Report

Air Quality: Detailed Assessment

A report produced for Watford Borough 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[1] provides a framework for air quality control through air quality management and air quality standards. These and other air quality standards[*] and their objectives have been enacted through the Air Quality Regulations in 1997, 2000 and 2002[2]. The Environment Act 1995 requires Local Authorities to undertake air quality reviews. In areas where an air quality objective is not anticipated to be met, Local Authorities are required to establish Air Quality Management Areas and implement action plans to improve air quality.

Stages 1-3 of the first round of air quality review and assessments have been completed by Watford Borough Council. The Council has proceeded to the second round of review and assessment in which sources of emissions to air are reassessed to identify whether the situation has changed since the first round, and if so, what impact this may have on predicted exceedences of the air quality objectives.

The First and Second Stage Review and Assessments undertaken by Watford Borough Council during the first round concluded that levels of benzene, 1,3-butadiene, carbon monoxide, sulphur dioxide and lead were already below the air quality objective levels.

The Third Stage Review and Assessment of NO_2 and particulate matter, PM_{10} concluded that concentrations of NO_2 and PM_{10} at certain locations close to major roads in the area were likely to exceed air quality objective limits. Watford Borough Council considered the potential for public exposure at these locations and concluded that there were no domestic properties within the likely area of exceedence. The Council was satisfied that there was no relevant public exposure and so no Air Quality Management Areas were declared

The second round of review and assessment is undertaken in two steps. The first step is an Updating and Screening Assessment, which updates the Stage 1 and 2 review and assessment previously undertaken for all pollutants identified in the Air Quality Regulations. Where a significant risk of exceedence is identified for a pollutant it is necessary for the local authority to proceed to a Detailed Assessment, equivalent to the previous Stage 3 assessments. Where a local authority does not need to undertake a Detailed Assessment, a progress report is required instead. Watford Borough Council have carried out an Updating and Screening Assessment and concluded that there was a

[*] 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.

significant risk of exceeding the air quality objectives at relevant locations near some of the busiest roads in Watford.

This report is a Detailed Assessment for Watford Borough Council as outlined in the Government's published guidance.

The general approach taken to this detailed assessment was to:

- Identify potential "hot spots" where there is expected to be the greatest potential for public exposure in the general area identified in the Updating and Screening Assessment as being at risk of exceedence;
- Collect and interpret additional data to support the detailed assessment, including detailed traffic flow data around potential hotspots;
- Consider recent continuous monitoring and diffusion tube measurements;
- Use monitoring data from the continuous monitors located close to Rickmansworth Road in Watford and at background sites in neighbouring authority areas to assess the ambient concentrations produced by the road traffic and to calibrate the output of modelling studies;
- Model the concentrations of NO_2 and PM_{10} around the potential hotspots, 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;
- Consider whether the authority should declare an Air Quality Management Area and provide recommendations on the scope and extent of any proposed Air Quality Management Area
- Identify the main emission sources contributing to exceedences of the objectives where they are predicted to occur.

It is recommended that Watford Borough Council consider declaring Air Quality Management Areas as shown below :

General Area	Description
St Albans Road	1) Residential properties with facades on the east side north of Bushey Mill Lane for a distance of 70 m; 2) Residential properties with facades on the east side between Bushey Mill lane and Balmoral Road within 40 m of bus stops and pedestrian crossings; 3) Residential properties between Balmoral Road and Leavesden Road with facades on east side or on west side within 40 m of bus stops and pedestrian crossings; 4) Residential properties with facades on both sides between Station Road and Beechen Grove within 40 m of bus stops
Rickmansworth Road	Residential properties with facades on the south side between Beechen Grove and Cassio Road
Farraline Road	Residential properties with facades on the north side
Pinner Road/Chalk Hill junction	1) Residential properties immediately to the north of the junction; 2) Residential properties with facades on the north side of Chalk Hill between junction and Aldenham Road 3) Residential property with façade on east side of Pinner Road near zebra crossing and bus stops near junction with Capel Road
Horseshoe Lane/A405 junction	1) Residential property on Horseshoe Lane, closest to junction 2) Two residential properties on St Albans Road nearest to the junction.
M1	1) 1 property on Ravenscroft closest to M1 2) 6 residential properties on the Gossamers closest to M1 3) 3 residential properties on Eastlea Avenue closest to M1

Special consideration should be given to the receptors close to the M1. Hertsmere Borough Council revoked their Air Quality Management Area covering Osprey Close because modelling for nitrogen dioxide for their Stage 4 assessment showed that predicted concentration for 2005 was slightly less than the objective. The modelling carried out for the present assessment, based on slightly different input data has predicted that the concentrations at the same receptor locations will be slightly greater than the objective. The difference between the two modelling assessments can be attributed to uncertainties in the model. It will be possible to resolve this issue using the diffusion tube measurement at Osprey Close when average bias adjustment factors for diffusion tubes for 2003 are reported (http://www.uwe.ac.uk/aqm/review/answers.html#RND3). It is recommended that Watford Borough Council delay their decision to declare an Air Quality Management Area for properties close to the M1 motorway until the bias adjustment factor for 2003 becomes available.[†]

It is recommended that Watford Borough Council do not declare an Air Quality Management for particulate matter PM_{10}. The assessment has been based on monitoring data for a relatively high pollution year 2002, has taken account of resuspended dusts conservatively, and has considered the effects of buses waiting at bus stops. Even so, the 24 hour objective is only just approached at the most exposed locations close to bus stops on St Albans Road. We believe that the conservative nature of this assessment provides an adequate margin of protection.

[†] These factors are expected to be available in April 2004. I have discussed this matter with the Review and Assessment helpdesk and it is likely that this approach will be acceptable to defra.

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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
kerbside	0 to 1 m from the kerb
Limit Value	An EU definition for an air quality standard of a pollutant listed in the air quality directives
$MW_{thermal}$	Megawatt thermal capacity
n	number of pairs of data
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
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

This section outlines the purpose of this Detailed Assessment for Watford Borough Council, and the scope of the assessment.

1.1 PURPOSE OF THE DETAILED ASSESSMENT

The first round of air quality review and assessments is now complete and all local authorities should have completed all necessary stages. Where the likelihood of exceedences of air quality objectives has been identified in areas of significant public exposure, an air quality management area should have been declared, followed by a further Stage 4 review and assessment, and the formulation of an action plan to eliminate exceedences. Local authorities were required to proceed to the second round of review and assessment in which sources of emissions to air are reassessed to identify whether the situation has changed since the first round of review and assessment, and if so, what impact this may have on predicted exceedences of the air quality objectives. Such changes might include significant traffic growth on a major road, which had not been foreseen, construction of a new industrial plant with emissions to air, or significant changes in the emissions of an existing plant.

The second round of review and assessment is undertaken in two steps. The first step is an Updating and Screening Assessment, which updates the Stage 1 and 2 review and assessments previously undertaken for all pollutants identified in the Air Quality Regulations. Where a significant risk of exceedence is identified for a pollutant it is necessary for the local authority to proceed to a Detailed Assessment, equivalent to the previous Stage 3 assessments. Where a local authority does not need to undertake a Detailed Assessment, a progress report is required instead.

Watford Borough Council have carried out an Updating and Screening Assessment and concluded that there was a significant risk of exceeding the air quality objectives near some of the busiest roads in Watford. This report is a Detailed Assessment for Watford Borough Council as outlined in the Government's published guidance.

The purpose of the detailed assessment is to provide an accurate assessment of the likelihood of an anir quality objective being exceeded at locations with relevant exposure. This should be sufficiently detailed to allow the designation of any necessary AQMAs.

1.2 OVERVIEW OF APPROACH TAKEN

The general approach taken to this Detailed Assessment was to:

- Identify potential "hot spots" where there is expected to be the greatest potential for public exposure in the general area identified in the Updating and Screening Assessment as being at risk of exceedence;
- Collect and interpret additional data to support the detailed assessment, including detailed traffic flow data around potential hotspots;
- Consider recent continuous monitoring and diffusion tube measurements;
- Use monitoring data from the continuous monitors located close to Rickmansworth Road in Watford and at background sites in neighbouring

authority areas to assess the ambient concentrations produced by the road traffic and to calibrate the output of modelling studies;

- Model the concentrations of NO_2 and PM_{10} around the potential hotspots, 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;
- Consider whether the authority should declare an Air Quality Management Area and provide recommendations on the scope and extent of any proposed Air Quality Management Area.

1.3 RELEVANT DEFRA DOCUMENTATION USED

This report takes into account the guidance in LAQM.TG(03)[3], published January 2003.

1.4 POLLUTANTS CONSIDERED IN THIS REPORT

Table 1.1 lists the pollutants included in the Air Quality Regulations[2] for the purposes of Review and Assessment. Nitrogen dioxide and particulate matter, PM10 are considered in this report. The Updating and Screening Assessment concluded that detailed assessment of other pollutants was not required.

Table 1.1 Objectives included in the Air Quality Regulations 2000 and (Amendment) Regulations 2002 for the purpose of Local Air Quality Management

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Benzene All authorities	16.25 μg/m^3	running annual mean	31.12.2003
Authorities in England and Wales only	5.00 μg/m^3	annual mean	31.12.2010
Authorities in open areas and coastal areas should be cleaner as air changes more frequently and Northern Ireland only	3.25 μg/m^3	running annual mean	31.12.2010
1,3-Butadiene	2.25 μg/m^3	running annual mean	31.12.2003
Carbon monoxide Authorities in England, Wales and Northern Ireland only	10.0 mg/m^3	maximum daily running 8-hour mean	31.12.2003
Authorities in Scotland only	10.0 mg/m^3	running 8-hour mean	31.12.2003
Lead	0.5 μg/m^3 0.25 μg/m^3	annual mean annual mean	31.12.2004 31.12.2008
Nitrogen dioxide[b]	200 μg/m^3 not to be exceeded more than 18 times a year 40 μg/m^3	1 hour mean annual mean	31.12.2005 31.12.2005
Particles (PM_{10}) (gravimetric)[c] All authorities	50 μg/m^3 not to be exceeded more than 35 times a year	24 hour mean	31.12.2004

	40 μg/m^3	annual mean	31.12.2004
Authorities in Scotland only[d]	50 μg/m^3 not to be exceeded more than 7 times a year	24 hour mean	31.12.2010
	18 μg/m^3	annual mean	31.12.2010
Sulphur dioxide	350 μg/m^3 not to be exceeded more than 24 times a year	1 hour mean	31.12.2004
	125 μg/m^3 not to be exceeded more than 3 times a year	24 hour mean	31.12.2004
	266 μg/m^3 not to be exceeded more than 35 times a year	15 minute mean	31.12.2005

b. The objectives for nitrogen dioxide are provisional.
c. Measured using the European gravimetric transfer standard sampler or equivalent.
d. These 2010 Air Quality Objectives for PM10 apply in Scotland only, as set out in the Air Quality (Scotland) Amendment Regulations 2002.

The new national particles objectives for England, Wales and Greater London are not currently included in Regulations for the purpose of LAQM. The Government and the Welsh Assembly Government however intends that the new particles objectives will be included in Regulations as soon as practicable after the review of the EU's first air quality daughter directive, which is due to be completed in 2004. The new particles objectives for England, Wales and Greater London are shown in Table 1.2. Whilst authorities have no obligation to review and assess against them, they may find it helpful to do so, in order to assist with longer-term planning, and the assessment of development proposals in their local areas. Assessment against these proposed objectives is provided in this report.

Table 1.2: Proposed new particles objectives for England, Wales and Greater London (not included in Regulations)

Region	**Air Quality Objective**		**Date to be achieved by**
	Concentration	**Measured as**	
London	50 μg/m^3 not to be exceeded more than 10 times a year	24 hour mean	31.12.2010
London	23 μg/m^3	annual mean	31.12.2010
London	20 μg/m^3	annual mean	31.12.2015
Rest of England and Wales	50 μg/m^3 not to be exceeded more than 7 times a year	24 hour mean	31.12.2010
Rest of England and Wales	20 μg/m^3	annual mean	31.12.2010

2 The UK 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)[1].

2.1.1 National Air Quality Standards

At the centre of the Air Quality Strategy 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. These standards and associated specific objectives to be achieved between 2003 and 2010 are shown in Table 1.1.

2.1.2 Timescales to achieve the objectives for the pollutants in Air Quality Strategy

In most local authorities in the UK, objectives will be met for most of the pollutants within the timescale of the objectives shown in Table 1.1. It is important to note that the objectives for NO_2 remain provisional. The Government has recognised the problems associated with achieving the standard for ozone and this will not therefore be a statutory requirement. Ozone is a secondary pollutant and transboundary in nature and it is recognised that local authorities themselves can exert little influence on concentrations when they are the result of regional primary emission patterns.

2.2 AIR QUALITY REVIEWS – THE APPROACHES AND EXPECTED OUTCOMES

Technical Guidance has been issued in 'Review and Assessment: Technical Guidance' LAQM.TG (03)[3] to enable air quality to be monitored, modelled, reviewed and assessed in an appropriate and consistent fashion. This updating and screening assessment has considered the procedures set out in this technical 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 therefore that reviews should be carried out in two steps. Both steps of review and assessment may be necessary and every authority is expected to undertake at least a first stage review and assessment of air quality in their authority area. The steps are briefly described in the following table, Table 2.1.

Table 2.1 Brief details of steps in the second Round of the Air Quality Review and Assessment process

Level of Assessment	Objective	Approach
Updating and Screening	To identify those matters that have changed since the last review and assessment, which might lead to a risk of an air quality objective being exceeded	Use a checklist to identify significant changes that require further consideration. Where such changes are identified, then apply simple screening tools to decide whether there is sufficient risk of an exceedence of an objective to justify a Detailed 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 sufficiently detailed to allow the designation or amendment of 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.
Annual Progress Reports	Local authorities should prepare annual air quality Progress Reports between subsequent rounds of reviews and assessments. The concept is that this will ensure continuity in the LAQM process.	The precise format for the Progress Report has not yet been determined, but will essentially follow the checklist approach that is set out in subsequent chapters of this document. Further details on the Progress Reports are provided via the Helpdesks. It is envisaged that these Progress Reports could be useful for the compilation of annual 'state of the environment' reports that many authorities already prepare .

The current deadline for completion of updating and screening assessments is May 2003, and for detailed assessments April 2004.

2.3 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 2.2 summarises the locations where the objectives should and should not apply.

Table 2.2 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 facades of offices or other places of work where members of the public do not have regular access.
		• Building facades of residential properties, schools, hospitals, libraries etc.	• Gardens of residential properties.
			• Kerbside sites (as opposed to locations at the building facade), 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 facade), or any other location where public exposure is expected to be short term.
		• Gardens of residential properties.	

Table 2.2 (continued) Typical locations where the objectives should and should not apply

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 be 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. Locations should also represent non-occupational exposure.

3 Information used to support this assessment

This section lists the key information used in this review and assessment.

3.1 REVIEW AND ASSESSMENT REPORTS

Watford Borough Council completed the following review and assessments of air quality during the first round of Review and Assessment (http://www.seiph.umds.ac.uk/envhealth/HBNet/la_reps/la_reps.html):

- Stage 1 (December 1998)[4]
- Stage 2
- Stage 3 (December 2000)

The Third Stage Review and Assessment of NO_2 concluded that concentrations of NO_2 and particulate matter, PM_{10} at certain locations close to major roads in the area were likely to exceed air quality objective limits. Watford Borough Council considered the potential for public exposure at these locations and concluded that there were no domestic properties within the likely area of exceedence. The Council was satisfied that there was no relevant public exposure and so no Air Quality Management Areas were declared

Watford Borough Council completed its Updating and Screening assessment in June 2003.

3.2 MAPS AND DISTANCES OF RECEPTORS FROM ROADS

Watford Borough Council provided electronic OS LandLine™ data which were used in the Geographical Information System (GIS) used in assessment. The maps were used to provide details of the location of road centrelines and road widths. Individual buildings or groups of buildings (receptors) were also identified. The distances of these receptors from the road were accurately determined from the maps.

3.3 ROAD TRAFFIC DATA

This section summarises the information used in this report; more detailed information is given in Appendix 1. Appendix 1 lists the locations of the traffic flow and speed measurement points, flow and speed data and other relevant traffic statistics.

Traffic flow data were taken from the NAEI 2000 roads database for many of the roads in Watford. Other traffic flow data was taken from Watford Borough Council’s Updating and Screening Assessment. The NAEI database provides details of traffic mix. Vehicle speeds were generally assumed to approach 50 kph in urban areas, 110 kph on the M1 motorway and 80 kph on non urban roads (corresponding to the appropriate speed limits) on straight sections of the roads. Reduced speeds in the range 20-50 kph were applied near to junctions. A diurnal variation in traffic flow was assumed, typical of urban roads near London.

The base year for the traffic flows was 2000. Traffic growth factors were calculated from the National Road Traffic Forecast and correction factors provided by the Tempro 4.2.2 database. The overall growth factors applied are shown in Table 3.1.

Table 3.1: Traffic growth factors applied

Year	**NRTF factor**	**Tempro factor**		**Overall growth factor**
		GB	Watford	
2000	107	1	1	1
2003	113	1.014	1.039	1.082
2004	115	1.018	1.051	1.110
2005	117	1.022	1.065	1.139
2010	127	1.047	1.144	1.297

3.4 TRAFFIC CONTROL MEASURES

Special consideration was given to traffic control measures on Horseshoe Lane, St Albans Road, Bushey Mill Lane, Vicarage Road and Pinner Road and at the Vicarage Road/ Wiggenhall Road junction. These locations were selected because the Updating and Screening assessment indicated that nitrogen dioxide concentration measurements by diffusion tube were higher than predicted by modelling using the Design Manual for Roads and Bridges. Watford Borough Council provided detailed information on the locations of bus stops, controlled pedestrian crossings, traffic light controlled junctions, level crossings and zebra crossings on these roads. Table 3.2 summarises the data provided.

Table 3.2: Traffic control measures

Road	Traffic control measures	Bus frequency, (one way)	Average bus waiting time	Average traffic light waiting time
Vicarage Road	Bus stops 4 Pedestrian crossings 1	0630-2230 3 per hour	40-60 seconds	45 seconds
Vicarage Road/ Wiggenhall Road junction	Pedestrian crossings 3			45 seconds
Horseshoe Lane	Bus stops 9 Pedestrian crossings 2 Traffic light controlled junctions 1	0630-2230 4 per hour	30-40 seconds	90-120 seconds
Pinner Road	Bus stops 7 Pedestrian crossings 2 Zebra crossing 1	i) 0700-2350 4 per hour ii) 0450-0100 12 per hour outside Bushey Station	i) 20-30 seconds ii) up to 1 minute	Notable rush hour congestion at zebra crossing
St Albans Road	Bus stops 16 Pedestrian crossings 2 Traffic light controlled junctions 6	0600-2330 8 per hour	60-90 seconds	45-60 seconds
Bushey Mill Lane	Bus stops 5 Pedestrian crossings 1 Traffic light controlled junctions 2 Level crossing 1	0630-2230 2 per hour	20-40 seconds	80 seconds

3.5 STREET CANYON PHOTOGRAPHIC SURVEY

The Updating and Screening Assessment concluded that there was a need to proceed to a detailed assessment of nitrogen dioxide in the vicinity of Cassio Road, Vicarage Road, Whippendell Road, Hagden Lane, Pinner Road, Chalk Hill, Bushey Mill Lane, Farraline Road, Woodford Road, Leavesden Road and Balmoral Road on the basis of narrow congested streets with residential properties close to the kerb.

The dispersion of pollutants is often restricted in narrow congested streets by the presence of buildings. These roads are often classified as “street canyons”. Technical Guidance Note LAQM.TG(03) para 6.30 defines a street canyon as a relatively narrow street with buildings on both sides, where the height of the buildings is generally greater than the width of the road. Further advice is given in Annex 3 of the Technical Guidance Note.

Watford Borough Council supplied a series of photographs of the streets identified in the USA. These are included in Appendix 2. The photographs were used in conjunction with the OS Landline data to assess whether the streets meet the definition of a street canyon.

None of the streets should be classified as "street canyons" according to the definition given in LAQM.TG(03). Leavesden Road is the most canyon-like, but has 2-storey terraced houses, approximately 10 m high and a width of 13 m between building faces. Furthermore, there are many side roads at approximately 60 m intervals which will improve the ventilation of the road.

3.6 AMBIENT MONITORING

The assessment has considered continuous automatic monitoring data from monitoring stations in Watford and neighbouring local authorities for nitrogen dioxide and particulate matter (PM_{10}). The continuous monitors from part of the Hertfordshire and Bedfordshire Network , HBNet operated and maintained by Kings College, London on behalf of the local authorities. Nitrogen dioxide concentrations are measured by ozone chemiluminescence. Particulate matter PM_{10} concentrations are measured by means of Tapered Element Oscillating Microbalance (TEOM) instruments: a factor of 1.3 was applied to convert these measurements to gravimetric equivalent values.

The Watford Town Hall roadside monitoring station (334850 390680) is located approximately 5 m from the side of the Rickmansworth Road at the Town Hall. The manifold inlet is approximately 4 metres high.

Table 3.3 shows the locations of urban background sites in neighbouring local authority areas.

Table 3.3 : Urban background monitoring sites in neighbouring local authorities

Local authority area	Site	OS Grid reference
Three Rivers	Rectory Road, Rickmansworth	505450, 194460
Dacorum	Civic Centre, Hemel Hempstead	505250, 207250
Hertsmere	Furzehill School, Borehamwood	519430, 196280

Nitrogen dioxide diffusion tube measurements were made at 8 locations throughout Watford during 2003. The Council's diffusion tubes are analysed at Harwell Scientifics using a procedure based on 50% acetone and 50%TEA. Diffusion tubes have not been collocated with the continuous monitor in Watford and so it is not possible to provide a reliable estimate of diffusion tube bias. Nevertheless, the diffusion tube measurements provide a useful indication of where the highest concentrations are expected to occur.

3.7 EMISSION FACTORS

The vehicle emission factors used for national mapping have recently been revised by defra and the devolved admininstrations[‡]. The most recent emission factors have been used in this detailed assessment.

In the Watford Stage 3 report, older emission factors were used. Using the newer factors will result in differences in the modelled results between the Stage 3 and the detailed assessment.

[‡] The new set of emission factors on the NAEI website (www.naei.org.uk/emissions/index.php) approved by DEFRA and DTLR for use in emissions and air quality modelling, following consultation of the TRL Report "Exhaust Emission Factors 2001: Database and Emission Factors" by TJ Barlow, AJ Hickman and P Boulter, TRL, September 2001

4 Detailed Assessment for Nitrogen Dioxide

4.1 THE NATIONAL PERSPECTIVE

The principal source of NOx emissions is road transport, which accounted for about 46% of total UK emissions in 2001. Major roads carrying large volumes of high-speed traffic (such as motorways and other primary routes) are a predominant source, as are conurbations and city centres with congested traffic. Within most urban areas, the contribution of road transport to local emissions will be much greater than for the national picture.

Meeting the annual mean objective in 2005, and the limit value in 2010, is expected to be considerably more demanding than achieving the 1-hour objective. National studies have indicated that the annual mean objective is likely to be achieved at all urban background locations outside of London by 2005, but that the objective may be exceeded more widely at roadside sites throughout the UK in close proximity to busy road links. Projections for 2010 indicate that the EU limit value may still be exceeded at urban background sites in London, and at roadside locations in other cities.

4.2 STANDARDS AND OBJECTIVES FOR NITROGEN DIOXIDE

The Government and the Devolved Administrations have adopted two Air Quality Objectives for nitrogen dioxide, as an annual mean concentration of 40 μgm^{-3}, and a 1-hour mean concentration of 200 μgm^{-3} not to be exceeded more than 18 times per year. The objectives are to be achieved by the end of 2005.

4.3 CONCLUSIONS OF THE FIRST ROUND OF REVIEW AND ASSESSMENT FOR NITROGEN DIOXIDE

The Third Stage Review and Assessment of NO_2 concluded that concentrations of NO_2 at certain locations close to major roads in the area were likely to exceed air quality objective limits. Watford Borough Council considered the potential for public exposure at these locations and concluded that there were no domestic properties within the likely area of exceedence. The Council was satisfied that there was no relevant public exposure and so no Air Quality Management Areas were declared

4.4 UPDATING AND SCREENING ASSESSMENT

The Updating and Screening Assessment for nitrogen dioxide concluded that there was a need to proceed to a detailed assessment for nitrogen dioxide at many locations close to roads in Watford. Table 4.1 lists the locations identified and the updating and assessment criteria that lead to their selection. Several of the roads were selected for detailed assessment on a precautionary basis i.e. they have been included because there was no evidence on which to exclude them for further consideration . Roads selected on this precautionary basis alone are identified in Table 4.1.

Table 4.1: Sites identified by Updating and Screening Assessment as requiring detailed assessment for nitrogen dioxide

Road	Reasons for detailed assessment
Pinner Road	Diffusion tube data **Narrow congested streets** Close to the objective
Vicarage Road	Diffusion tube data Narrow congested streets
Rickmansworth Road	Continuous monitoring data
St Albans Road	Diffusion tube data
Horseshoe Lane	Diffusion tube data
Cassio Road	Narrow congested streets
Hagden Lane	**Narrow congested streets**
Chalk Hill	**Narrow congested streets** **Busy streets with >1 hour exposure**
Bushey Mill Lane	**Narrow congested streets** **High flow of buses or HGVs** **Increased traffic flow**
Farraline Road	**Narrow congested streets**
Woodford Road	**Narrow congested streets**
Leavesden Road	**Narrow congested streets**
Balmoral Road	**Narrow congested streets**
M1	Close to the objective
A41	Close to the objective
A411 Hempstead Road	Close to the objective
C74 Whippendell Road	Narrow congested streets Close to the objective
Reasons are shown in **bold** where the decision to proceed to detailed assessment was taken on a precautionary basis	

The updating and screening assessment identified the authorised Processes operating in the Watford Borough Council area. It concluded that there are no processes operating in the Borough that fall within the source categories that could give rise to nitrogen dioxide emissions. No further consideration has been given to these processes in this detailed assessment for nitrogen dioxide.

4.5 BACKGROUND CONCENTRATIONS FOR NITROGEN DIOXIDE

The estimated annual average background nitrogen dioxide (NO_2) concentration provided by the UK background maps[6] for 2005 was 29.9 μgm^{-3} averaged across Watford with a maximum concentration of 31.3 μgm^{-3} .

The estimated annual average background oxides of nitrogen (NO_x) concentration provided by the UK background maps[6] for 2005 was 53.5 μgm^{-3} averaged across Watford with a maximum concentration of 61.6 μgm^{-3} .

4.6 ASSESSMENT OF MONITORING DATA

Table 4.2 summarises the measurements of nitrogen dioxide concentrations at continuous monitoring stations in Watford and neighbouring local authorities for relevant periods .

Table 4.2: Continuous monitoring data

Site	**Period**	**NO_x, concentration, µg m^{-3} as NO_2**	**NO_2 Concentration, µg m^{-3}**	
		Period average	**Period average**	**99.8th percentile hourly**
Watford	1999		44	
	2000	86.5	39.9	124
	2001	104.2	45.6	163
	2002	85.2	43.5	143
Dacorum	2001	56.7	28.4	91
	2002*	61.8	31.4	130
Three Rivers	2002	78.1	29.5	111
Hertsmere	2002		27	

* less than 75 % data capture

The annual mean nitrogen dioxide concentrations measured at the Watford roadside site in 1999,2001 and 2002 were significantly greater than the annual mean objective of 40 µg m^{-3}. The concentrations at sites further from major roads in neighbouring local authorities were significantly less than the objective.

It is anticipated that nitrogen dioxide concentrations will decrease from current levels by 2005. Applying correction factors provided by LAQM TG(03) (0.892/.969) to the annual mean nitrogen dioxide concentrations for 2002 shown in Table 4.2 indicates that the nitrogen dioxide concentration at the Watford roadside site will be very close to the 40 µg m^{-3} objective in 2005. The concentrations at sites further from major roads in neighbouring local authorities will remain less than the objective.

The 1-hour mean nitrogen dioxide concentrations measured at all the sites have not exceeded the hourly objective of 200 µg m^{-3} more than 18 times in a year (the 99.8th percentile).

Nitrogen dioxide diffusion tube measurements were made at 8 locations throughout Watford during January-November 2003. Diffusion tubes have not been collocated with the continuous monitors in Watford and so it is not possible to adjust the 2003 data for diffusion tube bias. Nevertheless, the diffusion tube measurements provide a useful indication of where the highest concentrations are expected to occur. Table 4.3 summarises the nitrogen dioxide concentrations measured at the 8 sites in 2001,2002 and 2003. Table 4.3 also shows data for 2001 and 2002 adjusted for diffusion tube bias on the basis of collocation studies for Harwell Scientifics 50% TEA in acetone tubes in other local authorities (http://www.uwe.ac.uk/aqm/review/answers.html#RND3).
The 2001 and 2002 data adjusted for bias have also been projected forwards to 2005 using correction factors provided by LAQM. TG(03). Box 6.7.

Table 4.3: Nitrogen dioxide concentrations measured by diffusion tube, 2001-2003

Site	**Nitrogen dioxide concentrations, μg m^{-3}**		
Measurement period	**2001**	**2002**	**January to November 2003**
Hospital Vicarage Road	44.4 (raw data) 34.6 (bias adjusted) 31.4 (2005 projected)	50.1 (raw data) 42.1 (bias adjusted) 39.3 (2005 projected)	55.8
Grove pumping station, Hempstead Road	23.5 (raw data) 18.3 (bias adjusted) 16.6 (2005 projected)	26 (raw data) 21.8 (bias adjusted) 20.4 (2005 projected)	27.2
Leisure Centre, Horseshoe Lane	35.8 (raw data) 27.9 (bias adjusted) 25.4 (2005 projected)	36.3 (raw data) 30.5 (bias adjusted) 28.5 (2005 projected)	37.9
Pinner Road	60.5 (raw data) 47.2 (bias adjusted) 42.8 (2005 projected)	56.2 (raw data) 47.2 (bias adjusted) 44.1 (2005 projected)	65.8
High Road, Leavesden		61.6 (raw data) 51.7 (bias adjusted) 48.3 (2005 projected)	47.2
Osprey Close			48.0
St Albans Road			83.0
Westland Road			45.5

The 2001 and 2002 diffusion tube measurements indicate that the annual average objective will be met at the Hospital, Grove Pumping station and Horseshoe Lane Leisure Centre sites. It seems likely that the objective will not be met at the Pinner Road site or at the Leavesden High Road site.

Although diffusion tubes without bias adjustment can only provide an indicative assessment of nitrogen dioxide concentrations, it is clear that there is potentially a significant chance that the 40 μg m^{-3} objective will be exceeded at the Osprey Close and St Albans Road sites.

The Hospital Vicarage Road site is approximately 2 m from the road on an access road between Watford General Hospital and Watford Football Club. It is possible that there will be relevant exposure of members of the public at this location.

The Pinner Road diffusion tube site is on a post at the kerbside at the junction of Villiers Road and Pinner Road. It is unlikely to be representative of exposure of members of the public over the annual averaging time.

The Leavesden High Road site is close to the road and not representative of public exposure: it was not identified as requiring detailed assessment in the Updating and Screening Assessment.

The St Albans road diffusion tube is mounted on a post less than 1 m from the kerb on the St Albans Road and approximately 3 m from a light controlled pedestrian crossing, where it is likely to be influenced by queueing traffic. It is unlikely to be representative of public exposure over the annual averaging period, although short term exposure relating to the 1 hour objective may be considered relevant.

The Osprey Close site is in the vicinity of residential properties close to the M1 motorway and is likely to be representative of exposure of members of the public.

4.7 ROAD CAPACITY

Watford Borough Council have been unable to provide traffic data for a small number of minor roads including Woodford Road. This road is a 2-way single carriageway road with flows controlled by traffic light junctions on the A412 St Albans Road. It was assumed that at peak times a constant stream of vehicles travels along the road, separated by the stopping distance recommended by the Highway Code. It was further assumed that the traffic lights allow traffic to pass onto or off the major road, the A412, for one third of the time. The estimated 2-way capacity of the road at peak times is thus estimated to be 1250 vehicles per hour. Annual average daily traffic flows have then been estimated from the peak hourly flow by multiplying by 10 on the basis of typical diurnal traffic variation. Thus, it is estimated that it is unlikely that traffic flows on Woodford Road will significantly exceed 12500 vehicles per day. The percentage of heavy duty vehicles in the vehicle fleet using Woodford Road was assumed to be the same as that on the A412.

4.8 TRAFFIC QUEUES

Queues of traffic build up at traffic lights and pedestrian crossings at peak times. 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. Thus each stationary vehicle was assumed to emit at the rate of $5 \times E$ g/h, where E is the emissions factor at 5 kph in g/km. Queuing vehicles were assumed to be 5 m apart. The average queue length at traffic lights and pedestrian crossings was estimated from the annual average daily traffic flow and the waiting times shown in Table 3.2. It was assumed that significant queues could form during 8 hours of the day and that traffic lights allowed vehicle passage for 50 % of that time.

Buses emit significant oxides of nitrogen while waiting at bus stops. Stationary buses were also assumed to emit at the rate of $5 \times E$ g/h, where E is the emissions factor at 5 kph in g/km. The proportion of time that buses are present at each bus stop was estimated from Table 3.2.

The level crossing on Bushey Mill Lane also creates significant traffic queues. It was estimated from the train timetable that the level crossing is closed approximately 60 times per day. It was assumed that the gates would be closed for three minutes for each train. Average queue lengths were estimated to be 65 m each way, extending to 150 m each way during peak periods.

4.9 OVERVIEW OF THE AIR QUALITY MODELLING

4.9.1 Summary of the models used

The air quality impact from roads has been assessed using our proprietary urban model (LADS Urban). There are two parts to this model:

- The *Local Area Dispersion System (LADS) model*. This model calculates background concentrations of oxides of nitrogen on a 1 km x 1 km grid. The estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 2000 National Atmospheric Emissions Inventory.
- The *DISP model*. This model is a tool for calculating atmospheric dispersion using a 10 m x 10 m x 3 m volume-source kernel derived from ADMS3.1 to represent elements of the road. The volume source depth takes account of the initial mixing caused by the turbulence induced by the vehicles. Estimates of emissions from vehicles have been calculated using the latest (and finalised for this round of Review and Assessment) vehicle emission factors.

Particular attention was paid to the avoidance of "double counting" of the contribution from major roads in the modelled areas. Thus the emissions from sections of roads modelled using DISP were removed from the LADS inventory.

Hourly sequential meteorological data for 2000 from London Heathrow, approximately 30 km south-west of Watford was used. A surface roughness of 1 m was used in the modelling to represent the urban conditions corresponding to the most exposed sites. An intelligent gridding system was used with receptors at 10 m intervals on a rectangular grid within 150 m of the modelled roads and more widely spaced receptors elsewhere.

The LADS Urban model calculates nitrogen dioxide concentrations from predicted oxides of nitrogen concentrations using empirical relationships determined from monitoring results throughout the UK. For the Watford study, the empirical relationship between roadside oxides of nitrogen contribution and roadside nitrogen dioxide contribution provided by LAQM.TG(03) was used.

4.9.2 Validation and verification of the model

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 **netcen** air quality review and assessments. Details of the model validation are given in Appendix 3.

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. Table 4.4 compares modelled predictions using LADS Urban of oxides of nitrogen and nitrogen dioxide concentrations with measured values at continuous monitoring sites in Watford and neighbouring local authority areas for 2002.

Fig.4.1 provides a graphical comparison of modelled and measured nitrogen dioxide concentrations.

Table 4.4: Comparison of modelled and measured concentrations

	Oxides of nitrogen concentration, $\mu g\ m^{-3}$		Nitrogen dioxide concentration, $\mu g\ m^{-3}$	
	Modelled	Measured	Modelled	Measured
Watford	97	85	39.4	43.5
Three Rivers	52	78	29.7	29.5
Dacorum	41	57 (2001)	25.7	28.4 (2001)
Hertsmere		No data	29.7	27

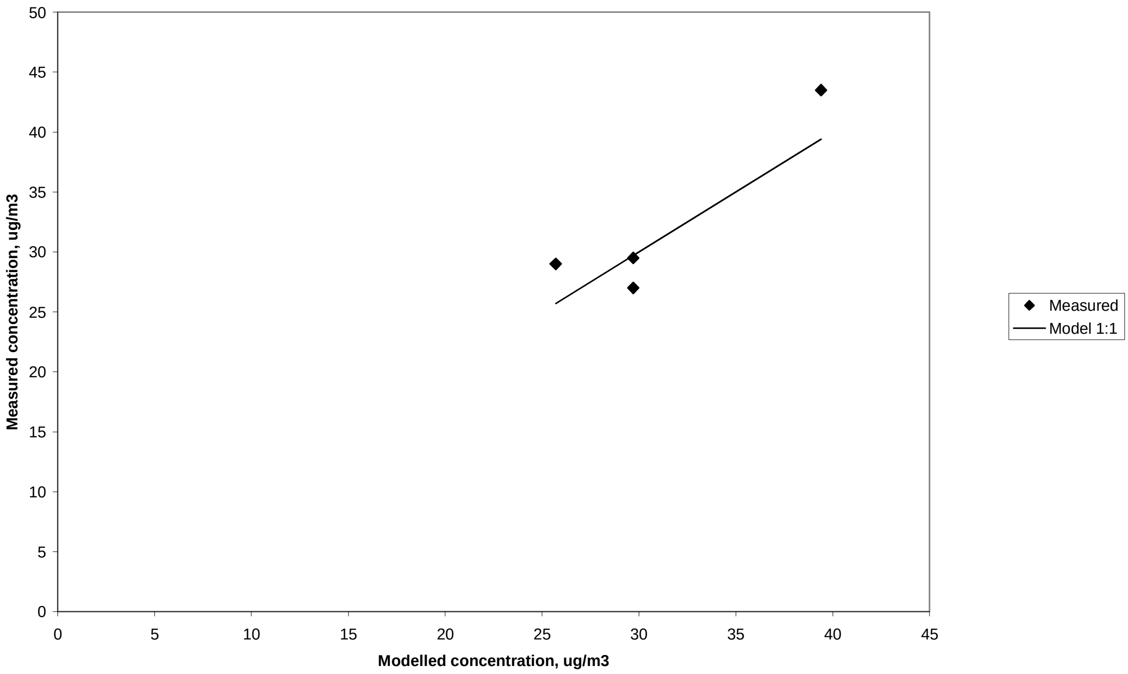

Fig.4.1 . Comparison of measured and modelled nitrogen dioxide concentrations

4.9.3 Bias adjustment of the model

Bias adjustment is the process where the concentrations of the model are adjusted to agree with local air quality monitoring data. In this case, the model has provided satisfactory predictions of the measured nitrogen dioxide concentrations without adjustment and so no adjustment has been made.

4.9.4 Model 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 and dispersion conditions. Table 4.5 shows confidence levels for modelled nitrogen dioxide concentrations based on a statistical analysis of a comparison of modelled and measured concentrations in London (Appendix 3). In this report, we present predicted concentrations as isopleths (lines of constant concentration) superimposed on a map of the local area. The concentration values selected reflect the uncertainty bands shown in Table 4.5. Predicted concentrations in excess of 40 $\mu g\ m^{-3}$ indicate that there is more than 50 % chance of exceeding the annual average objective for nitrogen dioxide. Public exposure in these areas should be considered in order to assess whether it will be necessary to declare and Air Quality Management Area for nitrogen dioxide.

Table 4.5 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	Annual average objective
Very unlikely	Less than 5%	< 28
Unlikely	5 to 20%	28 to 34
Possible	20 to 50%	34 to 40
Probable	50 to 80%	40 to 46
Likely	80 to 95%	46 to 52
Very likely	More than 95%	> 52

4.10 DETAILED MODELLING RESULTS

In this section, nitrogen dioxide concentrations predicted for 2005 are presented as a series of contour plots . Concentrations may be first shown over a wide area for the modelled roads. More detailed plots are then shown around potential hotspots.

4.10.1 Central, Vicarage, Nascot, Callowland and Tudor wards

Fig. 4.2 shows predicted nitrogen dioxide concentrations for for 2005 for the modelled roads in the Central, Vicarage, Nascot, Callowland and Tudor wards. Predicted concentrations are less than the objective along the following roads identified in the Updating and Screening Assessment:

Cassio Road
Hagden Lane
Bushey Mill Lane
Woodford Road
Leavesden Road
Balmoral Road
Hempstead Road
Whippendell Road

Fig. 4.3 shows the predicted nitrogen dioxide concentrations for St Albans Road between Bushey Mill Lane and Balmoral Road. Exceedences of the annual average objective are predicted to occur at residential properties on the east side of St Albans Road. These include properties near the junction with Bushey Mill Lane and Balmoral Road and those near bus stops and the pedestrian crossing. Concentrations are predicted to be increased as the result of queueing traffic at the level crossing on Bushey Mill Lane, but not sufficiently to exceed the objective.

Fig.4.4 shows the predicted nitrogen dioxide concentrations for St Albans Road between Balmoral Road and Leavesden Road. Exceedences of the annual average objective are predicted to occur at residential properties on the both sides of St Albans Road. These include properties near the junctions with Balmoral Road and with Leavesden Road and those near bus stops and the pedestrian crossing.

Fig.4.5 shows the predicted nitrogen dioxide concentrations for St Albans Road and Rickmansworth Road between Watford Junction station and Cassiobury Park Avenue. Exceedences of the annual average objective are predicted to occur at residential properties on the both sides of St Albans Road. These include properties near the junctions with Station Road and those near bus stops. Properties on the south east side of Rickmansworth Road between Beechen Grove and Cassio Road are also predicted to exceed the annual average objective.

Fig.4.6 shows the predicted nitrogen dioxide concentrations for 2005 for Rickmansworth Road between Cassiobury Park Avenue and Whippendell Road. The annual mean objective is predicted to be met at all properties along this section of road, although the objective is approached on the north side of Rickmansworth Road between Station Approach and Queen Mary Avenue.

Fig 4.7 shows the predicted nitrogen dioxide concentrations for 2005 for Vicarage Road between Wiggendell Road and Hagden Lane. No exceedences of the objective are predicted to occur on Vicarage Road, itself but it is likely that the objective will be exceeded at properties on the north side of Farraline Road. The predicted nitrogen dioxide concentration for 2005 at the Hospital diffusion tube site is 36 $\mu g\ m^{-3}$, which agrees well with predictions based on the measurements at the site (31.4 $\mu g\ m^{-3}$ for 2001 data and 39.3 $\mu g\ m^{-3}$ for 2002 data).

4.10.2 Oxhey ward

Fig. 4.8 shows the predicted nitrogen dioxide concentrations for 2005 for the Pinner Road/Chalk Hill junction. It is predicted that the annual average objective for nitrogen dioxide will be exceeded at properties at the junction to the north and on the north side of Chalk Hill between the junction and Aldenham Road. It is also likely that the objective will not be met at a residential property near the zebra crossing and bus stops near the junction of Pinner Road and Capel Road.

The predicted concentration at the Pinner Road diffusion tube site for 2005 was 39 $\mu g\ m^{-3}$ compared with the projected values based on the measurements of 42.8 $\mu g\ m^{-3}$ for 2001 data and 44.1 for 2002 data. The slight underestimation is likely to arise because the contribution from traffic on Villiers Road was not explicitly included in the model.

The Updating and Screening Assessment identified the need to proceed to a detailed assessment of nitrogen dioxide in the vicinity of Chalk Hill on the basis of busy streets where people may spend one hour or more close to traffic. Advice on the assessment of modelled concentrations against the 1 hour objective is provided by the Review and Assessment helpdesk website (http://www.uwe.ac.uk/aqm/review/RND3). This advises that it would be appropriate to base the decision of a likely exceedence of the 1-hour nitrogen dioxide objective on an exceedence of 60 $\mu g\ m^{-3}$ as an annual mean. There are no areas in the vicinity of Chalk Hill where the modelled annual average concentration exceeds 60 $\mu g\ m^{-3}$. It is therefore unlikely that the 1 hour objective will be exceeded.

4.10.3 A41 and A405

Fig.4.9 shows predicted concentrations near major roads in the north of the borough including the A41, A405, A412 and Horseshoe Lane. The annual mean objective is only exceeded by the predicted concentrations at residential properties in a small area near the A405/A412/Horseshoe Lane junction.

4.10.4 M1 motorway through Meriden ward

Fig.4.10 shows predicted concentrations near the M1 motorway in the vicinity of Ravenscroft and the Gossamers. The nitrogen dioxide concentration is predicted to exceed the annual average objective of 40 $\mu g\ m^{-3}$ at one property on Ravenscroft and six properties on The Gossamers.

It is also predicted that the concentration will exceed the objective at properties on Osprey Close in neighbouring Hertsmere. These properties were considered in Hertsmere District Council’s Stage 4 Review and Assessment in October2002. In that assessment the predicted nitrogen dioxide concentration for 2005 was very slightly under the 40 μg m^{-3} objective and the Air Quality Management Area was revoked. The small differences in predicted concentrations between the two assessments arise for a number of reasons:

- increased baseline traffic flows;
- larger increases in traffic flows are predicted by later versions of the TEMPRO database;
- a higher proportion of oxides of nitrogen is assumed to be converted to nitrogen dioxide following Technical Guidance LAQM. TG(03);
- a larger number of monitoring sites have been used to verify the model.

The Hertsmere assessment was based on the comparison of modelled predictions with the results from a single monitoring station (Furzehill School) whereas this assessment has been based on data from four monitoring stations. Had this assessment been based on the data from Furzehill School alone, then the predicted nitrogen dioxide concentrations close to the M1 would have been approximately 3 μg m^{-3} lower, consistent with the Hertsmere assessment. The difference between the two assessments is within the expected range of uncertainty. Watford Borough Council have monitored nitrogen dioxide concentrations on Osprey Close during 2003 by diffusion tube: the measured concentration was 48 μg m^{-3} without bias correction. Taken at face value (note AQMAs should not be declared on the bass of unadjusted diffusion tube data alone), this measurement would support the contention that the concentration in 2005 is likely to exceed the objective. However, if a diffusion tube bias correction factor similar to that applied in previous years was applied to the Osprey Close data, then projected concentrations would be slightly less than the objective for 2005.

Fig.4.11 shows predicted concentrations near the M1 motorway in the vicinity of Butterwick, Westlea Avenue and Eastlea Avenue. The nitrogen dioxide concentration is predicted to exceed the annual average objective of 40 μg m^{-3} at three properties on Eastlea Avenue.

4.11 SOURCE APPORTIONMENT

4.11.1 Source apportionment of 'base case' predictions

Source apportionment is the process whereby the contributions from the sources of a pollutant are determined. In local air quality, the relevant sources could include: traffic; local background; industrial and domestic. Contributions from the different types of vehicles (for example, cars, lorries and buses) can also be considered to highlight which class of vehicle is contributing most to the emissions from traffic. Source apportionment allows the most important source or sources to be identified and options to reduce ambient concentrations of pollutants can then be considered and assessed.

The source apportionment should:

- Confirm that exceedences of NO_2 are due to road traffic
- Determine the extent to which different vehicle types are responsible for the emission contributions to NO_2: this will allow traffic management scenarios to be modelled/tested to reduce the exceedences
- Quantify what proportion of the exceedences of NO_2 is due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedence, or, whether national measures would be a suitable approach to achieving the air quality objectives

4.11.2 What is the 'base case'?

The base case in this assessment is defined as the annual mean concentrations of NO_2 that are predicted in the absence of any measures to improve air quality in Watford. They are the concentrations that should be relevant to defining the extent of Air Quality Management Areas.

4.11.3 Receptors considered

The most affected receptors where there is potential relevant public exposure have been considered: these are shown in Table 4.6.

Table 4.6: Most affected receptors exceeding annual average objective

General Area	Description	OS Grid reference of receptor
St Albans Road	1) Residential properties with facades on the east side north of Bushey Mill Lane for a distance of 70 m; 2) Residential properties with facades on the east side between Bushey Mill lane and Balmoral Road within 40 m of bus stops and pedestrian crossings; 3) Residential properties between Balmoral Road and Leavesden Road with facades on east side or on west side within 40 m of bus stops and pedestrian crossings; 4) Residential properties with facades on both sides between Station Road and Beechen Grove within 40 m of bus stops	510970, 198970 511010, 198330 510900,197750 510760, 197220
Rickmansworth Road	Residential properties with facades on the south side between Beechen Grove and Cassio Road	510750, 196750
Farraline Road	Residential properties with facades on the north side	510770, 196030
Pinner Road/Chalk Hill junction	4) Residential properties immediately to the north of the junction; 5) Residential properties with facades on the north side of Chalk Hill between junction and Aldenham Road 6) Residential property with façade on east side of Pinner Road near zebra crossing and bus stops near junction with Capel Road	511870, 195510 511970, 195430 511950, 195300
Horseshoe Lane/A405 junction	3) Residential property on Horseshoe Lane, closest to junction 4) Two residential properties on St Albans Road nearest to the junction.	511680, 200700 511690, 200620
M1	4) 1 property on Ravenscroft closest to M1	512270, 199880

	5) 6 residential properties on the Gossamers closest to M1 6) 3 residential properties on Eastlea Avenue closest to M1	512290, 199570 512470, 198950

4.11.4 Sources of pollution considered

We have considered the effect of the following sources in this detailed assessment at the receptors considered:

- Background from sources outside the local area
- Moving traffic
- Traffic stationary at bus stops, pedestrian crossings and traffic lights

The concentrations of oxides of nitrogen concentrations apportioned to each source category and the fractions of the total concentrations are shown in Table 4.7.

Table 4.7: Apportionment of oxides of nitrogen concentrations at most affected receptors

	Source					
Concentrations, $\mu g\ m^{-3}$	Receptor	Total	Background	Roads	Moving	Stationary
St Albans Road	1	122	49.5	72.5	48.5	24.0
	2	148	50.1	98	47.3	50.7
	3	168	49.6	118	43.3	75.1
	4	126	48.8	77.2	24.9	52.3
Rickmansworth Road	1	109	47.5	61.1	61.0	0.1
Farraline Road	1	139	49.3	89.2	63.8	25.4
Pinner Road/Chalk Hill junction	1	112	49.5	62.8	62.6	0.2
	2	110	49.4	60.5	59.5	1.0
	3	115	48.6	66.3	24.9	41.4
Horseshoe lane/A405 junction	1	116	51.1	64.7	64.7	
	2	105	51.4	53.4	53.4	
M1	1	104	54.1	50.1	50.1	
	2	107	54.3	53.0	53.0	
	3	114	54.5	59.3	59.3	

At many of the receptor sites, the contribution from stationary vehicles at bus stops, pedestrian crossings and traffic lights provides a significant part of the total oxides of nitrogen concentrations. The receptors on St Albans Road and at the Pinner Road zebra crossing would meet the objective for nitrogen dioxide if the traffic were free flowing.

4.12 RECOMMENDATIONS

It is recommended that Watford Borough Council consider declaring Air Quality Management Areas as shown in Table 4.8:

Table 4.8: Potential Air Quality Management Areas

General Area	Description
St Albans Road	1) Residential properties with facades on the east side north of Bushey Mill Lane for a distance of 70 m; 2) Residential properties with facades on the east side between Bushey Mill lane and Balmoral Road within 40 m of bus stops and pedestrian crossings; 3) Residential properties between Balmoral Road and Leavesden Road with facades on east side or on west side within 40 m of bus stops and pedestrian crossings; 4) Residential properties with facades on both sides between Station Road and Beechen Grove within 40 m of bus stops
Rickmansworth Road	Residential properties with facades on the south side between Beechen Grove and Cassio Road
Farraline Road	Residential properties with facades on the north side
Pinner Road/Chalk Hill junction	7) Residential properties immediately to the north of the junction; 8) Residential properties with facades on the north side of Chalk Hill between junction and Aldenham Road 9) Residential property with façade on east side of Pinner Road near zebra crossing and bus stops near junction with Capel Road
Horseshoe Lane/A405 junction	5) Residential property on Horseshoe Lane, closest to junction 6) Two residential properties on St Albans Road nearest to the junction.
M1	7) 1 property on Ravenscroft closest to M1 8) 6 residential properties on the Gossamers closest to M1 9) 3 residential properties on Eastlea Avenue closest to M1

Special consideration should be given to the receptors close to the M1. Hertsmere Borough Council revoked their Air Quality Management Area covering Osprey Close because modelling for their Stage 4 assessment showed that predicted concentration for 2005 was slightly less than the objective. The modelling carried out for this assessment, based on slightly different input data has predicted that the concentrations at the same receptor locations will be slightly greater than the objective. The difference between the two modelling assessments can be attributed to uncertainties in the model. It will be possible to resolve this issue using the diffusion tube measurement at Osprey Close when average bias adjustment factors for diffusion tubes for 2003 are reported (http://www.uwe.ac.uk/aqm/review/answers.html#RND3). It is recommended that Watford Borough Council delay their decision to declare an Air Quality Management

Area for properties close to the M1 motorway until the bias adjustment factor for 2003 becomes available.[§]

[§] These factors are expected to be available in April 2004. I have discussed this matter with the Review and Assessment helpdesk and it is likely that this approach will be acceptable to defra.

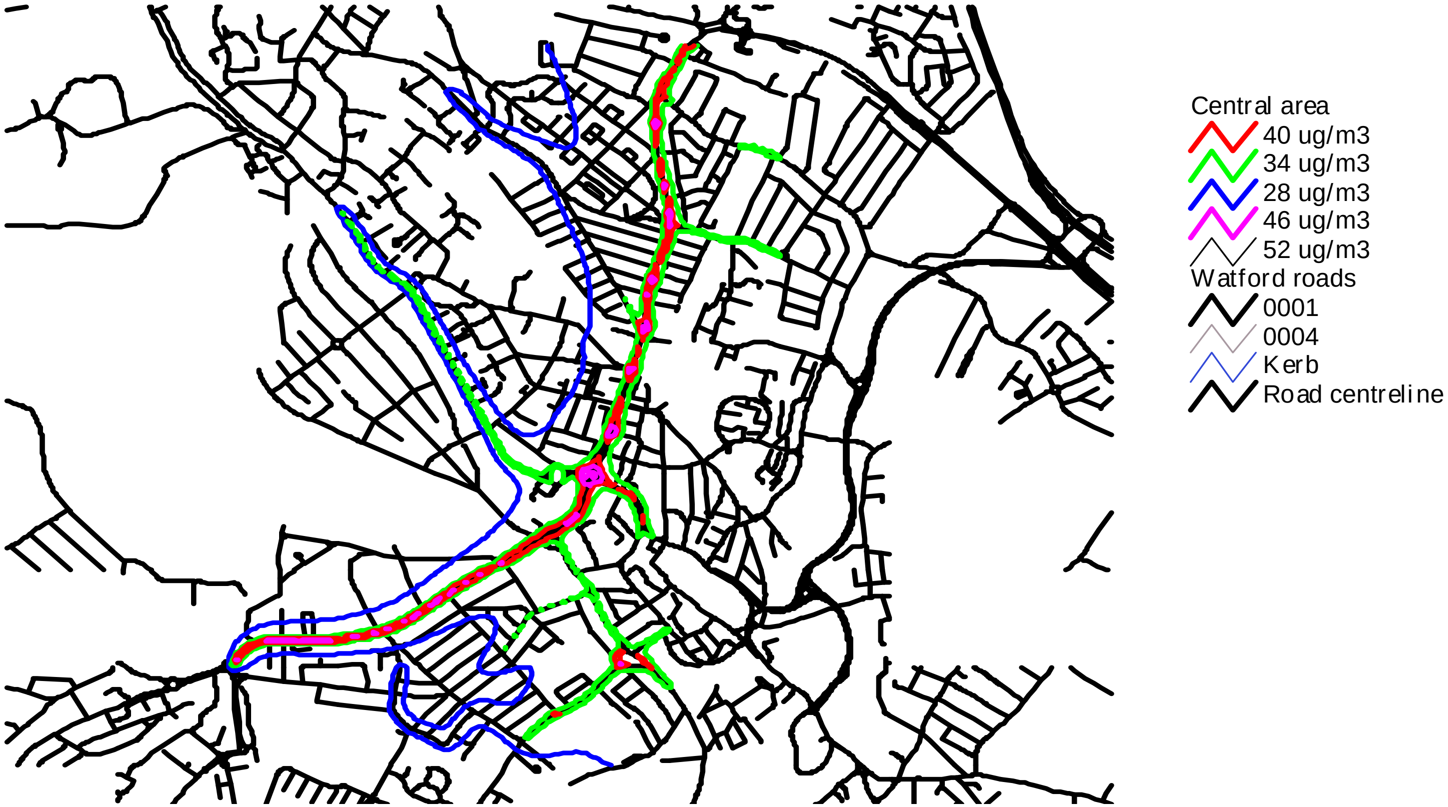

Fig.4.2 Predicted nitrogen dioxide concentrations for 2005 for the modelled roads in the Central, Vicarage, Nascot, Callowland and Tudor wards.

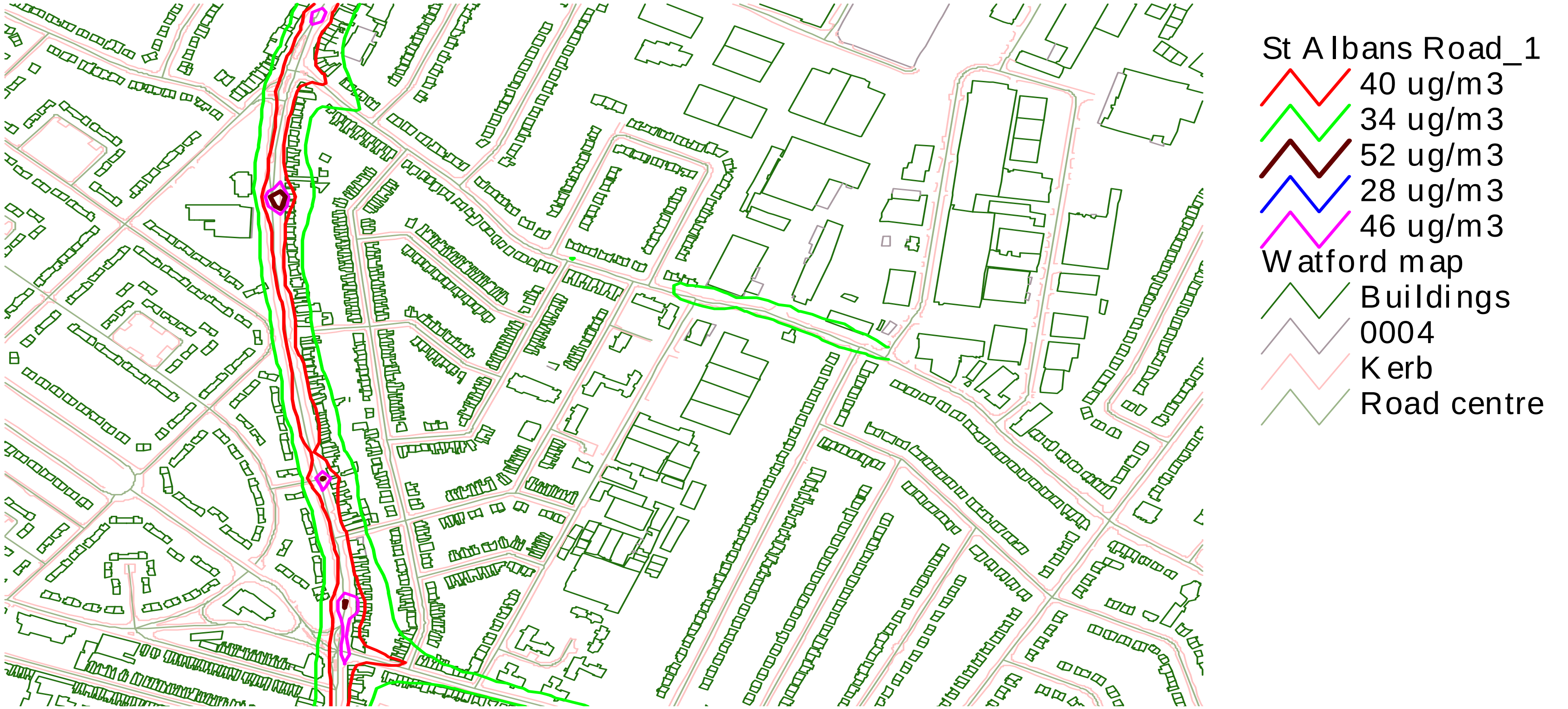

Fig.4.3: Predicted nitrogen dioxide concentrations for 2005 for St Albans Road between Bushey Mill Lane and Balmoral Road.

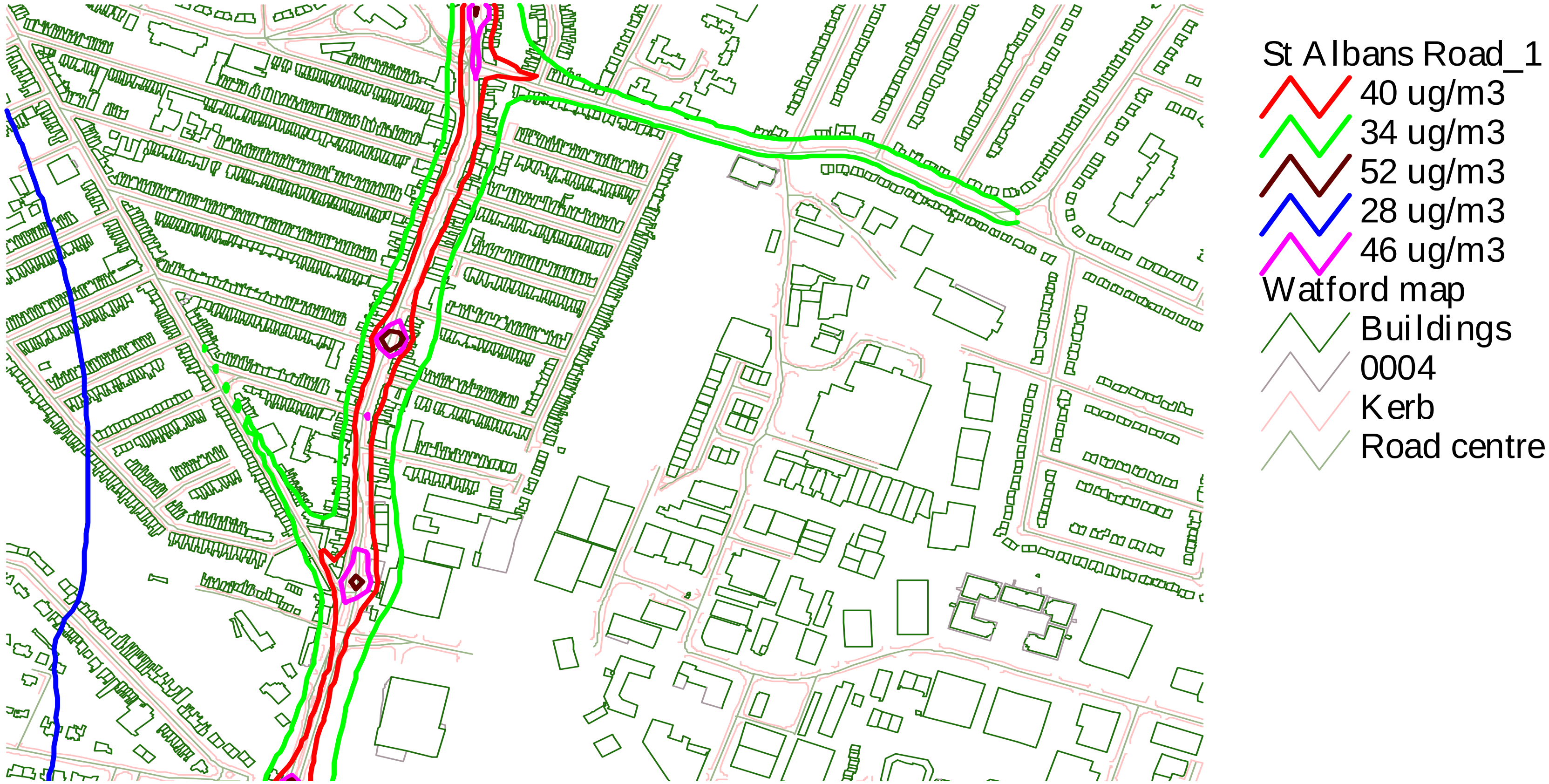

Fig.4.4: Predicted nitrogen dioxide concentrations for 2005 for St Albans Road between Balmoral Road and Leavesden Road

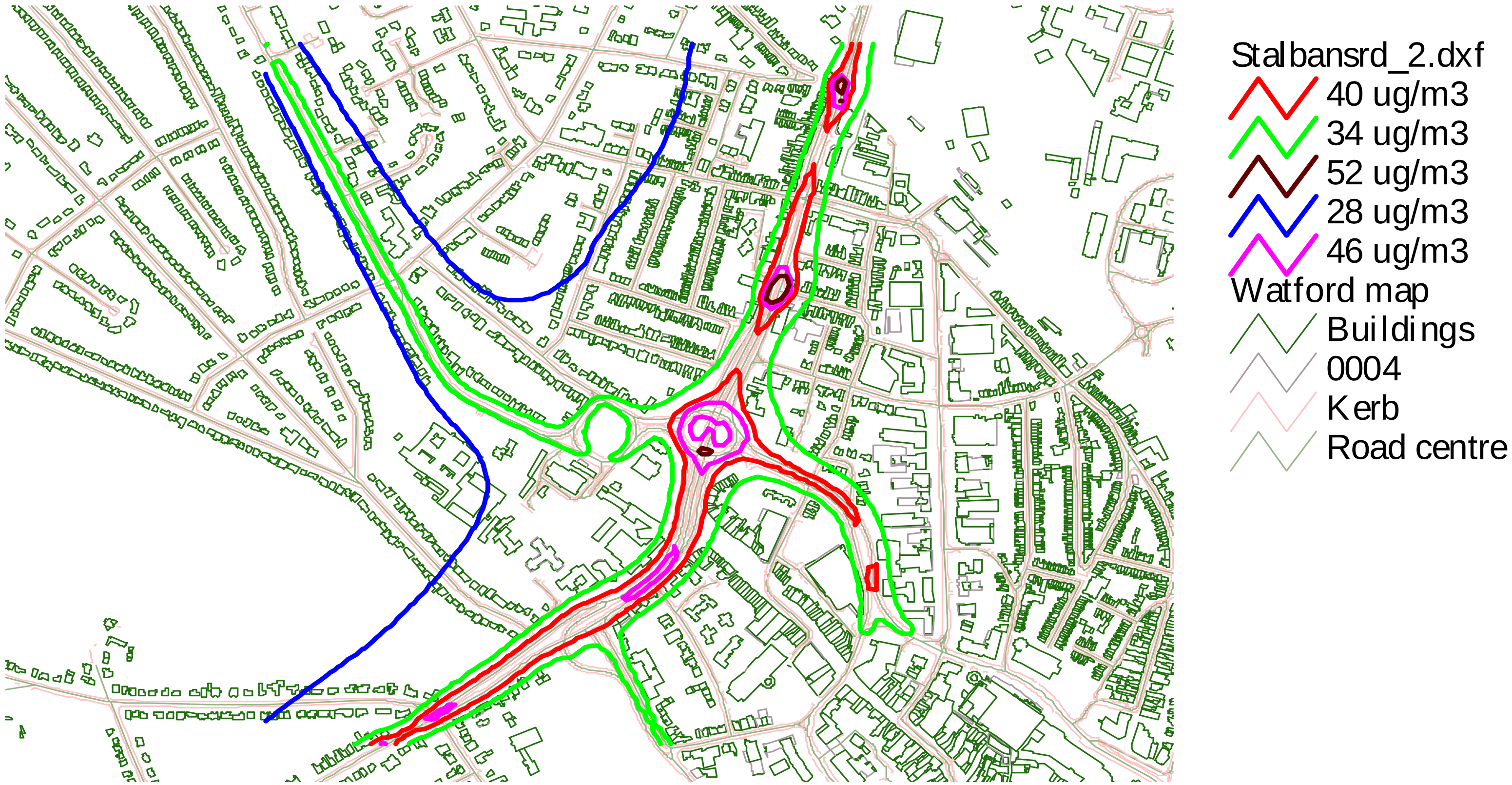

Fig.4.5: Predicted nitrogen dioxide concentrations for 2005 for St Albans Road and Rickmansworth Road between Watford Junction station and Cassiobury Park Avenue

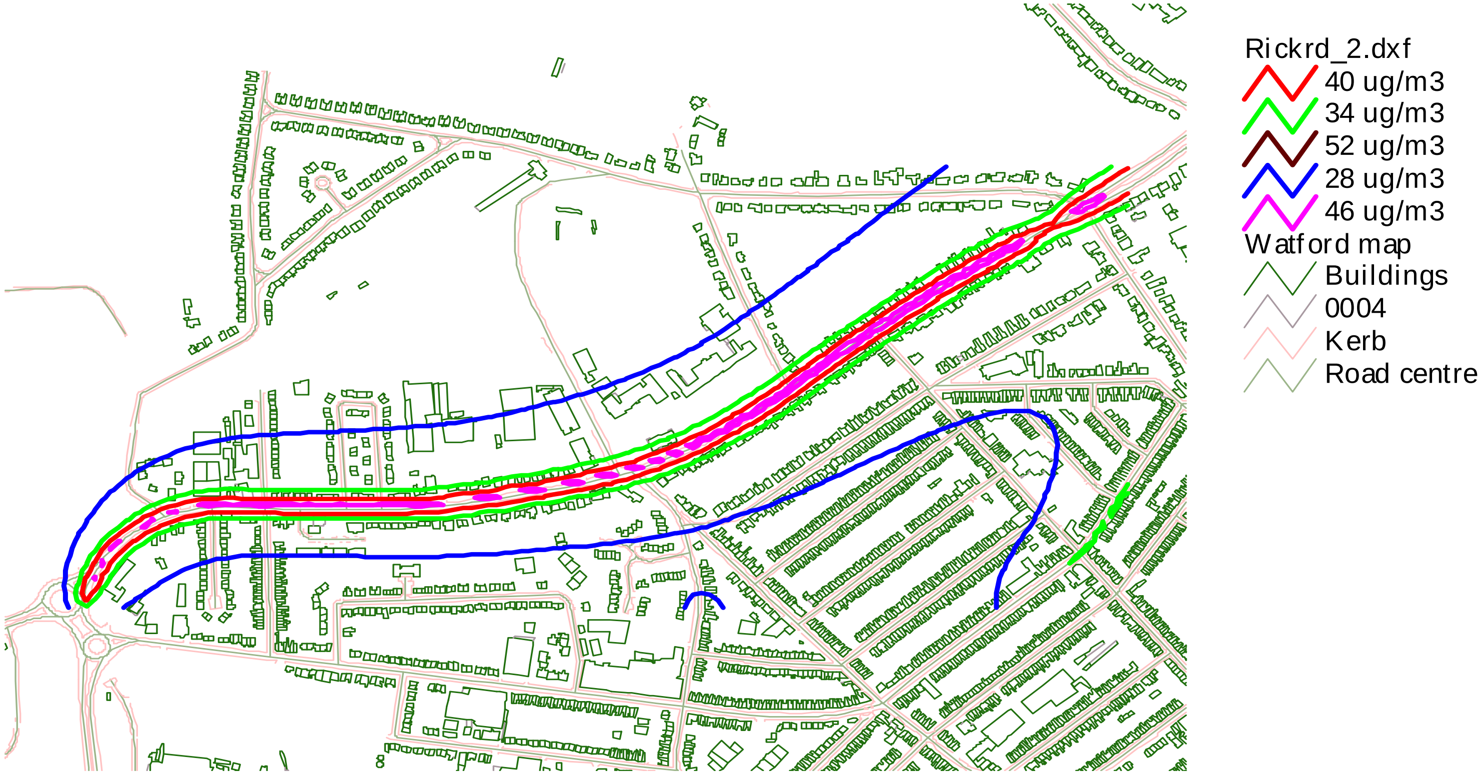

Fig.4.6: Predicted nitrogen dioxide concentrations for 2005 for Rickmansworth Road between Cassiobury Park Avenue and Whippendell Road

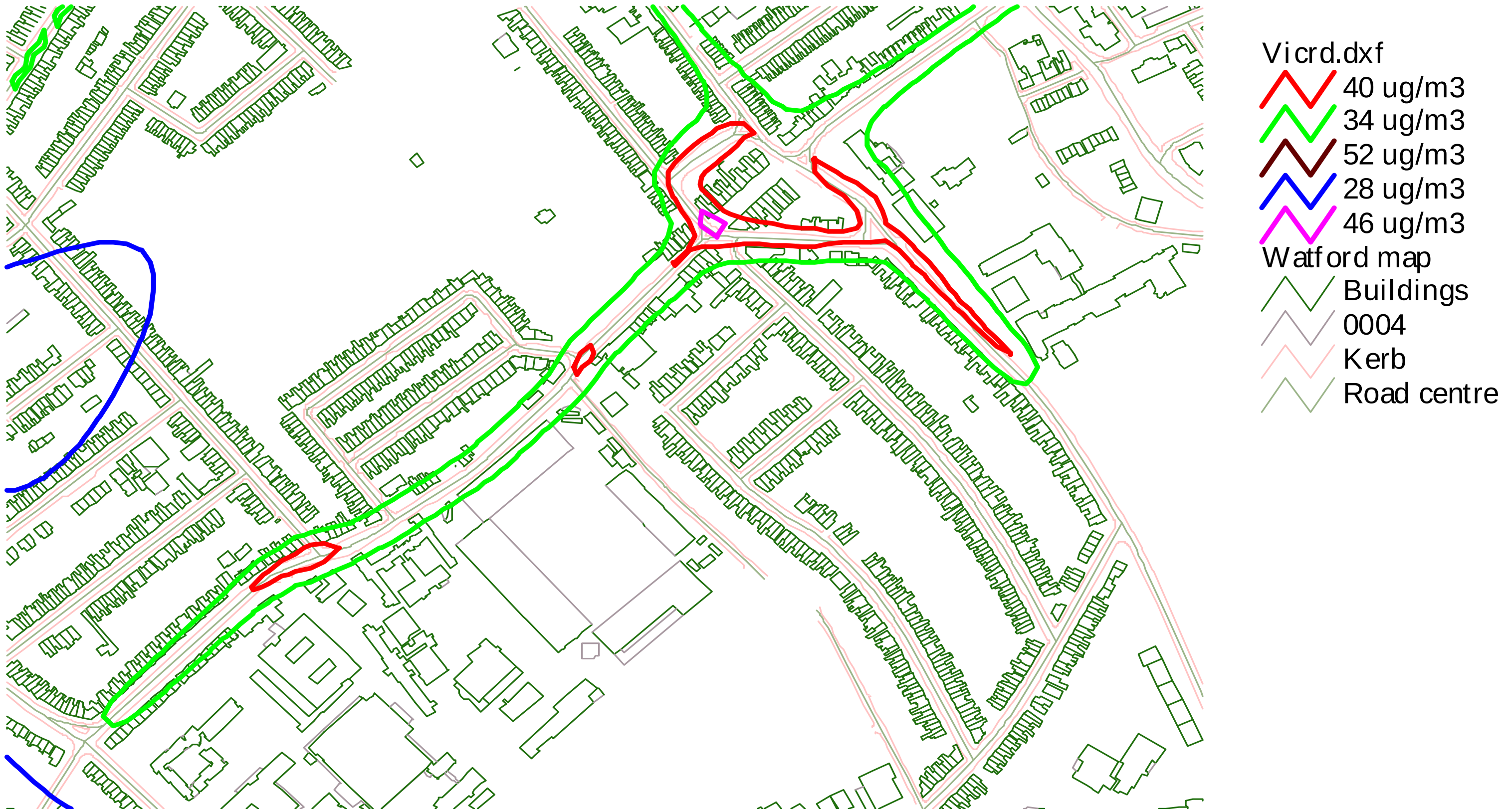

Fig.4.7: Predicted nitrogen dioxide concentrations for 2005 for Vicarage Road between Wiggendell Road and Hagden Lane

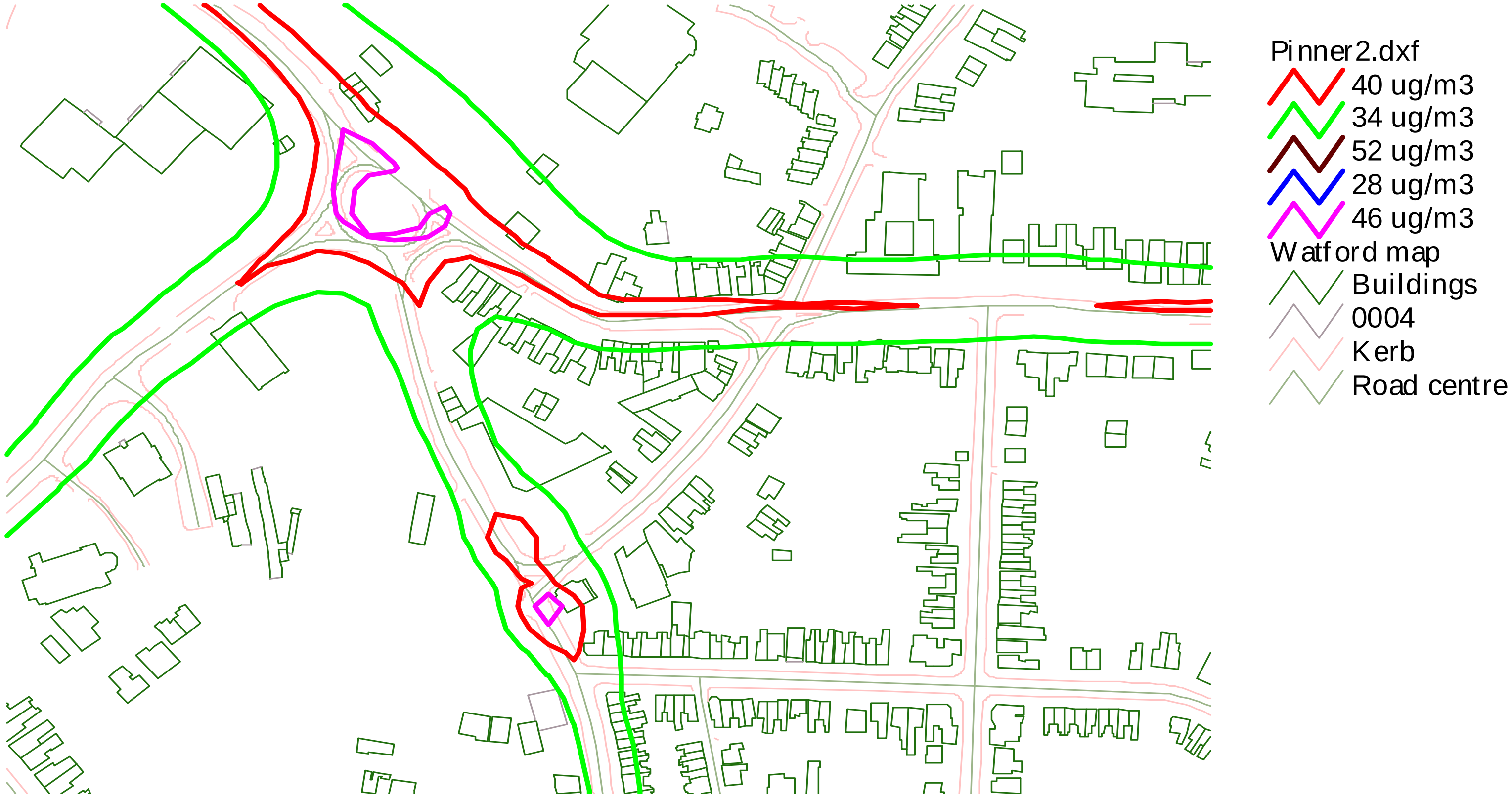

Fig. 4.8: Predicted nitrogen dioxide concentrations for 2005 for the Pinner Road/Chalk Hill junction

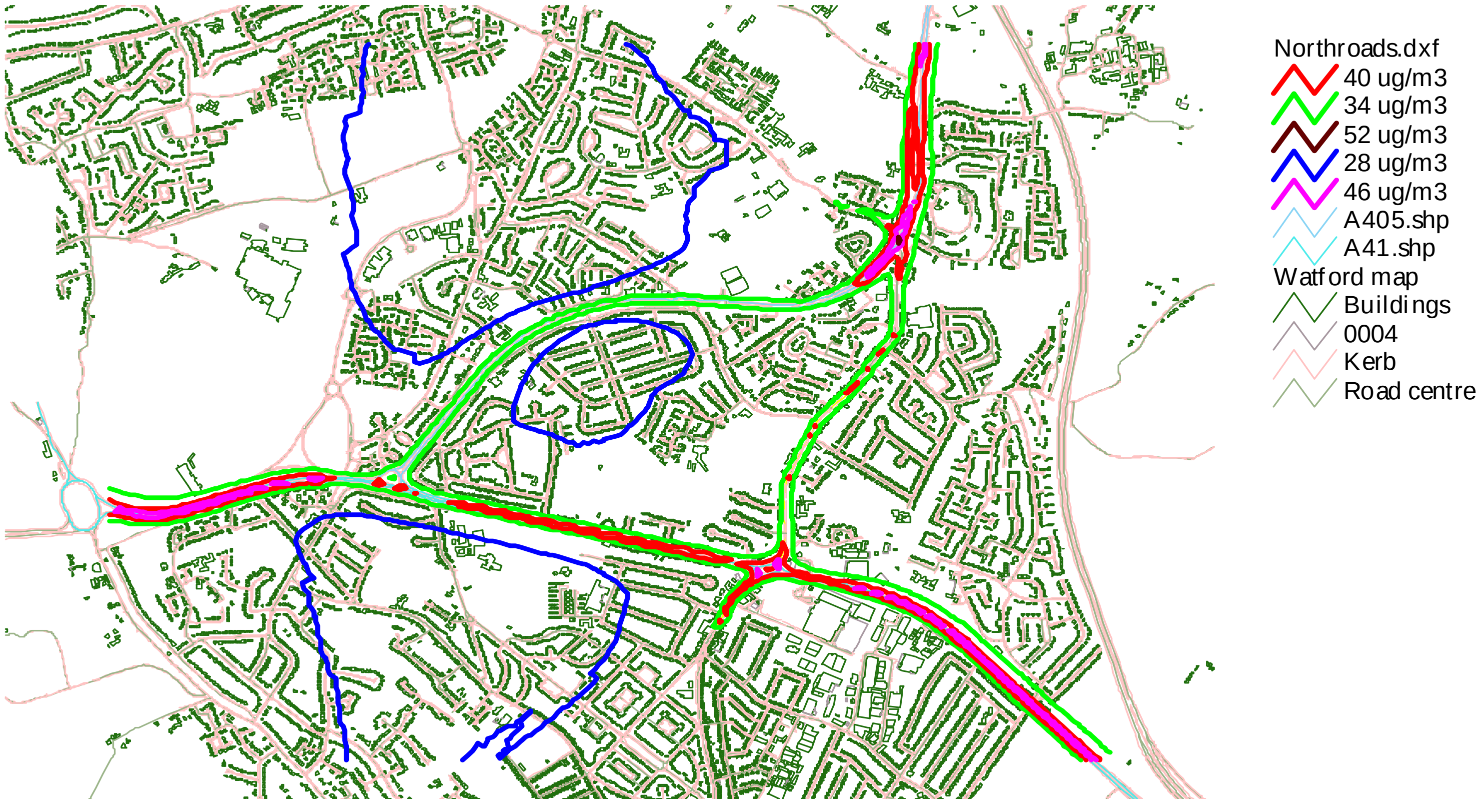

Fig.4.9: Predicted concentrations near major roads in the north of the borough including the A41, A405, A412 and Horseshoe Lane.

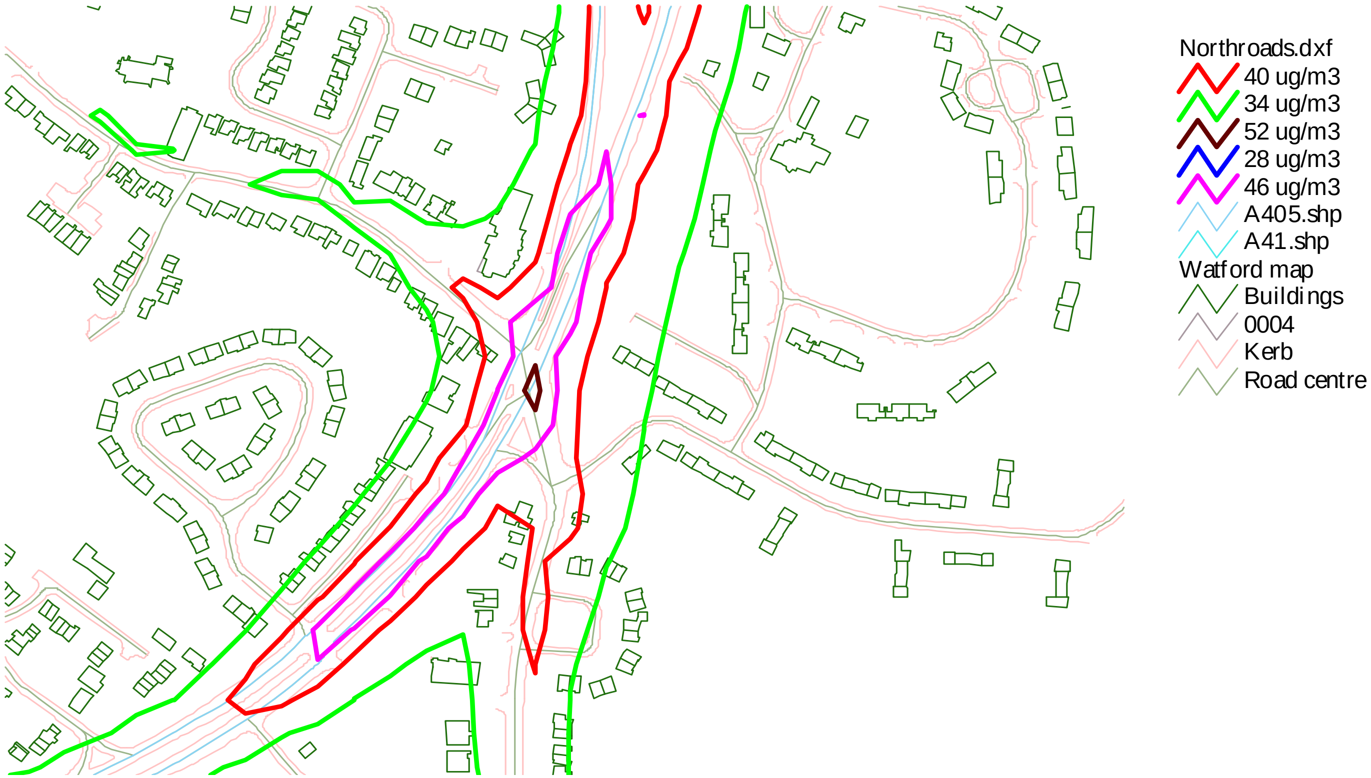

Fig.4.10: Predicted concentrations near the A405/A412/Horseshoe Lane junction

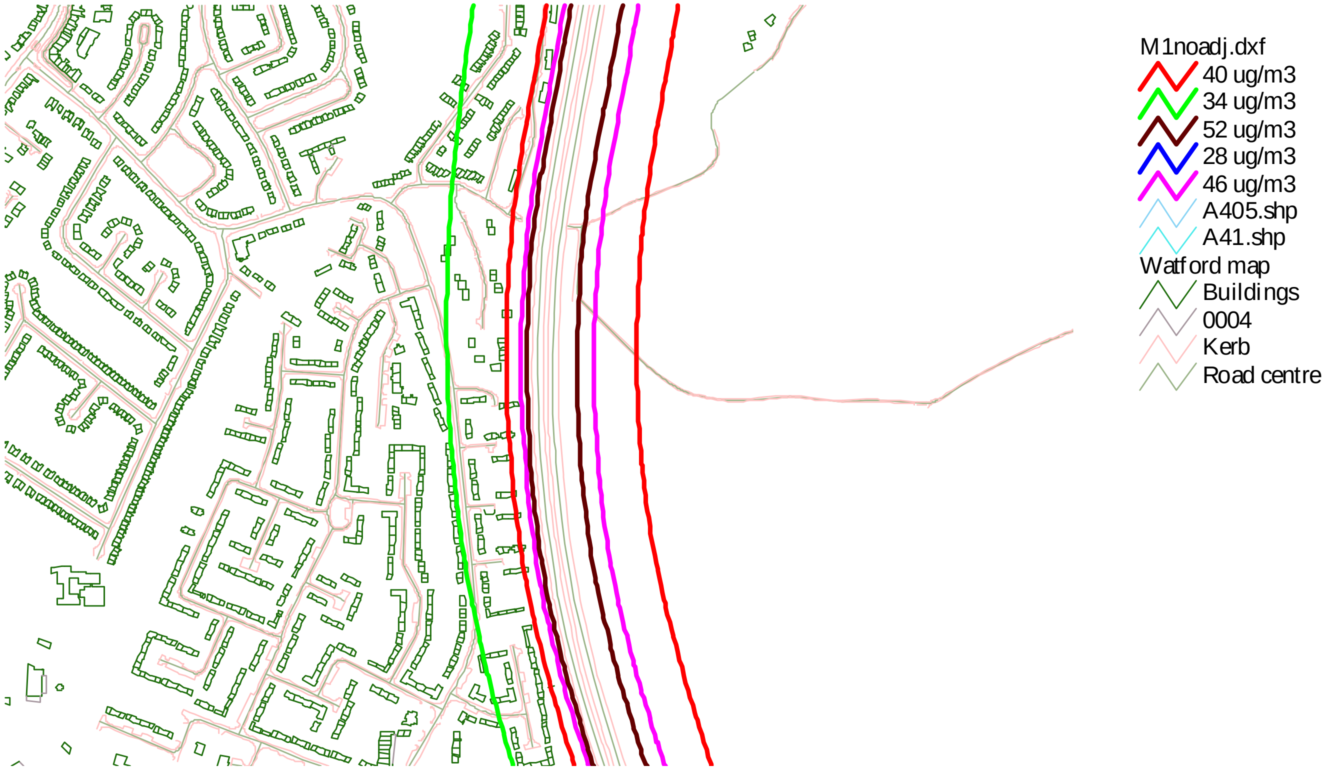

Fig.4.11: Predicted concentrations near the M1 motorway in the vicinity of Ravenscroft and the Gossamers.

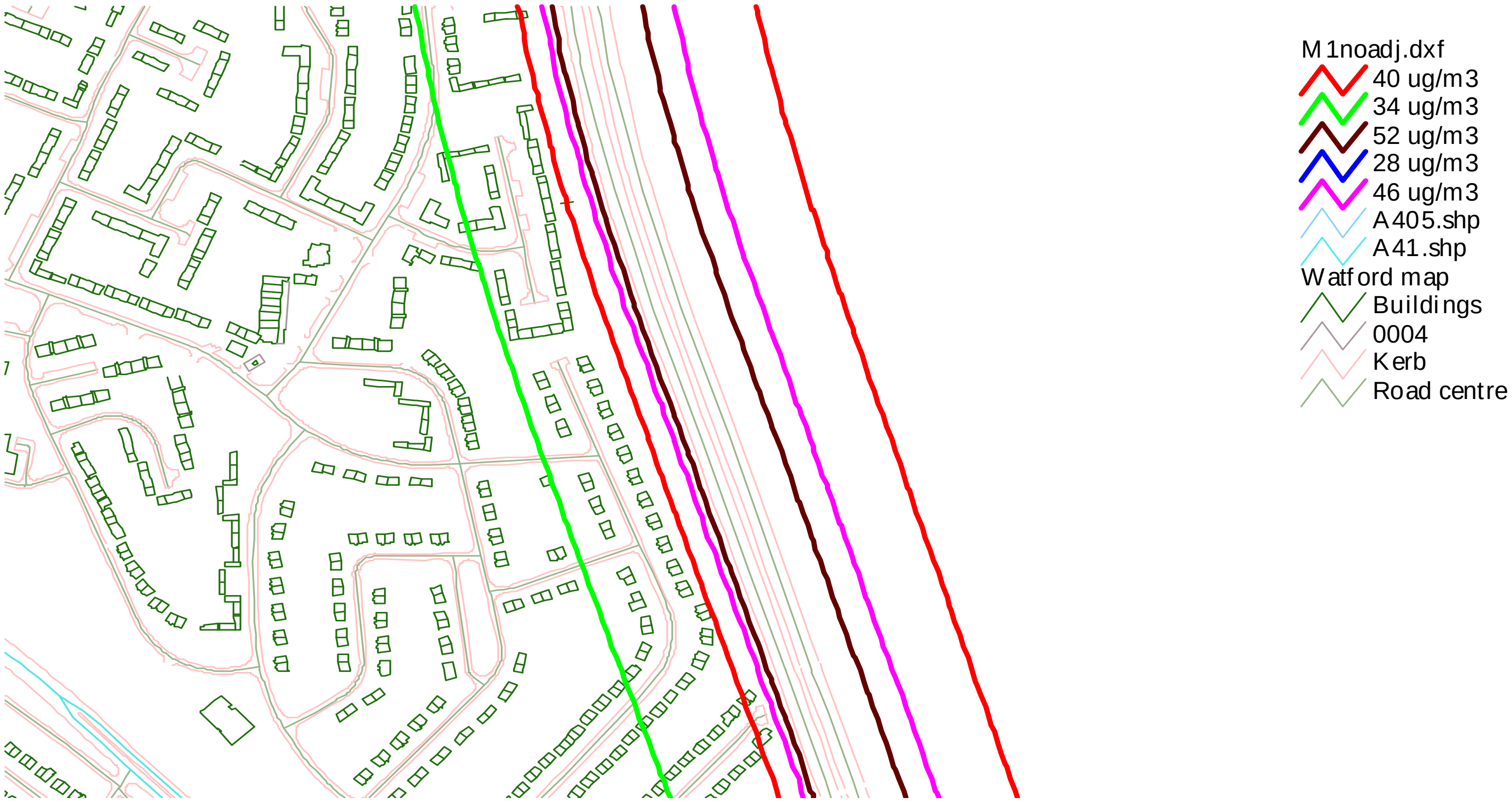

Fig.4.12: Predicted concentrations near the M1 motorway in the vicinity of Butterwick, Westlea Avenue and Eastlea Avenue.

5 Detailed Assessment for PM_{10}

5.1 THE NATIONAL PERSPECTIVE

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.

5.2 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. In addition there are objectives of 50 μgm^{-3} as the fixed 24-hour mean to be exceeded on no more than 7 days per year, and 20 μgm^{-3} as the annual mean to be achieved by the end of 2010 which are not included in the Regulations. The objectives are based upon measurements carried out using the European gravimetric transfer reference sampler or equivalent.

5.3 CONCLUSIONS OF THE FIRST ROUND OF REVIEW AND ASSESSMENT FOR PM_{10}

The Third Stage Review and Assessment of PM_{10} concluded that concentrations at certain locations close to major roads in the area were likely to exceed air quality objective limits. Watford Borough Council considered the potential for public exposure at these locations and concluded that there were no domestic properties within the likely area of exceedence. The Council was satisfied that there was no relevant public exposure and so no Air Quality Management Areas were declared

5.4 UPDATING AND SCREENING ASSESSMENT

The Updating and Screening Assessment for PM_{10} concluded that there was a need to proceed to a detailed assessment at many locations close to roads in Watford. Table 4.1

lists the locations identified and the updating and assessment criteria that lead to their selection. Several of the roads were selected for detailed assessment on a precautionary basis i.e. they have been included because there was no evidence on which to exclude them for further consideration . Roads selected on this precautionary basis alone are identified in Table 5.1.

Table 5.1: Roads identified as requiring further assessment for PM_{10} by the Updating and Screening Assessment

Road	**Reasons for detailed assessment**
Junction of A405 Kingsway, A412 St Albans Road and C88 Horseshoe lane	DMRB assessment of junction
Junction A411 Hempstead Road and A412 St Albans Road	DMRB assessment of junction
Junction A4178 Wiggenhall Road and A412 Rickmansworth Road	DMRB assessment of junction
Junction A4178 Wiggenhall Road and C74 Whippendell Road	DMRB assessment of junction
Junction A4178 Wiggenhall Road and A4145 Vicarage road	DMRB assessment of junction
Wiggenhall Road	Close to the objective
Pinner Road	Close to the objective
Rickmansworth Road	Close to the objective
Bushey Mill Lane	**High flow of buses or HGVs** **Increased traffic flow**
M1	Close to the objective
A41	Close to the objective
A411 Hempstead Road	Close to the objective
Reasons are shown in **bold** where the decision to proceed to detailed assessment was taken on a precautionary basis	

The updating and screening assessment identified the authorised processes operating in the Watford Borough Council area. There are two processes operating in the Borough that fall within the source categories that could give rise to PM_{10} emissions. Neogene Paints limited is located on Caxton Way, more than 500 metres from any of the roads identified in the Updating and Screening Assessment. Sun Chemicals is located in Sandown Road: Sandown Road runs between Balmoral Road and Bushey Mill Lane and so is close to some of the roads of interest. However, both these processes were considered as part of the first round of review and assessment and found not to be significant PM_{10} emitters. The Updating and Screening assessment confirmed that no significant increase in emissions since the first round had been identified. No further consideration has been given to these processes in this detailed assessment for PM_{10}.

5.5 BACKGROUND CONCENTRATIONS FOR PM_{10}

The estimated annual average background PM_{10} concentration provided by the UK background maps[6] for 2001 was 21.7 μgm^{-3} gravimetric averaged across Watford with a maximum concentration of 22.0 μgm^{-3} . The estimated annual average background PM_{10} concentration for 2004 was 20.9 μgm^{-3} averaged across Watford with a maximum concentration of 21.2 μgm^{-3} .

5.6 ASSESSMENT OF MONITORING DATA

Table 5.2 summarises the measurements of nitrogen dioxide concentrations at continuous monitoring stations in Watford and neighbouring local authorities for relevant periods .

Table 5.2: Continuous PM_{10} monitoring data

Site	Year	Annual average concentration, $\mu g\ m^{-3}$ gravimetric	Number of 24 hour exceedances of 50 $\mu g\ m^{-3}$
Watford	1999	20	0
	2000	20	6
	2001	20	10
	2002	25	6
Dacorum	1999	16	0
	2000	16	3
	2001	16	3
	2002	21	6
Three Rivers	1999	17*	
	2000	16	2
	2001	17	9
	2002	23	12
Hertsmere	1999	17	0
	2000	16	2
	2001	16	4
	2002	22	7

*less than 75 % data capture

The continuous monitoring data indicates that both the annual average objective of 40 $\mu g\ m^{-3}$ and the 24 hour objective of 50 $\mu g\ m^{-3}$ not to be exceeded more than 35 times in a year have both been met in recent years at all four monitoring sites.

Comparison of the data for 1999-2002 indicates that annual average concentrations at each of the sites in 2002 were typically 5-6 $\mu g\ m^{-3}$ higher than in the three previous years. In most cases, the number of exceedences was also greater in 2002 than in previous years. It may be concluded that an assessment based on 2002 monitoring data is likely to be conservative.

5.7 DETAILED MODELLING

5.7.1 Dispersion model

The LADS Urban model described in Section 4 was also used for PM_{10}. The same data and assumptions were used to characterise the traffic and the dispersion conditions.

The Lads Urban model calculates the annual average PM_{10} concentration. An empirical relationship provided by Technical Guidance LAQM.TG(03) was then used to assess the number of exceedences of the 24 hour objective. Comparison of the empirical relationship with the monitoring data shown in Table 5.2 confirms the validity of this relationship in the Watford area.

5.7.2 Validation and verification of the model

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 **netcen** air quality review and assessments. 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 5.3 compares modelled predictions using LADS Urban with measured values at continuous monitoring sites in Watford and neighbouring local authority areas for 2002.

Table 5.3: Comparion of measured and modelled PM_{10} concentrations

	Annual average, $\mu g\ m^{-3}$		Number of exceedences of 24 hour objective	
	Modelled	Measured	Modelled	Measured
Dacorum	21.5	21	5	6
Hertsmere	22	22	6	7
Three Rivers	21.2	23	5	12
Watford	23.1	25	8	6
Roadside	24.5 *	25	11	6
*Modelled road contribution multiplied by a factor of 2 to allow for resuspended dusts				

5.7.3 Bias adjustment

Bias adjustment is the process where the concentrations of the model are adjusted to agree with local air quality monitoring data. In this case, the model has provided satisfactory predictions of the measured concentrations without adjustment at the background locations.

The model has underestimated the road contribution at the Watford roadside monitoring site. It has only taken account of the contribution from particles emitted from the vehicle exhausts. 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. The modelled roadside contribution has therefore been multiplied by a factor of two when making model predictions. Table 5.3 shows that this adjustment provides a better estimate of the measured concentration at the Watford roadside monitoring station. However, this adjustment is likely to lead to 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.

5.7.4 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. The modelling assessment has been carried out based on monitoring data for 2002, which was a "high" pollution year for PM_{10} and so it is likely that the model prediction represent a worst case. Furthermore, the allowance for resuspension also provides an additional margin when applied at locations such as bus stops where there resuspension is proportionately less.

5.8 DETAILED MODELLING RESULTS

In this section, nitrogen dioxide concentrations predicted for 2005 are presented as a series of contour plots. Concentrations may be first shown over a wide area for the modelled roads. More detailed plots are then shown around potential hotspots.

5.8.1 Central, Vicarage, Nascot, Callowland and Tudor wards

Fig. 5.1 shows the numbers of exceedences of the 24 hour objective for 2004 for the modelled roads in the Central, Vicarage, Nascot, Callowland and Tudor wards. Predicted annual average concentrations are less than the annual average objective for 2004 at all locations modelled. Predicted concentrations are less than the objectives along the following roads and junctions identified in the Updating and Screening Assessment:

Cassio Road
Bushey Mill Lane
Hempstead Road
Whiggenhall Road
Rickmansworth Road
Junction of A411 Hempstead Road and A412 St Albans Road
Junction of A4178 Cassio Road and A412 Rickmansworth Road
Junction of A4178 Whiggenhall Road and C74 Whippendell Road
Junction of A4178 Whiggenhall Road and A4145 Vicarage Road

Fig. 5.2 shows more detail for the area of St Albans Road near the junction with Bushey Mill Lane. The number of predicted exceedences of the objective approaches 35 at two properties on the east side of the road close to the bus stop.

Fig. 5.3 shows more detail for the area of St Albans Road near the junction with Leavesden Road. The number of predicted exceedences of the objective approaches 35 at two properties on the east side of the road close to the bus stop opposite Victoria Road.

Fig. 5.4 shows more detail for the area of St Albans Road near the junction with Hempstead road. The number of predicted exceedences of the objective approaches 35 at one property on the east side of the road close to the bus stop on the corner with Wellington Road.

5.8.2 Pinner Road

Fig.5.5 shows predicted concentrations near roads modelled in Oxhey ward including Pinner Road. The model predictions show that it is not likely that the objectives for PM_{10} for 2004 will be exceeded at any of the locations modelled.

5.8.3 A41 and A405

Fig. 5.6 shows predicted concentrations near major roads in the north of the borough including the A41, A405, A412 and Horseshoe Lane. The annual mean objective is met at all locations modelled throughout the area. The 24 hour standard of 50 $\mu g\ m^{-3}$ is only exceeded by predicted concentrations more than 35 times in a year in a small area n the middle of the road at the junction between the A405 Kingsway, A412 St Albans Road and C88 Horseshoe Lane. There is no relvant public exposure at this location.

5.8.4 M1

Fig. 5.7 shows predicted concentrations road modelled near the M1. The model predictions show that it is not likely that the objectives for PM_{10} for 2004 will be exceeded at any location where members of the public will be exposed over the averaging times of the objectives.

5.9 RECOMMENDATIONS

It is recommended that Watford Borough Council do not declare an Air Quality Management Area for particulate matter PM_{10}. The assessment has been based on monitoring data for a relatively high pollution year 2002, has conservatively taken account of resuspended dusts, and has considered the effects of buses waiting at bus stops. Even so the 24 hour objective is only just approached at the most exposed locations close to bus stops on St Albans Road. We believe that the conservative nature of this assessment provides an adequate margin of protection.

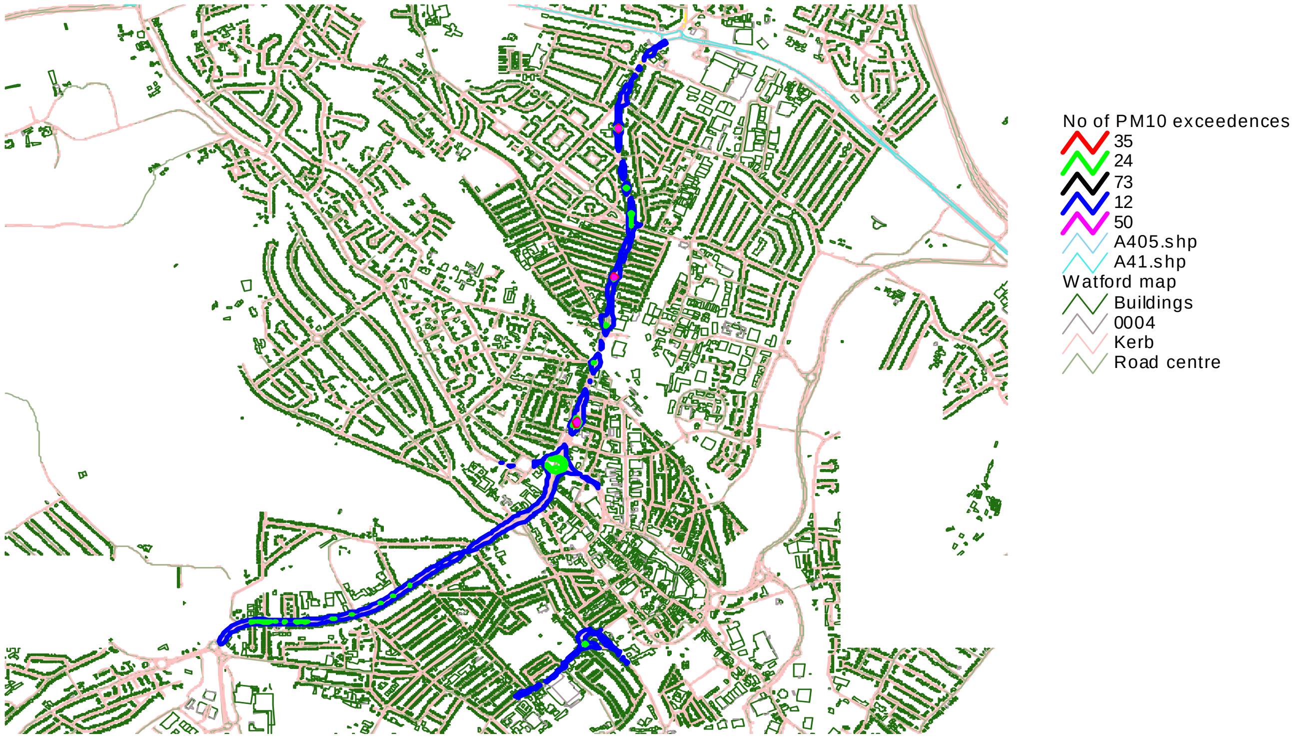

Fig.5.1: Number of exceedences of the 24 hour average standard near modelled roads in Central, Vicarage, Nascot, Callowland and Tudor wards in 2004

Fig.5.2: Number of exceedences of the 24 hour average standard near modelled roads St Albans Road near junction with Bushey Mill Lane in 2004

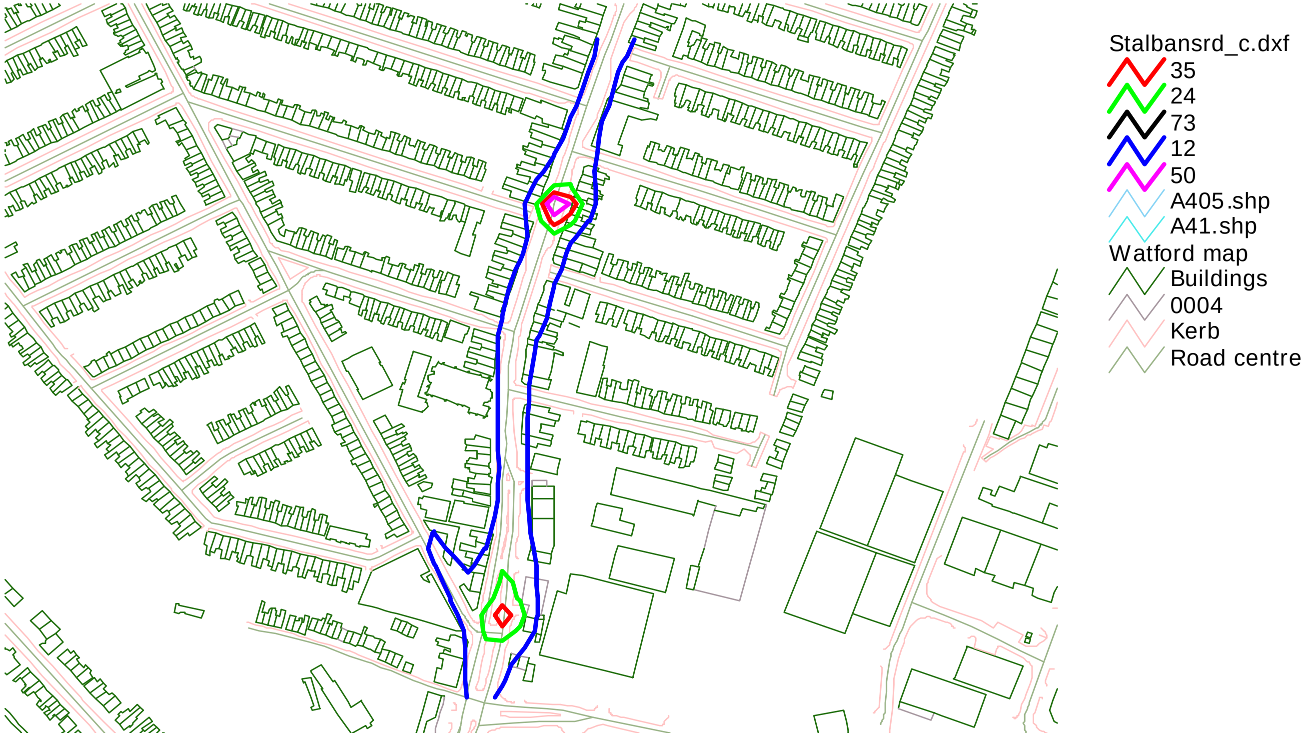

Fig.5.3: Number of exceedences of the 24 hour average standard near modelled roads on St Albans Road near junction with Leavesden Road in 2004

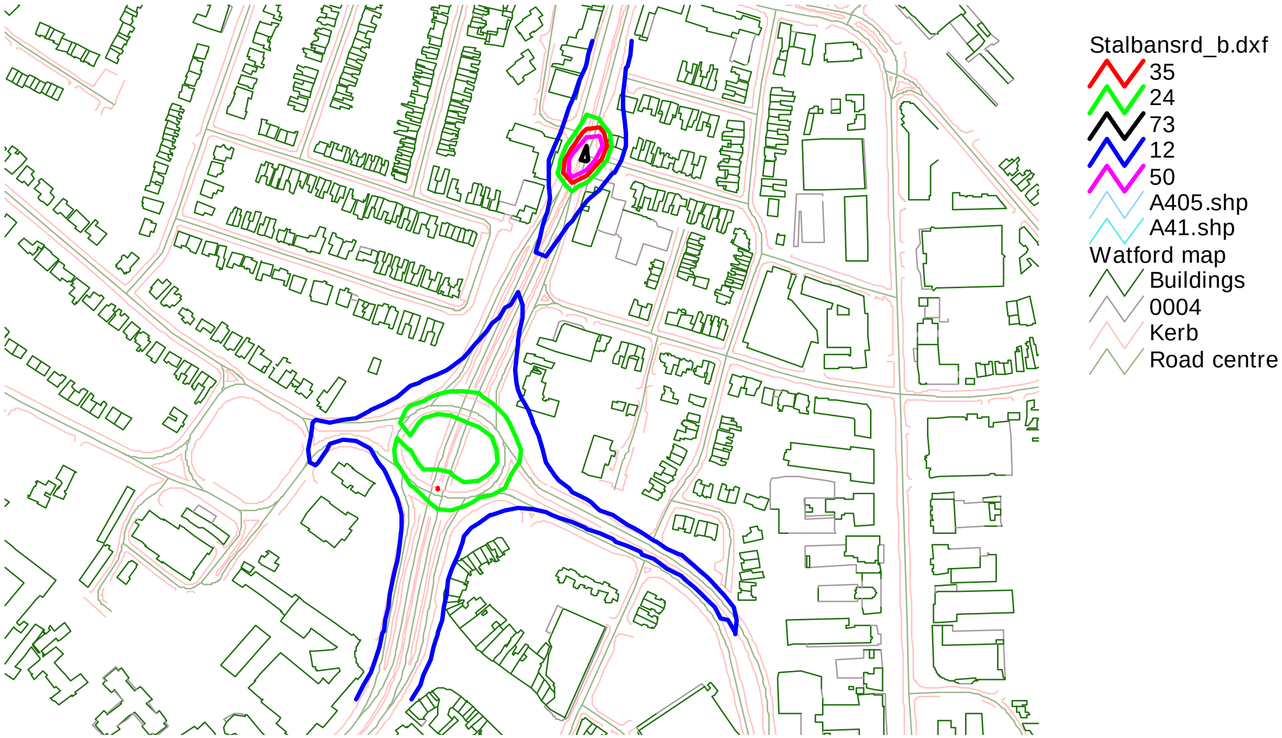

Fig5.4: Number of exceedences of the 24 hour average standard near modelled roads St Albans Road near junction with A411 Hempstead Road

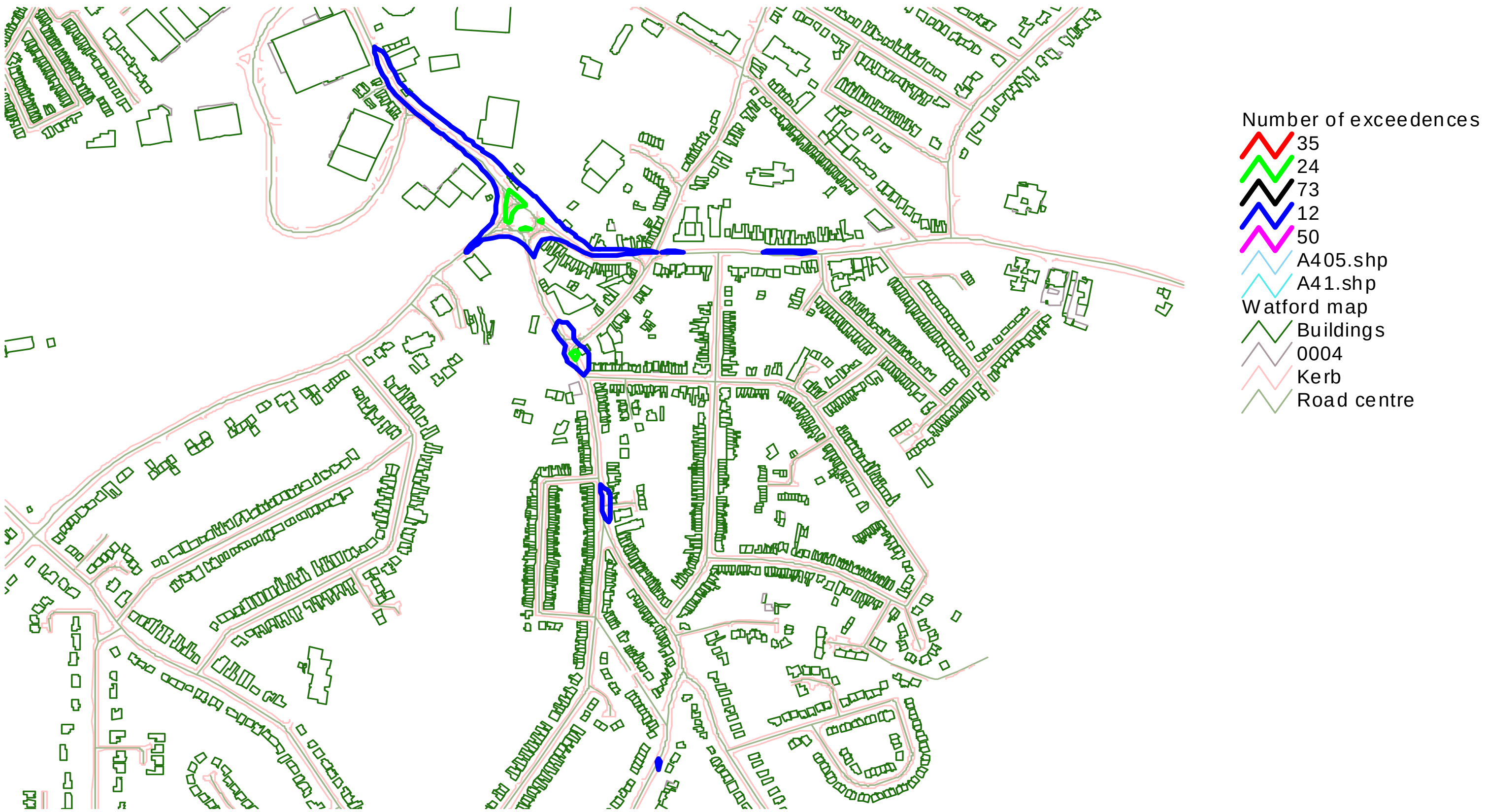

Fig.5.5: Number of exceedences of the 24 hour average standard near modelled roads in Oxhey

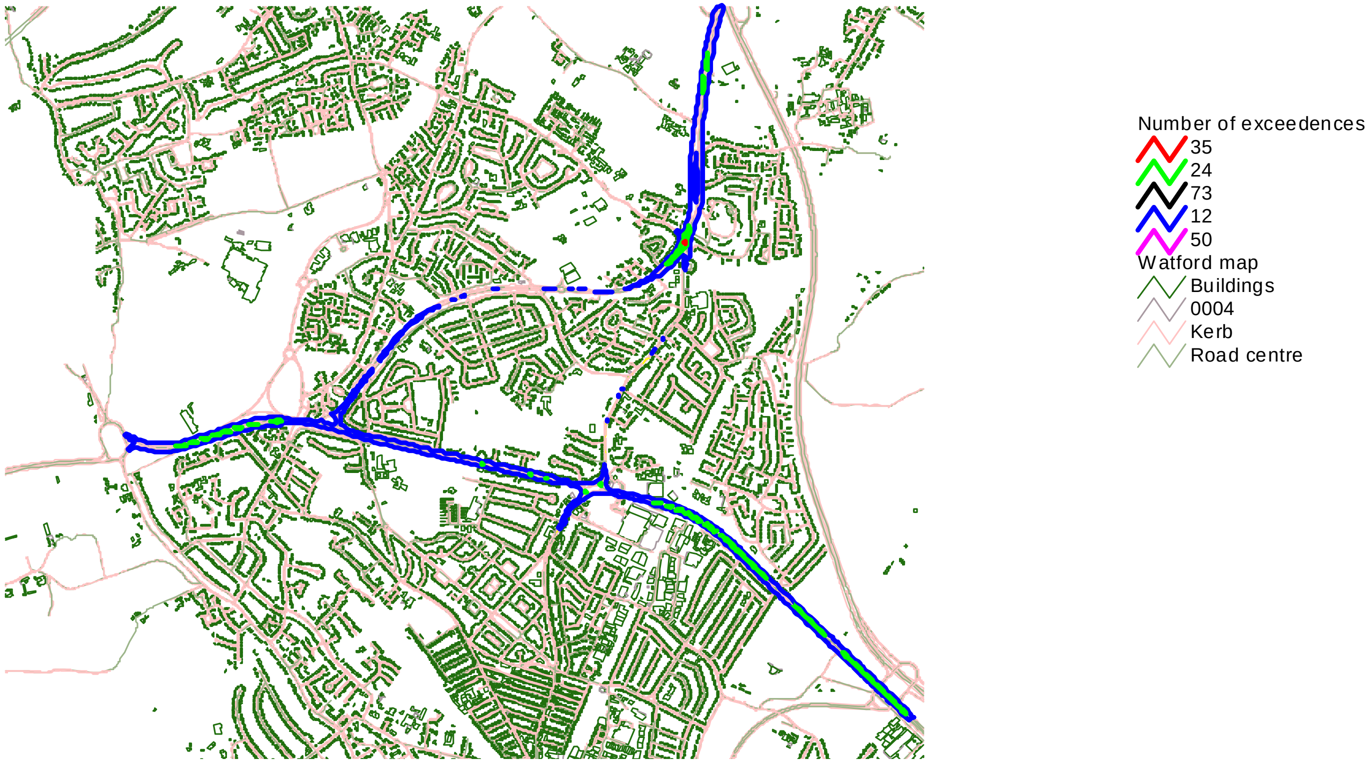

Fig5.6:. Number of exceedences of the 24 hour average standard near modelled roads in the north of the Borough

Fig.5.7: Number of exceedences of the 24 hour average standard near the M1

6 References

1. DETR (2000b) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Department of the Environment, Transport and the Regions. Cm 4548, SE 2000/3, NIA 7.

2. The Air Quality Amendment Regulations 2002, ISBN 0 11061468 2.

3. Part IV of the Environment Act 1995. Local Air Quality Management. LAQM.TG(03) January 2003.

4. Watford Borough Council First Round Review and assessment reports:

   (http://www.seiph.umds.ac.uk/envhealth/HBNet/la_reps/la_reps.html):

   - Stage 1 (December 1998)[4]
   - Stage 2
   - Stage 3 (December 2000)

5. Watford Borough Council Updating and Screening Assessment. 2003

6. Maps of Estimated Ambient Air Pollution in 2001 and Projections for Other Years. http://www.airquality.co.uk/archive/laqm/tools.php

7. Design Manual For Roads and Bridges, Version 1.01. Highways Agency 2003

Appendices

CONTENTS

Appendix 1
Traffic data

NAEI Data warehouse, 2000 data

Censusid00	Road _no	Census point location, m		Annual average daily traffic flow	Percent HDV
		x	y		
7651	A4125	511508	195232	19614	3.30
8291	A411	510836	196609	27121	6.04
8582	A4178	511000	195895	22386	2.82
8707	A412	510800	197500	20909	4.61
17017	A405	511001	200417	17306	3.09
17027	A411	510000	197600	20002	3.03
18276	A411	511138	196034	23137	2.18
18397	A4178	510530	196580	13894	1.63
18537	A411	511960	195420	18569	5.00
18565	A4178	510869	196054	17381	4.38
26461	A41	512000	198900	33150	2.70
27722	A4145	510055	195708	4730	6.36
27953	A4178	510675	196300	12771	2.69
28319	A411	510851	196840	26300	3.11
37122	A411	511500	196280	31047	2.58
38374	A411	510682	196520	7199	1.81
46464	A41	510090	199560	27957	3.36
47714	A4145	510887	196115	10373	3.27
48358	A411	510873	196365	26968	5.34
48649	A4178	510808	196089	13234	4.38
57123	A412	511470	200000	15975	6.13
57768	A411	510999	196634	25480	3.65
58090	A412	510540	196740	46572	3.09
74675	A4008	511900	195380	12000	4.23
74676	A4008	512000	195370	2000	4.30
99434	A411	511750	196330	30431	2.09
99435	A4008	511800	197000	37716	3.03
57226	M1	511800	202450	62979	8.19

Hertfordshire County Council data

Road Name	Count*	No HGV	No PSV	Average Speed	Comments
Pinner Road	N/A	N/A	N/A	N/A	N/A
Chalk Hill (east of A4008/B462)	18026	451	342	38.4	2002 data
Dalton Way	N/A	N/A	N/A	N/A	N/A
Lower High Street	6734	31	157	31.0	Count & Speed data = Jun 2003; HGV & PSV data = 28 May 2002 and sampled during four peak hours only (7 - 9am and 5 - 7pm)
Vicarage Road (west of Farraline Road)	19748	592	296	27.2	2002 data
Hagden Lane	2744	87	25	N/A	All figures for six peak hours only (7 - 10am and 4 - 7pm) on 11 July 2001
Farraline Road	14278	484	112	N/A	All figures for a 12 hour period only, sampled on 3 Jul 2003
Merton Road	12267	417	200	N/A	All figures for a 12 hour period only, sampled on 6 Jun 1997
Cassio Road	8818	184	76	N/A	All figures for a 12 hour period only, sampled on 2 Oct 2002
Wiggenhall Road	26914	188	646	N/A	2002 data
Whippendell Road	11691	N/A	N/A	30.0	2002 data
Rickmansworth Road	36956	1223	369	N/A	All figures for a 12 hour period only, sampled on 2 Oct 2002
Beechen Grove	23847	N/A	N/A	38.0	March 2003 data
Hempstead Road	24656	N/A	N/A	N/A	2002 data
The Avenue	6836	N/A	N/A	30.0	June 2003 data
St. Albans Road	15605	N/A	N/A	N/A	2002 data
Leavesden Road	7582	N/A	N/A	28.0	Nov/Dec 2003 data
Balmoral Road	7348	N/A	N/A	37.0	May 2001 data
Bushey Mill Lane	3870	N/A	N/A	34.0	Jun/Jul 2000 data
Horseshoe Lane	8300	N/A	N/A	N/A	2002 data
A405 Kingsway North Orbital Road	18997	684	171	N/A	2002 data
M1, J4 - 5	87527	6127	613	N/A	2002 data
A41 Colne Way	34152	N/A	N/A	N/A	2002 data
A41, North Western Avenue	32628	N/A	N/A	N/A	2002 data
Woodford Road	N/A	N/A	N/A	N/A	N/A

Appendix 2

Photographs of narrow congested streets identified by the Updating and Screening Assessment

CONTENTS

Pinner Road

Vicarage Road

Cassio Road

Hagden Lane

Chalk Hill

Bushey Mill Lane from St Albans Road

Farraline Road

Woodford Road

Leavesden Road

Balmoral Road

Whippendell Road

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

6.1.1 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.

6.1.2 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

6.1.3 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

6.1.4 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.

6.1.5 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.

6.1.6 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	

6.1.7 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	

6.1.8 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.

6.1.9 Background concentrations

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

6.1.10 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}

$$NO_2 = 0.348.NO_x + 11.48 \text{ μg m}^{-3}$$

For $NO_x < 23.6$ μg m^{-3}

$$NO_2 = 0.833.NO_x \text{ μg m}^{-3}$$

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)

6.1.11 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

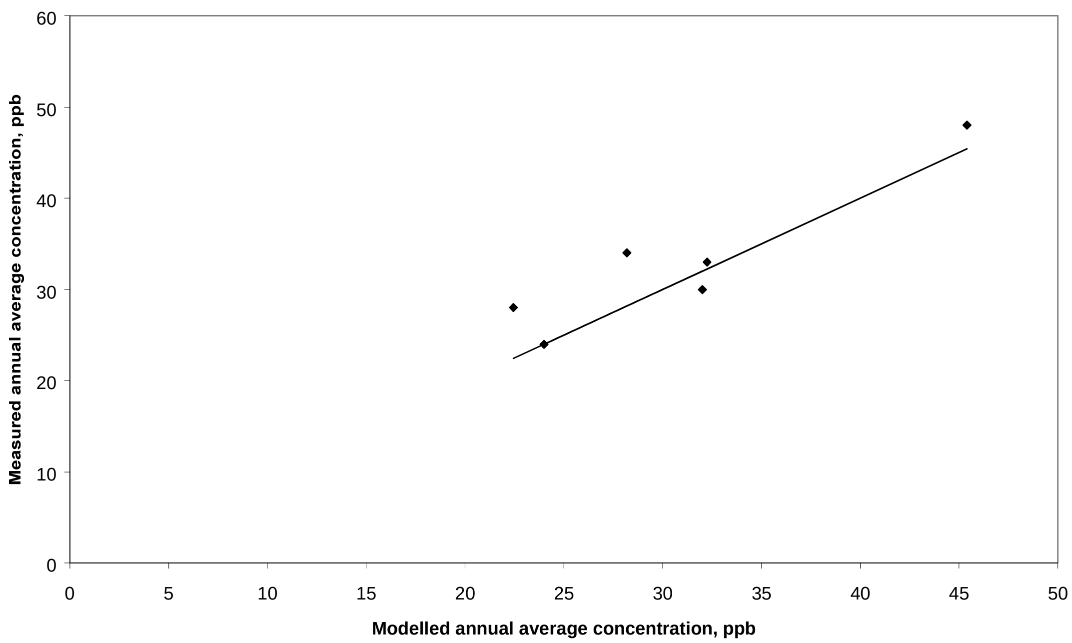

Fig. A3.1 Comparison of modelled and measured annual average nitrogen dioxide concentrations

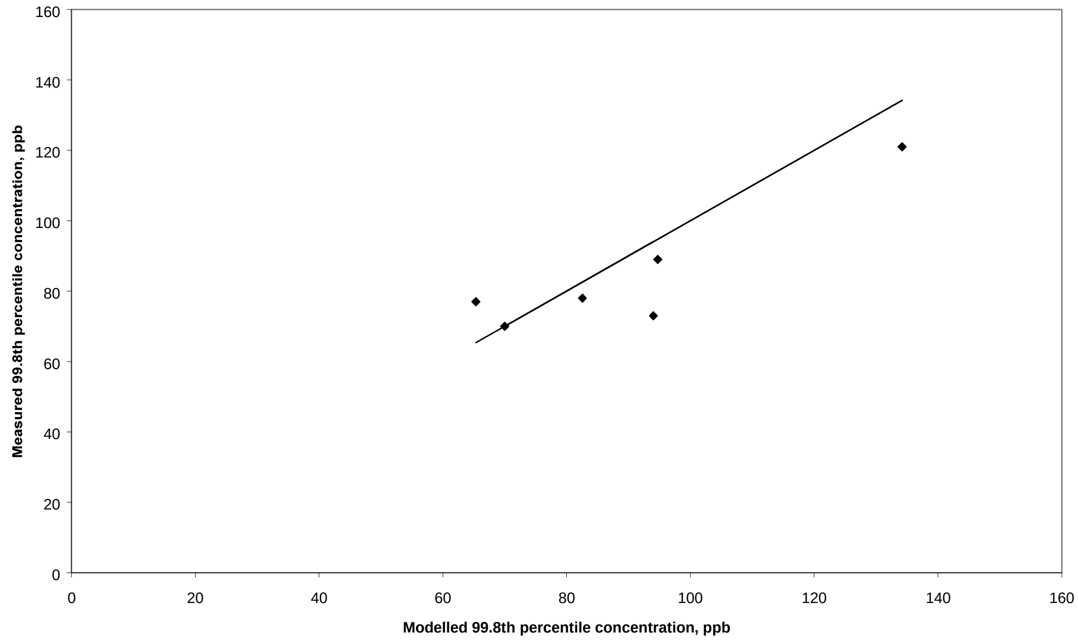

Fig. A3.2 Comparison of modelled and measured 99.8th percentile hourly average nitrogen dioxide concentrations

DISCUSSION

6.1.12 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.

6.1.13 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.

6.1.14 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.

6.1.15 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	99.8th 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 $\mu g\ m^{-3}$ objective will be exceeded if the modelled annual average concentration in 2005 is less than 34 $\mu g\ m^{-3}$ (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 $\mu g\ m^{-3}$ (i.e. 40/1.44).

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

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 99.8th percentile concentration of NO_2 from the annual concentration: the 99.8th 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 ($\mu g\ m^{-3}$)			
		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

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.

Model application

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.

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

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

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 90th percentile 24 hour average.

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	

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

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.

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.

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.

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) 90th percentile 24 hour average value calculated by adding background and road 90th percentiles

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

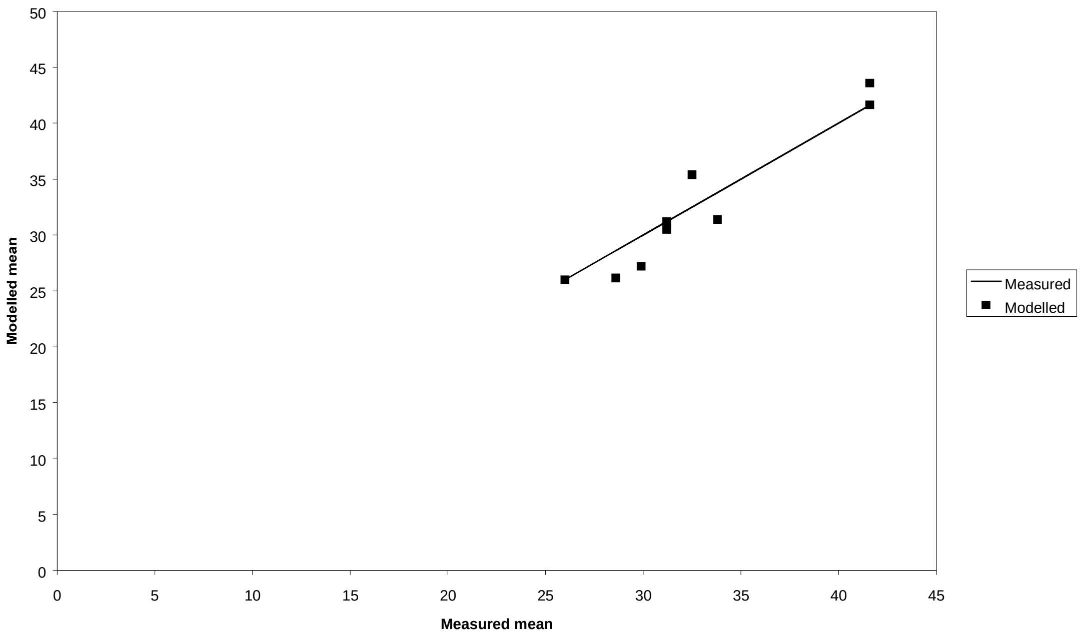

Fig. A4.1:Comparison of modelled and measured annual mean PM_{10} concentrations, $\mu g/m^3$ gravimetric

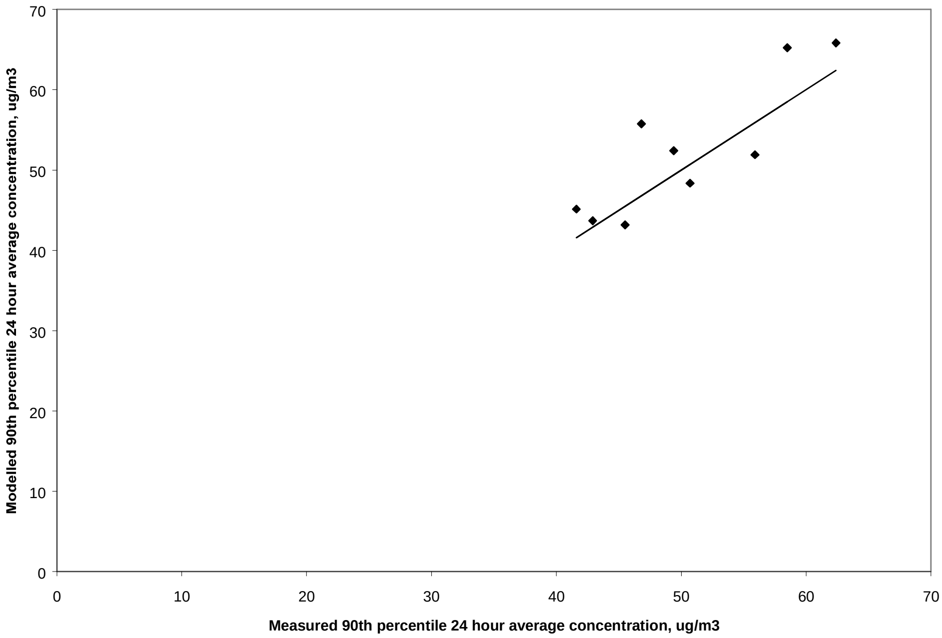

Fig. A4.2: Comparison of modelled and measured 90th percentile 24 hour average PM_{10} concentrations (Method 1), $\mu g/m^3$ gravimetric.

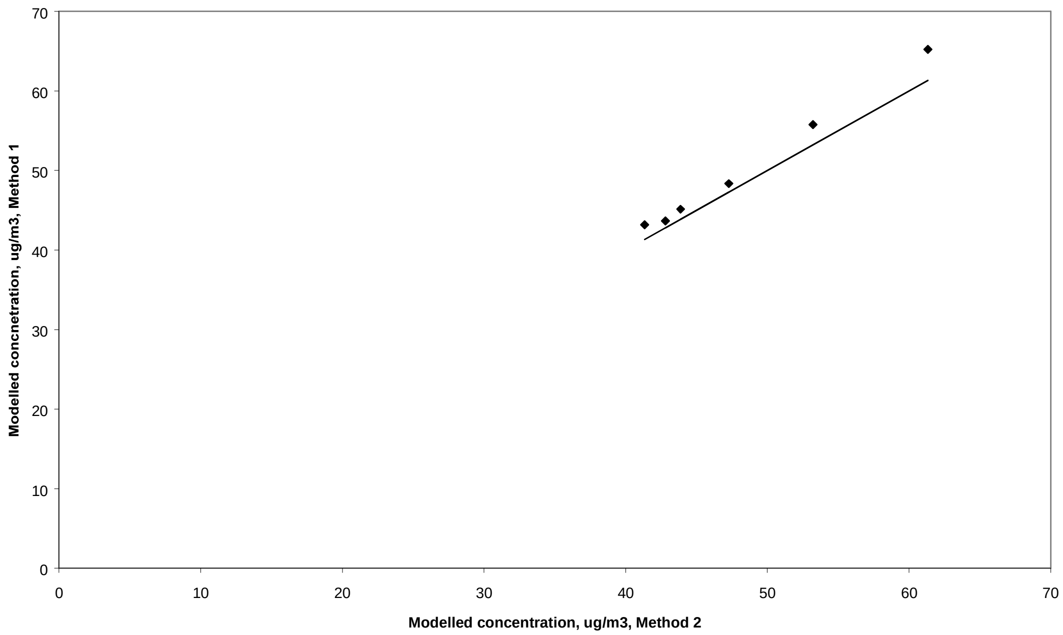

Fig. A4.3: Comparison of 90th percentile calculation methods, gravimetric units

Discussion

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.

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).

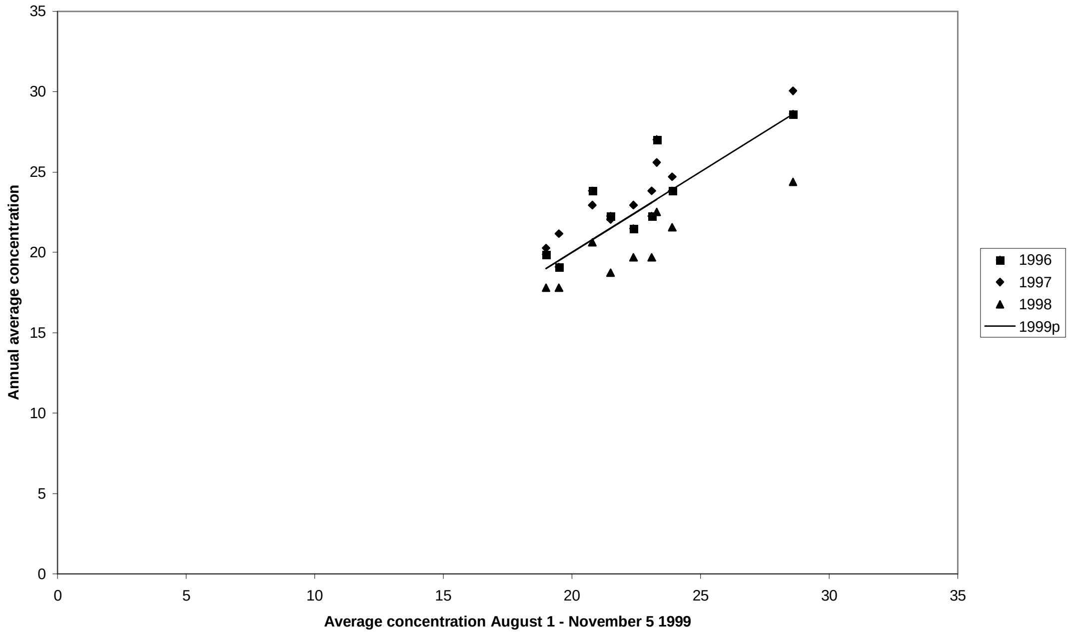

Fig. A4.4: Comparison of average concentrations (µg m^{-3} TEOM) during August 1-November 5 1999 with annual average concentrations

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, $\mu g\ m^{-3}$ gravimetric	
	Mean	90th 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 90th 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 90th percentile backgrounds and road contributions provides a good estimate of the value calculated as the 90th percentile of daily average background plus road concentrations.