling

The modelling programmes used in this assessment make a number of assumptions during the calculations. These include no consideration of terrain relief, or direct consideration of buildings over the surface being modelled. Modelling of pollutant concentrations on roads can sometimes provide misleading information on produced contour maps. For example, polygons and circles on certain areas of the contour maps, e.g. roundabouts or the centres of roads, can be generated. This is not a deficiency in the model – it is an artefact of the data. As such, these additional features should be ignored and the wider context and implications of the contour maps be considered.

Figure 3.1 AQMAs and the areas considered by this Detailed Assessment

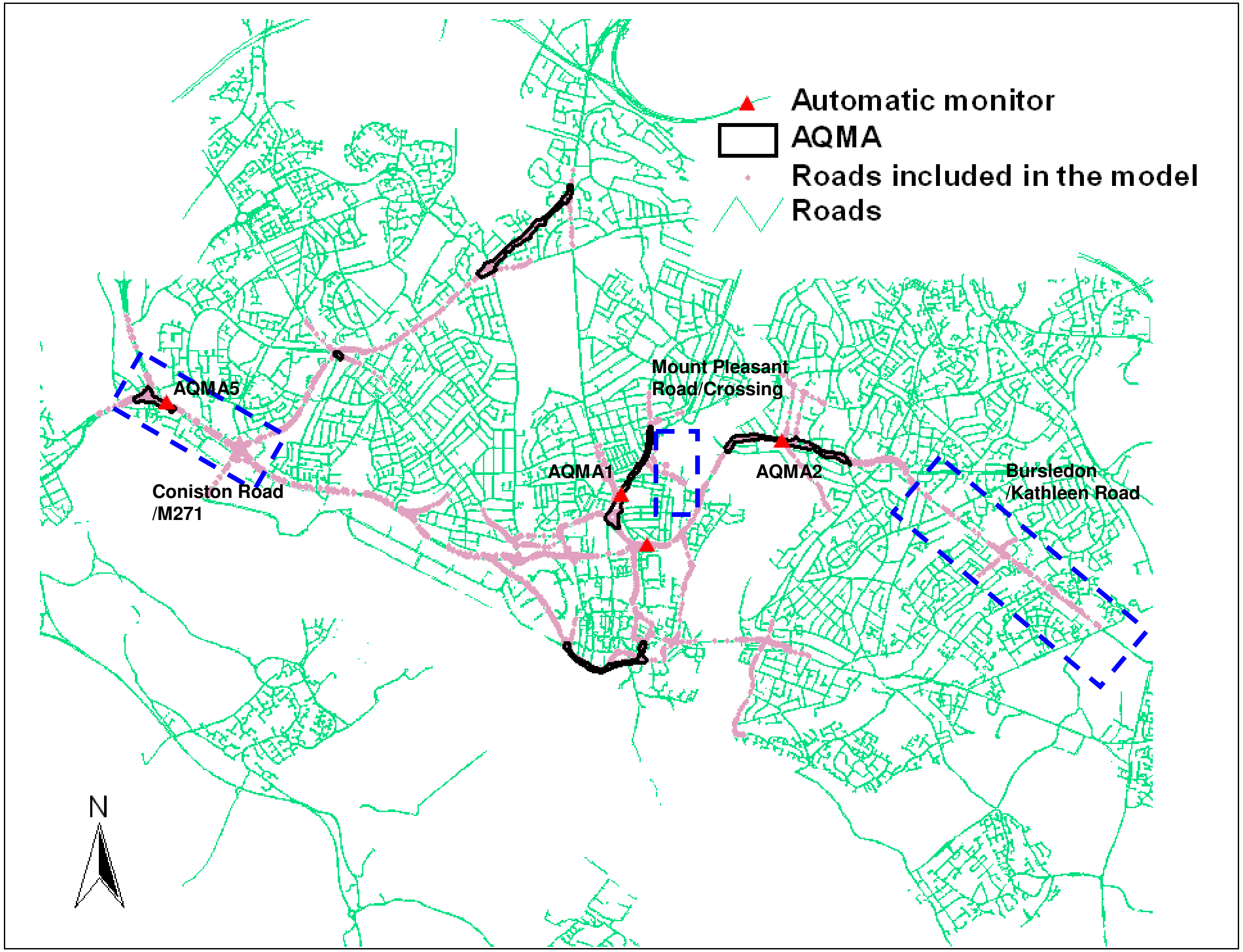


Figure 3.2 The Mount Pleasant Road/Crossing area

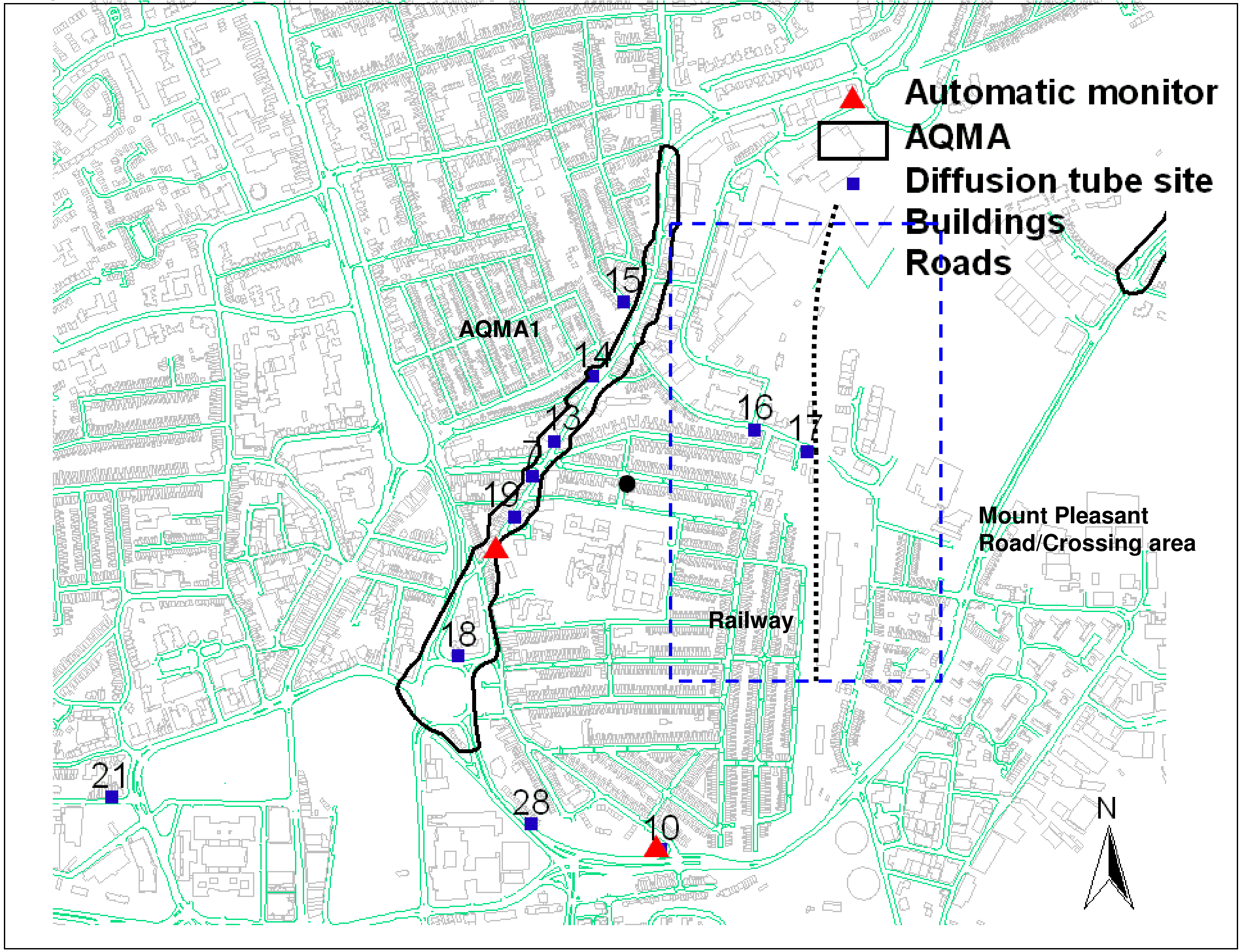


Figure 3.3 The Bursledon/Kathleen Road area

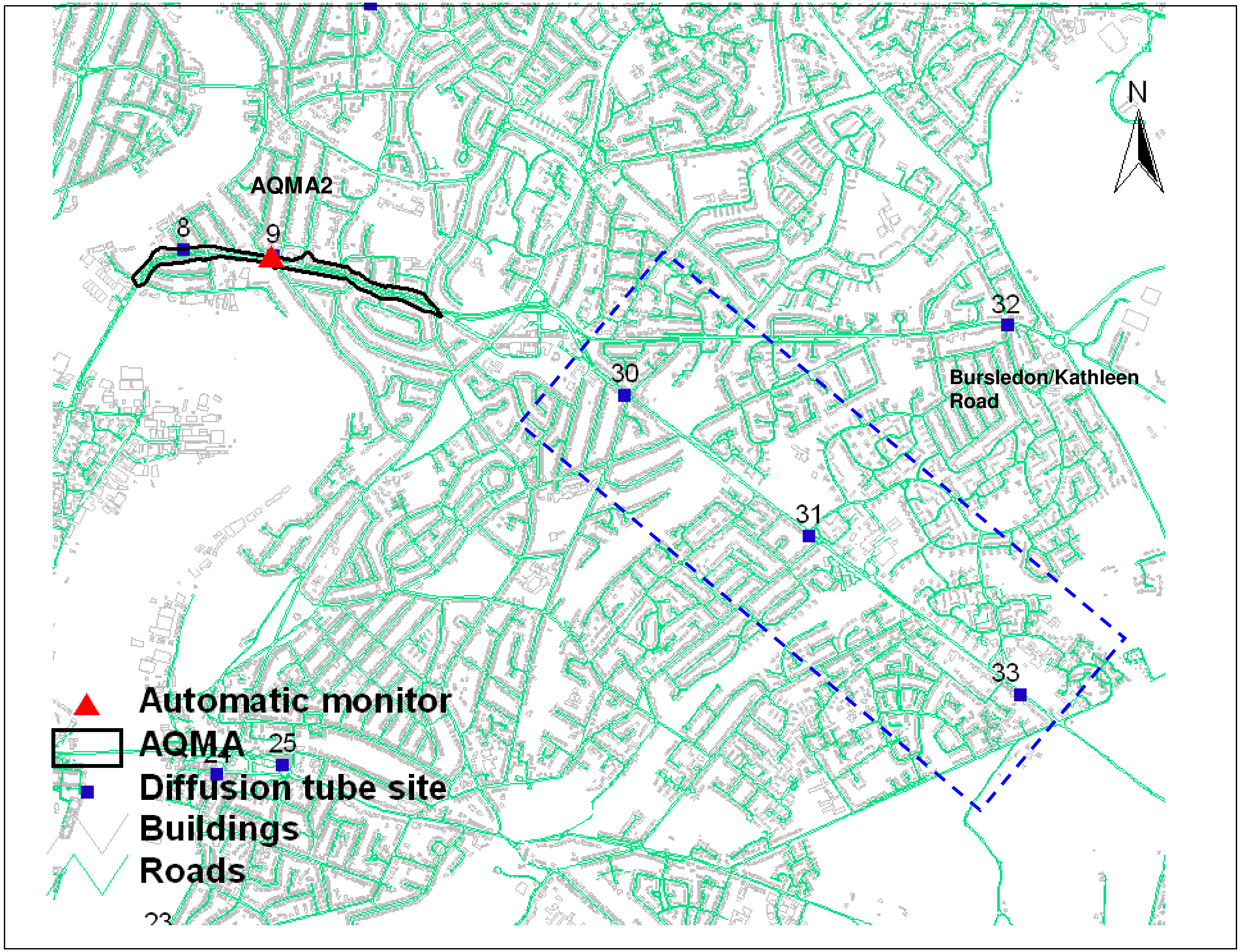
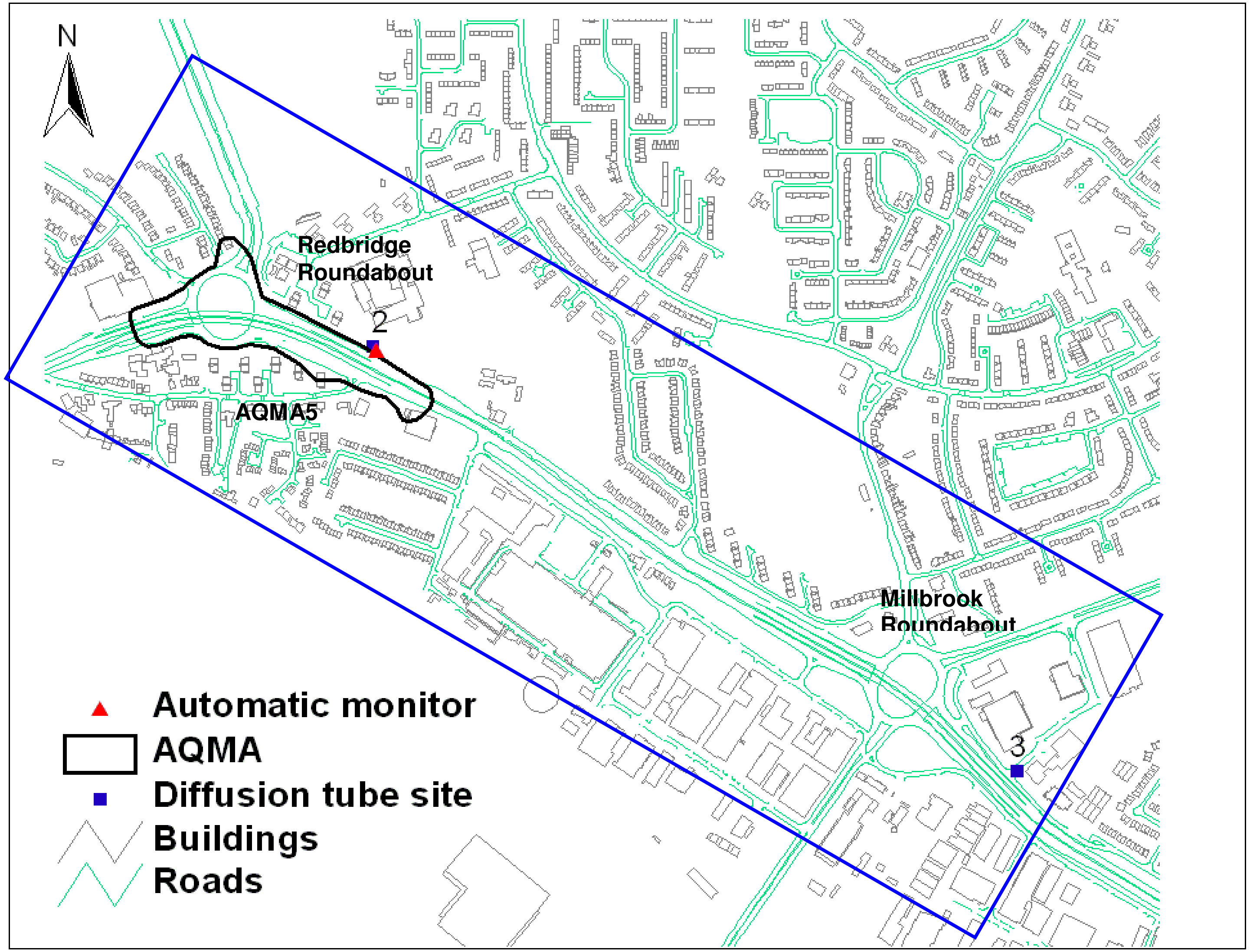


Figure 3.4 The area between Redbridge Roundabout and Millbrook Roundabout



4 Nitrogen Dioxide Monitoring and Model Bias

4.1 Introduction

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as NO_x, is road traffic, which is responsible for approximately half the emissions in Europe. NO and NO_2 concentrations are therefore greatest in urban areas where traffic is heaviest. Other important sources are power stations, heating plant and industrial processes.

Nitrogen oxides are released into the atmosphere mainly in the form of NO, which is then readily oxidised to NO_2 by reaction with ozone. Elevated levels of NO_x occur in urban environments under stable meteorological conditions, when the air mass is unable to disperse.

Nitrogen dioxide has a variety of environmental and health impacts. It is a respiratory irritant, may exacerbate asthma and possibly increase susceptibility to infections. In the presence of sunlight, it reacts with hydrocarbons to produce photochemical pollutants such as ozone. In addition, nitrogen oxides have a lifetime of approximately 1-day with respect to conversion to nitric acid. This nitric acid is in turn removed from the atmosphere by direct deposition to the ground, or transfer to aqueous droplets (e.g. cloud or rainwater), thereby contributing to acid deposition.

4.2 Latest standards and objectives for nitrogen dioxide

The National Air Quality Regulations (1997) set two provisional objectives to be achieved by 2005 for nitrogen dioxide:

- An annual average concentration of 40 $\mu g\ m^{-3}$ (21 ppb);
- A maximum hourly concentration of 286 $\mu g\ m^{-3}$ (150 ppb).

In June 1998, the Common Position on Air Quality Daughter Directives (AQDD) agreed the following objectives to be achieved by 31 December 2005 for nitrogen dioxide:

- An annual average concentration of 40 $\mu g\ m^{-3}$ (21 ppb);
- 200 $\mu g\ m^{-3}$ (100 ppb) as an hourly average with a maximum of 18 exceedences in a year.

The National Air Quality Strategy was reviewed in 1999. The Government proposed that the annual objective of 40 $\mu g\ m^{-3}$ to be retained and that the original hourly average to be replaced with the AQDD objective. The revised Air Quality Strategy for England, Scotland, Wales and Northern Ireland (DETR, 1999; 2000) included the proposed changes. These two objectives for nitrogen dioxide have been retained for the years to 2010 and beyond in the Air Quality Strategy published this year (DEFRA, 2007). Modelling studies suggest that in general achieving the annual mean of 40 $\mu g\ m^{-3}$ is more demanding than achieving the hourly objective. If the annual mean is achieved, the modelling suggests the hourly objectives will also be achieved.

4.3 The National Perspective

The main source of NO_x in the United Kingdom is road transport, which, in 2003 accounted for approximately 40% of emissions. Power generation contributed approximately 29% and domestic sources 5%. In urban areas, the proportion of local emissions due to road transport sources is larger (NAEI, 2005).

National measures are expected to produce reductions in NO_x emissions and achieve the objectives for NO_2 in many parts of the country. However, the results of the analysis set out in the National Air Quality Strategy suggest that for NO_2 a reduction in NO_x emissions over and above that achievable by national measures will be required to ensure that air quality objectives are achieved everywhere by the end of 2005. Local authorities with major roads, or highly congested roads, which have the potential to result in elevated levels of NO_2 in relevant locations, are expected to identify a need to progress to a Further Assessment for this pollutant.

4.4 Summary of previous air quality review and assessment report

The 2006 Further Assessment has predicted exceedences of the UK objective for annual mean NO_2 in 2005 in Southampton at the following locations:

- AQMA 1: Bevois Valley - An area along Onslow road from Bevois Hill down to (and encompassing) the Charlotte Place Roundabout
- AQMA 4: Town Quay - An area along the A33 Town Quay between West Quay Road Roundabout and Terminus Terrace (including Terminus Terrace between Platform Road and Bernard Street)
- AQMA 5: Redbridge Road - An area encompassing the Redbridge Road Flyover and Roundabout and sections of the approaching roads

Exceedences were also indicated by diffusion tubes and/or modelling in 2005 at the following areas outside the declared AQMAs:

- 5 Commercial Road (Site 21)
- Hill Lane (Site 22)
- The Avenue (Site 11)
- Near A33 in Millbrook Road at Aukland Road(Site 3), Regents Park Junction (Site 4) and Waterhouse Lane (Site 26).

Modelling of nitrogen dioxide concentrations in 2010 has indicated that a decline in nitrogen dioxide concentrations is expected when compared with 2005, with exceedences of the 40µg/m^3 annual mean objective only in AQMA 1 and AQMA 4.

4.5 MONITORING DATA

Nitrogen dioxide concentrations are monitored at four sites within Southampton city by continuous monitoring and by diffusion tubes at roadside as shown in Figure 4.1.

Continuous monitoring
Nitrogen dioxide concentrations are monitored by continuous monitors at four sites as:

- The Defra Automatic Urban Network station in Brintons Road by the Six Dials junction, established in 1994.
- A permanent station at Redbridge Community School, established in April 1999.
- A roadside station opposite 3 Onslow Road, established in July 2005.
- A mobile unit currently sited at Bitterne Road opposite Mays Carpets.

Detailed description of these sites, the measurement techniques and QA/QC procedures are given in the 2006 Further Assessment for Southampton.

The monitoring results for 2005 were given in the Southampton City Air Quality Report for 2005 (Appendix 2) and Table 4.1 below summarises the measured annual mean NO_2 concentrations by the automatic monitors in 2005 & 2006 and the OS coordinates of the monitors. The concentrations measured are consistently at or above the annual mean objective for nitrogen dioxide of 40 $\mu g/m^3$ at the site in Onslow Road and is projected to be still above the objective by 2010. The concentrations measured at Redbridge School and in Bitterne Road also reached the annual mean objective for nitrogen dioxide in 2006, but they are not projected to be above the objective by 2010.

Table 4.1 Summary of continuous nitrogen dioxide data for 2005 and 2006

	X	Y	2005			2006			2010
			Annual mean	Peak hour	Data capture %	Annual mean	Peak hour	Data capture %	Estimation based on 2006 measurements
Defra AURN station in Brintons Road	442583	112248	31	113	87.0	28	143	91.0	24.2
Permanent station at Redbridge School	437549	113721	36.5	153	93.2	**40**	145	93.4	34.6
Mobile unit in Bitterne Road	443987	113340	37	154	85.6	**40**	151	86.0	34.6
Roadside station in Onslow Road	442304	112771	**48.7**	NA	98.0	**54.3**	153	98.0	**47.0**

*The 2005 data for the roadside station in Onslow Road was gathered between 15/07/2005-31/12/2005

Diffusion tubes
Diffusion tube results are available at 37 roadside locations within the city of Southampton. The diffusion tubes were supplied and analysed by Gradko using 20% TEA/Water. The raw monthly diffusion tube data and their average concentrations in 2005 are given in Appendix 2 of the 2006 Further Assessment.

Diffusion tubes can under or over-read and if possible should be referred to the results of continuous monitoring. Diffusion tubes have been co-located with continuous automatic monitors at Redbridge Community School, Brintons Road (a AURN site) and Bitterne Road AMS in 2005. The results of these co-location studies were used to obtain the local bias adjustment factor. On the basis of the local collocation study in Southampton City, as shown in Table 4.2, a diffusion tube bias adjustment factor of 0.86 was calculated for Southampton using the AEA's diffusion tube precision and accuracy bias adjusting spreadsheet.

UWE, on behalf of DEFRA, publishes the results of UK-wide collocation studies on their website. Results for this preparation method by Gradko in 2005 indicate bias adjustment factors in the range of 0.82-1.27, as shown in Table 4.2, and an overall adjustment factor of 0.96 while including the three sites in Southampton. Because of the significance of local shipping emissions and the availability of local collocation results at three triplicate sites, it was decided to use the local bias adjustment factor in this study. The measurements and the adjusted data using the local adjustment factor of 0.86 in 2005 are summarised in Table 4.3 below. The adjustment factor in Southampton is 0.85 in 2006 as provided by Southampton City Council.

It should be taken into account that diffusion tubes are spot measurements and may be very sensitive to distance from the road as concentrations change rapidly with distance from the kerbside when comparing them with modelled results.

4.6 Assessing the monitoring data in 2005 & 2006

Table 4.4 below summarises the monitoring sites that have monitoring data for 2005 & 2006 and exceed the annual mean objective for NO_2 in any or both of the two years. The general patterns of exceedence are similar in the two years, with a few differences.

The continuous automatic monitoring shows that nitrogen dioxide concentration at the roadside monitoring station in Onslow Road (in AQMA 1) is well above the annual mean NO_2 objective in 2005 & 2006. The concentrations measured at Redbridge School (in AQMA 5) and in Bitterne Road (in AQMA 2) reached the annual mean objective for nitrogen dioxide in 2006.

Within the declared AQMAs, diffusion tubes at roadside locations indicate exceedences in the following streets for both years (Table 4.4):

- AQMA 1: 22-28 Onslow Road (Site 19), 41-59 Onslow Road (Site 13), Cranbury Place (Site 7)
- AQMA 5: Redbridge Community School (Site 2)

Diffusion tube data also indicate exceedences at the following locations outside the declared AQMAs in 2005 and 2006:

- 5 Commercial Road (Site 21)
- 305 Millbrook Road West
- Near A33 in Millbrook Road at Aukland Road (Site 3)
- Bursledon Road (Site 31)

Because all of the kerbside diffusion tubes are about 1m away from the road kerbs, the drop off rates quoted in the helpdesk FAQ http://www.uwe.ac.uk/aqm/review/mfaqroad.html#ROAD7 could be used to estimate the concentrations at nearest building facades. After scaling the diffusion tube results to the nearest building façade, exceedences were found in Commercial Road, 305 Millbrook Road West and Bursledon Road as shown in Table 4.4. Southampton City Council should consider declaring AQMAs at these three locations.

By 2010, exceedences are predicted in AQMA 1 by the roadside automatic monitor in Onslow Road and by four diffusion tubes as shown in Table 4.3 based on the measurements in 2006.

As the measured concentrations are well below 60µg/m^3 it is considered unlikely that the hourly mean objective for NO_2 is exceeded and therefore it should not be necessary to further assess concentrations at the kerbside.

Figure 4.1a NO_2 monitoring sites in Southampton

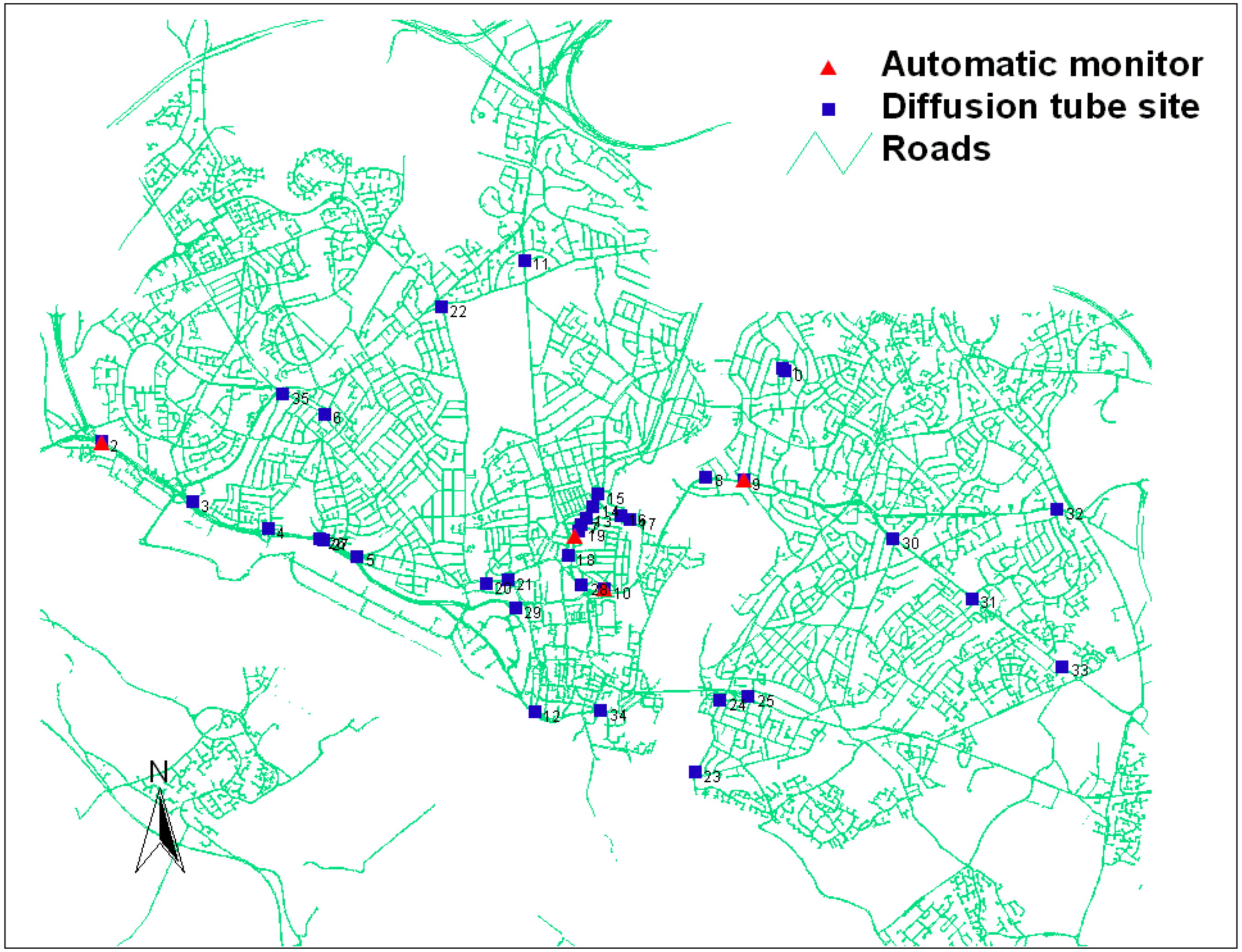


Table 4.2 The estimated diffusion tube bias adjustment factor for Southampton

Analysed By	Method	Year	Site Type	Local Authority	Length of Study (months)	Diffusion Tube Mean Conc. (Dm) (µg/m3)	Automatic Monitor Mean Conc. (Cm) (µg/m3)	Bias (B)	Tube Precision	Bias Adjustment Factor (A) (Cm/Dm)
Gradko	20% TEA in Water	2005	R	Exeter CC	10	37	44	-16.4%	G	1.20
Gradko	20% TEA in Water	2005	R	South Lakeland DC	12	31	26	22.1%	G	0.82
Gradko	20% TEA in Water	2005	UB	LB Ealing	12	42	39	7.6%	G	0.93
Gradko	20% TEA in Water	2005	R	LB Ealing	12	58	59	-0.4%	G	1.00
Gradko	20% TEA in Water	2005	R	LB Ealing	10	76	96	-21.4%	G	1.27
Gradko	20% TEA in Water	2005	R	Dartford Council	9	61	63	-2.8%	G	1.03
Gradko	20% TEA in Water	2005	R	North Warwickshire BC	9	52	43	19.8%	G	0.83
Gradko	20% TEA in Water	2005	B	St Albans DC	10	26	26	1.3%	G	0.99
Gradko	20% TEA in Water	2005	R	Rushmoor BC	10	41	39	6.0%	G	0.94
Gradko	20% TEA in Water	2005	UB	LB Ealing	12	42	39	7.6%	G	0.93
Gradko	20% TEA in Water	2005	UB	LB Ealing	12	42	39	7.6%	G	0.93
Gradko	20% TEA in Water	2005	UB	Southampton Brintons	10	37	31	20.60%	G	0.83
Gradko	20% TEA in Water	2005	UB	Southampton Redbridge	12	48	37	32.10%	G	0.76
Gradko	20% TEA in Water	2005	UB	Southampton Bitterne	11	37	37	-0.27%	G	1.00
					Overall adjustment factor					**0.96**
					Adjustment factor of the Southampton collocation study					**0.86**

Table 4.3 Nitrogen dioxide diffusion tube survey results for Southampton monitoring sites in 2005 & 2006

Site Number	X	Y	AQMA	Site Name	2005 Annual Mean (Unadjusted)	2005 Annual Mean (adjusted)	2006 Annual Mean (adjusted)	2010 Estimated based on 2006 measurements
0	444407	114424		Sandringham Road(garden)	24.2	20.8	19.1	16.54
1	444386	114450		Sandringham Road(lampost)	25.3	21.8	NA	NA
2	437543	113726	5	Redbridge School	48.2	**41.5**	**47.5**	**41.14**
3	438460	113122		Aukland Road	47.9	**41.2**	**41.8**	36.20
4	439218	112850		Regents Park Junction	47.1	**40.5**	39.4	34.12
5	440115	112571		Pilgrim Court	36	31.0	30.8	26.67
6	439787	113992	~6	Anglesea Road	45.8	39.4	39.6	34.29
7	442367	112896	1	Cranbury Place	58.7	**50.5**	**52.9**	**45.81**
8	443607	113369	2	Bitterne Road	36.5	31.4	37.6	32.56
9	443990	113340	2	Bitterne Road AMS	36.9	31.7	31.6	27.37
10	442591	112240	~1	Brintons Road	37.4	32.2	31.6	27.37
11	441796	115539	~3	The Avenue	47.7	**41.0**	**41.4**	35.85
12	441898	111007	4	Town Quay	51.1	**43.9**	37.8	32.73
13	442405	112957	1	41-59 Onslow Road	53.1	**45.7**	**45.5**	39.40
14	442472	113068	1	3 Rockstone Place	41.2	35.4	33.9	29.36
15	442524	113198	~1	13 Earls Road	36.7	31.6	31.3	27.11
16	442755	112975	~1	Mt Pleasant Road	41.2	35.4	33.1	28.66
17	442846	112939	~1	Mt PleasantCrossing	NA	NA	33.4	28.92
18	442238	112580	1	Charlotte Place	48.5	**41.7**	37.0	32.04
19	442336	112824	1	22-28 Onslow Road	50.3	**43.3**	**41.8**	36.20
20	441408	112294		Wyndham Court	39	33.5	29.9	25.89
21	441629	112332	~1	5 Commercial Road	50.6	**43.5**	**41.9**	36.29
22	440958	115068	~3	Hill Lane	47.8	**41.1**	38.8	33.60
23	443501	110395		Victoria Road	32.1	27.6	23.1	20.00
24	443751	111121		Victoria Road/Portsmouth Road	46.3	39.8	39.4	34.12
25	444031	111162		Portsmouth Road	30.9	26.6	30.8	26.67
26	439741	112746		Waterhouse Lane	56	**48.2**	NA	NA
28	442366	112285	~1	St Andrews Road	42.3	36.4	34.7	30.05
29	441710	112047		Fitzhugh Street	38.3	32.9	33.7	29.18
30	445493	112745		Bursledon/Ruby Road	38.8	33.4	33.3	28.84
31	446283	112145		Bursledon/Kathleen Road	48.9	**42.1**	**42.8**	37.06
32	447135	113043		Thornhill Park/Hinkler Road	31.3	26.9	25.9	22.43
33	447188	111463		468 Bursledon Road	35.5	30.5	26.9	23.30
34	442555	111021	4	Canute Road	38.7	33.3	32.5	28.15
35	NA	NA		432 Winchester Road	NA	NA	30.6	26.50
36	NA	NA		347A Winchester Road	NA	NA	**42.9**	37.15
37	NA	NA		148 Romsey Road	NA	NA	**46.2**	**40.01**
38	NA	NA		Kerb 305 Millbrook Road	NA	NA	**52.3**	**45.29**

Figures in **bold** indicate predicted exceedence of the UK objective in 2005 or 2006.
~ indicates the nearest AQMA of the diffusion tube site.

Table 4.4 Monitoring sites exceeding the objective for annual mean NO2 concentration in Southampton monitoring in 2005 and/or 2006

Site Number	AQMA Number	Site Name	2005 Annual Mean	2006 Annual Mean	Distance to receptor (m)	Distance scaling factor	2006 Annual mean at facade
Automatic monitor	5	Redbridge School	36.5	**40.0**			
Automatic monitor	2	Brtterne Road	37.0	**40.0**			
Automatic monitor	1	Onslow Road	**48.7**	**54.3**			
2	5	Redbridge School	**41.5**	**47.5**	3	0.95	**45.13**
3	Outside AQMA	Aukland Road	**41.2**	**41.8**	3	0.95	39.71
4	Outside AQMA	Regents Park Junction	**40.5**	39.4	2	1.00	39.40
7	1	Cranbury Place	**50.5**	**52.9**	1	1.00	**52.90**
11	Outside AQMA	The Avenue	**41.0**	**41.4**	6	0.90	37.26
12	4	Town Quay	**43.9**	37.8	1	1.00	37.80
13	1	41-59 Onslow Road	**45.7**	**45.5**	2	1.00	**45.50**
18	1	Charlotte Place	**41.7**	37.0	6	0.90	33.30
19	1	22-28 Onslow Road	**43.3**	**41.8**	2	1.00	**41.80**
21	Outside AQMA	5 Commercial Road	**43.5**	**41.9**	1	1.00	**41.90**
22	Outside AQMA	Hill Lane	**41.1**	38.8	6	0.90	34.92
26	Outside AQMA	305 Millbrook Road West*	**48.2**	**52.3**	5	0.85	**44.46**
31	Outside AQMA	Bursledon/Kathleen Road	**42.1**	**42.8**	3	0.95	**40.66**

Figures in **bold** indicate predicted exceedence of the UK objective in 2005
* 305 Millbrook Road West was renamed from the diffusion tube site as Waterhouse Lane in 2005

4.7 Modelling methodology

Air quality impact from road traffic emissions in this modelling was calculated using **AEA**'s proprietary urban model. There are two parts to this model:

- ***The Local Area Dispersion System (LADS) model.*** This model was used to calculate background concentrations of oxides of nitrogen on a 1 km x 1 km grid. Estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 2003 National Atmospheric Emission Inventory disaggregated inventory, projected forward to 2005 and 2010 using factors in the **Defra** Technical Guidance.

- ***The LADS-URBAN model.*** This model is a tool for calculating atmospheric dispersion using a point-source kernel. Estimates of emissions from vehicles were calculated using the latest emission factors. The dispersion kernels for the LADS-URBAN model were derived from model runs using ADMS V3.3. DETR Standard Diurnal Traffic Flow distribution was used as the daily time varying emission factor of the site in the model.

This advanced two-component model is suitable for modelling road traffic emissions as defined in "Review and assessment: Selection and Use of Dispersion Models, LAQM.TG3 (00)", and in the Technical Guidance LAQM.TG(03). The predicted background and traffic NOx concentrations were converted to NO_2 concentrations using the polynomial fits given by AQEG (2004).

Concentrations of NO_2 from road traffic emissions were assessed using a high-resolution approach; with air quality modelled at 10 m intervals along all of the roads assessed. This high spatial resolution is recommended in LAQM.TG3 (00) and in LAQM.TG (03).

4.8 Traffic modelling summary

In this study, the concentrations of NO_2 at receptors close to the roads and junctions of interest have been modelled using ADMS-3.3 as a dispersion kernel model.

The roads were defined as volume sources, 3m deep, and were broken up in to a series of adjoining segments. The length of these segments was dictated by the way in which the OS LandLine data was digitised and varied from one or two metres in length (where the road rapidly changed direction) to hundreds of metres in length (where the road was essentially straight). The OS LandLine data was used to provide the co-ordinates of the centre line of the road, and the road widths. Therefore, the positions of the volume sources (here the roads) were accurate to approximately a metre.

Where queuing of vehicles was reported, emissions from stationary vehicles exhausts were estimated on the basis that the engine power output and hence emissions were the same as those at a speed of 5 kph. Queuing vehicles were assumed to be 5m apart (including the vehicle).

4.9 Shipping modelling summary

Shipping emissions were modelled as line sources using ADMS 3.3 and LADS-URBAN.

The movements of ships to/from the port were defined by lines, 30m high, and were represented by a series of adjoining segments with emission rates estimated as given in Table A1.7 in Appendix A. The emissions by ships staying in berths were defined as point sources, 30m high, with emission rates as given in Table A1.7 in Appendix A. Shipping emissions outside the port were not included in the model explicitly, but through the background consideration.

4.10 Train modelling summary

Train emissions were modelled as line sources using ADMS 3.3 and LADS-URBAN.

The railway was defined as lines, 5m high, and was represented by a series of adjoining segments with emission rates as given in Table A1.6 in Appendix A. The railway that is more 250m away from the Mount Pleasant Crossing was not modelled as line sources explicitly, but through the background consideration.

4.11 Sources of background (non-traffic) emissions data

Background emissions of oxides of nitrogen (NO_x) from sources not modelled in detail have been taken from the 2003 UK National Atmospheric Emissions Inventory (www.naei.org.uk) and scaled to the year of interest where necessary following the recommended procedures in LAQM. TG(03). The contribution to emissions from the roads modelled in detail has been omitted where this would lead to double counting of the local impact of emissions.

The background maps of NOx and NO_2 in Southampton for 2005 and 2010 were taken from UK Air Quality Archive (www.airquality.co.uk). The estimated annual mean concentrations for NOx and NO_2 concentrations in Southampton and at diffusion tube sites within the areas assessed here are given in Table 4.5 below.

Table 4.5 Background concentrations in Southampton and at sites within the areas assessed

Site	NOx		NO_2	
	2005	2010	2005	2010
Mean concentration in Southampton	31.9	25.6	22	19.3
Max concentration in Southampton	40	31.6	25.7	22.1
Diffusion tube site 17 at Mount Pleasant Crossing	30.4	24.6	21.4	18.8
Diffusion tube site 31 at Bursledon/Kathleen Road	36.4	29.7	24	21.3

4.12 Model bias adjustment

Model bias adjustment is where the model is tested against measurements by automatic monitors at locations near to the areas of concern and adjusted if large differences exist between predictions and measurements. Predictions of the bias adjusted model are then compared with the results of diffusion tubes to verify the model's robustness.

Table 4.6 compares predictions using LADS-URBAN with measured values at the four continuous monitoring sites in Southampton for 2005. The predictions are slightly different from the data given in the report for 2006 Further Assessment because of the updated traffic data at several locations. However, the agreement between the model and the automatic monitors is still very good at all four automatic monitoring sites, as shown in Figure 4.2 and in Table 4.6 below, and the overall difference of these four sites is only 2%.

The model has the maximum over-prediction of 13% at the permanent station at Redbridge Community School, and has the maximum under-prediction of 11% at the mobile unit sited in Bitterne Road opposite Mays Carpets. Descriptions of the automatic monitors can be found in Appendix B. The automatic monitor at Redbridge School is near to a very busy road with over 80000 vehicles per day and is 200m away from a roundabout with long queues all the day. Errors in estimating the traffic volume, speed, composition and congestion could have contributed to the over-prediction. The assessment model has not included a railway line near to the automatic monitor in Bitterne Road. Even though it was confirmed that most of the trains passing that point have electric engines, ignoring this railway line should have contributed to the under-prediction.

Table 4.6 Comparison of modelled and measured concentrations by automatic monitors for 2005 (Base Year)

X	Y	Site Name	2005 measured Mean	2005 Predicted	Difference %
442304	112771	Roadside station at Onslow Road	**48.7**	**50.66**	4%
442583	112248	Defra AURN station at Brintons Road	31	31.19	1%
437549	113721	Permanent station at Redbridge School	36.5	**41.18**	13%
443987	113340	Mobile unit at Bitterne Road	37	32.88	-11%
		Average	**38.30**	**38.98**	**2%**

Figures in **bold** indicate predicted exceedences of the UK objective in 2005

For this Detailed Assessment, the model was bias adjusted against the nearest automatic monitors to each of the two area assessed. As to Mount Pleasant Road/Crossing, the area is 500m away from the automatic monitor in Onslow Road and 750m from the Defra AURN station in Brintons Road, the model has a 2.5% over-prediction against the measurements in 2005 at those two sites (as shown in Table 4.6). The predictions were considered to be very good and no bias adjustment was applied for this Detailed Assessment. As to the Bursledon/Kathleen Road area, the area is 2500m away from the mobile automatic monitor in Bitterne Road and the model has under-predicted the annual mean NO_2 in 2005 by 11% at the site. Therefore, the model was bias adjusted to match the measurements by the automatic Monitor in Bitterne Road and the bias adjusted model was applied for the Bursledon/Kathleen Road area.

The agreement between model predictions and adjusted diffusion tube data near to the two areas assessed is generally good. Table 4.7 below and Figure 4.3 illustrate the agreement between the model and diffusion tubes. The model predicted within 25% of the diffusion tube data at over 93% of the sites and within 10% at over two thirds of the sites. The difference between the averages of measured and predicted annual mean NO_2 concentrations of all the relevant diffusion tube sites is 1% as given in Table 4.7 below.

It should be taken into account that diffusion tubes are spot measurements and are very sensitive to distance to the road as concentrations change rapidly with distance from the kerbside. Because most of the diffusion tubes in Southampton locate at kerbside, small errors in their locations (less than 1m) could cause have caused the large differences shown in Table 4.7. Uncertainty regarding traffic speeds and queuing and congestion are likely to have lead to some errors in the calculation of emissions; local street canyons should have also contributed to the differences.

Figure 4.2 Regression analysis of modelled and automatic monitor measured nitrogen dioxide concentrations in 2005

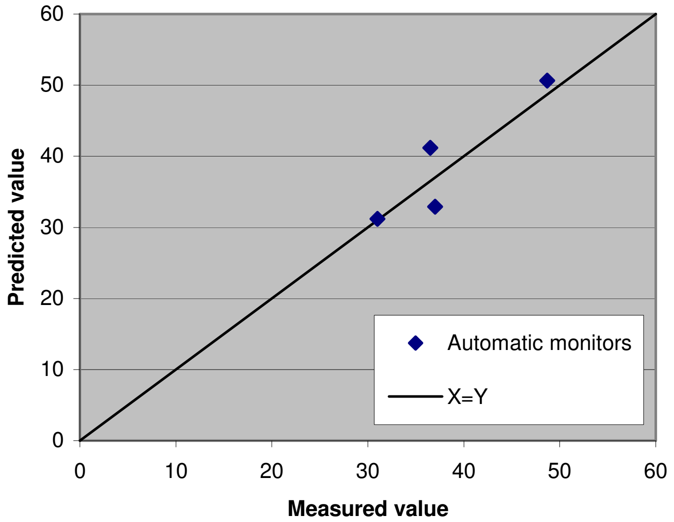
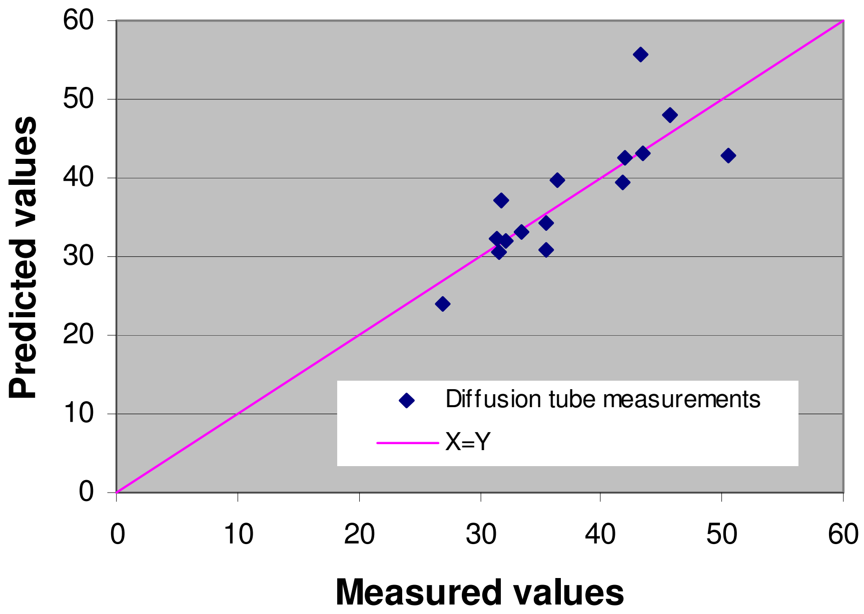


Table 4.7: Comparison of modelled and measured concentrations at diffusion tube sites for 2005 (Base Year)

Site Number	X	Y	Site Name	2005 measured Mean (adjusted)	2005 Predicted	Difference %
7	442367	112896	Cranbury Place	**50.48**	**42.83**	-15%
8	443607	113369	Bitterne Road	31.39	32.26	3%
9	443990	113340	Bitterne Road AMS	31.73	37.05	17%
10	442591	112240	Brintons Road	32.16	31.93	-1%
13	442405	112957	41-59 Onslow Road	**45.67**	**47.91**	5%
14	442472	113068	3 Rockstone Place	35.43	34.32	-3%
15	442524	113198	13 Earls Road	31.56	30.63	-3%
16	442755	112975	Mt Pleasant Road	35.43	30.84	-13%
18	442238	112580	Charlotte Place	**41.71**	39.54	-5%
19	442336	112824	22-28 Onslow Road	**43.26**	**55.73**	29%
21	441629	112332	5 Commercial Road	**43.52**	**43.10**	-1%
28	442366	112285	St Andrews Road	36.38	39.61	9%
30	445493	112745	Bursledon/Ruby Road	33.37	33.07	-1%
31	446283	112145	Bursledon/Kathleen Road	**42.05**	**42.67**	1%
32	447135	113043	Thornhill Park/Hinkler Road	26.92	24.01	-11%
			Average	**37.40**	**37.70**	**1%**

Figures in **bold** indicate predicted exceedences of the UK objective in 2005.

Figure 4.3 Regression analysis of modelled and diffusion tube measured nitrogen dioxide concentration in 2005



4.13 Model validation

In simple terms, model validation is where the model is tested at a range of locations and is judged suitable to use for a given application. The modelling approach used in this assessment has been validated, and used in numerous **AEA Energy & Environment** air quality review and assessments. Statistical techniques have been used to assess the likelihood that there will be an exceedence of the air quality objectives given the modelled concentration. The validation statistics are given in Appendix 3. Confidence limits for the predicted concentrations were calculated based on the validation studies by applying statistical techniques based on Student's t distribution. The confidence limits took account of uncertainties resulting from:

- Model errors at the receptor site;
- Model errors at the reference site;
- Uncertainty resulting from year to year variations in atmospheric conditions.

The confidence limits have been used to estimate the likelihood of exceeding the objectives at locations close to the roads. The following descriptions have been assigned to levels of risk of exceeding the objectives.

It would be recommended that Southampton City Council generally consider declaring or reconfirming an AQMA where the probability of exceedence in 2005 is greater than 50% ("Probable").

Table 4.8: Uncertainties in the modelled concentrations for NO_2.

Description	Chance of exceeding objective	Modelled annual average concentrations, $\mu g/m^3$	
		Likelihood of exceeding annual average objective	Likelihood of exceeding hourly average objective
Very unlikely	Less than 5%	<28	<38
Unlikely	5-20%	28-34	38-52
Possible	20-50%	34-40	52-67
Probable	50-80%	40-46	67-82
Likely	80-95%	46-52	82-95
Very likely	More than 95%	>52	>95

The confidence limits for the 'probable' and 'likely' annual average and hourly objective concentrations have been set equal to those for 'possible' and 'unlikely', respectively. In reality, the intervals of concentration increase in size as the probability of exceeding the annual and hourly objective increases from 'unlikely' to 'likely'. The advantage to setting symmetrical concentration intervals is that the concentration contours on the maps become simpler to interpret. This is a mildly conservative approach to assessing the likelihood of exceedences of the NO_2 objectives since a greater geographical area will be included using the smaller confidence intervals.

A simple linear relationship can be used to predict the 99.8^{th} hourly percentile concentration of NO_2 from the annual concentration: the 99.8^{th} percentile is three times the annual mean at kerbside/roadside locations. Therefore, plots of the modelled annual mean NO_2 concentrations can be used to show exceedences of both the annual and hourly NO_2 objectives. However, the magnitude of the concentrations used to judge exceedences of the hourly objective need to be adjusted so they may be used directly with the plots of annual concentration. This has been performed by simply dividing the concentrations of the confidence limits by three.

5 Modelling results for nitrogen dioxide

5.1 2005 NO_2 modelling results (Base Case)

Mount Pleasant Road/Crossing

Figure 5.1 shows the modelled annual mean NO_2 concentrations in the Mount Pleasant Road/Crossing area in 2005. The agreement between predictions and measurements by the diffusion tube at Mount Pleasant Road (Site 16 in Table 4.6) is good. The model has an under-prediction of 13% at this site. The diffusion tube at Mount Pleasant Crossing (Site 17) was established from 2006 and there was no data at the site for 2005.

The model predicts that the annual mean objective of 40µg/m^3 for nitrogen dioxide has not been exceeded in the area, including Mount Pleasant Crossing in 2005, and this was confirmed by the 2006 diffusion tube data at Mount Pleasant Road and an additional tube at Mount Pleasant Crossing as given in Table 4.3.The highest predicted annual mean NO_2 concentration at building facades in this area is 35.7µg/m^3.

Within this area, the model predicts that it is ***possible*** (with a probability of 20-50%) that the annual average objective has been exceeded in 2005 and it is ***very unlikely*** (with a probability less than 5%) the hourly mean objective to be exceeded in 2005 (Table 4.8).

Bursledon/Kathleen Road

Figure 5.2 shows the modelled annual mean NO_2 concentrations in Bursledon Road in 2005. The bias adjusted model has predicted the annual mean NO_2 concentrations in this area very well as summarised in Table 5.1 below. An overall under-prediction of the three diffusion tubes in Bursledon Road is 3.4% and this is considered to be good. The prediction at the diffusion tube site indicating exceedences is an over-prediction by 1.5%.

The model predicts that the annual average objective of 40µg/m^3 for nitrogen dioxide has not been exceeded in the area and the highest predicted NO_2 concentration at building facades in this area is 37.6 µg/m^3 near to the junction between Bursledon Road and Kathleen Road.

Table 5.1 Comparing the measured and modelled NO_2 concentration in Bursledon Road

Site Number	X	Y	Site Name	2005 measured Mean (adjusted)	2005 Predicted	Difference %
30	445493	112745	Bursledon/Ruby Road	33.37	33.07	-0.9%
31	446283	112145	Bursledon/Kathleen Road	42.05	42.67	1.5%
32	447135	113043	Thornhill Park/Hinkler Road	26.92	24.01	-10.8%
			Average	34.11	33.25	-3.4%

The figures for the diffusion tubes were adjusted as shown in Table 4.3.

Within this area, the model predicts that it is ***possible*** (with a probability of 20-50%) that the annual mean objective has been exceeded in 2005 and it is ***very unlikely*** (with a probability less than 5%) the hourly mean objective to be exceeded in 2005 (Table 4.8).

However, the diffusion tube at the junction between Bursledon Road and Kathleen Road indicated exceedences (Site 31) in 2005 and 2006. This tube is about 1m away from the road kerb and 3m away from the nearest buildings. Applying an adjustment factor of 0.95 as recommended by the Air Quality Review and Assessment website (www.uwe.ac.uk/aqm/review) for estimating NO_2 concentration at building facades using nearby roadside measurements, there is an exceedence at the nearest building facade to Site 31 in 2006 (as shown in Table 4.4). Therefore, it is recommended that Southampton City Council either to have an additional diffusion tube at the nearest building facade to Site 31 for 12 months and to declare an AQMA If exceedences are indicated by this new diffusion tube, or declare an AQMA including the nearest property to site 31 now.

5.2 2010 NO_2 modelling results

Mount Pleasant Road/Crossing

Despite the estimated reduction in background NO_2 concentration resulted by national measures, the predicted annual mean NO_2 concentration in this area will increase slightly by 2010. The increase is due to the estimated large increase in freight diesel trains passing this area each day as given in Table A1.5 in Appendix 1. Figure 5.3 shows the modelled annual mean NO_2 concentrations in the Mount Pleasant Road/Crossing in 2010.

The model predicts that the annual mean objective of 40µg/m^3 for nitrogen dioxide will not be exceeded in the area in 2010. The highest predicted annual mean NO_2 concentration at building facades in this area is 36.7µg/m^3.

Within this area, the model predicts that it is ***possible*** (with a probability of 20-50%) that the annual average objective for NO_2 will be exceeded in 2010 and it is ***very unlikely*** (with a probability less than 5%) the hourly mean objective for NO_2 to be exceeded in 2010 (Table 4.8).

Bursledon/Kathleen Road

Figure 5.4 shows the modelled annual mean NO_2 concentrations at the junction between Bursledon Road and Kathleen Road in 2010. The model predicts that the annual mean objective of 40µg/m^3 for nitrogen dioxide will not be exceeded in the area in 2010. The highest predicted annual mean NO_2 concentration at building facades in this area is only 33.0µg/m^3.

Within this area, the model predicts that it is ***unlikely*** (with a probability of 5-20%) that the annual mean objective for NO_2 will be exceeded in 2010 and it is ***very unlikely*** (with a probability less than 5%) the hourly mean objective for NO_2 to be exceeded in 2010 (Table 4.8).

Figure 5.1 Modelled contours of annual mean NO_2 concentration at Mount Pleasant Crossing and surrounding areas in 2005

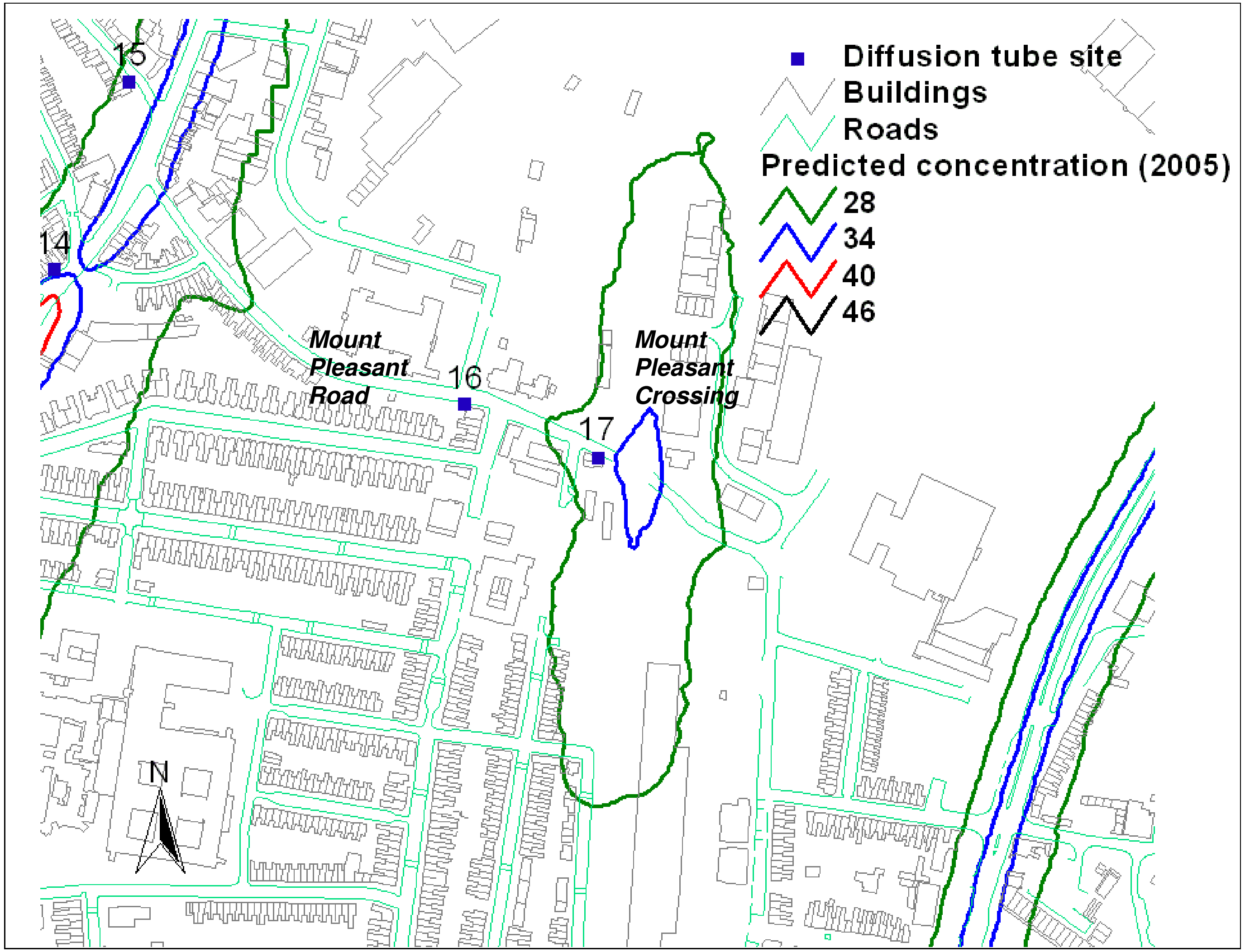


Figure 5.2 Modelled contours of annual mean NO_2 concentration in Bursledon Road and surrounding areas in 2005

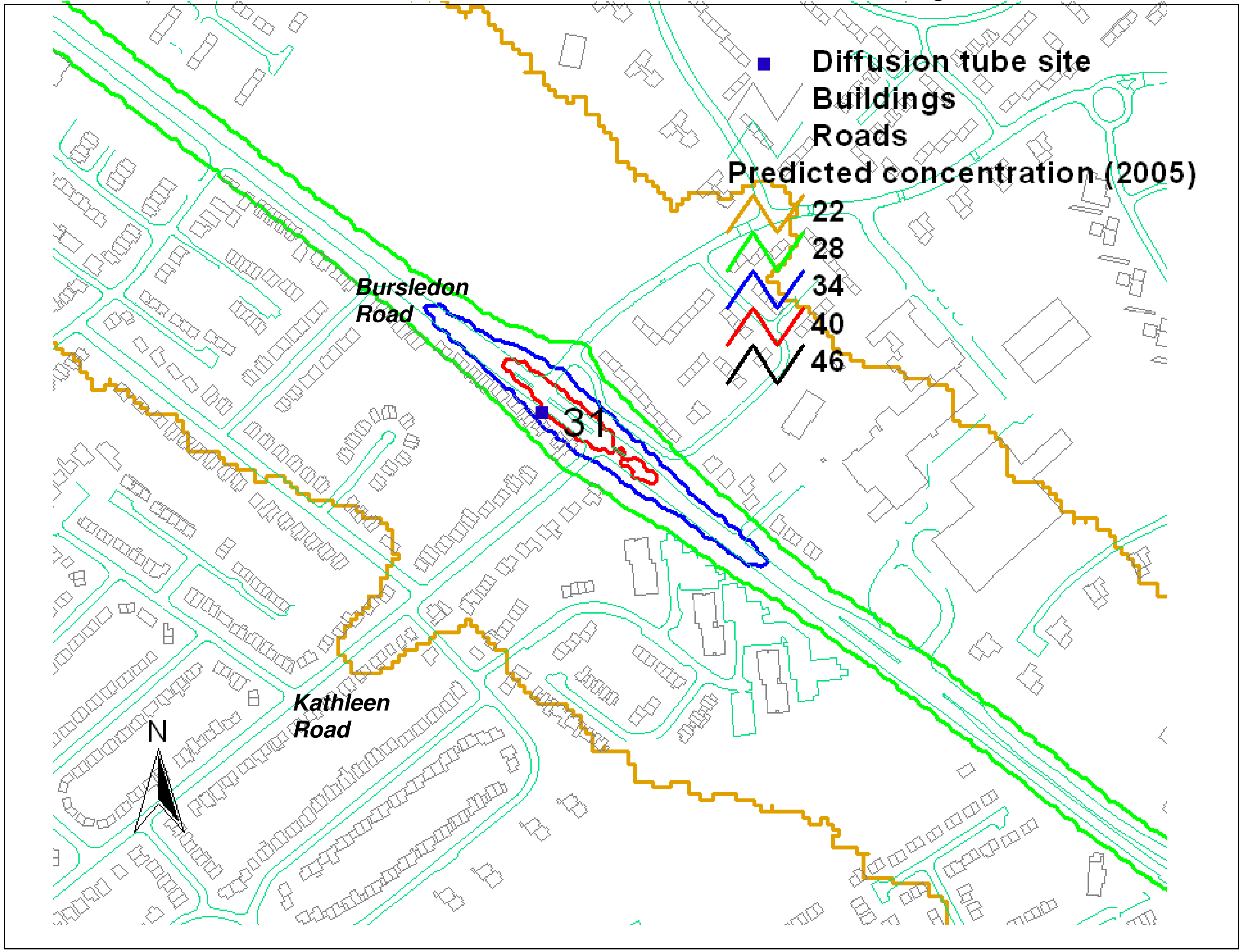


Figure 5.3 Modelled contours of annual mean NO_2 concentration at Mount Pleasant Crossing and surrounding areas in 2010

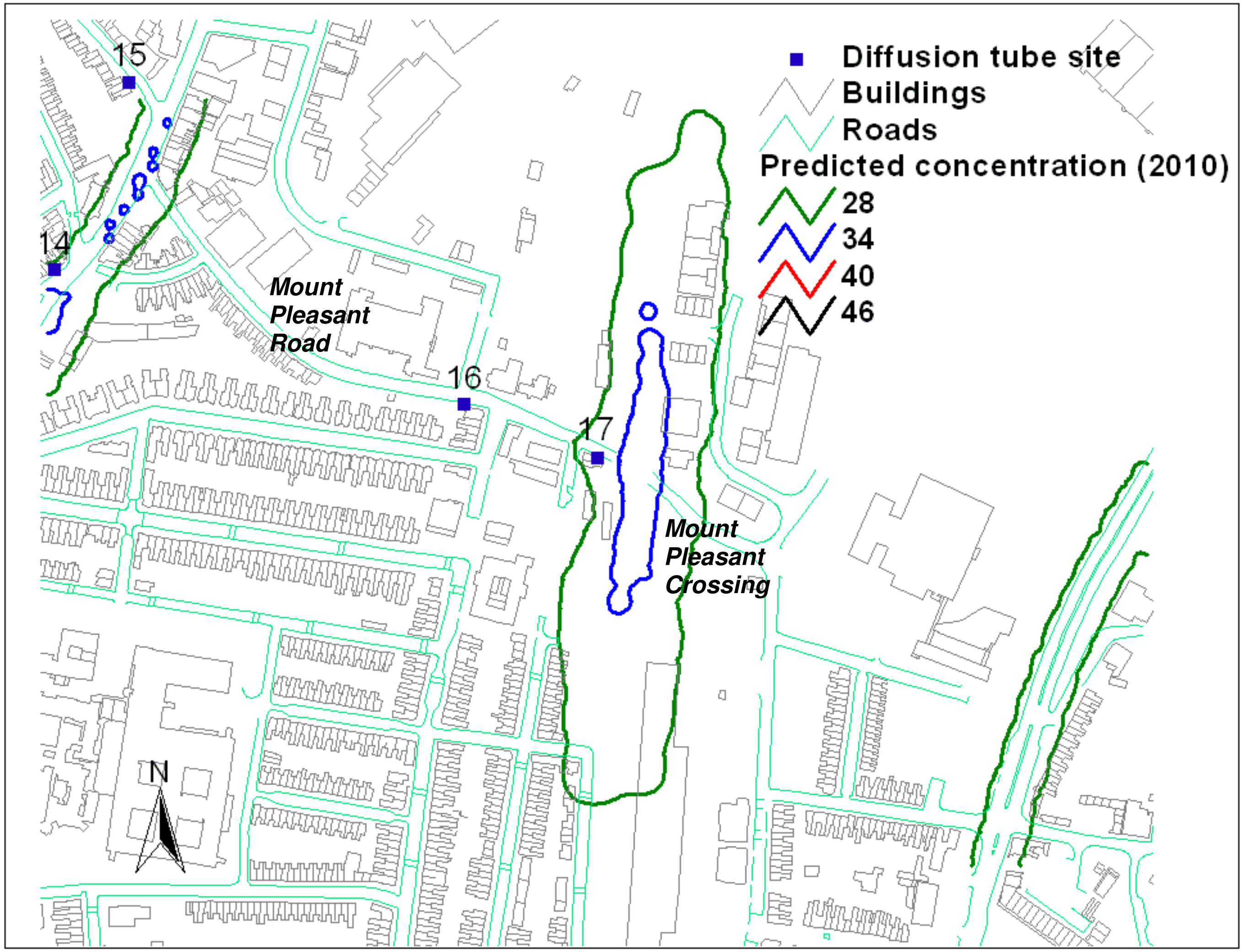
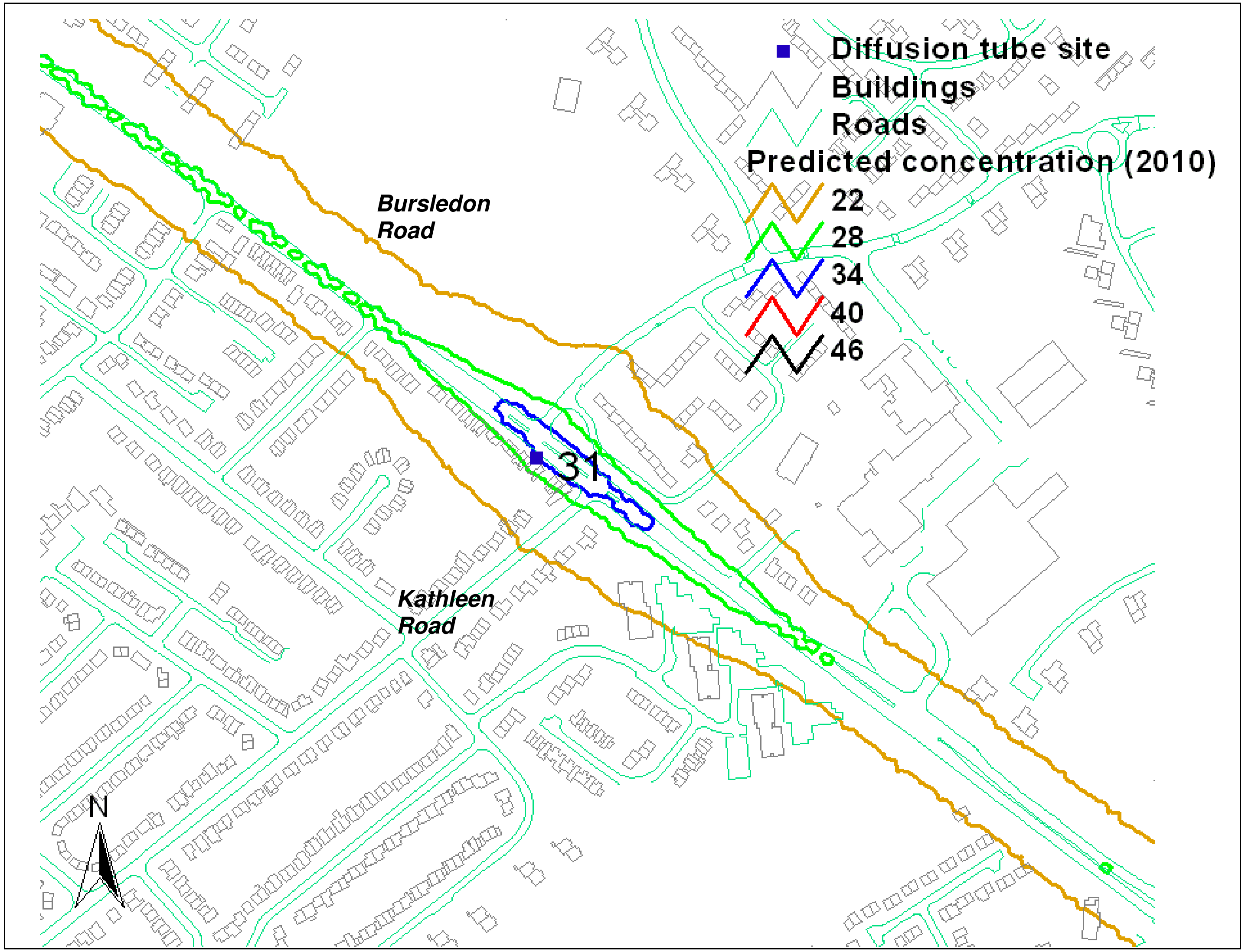


Figure 5.4 Modelled contours of annual mean NO_2 concentration in Bursledon Road and surrounding areas in 2010



6 PM_{10} monitoring and model validation

6.1 Introduction

National UK emissions of primary PM_{10} have been estimated as totalling 182,000 tonnes in 2001. Of this total, around 18% was derived from road transport sources. It should be noted that, in general, the emissions estimates for PM_{10} are less accurate than those for the other pollutants with prescribed objectives, especially for sources other than road transport.

The Government established the Airborne Particles Expert Group (APEG) to advise on sources of PM_{10} in the UK and current and future ambient concentrations. Their conclusions were published in January 1999 (APEG, 1999). APEG concluded that a significant proportion of the current annual average PM_{10} is due to the secondary formation of particulate sulphates and nitrates, resulting from the oxidation of sulphur and nitrogen oxides. These are regional scale pollutants and the annual concentrations do not vary greatly over a scale of tens of kilometres. There are also natural or semi-natural sources such as wind-blown dust and sea salt particles. The impact of local urban sources is superimposed on this regional background. Such local sources are generally responsible for winter episodes of hourly mean concentrations of PM_{10} above 100 $\mu g\ m^{-3}$ associated with poor dispersion. However, it is clear that many of the sources of PM_{10} are outside the control of individual local authorities and the estimation of future concentrations of PM_{10} are in part dependent on predictions of the secondary particle component.

6.2 Standard and objective for PM_{10}

The Government and the Devolved Administrations have adopted two Air Quality Objectives for fine particles (PM_{10}), which are equivalent to the EU Stage 1 limit values in the first Air Quality Daughter Directive. The objectives are 40 μgm^{-3} as the annual mean, and 50 μgm^{-3} as the fixed 24-hour mean to be exceeded on no more than 35 days per year, to be achieved by the end of 2004. The 2007 UK Air Quality Strategy sets annual mean objective of 25 μgm^{-3} for $PM_{2.5}$ to be met by 2020 in UK (except Scotland) and a target of 15% reduction in $PM_{2.5}$ concentration at urban background for UK urban areas.

6.3 Monitoring & updating and screening assessment

PM_{10} is currently monitored at three sites in Southampton using TEOM analysers, i.e. the Defra AURN station in Brintons Road, the permanent station at Redbridge School and the mobile monitoring unit in Bitterne Road.

The monitoring station in Brintons Road is the longest running site that measures PM_{10} in Southampton. It was established in 1994 and is part of the Automatic Urban and Rural Network (AURN). The 50ug/m^3 objective as a fixed 24-hour mean, not to be exceeded on more than 35 days per year, has been achieved every year except 1996 when there were 36 exceedences. Since then the numbers of exceedences at the site have rapidly decreased, with only 3 exceedences recorded in 2004 (96% data capture) and in 2005 (91% data capture). Monitored annual mean concentrations were well below the current air quality standard of 40ug/m^3, with typical values of 24-27ug/m^3 being recorded over the past 8 years. A high of 31ug/m^3 was recorded in 1997.

The TEOM analyser at Redbridge has monitored particulates since the year 2000. The 50ug/m^3 objective as a fixed 24-hour mean, not to be exceeded on more than 35 days per year, has been achieved every year with only 6 exceedences recorded in 2002. The annual mean PM_{10} concentrations have been fairly constant with recorded values in the range of 27-28ug/m3.

The mobile TEOM analyser in Bitterne Road has been at the site since 2001. 10 exceedences of the 24-hour mean objective were recorded in 2001 and 2004, and only 3 exceedences were recorded in 2002 and 2005. The annual mean PM_{10} concentrations have been in the range between 24-25 ug/m^3, with a high of 27ug/m^3 in 2003.

The 2006 updating and screening assessment has found that the current monitoring data from pollution 'hotspots' in the city indicate that Southampton is unlikely to exceed the air quality standards for PM_{10}. However, DMRB has highlighted a couple of junctions close to or exceeding the current standards and suggested a detailed assessment for PM_{10} for the junction between Coniston Road / M271, i.e. the Redbridge Roundabout.

6.4 Background concentrations for PM_{10}

The background maps of PM_{10} were taken from UK Air Quality Archive (www.airquality.co.uk) for 2004, 2005 and 2010. The estimated annual average background PM_{10} concentration from the maps for 2005 is 22.6 μgm^{-3} gravimetric averaged across Southampton with a maximum concentration of 24.3 μgm^{-3}. The estimated annual mean background PM_{10} concentration for 2010 was 20.7 μgm^{-3} across Southampton with a maximum concentration of 22.2 μgm^{-3}.

6.5 Assessment of latest monitoring data

Table 6.1 summarises the measurements of PM_{10} concentrations at continuous monitoring sites in Southampton for 2005 and 2006. The continuous monitoring data indicates that both the annual mean objective of 40 μg m^{-3} and the 24-hour objective of 50 μg m^{-3} not to be exceeded more than 35 times in a year have been met in recent years.

Table 6.1 Continuous PM_{10} monitoring data for 2005 and 2006

Site	Year	Annual average concentration μg m^{-3} gravimetric	Number of 24 hour exceedences of 50 μg m^{-3}
Defra AURN station at Brintons Road	2005	26	5
	2006	26	5
Permanent monitoring station at Redbridge School	2005	27.2	9
	2006	30.4	14
Mobile monitoring unit at Bitterne Road	2005	23.7*	3
	2006	27.7	7

6.6 Model validation

Dispersion model

The AEA's LADS-URBAN model described in Section 4 is applicable for PM_{10}. In addition to the data and assumptions used to characterise traffic and dispersion conditions described in Section 4 for NO_2, particle emission from brake and tyre wear were included for PM_{10}. The emission factors of brake and tyre wear given by the Air Quality Expert Group (2005) were used in this assessment and summarised in Table 6.2.

Table 6.2 Average PM_{10} emission factors for tyre and brake wear in the UK (Air Quality Expert Group, 2005)

	Tyre wear	Brake wear
Cars	0.00874 g/km	0.0117 g/km
LGVs	0.01380 g/km	0.0182 g/km
HGVs	0.00918 g axle/ km	0.0510 g/km
Buses	0.00937 g axle/ km	0.0536 g/km

Validation and Bias adjustment
In simple terms, model validation is where the model is tested at a range of locations near to the area of concern and is judged suitable to use for a given application. The modelling approach used in this assessment has been validated and used in numerous air quality review and assessments by AEA Energy & Environment. Details of the model validation are given in Appendix 4.

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. Table 6.3 compares predictions using LADS-URBAN with measured values at the three continuous monitoring sites in Southampton for 2005. The model has slight under-predictions at two sites and a small over-prediction at the other site. The overall difference between the predictions and measurements is less than 1%. This is considered to be very good.

Bias adjustment of a prediction model is the process where the predicted concentrations by a model are adjusted to agree with local air quality monitoring data. In this case, the model has provided satisfactory predictions of the annual mean concentrations without adjustment. Therefore the model was applied for this detailed assessment in Southampton without adjustment.

The LADS-URBAN model calculates the annual mean PM_{10} concentrations. An empirical relationship provided by Technical Guidance LAQM.TG(03) was then used to estimate the number of exceedences of the 24-hour objective. Comparison of the estimated number of exceedences of the 24-hour objective by the empirical relationship with the monitoring data shown in Table 6.3 confirms that this relationship would over-predict the exceedences of the 24-hour objective in Southampton.

Table 6.3 Comparison of measured and modelled PM_{10} concentrations for 2005

	Annual average, $\mu g\ m^{-3}$			**Number of exceedences of 24 hour objective**		
	Modelled	Measured	Difference (%)	Estimated using the **modelled** concentration	Measured	Estimated using the **measured** concentration
Defra AURN station at Brintons Road	25	26	-3.8	12	3	15
Permanent monitoring station at Redbridge School	26.4	27.2	-2.9	16	9	18
Mobile monitoring unit at Bitterne Road	25.3	23.7	6.8	13	3	13

This unadjusted model for PM_{10} is likely to have some under-predictions of roadside PM_{10} concentrations. The model has taken account of the contributions from particles emitted from the vehicle exhausts, brake & tyre wears, but not coarse particles by resuspension. Technical Guidance LAQM TG (03) indicates that the roadside enhancement of PM_{10} concentrations comprises of roughly equal halves of fine particles emitted from vehicle exhausts and coarse particles generated by resuspension (including brake and tyre wear). However, an adjustment for the coarse particles by doubling the concentrations of fine particles would lead to double counting the emission from brake and tyre wear and some overestimation of PM_{10} concentrations at locations where there is less potential for resuspension: for example, there may be proportionately less resuspension at bus stops where there is a significant contribution from vehicle exhausts but little turbulent resuspension by the stationary buses.

Uncertainty

The results of dispersion modelling of pollutant concentrations are necessarily uncertain because of the uncertainties in the estimation of rates of emission, meteorological data, dispersion conditions and background concentrations in future years.

7 Modelling results for PM_{10} from Redbridge R/B to Millbrook R/B

In this section, PM_{10} concentrations predicted for 2005, 2010 and 2012 are presented as a series of contour plots and are assessed against Air Quality Objectives for fine particles (PM_{10}). Concentrations may be first shown over a wide area for the modelled roads and more detailed plots are then shown around potential hotspots.

7.1 2005 PM_{10} modelling results (Base Case)

Figure 7.1 shows the predicted PM_{10} concentration between Redbridge Roundabout and Millbrook Roundabout in 2005. The model predicts that the annual mean objective of 40µg/m^3 for PM_{10} has not been exceeded in this area in 2005. The highest predicted NO_2 concentration at relevant locations in this air area is only 27.7 µg/m^3.

Figure 7.2 shows the predicted number of exceedences of the 24-hour objective in 2005. The model predicts that the 24-hour mean objective of 50µg/m^3 for PM_{10} has not been exceeded more than 35 times in this area in 2005 as required by the Air Quality Objectives. The highest number of predicted exceedences at relevant locations in this area is 20 days.

The predicted annual mean PM_{10} concentrations are high at the two roundabouts due to long queues and high volumes of HDVs. Figure 7.3 shows the details of the predicted annual mean PM_{10} concentration at the Redbridge roundabout, i.e. the junction between Coniston Road / M271 which was identified as a hotspot by the 2006 updating and screening assessment. No exceedence to the annual mean was predicted at relevant locations in this area in 2005, and exceedences to the 24-hour mean of 50µg/m^3 for PM_{10} will not be more than 35 times in 2005.

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7.2 2010 PM_{10} modelling results

Even though the HDV traffic volume is forecasted to increase by 3% per annum to 2012 in this area, the annual mean PM_{10} concentration is predicted to fall due to the reduction in background concentration resulted by national measures. Figure 7.4 shows the predicted annual mean PM_{10} concentrations between Redbridge Roundabout and Millbrook Roundabout in 2010. The model predicts that the annual mean objective of 40µg/m^3 for PM_{10} to be achieved by 2004 will not be exceeded in this area in 2010. The highest predicted NO_2 concentration at relevant locations in this air area is only 25.1 µg/m^3.

Figure 7.5 shows the predicted number of exceedences of the 24-hour objective in 2010. The model predicts that the 24-hour mean objective of 50µg/m^3 for PM_{10} will not be exceeded more than 35 times in this area in 2010. The highest number of predicted exceedences at relevant locations in this area is only 13 days, which is far below 35 days per year as required by the objectives.

Going forward, the 2007 UK Air Quality Strategy has set an annual mean objective of 25 µgm^{-3} for $PM_{2.5}$ to be met by 2020 in UK (except Scotland) and a target of 15% reduction in $PM_{2.5}$ concentration at urban background for UK urban areas. However, local authorities haven't been required to review air quality against these new objectives.

7.3 2012 PM_{10} modelling results

Figure 7.6 shows the predicted annual mean PM_{10} concentration between Redbridge Roundabout and Millbrook Roundabout in 2012. The model predicts that the annual mean objective of 40µg/m^3 for PM_{10} to be met by 2004 will not be exceeded in this area in 2012. The highest predicted PM_{10} concentration at relevant locations in this area is only 24.5 µg/m^3.

Figure 7.7 shows the predicted numbers of exceedences of the 24-hour objective in 2012. The model predicts that there will be no exceedence of the 24-hour mean objective of 50µg/m^3 for PM_{10} to be met by 2004 in this area in 2012. The highest predicted number of exceedences at relevant locations in this area is 11 days, which is far below 35 days per year required.

The measurements shown in Table 6.1 indicate that annual average concentrations at two sites in 2006 were 3-4 µg m^{-3} higher than that in 2005. This may indicate that the assessment based on 2005 monitoring data is likely to be conservative. However, even if 2006 is used as the base year, there will be still no exceedences of annual mean and 24-hour mean objectives for PM_{10} in 2010 and 2012.

Figure 7.1 Modelled contours of annual mean PM_{10} concentration between Redbridge R/B and Millbrook R/B in 2005

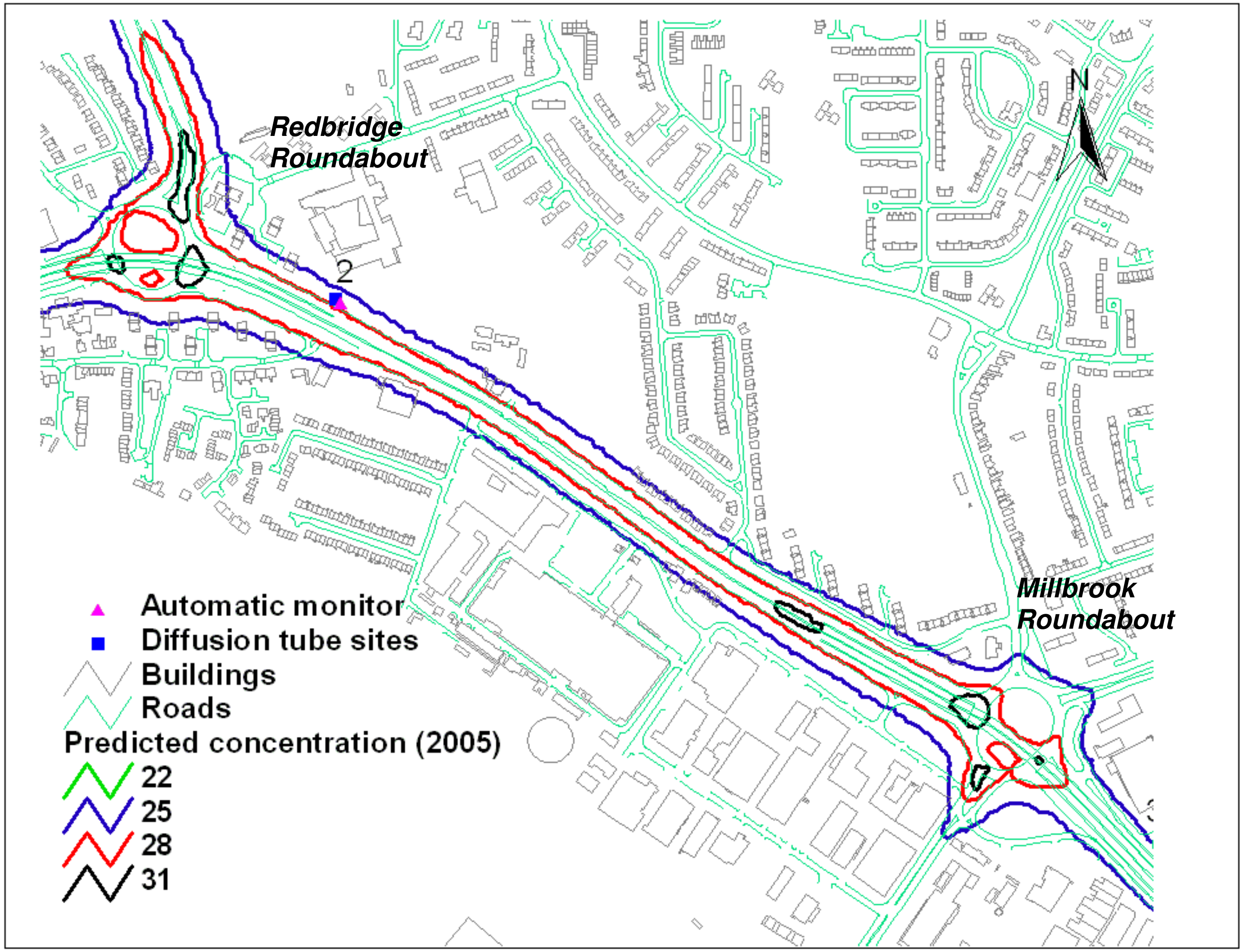


Figure 7.2 Modelled contours of numbers of exceedences of the 24-hour objective between Redbridge R/B and Millbrook R/B in 2005

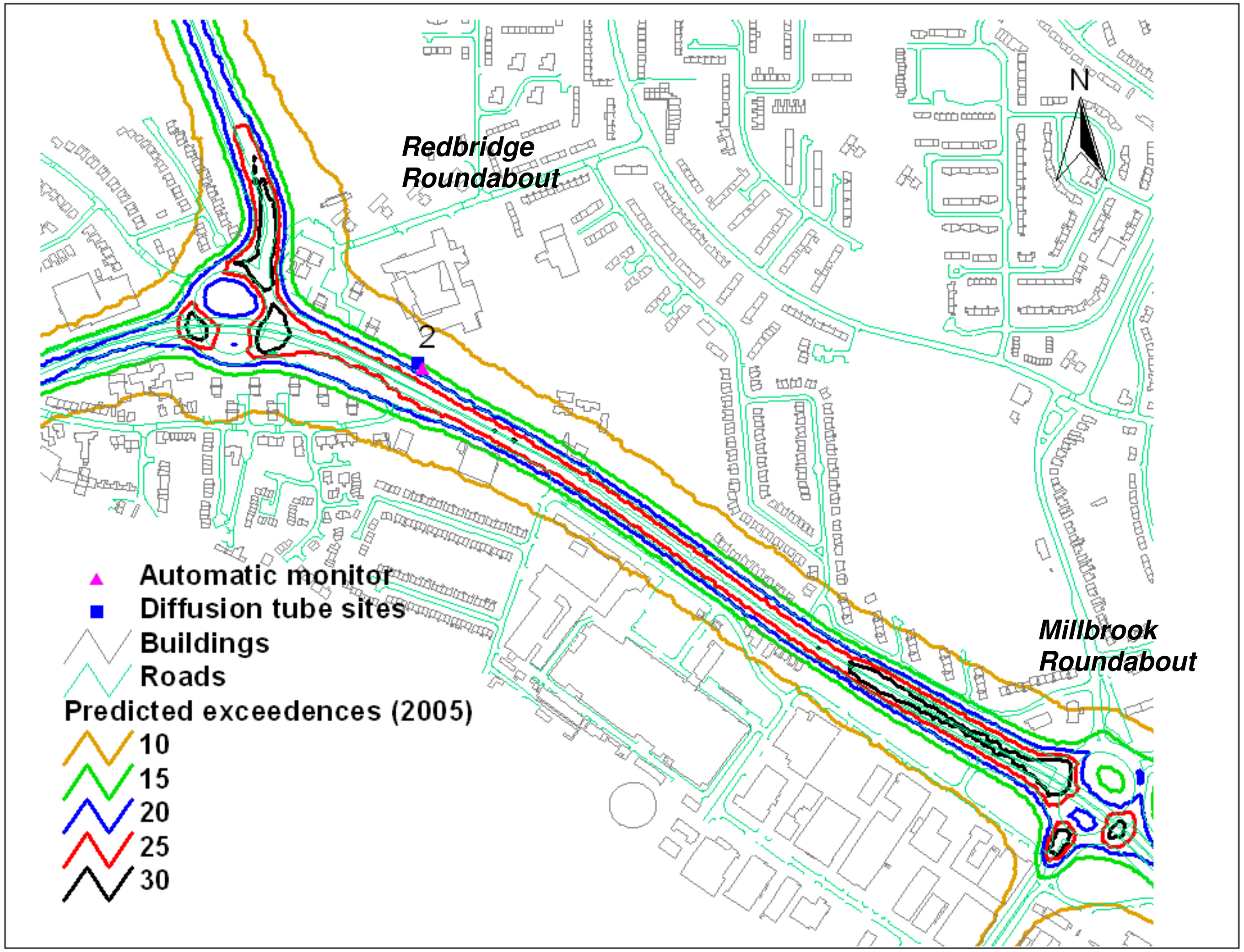


Figure 7.3 Modelled contour of annual mean PM10 concentration at the Redbridge R/B in 2005

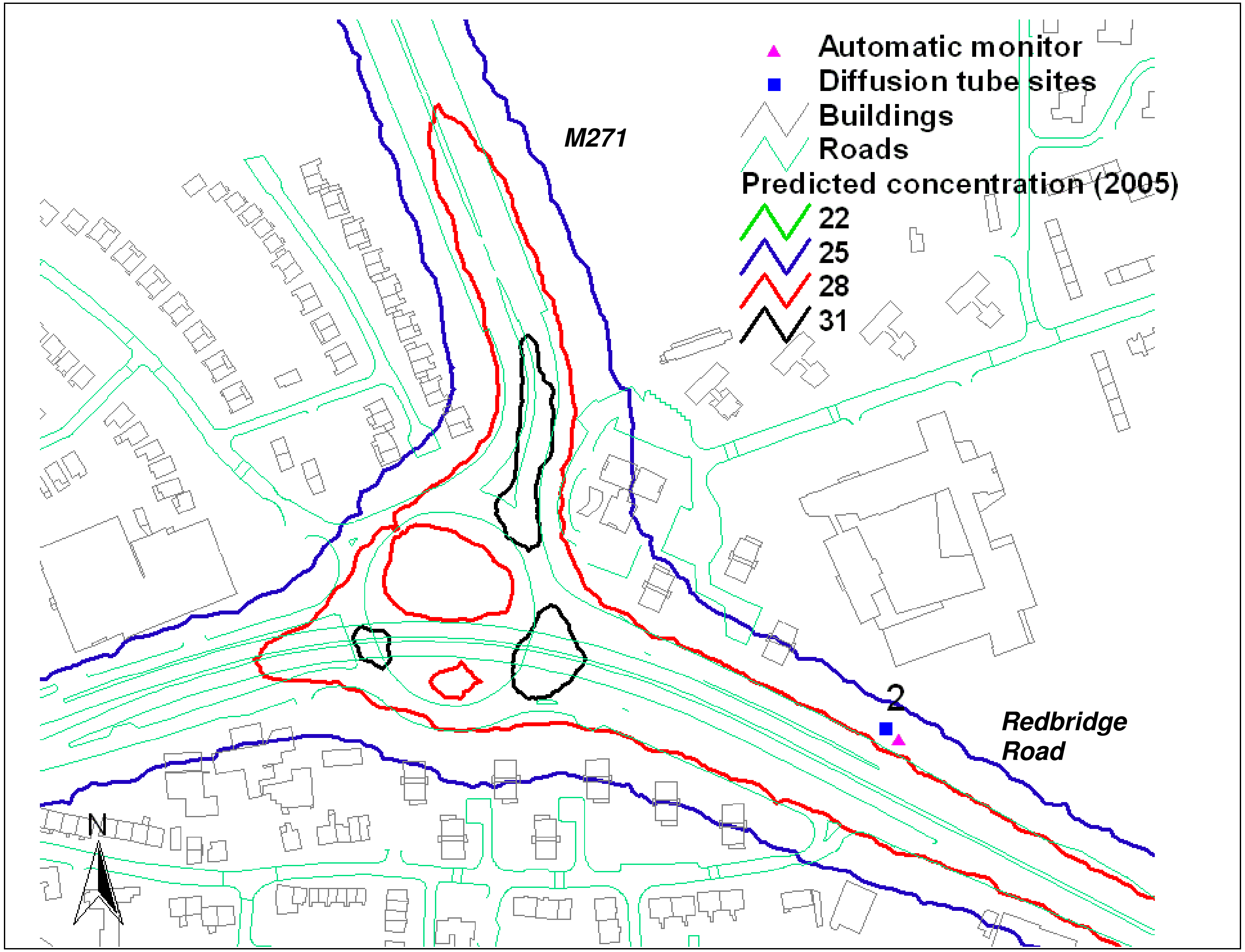


Figure 7.4 Modelled contours of annual mean PM_{10} concentration between Redbridge R/B and Millbrook R/B in 2010

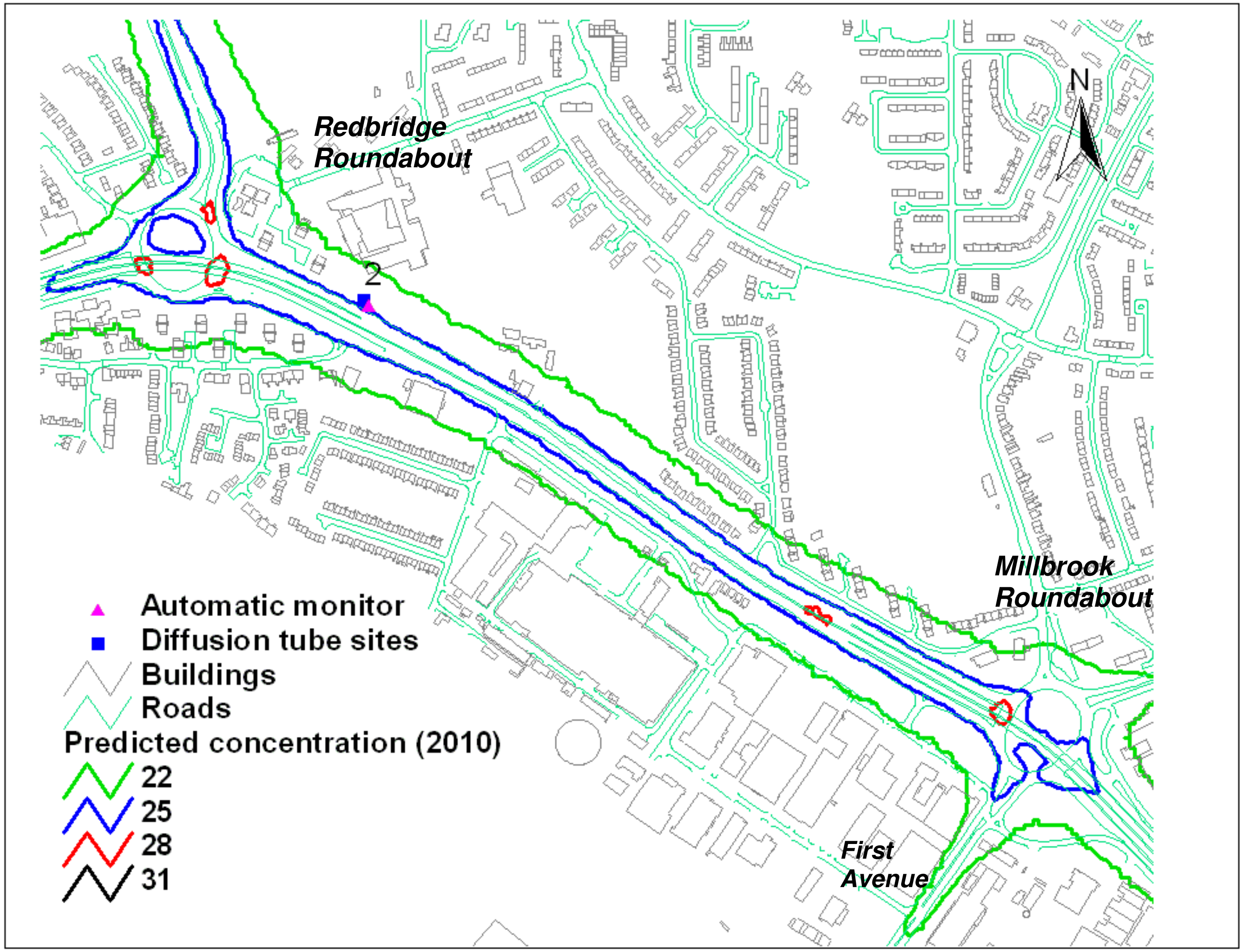


Figure 7.5 Modelled contours of number of exceedences of the 24-hour objective between Redbridge R/B and Millbrook R/B in 2010

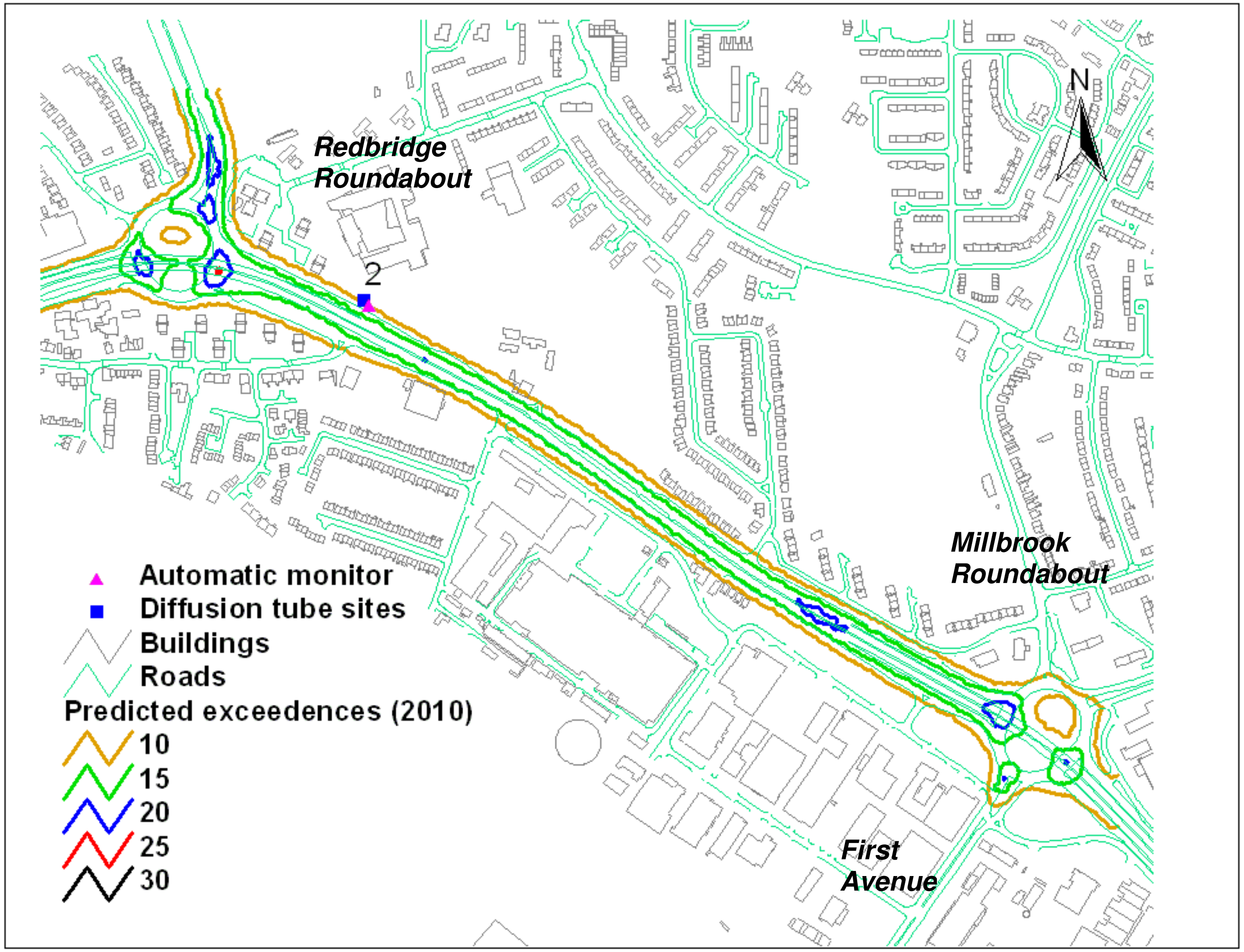


Figure 7.6 Modelled contours of annual mean PM_{10} concentration between Redbridge R/B and Millbrook R/B in 2012 Crown copyright 2006.

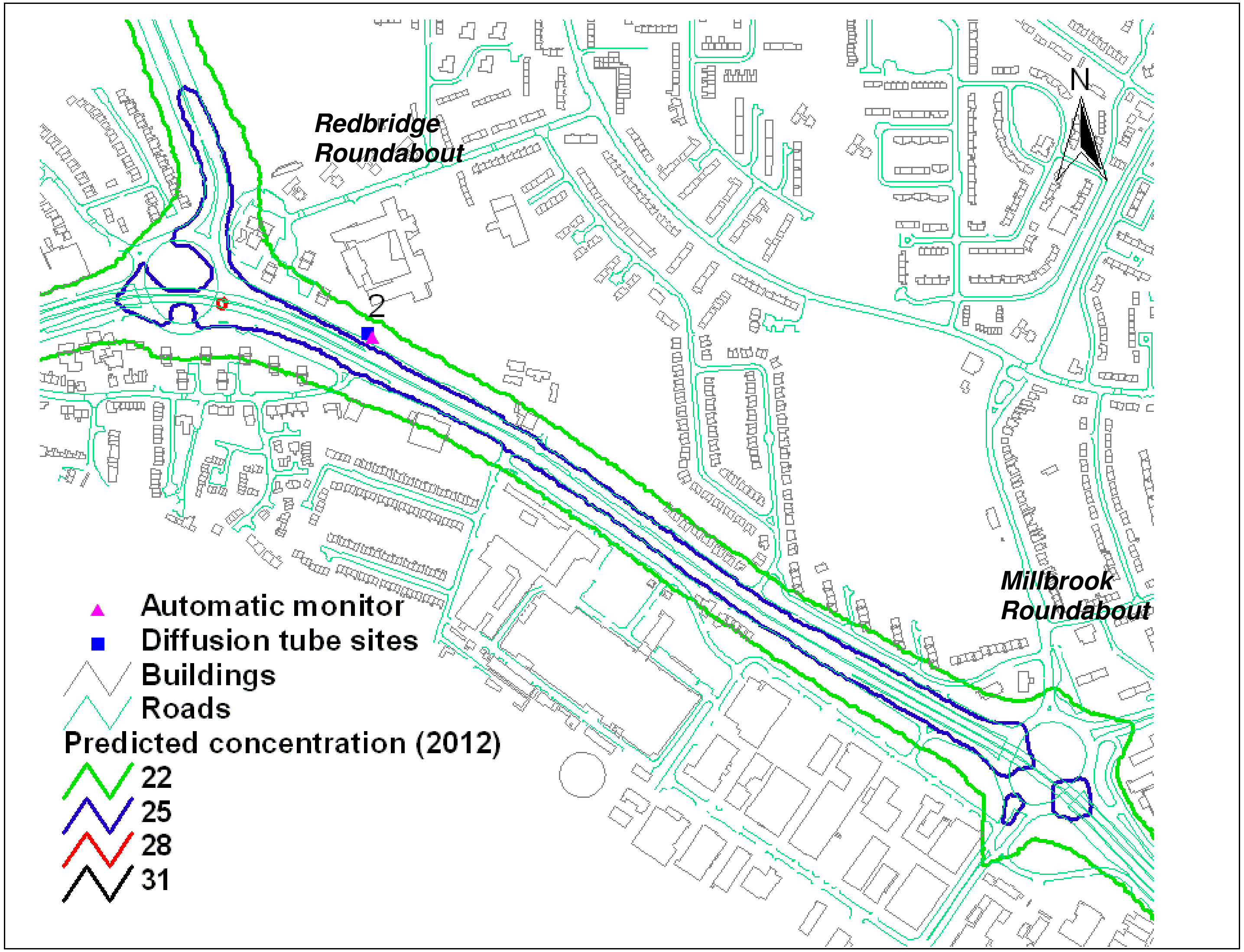
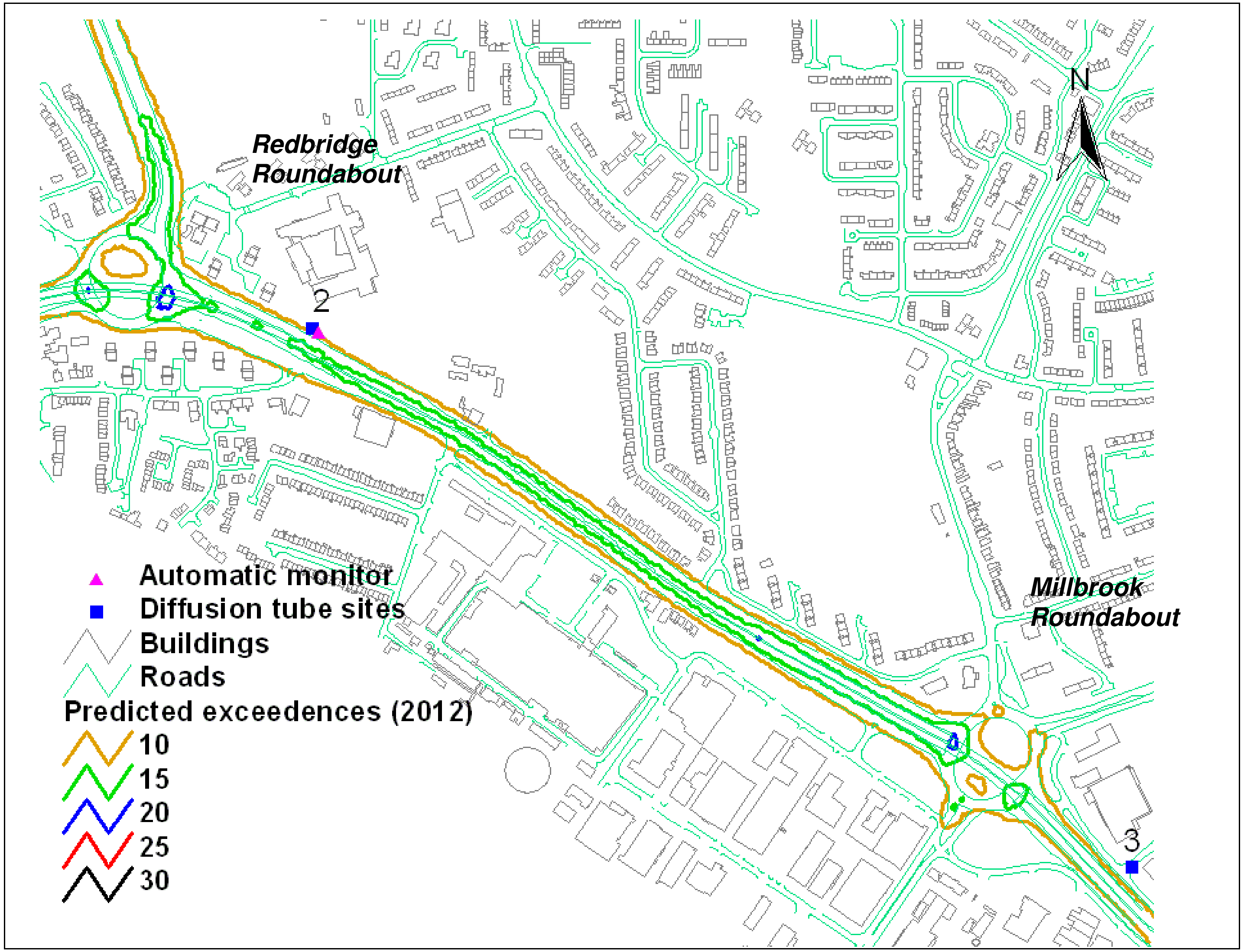


Figure 7.7 Modelled contours of the number of exceedences of the 24-hour objective between Redbridge R/B and Millbrook R/B in 2012



8 Recommendations

8.1 Summary of modelling predictions

Nitrogen dioxide

In 2005, diffusion tubes and model indicated no exceedence of the annual mean and the hourly mean objectives for NO_2 in the Mount Pleasant Road/ Crossing area.

Exceedences of the annual mean objective were indicated by a diffusion tube in Bursledon Road, but not by the model. It was estimated that the annual mean objective for NO_2 has been exceeded at the nearest building facade to the diffusion tube at the junction between Bursledon Road and Kathleen Road based on the diffusion tube result of 2006 and the scaling factor from the Air Quality Review and Assessment website by UWE (www.uwe.ac.uk/aqm/review).

No exceedence to the objectives for NO_2 is predicted in the Mount Pleasant Road/Crossing and in Bursledon Road in 2010.

PM_{10}

The model predicts that the annual mean objective of 40µg/m^3 for PM_{10} has not been exceeded in the area between Redbridge R/B and Millbrook R/B in 2005. The highest predicted PM_{10} concentration at the relevant locations in the area is 27.7 µg/m^3.

The model predicts that the 24-hour mean objective of 50µg/m^3 not to be exceeded more 35 time per year has not been exceeded in the area between Redbridge R/B and Millbrook R/B in 2005. Even though the model is likely to over-predict the number of exceedences of the 24-hour mean objective for PM_{10}, the highest number of predicted exceedences at relevant locations is 20 days.

Despite the forecasted fast growth of traffic volume to Gate 20 of Southampton Port, no exceedence to the objectives for PM_{10} to be met by 2004 is predicted in the area between Redbridge Roundabout and Millbrook Roundabout in 2010 and 2012.

8.2 Recommendations

Below are our recommendations for the areas assessed in this report:

- Southampton City Council should continue the monitoring by diffusion tubes at Mount Pleasant Crossing to confirm the predicted trend. The diffusion tube site at Mount Pleasant Road can be revoked.
- Southampton City Council could either introduce a diffusion tube site at the nearest building facade to diffusion tube Sites 31 in Bursledon Road for 12 months and declare an AQMA for NO_2 if exceedences are indicated at the new site or declare an AQMA including the nearest property to site 31 now.
- Because of exceedences indicated by diffusion tubes in 2005 & 2006 and by model (results were presented in the 2006 Further Assessment), Southampton City Council should consider declaring an AQMA for NO_2 in Commercial Road including an area as indicated in the 2006 Further Assessment.
- Because of exceedences indicated by diffusion tubes in 2005 and 2006, Southampton City Council should consider declaring an AQMA for NO_2 at 305 Millbrook Road West (named as Waterhouse Lane in the 2006 Further Assessment).

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Appendices

Appendix 1: Traffic data

Appendix 2: Monitoring data

Appendix 3: Model validations: Nitrogen dioxide roadside concentrations

Appendix 4: Model validations: PM_{10} roadside concentrations

Appendix 1

Traffic Data

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Figure A1.1 - Diagram of the traffic survey at the roundabout of Millbrook Flyover and on First Avenue by COUNT ON US on 29th March 2007

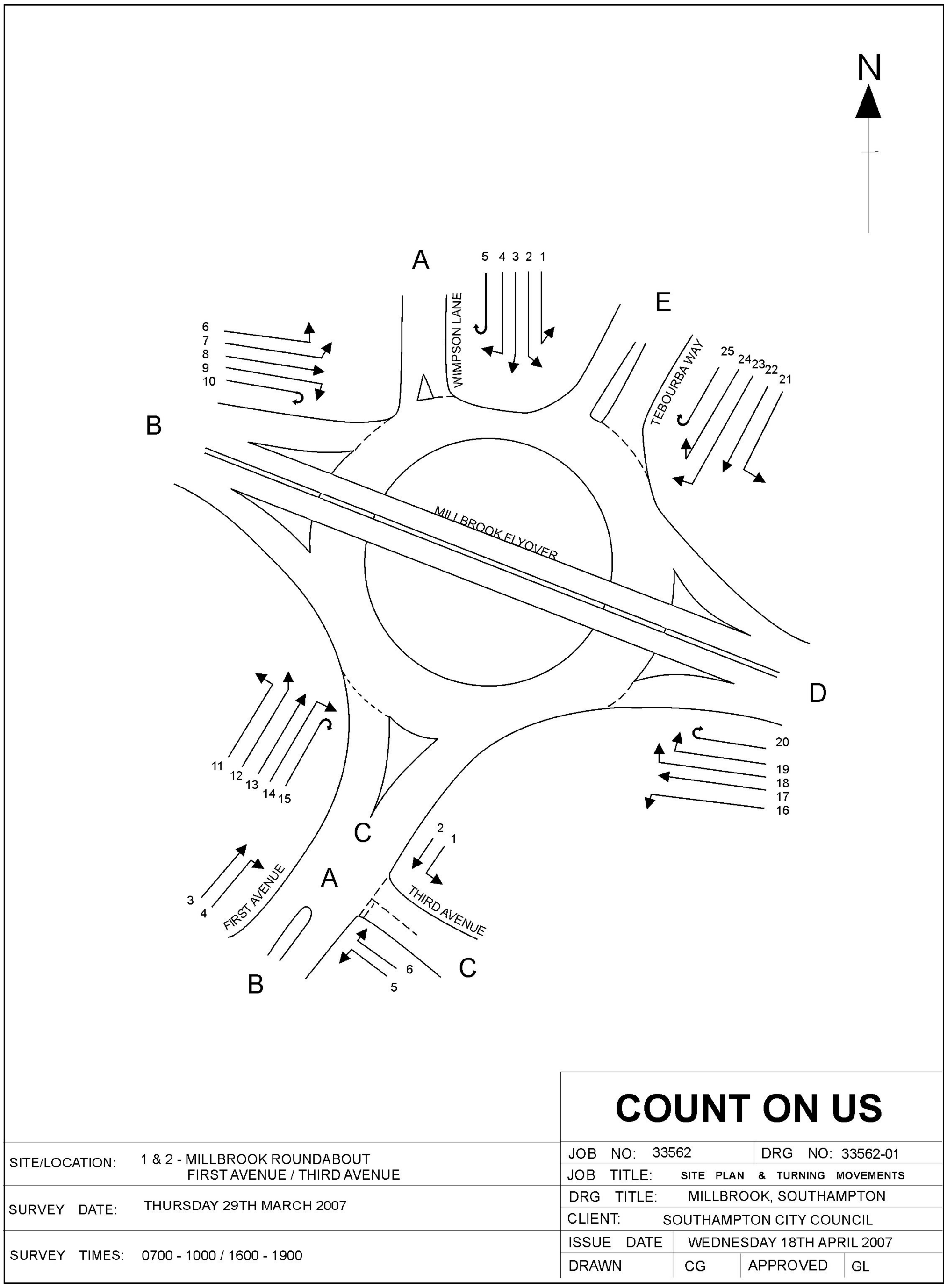

Table A1.1 – Summary of the traffic survey at the roundabout of Millbrook Flyover by COUNT ON US on 29th March 2007 between 7-10am & 4-7pm

Movement	Hourly traffic flow for peak hours	HDV %
1	36	0.8
2	213	3.5
3	51	7.7
4	213	7.8
5	1	0.0
6	186	10.7
7	462	16.8
8	152	19.2
9	319	95.5
10	44	7.0
11	304	130.0
12	131	10.0
13	33	0.3
14	64	10.3
15	0	0.2
16	50	15.5
17	63	12.2
18	203	4.0
19	80	5.7
20	10	0.3
21	135	4.5
22	85	3.2
23	459	10.8
24	19	0.0
25	0	0.0

Table A1.2 – Summary of the traffic queues at the roundabout of Millbrook flyover by COUNT ON US on 29th March 2007 between 7-10am

Road name	Queue length (M)		
	N/S	MID	O/S
Wimpson Lane	25	NA	63
A33	10	9	41
First Avenue	71	9	26
Millbrook Rd	17	28	19
Tebourba	30	NA	18

Table A1.3– Summary of the traffic survey on First Avenue by COUNT ON US on 29th March 2007 between 4-7pm

Movement	Hourly traffic flow for peak hours	HDV %
1	77	6.5
2	251	45.2
3	528	24.5
4	0	0.0
5	11	54.5
6	128	3.9

Table A1.4 – Additional traffic survey results in 2006

Road name and date of survey	AADT flow	%HGV	Average speed mph	Traffic queue
Bursledon Road 2006	17731	4%	30	100m long eastbound for 4 hours per day approaching the traffic light; 130m long westbound for 4 hours per day approaching the traffic light; 30m long either side of the traffic light for off-peak hours
Kathleen Road, 2006 (best estimation)	800	2%	30	
Hinkler Road, 2006	1920	1.6%	30	45m long for morning and afternoon rush hours; 20m long for off-peak hours
Mount Pleasant Road/Crossing, 2004	2719	6%	25	30m long either side of the crossing for all day
Imperial Road	1500	8%	Assumed to the same as Mount Pleasant Rd	
M271, 2006	52813	18.7%		300m long leading to Redbridge/Millbrook R/B for 4 hours of week day
Redbridge Road	80216	4.28%		200m long for 4 hours of week day on eastbound slip road coming off Redbridge/Millbrook R/B; 200m long for 4 hours of week day on westbound slip road coming off Redbridge/Millbrook R/B towards M271
Millbrook Road	56556	3.3%		

Table A1.5 – Traffic growth factors used to predict traffic flows in future years

From	To	Southampton Growth factor
2005	2010	1.086
2010	2012	1.027

Table A1.6 – Emission rates of Diesel trains passing Mount Pleasant Crossing

Parameter	Value	
	2005	**2010**
Train speed (mph)	20	20
Train NOx emission rate (g/Kw h)	14.03	14.03
Train engine size (kw)	2238	2238
EWS Class 66 trains per day	7	10
Freightliner Class 66 trains per day	30	43*
Passenger Class 66 trains per day	5	5
Total NOx emission per day (g/m)	38.79	53.56
NOx emission rate to use (g/m/s)	0.00045	0.00062

* Same growth rate were assumed as EWS Class 66 trains

Table A1.7 – NOx emission rates of shipping at Southampton port

Ship Type	Movements	
	Cruising (g/s/m)	**Staying in berths** (g/s/berth)
Container	1.1071E-04	3.1235E+00
Ro-Ro	1.4285E-04	2.3579E+00
General Cargo	8.4832E-05	2.6131E+00
Ferries (other)	1.7204E-05	1.9649E+00
Military	2.0732E-05	2.3579E+00
Passenger	2.0483E-05	2.1776E+00
Miscellaneous	3.2295E-04	2.3579E+00
IOW ferries	1.2501E-03	1.7574E+00
Hythe Ferries	6.0314E-04	1.7574E+00

Appendix 2

Monitoring Data

CONTENTS

SOUTHAMPTON CITY AIR QUALITY REPORT FOR 2005

Pollutant	Redbridge School	Bitterne Road/ Bullar Road by Mays Carpets	AURN Brintons Road (provisional data, may be subject to further quality control)
Particulate (PM_{10}) ug/m3	Average of 27.2ug/m3, peak day of 63.6ug/m^3 on the 7th October, 9 days above the daily mean standard Data Capture 93.8%	Average of 23.7 ug/m^3, peak day of 59 ug/m^3 on the 7th October, 3 days above the standard Data Capture 76%	Average of 26 ug/m^3, Peak day of 61 ug/m3 3 days above the standard. Data Capture 91%
Nitrogen Dioxide ppb	Average of 36.5 ug/m3 peak hour of 153 ug/m3 on 30th August Data Capture 93.2%	Average of 37 ug/m3, peak hour 154 ug/m3 on 20th December Data Capture 85.6%	Average of 31 ug/m3 peak hour of 113 ug/m3 Data Capture 87%
Sulphur Dioxide ppb	Average of 8.5 ug/m3 peak 15 minute of 165ug/m3 on 13th July Data Capture 93.1%	Average of 4.3 ug/m3, peak 15 minute 162 ug/m3 22nd June Data Capture 85.7%	Average of 4 ug/m3 peak 15 minute of 247 ug/m3 Data Capture 90%
Carbon Monoxide ppm	N/A	N/A	Average of 0.3 mg m3 peak 8 hour mean of 3.4 mg m3 Data Capture 88.5%
Ozone ppb	Average of 30.8 ug/m3 Peak 8 Hour of 102ug/m2 on 28th June 1 day above the standard Data Capture 93.8%	N/A	Average of 33 ug/m3 peak 8 hour mean of 90 ug/m3 0 day above the standard Data Capture 91.3%
Benzene	N/A	N/A	1.69 ug/m3 100% data capture (pumped diffusion tube)

Onslow Road, Bevois Valley Oxides of Nitrogen Station

In 2005 a small roadside monitoring station was installed opposite 3 Onslow Road on the pavement. This is within the Air Quality Management Area. After some initial problems with interruptions to the power supply, data was gathered from 15/7/05- 31/12/05 with 98% data capture. **The Nitrogen**

Dioxide mean for this 6 month period was 48.7 ug/m3, in line with the modelling prediction for this location.

Description of the Monitoring Stations in Southampton

DEFRA Automatic Urban Network Station, Brintons Road, by Six Dials Junction, established 1994, classified as an Urban Centre site. Approx. 8metres from the kerb of Northam Road, approx. 38000 vehicles per day. Monitors NOx, SO_2, O_3, CO, PM_{10}. and benzene by pumped diffusion tube. A residential area with houses close to the road.

Mobile Unit, (Groundhog) currently sited at Bitterne Road opposite Mays Carpets. Monitors NO_2, SO_2, and PM_{10}. Residential Area approx. 10 metres from Bitterne Road/Bullar Road Traffic Lights and close to railway line.
Previously sited at the Civic Centre Front Car Park & Wimpson Lane, Millbrook. 35,000 vehicles per day, 2.3% HGV, 30mph speed limit. On the edge of the Air Quailty Management Area.

Permanent Station, at Redbridge Community School, established April 99. Approx. 8 metres from the kerb of Redbridge Road the most heavily trafficked road in Southampton, a 3-lane dual carriageway, and 50-mph speed limit. This road is the designated route into the port for HGVs, approx. 80,000 vehicles per day, 7% HGV. Monitors NO_2, SO_2, O_3 and PM_{10}. A residential area with several schools and sports grounds next to the road.

Roadside Station, opposite 3 Onslow Road, within the Bevois Valley Air Quality Management Area. Established in July 2005. 18,000 vehicles per day, 2.6% HGV, 30mph speed limit. Only monitors oxides of nitrogen. 2 metres from the kerb.

Appendix 3

Model validation
Nitrogen dioxide roadside concentrations

CONTENTS

INTRODUCTION

The dispersion model ADMS-3 was used to predict nitrogen dioxide concentrations at roadside locations. ADMS-3 is a PC-based model that includes an up-to-date representation of the atmospheric processes that contribute to pollutant dispersion.

The model was used to predict

- the local contribution to pollutant concentrations from roads; and
- The contribution from urban background sources.

The contribution from urban background sources was calculated from the ADMS-3 output using the NETCEN Local Area Dispersion System (LADS) model. The LADS model provides efficient algorithms for applying the results of the dispersion model over large areas.

The model was verified by comparison with monitoring data obtained at a number of roadside, kerbside or near-road monitoring sites in London.

- London Marylebone
- Camden Roadside
- Haringey Roadside
- London Bloomsbury
- London North Kensington
- London A3 Roadside

London Marylebone site is located in a purpose built cabin on Marylebone Road opposite Madame Tussauds. The sampling point is located at a height of 3 m, around 1 m from the kerbside. Traffic flows of over 80,000 vehicles per day pass the site on six lanes. The road is frequently congested. The surrounding area forms a street canyon and comprises of education buildings, tourist attractions, shops and housing

Camden Roadside site (TQ267843) is located in a purpose built cabin on the north side of the Swiss Cottage Junction. The site is at the southern end of a broad street canyon. Sampling points are approximately 1 m from the kerbside of Finchley Road at a height of 3 m. Traffic flows of 37,000 vehicles per day pass the site and the road is often congested. Pedestrian traffic is also high. The surrounding area mainly consists of shops and offices.

London North Kensington site (TQ240817) is located within the grounds of Sion Manning School. The sampling point is located on a cabin, in the school grounds next to St Charles Square, at a height of 3 m. The surrounding area is mainly residential.

London A3 monitoring station (TQ193653) is within a self-contained, air-conditioned housing immediately adjacent to the A3 Kingston Bypass (6 lane carriageway). Traffic flow along the bypass is approximately 112,000 vehicles per day and is generally fast and free flowing with little congestion. The manifold inlet is approximately 2.5 m from the kerbside at a height of approximately 3 m. The surrounding area is generally open and comprises residential dwellings and light industrial and commercial properties.

London Bloomsbury monitoring station (TQ302820) is within a self-contained, air-conditioned housing located at within the southeast corner of central London gardens. The gardens are generally laid to grass with many mature trees. All four sides of the gardens are surrounded by a busy (35,000 vehicles per day), 2/4 lane one-way road system which is subject to frequent congestion. The nearest road lies at a distance of approximately 35 metres from the station. The manifold inlet is approximately 3 metres high. The area in the vicinity of the manifold is open, but there are mature trees within about 5 metres.

London Haringey site (TQ339906) is located in a purpose built cabin within the grounds of the Council Offices. The sampling point is at a height of 3 m located 5 m from High Road Tottenham (A1010) with traffic flows of around 20,000 vehicles per day. The road is frequently congested. The surrounding area consists of shops, offices and housing.

MODEL APPLICATION

Study area

Two study areas were defined- a local study area and an urban background study area. The local study area was defined for each of the monitoring sites extending 200 m in each direction (NSEW) from the monitoring site. Roads in the study area were identified. Each road in the study are was then treated as a quadrilateral volume source with depth 3 m, with spatial co-ordinates derived from OS maps. The urban background study area extended over an 80 km x 80 km area covering the London area. The background study area was divided into 1 km x 1 km squares-each 1 km square was then treated as a square volume source with depth 10 m.

Traffic flows in the local study area

Traffic flows, by vehicle category, on each of the roads within the local study area for 1996 were obtained from the DETR traffic flow database. The traffic flows were scaled to 1998 by factors shown in Table A3.1 obtained by linear interpolation from Transport Statistics GB, 1997.

Table A3.1 Traffic growth 1998:1996

	Growth factor
Cars	1.05
Light goods vehicles	1.05
Heavy goods vehicles	1.04
Buses	1.00
Motorcycles	1.00

Traffic flows follow a diurnal variation. Table A3.2 shows the assumed diurnal variation in traffic flows.

Table A3.2 Assumed diurnal traffic variation

Hour	Normalised traffic flow
0	0.20
1	0.11
2	0.10
3	0.07
4	0.08
5	0.18
6	0.49
7	1.33
8	1.97
9	1.50
10	1.33
11	1.46
12	1.47
13	1.51
14	1.62
15	1.74
16	1.94
17	1.91
18	1.53
19	1.12
20	0.88
21	0.68
22	0.46
23	0.33

Vehicle speeds in the local study area
Vehicle speeds were estimated on the basis of TSGB, 1997 data for central area, inner area and outer area average traffic speeds in London, 1968-1995 and for non-urban and urban roads for 1996. Table A3.3 shows the traffic speeds applied to each of the sites. The low speeds in Central London reflect the generally high levels of congestion in the area.

Table A3.3 Traffic speeds used in the modelling

Site	Road class	Vehicle speed, kph
London Marylebone	Central London	17.5
Camden Roadside	Central London	17.5
London Bloomsbury	Central London	17.5
London A3 Roadside	Non-urban dual carriageway	88
London Haringey	Outer London	32
London North Kensington	Background site	Not applicable

Vehicle emissions in the local study area
Vehicle emissions of oxides of nitrogen were estimated using the Highways Agency Design Manual for Roads and Bridges, 1999 (DMRB). DMRB provides a series of nomograms that allow the effect on emission rates of the proportion of heavy goods vehicles and the average vehicle speed to be taken into account. The estimated emissions are based on average speeds and take account of the variations in emissions that follow from normal patterns of acceleration and deceleration. DMRB provides estimates of the emissions of particulate material from vehicle exhausts.

Emissions in the urban background study area
Emission estimates for each 1 km square in the urban background study area were obtained from two emission inventories. The London inventory for 1995/6 (LRC, 1997) was used for most of the urban background study area: the National Atmospheric Emission Inventory, 1996 was used for areas within the urban background study area not covered by the London inventory.

The emission estimates for each square for 1996 were scaled to 1998 using factors taken from DMRB.

Meteorological data
Meteorological data for Heathrow Airport 1998 was used to represent meteorological conditions. The data set included wind speed and direction and cloud cover for each hour of the year. It was assumed that a surface roughness of 0.5 m was representative of the suburban area surrounding Heathrow Airport.

The meteorological conditions over London are affected by heat emissions from buildings and vehicles. This “urban heat island” effect reduces the frequency and severity of the stable atmospheric conditions that often lead to high pollutant concentrations. In order to take this into account the Monin-Obukhov length (a parameter used to characterise atmospheric stability in the model) has been assigned a lower limit as shown in Table A3.4.

Table A3.4: Monin-Obukhov limits applied

Site	Limit, m	Note
London Marylebone	100	Large conurbation
Camden Roadside	100	Large conurbation
London Bloomsbury	100	Large conurbation
London A3 Roadside	30	Mixed urban/industrial
London Haringey	30	Mixed urban/industrial
London North Kensington	100	Large conurbation
Small towns <50,000	10	
Urban background area	100	
Rural	1	

Surface roughness
The surface roughness is used in dispersion modelling to represent the roughness of the ground. Table A3.5 shows the surface roughness values applied.

Table A3.5 Surface roughness

Site	Surface roughness, m	Note
London Marylebone	2	Street canyon
Camden Roadside	1	City
London Bloomsbury	1	City
London A3 Roadside	0.5	Suburban
London Haringey	1	City
London North Kensington	1	Suburban
Urban background area	1	

Model output
The local model was used to estimate:

- Annual average road contribution of oxides of nitrogen ;
- road contribution to oxides of nitrogen concentrations for each hour of the year.

The urban background model was used to estimate:

- the contribution from urban background sources to annual average oxides of nitrogen concentrations;
- the contribution from roads considered in the local model to urban background concentrations;
- the contribution from urban background sources to oxides of nitrogen concentrations for each hour of the year.

Background concentrations
A rural background concentration of 20 $\mu g\ m^{-3}$ was added to the urban background oxides of nitrogen concentration.

Calculation of annual average nitrogen dioxide concentrations
Nitrogen dioxide is formed as the result of the oxidation of nitrogen oxides in air, primarily by ozone. The relationship between oxides of nitrogen concentrations and nitrogen dioxide concentrations is complex; an empirical approach has been adopted.

The contribution from locally modelled roads to urban background oxides of nitrogen concentrations was first subtracted from the calculated urban background concentration. The annual average urban background nitrogen dioxide concentration was then calculated from the corrected annual average urban background oxides of nitrogen concentration using the following empirical relationship based on monitoring data from AUN sites:

For NO_x>23.6 µg m^{-3}

$$NO_2 = 0.348.NO_x + 11.48 \ \mu g\ m^{-3}$$

For NO_x<23.6 µg m^{-3}

$$NO_2 = 0.833.NO_x \ \mu g\ m^{-3}$$

The contribution of road sources to nitrogen dioxide concentrations was then calculated using the following empirical relationship (Stedman):

$$NO_2 = 0.162.NO_x$$

The contributions from road and background sources to annual average nitrogen dioxide concentrations were then summed.

The calculated value was then corrected so that there was agreement between modelled and measured concentrations at a reference site (London North Kensington (LNK)):

NO_2(corrected, site)= NO_2(modelled, site)+ NO_2(measured, LNK)- NO_2(modelled, LNK)

Calculation of 99.8th percentile hourly average concentrations
A simple approach has been used to estimate 99.8th percentile values. The approach relies on an empirical relationship between 99.8th percentile of hourly mean nitrogen dioxide and annual mean concentrations at kerbside/roadside sites, 1990-1998:

NO_2(99.8th percentile)=3.0 NO_2(annual mean)

99.8 th percentile values were calculated on the basis of the modelled annual mean.

The calculated value was then corrected so that there was agreement between modelled and measured concentrations at a reference site (London North Kensington (LNK)):

NO_2(corrected, site)= NO_2(modelled, site)+ NO_2(measured, LNK)- NO_2(modelled, LNK)

RESULTS

Modelled results are shown in Table A3.6. Fig. A3.1 shows modelled annual average nitrogen dioxide concentrations plotted against the measured values. Similarly Fig. A3.2 shows modelled 99.8th percentile average nitrogen dioxide concentrations plotted against measured values.

Table A3.6 Comparison of modelled and measured concentrations

Site	Nitrogen dioxide concentration, ppb			
	Annual average		99.8th percentile hourly	
	Modelled	Measured	Modelled	Measured
London A3	32	30	94	73
North Kensington	24	24	70	70
Bloomsbury	28	34	83	78
Camden	32	33	95	89
London Marylebone	45	48	134	121
Haringey	22	28	65	77

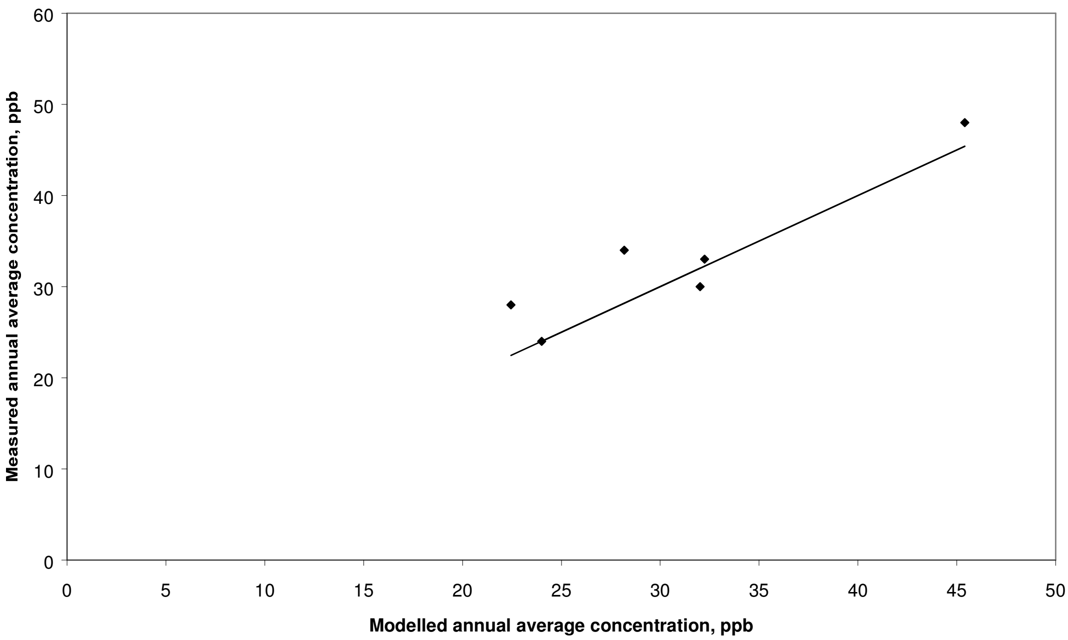

Fig. A3.1 Comparison of modelled and measured annual average nitrogen dioxide concentrations

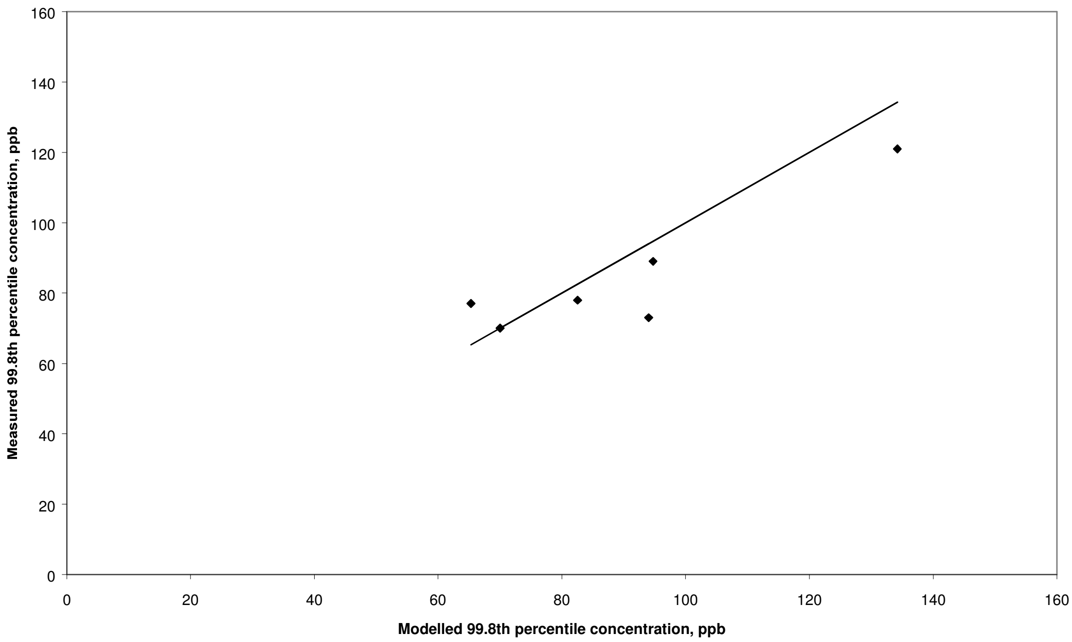

Fig. A3.2 Comparison of modelled and measured 99.8th percentile hourly average nitrogen dioxide concentrations

DISCUSSION

Model errors

The error in the modelled annual average at each site was calculated as a percentage of the modelled value. The standard deviation of the errors was then calculated: it was 12% with five degrees of freedom.

The error in the 99.8 th percentile concentration at each site was calculated as a percentage of the modelled value. The standard deviation of the errors was then calculated: it was also 12% with five degrees of freedom.

Year to year variation in background concentrations

Nitrogen dioxide concentrations at monitoring sites show some year to year variations. Reductions in emissions in the United Kingdom are responsible for some of the variation, but atmospheric influences and local effects also contribute to the variation.

In order to quantify the year to year variation monitoring data from AUN stations with more than 75% data in the each of the years 1996-1998 was analysed using the following procedure.

First, the expected concentrations in 1997 and 1996 were calculated from the 1998 data.

$$c_e = \frac{d_{1998}}{d_y}.c_{1998}$$

where c_{1996} is the concentration in 1998;

d_{1998}, d_y are correction factors to estimate nitrogen dioxide concentrations in future years (1996=1, 1997=0.95, 1998=0.91) from DETR guidance;

The difference between the measured value and the expected value was then determined for each site and normalised by dividing by the expected value. The standard deviation of normalised differences was determined for each site. A best estimate of the standard deviation from all sites was then calculated. The standard deviation of the annual mean was 0.097 with 2 degrees of freedom. The standard deviation of the 99.8th percentile hourly concentration was 0.21 with 2 degrees of freedom.

Short periods of monitoring data
Additional errors can be introduced where monitoring at the reference site (used to calibrate the modelling results against) takes place over periods less than a complete year, typically of three or six months.

In this case, a whole year of data was available at the monitoring site (1999 in Glasgow Centre), and so no correction was necessary for short periods of monitoring.

Confidence limits
Upper confidence limits for annual mean and 99.8th percentile concentrations were estimated statistically from the standard deviation of the model error and the year to year standard deviation:

$$u = c + \sqrt{(t_m s_m)^2 . \left(1 + \frac{1}{k}\right) + (t_y s_y)^2 + \sum (t_p s_p)^2 / k}$$

where:

s_m, s_y, s_p are the model error standard deviation , the year to year standard deviation and the standard error introduced using part year data;

c is the concentration calculated for the modelled year;

t_m, t_y, t_p are the values of Student's t distribution for the appropriate number of degrees of freedom at the desired confidence level;

k is the number of reference sites used in the estimation of the modelled concentration.

In many cases, the concentration estimate is based on a single reference site (k=1). However, improved estimates can be obtained where more than one reference site is used.

Table A3.7 shows confidence levels for predictions as a percentage of modelled values

Table A3.7 Upper confidence levels (k=1) for modelled concentrations for future years

Confidence level	Annual mean	99.8^{th} percentile
80 %	+19%	+27%
90%	+31%	+47%
95%	+44%	+70%

In practical terms,

- there is less than 1:5 chance (i.e.100-80=20%) that the 40 µg m^{-3} objective will be exceeded if the modelled annual average concentration in 2005 is less than 34 µg m^{-3} (i.e. 40/1.19);
- there is less than 1:20 (i.e. 100-5=5%) chance that the objective will be exceeded if the modelled roadside concentration is less than 28 µg m^{-3} (i.e. 40/1.44).

- Similarly, there is less than 1:5 chance that the 200 µg m^{-3} 99.8^{th} percentile concentration will be exceeded if the modelled concentration for 2005 is less than 157 µg m^{-3};
- there is less than 1:20 chance that the objective will be exceeded if the modelled concentration in 2005 is less than 117 µg m^{-3}.

In the figures shown in the report, the intervals of confidence limits for the 'probable' and 'likely' annual average and hourly objective concentrations have been set equal to those for 'possible' and 'unlikely', respectively. In reality, the intervals of concentration increase as the probability of exceeding the annual and hourly objective increases from 'unlikely' to 'likely'. The advantage to setting symmetrical concentration intervals is that the concentration contours on the maps become simpler to interpret. This is a mildly conservative approach to assessing the likelihood of exceedences of the NO_2 objectives since a greater geographical area will be included using the smaller confidence intervals.

A simple linear relationship can be used to predict the 99.8^{th} percentile concentration of NO_2 from the annual concentration: the 99.8^{th} percentile is three times the annual mean at kerbside/roadside locations. Therefore, plots of the modelled annual mean NO_2 concentrations can be used to show exceedences of both the annual and hourly NO_2 objectives. However, the magnitude of the concentrations used to judge exceedences of the hourly objective need to be adjusted so they may be used directly with the plots of annual concentration. This has been performed by simply dividing the concentrations of the confidence limits by three.

The following table shows the difference between assigning symmetrical confidence intervals and assigning intervals based directly on the statistics.

Table A3.8a Confidence levels for modelled concentrations for future years based on symmetrical concentration intervals and concentration intervals derived purely from the statistics

Description	Chance of exceeding objective	Confidence limits for the modelled annual average concentrations (µg m^{-3})			
		Annual average objective (symmetrical intervals)	Symmetrical intervals	Annual average objective (intervals based on statistics)	Interval
Very unlikely	Less than 5%	< 28		< 28	
Unlikely	5 to 20%	28 to 34	6.0	28 to 34	6.0
Possible	20 to 50%	34 to 40	6.3	34 to 40	6.3
Probable	50 to 80%	40 to 46	6.3	40 to 47	7.5
Likely	80 to 95%	46 to 52	6.0	47 to 58	10.3
Very likely	More than 95%	> 52		> 58	

Table A3.8b Confidence levels for modelled concentrations for future years based on symmetrical concentration intervals and concentration intervals derived purely from the statistics

Description	Chance of exceeding objective	Confidence limits for the modelled annual average concentrations (µg m^{-3})			
		Hourly average objective (symmetrical intervals)	Symmetrical intervals	Hourly average objective (intervals based on statistics)	Interval
Very unlikely	Less than 5%	< 39		< 39	
Unlikely	5 to 20%	39 to 52	13.2	39 to 52	13.2
Possible	20 to 50%	52 to 67	14.3	52 to 67	14.3
Probable	50 to 80%	67 to 81	14.3	67 to 85	18.1
Likely	80 to 95%	81 to 94	13.2	85 to 113	28.7
Very likely	More than 95%	> 94		> 113	

Appendix 4

Model validation-PM_{10} roadside concentrations

CONTENTS

A4.1 Introduction

The dispersion model ADMS-3 was used to predict PM10 concentrations at roadside locations. ADMS-3 is a PC-based model that includes an up-to-date representation of the atmospheric processes that contribute to pollutant dispersion.

The model was verified by comparison with monitoring data obtained at a number of roadside, kerbside or near-road monitoring sites in London. The monitoring sites considered were:

- London Marylebone
- Camden Roadside
- Haringey Roadside
- London Bloomsbury
- London North Kensington
- London A3 Roadside

London Marylebone site is located in a purpose built cabin on Marylebone Road opposite Mme Tussauds. The sampling point is located at a height of 3m, around 1m from the kerbside. Traffic flows of over 80,000 vehicles per day pass the site on six lanes. The road is frequently congested. The surrounding area forms a street canyon and comprises of education buildings, tourist attractions, shops and housing

Camden Roadside site (TQ267843) is located in a purpose built cabin on the north side of the Swiss Cottage Junction. The site is at the southern end of a broad street canyon. Sampling points are approximately 1 m from the kerbside of Finchley Road at a height of 3m. Traffic flows of 37,000 vehicles per day pass the site and the road is often congested. Pedestrian traffic is also high. The surrounding area mainly consists of shops and offices.

London North Kensington site (TQ240817) is located within the grounds of Sion Manning School. The sampling point is located on a cabin, in the school grounds next to St Charles Square, at a height of 3m. The surrounding area is mainly residential.

London A3 monitoring station (TQ193653) is within a self-contained, air-conditioned housing immediately adjacent to the A3 Kingston Bypass (6 lane carriageway). Traffic flow along the bypass is approximately 112,000 vehicles per day and is generally fast and free flowing with little congestion. The manifold inlet is approximately 2.5 m from the kerbside at a height of approximately 3m. The surrounding area is generally open and comprises residential dwellings and light industrial and commercial properties.

London Bloomsbury monitoring station (TQ302820) is within a self-contained, air-conditioned housing located at within the southeast corner of central London gardens. The gardens are generally laid to grass with many mature trees. All four sides of the gardens are surrounded by a busy (35,000 vehicles per day), 2/4 lane one-way road system which is subject to frequent congestion. The nearest road lies at a distance of approximately 35 metres from the station. The manifold inlet is approximately 3 metres high. The area in the vicinity of the manifold is open, but there are mature trees within about 5 metres.

London Haringey site (TQ339906) is located in a purpose built cabin within the grounds of the Council Offices. The sampling point is at a height of 3 m located 5m from High Road Tottenham (A1010) with traffic flows of around 20,000 vehicles per day. The road is frequently congested. The surrounding area consists of shops, offices and housing.

A4.2 Model application

A4.2.1 Study area

A study area was defined for each of the monitoring sites extending 200 m in each direction (NSEW) from the monitoring site. Roads in the study area were identified. Each road in the study area was then treated as a quadrilateral volume source with depth 3m, with spatial coordinates derived from OS maps.

A4.2.2 Traffic flows

Traffic flows, by vehicle category, on each of the roads within the study area for 1996 were obtained from the DETR traffic flow database. The traffic flows were scaled to 1998 by factors shown in Table A4.1 obtained by linear interpolation from Transport Statistics GB, 1997.

Table A4.1: Traffic growth 1998:1996

	Growth factor
Cars	1.05
Light goods vehicles	1.05
Heavy goods vehicles	1.04
Buses	1.00
Motorcycles	1.00

Traffic flows follow a diurnal variation. Table A3.2 shows the assumed diurnal variation in traffic flows.

Table A4.2: Assumed diurnal traffic variation

Hour	Normalised traffic flow
0	0.20
1	0.11
2	0.10
3	0.07
4	0.08
5	0.18
6	0.49
7	1.33
8	1.97
9	1.50
10	1.33
11	1.46
12	1.47
13	1.51
14	1.62
15	1.74
16	1.94
17	1.91
18	1.53
19	1.12
20	0.88
21	0.68
22	0.46
23	0.33

A4.2.3 Vehicle speeds

Vehicle speeds were estimated on the basis of TSGB, 1997 data for central area, inner area and outer area average traffic speeds in London, 1968-1995 and for non-urban and urban roads for 1996. Table A4.3 shows the traffic speeds applied to each of the sites. The low speeds in Central London reflect the generally high levels of congestion in the area.

Table A4.3: Traffic speeds used in the modelling

Site	Road class	Vehicle speed, kph
London Marylebone	Central London	17.5
Camden Roadside	Central London	17.5
London Bloomsbury	Central London	17.5
London A3 Roadside	Non-urban dual carriageway	88
London Haringey	Outer London	32
London North Kensington	Background site	Not applicable

A4.2.4 Vehicle emissions

Vehicle emissions were estimated using the Highways Agency Design Manual for Roads and Bridges, 1999 (DMRB). DMRB provides a series of nomograms that allow the effect on emission rates of the proportion of heavy goods vehicles and the average vehicle speed to be taken into account. The estimated emissions are based on average speeds and take account of the variations in emissions that follow from normal patterns of acceleration and deceleration. DMRB provides estimates of the emissions of particulate material from vehicle exhausts. Nearly all the exhaust material is in the sub 10 µm range and so it was assumed that all the particulate material released in the exhaust was PM_{10}.

PM_{10} is also released as the result of resuspension of roadside dusts from tyre wear, brake pad wear etc.. The rate of emission is uncertain: it has been suggested that resuspended dusts may be emitted at rates approaching those from vehicle exhausts. The rate of resuspension is expected to depend to some extent on wind speed, with relatively little resuspension occurring at low wind speeds. For this assessment it has been assumed that resuspended dusts are emitted at a rate of half the exhaust emissions when calculating annual average PM_{10}concentrations but resuspension has been ignored when calculating PM_{10}concentrations for the meteorological conditions (generally low wind speeds) corresponding to the 90^{th} percentile 24 hour average.

A4.2.5 Meteorological data

Meteorological data for Heathrow Airport 1998 was used to represent meteorological conditions. The data set included wind speed and direction and cloud cover for each hour of the year. It was assumed that a surface roughness of 0.5 m was representative of the suburban area surrounding Heathrow Airport.

The meteorological conditions over London are affected by heat emissions from buildings and vehicles. This "urban heat island" effect reduces the frequency and severity of the stable atmospheric conditions that often lead to high pollutant concentrations. In order to take this into account the Monin-Obukhov length (a parameter used to characterise atmospheric stability in the model) has been assigned a lower limit as shown in Table A4.4.

Table A4.4: Monin-Obukhov limits applied

Site	Limit, m	Note
London Marylebone	100	Large conurbation
Camden Roadside	100	Large conurbation
London Bloomsbury	100	Large conurbation
London A3 Roadside	30	Mixed urban/industrial
London Haringey	30	Mixed urban/industrial
London North Kensington	100	Large conurbation
Small towns <50,000	10	
Rural	1	

A4.2.6 Surface roughness

The surface roughness is used in dispersion modelling to represent the roughness of the ground. Table A4.5 shows the surface roughness values applied.

Table A4.5: Surface roughness

Site	Surface roughness, m	Note
London Marylebone	2	Street canyon
Camden Roadside	1	City
London Bloomsbury	1	City
London A3 Roadside	0.5	Suburban
London Haringey	1	City
London North Kensington	1	Suburban

A4.2.7 Model output

The model was used to estimate:

- Annual average road contribution ;
- 90 th percentile 24 hour average road contribution;
- road contribution for each hour of the year.

A4.2.8 Background concentrations

The London North Kensington site was used to provide an estimate of the background concentration of PM_{10}. The background concentration was then estimated at other sites on the basis of DETR background maps (http://www.aeat.co.uk/netcen/airqual/) for 1996. The background maps were corrected to 1998 by multiplying the concentrations by 0.82 (0.9 for 1997), based on the comparison of monitoring data at 17 monitoring sites with greater than 75% data capture in both years. Thus, background annual average concentrations at other sites were estimated using:

C_{av}(site, 1998)=C_{av}(LNK,measured,1998)+0.82*(C_{av}(site,map,1996)-C_{av}(LNK,map,1996))

The 90th percentile 24 hour average concentration at other sites were estimated using:

C_{90}(site, 1998)=C_{av}(LNK,measured,1998)*1.68+0.82*1.68*(C_{av}(site,map,1996)-C_{av}(LNK,map,1996))

The background concentrations for each hour used in the calculation of 90th %ile concentrations at other sites were estimated using:

C (site, 1998)=C (LNK,measured,1998)+0.82*1.68*(C_{av}(site,map,1996)-C_{av}(LNK,map,1996))

The factor 1.68 in the above equations is taken from an analysis of the relationship between the 90th percentile 24 hour average PM10 and the annual average PM10 concentration at UK Automatic Network sites 1992-1997.

The background concentrations and the DETR background map were based on TEOM measurements. In order to convert to gravimetric measurements the values were multiplied by a factor 1.3, following Pollutant Specific Guidance.

A4.2.9 Adding background concentrations

The modelled road contribution to PM_{10} were added to the background concentrations in a number of ways. For total annual average gravimetric concentrations:

C_{av}(total, site,1998)= C_{av}(background, site, 1998)*1.3+ C_{av}(roads, site, 1998)- C_{av}(roads, LNK, 1998)

90th percentile 24 hour average concentrations were estimated (Method 1):

C_{90}(total, site,1998)= C_{90}(background, site, 1998)*1.3+ C_{90}(roads, site, 1998)- C_{90}(roads, LNK, 1998)

The 90th %ile 24 hour average concentration was also estimated more formally by first calculating for each hour (Method 2):

C (total, site,1998)= C (background, site, 1998)*1.3+ C (roads, site, 1998)- C (roads, LNK, 1998)

then calculating the average concentration for each day and then determining the 36th highest daily average concentration.

A4.3 Results

Modelled results are shown in Table A4.6. Fig.A43.1 shows modelled annual average PM10 concentrations plotted against the measured values. Similarly Fig. A4.2 shows modelled 90 th percentile 24 hour average PM_{10} concentrations plotted against measured values (Method 1).

The two methods of calculating the 90th percentile concentration are compared in Fig. A4.3. It shows the value calculated by adding the 90th percentile road contribution to the 90th percentile background concentrated compared with the value calculated more formally by taking the 90th percentile of daily average background plus road concentrations.

Table A4.6: Model results summary

		Measured				Background, TEOM		Modelled road contribution, gravimetric		Modelled, gravimetric		
		Mean (TEOM)	Mean, gravimetric	90%ile TEOM	90 % gravimetric	DETR1996 map	Corrected to model year	Mean	90th%ile	Mean	90th%ile (1)	90th%ile (2)
1998	Haringey	22	28.6	35	45.5	27	18.36	2.28	3.08	26.15	43.18	41.34
	London Marylebone	32	41.6	45	58.5	29	20	17.60	21.55	43.60	65.23	61.33
	Camden	25	32.5	36	46.8	29	20	9.39	12.08	35.39	55.76	53.23
	Bloomsbury	23	29.9	32	41.6	29	20	1.20	1.46	27.20	45.14	43.87
	London A3	24	31.2	39	50.7	25	16.72	8.76	11.85	30.50	48.37	47.28
	North Kensington	20	26	33	42.9	29	20	0.00	0.00	26.00	43.68	42.80
1997	Camden	32	41.6	48	62.4	29	24	10.43	13.42	41.63	65.84	
	Haringey	26	33.8	43	55.9	27	22.2	2.53	3.42	31.39	51.91	
	North Kensington	24	31.2	38	49.4	29	24	0.00	0.00	31.20	52.42	

(1) 90^{th} percentile 24 hour average value calculated by adding background and road 90^{th} percentiles

(2) 90^{th} percentile 24 hour average value calculated by adding daily mean background and road concentrations and then calculating the 90 th percentile value

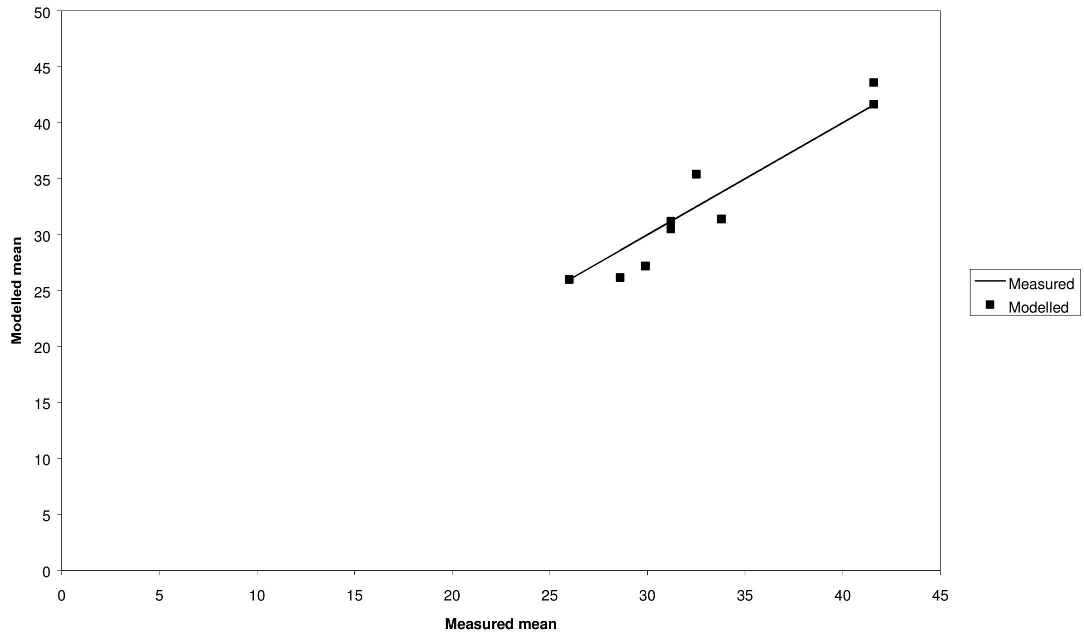

Fig. A4.1:Comparison of modelled and measured annual mean PM_{10} concentrations, $\mu g/m^3$ gravimetric

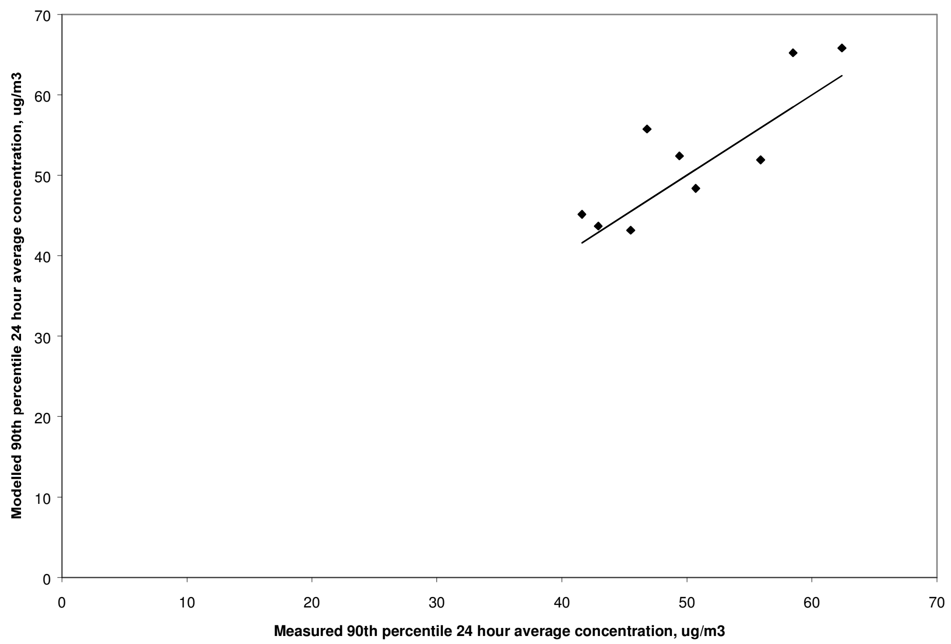

Fig. A4.2: Comparison of modelled and measured 90th percentile 24 hour average PM_{10} concentrations (Method 1), $\mu g/m^3$ gravimetric.

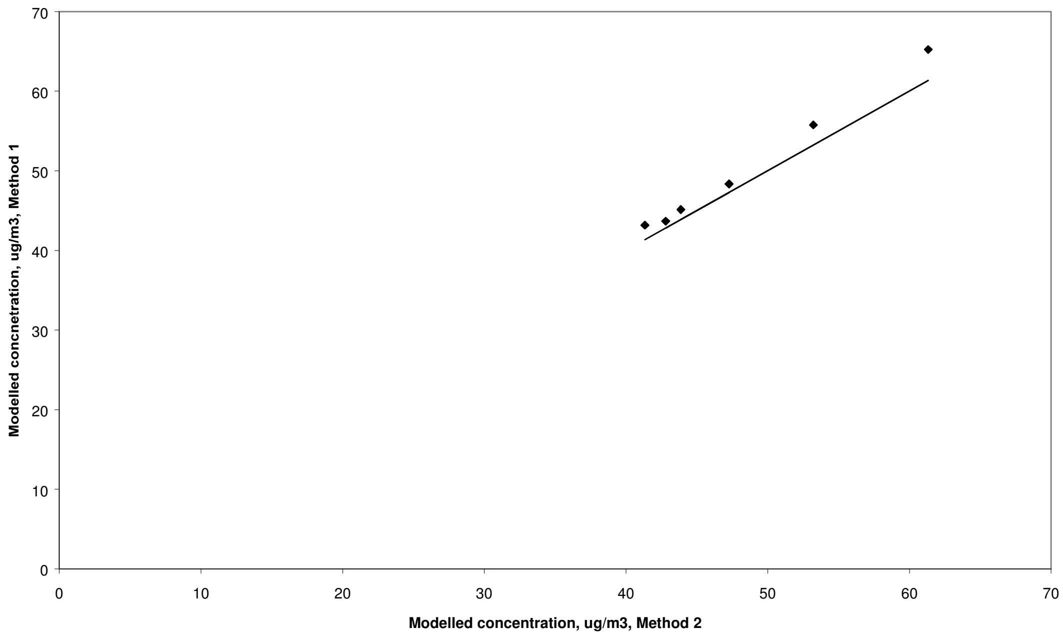

Fig. A4.3: Comparison of 90th percentile calculation methods, gravimetric units

A4.4 Discussion

A4.4.1 Model errors

The difference between the modelled and measured values were calculated. The standard deviation of the difference was then determined.

The estimated standard error was 2.0 μg m^{-3} and 4.3 μg m^{-3} (gravimetric) for the annual mean and 90th percentile concentrations respectively with 5 degrees of freedom.

A4.4.2 Year to year variation in background concentrations

PM10 concentrations at background sites show wide year to year variations. The year 1996 showed exceptionally high PM10 concentrations while 1998 showed relatively low concentrations. Reductions in emissions in the United Kingdom are responsible for some of the variation, but atmospheric influences have a significant effect.

Measurements of PM10 concentrations in Epping Forest District were carried out for a limited period (August 1 – November 5) during 1999. Monitoring data from other measurement sites in the London area was therefore assessed to determine whether measurements made over this period were representative of concentrations in 1996.

In order to quantify the year to year variation monitoring data from monitoring stations in the London area with more than 75% data in the each of the years 1996-1998 was analysed using the following procedure.

First, the expected annual average concentrations in 1999 were calculated from the 199x data.

$$c_e = (c_{av,199x} - 1.3.c_m.b_{199x} - 10.5).\frac{a_{199x}}{a_{1999}} + 1.3 \times b_{1999} \times c_m + 10.5$$

where $c_{av,199x}$ is the average concentration (gravimetric) in 199x;

the factor 1.3 is used to convert TEOM measurements to gravimetric;

c_m is the annual average secondary concentration (TEOM) from DETR map for 1996;

a_{1999}, a_{199x} are correction factors to estimate primary combustion PM10 concentration in 2004 from DETR guidance;

b_{year} is a correction factor to estimate secondary PM10 in future years from 1996 mapped data;
the factor 10.5 represents the contribution of coarse dusts to annual average concentrations (gravimetric).

The expected concentrations are plotted against the average concentration over the measurement period in Fig. .The difference between the measured average concentration for the period August 1 – November 5 1999 and the expected value was then determined for each site. The average difference and the standard deviation of the differences was determined.

The average difference in annual average (the bias) was –0.06 µg m^{-3} with standard deviation 1.95 µg m^{-3} with 26 degrees of freedom (both in TEOM units).

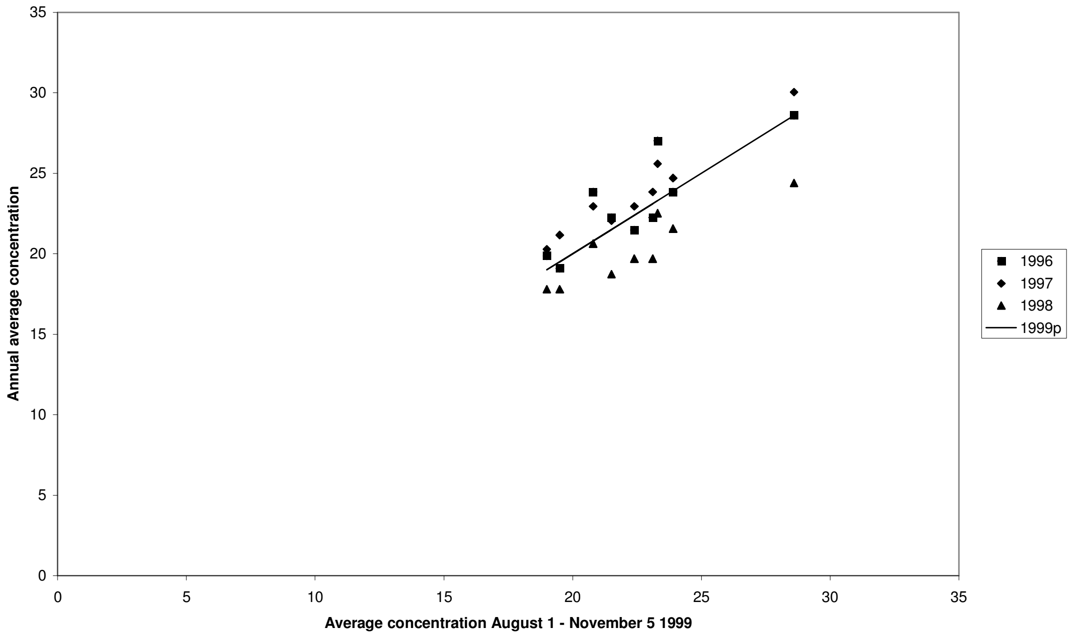

Fig. A4.4: Comparison of average concentrations (µg m^{-3} TEOM) during August 1-November 5 1999 with annual average concentrations

A4.4.3 Confidence limits

Upper confidence limits for predicted 90th percentile 24 hour average concentrations were estimated from the standard deviation of the model error and the year to year standard deviation:

$$u = c + 1.68.b + \sqrt{2.(t_m s_m)^2 + (1.68 t_y s_y)^2}$$

where s_m, s_y are the model error standard deviation and the standard deviation in the yearly bias, b;
c is the concentration calculated for the modelled year;
b is the bias between average annual concentrations and the concentrations for the measurement period at the reference site;
t_m, t_y are the values of Student's t distribution for the appropriate number of degrees of freedom at the desired confidence level;
the factor 2 allows for uncertainty in the estimates of concentrations at the reference site;
the factor 1.68 applies to 90th percentile concentrations only.

Table A4.7 shows confidence levels for predictions of concentrations in future years based on the use as reference of data from the Epping Forest District monitoring site.

Table A4.7: Confidence levels for prediction of concentrations in future years based on Epping Forest monitoring data

One sided confidence level	Upper confidence limits, µg m^{-3} gravimetric	
	Mean	90^{th} percentile 24 hour average
80%	+3.3	+6.5
90%	+5.2	+10.4
95%	+7.0	+14

In practical terms, there is less than 1:5 chance that the 50 ug/m3 objective will be exceeded in 2004 if the modelled 90^{th} percentile 24 hour average concentration is less than 43.5 ug/m3: there is less than 1:20 chance that the objective will be exceeded if the modelled roadside concentration is less than 36 ug/m3.

Alternative method of calculation

Figure A4.3 shows that the simple method of adding 90^{th} percentile backgrounds and road contributions provides a good estimate of the value calculated as the 90^{th} percentile of daily average background plus road concentrations.