

# Report

## UK air quality modelling for annual reporting 2003 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC

Report to The Department for Environment, Food and  
Rural Affairs, Welsh Assembly Government, the  
Scottish Executive and the Department of the  
Environment for Northern Ireland

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# Executive Summary

Directive 96/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive) establishes a framework under which the EU sets limit values or target values for the concentrations of specified air pollutants. Directive 1999/30/EC (the first Daughter Directive) sets the limit values to be achieved for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particles and lead. Directive 2000/69/EC (the second Daughter Directive) set limits to be achieved for benzene and carbon monoxide.

2003 is the third year for which an annual air quality assessment for the first Daughter Directive pollutants is required. This was the first year for which an annual air quality assessment was undertaken for the second Daughter Directive pollutants. A questionnaire has been completed for submission to the EU containing the results of this air quality assessment. The assessment takes the form of comparisons of measured and modelled air pollutant concentrations with the limit values set out in the Directives. Air quality modelling has been carried out to supplement the information available from the UK national air quality monitoring networks.

This report provides a summary of key results from the questionnaire and additional technical information on the modelling methods that have been used to assess SO<sub>2</sub>, NO<sub>2</sub> and NO<sub>x</sub>, PM<sub>10</sub>, benzene and CO concentrations throughout the UK. This includes:

- Details of modelling methods
- Information on the verification of the models used and comparisons with data quality objectives
- Detailed modelling results and comparison with limit values.

Maps of background concentrations of SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub>, benzene and CO in 2003 on a 1 km x 1 km grid have been prepared. Maps of roadside concentrations of NO<sub>2</sub>, PM<sub>10</sub>, benzene and CO have been prepared for 9882 urban major road links (A-roads and motorways).

The dominant contributions to measured SO<sub>2</sub> concentrations in the UK are typically from major point sources such as power stations and refineries, particularly in terms of high percentile concentrations. Emissions of SO<sub>2</sub> from point sources were therefore modelled in some detail. Area sources have been modelled using a dispersion kernel approach. For NO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, benzene and CO there are also an important contribution to ambient concentrations from area sources, particularly traffic sources and a slightly different modelling approach has therefore been adopted. The area source contribution has been modelled using a kernel-based area source model, which has been calibrated empirically using measurement data. Roadside concentrations of NO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, benzene and CO have been estimated by adding a roadside increment to the modelled background concentrations. This roadside increment has been calculated using road link emission estimates and dispersion coefficients derived empirically from roadside monitoring data.

The UK has been divided into 43 zones for air quality assessment. There are 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones. The status of the zones in relation to the limit values for all of the first and second Daughter Directive pollutants have been listed and reported to the EU in the questionnaire. The status has been determined from a combination of monitoring data and model results. The results of this assessment are summarised in Table E1 in terms of exceedences of limit values + margins of tolerance (LV + MOT) and limit values (LV).

Table E1 Summary results of air quality assessment for 2003

Pollutant	Averaging time	Number of zones exceeding limit value + margin of tolerance	Number of zones exceeding limit value <sup>1</sup>
SO <sub>2</sub>	1-hour	1 zone modelled (Eastern)	1 zone modelled (Eastern)
SO <sub>2</sub>	24-hour <sup>2</sup>	1 zone modelled (Eastern)	1 zone modelled (Eastern)
SO <sub>2</sub>	annual <sup>3</sup>	n/a	none
SO <sub>2</sub>	winter <sup>3</sup>	n/a	none
NO <sub>2</sub>	1-hour <sup>4</sup>	1 zone measured (Greater London Urban Area)	3 zones measured (London, Glasgow, South East)
NO <sub>2</sub>	annual	35 zones (5 measured + 30 modelled)	42 zones (10 measured + 32 modelled)
NO <sub>x</sub>	annual <sup>3</sup>	n/a	none
PM <sub>10</sub>	24-hour (Stage 1)	18 zones (2 measured + 16 modelled)	33 zones (10 measured + 23 modelled)
PM <sub>10</sub>	Annual (Stage 1)	10 zones (1 measured + 9 modelled)	15 zones (1 measured + 14 modelled)
PM <sub>10</sub>	24-hour <sup>5</sup> (Stage 2)	n/a	36 zones (36 measured)
PM <sub>10</sub>	annual <sup>6</sup> (Stage 2)	36 zones (8 measured + 28 modelled)	43 zones (35 measured + 8 modelled)
Lead	annual	none	none
Benzene	annual	none	1 zone modelled (Greater London Urban Area)
CO	8-hour	none	none

<sup>1</sup> Includes zones exceeding LV + MOT

<sup>2</sup> No MOT defined, LV + MOT = LV

<sup>3</sup> No MOT defined for vegetation and ecosystem LVs, which are already in force

<sup>4</sup> No modelling for 1-hour LV

<sup>5</sup> Stage 2 indicative LV, no MOT defined for 24-hour stage 2 LV, no modelling for 24-hour stage 2 LV

<sup>6</sup> Stage 2 indicative LV

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# 1 Introduction

## 1.1 THE FRAMEWORK AND FIRST AND SECOND DAUGHTER DIRECTIVES

Directive 96/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive (Council Directive 96/62/EC)) establishes a framework under which the EU sets limit values or target values for the concentrations of specified air pollutants in ambient air. Directive 1999/30/EC (the first Daughter Directive, AQDD1 (Council Directive 1999/30/EC)) sets the limit values to be achieved for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particles and lead. Directive 2000/69/EC (the second Daughter Directive, AQDD2) sets out the limit values to be achieved for benzene and carbon monoxide.

The Framework Directive includes a requirement for Member States to undertake preliminary assessments of ambient air quality, prior to the implementation of the Daughter Directives under Article 5 this Directive. The objectives of these assessments are to establish estimates for the overall distribution and levels of pollutants, and to identify additional monitoring required to fulfil obligations within the Framework Directive. Reports describing the preliminary assessment for the UK for AQDD1 and AQDD2 have been prepared (Bush 2000 and 2002). AQDD1 and AQDD2 define the number of air quality monitoring sites required on the basis of the concentrations of pollutants and population statistics. The number of monitoring sites required is significantly reduced if other means of assessment, in addition to fixed monitoring sites, are also available. Air quality modelling has therefore been carried out to supplement the information available from the UK national air quality monitoring networks and contribute to the assessments required by the Framework and subsequent Daughter Directives.

## 1.2 THIS REPORT

2003 is the third year for which an annual air quality assessment for the first Daughter Directive pollutants is required and the first year for which an annual air quality assessment of the second Daughter Directive pollutants is required. A questionnaire has been completed for submission to the EU containing the results of this air quality assessment. The assessment takes the form of comparisons of measured and modelled air pollutant concentrations with the limit values set out in the Directives. This report provides a summary of key results from the questionnaire and additional technical information on the modelling methods that have been used to assess concentrations throughout the UK.

Sections 2 to 6 describe the modelling methods used for estimation of SO<sub>2</sub>, NO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, benzene and CO concentrations. This includes

- Details of modelling methods
- Information on the verification of the models used and comparisons with data quality objectives
- Detailed modelling results.

The status of zones in relation to the limit values for the AQDD1 and AQDD2 pollutants have been listed and reported to the EU in the questionnaire and copies of these lists are



included in Section 7. The status has been determined from a combination of monitoring data and model results. Section 7 also includes a comparison of the results of similar assessments carried out for the calendar years 2002 and 2001 (Stedman et al, 2002, Stedman et al, 2003).

### 1.3 PRELIMINARY ASSESSMENTS AND DEFINITION OF ZONES

The preliminary assessment carried for AQDD1 (Bush, 2000) defined a set of zones to be used for air quality assessments in the UK. These zones are listed in Table 1.1 and illustrated in Figure 1.1. Information on the definition of zones is included in form 2 of the questionnaire. The zone codes listed in Table 1.1 are used throughout the questionnaire. The population (1991 census), area and the number of urban major road links in each zone are also shown. The zones are of two types: agglomeration zones (continuous urban areas with a population in excess of 250,000) and non-agglomeration zones. There are 28 agglomeration zones and 15 non-agglomeration zones, giving a total of 43 zones in the UK. The non-agglomeration zones in England correspond to the Government Office Regions, while those in Scotland, Wales and Northern Ireland were defined in conjunction with the Devolved Administrations.

Figure 1.1. UK zones and agglomerations for 2003 (red = agglomeration zones)

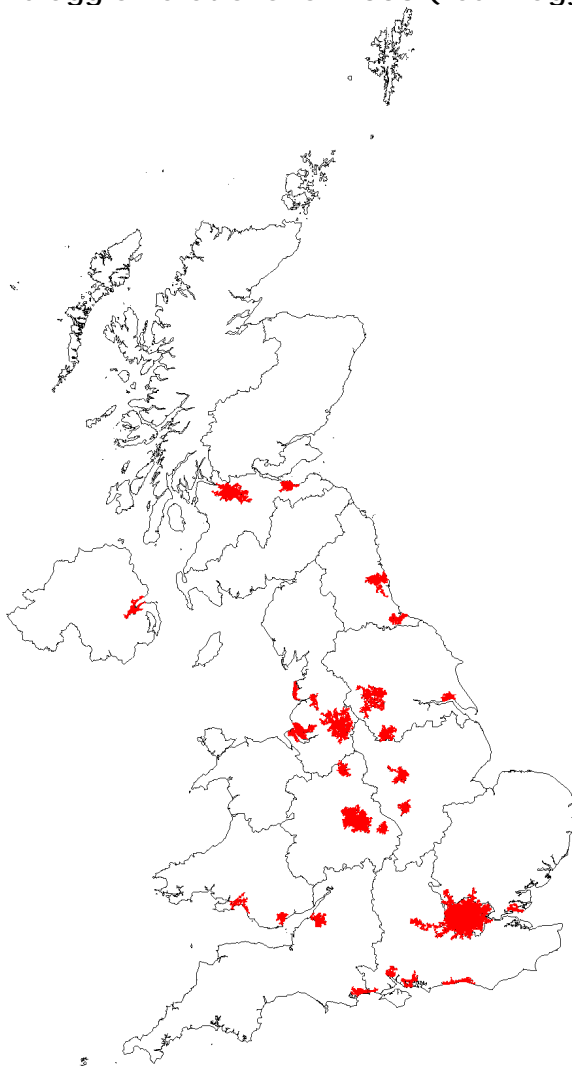


Table 1.1 Zones for AQDD1 reporting

Zone	Zone code	Ag or nonag*	Population	Area (km <sup>2</sup> )	Number of urban road links	Length of urban road links (km)
Greater London Urban Area	UK0001	ag	7650944	1624	2008	1885.8
West Midlands Urban Area	UK0002	ag	2296180	599	407	563.1
Greater Manchester Urban Area	UK0003	ag	2277330	538	564	658.4
West Yorkshire Urban Area	UK0004	ag	1445981	352	283	412.2
Tyneside	UK0005	ag	885981	212	173	205.0
Liverpool Urban Area	UK0006	ag	837998	181	273	218.5
Sheffield Urban Area	UK0007	ag	633362	168	113	158.2
Nottingham Urban Area	UK0008	ag	613726	151	116	117.5
Bristol Urban Area	UK0009	ag	522784	131	116	112.7
Brighton/Worthing/Littlehampton	UK0010	ag	437592	89	54	84.1
Leicester Urban Area	UK0011	ag	416601	92	72	92.3
Portsmouth Urban Area	UK0012	ag	409341	83	51	71.3
Teesside Urban Area	UK0013	ag	369609	102	57	72.6
The Potteries	UK0014	ag	367976	91	105	112.0
Bournemouth Urban Area	UK0015	ag	358321	109	52	67.3
Reading/Wokingham Urban Area	UK0016	ag	335757	94	69	83.0
Coventry/Bedworth	UK0017	ag	331248	74	30	34.3
Kingston upon Hull	UK0018	ag	310636	78	38	49.8
Southampton Urban Area	UK0019	ag	276752	74	58	69.0
Birkenhead Urban Area	UK0020	ag	270207	62	62	57.3
Southend Urban Area	UK0021	ag	266749	66	32	51.0
Blackpool Urban Area	UK0022	ag	261355	64	50	69.9
Preston Urban Area	UK0023	ag	256411	67	37	47.8
Glasgow Urban Area	UK0024	ag	1315544	441	212	312.3
Edinburgh Urban Area	UK0025	ag	416232	127	62	104.9
Cardiff Urban Area	UK0026	ag	306904	70	42	54.7
Swansea Urban Area	UK0027	ag	272456	87	31	65.0
Belfast Urban Area	UK0028	ag	475987	113	17	101.3
Eastern	UK0029	nonag	4788766	19103	619	870.5
South West	UK0030	nonag	3728319	23518	473	671.6
South East	UK0031	nonag	3702634	18664	884	1333.1
East Midlands	UK0032	nonag	2923045	15521	423	670.3
North West & Merseyside	UK0033	nonag	2823559	13186	571	969.9
Yorkshire & Humberside	UK0034	nonag	2446545	14797	355	713.3
West Midlands	UK0035	nonag	2154783	12189	355	525.9
North East	UK0036	nonag	1287979	8296	205	268.3
Central Scotland	UK0037	nonag	1628460	9225	202	340.9
North East Scotland	UK0038	nonag	933485	18595	137	233.4
Highland	UK0039	nonag	364639	38406	11	34.5
Scottish Borders	UK0040	nonag	246659	11145	37	58.6
South Wales	UK0041	nonag	1623660	12211	210	361.7
North Wales	UK0042	nonag	713762	8367	87	158.3
Northern Ireland	UK0043	nonag	1101868	13567	129	942.4
Total			55088127	242729	9882	14084.1

\* ag = agglomeration zone, nonag = non-agglomeration zone

The relevant preliminary assessments also defined the monitoring and modelling requirements for each zone based on an assessment of concentrations in relation to upper and lower assessment thresholds specified by AQDD1 and AQDD2. The minimum monitoring requirement for most pollutants in the majority of zones was found to be at least one monitoring site per zone, with the monitoring results to be supplemented with information from modelling studies. The preliminary assessment for lead indicated that concentrations in many zones were less than the lower assessment threshold. There is therefore no requirement to monitor lead concentrations in these zones (Bush 2000).

The limit values for the protection of ecosystems and vegetation presented in AQDD1 only apply in ecosystems and vegetation areas, which are defined by this Directive as areas which are 20 km from agglomerations and 5 km from motorways, other urban areas and industrial installations.

## 1.4 MONITORING SITES

The monitoring stations operating during 2003 for the purpose of AQDD1 and AQDD2 are listed in Table A1.1 in Appendix 1. This information is included in form 3 of the questionnaire. Not all sites had sufficient data capture during 2003 for data to be reported. The data quality objective (DQO) for AQDD1 and AQDD2 measurements is 90 % data capture. We have included all measurements with at least 75 % data capture in the analysis in order to ensure that we can make maximum use of data from the monitoring sites operational during 2003 for reporting purposes. Table A1.2 in Appendix 1 lists the measurements with more than 75% but less than 90% data capture and included in the analysis. Table A1.3 in Appendix 1 lists measurements with less than 75 % data capture. Lead data are reported for sites with greater than 75% data capture.

A detailed scrutiny of the exceedence status of each zone with respect to the limit values listed in Section 7 and the list of sites with data capture between 75% and 90% has been carried out and the results are summarised in Table A1.4 in Appendix 1. This has shown that the exceedence status of UK zones has not been changed by the inclusion of in the analysis of sites with data capture between 75% and 90%. Exclusion of these sites would have left several zones without monitoring data. This would either place a heavier reliance on the modelling results, where these are available, or left the zone with no assessment, where modelling results are unavailable.

## 1.5 LIMIT VALUES AND MARGINS OF TOLERANCE

The limit values (LV) and limit values + margins of tolerance (LV + MOT) included in AQDD1 and AQDD2 are listed in Tables 1.2 to 1.7. Stage 1 limit values for achievement by 2005 and indicative stage 2 limit values for achievement by 2010 have been set for PM<sub>10</sub>. The limit value + margin of tolerance varies from year to year from the date the Directives came into force until the date by which the limit value is to be met. Values for 2003 are listed in Tables 1.2 to 1.7. Where no margin of tolerance has been defined the limit value + margin of tolerance is effectively the same as the limit value. There are no margins of tolerance for the ecosystem and vegetation limit values because these limit values are already in force. The stage 2 annual mean limit value + margin of tolerance for PM<sub>10</sub> is 30 µg m<sup>-3</sup> from 2001 until 2005.

All exceedences of the limit value must be reported to the EU. Exceedences of the limit value + margin of tolerance (or limit value if no limit value + margin of tolerance has been set) also must be reported to the EU and trigger a requirement for the preparation of a 'plan and programme' for attaining the limit value within the specified time limit specified by the relevant Directive and a report to the EU on this 'plan and programme'.

Table 1.2. Limit values for SO<sub>2</sub>

	Averaging period	LV	LV + MOT 2003	Date by which LV is to be met
1. Hourly LV for the protection of human health	1 hour	350 µg m <sup>-3</sup> , not to be exceeded more than 24 times a calendar year	410 µg m <sup>-3</sup> , not to be exceeded more than 24 times a calendar year	1 January 2005
2. Daily LV for the protection of human health	24 hour	125 µg m <sup>-3</sup> , not to be exceeded more than 3 times a calendar year	N/A	1 January 2005
3. LV for the protection of ecosystems	Calendar year and winter	20 µg m <sup>-3</sup>	N/A	19 July 2001

Table 1.3. Limit values for NO<sub>2</sub> and NO<sub>x</sub>

	Averaging period	LV	LV + MOT 2003	Date by which LV is to be met
1. Hourly LV for the protection of human health	1 hour	200 µg m <sup>-3</sup> NO <sub>2</sub> not to be exceeded more than 18 times a calendar year	270 µg m <sup>-3</sup> , NO <sub>2</sub> not to be exceeded more than 18 times a calendar year	1 January 2010
2. Annual LV for the protection of human health	Calendar year	40 µg m <sup>-3</sup> NO <sub>2</sub>	54 µg m <sup>-3</sup> , NO <sub>2</sub>	1 January 2010
3. LV for the protection of vegetation	Calendar year	30 µg m <sup>-3</sup> NO <sub>x</sub> , as NO <sub>2</sub>	N/A	19 July 2001

Table 1.4a. Limit values for PM<sub>10</sub> (Stage 1)

	Averaging period	LV	LV + MOT 2003	Date by which LV is to be met
1. 24-hour LV for the protection of human health	24 hour	50 µg m <sup>-3</sup> not to be exceeded more than 35 times a calendar year	60 µg m <sup>-3</sup> not to be exceeded more than 35 times a calendar year	1 January 2005
2. Annual LV for the protection of human health	Calendar year	40 µg m <sup>-3</sup>	43 µg m <sup>-3</sup>	1 January 2005

**Table 1.4b. Indicative limit values for PM<sub>10</sub> (Stage 2)**

	Averaging period	LV	LV + MOT 2003	Date by which LV is to be met
1. 24-hour LV for the protection of human health	24 hour	50 µg m <sup>-3</sup> not to be exceeded more than 7 times a calendar year	N/A	1 January 2010
2. Annual LV for the protection of human health	Calendar year	20 µg m <sup>-3</sup>	30 µg m <sup>-3</sup>	1 January 2010

**Table 1.5. Limit values for lead**

	Averaging period	LV	LV + MOT 2003	Date by which LV is to be met
Annual LV for the protection of human health	Calendar year	0.5 µg m <sup>-3</sup>	0.7 µg m <sup>-3</sup>	1 January 2005

**Table 1.6. Limit values for benzene**

	Averaging period	LV	LV + MOT 2003	Date by which LV is to be met
Annual LV for the protection of human health	Calendar year	5 µg m <sup>-3</sup>	10 µg m <sup>-3</sup>	1 January 2010

**Table 1.7. Limit values for CO**

	Averaging period	LV	LV + MOT 2003	Date by which LV is to be met
8-hour LV for the protection of human health	Maximum daily 8-hour mean	10 mg m <sup>-3</sup>	14 mg m <sup>-3</sup>	1 January 2005

## 1.6 DATA QUALITY OBJECTIVES FOR MODELLING RESULTS AND MODEL VERIFICATION

AQDD1 sets data quality objectives in terms of accuracy, which act as a guide for quality assurance programmes when identifying an acceptable level of accuracy for assessment methods appropriate for supplementary assessment under the Directive. Accuracy is defined in the Directives as the maximum deviation of the measured and calculated concentration levels, over the period considered by the limit value, without taking into account the timing of events.

DQOs are have been set at 50-60% (we have compared with 50%) for hourly averages, 50% for daily averages and 30 % for annual averages of SO<sub>2</sub>, NO<sub>2</sub> and NO<sub>x</sub>. For PM<sub>10</sub> and lead the DQO for annual averages is 50%. DQOs have not been defined for daily averages of PM<sub>10</sub> at present. AQDD2 sets the DQOs applicable to assessment methods for annual average benzene and 8-hour average CO concentrations at 50%.

The empirical models used to calculate the maps of air pollutants presented in this report have been calibrated using the national network monitoring data (for sites listed in Appendix 1). Data from these sites alone cannot, therefore, be used to assess the reliability of the mapped estimates in relation to the DQOs for modelling. Measurement data from sites not included in the calibration are required to make this assessment. Data from sites quality assured by netcen under contract and not part of the national network, including Local Authority sites in the netcen Calibration Club, have therefore been used for the verification of the modelled estimates. The description 'Verification Sites' is used to describe all the monitoring sites included in the verification analysis, as only a subset of these sites, quality assured under contract by netcen, are formally members of the Calibration Club. The monitoring sites used for this comparison are listed in Appendix 2. Sites with a data capture of at least 75% have been included in the verification analysis. This is the same data capture threshold as that applied for the national network sites used to calibrate the models. Model verification results are listed in the following sections on each pollutant.

## 1.7 AIR QUALITY MODELLING

Full details of the modelling methods implemented are given in the following sections. A brief introduction is presented here. Maps of background concentrations of SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub>, benzene and CO have been prepared on a 1 km x 1 km grid for the 2003 calendar year. Maps of roadside concentrations of NO<sub>2</sub>, PM<sub>10</sub> and benzene and CO have also been prepared for 9,882 urban major road links (A-roads and motorways).

The dominant contributions to ambient SO<sub>2</sub> concentrations in the UK are typically from major point sources such as power stations and refineries, particularly in terms of high percentile concentrations. Emissions of SO<sub>2</sub> from point sources were therefore modelled explicitly in some detail, whereas area sources have been modelled using a dispersion kernel approach. A dispersion kernel describes the contributions to ambient concentrations of a pollutant at a central receptor location from a regular array of sources of unit emission strength. The residual contribution to ambient annual mean SO<sub>2</sub> concentrations from sources not modelled has been estimated by subtracting the modelled components from measured data.

For NO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, benzene and CO there are also important contributions to ambient concentrations from area sources, particularly traffic sources, and a slightly different modelling approach has therefore been adopted. Point sources have been modelled explicitly for all these pollutants. For benzene contributions from large combustion sources have been modelled explicitly. Contributions from other point source have been modelled using a volume source dispersion kernel approach in order to represent the process and fugitive emission release characteristics of these sources. Rural network measurements have been used to define regional concentrations of NO<sub>2</sub>, NO<sub>x</sub> and secondary PM<sub>10</sub>. Regional benzene concentrations have been estimated from rural NO<sub>2</sub> concentrations. The area source contribution to ambient NO<sub>x</sub>, PM<sub>10</sub>, benzene and CO concentrations has been modelled using a dispersion kernel approach. The coefficients calibrating these area source models have been determined empirically using measurement data from the national networks.

Roadside concentrations of NO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, benzene and CO have been estimated by adding a roadside increment to the modelled background concentrations. The roadside increment has been calculated from road link emission estimates using dispersion coefficients derived empirically using data from roadside monitoring sites.

Emissions estimates for the UK are provided by the National Atmospheric Emission Inventory (Dore et al, 2004). Emission maps from the 2002 NAEI have been used for the modelling work described here. Emission estimates for area sources have been scaled to values appropriate to 2003, using UK sector total emissions from 2002 and 2003. Owing to the likely significant influence of large SO<sub>2</sub> sources upon modelled high percentile concentrations, 2003 emissions estimates for power stations and other large sources with greater than 500 tonnes emission per annum were collected from the Environment Agency's Pollution Inventory (Claudia Thornton, *pers comm.* 2004), the Scottish Environmental Protection Agency (Wendy Thornton, *pers comm.* 2004) and The Industrial Pollution and Radiochemical Inspectorate in Northern Ireland (Michael McGarry *pers comm.*, 2004). Ambient concentrations are, however, less sensitive to the emissions from large point sources for the other pollutants and emissions estimates for 2002 have been directly applied to model concentrations in 2003.

## 2 SO<sub>2</sub>

### 2.1 INTRODUCTION

Maps of annual mean, winter mean, 99.73 percentile of hourly mean SO<sub>2</sub> concentrations and 99.18 percentile of daily mean SO<sub>2</sub> concentrations have been calculated using methods based on those described by Abbott and Vincent (1999). (The percentile concentrations presented here correspond to the number of allowed exceedences of the 1-hour and 24-hour limit values for SO<sub>2</sub>). Emissions from point and area sources have been modelled separately. Emissions from larger point sources were modelled explicitly using the dispersion model ADMS 3.1. Emissions from smaller point sources and area sources were modelled using 1 km x 1 km emission grids and a dispersion kernel approach.

A number of receptor areas were defined, which together covered the country. Each receptor area was 150 km x 150 km. For larger point sources (sources with emissions ≥500 tonnes per year) all sources within the receptor area and sources in the adjoining 150 km x 150 km squares were assumed to influence concentrations within the receptor area. Concentrations were calculated on a regular 5 km x 5 km grid using ADMS 3.1 and sequential meteorological data for 2003 from Waddington. This approach ensures that the combined impact of several sources on ambient high percentile concentrations is estimated correctly (it is not possible to add together the percentiles from different sources at an individual receptor because the percentiles are unlikely to correspond to the same hour of the year).

The contribution to ambient annual mean SO<sub>2</sub> concentrations from emissions from small point sources (sources with emissions <500 tonnes per year) was calculated using the dispersion kernel based small point model described in Appendix 3. The contribution from area sources to annual mean SO<sub>2</sub> concentrations was also estimated using a dispersion kernel based approach. The derivation of the area source model kernels is described in Appendix 4. Dispersion kernels were calculated using ADMS 3.1 and hourly sequential meteorological data for 2003 from Heathrow.

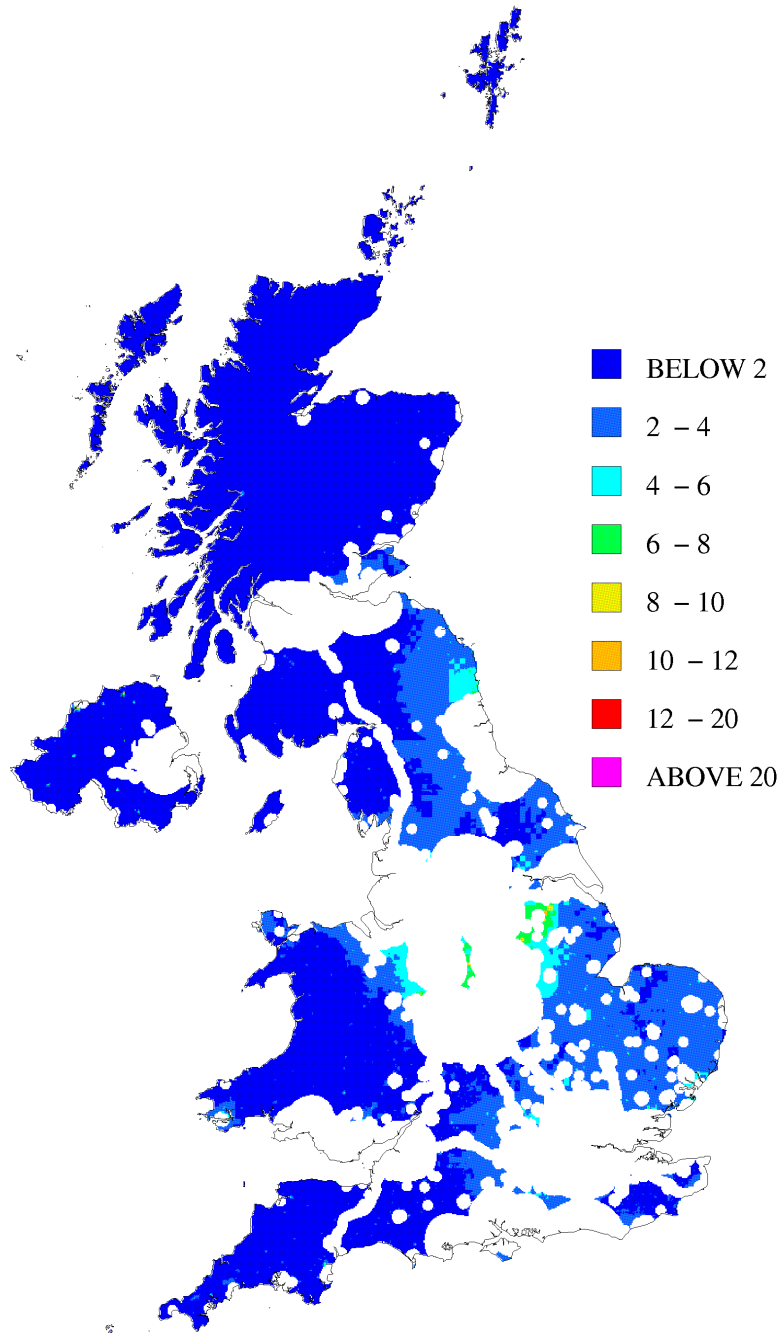
The contributions to annual mean and high percentile concentrations from the different sources were then summed and calibrated as described below. The map of winter mean SO<sub>2</sub> concentrations was derived from the annual mean map.

A different method was used to calculate the high percentile concentrations in Northern Ireland, where the dominant source for peak SO<sub>2</sub> concentrations is domestic emissions (see section 3.2).

## 2.2 MAPS OF WINTER AND ANNUAL MEAN CONCENTRATIONS

A map of annual mean SO<sub>2</sub> concentration for 2003 in ecosystem areas is shown in Figure 2.1.

Figure 2.1. Annual mean SO<sub>2</sub> concentration, 2003 ( $\mu\text{g m}^{-3}$ ) in ecosystem areas

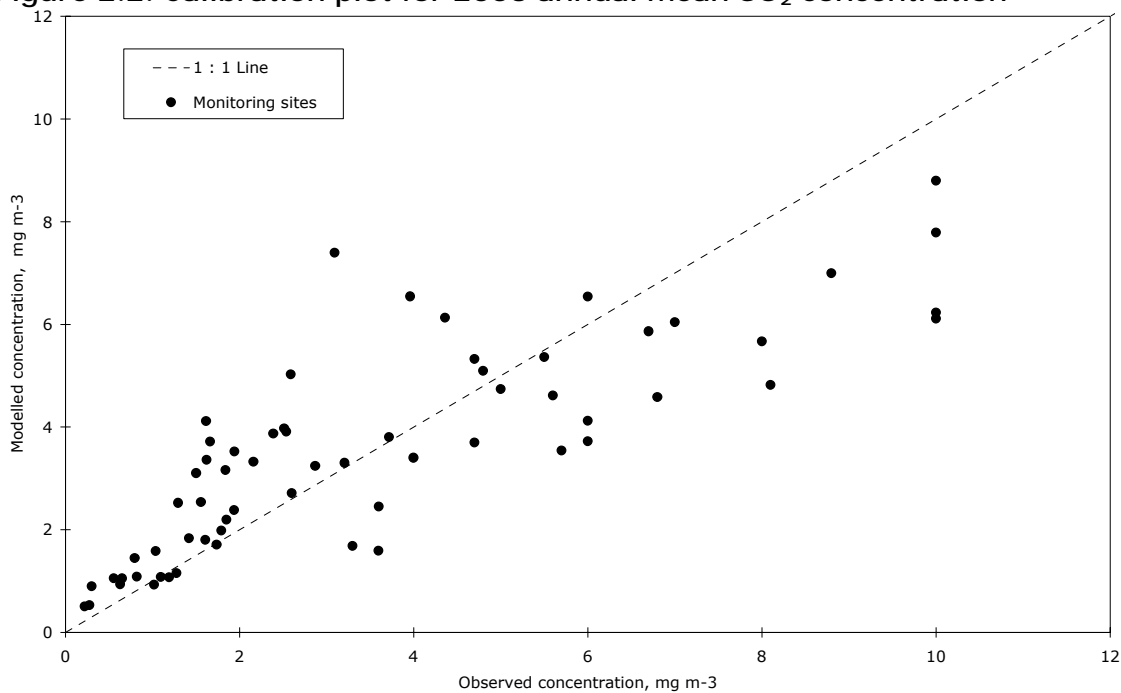




Measured annual mean SO<sub>2</sub> concentrations were used to calibrate the annual mean SO<sub>2</sub> model output to ensure that the final predicted concentrations matched the concentrations measured at these sites. Measured concentrations from Rural SO<sub>2</sub> Monitoring Network sites (Lawrence, *pers comm*, 2004), rural, suburban and industrial sites in the national automatic monitoring networks and rural automatic monitoring sites maintained by the electricity generating companies were used to calibrate the model. A list of the sites maintained by the electricity generating companies is included in Appendix 2. The calibration plot for 2003 is shown in Figure 2.2. Linear regression analysis of modelled and measured concentrations at rural monitoring sites was carried out to establish the values of the coefficient and constant in the following equation:

$$\text{Annual average} = \text{Modelled Area and Small Point Sources} + 0.89 \times \text{Modelled Part A} + 0.49$$

Figure 2.2. Calibration plot for 2003 annual mean SO<sub>2</sub> concentration



The residual concentrations were then calculated at each of the calibration monitoring sites:

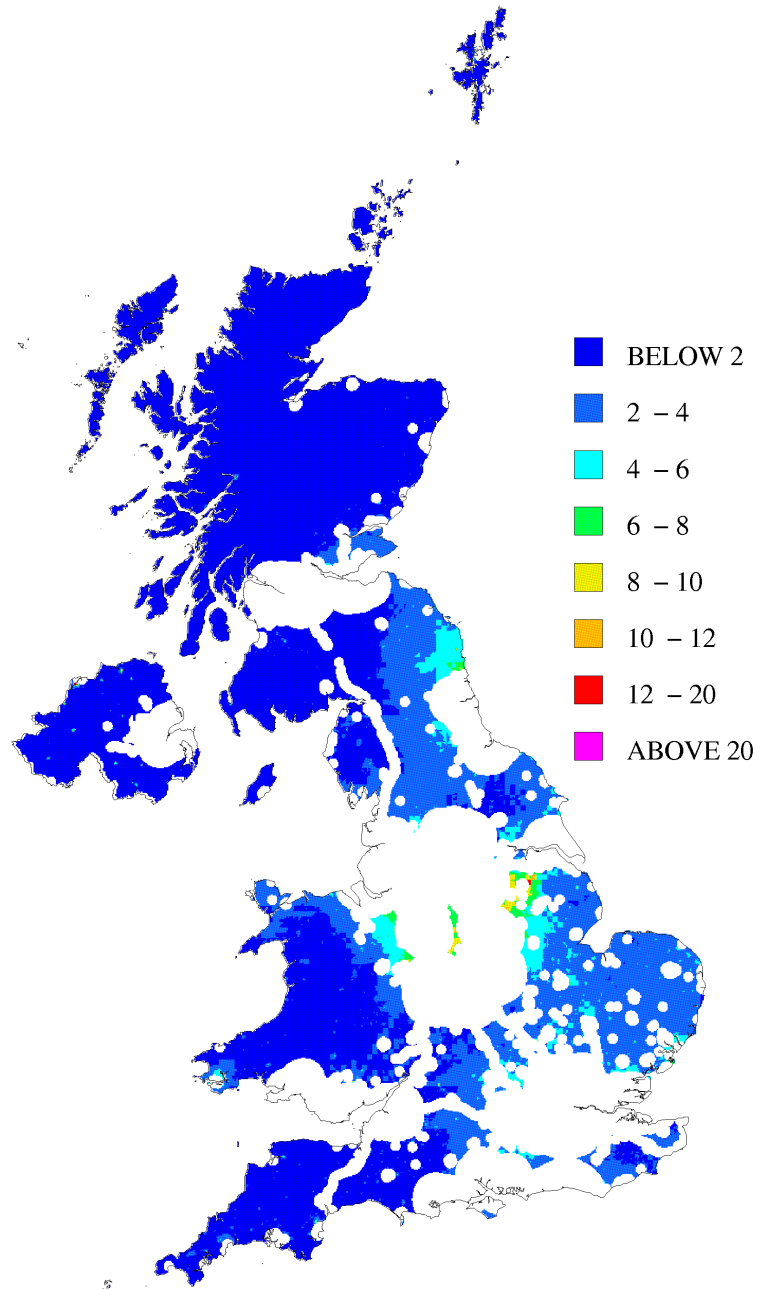
$$\text{Residual} = \text{Measured} - \text{Regression Model}$$

These residual contributions are associated partly with errors in the model and partly with the contributions from more distant sources, not modelled in this study. They include, for example, contributions from emissions from sources on continental Europe. The residual concentrations were interpolated across the country to provide a map of residuals using simple kriging. The final map was calculated from:

$$\text{Mapped Value} = \text{Modelled Area and Small Point Sources} + 0.89 \times \text{Modelled Part A} + 0.49 + \text{Residual}$$

A map of winter mean SO<sub>2</sub> concentrations for the period October 2002 to March 2003 has also been calculated and is shown in Figure 2.3. This map was calculated by multiplying the annual mean map for 2003 by 1.16, the average ratio between the 2002-2003 winter means and 2003 annual means measured at Rural SO<sub>2</sub> monitoring sites.

Figure 2.3. Winter mean SO<sub>2</sub> concentration, 2002-2003 ( $\mu\text{g m}^{-3}$ ) in ecosystem areas



## 2.3 MAPS OF PERCENTILE CONCENTRATIONS FOR COMPARISON WITH THE 1-HOUR AND 24-HOUR LIMIT VALUES

Maps of 99.73 percentile of 1-hour mean and 99.18 percentile of 24-hour mean SO<sub>2</sub> concentration in 2003 are shown in Figures 2.4 and 2.5 and were calculated for comparison with the 1-hour and 24-hour limit values for SO<sub>2</sub>.

Figure 2.4. 99.73 percentile of 1-hour mean SO<sub>2</sub> concentration, 2003 ( $\mu\text{g m}^{-3}$ )

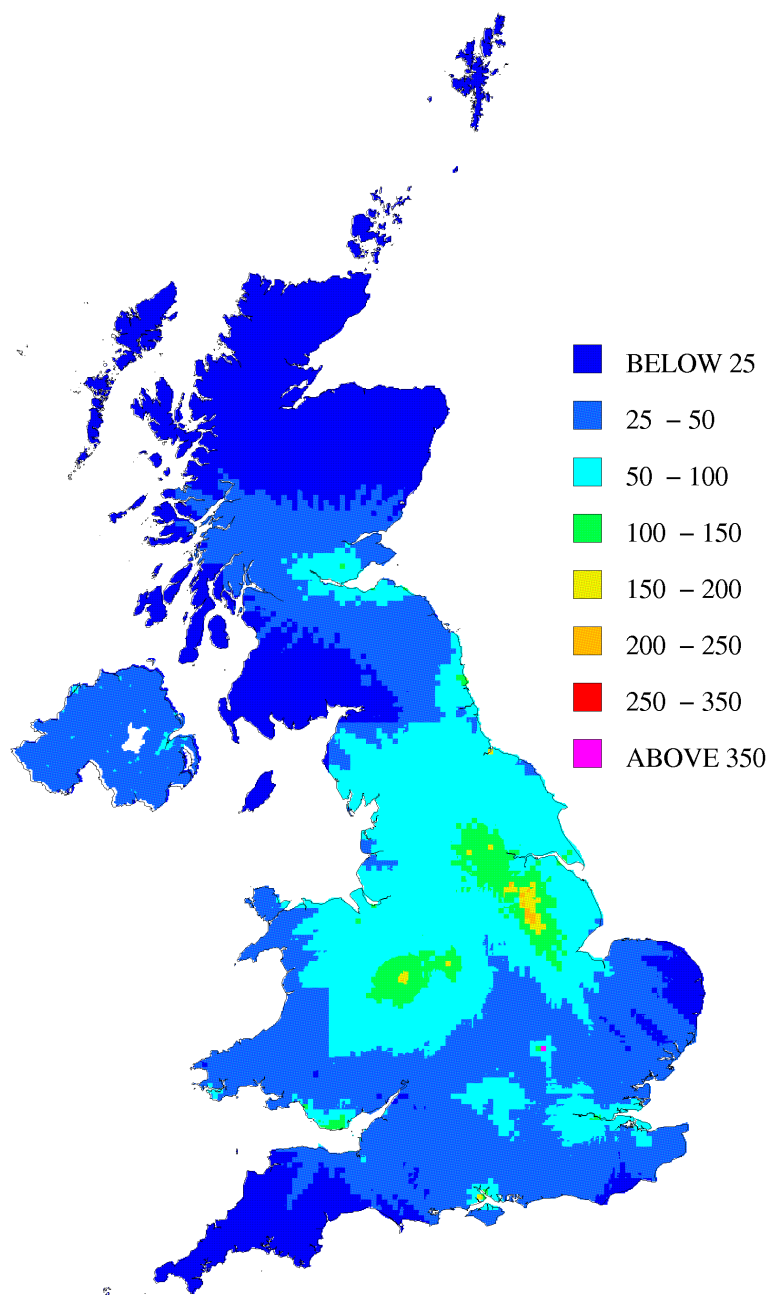
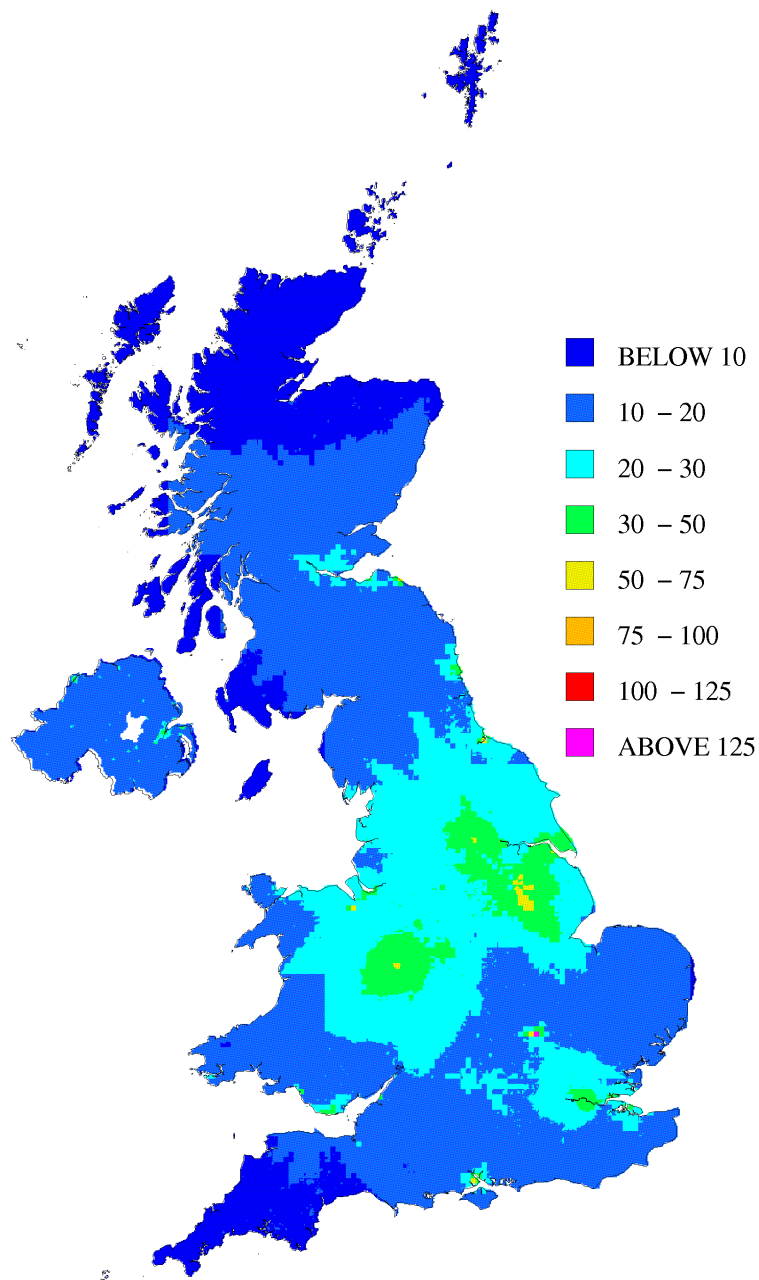


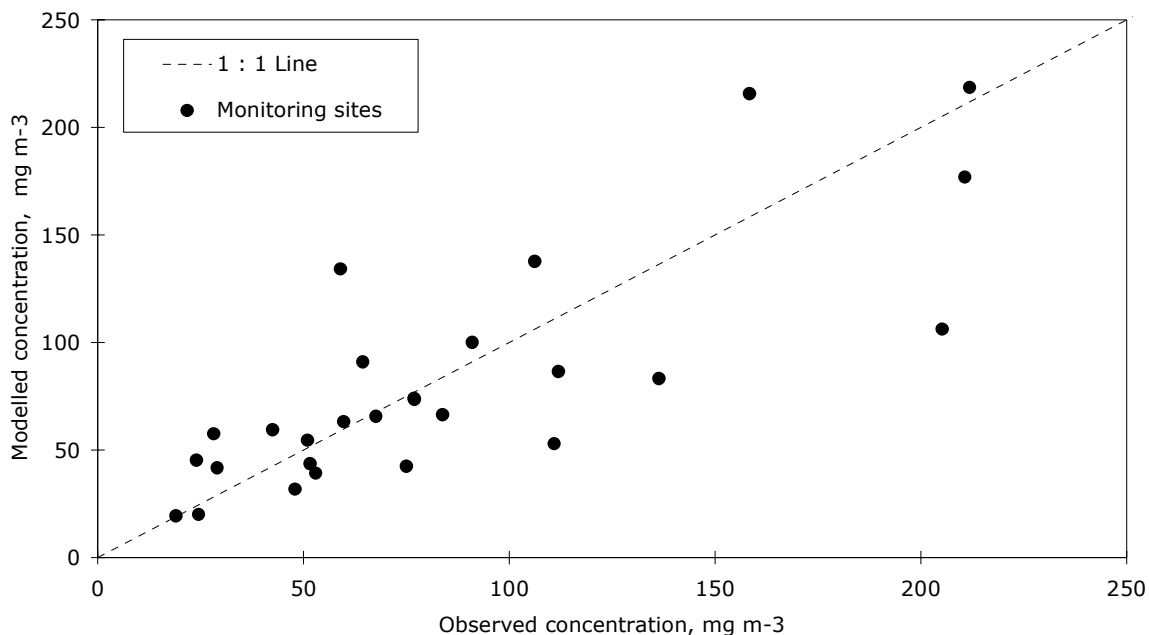
Figure 2.5. 99.18 percentile of 24-hour mean SO<sub>2</sub> concentration, 2003 ( $\mu\text{g m}^{-3}$ )

Measured concentrations from the national automatic monitoring networks and rural automatic monitoring sites maintained by the electricity generating companies were used to calibrate the percentile models. The calibration plots for the 99.73 percentile of hourly mean concentrations and 99.18 percentile of daily means are presented in Figures 2.6 and 2.7, respectively. The values of the coefficients and constants in the following equations were determined to find the best fit to the measured values:

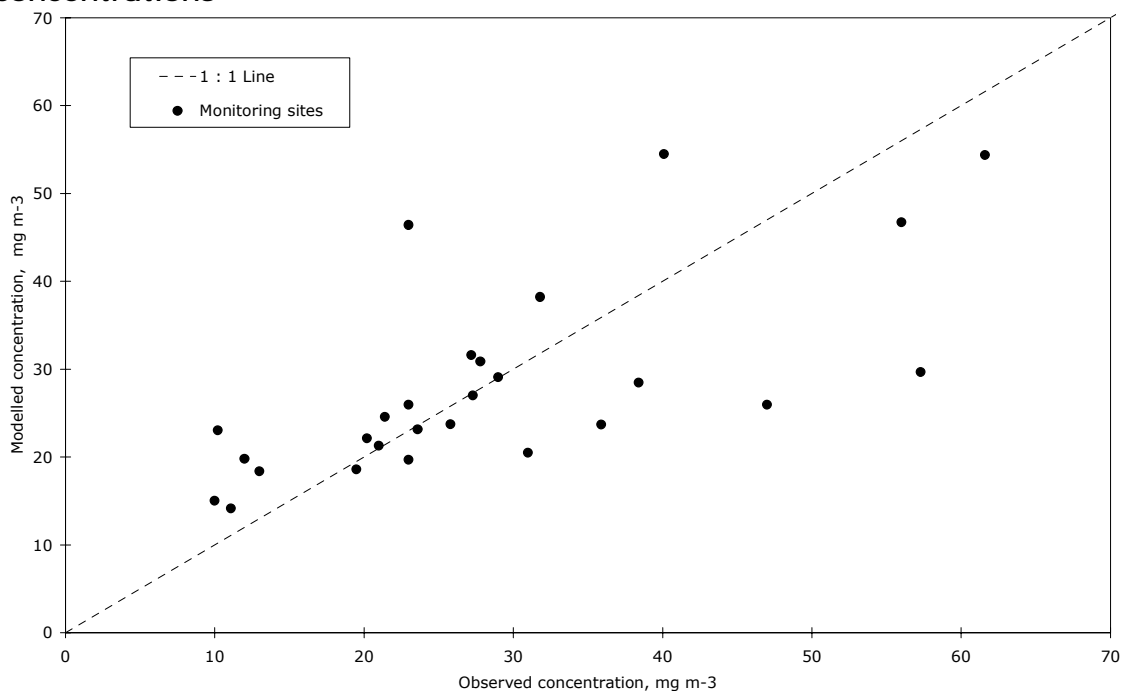
$$\text{Predicted 99.73 \%ile} = 1.0 \times \text{Modelled Point Sources 99.73 \%ile} + \text{Modelled Annual Mean for Area and Small Point Sources} + 5.0$$

$$\text{Predicted 99.18 \%ile} = 1.0 \times \text{Modelled Point Sources 99.18 \%ile} + \text{Modelled Annual Mean for Area and Small Point Sources} + 9.0$$

**Figure 2.6. Calibration plot for 2003 99.73 percentile of 1-hour mean SO<sub>2</sub> concentrations**



**Figure 2.7. Calibration plot for 2003 99.18 percentile of 24-hour mean SO<sub>2</sub> concentrations**



An alternative method was used to predict the high percentile concentrations in Northern Ireland. This was required because area sources, predominately emissions from domestic coal fires, make a more significant contribution to observed high percentile concentrations in Northern Ireland than in the rest of the United Kingdom. Conversely, the smaller number of point sources in Northern Ireland means that these sources make a smaller contribution to the observed high percentile concentrations.

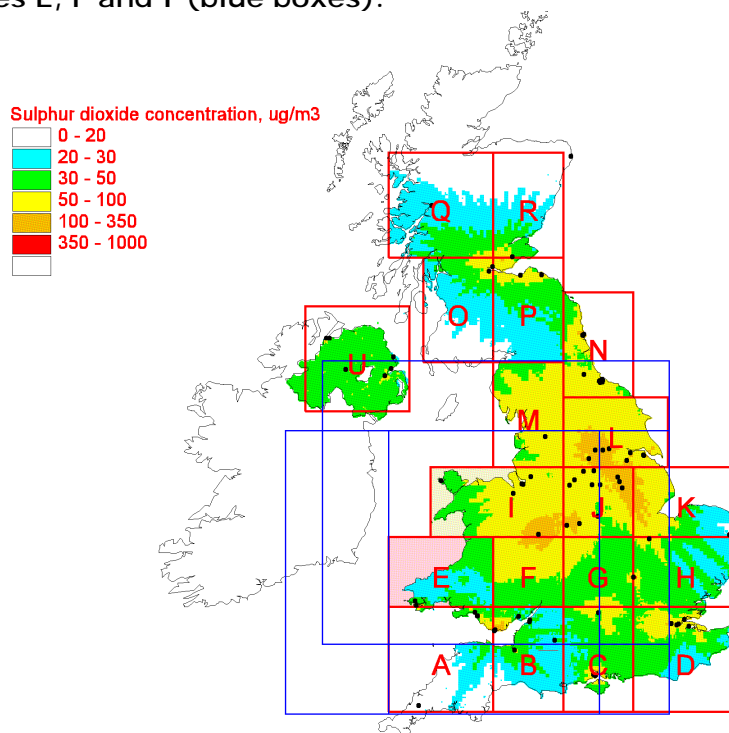
Maps of high percentile concentrations in Northern Ireland have been calculated from the mapped annual mean SO<sub>2</sub> concentrations using relationships between measured annual mean and measured high percentile concentrations in Northern Ireland during 2003 at national network and netcen Calibration Club monitoring sites. These relationships are presented in section 2.4. The relationships in Northern Ireland are considerably more robust than in other parts of the UK because the dominant source for both annual mean and peak concentration is the same.

$$\text{Predicted 99.73 \%ile in Northern Ireland} = 4.8397 \times \text{Modelled Annual Mean} + 34.553$$

$$\text{Predicted 99.18 \%ile in Northern Ireland} = 2.6503 \times \text{Modelled Annual Mean} + 11.025$$

Figures 2.4 and 2.5 also show some degree of spatial discontinuity in the predicted SO<sub>2</sub> concentrations, in particular this is represented by straight line concentration gradients observed in mid Wales, Cumbria and Northumberland. These features of the predicted concentration maps are artefacts of the modelling approach used and the effective distance over which the dispersion model operates. In modelling high percentile SO<sub>2</sub> concentrations on a national scale, the UK has been broken down into 19 separate receptor tiles (model runs), as presented in Figure 2.8. Within each separate tile, emissions from large point sources are included and also those in a 150km area surrounding the edge of the receptor tile.

**Figure 2.8 Receptor tiles composing the UK, location of large point sources (black dots) and the geographical extent of areas contributing emissions to receptor squares E, F and I (blue boxes).**



The discontinuities observed in Figures 2.4 and 2.5 occur when the 150km area surrounding each tile cause the inclusion (or exclusion) of significant point source emissions in the model run for a given receptor tile. The example presented in Figure 2.8 describes the areas (blue boxes) surrounding tiles E, F and I and it is notable that tiles I and F include the major point sources in the Trent and Aire Valley, however for tile E, which is geographically located further south, emissions from these source are not included in the model run this model run resulting in a discrete concentration gradient in the model output.

## 2.4 VERIFICATION OF MAPPED VALUES

Figures 2.9, 2.10 and 2.11 show comparisons of modelled and measured annual mean, 99.73 percentile of 1-hour means and 99.18 percentile of 24-hour means SO<sub>2</sub> concentrations in 2003 at monitoring site locations in the UK. Both the national network sites used to calibrate the models and the verification sites are shown. Lines representing  $y = x - 30\%$  and  $y = x + 30\%$  and  $y = x - 50\%$  and  $y = x + 50\%$  are also shown (the AQDD1 data quality objective for modelled annual mean and percentile SO<sub>2</sub> concentrations respectively).

Figure 2.9. Verification of annual mean SO<sub>2</sub> model 2003

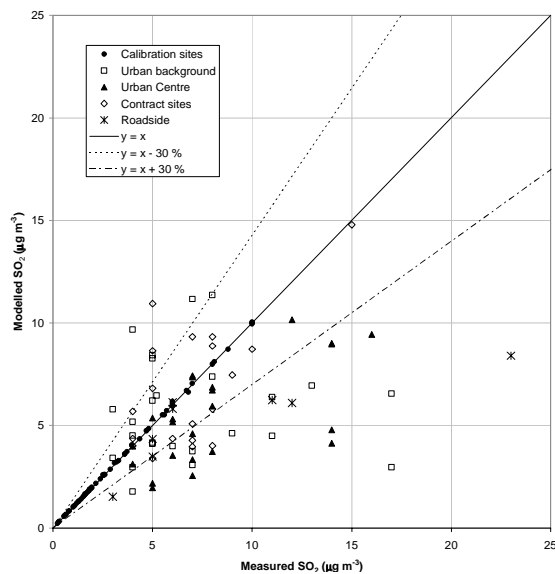
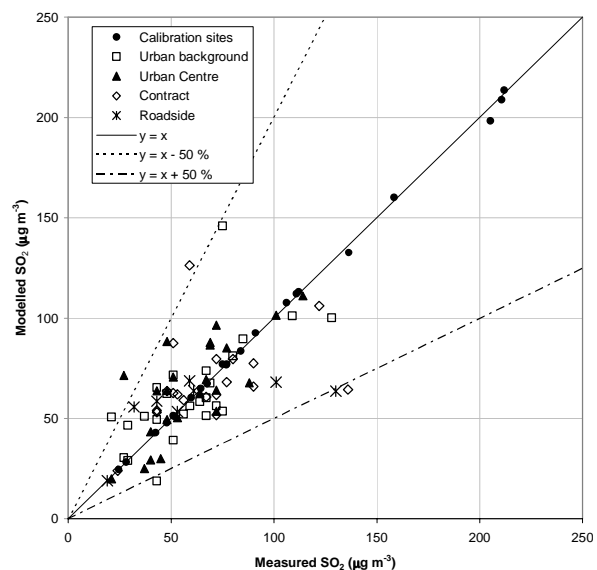
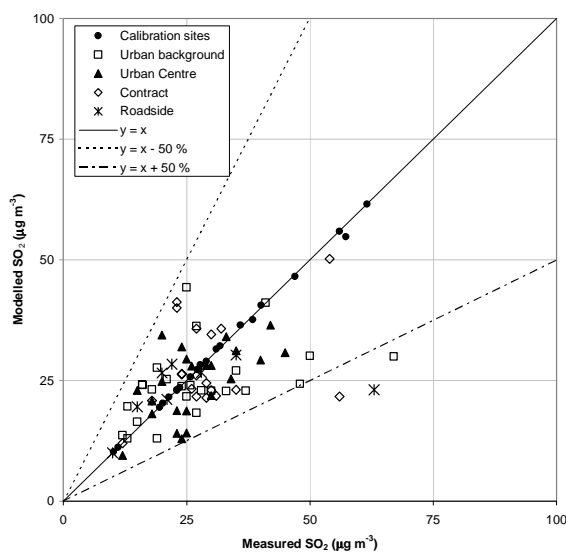


Figure 2.10. Verification of 99.73 percentile of 1-hour mean SO<sub>2</sub> model 2003



**Figure 2.11. Verification of 99.18 percentile of 24-hour mean SO<sub>2</sub> model 2003**



The agreement between modelled and measured annual mean SO<sub>2</sub> is generally poor in comparison with modelled high percentile concentrations. This observation is especially evident at the higher concentrations and is thought to be largely due to the poor characterisation of emission sources in each locality. This is a particular issue in locations where area sources such as domestic heating or Part B industrial emissions make a significant contribution to ambient concentrations. The information available from the NAEI at a 1 km x 1 km level is insufficiently detailed to characterise domestic emissions at the level of fuel use within individual housing estates. The annual mean SO<sub>2</sub> map is, however, only required for comparison with the limit value for the protection of ecosystems in ecosystem areas, which are outside of urban areas. Indeed the great majority of the measured and modelled annual mean SO<sub>2</sub> concentrations, even in urban areas, are below 20 µg m<sup>-3</sup>, the limit value for ecosystem areas.

The agreement between modelled and measured high percentile SO<sub>2</sub> concentrations is much better than for annual means. This shows that the emissions from the major point sources are well characterised within the NAEI and that the modelling methods are able to estimate the impact of these emissions on high percentile concentrations. Summary statistics for the comparison between modelled and measured SO<sub>2</sub> concentrations and the percentage of sites for which the modelled values are outside the data quality objectives (DQOs) are listed in Tables 2.1, 2.2 and 2.3.

**Table 2.1. Summary statistics for comparison between modelled and measured annual mean concentrations of SO<sub>2</sub> at background sites**

	Mean of measurements (µg m <sup>-3</sup> )	Mean of model estimates (µg m <sup>-3</sup> )	r <sup>2</sup>	% of sites outside DQO of ±30%	Number of sites
<b>National Network</b>	5.5	4.4	0.45	32%	108 <sup>a</sup>
<b>Verification Sites</b>	6.7	6.3	0.56	40%	43

a. includes measurement data from sites in Defra's AURN and Rural Acid Rain Monitoring Network



**Table 2.2 Summary statistics for comparison between modelled and measured 99.73 percentile of 1-hour mean concentrations of SO<sub>2</sub> at background sites**

	Mean of measurements (µg mg m <sup>-3</sup> )	Mean of model estimates (µg m <sup>-3</sup> )	r <sup>2</sup>	% of sites outside DQO of ±50%	Number of sites
National Network	27.2	26.8	0.21	17%	69 <sup>b</sup>
Verification Sites	32.1	32.8	0.66	7%	43

b. includes measurement data from sites in Defra's AURN only

**Table 2.3 Summary statistics for comparison between modelled and measured 99.18 percentile of 24-hour mean concentrations of SO<sub>2</sub> at background sites**

	Mean of measurements (µg m <sup>-3</sup> )	Mean of model estimates (µg m <sup>-3</sup> )	r <sup>2</sup>	% of sites outside DQO of ±50%	Number of sites
National Network	62.4	71.0	0.30	25%	69 <sup>b</sup>
Verification Sites	91.9	96.0	0.83	7%	43

b. includes measurement data from sites in Defra's AURN only

## 2.5 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

The modelling results, in terms of a comparison of modelled concentrations with the hourly and daily limit value by zone, are summarised in Table 2.4. These data have also been presented in form 19a of the questionnaire. The SO<sub>2</sub> annual and winter mean limit value for the protection of ecosystems was not exceeded in ecosystem areas in any of the non-agglomeration zones in 2003. This limit value does not apply in agglomeration zones, according to the definition in the Directive (see Section 1.3). Method A in Table 2.4 refers to the modelling method described in this report.

**Table 2.4 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII (II), 2000/69/EC Article 5(3) and Annex VI (II) and 2002/3/EC Article 9(1) and Annex VII (II))**

Zone	Zone code	Above LV for health (1hr mean)				Above LV for health (24hr mean)			
		Area		Population exposed		Area		Population exposed	
		km <sup>2</sup>	Method	Number	Method	km <sup>2</sup>	Method	Number	Method
Greater London Urban Area	UK0001	0	A	0	A	0	A	0	A
West Midlands Urban Area	UK0002	0	A	0	A	0	A	0	A
Greater Manchester Urban Area	UK0003	0	A	0	A	0	A	0	A
West Yorkshire Urban Area	UK0004	0	A	0	A	0	A	0	A
Tyneside	UK0005	0	A	0	A	0	A	0	A
Liverpool Urban Area	UK0006	0	A	0	A	0	A	0	A
Sheffield Urban Area	UK0007	0	A	0	A	0	A	0	A
Nottingham Urban Area	UK0008	0	A	0	A	0	A	0	A
Bristol Urban Area	UK0009	0	A	0	A	0	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	A	0	A	0	A	0	A
Leicester Urban Area	UK0011	0	A	0	A	0	A	0	A
Portsmouth Urban Area	UK0012	0	A	0	A	0	A	0	A
Teesside Urban Area	UK0013	0	A	0	A	0	A	0	A
The Potteries	UK0014	0	A	0	A	0	A	0	A
Bournemouth Urban Area	UK0015	0	A	0	A	0	A	0	A
Reading/Wokingham Urban Area	UK0016	0	A	0	A	0	A	0	A
Coventry/Bedworth	UK0017	0	A	0	A	0	A	0	A
Kingston upon Hull	UK0018	0	A	0	A	0	A	0	A
Southampton Urban Area	UK0019	0	A	0	A	0	A	0	A
Birkenhead Urban Area	UK0020	0	A	0	A	0	A	0	A
Southend Urban Area	UK0021	0	A	0	A	0	A	0	A
Blackpool Urban Area	UK0022	0	A	0	A	0	A	0	A
Preston Urban Area	UK0023	0	A	0	A	0	A	0	A
Glasgow Urban Area	UK0024	0	A	0	A	0	A	0	A
Edinburgh Urban Area	UK0025	0	A	0	A	0	A	0	A
Cardiff Urban Area	UK0026	0	A	0	A	0	A	0	A
Swansea Urban Area	UK0027	0	A	0	A	0	A	0	A
Belfast Urban Area	UK0028	0	A	0	A	0	A	0	A
Eastern	UK0029	25	A	3864	A	25	A	3864	A
South West	UK0030	0	A	0	A	0	A	0	A
South East	UK0031	0	A	0	A	0	A	0	A
East Midlands	UK0032	0	A	0	A	0	A	0	A
North West & Merseyside	UK0033	0	A	0	A	0	A	0	A
Yorkshire & Humberside	UK0034	0	A	0	A	0	A	0	A
West Midlands	UK0035	0	A	0	A	0	A	0	A
North East	UK0036	0	A	0	A	0	A	0	A
Central Scotland	UK0037	0	A	0	A	0	A	0	A
North East Scotland	UK0038	0	A	0	A	0	A	0	A
Highland	UK0039	0	A	0	A	0	A	0	A
Scottish Borders	UK0040	0	A	0	A	0	A	0	A
South Wales	UK0041	0	A	0	A	0	A	0	A
North Wales	UK0042	0	A	0	A	0	A	0	A
Northern Ireland	UK0043	0	A	0	A	0	A	0	A

## 3 NO<sub>2</sub>/NO<sub>x</sub>

### 3.1 INTRODUCTION

Maps of annual mean NO<sub>2</sub> concentrations at background and roadside locations in 2003 are presented in Figures 3.1 and 3.2. A detailed description of the modelling methods used is available from earlier publications (Stedman et al, 1997, Stedman et al, 2001c, Stedman and Bush, 2000, Stedman et al, 2001b, Stedman et al, 2002, Stedman et al, 2003). A summary is provided here with a particular emphasis given to revisions to the methods for the 2003 maps.

Figure 3.1. Annual mean background NO<sub>2</sub> concentration, 2003 ( $\mu\text{g m}^{-3}$ )

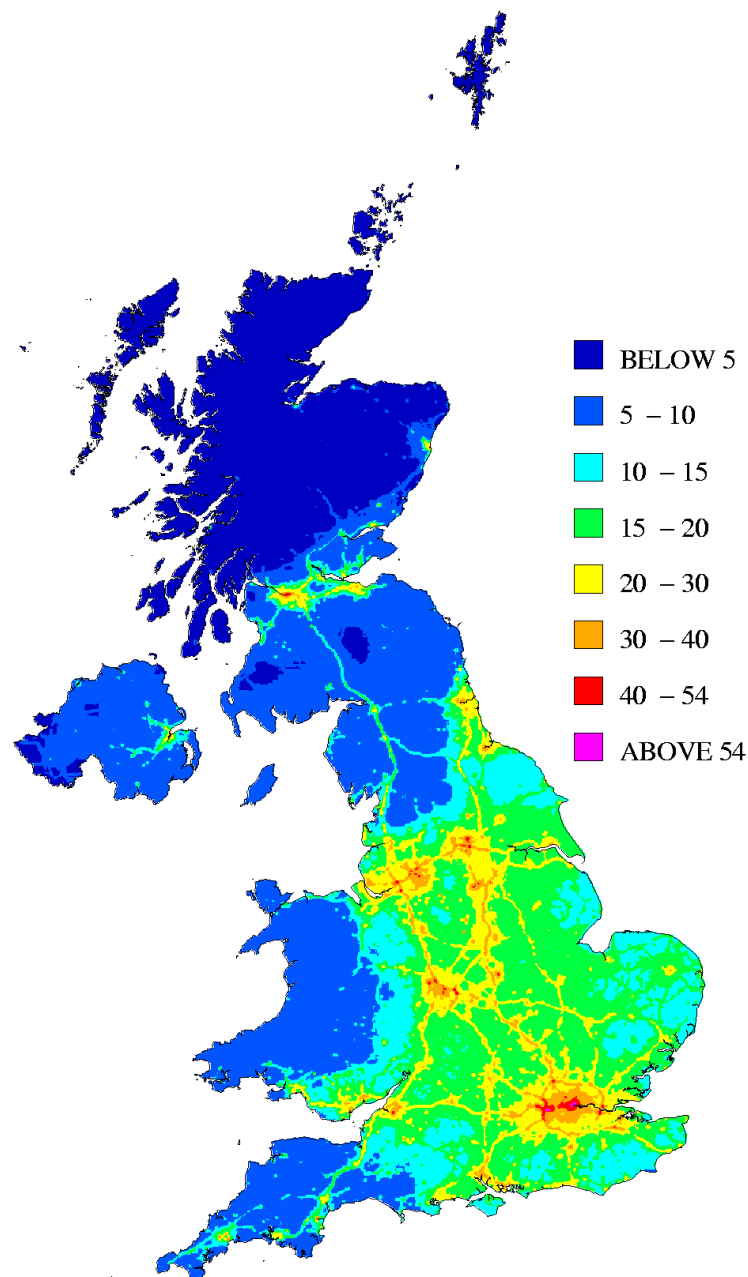
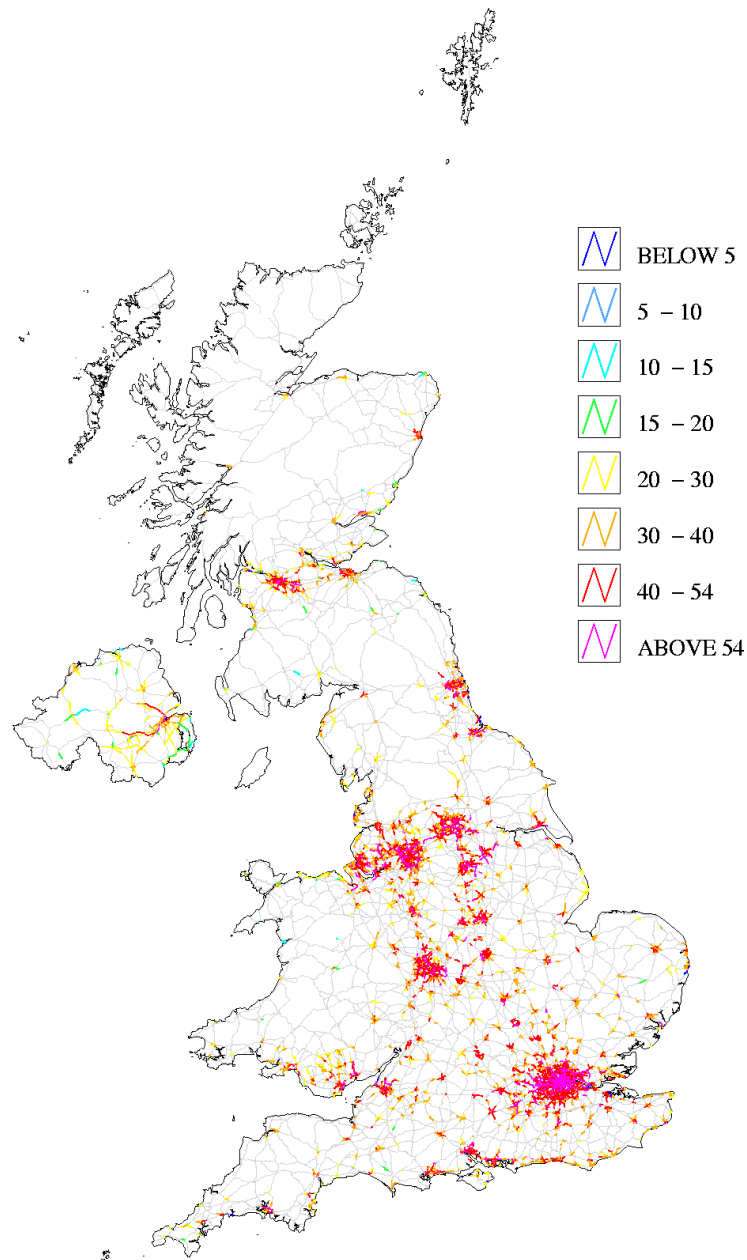


Figure 3.2. Urban major roads, annual mean roadside NO<sub>2</sub> concentration, 2003 (µg m<sup>-3</sup>)



The modelling presented in this report for NO<sub>x</sub> and NO<sub>2</sub> has been restricted to estimation of annual mean concentrations for comparison with the annual mean limit value. No attempt has been made to model hourly concentrations for comparison with the 1-hour limit value. The annual mean limit value is expected to be more stringent than the 1-hour limit value in the majority of situations (AQEG, 2004).

It has been considered that annual mean background NO<sub>x</sub> concentrations are made up of contributions from

- Distant sources (characterised by the rural background concentration)
- Large point sources

- Small point sources
- Local area sources

Hence,  $\text{NO}_x$  concentrations at locations away from busy roads may be estimated as:

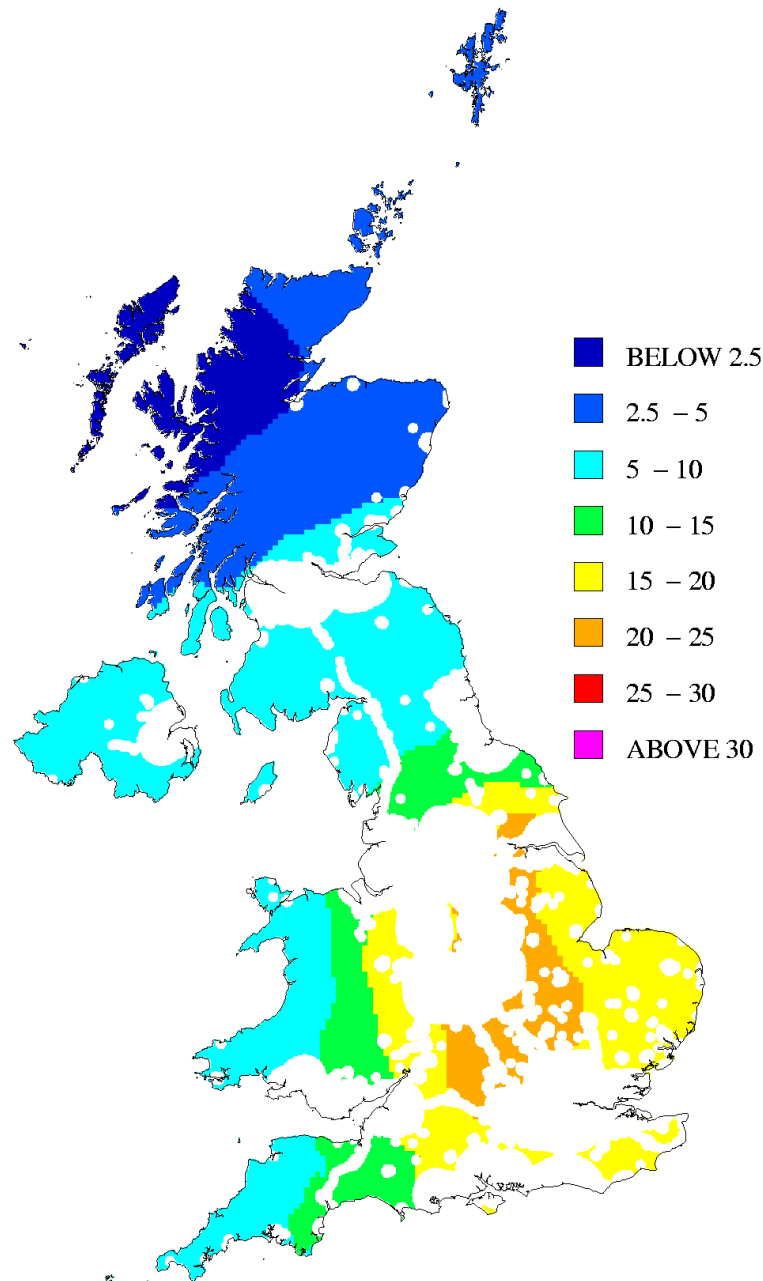
*Estimated background  $\text{NO}_x$  concentration ( $\mu\text{g m}^{-3}$ , as  $\text{NO}_2$ ) = corrected rural  $\text{NO}_x$  concentration ( $\mu\text{g m}^{-3}$ , as  $\text{NO}_2$ ) + contributions from large point sources ( $\mu\text{g m}^{-3}$ , as  $\text{NO}_2$ ) + contributions from small point sources ( $\mu\text{g m}^{-3}$ , as  $\text{NO}_2$ ) + contributions from area sources ( $\mu\text{g m}^{-3}$ , as  $\text{NO}_2$ )*

The area source model has been calibrated using data from the national automatic monitoring networks for 2003.

At locations close to busy roads an additional roadside contribution was added to account for contributions to total  $\text{NO}_x$  from road traffic sources.

In order to estimate the  $\text{NO}_2$  concentrations, modelled  $\text{NO}_x$  concentrations derived from the approach outlined above are converted to  $\text{NO}_2$ . In the past empirically derived coefficients have been used to represent proportion of total  $\text{NO}_x$  existing as  $\text{NO}_2$ . However, for the 2003  $\text{NO}_2$  maps presented in this report, an oxidant partitioning model has been used to describe the complex inter-relationships of  $\text{NO}$ ,  $\text{NO}_2$  and ozone as a set of chemically coupled species (Jenkins, 2004). This updated approach provides additional insights into the factors controlling ambient levels of  $\text{NO}_2$  (and ozone), and how they may vary with  $\text{NO}_x$  concentration.

A map of annual mean  $\text{NO}_x$  concentrations in vegetation areas is presented in Figure 3.3. This map has been calculated by interpolation of rural  $\text{NO}_2$  measurements followed by multiplication by the empirically derived factor (described in Section 3.2) to estimate rural  $\text{NO}_x$  from the interpolated  $\text{NO}_2$  concentration.

Figure 3.3. Annual mean Rural NO<sub>x</sub> concentration, 2003 ( $\mu\text{g m}^{-3}$ , as NO<sub>2</sub>)

## 3.2 EMPIRICAL RELATIONSHIPS BETWEEN NO<sub>2</sub> AND NO<sub>x</sub> CONCENTRATIONS

Maps of estimated annual mean NO<sub>2</sub> concentrations (Figure 3.1 and 3.2) have been calculated from modelled NO<sub>x</sub> concentration using relationships presented in the oxidant-partitioning model (Jenkins, 2004). Using this method for predicting NO<sub>2</sub> offers an improved way of treating the NO<sub>x</sub> to NO<sub>2</sub> relationship via representative expressions which account for the chemical coupling of O<sub>3</sub>, NO and NO<sub>2</sub> within the atmosphere. In particular, the new approach has the advantage of enabling the models to address emission scenarios with varying regional oxidant levels or primary NO<sub>2</sub> emissions.

The oxidant-partitioning model has been used to calculate NO<sub>2</sub> from modelled NO<sub>x</sub> concentrations at background and roadside locations in 2003. The expressions presented below have been used to describe the variation of annual mean [NO<sub>2</sub>] with [NO<sub>x</sub>] (in ppb, where 1 ppb NO<sub>2</sub> = 1.91 µg m<sup>-3</sup>). Equation (i) being substituted for f(NO<sub>x</sub>) at locations directly influenced by roads and equation (ii) for f(NO<sub>x</sub>) at all other locations.

$$\text{Central London: } [\text{NO}_2] = (0.140[\text{NO}_x] + 34.7) \cdot f(\text{NO}_x)$$

$$\text{Inner London: } [\text{NO}_2] = (0.128[\text{NO}_x] + 34.7) \cdot f(\text{NO}_x)$$

$$\text{Elsewhere: } [\text{NO}_2] = (0.093[\text{NO}_x] + B) \cdot f(\text{NO}_x)$$

$$[\text{NO}_2]/[\text{OX}] = (8.962 \times 10^{-2}) + (1.474 \times 10^{-2} [\text{NO}_x]) - (1.290 \times 10^{-4} [\text{NO}_x]^2) + (5.527 \times 10^{-7} [\text{NO}_x]^3) - (8.906 \times 10^{-10} [\text{NO}_x]^4) \tag{i}$$

$$[\text{NO}_2]/[\text{OX}] = (1.015 \times 10^{-1}) + (1.367 \times 10^{-2} [\text{NO}_x]) - (6.127 \times 10^{-5} [\text{NO}_x]^2) - (4.464 \times 10^{-8} [\text{NO}_x]^3) \tag{ii}$$

The appropriate values of B (Oxidant [OX]) are given in Table 3.1 and have been applied to equations applicable to locations outside London where levels of oxidant vary regionally. Testing of this oxidant partitioning model for roadside monitoring sites outside London indicated that it tended to over-predict roadside NO<sub>2</sub> concentrations at roadside NO<sub>x</sub> concentrations lower than about 150 µg m<sup>-3</sup>, as NO<sub>2</sub>. A variable local oxidant proportion was therefore applied, with a value of 0.03 at a NO<sub>x</sub> concentration of zero, rising linearly to 0.093 at 150 µg m<sup>-3</sup>, as NO<sub>2</sub>.

**Table 3.1 Summary of regional oxidant (OX) concentrations determined from an analysis of O<sub>3</sub> and NO<sub>x</sub> in 13 UK areas (source Jenkins 2004)**

Region	Locations	Regional oxidant (ppb)
1	Central Scotland / Highlands, Northern Ireland, North East	34.4
2	North West, Yorkshire and Humberside	33.8
3	West Midlands, East Midlands, Eastern	32.4
4	South Wales, South West, South East, London	34.7

The oxidant-partitioning model does not apply at NO<sub>x</sub> concentrations lower than 17 µg m<sup>-3</sup>, as NO<sub>2</sub>. At NO<sub>x</sub> concentrations of less than 17 µg m<sup>-3</sup> as NO<sub>2</sub>, NO<sub>2</sub> concentrations have been estimated using the relationship previously suggested by Stedman et al (2003) for rural locations:

$$[\text{NO}_2] = [\text{NO}_x] \times 0.7835$$

### 3.3 CONTRIBUTIONS FROM LARGE POINT SOURCES

Contributions to ground level annual mean NO<sub>x</sub> concentrations from large point sources (those with annual emission greater than 500 tonnes) in the 2002 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model. Prior to the modelling exercise a survey of Part A authorisation notices held by the Environment Agency was conducted for all point sources with annual emissions greater than 500

tonnes as identified in the 2002 NAEI. Parameters characterising the release to atmosphere were collected. Parameters collected were:

- Stack height
- Stack diameter
- Discharge velocity
- Discharge temperature.

Where release parameters were unavailable, engineering assumptions were applied. Previously collated datasets on emission release parameters from large SO<sub>2</sub> point sources were also used to characterise the release of emission (Abbott and Vincent, 1999).

The contribution to annual mean NO<sub>x</sub> concentrations from NO<sub>x</sub> point sources with greater than 500 tonnes per annum emission, was modelled using ADMS 3.1 and sequential meteorological data for 2003 from Waddington. A total of 170 point sources were modelled. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100 km x 100 km square composed of a regularly spaced 5 km x 5 km resolution receptor grid. Each receptor grid was centred on the point source.

### 3.4 CONTRIBUTIONS FROM SMALL POINT SOURCES

Contributions from NO<sub>x</sub> point sources with less than 500 tonnes per annum emissions were modelled using the small points model described in Appendix 3.

### 3.5 CONTRIBUTIONS FROM RURAL BACKGROUND CONCENTRATIONS

Diffusion tube measurement data from the Acid Deposition Monitoring Network (Lawrence, *pers comm* 2004) were used to estimate rural annual mean background NO<sub>2</sub> concentrations. Rural NO<sub>x</sub> was estimated from rural NO<sub>2</sub> by dividing by 0.7835 (section 3.2). In a number of instances, measurements from this network are influenced by contributions from nearby point and area sources. Hence, for this modelling exercise, in which contributions to ground level concentrations are modelled explicitly by dispersion modelling techniques, it is necessary to remove contributions from point and area sources from the rural background measurement data to avoid double counting of these contributions. The correction procedure is as follows:

$$\text{Corrected rural background } (\mu\text{g m}^{-3}) = \text{Uncorrected rural background } (\mu\text{g m}^{-3}) - (A + B + C)$$

Where: A = an estimate of the contribution from area source components, derived using the area source model described below but with the empirical coefficients derived from a comparison of 2002 monitoring data and emissions.

B = sum of contributions from large point sources

C = sum of contributions from small point sources

Corrected rural measurement data were interpolated to obtain estimates of the regional background concentration throughout the UK.

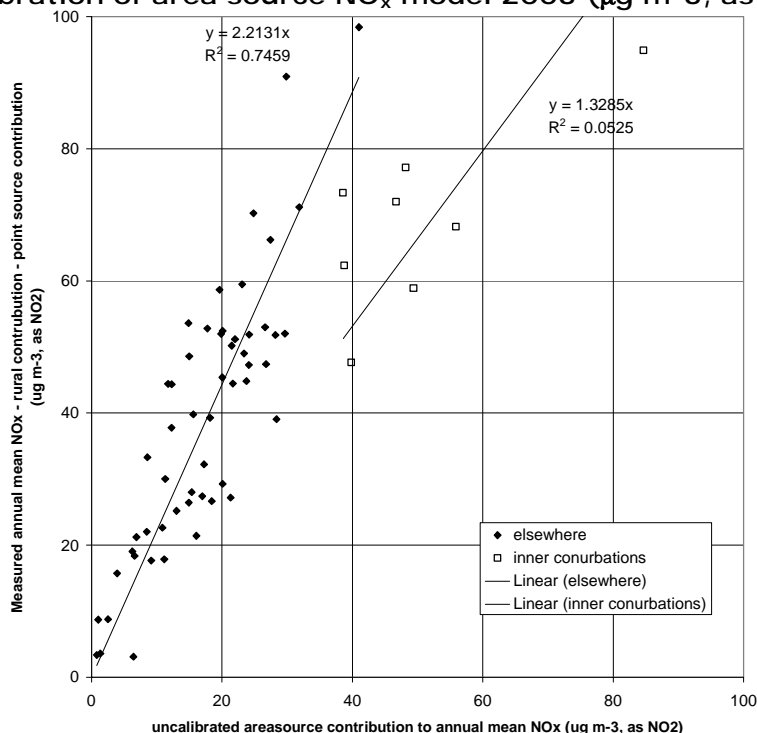
### 3.6 CONTRIBUTIONS FROM AREA SOURCES

Figure 3.4 shows the calibration of the area source model. The modelled concentrations from all point sources and corrected rural NO<sub>x</sub> concentrations have been subtracted from



the measured annual mean NO<sub>x</sub> concentration at background sites. This corrected background concentration is compared with the modelled area source contribution to annual mean NO<sub>x</sub>. An empirical method has been used to calculate the contribution to ambient concentrations from area sources. This approach applies an ADMS derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33 km x 33 km square surrounding each monitoring site. Hourly sequential meteorological data from Heathrow in 2003 has been used to construct the dispersion kernels, as described in Appendix 4.

Figure 3.4. Calibration of area source NO<sub>x</sub> model 2003 (µg m<sup>-3</sup>, as NO<sub>2</sub>)



Examination of Figure 3.4 shows that the monitoring sites fall into two groups:

- Inner conurbations
- Elsewhere.

'Inner conurbations' includes Inner and Central London and central Birmingham and Manchester as defined by DfT (2003).

Adjustment factors were applied to the emissions from selected sources. NO<sub>x</sub> emissions from aircraft were multiplied by 0.36, the proportion of total NO<sub>x</sub> emission from aircraft activity that takes place while the aircraft wheels are on the ground. The contribution to ground level concentrations from emissions while the aircraft is airborne will be much smaller and has not been modelled. (By convention, emission inventories include emissions from aircraft both on the ground and on take off and landing up to 1000 m.) An empirical factor of 0.25 was applied to NO<sub>x</sub> emissions from ships.

The modelled area source contribution was multiplied by the relevant empirical coefficient to calculate the calibrated area source contribution for each grid square in the country. The corrected rural and point source contributions were then added, resulting in a map of background NO<sub>x</sub> concentrations. The map of background NO<sub>2</sub> concentrations was then calculated from this NO<sub>x</sub> map using the NO<sub>x</sub> to NO<sub>2</sub> relationships presented in Section 3.2.

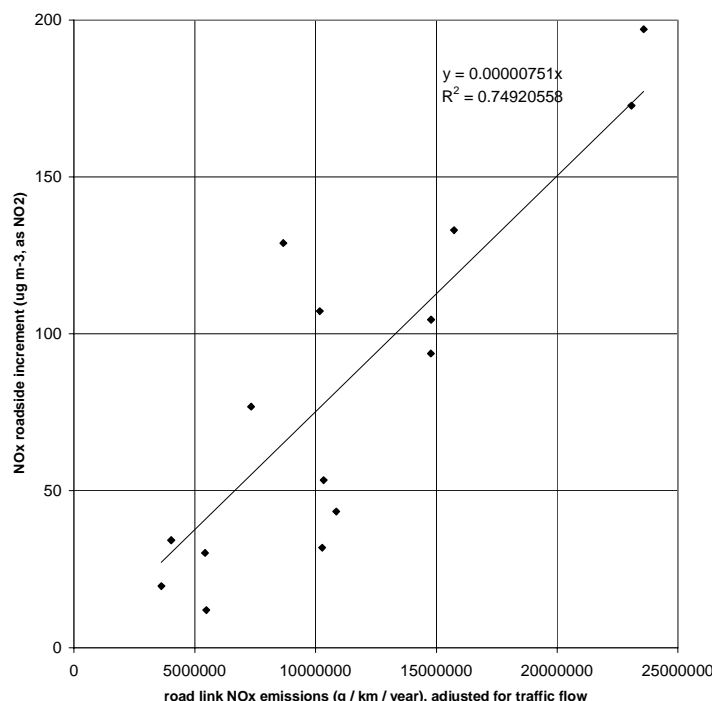
### 3.7 ROADSIDE CONCENTRATIONS

We have considered that the annual mean concentration of NO<sub>x</sub> at a roadside location is made up of two parts: the background concentration (as described above) and a roadside increment:

$$\text{roadside NO}_x \text{ concentration} = \text{background NO}_x \text{ concentration} + \text{NO}_x \text{ roadside increment}$$

The NAEI provides estimates of NO<sub>x</sub> emissions for major road links in the UK for 2002 (Dore *et al*, 2004) and these have been adjusted to provide estimates of emissions in 2003. Figure 3.5 shows a comparison of the roadside increment of annual mean NO<sub>x</sub> concentrations at roadside or kerbside national automatic monitoring sites with NO<sub>x</sub> emission estimates for the individual road links alongside which these sites are located. The background NO<sub>x</sub> component at these roadside monitoring sites was derived from the map described in Section 3.6 above. The roadside increment is calculated by multiplying an adjusted road link emission (see below) by the empirical dispersion coefficient determined from this graph. Roadside concentrations for urban roads only are reported to the EU and included in this report.

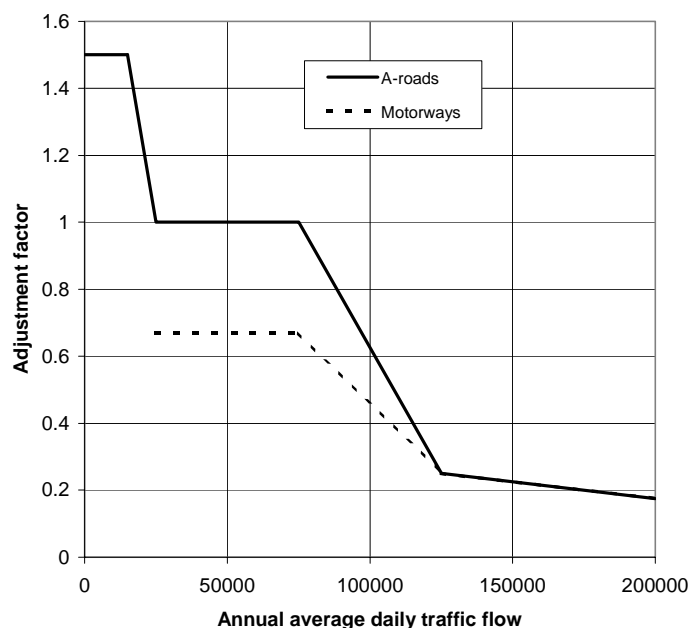
Figure 3.5. Calibration of NO<sub>x</sub> roadside increment model



The dispersion of emissions from vehicles travelling along a road is influenced by a number of different factors, which include the width of the road and other factors, which contribute to make the dispersal of emissions less efficient on roads with lower flows. This is probably because roads with lower flows are more likely to have slower moving traffic which subsequently offers less initial dispersion due to mechanical and thermal turbulence, and also because roads with lower flows are more likely to be in built up urban areas with buildings close to the road, giving a more confined setting and reduced dispersion. Detailed information on the dispersion characteristics of each urban major road link within the NAEI is not available. Dispersion will, however, tend to be more

efficient on wider roads, such as motorways than on smaller roads in town centres. We have therefore adopted an approach similar to that used within the DMRB Screening Model (Highways Agency, 2003) and applied adjustment factors to the estimated emissions. These adjustment factors are illustrated in Figure 3.6 and depend on the total traffic flow on each link and are higher for the roads with the lowest flow and lower for roads with the highest flow. Thus the traffic flow is used as a surrogate for road width and other factors influencing dispersion. Motorways are generally wider than A-roads and the emission have therefore been adjusted accordingly, as illustrated in Figure 3.6

Figure 3.6 The adjustment factors applied to road link emissions



The roadside NO<sub>2</sub> concentration was then calculated from the modelled roadside NO<sub>x</sub> concentration using the oxidant partitioning model described in Section 3.2.

### 3.8 VERIFICATION OF MAPPED VALUES

Figures 3.7 and 3.8 show comparisons of modelled and measured annual mean NO<sub>x</sub> and NO<sub>2</sub> concentration in 2003 at background monitoring site locations. Figure 3.9 and 3.10 show similar comparisons for roadside sites. Both the national network sites used to calibrate the models and the verification sites are shown. Lines representing  $y = x - 30\%$  and  $y = x + 30\%$  are also shown (this is the AQDD1 data quality objective for modelled annual mean NO<sub>2</sub> and NO<sub>x</sub> concentrations). There is no requirement under AQDD1 to report modelled annual mean NO<sub>x</sub> concentrations for comparison with limit values for the protection of human health (the NO<sub>x</sub> limit value for the protection of vegetation only applies in vegetation areas). However, comparisons of modelled and measured NO<sub>x</sub> concentrations and of the modelled NO<sub>x</sub> concentrations with the data quality objectives are presented here alongside the comparisons for NO<sub>2</sub>. This provides an additional check on the reliability of our modelled estimates of NO<sub>2</sub> because the non-linear relationships between NO<sub>x</sub> and NO<sub>2</sub> tend to cause modelled NO<sub>2</sub> concentrations to be relatively insensitive to errors in the dispersion modelling of NO<sub>x</sub>.

Figure 3.7. Verification of background annual mean NO<sub>x</sub> model 2003

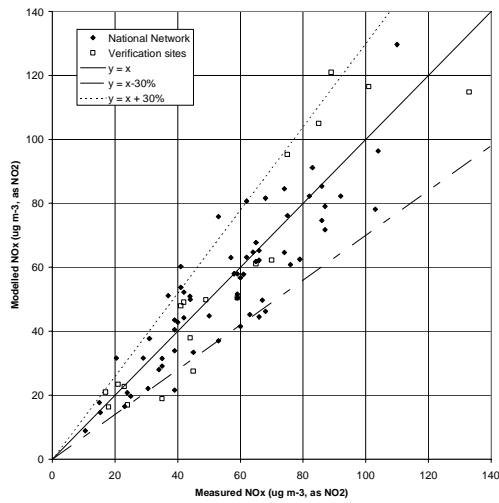


Figure 3.8. Verification of background annual mean NO<sub>2</sub> model 2003

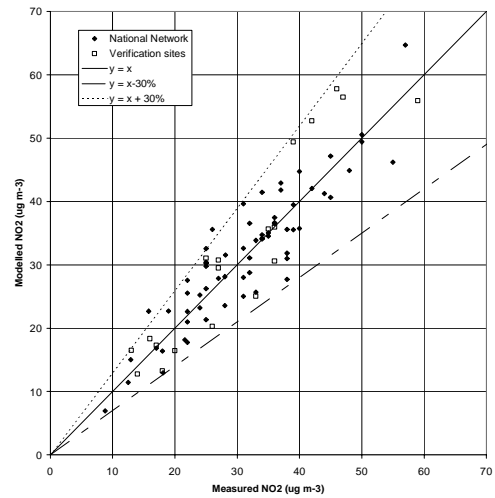


Figure 3.9. Verification of roadside annual mean NO<sub>x</sub> model 2003

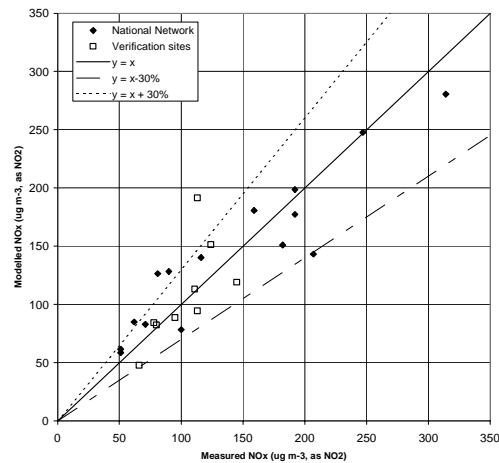
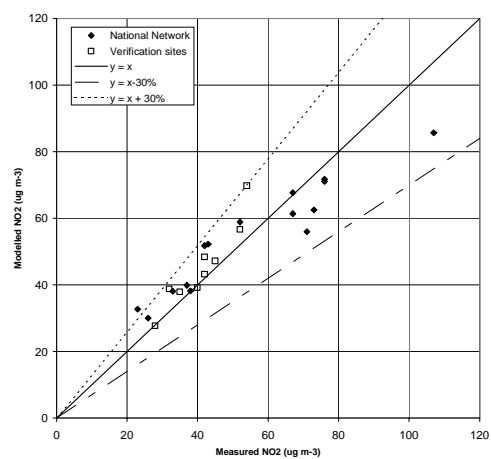


Figure 3.10. Verification of roadside annual mean NO<sub>2</sub> model 2003



Summary statistics for the comparison between modelled and measured NO<sub>x</sub> and NO<sub>2</sub> concentrations are listed in Tables 3.2 and 3.3. The percentages of monitoring sites for which the modelled annual mean concentrations fall outside the data quality objectives is generally greater for NO<sub>x</sub> than for NO<sub>2</sub>, for the reasons discussed above.

Table 3.2. Summary statistics for comparison between modelled and measured NO<sub>x</sub> and NO<sub>2</sub> concentrations at background sites ( $\mu\text{g m}^{-3}$ , as NO<sub>2</sub>)

		Mean of measurements ( $\mu\text{g m}^{-3}$ , as NO <sub>2</sub> )	Mean of model estimates ( $\mu\text{g m}^{-3}$ , as NO <sub>2</sub> )	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	NO <sub>x</sub>	55.8	53.7	0.79	17%	64
Verification Sites	NO <sub>x</sub>	54.5	55.7	0.87	16%	19
National Network	NO <sub>2</sub>	31.4	31.6	0.83	5%	64
Verification Sites	NO <sub>2</sub>	30.3	31.9	0.87	0%	19

Table 3.3. Summary statistics for comparison between modelled and measured NO<sub>x</sub> and NO<sub>2</sub> concentrations at roadside sites ( $\mu\text{g m}^{-3}$ , as NO<sub>2</sub>)

		Mean of measurements ( $\mu\text{g m}^{-3}$ , as NO <sub>2</sub> )	Mean of model estimates ( $\mu\text{g m}^{-3}$ , as NO <sub>2</sub> )	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	NO <sub>x</sub>	141.0	142.6	0.87	27%	15
Verification Sites	NO <sub>x</sub>	102.8	108.0	0.44	11%	9
National Network	NO <sub>2</sub>	55.4	54.5	0.91	7%	15
Verification Sites	NO <sub>2</sub>	41.1	45.4	0.88	0%	9

### 3.9 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

The modelling results, in terms of a comparison of modelled concentrations with the annual mean limit value by zone, are summarised in Table 3.4. These data have also been presented in form 19b of the questionnaire. We have added the number of road links exceeding the limit value for comparison with other UK studies. The NO<sub>x</sub> annual mean limit value for the protection of vegetation was not exceeded in vegetation areas in any of the non-agglomeration zones in 2003. This limit value does not apply in agglomeration zones, according to the definition in the Directive (see Section 1.3). Method A in this table refers to the modelling method described in this report.

Estimates of area and population exposed have been derived from the background maps only. No attempt has been made to derive estimates using maps of roadside concentrations as these maps will only apply to within approximately 10 metres from the road kerb.

Table 3.4 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII (II))								
- Form 19b Results of and methods used for supplementary assessment for NO <sub>2</sub> /NO <sub>x</sub>								
Zone	Zone code	Above LV for health (annual mean)						
		Area		Road length			Population exposed	
		km <sup>2</sup>	Method	links	km	Method	Number	Method
Greater London Urban Area	UK0001	232	A	1914	1775.4	A	1772254	A
West Midlands Urban Area	UK0002	35	A	337	465.7	A	109437	A
Greater Manchester Urban Area	UK0003	14	A	457	501.3	A	51615	A
West Yorkshire Urban Area	UK0004	22	A	232	305.7	A	63625	A
Tyneside	UK0005	0	A	110	120.2	A	0	A
Liverpool Urban Area	UK0006	0	A	202	155.8	A	0	A
Sheffield Urban Area	UK0007	9	A	104	141.0	A	15508	A
Nottingham Urban Area	UK0008	0	A	96	87.2	A	0	A
Bristol Urban Area	UK0009	6	A	90	88.3	A	29288	A
Brighton/Worthing/Littlehampton	UK0010	0	A	26	39.4	A	0	A
Leicester Urban Area	UK0011	5	A	59	71.4	A	15726	A
Portsmouth Urban Area	UK0012	0	A	35	45.1	A	0	A
Teesside Urban Area	UK0013	0	A	36	39.2	A	0	A
The Potteries	UK0014	0	A	59	50.9	A	0	A
Bournemouth Urban Area	UK0015	0	A	20	25.5	A	0	A
Reading/Wokingham Urban Area	UK0016	0	A	53	54.9	A	0	A
Coventry/Bedworth	UK0017	0	A	27	28.5	A	0	A
Kingston upon Hull	UK0018	0	A	31	38.8	A	0	A
Southampton Urban Area	UK0019	0	A	49	61.2	A	0	A
Birkenhead Urban Area	UK0020	0	A	28	25.2	A	0	A
Southend Urban Area	UK0021	0	A	12	16.5	A	0	A
Blackpool Urban Area	UK0022	0	A	2	3.6	A	0	A
Preston Urban Area	UK0023	0	A	30	38.3	A	0	A
Glasgow Urban Area	UK0024	15	A	141	205.6	A	63758	A
Edinburgh Urban Area	UK0025	0	A	30	56.3	A	0	A
Cardiff Urban Area	UK0026	0	A	27	37.6	A	0	A
Swansea Urban Area	UK0027	0	A	7	11.3	A	0	A
Belfast Urban Area	UK0028	0	A	10	53.8	A	0	A
Eastern	UK0029	15	A	225	313.7	A	6635	A
South West	UK0030	3	A	158	223.5	A	3779	A
South East	UK0031	95	A	415	636.4	A	102912	A
East Midlands	UK0032	1	A	182	249.7	A	123	A
North West & Merseyside	UK0033	29	A	269	430.5	A	32276	A
Yorkshire & Humberside	UK0034	20	A	204	404.6	A	23955	A
West Midlands	UK0035	15	A	108	163.2	A	12954	A
North East	UK0036	0	A	93	123.9	A	0	A
Central Scotland	UK0037	0	A	36	59.1	A	0	A
North East Scotland	UK0038	0	A	36	49.3	A	0	A
Highland	UK0039	0	A	1	0.9	A	0	A
Scottish Borders	UK0040	0	A	0	0.0	A	0	A
South Wales	UK0041	0	A	52	97.5	A	0	A
North Wales	UK0042	0	A	12	21.3	A	0	A
Northern Ireland	UK0043	0	A	9	76.8	A	0	A
Total		516		6024	7394		2303843	

# 4 PM<sub>10</sub>

## 4.1 INTRODUCTION

Maps of annual mean PM<sub>10</sub> in 2003 at background and roadside locations are shown in Figures 4.1 and 4.2. Detailed descriptions of the modelling methods used are available (Stedman and Bush, 2000, Stedman, et al 2001b, Stedman, et al 2002 and Stedman et al 2003). A summary is provided here with a particular emphasis given to revisions to the methods for the 2003 maps.

Figure 4.1. Annual mean background PM<sub>10</sub> concentration, 2003 ( $\mu\text{g m}^{-3}$ , gravimetric)

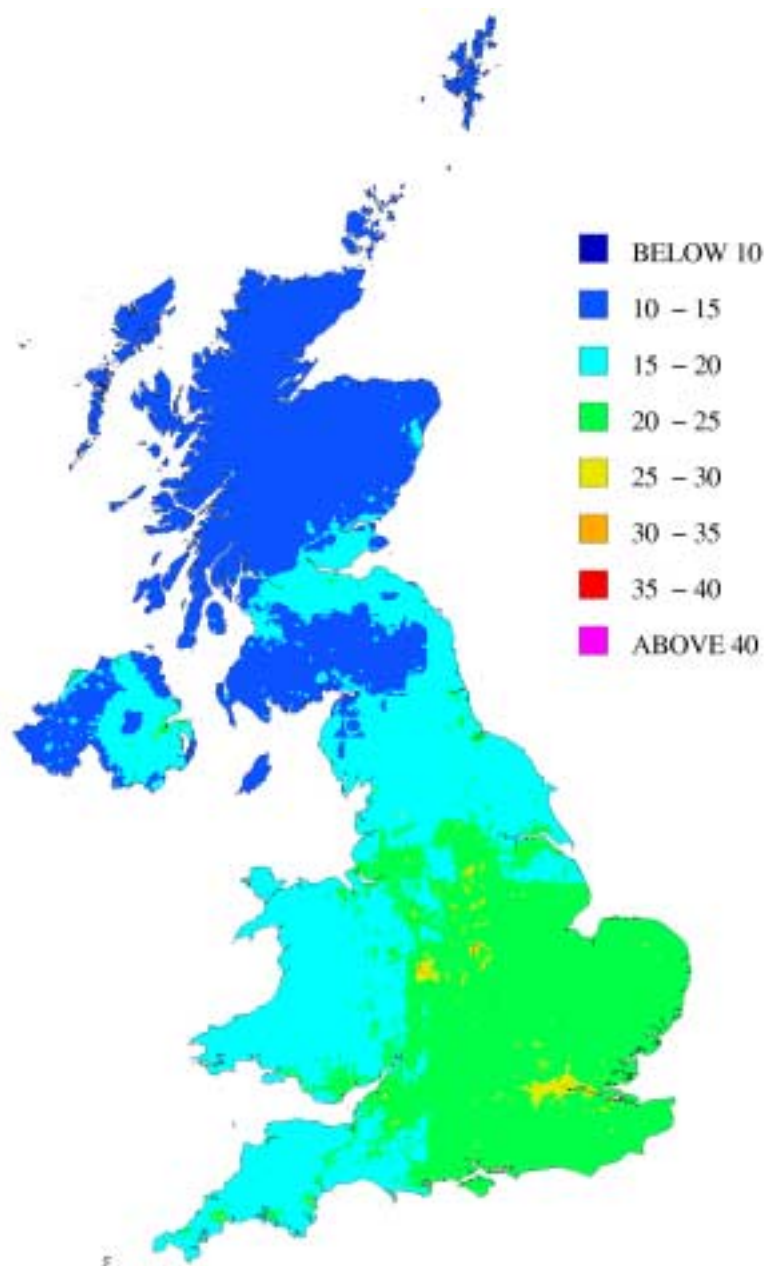
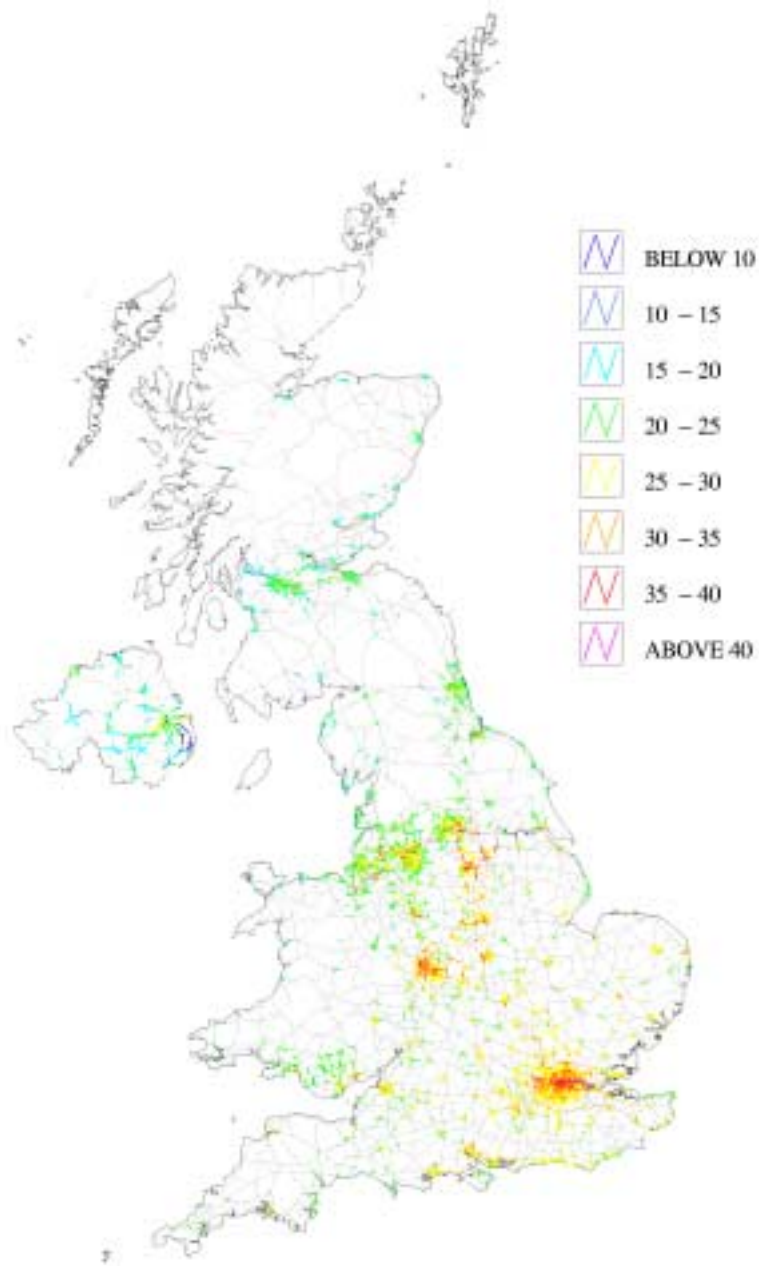


Figure 4.2. Urban major roads, annual mean roadside PM<sub>10</sub> concentration, 2003 ( $\mu\text{g m}^{-3}$ , gravimetric)



The information on the source apportionment of ambient particle concentrations in the UK available from the APEG receptor model (APEG, 1999, Stedman et al, 2001a) has been applied to the calculation of maps of annual mean concentrations. A regression analysis has been carried out to divide measured daily average PM<sub>10</sub> concentrations (as measured by TEOM or equivalent monitor at selected monitoring sites) into three components:

- primary combustion PM<sub>10</sub> (from co-located NO<sub>x</sub> measurements)
- secondary PM<sub>10</sub> (from rural sulphate measurements)
- 'other' PM<sub>10</sub> (the residual).

The regression analysis was carried out for the calendar year of monitoring data for each site to determine the coefficients A and B:



$$[\text{measured } PM_{10} (\mu\text{g m}^{-3}, \text{TEOM})] = A [\text{measured } NO_x (\mu\text{g m}^{-3}, \text{as } NO_2)] + B [\text{measured sulphate } (\mu\text{g m}^{-3})] + C (\mu\text{g m}^{-3}, \text{TEOM})$$

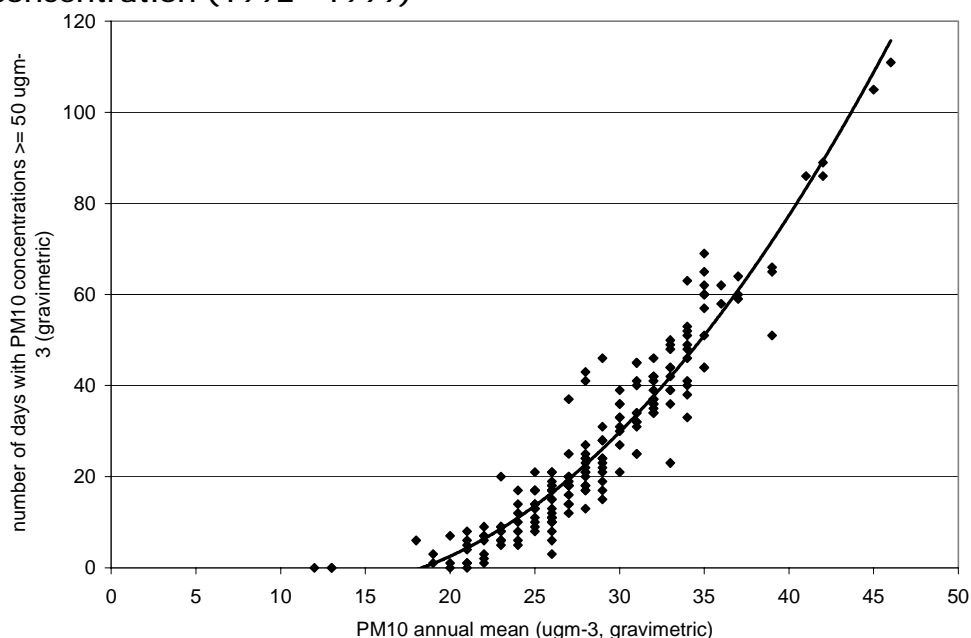
These coefficients can then be used to divide the measured concentration into the three components and the contributions from each component to the annual mean concentration can be calculated. The maps of background concentrations are made up of contributions from

- Large point sources of primary particles
- Small point sources of primary particles
- Area sources of primary particles
- Secondary particles
- Coarse particles.

An additional roadside increment is added for roadside locations.

24-hour mean concentrations have not been explicitly modelled for comparison with the 24-hour limit values. An annual mean concentration of  $31.5 \mu\text{g m}^{-3}$ , gravimetric has been taken to be equivalent to 35 days with 24-hour mean concentrations greater than  $50 \mu\text{g m}^{-3}$  gravimetric (the stage 1 24-hour limit value). This equivalence is derived from an analysis of monitoring data (Stedman et al, 2001b) and is reproduced in Figure 4.3. The relationship between the number of days with concentrations greater than  $50 \mu\text{g m}^{-3}$ , gravimetric and annual mean is less certain at lower numbers of exceedences and no attempt has been made to model exceedences of the indicative stage 2 24-hour limit value of 7 exceedences of  $50 \mu\text{g m}^{-3}$ , gravimetric. In any case, the stage 2 annual mean limit value is expected to be as stringent as the stage 2 24-hour limit value (AQEG, 2004a).

**Figure 4.3. The relationship between the number of days with  $PM_{10}$  concentrations greater than or equal to  $50 \mu\text{g m}^{-3}$  and annual mean concentration (1992 –1999)**



The reference method for the limit values for  $PM_{10}$  is the use of a gravimetric instrument. The analysis presented here is based on TEOM (Tapered Element Oscillating Microbalance) instruments, which are currently widely used within the UK national

monitoring networks. We have applied a scaling factor of 1.3 to all data before comparing with the limit value, as suggested by APEG (1999), and recommended as an interim measure by the EC Working Group set up to address the issue of scaling automatic PM<sub>10</sub> measurements in advance of Member States undertaking their own detailed inter-comparisons with the Directive Reference Method. Measurements of PM<sub>10</sub> concentrations using gravimetric instruments are now available for a number of sites in the UK. These measurements provide an additional independent verification of the model results.

## 4.2 SECONDARY PARTICLE CONTRIBUTIONS

For simplicity, secondary particles are assumed to consist of sulphates and nitrates only. A map of secondary PM<sub>10</sub> particle concentrations across the UK has been calculated from rural measurements of sulphate and nitrate concentrations by interpolation onto a 20 km x 20 km grid. Sulphate and nitrate particle concentrations were measured on a monthly basis at 12 rural sites using a denuder method during 2003 (Tang *pers comm.* 2004). Sulphate was measured on a daily basis at 5 of these sites (the daily measurements were used in the APEG receptor model described above).

Sulphate was assumed to be largely present as ammonium sulphate and sulphate concentrations were multiplied by 1.354 to take the presence of the counter ion into account. The mean value of the APEG receptor model coefficient, B, relating secondary PM<sub>10</sub> concentrations to sulphate concentrations in 2003 was 3.00, averaged over 11 urban background monitoring sites at which the receptor modelling has been performed. A comparison of interpolated sulphate and nitrate concentrations at these locations indicates that a scaling factor for nitrate concentrations of 1.0 is equivalent (along with a sulphate scaling factor of 1.354) to the sulphate to nitrate ratio implied by the coefficient derived from the APEG receptor model. (An equivalent B factor derived from the interpolated concentration fields at these 11 locations was 3.01). TEOM instruments are known to be subject to partial losses of the more volatile particle components, such as ammonium nitrate. This is the reason why a scaling factor of greater than 1.0 is not required to take account of the counter ions associated with the measured nitrate concentrations. In this instance the losses of nitrate mass have been found to be approximately equivalent to the mass of the counter ions associated with the remaining nitrate. It is quite possible that a scaling factor different from 1.0 would be found for other years or locations.

## 4.3 CONTRIBUTIONS FROM LARGE POINT SOURCES

Contributions to ground level annual mean PM<sub>10</sub> concentrations from large point sources (those with annual emission greater than 200 tonnes) in the 2002 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model.

The contribution to annual mean PM<sub>10</sub> concentrations from PM<sub>10</sub> point sources with greater than 200 tonnes per annum emission, was modelled using ADMS 3.1. Sequential meteorological data for 2003 from Waddington was applied. A total of 63 point sources were modelled. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100 km x 100 km square composed of a regularly spaced 5 km x 5 km resolution receptor grid. Each receptor grid was centred on the point source.

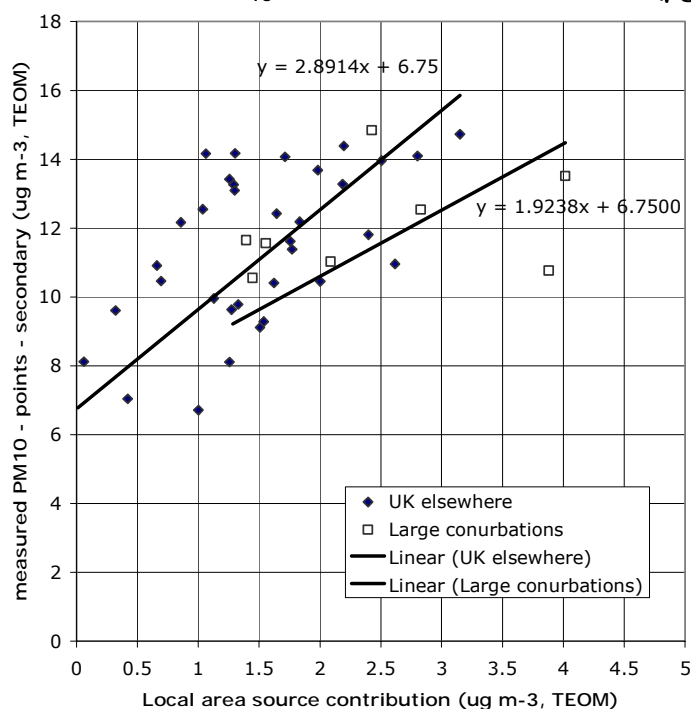
## 4.4 CONTRIBUTIONS FROM SMALL POINT SOURCES

Contributions from PM<sub>10</sub> point sources with less than 200 tonnes per annum release were modelled using the small points model described in Appendix 3.

## 4.5 CONTRIBUTIONS FROM AREA SOURCES

Figure 4.4 shows the calibration of the area source model. The modelled large point and small point source and mapped secondary PM<sub>10</sub> have been subtracted from the measured annual mean PM<sub>10</sub> concentration at background sites and compared with the modelled area source contribution to annual mean PM<sub>10</sub> concentration. Calibration plots are shown in µg m<sup>-3</sup>, TEOM, since TEOM measurements have been used to calibrate the models. (Concentrations have been converted to µg m<sup>-3</sup>, gravimetric before comparison with the limit values.) An empirical method, in which an ADMS derived dispersion kernel has been used to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33 km x 33 km square surrounding each monitoring site. Hourly sequential meteorological data from Heathrow in 2003 was used to construct the dispersion kernels, as described in Appendix 4.

Figure 4.4. Calibration of PM<sub>10</sub> area source model 2003 (µg m<sup>-3</sup>, TEOM)



Following the same approach as for NO<sub>x</sub>, the monitoring sites fall into two groups:

- Inner conurbations
- Elsewhere.

Adjustment factors were applied to the emissions from selected sources. Particle emissions from aircraft were multiplied by 0.5, to account for the proportion of total emissions from this sector that takes place while the aircraft wheels are on the ground.

The contribution to ground level concentrations from emissions while the aircraft is airborne will be much smaller and has not been modelled. (By convention, emission inventories include emissions from aircraft both on the ground and on take off and landing up to 1000 m.) A factor of 0.25 was applied to particle emissions from ships. Emissions from quarries and construction were estimated using revised methods developed for the compilation of the 2003 NAEI and no additional scaling factors were applied for these sources (Passant *pers comm*, 2004).

The modelled area source contribution was multiplied by the relevant empirical coefficient to calculate the calibrated area source contribution for each grid square in the country. The modelled point source and mapped secondary particle concentrations were then added.

## 4.6 COARSE PARTICLES

A constant coarse particle concentration of  $8.8 \mu\text{g m}^{-3}$ , gravimetric ( $6.75 \mu\text{g m}^{-3}$ , TEOM) is the final component of the mapped  $\text{PM}_{10}$  concentration at background locations. This value was derived from the intercept of the regression analyses to determine the empirical dispersion coefficients. It is somewhat smaller than the residuals obtained from the 2003 APEG receptor modelling. This is because of the inclusion of some coarse particle emissions in the area source modelling (principally from quarries, construction and break and tyre wear). These contributions were assigned to the residual in the APEG receptor modelling approach. Emissions of coarse particles from other sources such as wind blown dusts, sea salt and agricultural activities are not well characterised in emission inventories and are therefore included in this constant  $8.8 \mu\text{g m}^{-3}$ , gravimetric contribution, and not modelled explicitly.

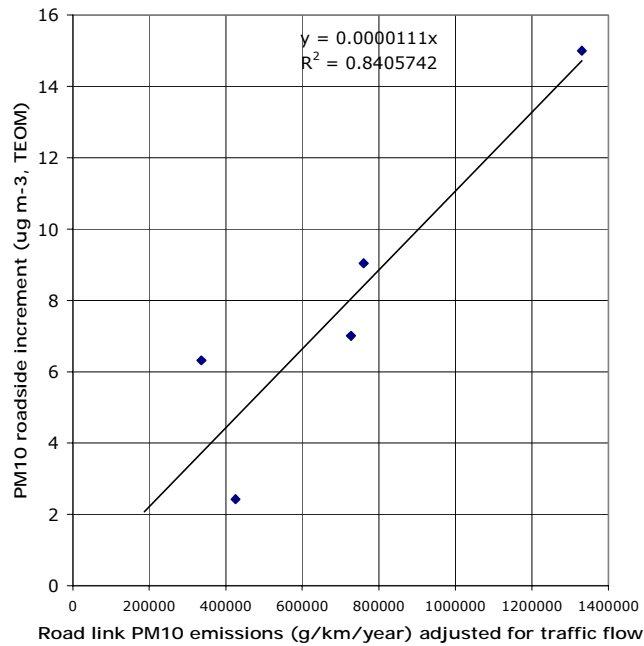
## 4.7 ROADSIDE CONCENTRATIONS

We have considered that the annual mean concentration of  $\text{PM}_{10}$  at a roadside location is made up of two parts: the background concentration (as described above) and a roadside increment:

$$\text{roadside concentration} = \text{background concentration} + \text{roadside increment}$$

The NAEI provides estimates of  $\text{PM}_{10}$  emissions for major road links in the UK for 2002 (Dore et al, 2004) and these have been adjusted to provide estimates of emissions in 2003. Figure 4.5 shows a comparison of the roadside increment of annual mean  $\text{PM}_{10}$  concentrations at roadside or kerbside national automatic monitoring sites with  $\text{PM}_{10}$  emission estimates for the individual road links alongside which these sites are located. Emissions were adjusted for annual average daily traffic flow using the method described in section 3.7. Roadside concentrations for urban roads only are reported to the EU and included in this report.

Figure 4.5. Calibration of PM<sub>10</sub> roadside increment model, 2003



## 4.8 VERIFICATION OF MAPPED VALUES

Figures 4.6 and 4.7 show comparisons of modelled and measured annual mean PM<sub>10</sub> concentration in 2003 at both background and roadside monitoring site locations. Both the national network sites used to calibrate the models and verification sites are shown. Lines representing  $y = x - 50\%$  and  $y = x + 50\%$  are also shown because 50% is the AQDD1 data quality objective for modelled annual mean PM<sub>10</sub> concentrations. Summary statistics for the comparison between modelled and measured PM<sub>10</sub> concentrations are presented in Tables 4.1 and 4.2. All of the modelled values are within the data quality objectives.

Figure 4.6. Verification of background annual mean PM<sub>10</sub> model 2003

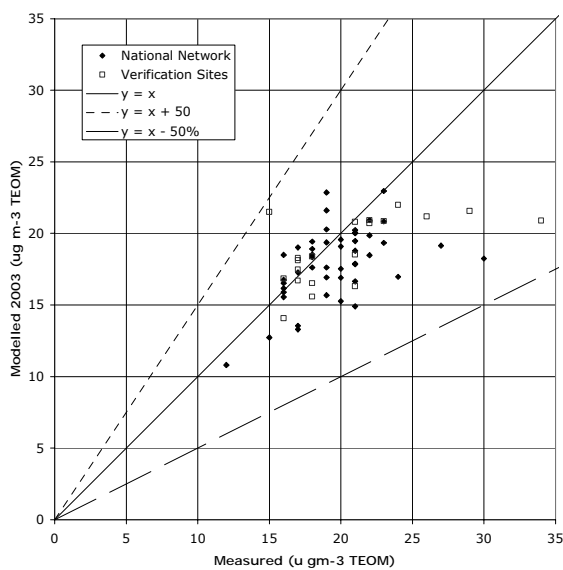


Figure 4.7. Verification of roadside annual mean PM<sub>10</sub> model 2003

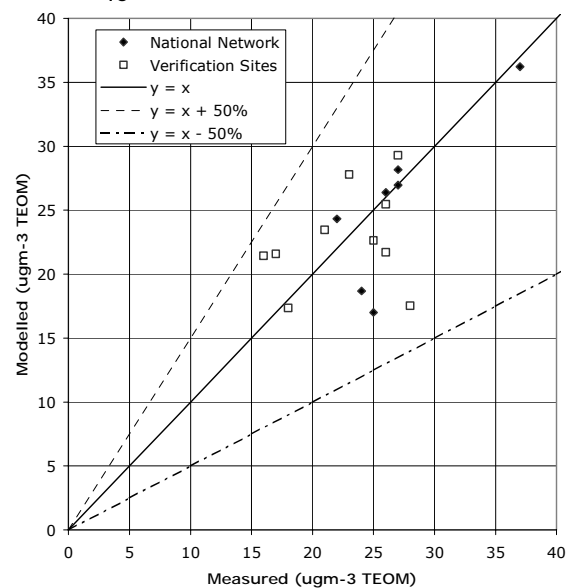


Table 4.1 Summary statistics for comparison between modelled and measured concentrations of PM<sub>10</sub> at background sites

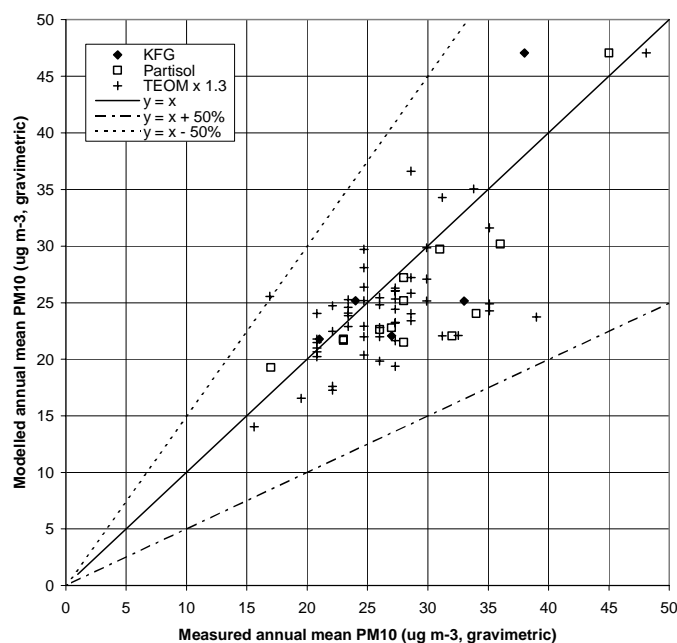
	Mean of measurements (µg m <sup>-3</sup> , TEOM)	Mean of model estimates (µg m <sup>-3</sup> , TEOM)	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	19.6	18.0	0.25	0%	47
Verification Sites	20.0	18.9	0.37	0%	20

Table 4.2 Summary statistics for comparison between modelled and measured concentrations of PM<sub>10</sub> at roadside sites

	Mean of measurements (µg m <sup>-3</sup> , TEOM)	Mean of model estimates (µg m <sup>-3</sup> , TEOM)	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	26.9	25.4	0.66	0%	7
Verification Sites	22.7	22.8	0.09	0%	10

The PM<sub>10</sub> models were calibrated using measurement data from TEOM instruments. Measurements of PM<sub>10</sub> concentrations using gravimetric instruments (Kleinfiltergerät (KFG) and Partisol instruments) are now available for a number of sites in the UK. These measurements provide an additional independent verification of the model results. A comparison of measured annual mean concentrations in 2003 with estimates calculated by multiplying the modelled PM<sub>10</sub> concentrations (TEOM) by 1.3 is presented in Figure 4.8. All of the estimates are well within the data quality objectives.

Figure 4.8. Verification of annual mean TEOM PM<sub>10</sub> x 1.3 model 2003: comparison with gravimetric measurements



## 4.9 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

The modelling results, in terms of a comparison of modelled concentrations with the stage 1 and stage limit 2 values by zone, are summarised in Tables 4.3 and 4.4. These data are also presented in form 19c of the questionnaire. We have added the number of road links exceeding the limit value for comparison with other UK studies. We have not modelled 24-hour mean concentrations for comparison with the stage 2 24-hour limit value, as discussed in Section 4.1. Method A in this table refers to the annual mean modelling methods described in this report. Method C refers to the annual mean modelling methods described in this report and the use of an annual mean threshold concentration as equivalent to the stage 1 24-hour limit value.

Estimates of area and population exposed have been derived from the background maps only. No attempt has been made to derive estimates using maps of roadside concentrations as these maps will only apply to within approximately 10 metres from the road kerb.

Table 4.3 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII (II))															
- Form 19c.1 Results of and methods used for supplementary assessment for PM <sub>10</sub> (Stage 1)															
Zone	Zone code	Above LV (24hr mean)						Above LV (annual mean)							
		Area		Road length		Population exposed		Area		Road length		Population exposed			
		km <sup>2</sup>	Method	links	km	Method	Number	Method	km <sup>2</sup>	Method	links	km	Method	Number	Method
Greater London Urban Area	UK0001	0	C	1017	747.6	C	0	C	0	A	133	84.0	A	0	A
West Midlands Urban Area	UK0002	13	C	188	230.1	C	37317	C	0	A	17	30.4	A	0	A
Greater Manchester Urban Area	UK0003	0	C	32	39.5	C	0	C	0	A	0	0.0	A	0	A
West Yorkshire Urban Area	UK0004	0	C	45	35.1	C	0	C	0	A	1	2.5	A	0	A
Tyneside	UK0005	0	C	7	7.5	C	0	C	0	A	0	0.0	A	0	A
Liverpool Urban Area	UK0006	0	C	2	1.0	C	0	C	0	A	0	0.0	A	0	A
Sheffield Urban Area	UK0007	4	C	50	62.2	C	1165	C	0	A	1	1.7	A	0	A
Nottingham Urban Area	UK0008	0	C	14	12.0	C	0	C	0	A	0	0.0	A	0	A
Bristol Urban Area	UK0009	0	C	21	17.4	C	0	C	0	A	1	0.7	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Leicester Urban Area	UK0011	0	C	10	6.3	C	0	C	0	A	0	0.0	A	0	A
Portsmouth Urban Area	UK0012	0	C	6	8.4	C	0	C	0	A	2	3.3	A	0	A
Teesside Urban Area	UK0013	0	C	7	6.8	C	0	C	0	A	1	1.2	A	0	A
The Potteries	UK0014	0	C	17	19.3	C	0	C	0	A	2	1.1	A	0	A
Bournemouth Urban Area	UK0015	0	C	2	4.0	C	0	C	0	A	0	0.0	A	0	A
Reading/Wokingham Urban Area	UK0016	0	C	4	4.9	C	0	C	0	A	0	0.0	A	0	A
Coventry/Bedworth	UK0017	0	C	1	2.5	C	0	C	0	A	0	0.0	A	0	A
Kingston upon Hull	UK0018	0	C	6	8.7	C	0	C	0	A	0	0.0	A	0	A
Southampton Urban Area	UK0019	0	C	8	12.6	C	0	C	0	A	0	0.0	A	0	A
Birkenhead Urban Area	UK0020	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Southend Urban Area	UK0021	0	C	2	3.0	C	0	C	0	A	0	0.0	A	0	A
Blackpool Urban Area	UK0022	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Preston Urban Area	UK0023	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Glasgow Urban Area	UK0024	0	C	3	5.1	C	0	C	0	A	0	0.0	A	0	A
Edinburgh Urban Area	UK0025	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Cardiff Urban Area	UK0026	0	C	2	1.7	C	0	C	0	A	0	0.0	A	0	A
Swansea Urban Area	UK0027	0	C	2	3.4	C	0	C	0	A	0	0.0	A	0	A



Table 4.3 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII (II))															
- Form 19c.1 Results of and methods used for supplementary assessment for PM <sub>10</sub> (Stage 1)															
Zone	Zone code	Above LV (24hr mean)							Above LV (annual mean)						
		Area		Road length			Population exposed		Area		Road length			Population exposed	
		km <sup>2</sup>	Method	links	km	Method	Number	Method	km <sup>2</sup>	Method	links	km	Method	Number	Method
Belfast Urban Area	UK0028	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Eastern	UK0029	0	C	28	64.6	C	0	C	0	A	3	8.5	A	0	A
South West	UK0030	0	C	9	15.1	C	0	C	0	A	0	0.0	A	0	A
South East	UK0031	0	C	51	111.1	C	0	C	0	A	2	4.0	A	0	A
East Midlands	UK0032	50	C	32	59.8	C	25322	C	0	A	3	3.6	A	0	A
North West & Merseyside	UK0033	0	C	40	81.0	C	0	C	0	A	1	1.6	A	0	A
Yorkshire & Humberside	UK0034	0	C	42	139.0	C	0	C	0	A	12	48.0	A	0	A
West Midlands	UK0035	0	C	21	42.2	C	0	C	0	A	0	0.0	A	0	A
North East	UK0036	0	C	12	17.0	C	0	C	0	A	5	6.1	A	0	A
Central Scotland	UK0037	0	C	4	9.5	C	0	C	0	A	1	2.8	A	0	A
North East Scotland	UK0038	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Highland	UK0039	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Scottish Borders	UK0040	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
South Wales	UK0041	0	C	5	11.9	C	0	C	0	A	0	0.0	A	0	A
North Wales	UK0042	0	C	3	5.7	C	0	C	0	A	0	0.0	A	0	A
Northern Ireland	UK0043	0	C	0	0.0	C	0	C	0	A	0	0.0	A	0	A
Total		67		1693	1796.1		63805		0		185	199.6		0	

Table 4.4 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII (II))															
- Form 19c.2 Results of and methods used for supplementary assessment for PM <sub>10</sub> (Stage 2)															
Zone	Zone code	Above LV (24hr mean)						Above LV (annual mean)							
		Area		Road length		Population exposed		Area		Road length			Population exposed		
		km <sup>2</sup>	Method	links	km	Method	Number	Method	km <sup>2</sup>	Method	links	km	Method	Number	Method
Greater London Urban Area	UK0001								1624	A	2006	1884.6	A	7730326	A
West Midlands Urban Area	UK0002								599	A	407	563.1	A	2080248	A
Greater Manchester Urban Area	UK0003								528	A	564	658.4	A	1798361	A
West Yorkshire Urban Area	UK0004								328	A	283	412.2	A	1070436	A
Tyneside	UK0005								60	A	167	196.1	A	184903	A
Liverpool Urban Area	UK0006								162	A	273	218.5	A	637269	A
Sheffield Urban Area	UK0007								168	A	113	158.2	A	528579	A
Nottingham Urban Area	UK0008								151	A	116	117.5	A	519341	A
Bristol Urban Area	UK0009								131	A	116	112.7	A	472862	A
Brighton/Worthing/Littlehampton	UK0010								89	A	51	82.0	A	369031	A
Leicester Urban Area	UK0011								92	A	72	92.3	A	353159	A
Portsmouth Urban Area	UK0012								83	A	51	71.3	A	340174	A
Teesside Urban Area	UK0013								74	A	57	72.6	A	200822	A
The Potteries	UK0014								91	A	105	112.0	A	264165	A
Bournemouth Urban Area	UK0015								109	A	52	67.3	A	327100	A
Reading/Wokingham Urban Area	UK0016								94	A	69	83.0	A	297794	A
Coventry/Bedworth	UK0017								74	A	30	34.3	A	274511	A
Kingston upon Hull	UK0018								77	A	38	49.8	A	252018	A
Southampton Urban Area	UK0019								74	A	58	69.0	A	256715	A
Birkenhead Urban Area	UK0020								40	A	60	54.1	A	156790	A
Southend Urban Area	UK0021								66	A	32	51.0	A	222883	A
Blackpool Urban Area	UK0022								5	A	46	60.8	A	27349	A
Preston Urban Area	UK0023								39	A	37	47.8	A	123985	A
Glasgow Urban Area	UK0024								20	A	174	254.9	A	77942	A
Edinburgh Urban Area	UK0025								1	A	52	89.0	A	2034	A
Cardiff Urban Area	UK0026								68	A	38	53.7	A	252333	A

Table 4.4 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII (II))															
- Form 19c.2 Results of and methods used for supplementary assessment for PM <sub>10</sub> (Stage 2)															
Zone	Zone code	Above LV (24hr mean)						Above LV (annual mean)							
		Area		Road length		Population exposed		Area		Road length			Population exposed		
		km <sup>2</sup>	Method	links	km	Method	Number	Method	km <sup>2</sup>	Method	links	km	Method	Number	Method
Swansea Urban Area	UK0027								57	A	31	65.0	A	137119	A
Belfast Urban Area	UK0028								73	A	17	101.3	A	250293	A
Eastern	UK0029								19106	A	606	853.8	A	4889632	A
South West	UK0030								8887	A	466	659.9	A	3001698	A
South East	UK0031								18677	A	877	1317.6	A	6263158	A
East Midlands	UK0032								13737	A	423	670.3	A	3258529	A
North West & Merseyside	UK0033								2051	A	545	913.7	A	2056562	A
Yorkshire & Humberside	UK0034								3202	A	352	702.2	A	2091908	A
West Midlands	UK0035								5880	A	355	525.9	A	2355283	A
North East	UK0036								215	A	179	229.1	A	251944	A
Central Scotland	UK0037								50	A	115	172.4	A	62073	A
North East Scotland	UK0038								1	A	78	102.9	A	143	A
Highland	UK0039								0	A	4	13.6	A	0	A
Scottish Borders	UK0040								0	A	11	10.6	A	0	A
South Wales	UK0041								986	A	203	351.7	A	891001	A
North Wales	UK0042								256	A	70	127.2	A	158603	A
Northern Ireland	UK0043								174	A	71	449.1	A	371700	A
Total									78199		9470	12932.4		44860775	

# 5 Benzene

## 5.1 INTRODUCTION

Maps of annual mean benzene concentrations at background and roadside locations in 2003 are presented in Figures 5.1 and 5.2. Benzene concentrations have been calculated using a similar approach to that adopted for  $\text{NO}_x$  and  $\text{NO}_2$  although a different approach has been adopted for the modelling of fugitive and process emissions from point sources.

Figure 5.1. Annual mean background benzene concentration, 2003 ( $\mu\text{g m}^{-3}$ )

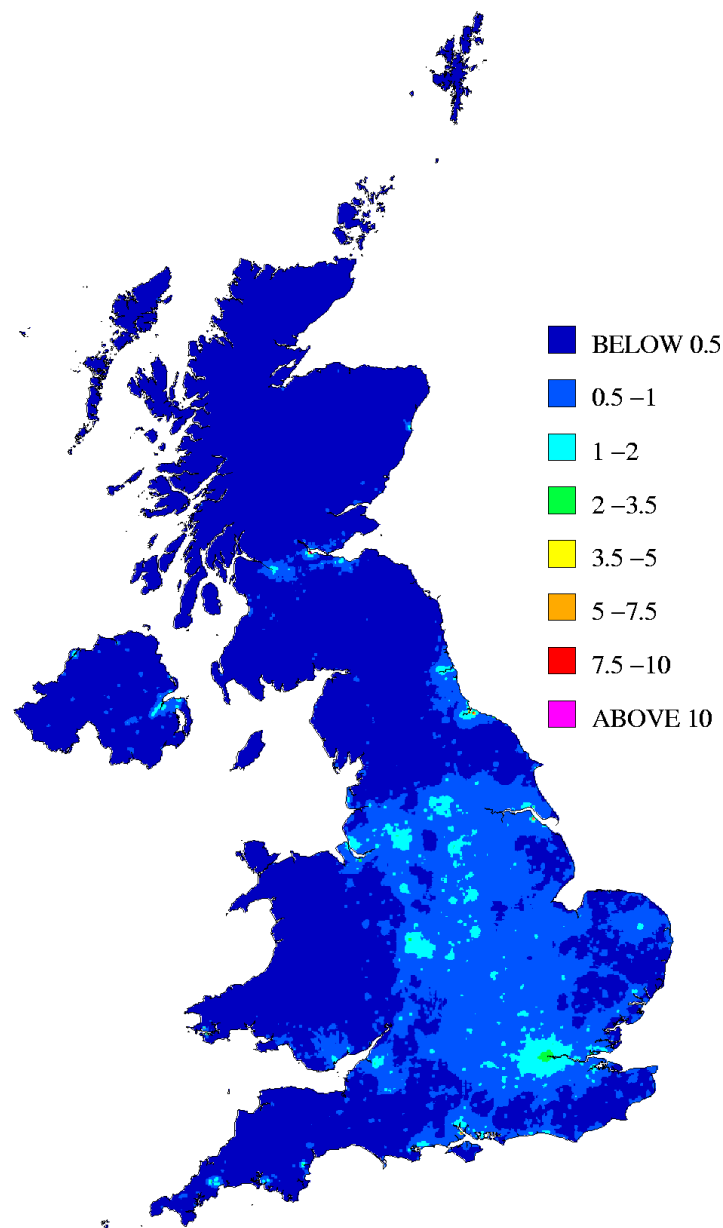
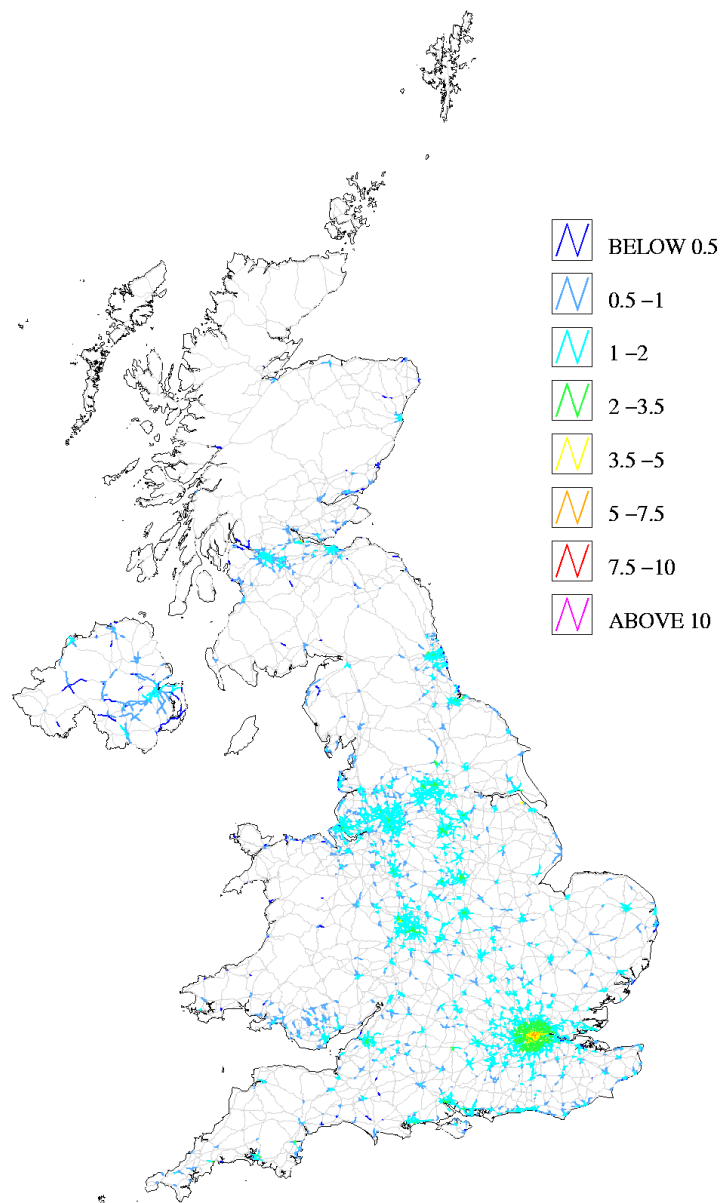


Figure 5.2. Urban major roads, annual mean roadside benzene concentration, 2003 ( $\mu\text{g m}^{-3}$ )



It has been considered that annual mean background benzene concentrations are made up of contributions from

- Distant sources (characterised by an estimate of rural background concentration)
- Combustion point sources
- Fugitive and process point sources
- Local area sources.

The area source model has been calibrated using data from the national monitoring networks.

At locations close to busy roads an additional roadside contribution was added to account for contributions to total benzene from road traffic sources.

## 5.2 CONTRIBUTIONS FROM COMBUSTION POINT SOURCES

Contributions to ground level annual mean benzene concentrations from large combustion related point sources (those with annual emission greater than 5 tonnes) in the 2002 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model. The contribution to annual mean benzene concentrations from these sources was modelled using ADMS 3.1 and sequential meteorological data for 2003 from Waddington. A total of 38 point sources were modelled. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100 km x 100 km square composed of a regularly spaced 5 km x 5 km resolution receptor grid. Each receptor grid was centred on the point source.

## 5.3 CONTRIBUTIONS FROM FUGITIVE AND PROCESS POINT SOURCES

The contributions to ambient concentrations from fugitive and process emission point sources were modelled using a modified version of the small points model described in Appendix 3. The emissions from these sources are not generally as well characterised in terms of the exact locations and release parameters as emissions from combustion sources. These emissions were therefore represented as volume sources with a depth of 75 m and dimensions of 100 m x 100 m. A dispersion kernel was used to calculate the out-of-square concentrations. The in-square concentration was estimated as the average of concentrations from this volume source at receptor spacing of 20 m within the 1 km x 1 km grid square. Comparison of the estimated concentrations with the annual mean benzene concentration measured at the Grangemouth monitoring site suggested that this model significantly overestimated ambient concentration close to refineries. We therefore applied a GIS mask to the locations of refineries within our final map and no attempt was made to estimate concentrations in these locations. More research is needed to characterise the benzene emissions from these sources in more detail. The measured annual mean benzene concentration at the Grangemouth monitoring site during 2003 was  $1.59 \mu\text{g m}^{-3}$ , which is well below the limit value.

## 5.4 CONTRIBUTIONS FROM RURAL BACKGROUND CONCENTRATIONS

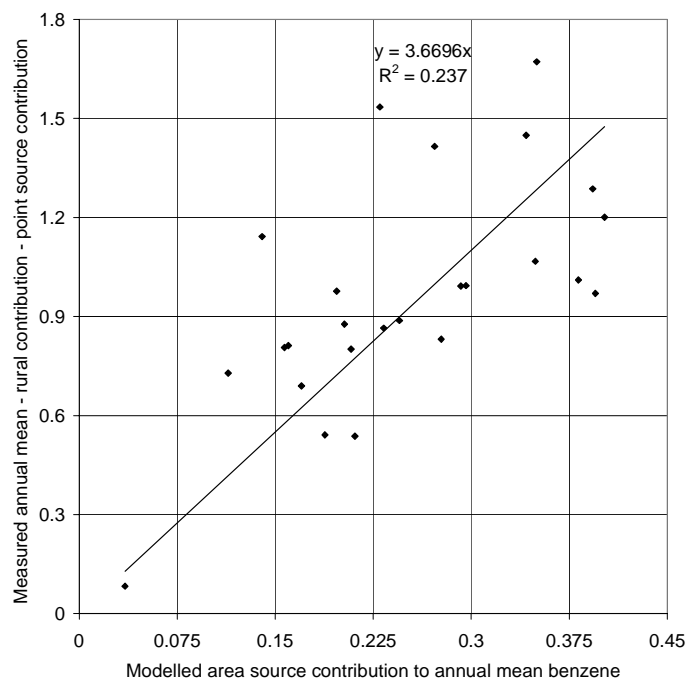
Regional rural benzene concentrations were estimated from the map of rural  $\text{NO}_x$  concentration described in section 3.5. A factor of 0.0295 was applied to the map of  $\text{NO}_x$  concentrations, which is the ratio of the measured annual mean benzene and  $\text{NO}_x$  concentrations at the rural Harwell monitoring site.

## 5.5 CONTRIBUTIONS FROM AREA SOURCES

Figure 5.3 shows the calibration of the area source model. The modelled concentrations from point sources and estimated rural benzene concentrations have been subtracted from the measured annual mean concentration at automatic and pumped tube background measurement sites. This corrected background concentration is compared

with the modelled area source contribution to annual mean benzene. An empirical method has been used to calculate the contribution to ambient concentrations from area sources. This approach applies an ADMS derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33 km x 33 km square surrounding each monitoring site. Hourly sequential meteorological data from Heathrow in 2003 has been used to construct the dispersion kernels, as described in Appendix 4.

Figure 5.3. Calibration of area source benzene model 2003 ( $\mu\text{g m}^{-3}$ )



London Bloomsbury is the only background monitoring site in an inner conurbation. The empirical calibration factor for inner conurbations was therefore derived from the 'elsewhere' factor using the relationship between the inner conurbations and elsewhere factors for  $\text{NO}_x$ :

$$\text{Inner conurbation benzene} = (\text{Inner conurbation } \text{NO}_x / \text{Elsewhere } \text{NO}_x) * \text{Elsewhere benzene}$$

Adjustment factors were applied to the emissions from selected sources. Emissions from aircraft were multiplied by 0.36 to take account of the fact that some of the emission takes place while the aircraft are in the air, as described in Section 3.6. An empirical factor of 0.25 was applied to benzene emissions from ships.

The modelled area source contribution was multiplied by the relevant empirical coefficient to calculate the calibrated area source contribution for each grid square in the country. The rural and point source contributions were then added, resulting in a map of background benzene concentrations.

## 5.6 ROADSIDE CONCENTRATIONS

We have considered that the annual mean concentration of benzene at a roadside location is made up of two parts: the background concentration (as described above) and a roadside increment. A comparison of measured roadside benzene concentrations and road link emissions did not provide a robust coefficient. The empirical coefficient derived for the NO<sub>x</sub> roadside increment model described in Section 3.7 was therefore used for benzene. Roadside concentrations for urban roads only are reported to the EU and included in this report.

## 5.7 VERIFICATION OF MAPPED VALUES

Figures 5.4 and 5.5 show comparisons of the modelled and measured annual mean benzene concentrations for background and roadside locations. Lines showing  $y = x - 50\%$  and  $y = x + 50\%$  are included in these charts – these represent the AQDD2 data quality objective for modelled benzene concentrations. Benzene concentrations are not routinely measured at as many locations as other the pollutants covered by AQDD1 and AQDD2. Therefore, the modelled benzene concentrations have only been compared with measurements at national network sites in this study.

Figure 5.4. Verification of background annual mean benzene model 2003

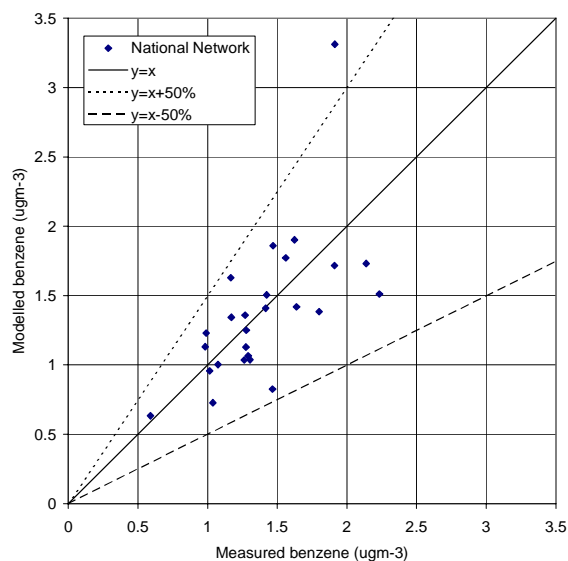
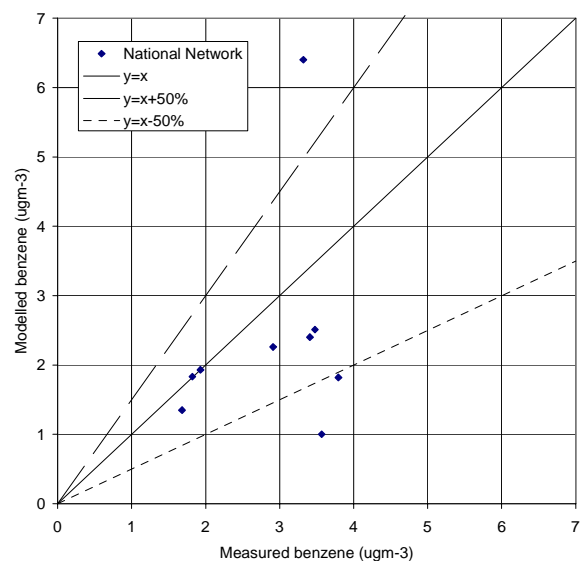


Figure 5.5. Verification of roadside annual mean benzene model 2003



Summary statistics for the comparison between modelled and measured benzene concentrations are listed in Tables 5.1 and 5.2. The modelled and measured concentrations at Grangemouth have been excluded from this analysis because the model has been found to over predict close to refineries.



Table 5.1 Summary statistics for comparison between modelled and measured benzene concentrations at background sites ( $\mu\text{g m}^{-3}$ )

	Mean of measurements ( $\mu\text{g m}^{-3}$ )	Mean of model estimates ( $\mu\text{g m}^{-3}$ )	$r^2$	% outside data quality objectives	Number of sites
National Network	1.4	1.4	0.39	4%	26

Table 5.2 Summary statistics for comparison between modelled and measured benzene concentrations at roadside sites ( $\mu\text{g m}^{-3}$ )

	Mean of measurements ( $\mu\text{g m}^{-3}$ )	Mean of model estimates ( $\mu\text{g m}^{-3}$ )	$r^2$	% outside data quality objectives	Number of sites
National Network	2.9	2.4	0.06	33%	9

## 5.8 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

The modelling results, in terms of a comparison of modelled concentrations with the annual mean limit value by zone, are summarised in Table 5.3. These data have also been presented in form 19e of the questionnaire. We have added the number of road links exceeding the limit value for comparison with other UK studies. Method A in this table refers to the modelling method described in this report.

Estimates of area and population exposed have been derived from the background maps only. No attempt has been made to derive estimates using maps of roadside concentrations as these maps will only apply to within approximately 10 metres from the road kerb.

Table 5.3 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII (II), 2000/69/EC Article 5(3) and Annex VI (II) and 2002/3/EC Article 9(1) and Annex VII (II))								
- Form 19e Results of and methods used for supplementary assessment for benzene								
Zone	Zone code	Above LV						
		Area		Road length			Population exposed	
		km <sup>2</sup>	Method	links	km	Method	Number	Method
Greater London Urban Area	UK0001	0	A	151	71	A	0	A
West Midlands Urban Area	UK0002	0	A	0	0	A	0	A
Greater Manchester Urban Area	UK0003	0	A	0	0	A	0	A
West Yorkshire Urban Area	UK0004	0	A	0	0	A	0	A
Tyneside	UK0005	0	A	0	0	A	0	A
Liverpool Urban Area	UK0006	0	A	0	0	A	0	A
Sheffield Urban Area	UK0007	0	A	0	0	A	0	A
Nottingham Urban Area	UK0008	0	A	0	0	A	0	A
Bristol Urban Area	UK0009	0	A	0	0	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	A	0	0	A	0	A
Leicester Urban Area	UK0011	0	A	0	0	A	0	A
Portsmouth Urban Area	UK0012	0	A	0	0	A	0	A
Teesside Urban Area	UK0013	0	A	0	0	A	0	A
The Potteries	UK0014	0	A	0	0	A	0	A
Bournemouth Urban Area	UK0015	0	A	0	0	A	0	A
Reading/Wokingham Urban Area	UK0016	0	A	0	0	A	0	A
Coventry/Bedworth	UK0017	0	A	0	0	A	0	A
Kingston upon Hull	UK0018	0	A	0	0	A	0	A
Southampton Urban Area	UK0019	0	A	0	0	A	0	A
Birkenhead Urban Area	UK0020	0	A	0	0	A	0	A
Southend Urban Area	UK0021	0	A	0	0	A	0	A
Blackpool Urban Area	UK0022	0	A	0	0	A	0	A
Preston Urban Area	UK0023	0	A	0	0	A	0	A
Glasgow Urban Area	UK0024	0	A	0	0	A	0	A
Edinburgh Urban Area	UK0025	0	A	0	0	A	0	A
Cardiff Urban Area	UK0026	0	A	0	0	A	0	A
Swansea Urban Area	UK0027	0	A	0	0	A	0	A
Belfast Urban Area	UK0028	0	A	0	0	A	0	A
Eastern	UK0029	0	A	0	0	A	0	A
South West	UK0030	0	A	0	0	A	0	A
South East	UK0031	0	A	0	0	A	0	A
East Midlands	UK0032	0	A	0	0	A	0	A
North West & Merseyside	UK0033	0	A	0	0	A	0	A
Yorkshire & Humberside	UK0034	0	A	0	0	A	0	A
West Midlands	UK0035	0	A	0	0	A	0	A
North East	UK0036	0	A	0	0	A	0	A
Central Scotland	UK0037	0	A	0	0	A	0	A
North East Scotland	UK0038	0	A	0	0	A	0	A
Highland	UK0039	0	A	0	0	A	0	A
Scottish Borders	UK0040	0	A	0	0	A	0	A
South Wales	UK0041	0	A	0	0	A	0	A
North Wales	UK0042	0	A	0	0	A	0	A
Northern Ireland	UK0043	0	A	0	0	A	0	A
Total		0		151	71		0	

# 6 CO

## 6.1 INTRODUCTION

Maps of annual mean CO concentrations at background and roadside locations in 2003 are presented in Figures 6.1 and 6.2. Maps of maximum 8-hour mean CO concentrations at background and roadside locations in 2003 are presented in Figures 6.3 and 6.4. Only the maximum 8-hour mean maps are required for comparison with the AQDD2 limit value but the annual mean maps were also prepared as intermediate steps within the modelling exercise and are therefore also presented here. CO concentrations have been calculated using a similar approach to that adopted for NO<sub>x</sub> and NO<sub>2</sub> but without the inclusion of a mapped regional rural component because regional rural CO concentrations in the UK are not well characterised within the monitoring networks.

It has been considered that annual mean background CO concentrations are made up of contributions from

- Large point sources
- Small point sources
- Local area sources

The area source model has been calibrated using data from the national monitoring networks. At locations close to busy roads an additional roadside contribution was added to account for contributions to total CO from road traffic sources.

The relationships used in the calibration of the CO annual mean and maximum 8-hour models were not particularly robust, especially the relationships involving the maximum 8-hour concentrations. Therefore, annual mean concentrations were modelled first and this output was then used to calibrate the maximum 8-hour model.

Figure 6.1. Annual mean background CO concentration, 2003 ( $\text{mg m}^{-3}$ )

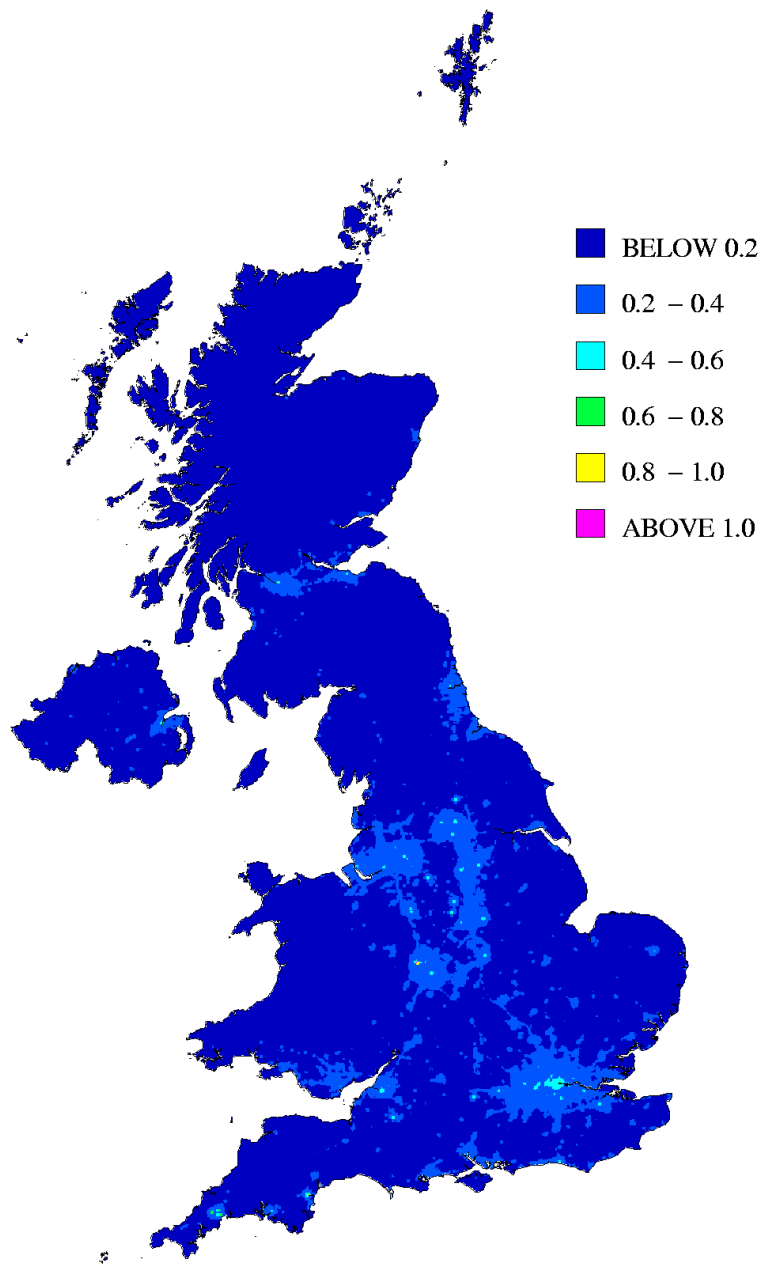


Figure 6.2. Urban major roads, annual mean roadside CO concentration, 2003 (mg m<sup>-3</sup>)

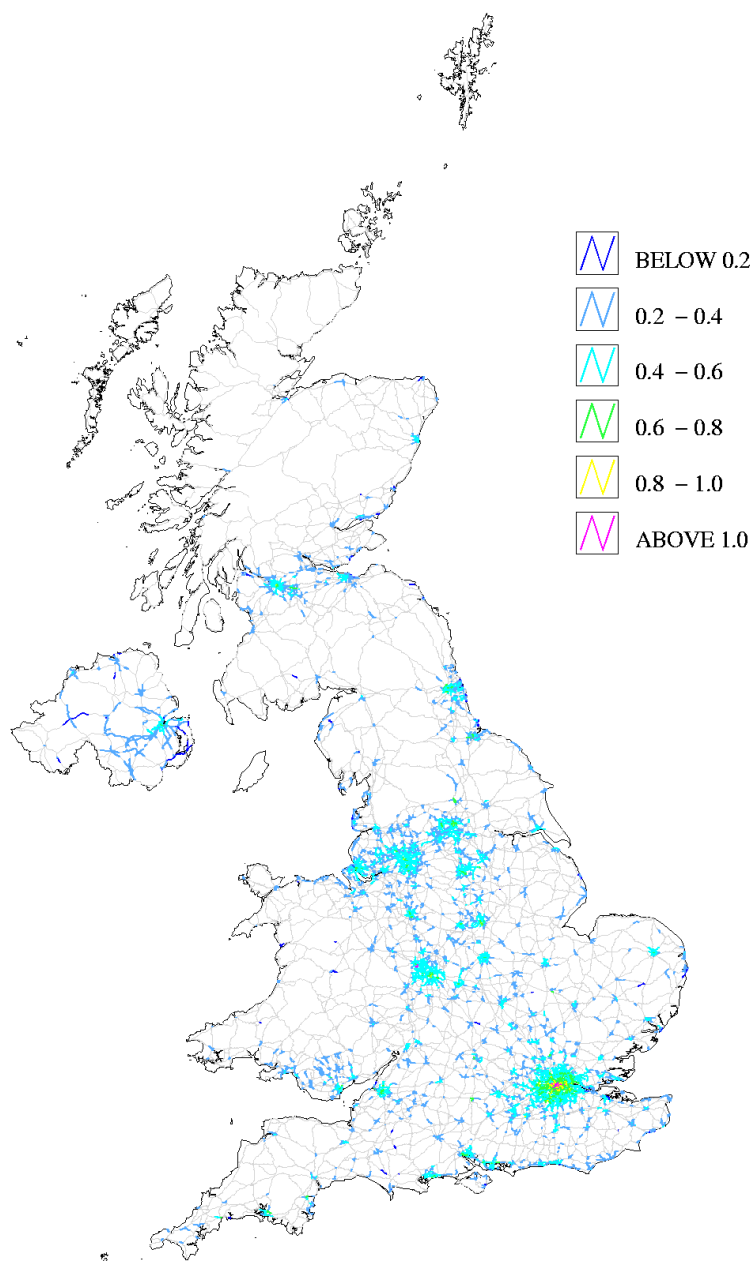


Figure 6.3. Maximum 8-hour mean background CO concentration, 2003 ( $\text{mg m}^{-3}$ )

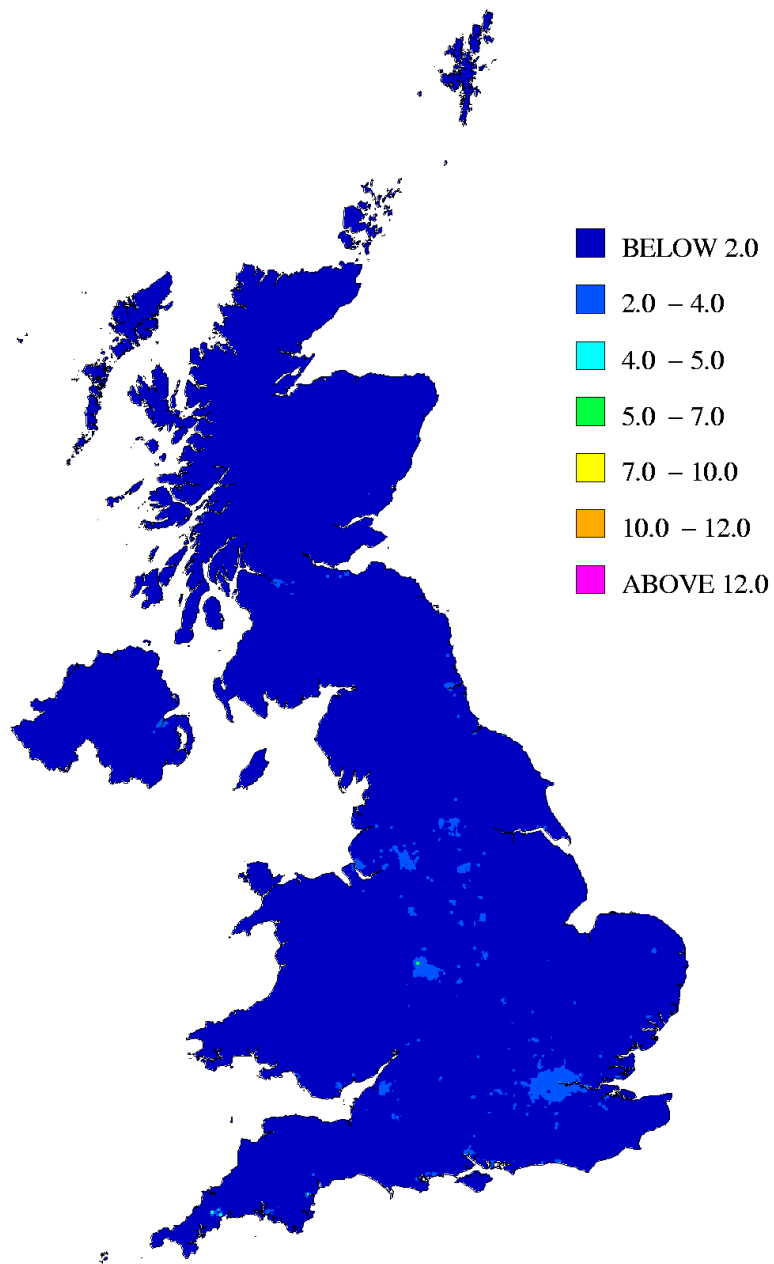
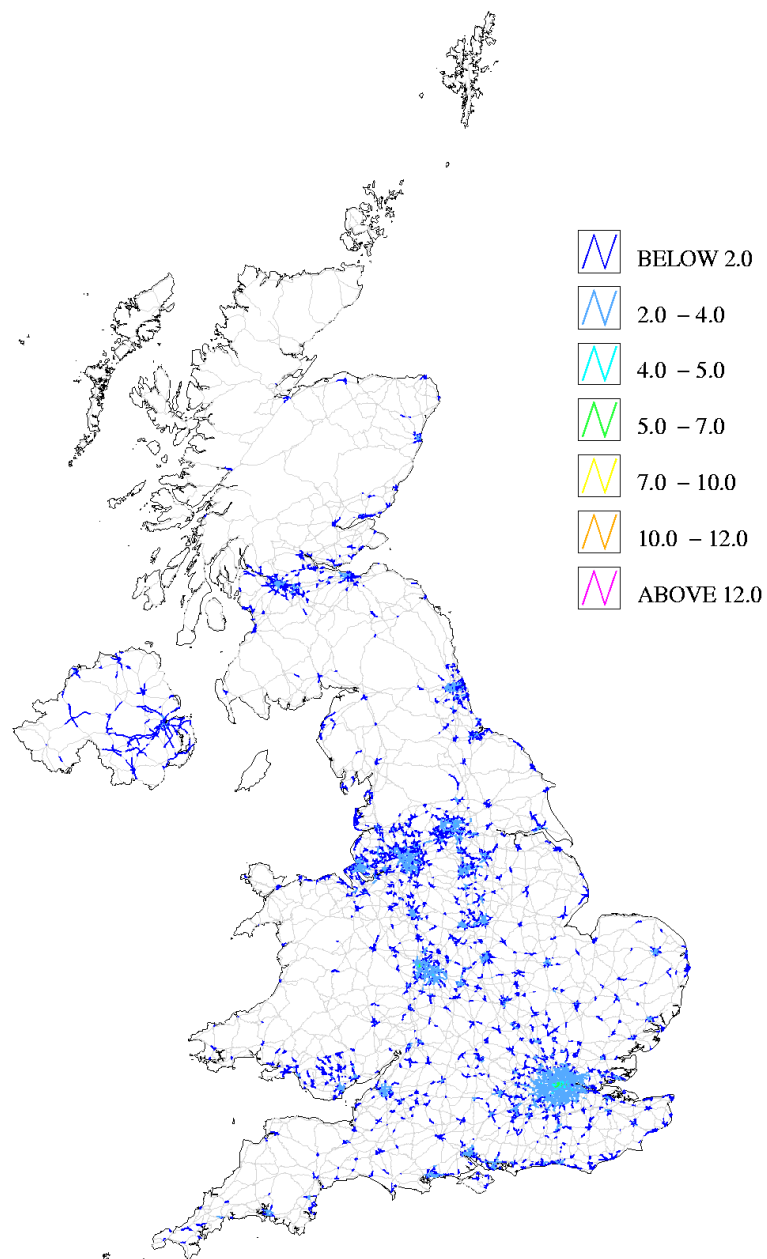


Figure 6.4. Urban major roads, maximum 8-hour mean roadside CO concentration, 2003 ( $\text{mg m}^{-3}$ )



## 6.2 CONTRIBUTIONS FROM LARGE POINT SOURCES

Contributions to ground level annual mean CO concentrations from large point sources (those with annual emission greater than 3000 tonnes) in the 2002 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model. The contribution to annual mean CO concentrations from point sources was modelled using ADMS 3.1 and sequential meteorological data for 2003 from Waddington. A total of 31

point sources were modelled. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100 km x 100 km square composed of a regularly spaced 5 km x 5 km resolution receptor grid. Each receptor grid was centred on the point source.

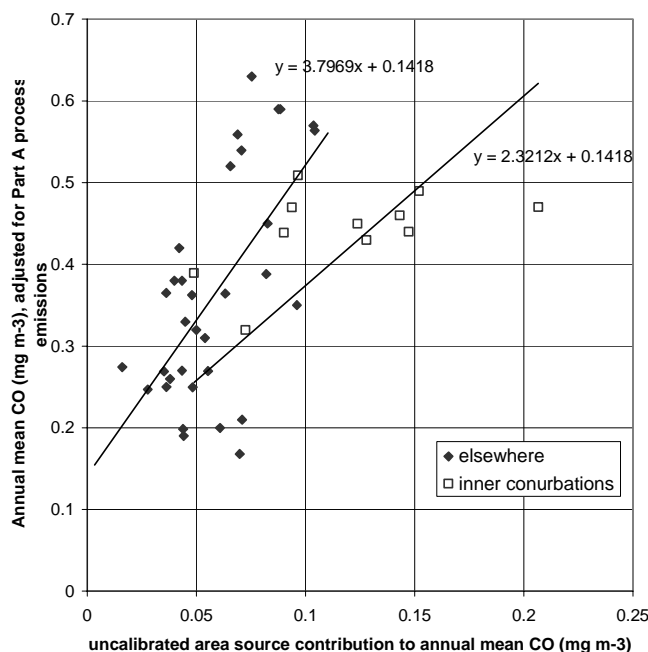
### 6.3 CONTRIBUTIONS FROM SMALL POINT SOURCES

Contributions from CO point sources with less than 3000 tonnes per annum release were modelled using the small points model described in Appendix 3.

### 6.4 CONTRIBUTIONS FROM AREA SOURCES

Figure 6.5 shows the calibration of the annual mean area source CO model for background locations. Measured annual mean CO concentrations at background sites have been corrected for contributions from modelled large and small point sources and compared with the modelled area source contribution to annual mean CO concentration. Calibration plots are shown in  $\text{mg m}^{-3}$ . An empirical method has been used to calculate the contribution to ambient concentrations from area sources. This approach applies an ADMS derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33 km x 33 km square surrounding each monitoring site. Hourly sequential meteorological data from Heathrow in 2003 has been used to construct the dispersion kernels, as described in Appendix 4.

Figure 6.5. Calibration of 2003 background annual mean CO model ( $\text{mg m}^{-3}$ )



Examination of Figure 6.5 shows that the monitoring sites fall into two groups:

- Inner conurbations
- Elsewhere.



'Inner conurbations' includes Inner and Central London and central Birmingham and Manchester as defined by DfT (2003). The intercept for the elsewhere relationship was taken to represent regional rural annual mean CO concentrations in the UK.

Adjustment factors were applied to the emissions from selected sources. As for NO<sub>x</sub>, emissions from aircraft were multiplied by 0.36 and an empirical factor of 0.25 was applied to emissions from ships.

The modelled area source contribution was multiplied by the relevant empirical coefficient to calculate the calibrated area source contribution for each grid square in the country. The point source contributions and constant regional rural concentration were then added, resulting in a map of background annual mean CO concentrations shown in Figure 6.1.

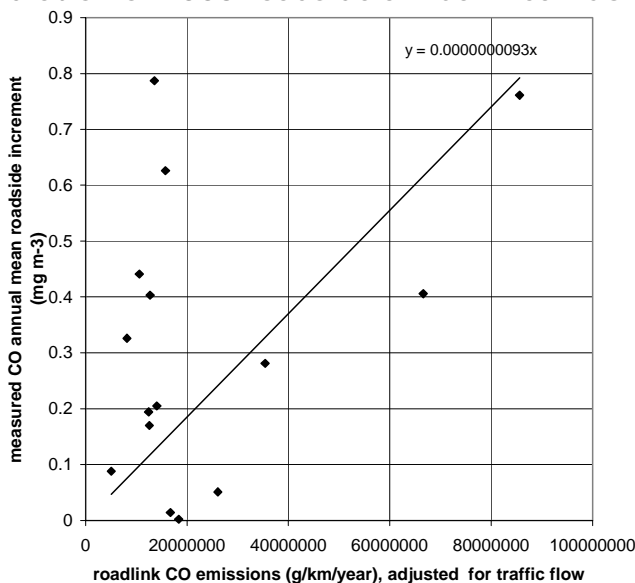
## 6.5 ROADSIDE ANNUAL MEAN CO CONCENTRATIONS

We have considered that the annual mean concentration of CO at a roadside location is made up of two parts: the background concentration (as described above) and a roadside increment:

$$\text{roadside CO concentration} = \text{background CO concentration} + \text{CO roadside increment}$$

The NAEI provides estimates of CO emissions for major road links in the UK for 2002 (Dore et al, 2004) and these have been adjusted to provide estimates of emissions in 2003. The background CO component at these roadside monitoring sites was derived from the map described above. The roadside increment was calculated by multiplying an adjusted road link emission by the empirical dispersion coefficient determined from Figure 6.6. The traffic flow adjustment factors used were the same as those applied in the roadside NO<sub>x</sub> modelling and are presented in Figure 3.8. The relationship between the measured annual mean roadside CO concentration and road link emissions is clearly poor. This is due to a combination of the greater uncertainty associated with current low measured CO concentrations and road link emission inventories. Emissions of CO are highly dependent on local traffic conditions, particularly at low speeds and detailed information on speeds and congestion are not available from national inventories. The map of annual mean roadside CO concentrations is shown in Figure 6.2.

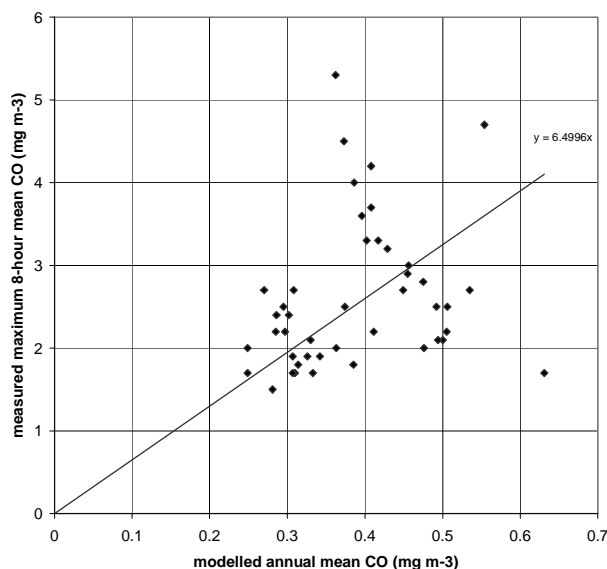
Figure 6.6. Calibration of 2003 roadside annual mean CO model (mg m<sup>-3</sup>)



## 6.6 MODELLING THE MAXIMUM 8-HOUR MEAN CO CONCENTRATION

The map of maximum 8-hour mean CO concentrations at background locations shown in Figure 6.3 was calculated from the map of background annual mean CO concentrations by scaling annual mean map with the relationship between modelled annual mean concentrations and the measured maximum 8-hour concentrations from the national network. Figure 6.7 shows this relationship.

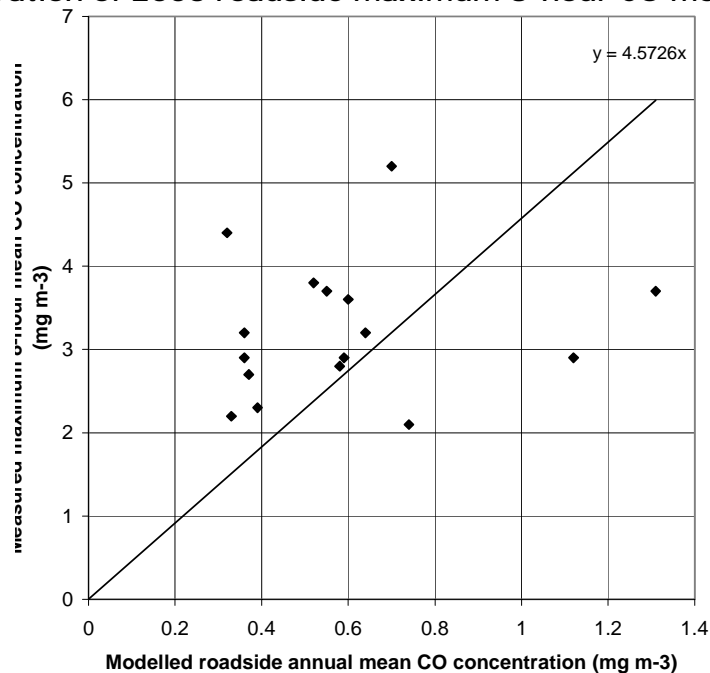
Figure 6.7 Calibration of 2003 background maximum 8-hour mean CO model (mg m<sup>-3</sup>)



The map of maximum 8-hour mean CO concentrations at roadside locations shown in Figure 6.4 was calculated from map of annual mean concentrations at roadside locations.

The empirical relationship used to scale the annual mean roadside map to derive the maximum 8-hour mean map is presented in Figure 6.8.

Figure 6.8. Calibration of 2003 roadside maximum 8-hour CO model ( $\text{mg m}^{-3}$ )



Roadside concentrations for urban roads only are reported to the EU and included in this report.

## 6.7 VERIFICATION OF MAPPED VALUES

Figures 6.5 to 6.8 show comparisons of the modelled and measured annual mean and maximum 8-hour CO concentrations for background and roadside locations. The national network sites used to calibrate the models are shown in addition to the verification sites. Lines showing  $y = x - 50\%$  and  $y = x + 50\%$  are included in these charts – these represent the AQDD2 data quality objective for modelled carbon monoxide concentrations. Summary statistics for the comparison between modelled and measured carbon monoxide concentrations are listed in Tables 6.1 to 6.4.

Figure 6.5. Verification of background annual mean CO model 2003

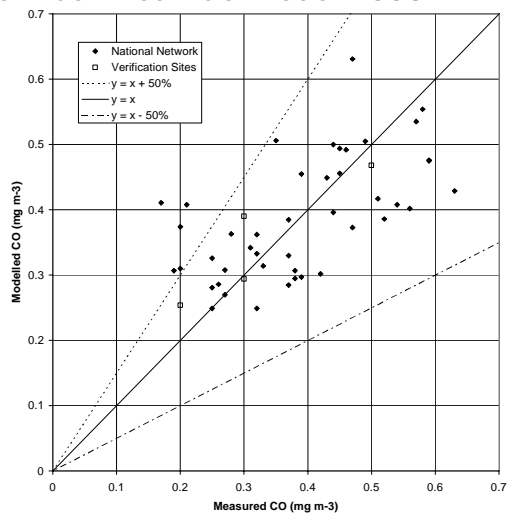


Figure 6.6. Verification of background maximum 8-hour mean CO model 2003

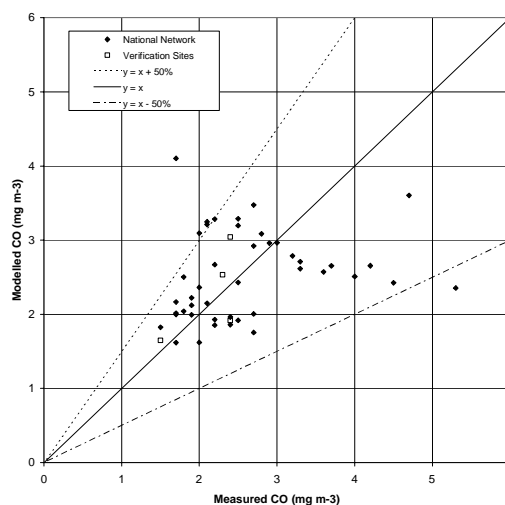


Figure 6.7. Verification of roadside annual mean CO model 2003

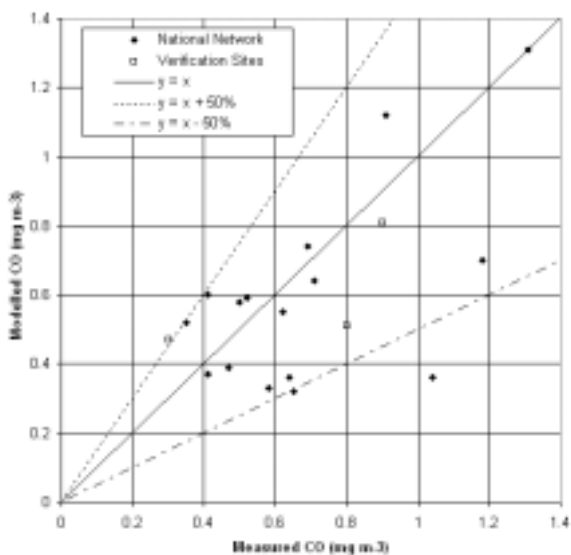


Figure 6.8. Verification of roadside maximum 8-hour mean CO model 2003

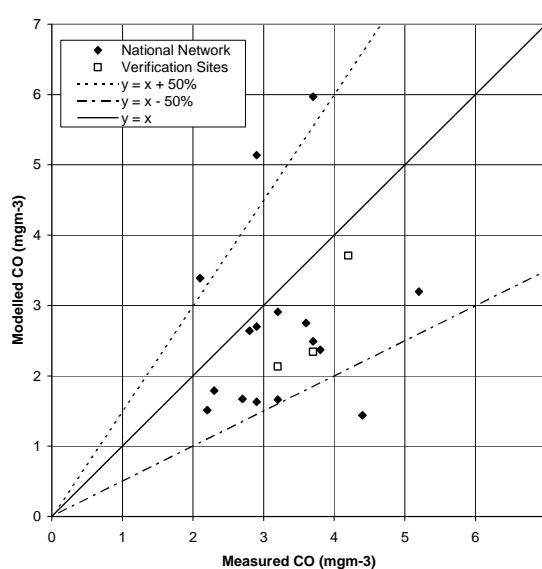


Table 6.1. Summary statistics for comparison between modelled and measured annual mean CO concentrations at background sites (mg m<sup>-3</sup>)

	Mean of measurements (mg m <sup>-3</sup> )	Mean of model estimates (mg m <sup>-3</sup> )	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	0.39	0.39	0.37	9%	44
Verification Sites	0.33	0.35	0.83	0%	4

Table 6.2. Summary statistics for comparison between modelled and measured maximum 8-hour mean CO concentrations at background sites (mg m<sup>-3</sup>)

	Mean of measurements (mg m <sup>-3</sup> )	Mean of model estimates (mg m <sup>-3</sup> )	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	2.60	2.52	0.06	11%	44
Verification Sites	2.15	2.28	0.45	0%	4

Table 6.3. Summary statistics for comparison between modelled and measured annual mean CO concentrations at roadside sites (mg m<sup>-3</sup>)

	Mean of measurements (mg m <sup>-3</sup> )	Mean of model estimates (mg m <sup>-3</sup> )	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	0.70	0.37	0.37	6%	17
Verification Sites	0.67	0.33	0.50	33%	3

Table 6.4. Summary statistics for comparison between modelled and measured maximum 8-hour mean CO concentrations at roadside sites (mg m<sup>-3</sup>)

	Mean of measurements (mg m <sup>-3</sup> )	Mean of model estimates (mg m <sup>-3</sup> )	r <sup>2</sup>	% outside data quality objectives	Number of sites
National Network	3.26	2.39	0.02	24%	17
Verification Sites	3.70	2.17	0.85	0%	3

## 6.8 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

Modelling results for CO have not been tabulated here because the modelled and measured CO concentrations are below the limit value for all zones.

# 7 Lists of zones in relation to Limit Values and Margins of Tolerance

## 7.1 RESULTS FOR 2003

The tables included in this section are from form 8 of the questionnaire. Exceedence (or otherwise of the limit vale (LV) and limit value plus margin of tolerance (LV + MOT) where this exists are indicated by a 'y' for measured exceedences and with an 'm' for modelled exceedences. If both measurements and model estimates show that a threshold has been exceeded then the measurements are regarded as the primary basis for compliance status and 'y' is therefore used. An 'm' in the columns marked >LV + MOT or  $\leq$ LV + MOT; > LV indicates that modelled concentrations were higher than measured concentrations or on rare occasions that measurements were not available for that zone and modelled values were therefore used. Modelled concentration may be higher than measured concentrations because the modelling studies provide estimates of concentrations over the entire zone. It is possible that the locations of the monitoring sites do not correspond to the location of the highest concentration in the zone. There may, for example, be no roadside monitoring sites in a zone. An 'm' in the columns marked  $\leq$ LV indicates that measurements were not available for that zone and modelled values were therefore used. A 'n' indicates that the limit value is not applicable for that zone. The ecosystem and vegetation limit values, for example, do not apply in agglomeration zones. A blank cell indicates that no assessment has been made.

The results of the air quality assessments for SO<sub>2</sub>, NO<sub>2</sub> and NO<sub>x</sub>, PM<sub>10</sub>, lead, benzene and CO are listed in Tables 7.1 to 7.6.

Table 7.1. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)										
- Form 8a List of zones in relation to limit value exceedences for SO <sub>2</sub>										
Zone	Zone code	LV for health (1hr mean)			LV for health (24hr mean)		LV for ecosystems (annual mean)		LV for ecosystems (winter mean)	
		>LV+ MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV	>LV	≤LV	>LV	≤LV
Greater London Urban Area	UK0001			y		y		n		n
West Midlands Urban Area	UK0002			y		y		n		n
Greater Manchester Urban Area	UK0003			y		y		n		n
West Yorkshire Urban Area	UK0004			y		y		n		n
Tyneside	UK0005			y		y		n		n
Liverpool Urban Area	UK0006			m		m		n		n
Sheffield Urban Area	UK0007			y		y		n		n
Nottingham Urban Area	UK0008			y		y		n		n
Bristol Urban Area	UK0009			y		y		n		n
Brighton/Worthing/Littlehampton	UK0010			y		y		n		n
Leicester Urban Area	UK0011			y		y		n		n
Portsmouth Urban Area	UK0012			y		y		n		n
Teesside Urban Area	UK0013			y		y		n		n
The Potteries	UK0014			y		y		n		n
Bournemouth Urban Area	UK0015			y		y		n		n
Reading/Wokingham Urban Area	UK0016			m		m		n		n
Coventry/Bedworth	UK0017			y		y		n		n
Kingston upon Hull	UK0018			y		y		n		n
Southampton Urban Area	UK0019			y		y		n		n
Birkenhead Urban Area	UK0020			y		y		n		n
Southend Urban Area	UK0021			y		y		n		n
Blackpool Urban Area	UK0022			m		m		n		n
Preston Urban Area	UK0023			y		y		n		n

Table 7.1. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

- Form 8a List of zones in relation to limit value exceedences for SO <sub>2</sub>										
Zone	Zone code	LV for health (1hr mean)			LV for health (24hr mean)		LV for ecosystems (annual mean)		LV for ecosystems (winter mean)	
		>LV+ MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV	>LV	≤LV	>LV	≤LV
Glasgow Urban Area	UK0024			y		y		n		n
Edinburgh Urban Area	UK0025			m		m		n		n
Cardiff Urban Area	UK0026			y		y		n		n
Swansea Urban Area	UK0027			y		y		n		n
Belfast Urban Area	UK0028			y		y		n		n
Eastern	UK0029	m			m			y		y
South West	UK0030			y		y		m		m
South East	UK0031			y		y		y		y
East Midlands	UK0032			y		y		y		y
North West & Merseyside	UK0033			y		y		m		m
Yorkshire & Humberside	UK0034			y		y		m		m
West Midlands	UK0035			y		y		m		m
North East	UK0036			y		y		m		m
Central Scotland	UK0037			y		y		m		m
North East Scotland	UK0038			y		y		m		m
Highland	UK0039			m		m		m		m
Scottish Borders	UK0040			m		m		m		m
South Wales	UK0041			y		y		m		m
North Wales	UK0042			y		y		m		m
Northern Ireland	UK0043			y		y		m		m



Table 7.2. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

- Form 8b List of zones in relation to limit value exceedences for NO<sub>2</sub>/NO<sub>x</sub>

Zone	Zone code	LV for health (1hr mean)			LV for health (annual mean)			LV for vegetation	
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV
Greater London Urban Area	UK0001	y			y				n
West Midlands Urban Area	UK0002			y	m				n
Greater Manchester Urban Area	UK0003			y	y				n
West Yorkshire Urban Area	UK0004			y	m				n
Tyneside	UK0005			y	m				n
Liverpool Urban Area	UK0006				m				n
Sheffield Urban Area	UK0007			y	m				n
Nottingham Urban Area	UK0008			y	m				n
Bristol Urban Area	UK0009			y	m				n
Brighton/Worthing/Littlehampton	UK0010			y		y			n
Leicester Urban Area	UK0011			y	m				n
Portsmouth Urban Area	UK0012			y	m				n
Teesside Urban Area	UK0013			y	m				n
The Potteries	UK0014			y	m				n
Bournemouth Urban Area	UK0015			y		m			n
Reading/Wokingham Urban Area	UK0016				m				n
Coventry/Bedworth	UK0017			y		m			n
Kingston upon Hull	UK0018			y	m				n
Southampton Urban Area	UK0019			y	m				n
Birkenhead Urban Area	UK0020			y		m			n
Southend Urban Area	UK0021			y	m				n
Blackpool Urban Area	UK0022			y		m			n
Preston Urban Area	UK0023			y		m			n
Glasgow Urban Area	UK0024		y		y				n
Edinburgh Urban Area	UK0025				m				n
Cardiff Urban Area	UK0026			y	m				n
Swansea Urban Area	UK0027			y	m				n
Belfast Urban Area	UK0028			y	m				n

Table 7.2. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

- Form 8b List of zones in relation to limit value exceedences for NO<sub>2</sub>/NO<sub>x</sub>

Zone	Zone code	LV for health (1hr mean)			LV for health (annual mean)			LV for vegetation	
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV
Eastern	UK0029			y	m				y
South West	UK0030			y	y				m
South East	UK0031		y		y				y
East Midlands	UK0032			y	m				y
North West & Merseyside	UK0033			y	m				m
Yorkshire & Humberside	UK0034			y	m				m
West Midlands	UK0035				m				m
North East	UK0036			y	m				m
Central Scotland	UK0037			y	m				m
North East Scotland	UK0038			y	m				m
Highland	UK0039			y		m			m
Scottish Borders	UK0040			y			y		m
South Wales	UK0041			y	m				y
North Wales	UK0042			y	m				m
Northern Ireland	UK0043			y	m				m

Table 7.3. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)												
- Form 8c List of zones in relation to limit value exceedences for PM <sub>10</sub>												
Zone	Zone code	LV (24hr mean) Stage 1			LV (annual mean) Stage 1			LV (24hr mean) Stage 2		LV (annual mean) Stage 2		
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV
Greater London Urban Area	UK0001	y			y			y		y		
West Midlands Urban Area	UK0002	m			m			y		m		
Greater Manchester Urban Area	UK0003		y				y	y		y		
West Yorkshire Urban Area	UK0004	m			m			y		m		
Tyneside	UK0005		m				y	y		m		
Liverpool Urban Area	UK0006		m				m			m		
Sheffield Urban Area	UK0007	m				m		y		m		
Nottingham Urban Area	UK0008		m				y	y		m		
Bristol Urban Area	UK0009	m				m		y		m		
Brighton/Worthing/Littlehampton	UK0010			y			y	y		y		
Leicester Urban Area	UK0011		m				y	y		m		
Portsmouth Urban Area	UK0012	m			m			y		m		
Teesside Urban Area	UK0013	m			m			y		m		
The Potteries	UK0014	m				m				m		
Bournemouth Urban Area	UK0015		m				y	y		m		
Reading/Wokingham Urban Area	UK0016		m				m			m		
Coventry/Bedworth	UK0017		m				y		y	m		
Kingston upon Hull	UK0018	m					y	y		m		
Southampton Urban Area	UK0019	m					y	y		m		
Birkenhead Urban Area	UK0020			y			y	y			m	
Southend Urban Area	UK0021		m				y	y		m		

Table 7.3. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)												
- Form 8c List of zones in relation to limit value exceedences for PM <sub>10</sub>												
Zone	Zone code	LV (24hr mean) Stage 1			LV (annual mean) Stage 1			LV (24hr mean) Stage 2		LV (annual mean) Stage 2		
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV
Blackpool Urban Area	UK0022			y			y	y			y	
Preston Urban Area	UK0023			y			y	y			y	
Glasgow Urban Area	UK0024		y				y	y		y		
Edinburgh Urban Area	UK0025			m			m				m	
Cardiff Urban Area	UK0026		y				y	y		y		
Swansea Urban Area	UK0027		y				y	y		y		
Belfast Urban Area	UK0028			y			y	y		m		
Eastern	UK0029	m			m			y		m		
South West	UK0030		m				y		y	m		
South East	UK0031	m			m			y		m		
East Midlands	UK0032	m			m			y		m		
North West & Merseyside	UK0033	m				m		y		m		
Yorkshire & Humberside	UK0034	y			m			y		y		
West Midlands	UK0035	m					y	y		m		
North East	UK0036	m			m			y		y		
Central Scotland	UK0037		m			m		y		m		
North East Scotland	UK0038			y			y	y		m		
Highland	UK0039			y			y	y			m	
Scottish Borders	UK0040			y			y	y			y	
South Wales	UK0041	m					y		y	m		
North Wales	UK0042		y				y	y		m		
Northern Ireland	UK0043			y			y	y			y	

**Table 7.4. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)**

**- Form 8d List of zones in relation to limit value exceedences for lead**

Zone	Zone code	LV		
		>LV+MOT	≤LV+MOT; >LV	≤LV
Greater London Urban Area	r hMMMN			y
West Midlands Urban Area	r hMMM0			y
Greater Manchester Urban Area	r hMMM P			y
West Yorkshire Urban Area	r hMMM Q			y
Tyneside	r hMMMR			
Liverpool Urban Area	r hMMMS			
Sheffield Urban Area	r hMMMT			y
Nottingham Urban Area	r hMMMU			
Bristol Urban Area	r hMMMV			
Brighton/Worthing/Littlehampton	r hMMNM			
Leicester Urban Area	r hMMNN			
Portsmouth Urban Area	r hMMNO			
Teesside Urban Area	r hMMNP			
The Potteries	r hMMNQ			
Bournemouth Urban Area	r hMMNR			
Reading/Wokingham Urban Area	r hMMNS			
Coventry/Bedworth	r hMMNT			
Kingston upon Hull	r hMMNU			
Southampton Urban Area	r hMMNV			
Birkenhead Urban Area	r hMMOM			
Southend Urban Area	r hMMON			
Blackpool Urban Area	r hMMOO			
Preston Urban Area	r hMMOP			
Glasgow Urban Area	r hMMOQ			y
Edinburgh Urban Area	r hMMOR			
Cardiff Urban Area	r hMMOS			y
Swansea Urban Area	r hMMOT			

**Table 7.4. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)**

**- Form 8d List of zones in relation to limit value exceedences for lead**

Zone	Zone code	LV		
		>LV+MOT	≤LV+MOT; >LV	≤LV
Belfast Urban Area	r hM MOU			
Eastern	r hM MOV			
South West	r hM MPM			y
South East	r hM MPN			
East Midlands	r hM MPO			
North West & Merseyside	r hM MPP			
Yorkshire & Humberside	r hM MPQ			
West Midlands	r hM MPR			
North East	r hM MPS			
Central Scotland	r hM MPT			
North East Scotland	r hM MPU			
Highland	r hM MPV			
Scottish Borders	r hM MQM			y
South Wales	r hM MQN			
North Wales	r hM MQO			
Northern Ireland	r hM MQP			

Table 7.5 List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

- Form 8e List of zones in relation to limit value exceedences for benzene

Zone	Zone code	LV		
		>LV + MOT	≤LV+MOT; >LV	≤LV
Greater London Urban Area	UK0001		m	
West Midlands Urban Area	UK0002			y
Greater Manchester Urban Area	UK0003			y
West Yorkshire Urban Area	UK0004			y
Tyneside	UK0005			y
Liverpool Urban Area	UK0006			y
Sheffield Urban Area	UK0007			y
Nottingham Urban Area	UK0008			y
Bristol Urban Area	UK0009			y
Brighton/Worthing/Littlehampton	UK0010			y
Leicester Urban Area	UK0011			y
Portsmouth Urban Area	UK0012			y
Teesside Urban Area	UK0013			y
The Potteries	UK0014			y
Bournemouth Urban Area	UK0015			y
Reading/Wokingham Urban Area	UK0016			y
Coventry/Bedworth	UK0017			y
Kingston upon Hull	UK0018			y
Southampton Urban Area	UK0019			y
Birkenhead Urban Area	UK0020			m
Southend Urban Area	UK0021			y

Table 7.5 List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

- Form 8e List of zones in relation to limit value exceedences for benzene

Zone	Zone code	LV		
		>LV + MOT	≤LV+MOT; >LV	≤LV
Blackpool Urban Area	UK0022			m
Preston Urban Area	UK0023			m
Glasgow Urban Area	UK0024			m
Edinburgh Urban Area	UK0025			y
Cardiff Urban Area	UK0026			m
Swansea Urban Area	UK0027			m
Belfast Urban Area	UK0028			y
Eastern	UK0029			y
South West	UK0030			y
South East	UK0031			y
East Midlands	UK0032			y
North West & Merseyside	UK0033			y
Yorkshire & Humberside	UK0034			y
West Midlands	UK0035			y
North East	UK0036			y
Central Scotland	UK0037			y
North East Scotland	UK0038			m
Highland	UK0039			m
Scottish Borders	UK0040			m
South Wales	UK0041			y
North Wales	UK0042			m
Northern Ireland	UK0043			m

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Table 7.6 List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

- Form 8f List of zones in relation to limit value for carbon monoxide

Zone	Zone code	LV		
		>LV + MOT	≤LV + MOT; >LV	≤LV
Greater London Urban Area	UK0001			y
West Midlands Urban Area	UK0002			y
Greater Manchester Urban Area	UK0003			y
West Yorkshire Urban Area	UK0004			y
Tyneside	UK0005			y
Liverpool Urban Area	UK0006			m
Sheffield Urban Area	UK0007			y
Nottingham Urban Area	UK0008			y
Bristol Urban Area	UK0009			y
Brighton/Worthing/Littlehampton	UK0010			y
Leicester Urban Area	UK0011			y
Portsmouth Urban Area	UK0012			y
Teesside Urban Area	UK0013			y
The Potteries	UK0014			y
Bournemouth Urban Area	UK0015			y
Reading/Wokingham Urban Area	UK0016			m
Coventry/Bedworth	UK0017			y
Kingston upon Hull	UK0018			y
Southampton Urban Area	UK0019			m
Birkenhead Urban Area	UK0020			y
Southend Urban Area	UK0021			y
Blackpool Urban Area	UK0022			y
Preston Urban Area	UK0023			y

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Table 7.6 List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

- Form 8f List of zones in relation to limit value for carbon monoxide

Zone	Zone code	LV		
		>LV + MOT	≤LV + MOT; >LV	≤LV
Glasgow Urban Area	UK0024			y
Edinburgh Urban Area	UK0025			m
Cardiff Urban Area	UK0026			y
Swansea Urban Area	UK0027			y
Belfast Urban Area	UK0028			y
Eastern	UK0029			y
South West	UK0030			y
South East	UK0031			y
East Midlands	UK0032			y
North West & Merseyside	UK0033			y
Yorkshire & Humberside	UK0034			y
West Midlands	UK0035			y
North East	UK0036			y
Central Scotland	UK0037			m
North East Scotland	UK0038			y
Highland	UK0039			y
Scottish Borders	UK0040			y
South Wales	UK0041			y
North Wales	UK0042			y
Northern Ireland	UK0043			y

## 7.2 MEASURED EXCEEDENCES OF LIMIT VALUES + MARGINS TOLERANCE

Form 11 of the questionnaire requires reasons associated with the measured exceedences of the limit value and margin of tolerance to be documented. This information is summarised in Tables 7.7 to 7.9 for monitoring stations in the UK at which exceedences of the limit value and margin of tolerance were measured. Measured exceedences of the limit value and margin of tolerance for 1-hour mean NO<sub>2</sub> are listed in Table 7.7. Measured exceedences of the limit value and margin of tolerance for annual mean NO<sub>2</sub> are listed in Table 7.8. Measured exceedences of the limit value and margin of tolerance for 24-hour mean PM<sub>10</sub> are listed in Table 7.9 and 7.10.

**Table 7.7. Measured exceedences of the 1-hour mean NO<sub>2</sub> limit value plus margin of tolerance, 2003 (form 11e). London Marylebone Road (Greater London Urban Area)**

Month	Day of month	Hour	Level (µg m <sup>-3</sup> )	Reason code(s)
April	11	7	275	S2
June	4	8	275	S2
June	17	9	281	S2; S10
August	21	8	279	S2
September	5	17	275	S2; S10
September	5	19	283	S2; S10
September	16	7	283	S2; S10
September	16	8	275	S2; S10
September	16	10	283	S2; S10
September	17	8	279	S2; S10
September	17	13	296	S2; S10
September	17	15	316	S2; S10
September	17	16	281	S2; S10
September	17	17	281	S2; S10
September	26	8	293	S2
September	26	12	285	S2
October	8	7	273	S2
October	27	9	308	S2
October	28	8	275	S2
November	4	7	281	S2
November	4	8	279	S2
November	13	8	281	S2
November	14	9	283	S2
November	17	8	295	S2
November	17	14	275	S2
November	17	16	291	S2
November	26	16	272	S2
November	27	16	293	S2
November	27	17	283	S2
November	28	7	273	S2
November	28	8	275	S2
December	10	14	340	S2

Month	Day of month	Hour	Level ( $\mu\text{g m}^{-3}$ )	Reason code(s)
December	10	15	394	S2
December	10	16	333	S2
December	10	17	321	S2
December	10	18	285	S2
December	10	19	319	S2
December	10	20	273	S2
December	11	13	333	S2
December	16	7	281	S2
December	16	8	298	S2
December	16	9	300	S2
December	16	13	291	S2
December	16	15	281	S2
December	16	16	317	S2
December	19	9	281	S2

S2 = Proximity to a major road

S10 = Transport of air pollution from sources outside the Member State

**Table 7.8. Measured exceedences of the annual mean NO<sub>2</sub> limit value plus margin of tolerance, 2003 (form 11f)**

Site	Zone	Level ( $\mu\text{g m}^{-3}$ )	Reason code
London A3 Roadside	Greater London Urban Area	73	S2
London Cromwell Road 2	Greater London Urban Area	76	S2
London Lewisham	Greater London Urban Area	55	S2
London Marylebone Road	Greater London Urban Area	107	S2
London Wandsworth	Greater London Urban Area	63	S2
Southwark Roadside	Greater London Urban Area	67	S2
Tower Hamlets Roadside	Greater London Urban Area	67	S2
West London	Greater London Urban Area	55	S1
Bury Roadside	Greater Manchester Urban Area	76	S2
Bath Roadside	South West	61	S2
Oxford Centre	South East	72	S2
Glasgow Kerbside	Glasgow Urban Area	75	S2

S1 = Heavily trafficked urban centre

S2 = Proximity to a major road

**Table 7.9. Measured exceedences of the 24-hour mean PM<sub>10</sub> limit value plus margin of tolerance, 2003 (form 11h). London Marylebone Road (Greater London Urban Area)**

Month	Day of month	Level ( $\mu\text{g m}^{-3}$ )	Reason code(s)
January	12	68	S2
January	14	65	S2
January	15	61	S2
January	16	69	S2
January	24	74	S2
February	6	88	S2
February	7	61	S2
February	18	67	S2
February	19	91	S2
February	20	78	S2

Month	Day of month	Level ( $\mu\text{g m}^{-3}$ )	Reason code(s)
February	21	95	S2
February	22	100	S2
February	23	63	S2
February	24	64	S2
February	25	84	S2
February	26	80	S2
February	27	67	S2
March	10	66	S2
March	20	71	S2;S10
March	23	61	S2;S10
March	24	85	S2;S10
March	25	80	S2;S10
March	26	84	S2;S10
March	27	71	S2;S10
March	28	76	S2;S10
March	29	74	S2;S10
April	14	78	S2;S8
April	15	87	S2;S8
April	16	76	S2;S8;S10
April	17	69	S2;S8;S10
April	20	79	S2;S10
April	22	66	S2;S10
April	23	64	S2;S10
April	24	76	S2;S10
May	31	70	S2
June	4	63	S2
June	10	70	S2
June	16	71	S2
June	17	70	S2
June	30	61	S2
July	10	64	S2
July	14	61	S2;S10
July	15	65	S2;S10
July	16	76	S2;S10
August	1	63	S2
August	4	65	S2
August	6	81	S2
August	7	67	S2
August	8	86	S2;S10
August	9	94	S2;S10
August	10	89	S2;S10
August	11	92	S2;S10
August	12	68	S2;S10
August	18	62	S2
September	4	66	S2;S10
September	5	66	S2;S10
September	11	65	S2;S10
September	15	66	S2;S10
September	16	71	S2;S10
September	17	77	S2;S10

Month	Day of month	Level ( $\mu\text{g m}^{-3}$ )	Reason code(s)
September	18	86	S2;S10
September	19	86	S2;S10
September	20	82	S2;S10
October	28	73	S2
November	4	76	S2
November	6	77	S2
November	7	66	S2
November	13	67	S2
November	14	65	S2
November	27	65	S2
November	28	70	S2
December	9	66	S2
December	10	61	S2
December	16	84	S2
December	17	67	S2
December	18	72	S2
December	19	91	S2

S2 = Proximity to a major road

S8 = Natural source(s) or natural event(s)

S10 = Transport of air pollution from sources outside the Member State

**Table 7.10. Measured exceedences of the 24-hour mean PM<sub>10</sub> limit value plus margin of tolerance, 2003 (form 11h). Scunthorpe (Yorkshire & Humberside)**

Month	Day of month	Level ( $\mu\text{g m}^{-3}$ )	Reason code(s)
February	13	72	S3
February	14	70	S3
February	17	68	S3
February	18	70	S3
February	19	64	S3
February	20	79	S3
February	21	83	S3
February	22	91	S3
February	25	103	S3
February	26	88	S3
February	27	107	S3
March	14	64	S3
March	15	70	S3
March	17	64	S3;S10
March	19	81	S3;S10
March	21	76	S3;S10
March	22	67	S3;S10
March	23	73	S3;S10
March	24	67	S3;S10
March	25	70	S3;S10
March	26	91	S3;S10
March	27	94	S3;S10
March	28	94	S3;S10
March	29	105	S3;S10
March	31	66	S3
April	7	83	S3

Month	Day of month	Level ( $\mu\text{g m}^{-3}$ )	Reason code(s)
April	8	67	S3
April	13	117	S3;S10
April	14	137	S3;S10;S8
April	15	134	S3;S10;S8
April	16	132	S3;S10;S8
April	17	152	S3;S10;S8
April	18	97	S3;S10;S8
April	19	81	S3;S10
April	20	107	S3;S10
April	21	65	S3;S10
April	23	97	S3;S10
April	24	77	S3;S10
April	25	73	S3;S10
May	29	88	S3;S10
May	30	99	S3;S10
May	31	96	S3;S10
June	3	87	S3
June	16	92	S3
June	25	68	S3
July	13	66	S3
July	14	95	S3
July	15	97	S3
July	16	108	S3
August	4	95	S3;S10
August	5	98	S3;S10
August	6	86	S3;S10
August	10	97	S3;S10
August	17	67	S3
September	4	63	S3;S10
September	5	69	S3;S10
September	30	88	S3;S10
October	1	70	S3;S10
October	12	68	S3
October	13	90	S3
October	14	102	S3
October	15	87	S3
October	17	61	S3
November	6	72	S3
November	7	76	S3
November	8	61	S3
November	10	71	S3
December	8	68	S3
December	9	80	S3
December	18	71	S3

S3 = Local industry including power production

S8 = Natural source(s) or natural event(s)

S10 = Transport of air pollution from sources outside the Member State

### 7.3 COMPARISON WITH 2002 AND 2001

Tables 7.11 and 7.12 provide a comparison of the monitoring and modelling results for 2003 with the results of the air quality assessments reported to the EU for 2001 and 2002 (Stedman, et al 2002, Stedman, et al 2003). The listed numbers of zones exceeding the LV in Table 7.12 include the zones exceeding the LV + MOT. An exceedence of the LV can be determined by either measurements or modelling. Where an exceedence of the LV + MOT has been determined by modelling, the exceedence of the LV in this zone may still be determined by either measurements or modelling but this distinction is not shown in Tables 7.1 to 7.6.

Modelled exceedences of the 1-hour LV + MOT and 24-hour LV for SO<sub>2</sub> have been reported for 2003. The modelling analysis indicates that these exceedences were associated with emissions from a brick works. There were no reported exceedences of the annual or winter mean limit values for SO<sub>2</sub> in ecosystem areas.

An exceedence of the 1-hour LV + MOT for NO<sub>2</sub> has been reported for the first time in 2003. The reasons for this exceedence at the London Marylebone Road site are currently being investigated and appear to be related to an increase in NO<sub>2</sub> concentrations without an associated increase in NO<sub>x</sub> concentrations. Reasons may include changes in traffic management and fleet emission characteristics. There were more zones with reported exceedences of the LV and LV + MOT for annual mean NO<sub>2</sub> in 2003 than in 2001 or 2002. This was due to a combination of the photochemical episodes associated with the warm weather in 2003 and revisions to the model methods used to calculate roadside NO<sub>2</sub> concentrations from roadside NO<sub>x</sub>. There were no reported exceedences of the annual mean LV for NO<sub>x</sub> in vegetation areas.

There were many more zones with reported exceedences of the LV + MOT and LV for PM<sub>10</sub> in 2003 than in 2001 or 2002. This was due to the unusually high secondary PM<sub>10</sub> during 2003.

There were no exceedences for Lead in 2001, 2002 or 2003.

2003 is the first year for which the air quality assessments for benzene and CO have been completed. Benzene concentrations were below the LV in all zones except for the Greater London Urban Area. CO concentrations were below the LV in all zones.



Table 7.11 Exceedences of limit values plus margins of tolerance

Pollutant	Averaging time	2003	2002	2001
SO <sub>2</sub>	1-hour	1 zone modelled (Eastern)	none	none
SO <sub>2</sub>	24-hour <sup>1</sup>	1 zone modelled (Eastern)	none	1 zone measured (Belfast Urban Area)
SO <sub>2</sub>	annual <sup>2</sup>	n/a	n/a	n/a
SO <sub>2</sub>	winter <sup>2</sup>	n/a	n/a	n/a
NO <sub>2</sub>	1-hour <sup>3</sup>	1 zone measured (Greater London Urban Area)	none	none
NO <sub>2</sub>	annual	35 zones (5 measured + 30 modelled)	19 Zones (5 measured + 14 modelled)	21 Zones (4 measured + 17 modelled)
NO <sub>x</sub>	annual <sup>2</sup>	n/a	n/a	n/a
PM <sub>10</sub>	24-hour (Stage 1)	18 zones (2 measured + 16 modelled)	1 zone modelled (Greater London Urban Area)	1 zone modelled (Greater London Urban Area)
PM <sub>10</sub>	annual (Stage 1)	10 zones (1 measured + 9 modelled)	1 zone modelled (Greater London Urban Area)	1 zone modelled (Greater London Urban Area)
PM <sub>10</sub>	24-hour <sup>4</sup> (Stage 2)	n/a	n/a	n/a
PM <sub>10</sub>	annual <sup>5</sup> (Stage 2)	36 zones (8 measured + 28 modelled)	22 zones (3 measured + 18 modelled)	not assessed
Lead	annual	none	none	none
Benzene	annual	none	not assessed	not assessed
CO	8-hour	none	not assessed	not assessed

<sup>1</sup> No MOT defined, LV + MOT = LV

<sup>2</sup> Applies to vegetation and ecosystem areas only. No MOT defined, LVs are already in force

<sup>3</sup> No modelling for 1-hour LV

<sup>4</sup> Stage 2 indicative LV, no MOT defined for 24-hour LV, no modelling for 24-hour Stage 2 LV

<sup>5</sup> Stage 2 indicative LV

Table 7.12 Exceedences of limit values

Pollutant	Averaging time	2003	2002	2001
SO <sub>2</sub>	1-hour	1 zone modelled (Eastern)	none	none
SO <sub>2</sub>	24-hour <sup>1</sup>	1 zone modelled (Eastern)	none	1 Zone measured (Belfast Urban Area)
SO <sub>2</sub>	Annual <sup>2</sup>	none	none	none
SO <sub>2</sub>	Winter <sup>2</sup>	none	none	not assessed
NO <sub>2</sub>	1-hour <sup>3</sup>	3 zones measured (London, Glasgow, South East)	1 zone measured (Glasgow Urban Area)	4 zones measured
NO <sub>2</sub>	Annual	42 zones (10 measured + 32 modelled)	36 zones (6 measured + 30 modelled)	38 zones (6 measured + 32 modelled)
NO <sub>x</sub>	Annual <sup>2</sup>	none	none	None
PM <sub>10</sub>	24-hour (Stage 1)	33 zones (10 measured + 23 modelled)	18 zones (1 measured + 17 modelled)	26 zones (5 measured + 21 modelled)
PM <sub>10</sub>	annual (Stage 1)	15 zones (1 measured + 14 modelled)	2 zones (Greater London Urban Area measured, Eastern modelled)	2 zones (Greater London Urban Area measured, Greater Manchester Urban Area modelled)
PM <sub>10</sub>	24-hour <sup>4</sup> (Stage 2)	36 zones (36 measured)	21 zones (21 measured)	25 zones (25 measured)
PM <sub>10</sub>	annual <sup>5</sup> (Stage 2)	43 zones (35 measured + 8 modelled)	42 zones (16 measured, 26 modelled)	43 zones (28 measured, 15 modelled)
Lead	Annual	none	none	none
Benzene	Annual	1 zone modelled (Greater London Urban Area)	not assessed	not assessed
CO	8-hour	none	not assessed	not assessed

<sup>1</sup> No MOT defined, LV + MOT = LV

<sup>2</sup> Applies to vegetation and ecosystem areas only. No MOT defined, LVs are already in force

<sup>3</sup> No modelling for 1-hour LV

<sup>4</sup> Stage 2 indicative LV, no modelling for 24-hour Stage 2 LV

<sup>5</sup> Stage 2 indicative LV

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## APPENDIX 1. NATIONAL NETWORK MONITORING SITES

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Table A1.1. Monitoring sites operating during 2003 for AQDD1 and AQDD2 reporting.

EoI station code	Local station code	Zone code(s)	Use for Directive							
			SO <sub>2</sub>	NO <sub>2</sub>	NO <sub>x</sub>	Lead	Benzene	CO	PM <sub>10</sub>	PM <sub>2,5</sub>
GB0729A	Aberdeen	UK0038	y	y				y	M3	
GB0031R	Aston Hill	UK0042		y	y					
GB0600A	Barnsley 12	UK0034	y							
GB0681A	Barnsley Gawber	UK0034	y	y				y		
GB0647A	Bath Roadside	UK0030		y				y		
GB0567A	Belfast Centre	UK0028	y	y				y	M3	
GB0696A	Belfast Clara St	UK0028							M1	
GB0514A	Belfast East	UK0028	y							
GB0421A	Billingham	UK0013		y						
GB0569A	Birmingham Centre	UK0002	y	y				y	M3	
GB0595A	Birmingham East	UK0002	y	y				y	M3	
GB0727A	Blackpool	UK0022	y	y				y	M3	
GB0654A	Bolton	UK0003	y	y				y	M3	
GB0741A	Bournemouth	UK0015	y	y				y	M2	
GB0689A	Bradford Centre	UK0004	y	y				y	M3	
GB0774A	Brentford Roadside	UK0001		y				y		
GB0693A	Brighton Roadside	UK0010		y				y		
GB0845A	Brighton Roadside PM10	UK0010							M2	
GB0585A	Bristol Centre	UK0009	y	y				y	M3	
GB0639A	Bristol Old Market	UK0009		y				y		
GB0652A	Bury Roadside	UK0003	y	y				y	M3	
GB0033R	Bush Estate	UK0037		y	y					
GB0726A	Cambridge Roadside	UK0029		y						
GB0636A	Camden Kerbside	UK0001		y					M3	
GB0737A	Canterbury	UK0031		y					M3	
GB0580A	Cardiff Centre	UK0026	y	y				y	M3	
GB0739A	Coventry Memorial Park	UK0017	y	y				y	M3	
GB0744A	Cwmbran	UK0041	y	y				y	M3	
GB0673A	Derry	UK0043	y	y				y	M3	
GB0740A	Dumfries	UK0040		y				y	M2	
GB0581A	Edinburgh Centre	UK0025	y	y				y	M3	
GB0839A	Edinburgh St Leonards	UK0025	y	y				y	M3	
GB0640A	Exeter Roadside	UK0030	y	y				y		
GB0641A	Glasgow Centre	UK0024	y	y				y	M3	
GB0452A	Glasgow City Chambers	UK0024		y				y		
GB0657A	Glasgow Kerbside	UK0024		y				y	M3	
GB0735A	Grangemouth	UK0037	y	y				y	M3	
GB0637A	Haringey Roadside	UK0001		y					M3	
GB0036R	Harwell	UK0031	y	y	y				M3	M3
GB0014R	High Muffles	UK0034		y	y					
GB0686A	Hove Roadside	UK0010	y	y				y		
GB0776A	Hull Freetown	UK0018	y	y				y	M3	
GB0742A	Inverness	UK0039		y				y	M2	
GB0037R	Ladybower	UK0032	y	y	y					

EoI station code	Local station code	Zone code(s)	Use for Directive							
			SO <sub>2</sub>	NO <sub>2</sub>	NO <sub>x</sub>	Lead	Benzene	CO	PM <sub>10</sub>	PM <sub>2.5</sub>
GB0643A	Leamington Spa	UK0035	y	y				y	M3	
GB0584A	Leeds Centre	UK0004	y	y				y	M3	
GB0597A	Leicester Centre	UK0011	y	y				y	M3	
GB0777A	Liverpool Speke	UK0006	y	y				y	M3	
GB0659A	London A3 Roadside	UK0001		y				y	M3	
GB0608A	London Bexley	UK0001	y	y				y	M3	
GB0566A	London Bloomsbury	UK0001	y	y				y	M3	M3
GB0616A	London Brent	UK0001	y	y				y	M3	
GB0697A	London Bromley	UK0001		y				y		
GB0695A	London Cromwell Road 2	UK0001	y	y				y		
GB0586A	London Eltham	UK0001	y	y					M3	
GB0650A	London Hackney	UK0001		y				y		
GB0642A	London Hillingdon	UK0001	y	y				y	M3	
GB0672A	London Lewisham	UK0001	y	y						
GB0682A	London Marylebone Road	UK0001	y	y				y	M3	M3
GB0620A	London N. Kensington	UK0001	y	y				y	M3	
GB0656A	London Southwark	UK0001	y	y				y		
GB0644A	London Teddington	UK0001	y	y						
GB0622A	London Wandsworth	UK0001		y						
GB0743A	London Westminster	UK0001	y	y				y	M2	
GB0006R	Lough Navar	UK0043							M3	
GB0038R	Lullington Heath	UK0031	y	y	y					
GB0613A	Manchester Piccadilly	UK0003	y	y				y	M3	
GB0649A	Manchester South	UK0003	y	y						
GB0453A	Manchester Town Hall	UK0003		y				y		
GB0838A	Market Harborough	UK0032		y	y			y		
GB0583A	Middlesbrough	UK0013	y	y				y	M3	
GB0043R	Narberth	UK0041	y	y	y				M3	
GB0568A	Newcastle Centre	UK0005	y	y				y	M3	
GB0738A	Northampton	UK0032	y	y				y	M3;M2	
GB0684A	Norwich Centre	UK0029	y	y				y	M3	
GB0678A	Norwich Roadside	UK0029		y						
GB0646A	Nottingham Centre	UK0008	y	y				y	M3	
GB0633A	Oxford Centre	UK0031	y	y				y		
GB0687A	Plymouth Centre	UK0030	y	y				y	M3	
GB0651A	Port Talbot	UK0027	y	y					M3	
GB0733A	Portsmouth	UK0012	y	y				y	M3	
GB0731A	Preston	UK0023	y	y				y	M3	
GB0683A	Reading	UK0016	y	y				y	M3	
GB0840A	Reading New Town	UK0016	y	y				y	M3	
GB0679A	Redcar	UK0013	y	y				y	M3	
GB0617A	Rochester	UK0031	y	y	y				M3	M3
GB0677A	Rotherham Centre	UK0007	y	y						
GB0660A	Salford Eccles	UK0003	y	y				y	M3	
GB0698A	Sandwell West Bromwich	UK0002	y	y				y		
GB0690A	Scunthorpe	UK0034	y						M3	
GB0615A	Sheffield Centre	UK0007	y	y				y	M3	

EoI station code	Local station code	Zone code(s)	Use for Directive							
			SO <sub>2</sub>	NO <sub>2</sub>	NO <sub>x</sub>	Lead	Benzene	CO	PM <sub>10</sub>	PM <sub>2.5</sub>
GB0538A	Sheffield Tinsley	UK0007		y				y		
GB0044R	Somerton	UK0030		y	y					
GB0598A	Southampton Centre	UK0019	y	y				y	M3	
GB0728A	Southend-on-Sea	UK0021	y	y				y	M3	
GB0667A	Southwark Roadside	UK0001	y	y				y		
GB0754A	St Osyth	UK0029		y	y			y		
GB0775A	Stockport Shaw Heath	UK0003	y	y				y	M3	
GB0734A	Stockton-on-Tees Yarm	UK0036		y				y	M3	
GB0658A	Stoke-on-Trent Centre	UK0014	y	y				y	M3	
GB0582A	Sunderland	UK0036	y							
GB0609A	Swansea	UK0027	y	y				y	M3	
GB0645A	Thurrock	UK0029	y	y				y	M3	
GB0642A	Tower Hamlets Roadside	UK0001		y				y		
GB0455A	Walsall Alumwell	UK0002		y						
GB0674A	Walsall Willenhall	UK0002		y						
GB0420A	West London	UK0001		y				y		
GB0045R	Wicken Fen	UK0029	y	y	y					
GB0736A	Wigan Leigh	UK0033	y	y				y	M3	
GB0730A	Wirral Tranmere	UK0020	y	y				y	M3	
GB0614A	Wolverhampton Centre	UK0002	y	y				y	M3	
GB0755A	Wrexham	UK0042	y	y				y	M2	
GB0013R	Yarner Wood	UK0030		y	y					
GB0635A	Brent Park	UK0001				y				
GB0417A	Brookside 2	UK0002				y				
GB0369A	Cardiff	UK0026				y				
GB0537A	Central London Lead	UK0001				y				
GB0332A	Cromwell Road Lead	UK0001				y				
GB0419A	Elswick 6	UK0005				y				
GB0361A	Eskdalemuir Lead	UK0040				y				
GB0260A	Glasgow	UK0024				y				
GB0789A	Hallen	UK0030				y				
GB0382A	IMI 2	UK0002				y				
GB0248A	Leeds Market Building	UK0004				y				
GB0846A	London Marylebone Road	UK0001				y				
GB0370A	Manchester	UK0003				y				
GB0241A	Motherwell	UK0024				y				
GB0892A	Rotherham	UK0007				y				
GB0791A	Wakefield	UK0004				y				
GB0804A	Barnsley Gawber HC	UK0034					y			
GB0806A	Belfast Centre HC	UK0028					y			
GB0805A	Belfast Roadside	UK0028					y			
GB0807A	Birmingham Roadside	UK0002					y			
GB0808A	Bournemouth HC	UK0015					y			
GB0809A	Bristol Old Market HC	UK0009					y			
GB0783A	Cardiff Centre HC	UK0026					y			
GB0811A	Coventry Memorial Park HC	UK0017					y			
GB0812A	Cwmbran HC	UK0041					y			



EoI station code	Local station code	Zone code(s)	Use for Directive							
			SO <sub>2</sub>	NO <sub>2</sub>	NO <sub>x</sub>	Lead	Benzene	CO	PM <sub>10</sub>	PM <sub>2.5</sub>
GB0813A	Edinburgh Med. Sch. HC	UK0025					y			
GB0784A	Glasgow Kerbside HC	UK0024					y			
GB0814A	Grangemouth HC	UK0037					y			
GB0815A	Haringey Roadside HC	UK0001					y			
GB0782A	Harwell HC	UK0031					y			
GB0816A	Hove Roadside HC	UK0010					y			
GB0817A	Hull Freetown HC	UK0018					y			
GB0818A	Leamington Spa HC	UK0035					y			
GB0819A	Leeds Centre HC	UK0004					y			
GB0820A	Leeds Roadside	UK0004					y			
GB0821A	Leicester Centre	UK0011					y			
GB0822A	Liverpool Centre HC	UK0006					y			
GB0810A	London Bloomsbury HC	UK0001					y			
GB0785A	London Marylebone Road HC	UK0001					y			
GB0823A	Manchester Piccadilly HC	UK0003					y			
GB00795A	Middlesbrough HC	UK0013					y			
GB0824A	Newcastle Centre HC	UK0005					y			
GB0827A	Northampton HC	UK0032					y			
GB0825A	Norwich Centre HC	UK0029					y			
GB0826A	Nottingham Centre HC	UK0008					y			
GB00828A	Oxford Centre HC	UK0031					y			
GB0829A	Plymouth Centre HC	UK0030					y			
GB0830A	Portsmouth HC	UK0012					y			
GB0831A	Reading HC	UK0016					y			
GB0833A	Sheffield Centre HC	UK0007					y			
GB0800A	Southampton Centre HC	UK0019					y			
GB0832A	Southend-on-Sea HC	UK0021					y			
GB0834A	Stockton-on-Tees Yarm HC	UK0036					y			
GB0835A	Wigan Leigh HC	UK0033					y			

y = monitoring for the Directive at that site

M1 = Beta Attenuation Monitor, M2 = Gravimetric, M3 = TEEM measurements for PM<sub>10</sub> and PM<sub>2.5</sub>

Table A1.2. Measurements with between 75 % and 90 % data capture (included in 2003 analysis)

Site	Data capture %				
	SO <sub>2</sub>	NO <sub>2</sub>	PM10	CO	Benzene
Aberdeen	+	88.4	+	+	nm
Belfast Centre	+	+	+	79.3	+
Birmingham Centre	89.7	87.6	85.7	+	nm
Bradford Centre	+	+	+	79.7	nm
Brighton Roadside	nm	86.6	nm	+	nm
Brighton Roadside PM10	nm	nm	75.1	nm	nm
Bristol Centre	+	87.5	+	85.8	nm
Bury Roadside	+	89.1	+	+	nm
Cambridge Roadside	nm	89.3	nm	nm	nm
Cardiff Centre	88.9	87.5	89.6	88	75.9
Coventry Memorial Park	86.9	87.4	81.6	82	88.4
Cwmbran	+	87.7	+	+	+
Exeter Roadside	+	+	nm	89.7	nm
Glasgow Centre	81	-	+	80.4	nm
Glasgow Kerbside	nm	+	+	+	84.9
Haringey Roadside	nm	87.9	+	nm	+
Harwell	+	87.1	+	nm	84.7
Hull Freetown	+	+	88.7	84.4	+
Leamington Spa	81.7	-	85.8	+	+
Leeds Centre	+	86.2	+	86.7	+
Leicester Centre	+	+	88.8	80.3	+
London A3 Roadside	nm	80.3	+	+	nm
London Bexley	+	88.6	+	+	nm
London Bromley	nm	+	nm	76.1	nm
London Cromwell Road 2	88.4	+	nm	88.9	nm
London Hillingdon	+	82.6	88.9	+	nm
Lullington Heath	85.8	88.3	nm	nm	nm
Middlesbrough	+	+	85.5	87.4	+
Narberth	-	79.4	-	nm	nm
Newcastle Centre	+	+	+	76.4	+
Norwich Centre	82.8	+	+	-	+
Nottingham Centre	+	78.7	+	+	+
Plymouth Centre	+	+	+	89.6	80.2
Portsmouth	81.9	+	+	+	+
Rochester	+	+	76.4	nm	nm
Rotherham Centre	90.9	+	nm	nm	nm
Salford Eccles	86.2	+	+	+	nm
Sandwell West Bromwich	+	85.7	nm	-	nm
Southend-on-Sea	81.6	82.6	83.5	86.5	85.7
Southwark Roadside	+	+	nm	-	nm
Stockton-on-Tees Yarm	nm	88.9	+	+	+
Wigan Leigh	86.5	+	+	+	80.2
Wolverhampton Centre	+	+	+	85.6	nm
Wrexham	+	+	86.6	+	nm

+ means data capture above 90%, - means less than 75% and nm means not measured at this site.

**Table A1.3. Measurements with less than 75 % data capture (not included in 2003 analysis but listed in Table A1.1 and form 3)**

Site	Data capture %					
	SO <sub>2</sub>	NO <sub>2</sub>	PM10	CO	Benzene	Lead
Aston Hill	nm	18.7	nm	nm	nm	nm
Birmingham East	+	+	29	69.7	nm	nm
Blackpool	54.9	+	+	+	nm	nm
Brentford Roadside	nm	41.6	nm	34	nm	nm
Bristol Old Market	nm	63.5	nm	+	+	nm
Bush Estate	nm	22.1	nm	nm	nm	nm
Camden Kerbside	nm	43.6	+	nm	nm	nm
Edinburgh Centre	44.1	45.8	44.1	33.8	nm	nm
Edinburgh St Leonards	10.4	10.4	3.4	10.4	nm	nm
Elswick 6	nm	nm	nm	nm	nm	25
Glasgow Centre	=	42.6	+	=	nm	nm
Grangemouth	+	+	+	52.7	+	nm
High Muffles	nm	18.5	nm	nm	nm	nm
Leamington Spa	=	66.5	=	+	+	nm
Liverpool Speke	51	56.9	56.9	56.8	71.2	nm
London Bloomsbury	+	+	58.2	+	+	nm
London Southwark	+	73.2	nm	+	nm	nm
London Westminster	69.2	68.9	64.4	+	nm	nm
Market Harborough	nm	5.3	nm	5.4	nm	nm
Narberth	9.3	=	59	nm	nm	nm
Northampton	+	+	61.9	+	+	nm
Norwich Centre	=	+	+	55.9	+	nm
Reading Centre	9.3	9.2	9.2	9.3	9.6	nm
Reading New Town	13.7	20.4	20.4	20.5	17.8	nm
Sandwell West Bromwich	+	=	nm	73.1	nm	nm
Sheffield Tinsley	nm	+	nm	57.3	nm	nm
Somerton	nm	40.4	nm	nm	nm	nm
Southampton Centre	+	+	+	73.6	+	nm
Southwark Roadside	+	+	nm	38.4	nm	nm
Stockport Shaw Heath	+	+	+	72.1	nm	nm
Stoke-on-Trent Centre	+	+	56.3	+	+	nm
Wicken Fen	+	59.8	nm	nm	nm	nm
Yarner Wood	nm	29.4	nm	nm	nm	nm

+ means data capture above 90%, = means between 75 and 90% data capture and nm means not measured at this site.

**Table A1.4. The effect of applying a data capture threshold of 90% on the results listed in form 8. There are no instances where this would change the overall exceedence status of the zone.**

Pollutant	Averaging time	Total**	Number of zones		
			No change in status of zone***	y becomes m in this zone	y becomes blank in this zone
SO <sub>2</sub>	1-hour	13	6	7	
SO <sub>2</sub>	24-hour	13	6	7	
NO <sub>2</sub>	1-hour	15	7		8
NO <sub>2</sub>	annual	15	13	2	
PM <sub>10</sub>	24-hour (Stage 1)	12	9	3	
PM <sub>10</sub>	Annual (Stage 1)	12	4	8	
PM <sub>10</sub> *	24-hour (Stage 2)	12	4		8
PM <sub>10</sub> *	Annual (Stage 2)	12	9	3	
Benzene	annual	7	2	5	
CO	Max. daily 8-hour mean	14	6	8	

\* Stage 2

\*\* The total number of zones with at least one monitoring site with data capture between 75 % and 90 %

\*\*\* No change in the status of the zone for which monitoring data for a site was between 75 % and 90 %. There would also be no effect in zones for which all sites had data capture greater than 90 %, which is the case in the majority of zones.

See sections 1.4 and 7.1.

## APPENDIX 2. MONITORING SITES USED TO VERIFY THE MAPPED ESTIMATES

Table A2.1. Monitoring sites used to verify the mapped estimates (all PM<sub>10</sub> measurements by TEOM).

Site	Authority or Company	Site Type	SO <sub>2</sub>	NO <sub>2</sub>	PM <sub>10</sub>	CO
Abingdon	Vale of White Horse DC	URBAN BACKGROUND	y		y	
Ards	Ards Borough Council	URBAN BACKGROUND	y			
Bacton Gas Terminal	BP Amoco Exploration	RURAL	y	y		
Birmingham Airport	Birmingham International Airport	URBAN BACKGROUND	y		y	y
Birmingham Hodge Hill	Birmingham City Council	URBAN BACKGROUND			y	
Birmingham Roadside 2	Birmingham City Council	ROADSIDE			y	
Birmingham Roadside 3	Birmingham City Council	ROADSIDE			y	
Birmingham Roadside 4	Birmingham City Council	ROADSIDE			y	
Boston High St	Boston Borough Council	ROADSIDE		y		
Bracknell Foxhill	Bracknell Forest BC	URBAN BACKGROUND		y		
Bury Radcliffe	Bury MBC	ROADSIDE		y		
Cambridge Gonville Place	Cambridge City Council	ROADSIDE		y	y	
Cambridge Newmarket Road	Cambridge City Council	URBAN BACKGROUND			y	
Cambridge Parker Street	Cambridge City Council	ROADSIDE		y		
Cambridge Silver Street	Cambridge City Council	ROADSIDE		y		
Carrickfergus Rosebrook Avenue	Carrickfergus Borough Council	URBAN BACKGROUND	y			
Castlereagh Espie Way	Castlereagh Borough Council	URBAN BACKGROUND	y			
Derry Brandywell	Derry City Council	URBAN BACKGROUND	y		y	
Guildford Gyratory	Guildford BC	ROADSIDE		y		y
Heathrow Bedfont Court	BAA	AIRPORT			y	
Heathrow Green Gates	BAA	AIRPORT		y	y	
Heathrow LHR2	BAA	AIRPORT		y	y	y
Heathrow Main Road	BAA	AIRPORT		y	y	y
Heathrow Moorbridge	BAA	AIRPORT			y	
Heathrow Oaks Road	BAA	AIRPORT		y	y	
Horley	Reigate and Banstead BC	URBAN BACKGROUND		y		
King's Lynn Railway Road	Kings Lynn and West Norfolk	ROADSIDE		y	y	
Lancaster Water Street	Lancaster City Council	ROADSIDE		y	y	
Lisburn Island Civic Centre	Lisburn City Council	ROADSIDE			y	y
Lisburn Lagan Valley Hospital	Lisburn City Council	ROADSIDE		y		
Newham Cam Road	London Borough of Newham	ROADSIDE		y	y	y
Newry Monaghan Row	Newry and Mourne DC	URBAN BACKGROUND	y	y	y	
Newry Trevor Hill	Newry and Mourne DC	ROADSIDE	y		y	
North Down Bangor	North Down BC	URBAN BACKGROUND				
North Lincs Killingholme	North Lincolnshire Council	URBAN BACKGROUND		y	y	
Oldham West Endhouse	Oldham Metropolitan Borough Council	URBAN BACKGROUND	y	y		

Oxford St Ebbes	Oxford City Council	URBAN BACKGROUND		y	y	
Ribble Valley Chatburn	Ribble Valley Borough Council	URBAN INDUSTRIAL	y	y	y	
Ribble Valley Lillands	Ribble Valley Borough Council	URBAN INDUSTRIAL	y	y	y	
Salford M60	Salford MBC	ROADSIDE	y		y	y
Slough Colnbrook	Slough Borough Council	URBAN BACKGROUND		y	y	
South Bucks Gerrards Cross	South Bucks District Council	KERBSIDE		y		
South Cambs Bar Hill	South Cambridgeshire DC	KERBSIDE		y		
South Holland	South Holland DC	RURAL		y	y	
Stockport Bredbury	Stockport Metropolitan BC	URBAN BACKGROUND		y		
Stockport Shaw Heath	Stockport Metropolitan BC	URBAN BACKGROUND	y			
Strabane Springhill Park	Strabane DC	URBAN BACKGROUND	y			
Sutton Bridge	South Holland DC	URBAN BACKGROUND			y	y
Tameside Two Trees School	Tameside Metropolitan BC	URBAN BACKGROUND	y	y	y	
Trafford	Trafford Metropolitan BC	URBAN BACKGROUND	y	y		
V Glamorgan Fonmon	Vale of Glamorgan Council	RURAL	y	y		

**Table A2.2. Additional monitoring sites maintained by the electricity generating companies used calibrate the SO<sub>2</sub> models.**

Site	Company
Gainsborough Cemetery	PowerGen
Grove Reservoir	PowerGen
Marton School	PowerGen
Thorney	PowerGen
Bottesford	PowerGen
Ruddington	PowerGen
Weston on Trent	PowerGen
Bentley Hall Farm	PowerGen
Stile Cop Cemetery	PowerGen
Telford Aqueduct	PowerGen
Telford School	PowerGen
Gillingham	PowerGen
Bexleyheath	Innogy
East Tilbury	Innogy
Northfleet	Innogy
West Thurrock	Innogy
Didcot South	Innogy
Font-y-gary	Innogy
Downes Ground Farm	Innogy
Hemingbrough	Innogy
North Featherstone	Innogy
Smeathalls Farm	Innogy
West Bank	Innogy

## APPENDIX 3. SMALL POINT SOURCE MODEL

### INTRODUCTION

Small industrial sources have generally been represented in earlier maps (Stedman et al, 2002) as 1 km square volume sources. However, this approach has in some cases lead to unreasonably high concentrations close to the source. The overestimation arises because the release height, buoyancy and momentum of discharges from industrial chimneys are not taken into account. A revised small point source model has been developed which uses dispersion kernels that will take these factors into account.

The dispersion model ADMS 3.1 was used to prepare the dispersion kernels.

### DISCHARGE CONDITIONS

The National Atmospheric Emission Inventory contains limited information concerning the discharge characteristics of individual emission sources. In many cases the information is limited to data on the total annual emission of individual pollutants. It is therefore necessary to make some general assumptions concerning the discharge height, the discharge temperature, the volumetric flow rate of the discharge and the discharge velocity. Our approach has been to make reasonable, but generally conservative assumptions corresponding to industrial practice.

#### Sulphur dioxide

For sulphur dioxide, it was assumed that the plant operates continuously throughout the year. The stack height was estimated using the following equations taken from the 3<sup>rd</sup> edition of the Chimney Heights Memorandum:

If the sulphur dioxide emission rate,  $R_A$  kg/h, is less than 10 kg/h, the chimney height,  $U$  m, is given by:

$$U = 6R_A^{0.5}$$

If  $R_A$  is in the range 10-100 kg/h:

$$U = 12R_A^{0.2}$$

Emission rates in excess of 100 kg/h were not considered in this study.

No account was taken of the effects of buildings: it was assumed that the increase in chimney height to take account of building effects provided by the Memorandum would compensate for the building effects.

It was then assumed that the sulphur dioxide concentration in the discharge would be at the limit for indigenous coal and liquid fuel for new and existing plant provided by Secretary of States Guidance-Boilers and Furnaces, 20-50 MW net rated thermal input PG1/3(95). The limit is 3000 mg m<sup>-3</sup> at reference conditions of 273 K, 101.3 kPa, 6% oxygen for solid fuel firing and 3% oxygen for liquid firing and dry gas. It was assumed that the oxygen content in the discharge corresponds with the reference condition. The moisture content of the discharge was ignored. It was assumed that the temperature of discharge was 373 K: higher temperatures would lead to improved buoyancy and hence lower ground level concentrations while lower temperatures usually result in

unacceptable water condensation. A discharge velocity of 10 m/s was selected to be representative of most combustion source discharges. The discharge diameter d m was calculated from;

$$d = \sqrt{\frac{4qT}{273\pi cv}}$$

where q is the sulphur dioxide emission rate, g/s  
 T is the discharge temperature, 373K  
 c is the emission concentration at reference conditions, 3 g m<sup>-3</sup>  
 v is the discharge velocity, 10 m/s

Table A3.1 shows the modelled stack heights and diameters.

**Table A3.1 Modelled stack heights and diameters for sulphur dioxide**

Emission rate			Stack height, m	Stack diameter, m
g/s	kg/h	t/a		
0.1	0.36	3.2	3.60	0.08
0.2	0.72	6.3	5.09	0.11
0.5	1.8	15.8	8.05	0.17
1	3.6	31.5	11.38	0.24
2	7.2	63.1	16.10	0.34
5	18	157.7	21.39	0.54
10	36	315.4	24.57	0.76
20	72	630.7	28.23	1.08

**Oxides of nitrogen**

For nitrogen dioxide, it was assumed that the plant operates continuously throughout the year. The stack height was estimated using the following equation taken from the 3<sup>rd</sup> edition of the Chimney Heights Memorandum for very low sulphur fuels:

$$U = 1.36Q^{0.6} (1 - 4.7 \times 10^{-5} Q^{1.69})$$

where Q is the gross heat input in MW.

This relationship applies for heat inputs up to 150 MW. For larger heat inputs a fixed height of 30 m was used corresponding to an approximate lower limit derived from available data on stack heights for large sources.

The gross heat input used in the above equation was calculated from the oxides of nitrogen emission rate using an emission factor of 10600 kg/MTh (0.100 g/MJ) for oxides of nitrogen emitted from natural gas combustion in non-domestic non-power station sources taken from the NAEI.

For fuels containing significant sulphur, the actual stack height will be greater to allow for the dispersion of sulphur dioxide so that the approach taken is expected to lead to an overestimate of ground level concentrations.

The emission limits for oxides of nitrogen provided by Secretary of States Guidance-Boilers and Furnaces, 20-50 MW net rated thermal input PG1/3(95) depend on the type of fuel and are in the range 140-650 mg m<sup>-3</sup> at reference conditions. A value of 300 mg



$\text{m}^{-3}$  was used in the calculation of the stack discharge diameter. Other assumptions concerning discharge conditions followed those made for sulphur dioxide above.

Table A3.2 shows the modelled stack heights and diameters.

**Table A3.2 Modelled stack heights and diameters for oxides of nitrogen**

Emission rate		Height, m	Diameter, m
g/s	t/a		
0.1	3.2	1.36	0.24
0.2	6.3	2.06	0.34
0.5	15.8	3.57	0.54
1	31.5	5.40	0.76
2	63.1	8.15	1.08
5	157.7	13.72	1.70
10	315.4	19.12	2.41
20	630.7	21.34	3.41
50	1576.8	30.00	5.38
100	3153.6	30.00	7.61

#### Particulate matter, $\text{PM}_{10}$

The stack heights and diameters used for oxides of nitrogen were also used to provide the kernels for particulate matter  $\text{PM}_{10}$ . This will provide a conservative assessment of  $\text{PM}_{10}$  concentrations for the following reasons. The emission limits for total particulate matter provided by Secretary of States Guidance-Boilers and Furnaces, 20-50 MW net rated thermal input PG1/3(95) depend on the type of fuel and are in the range 5-300  $\text{mg m}^{-3}$  at reference conditions. The emission limit for total particulate matter includes but is not limited to the contribution from  $\text{PM}_{10}$ .

## DISPERSION MODELLING

The dispersion model ADMS3.1 was used to predict ground level concentrations on two receptor grids:

- an "in-square" grid covering an area 1 km x 1 km with the source at the centre and with receptors at 33.3 m intervals;
- an "outer-grid" covering an area 30 km x 30 km with the source at the centre and with receptors at 1 km intervals.

A surface roughness value of 0.5 m was used, corresponding to areas of open suburbia. Meteorological data for Heathrow for the years 1993-2002 was used in the assessment, with most model runs using the 2000 data.

## RESULTS

#### Sulphur dioxide

Table A3.3 shows the predicted "in-square average" concentration for the 1 km square centred on the emission source for 2000 meteorological data.

**Table A3.3 Predicted in-square concentration, for sulphur dioxide**

Emission rate, g/s	Average in square concentration , $\mu\text{g m}^{-3}$
0.1	0.599
0.2	0.934
0.5	1.555
1	2.19
2	2.92
5	4.57
10	6.56
20	8.86

The results shown in Table A3.3 may be approximated by the relationship

$$C=Aq^{0.5}$$

where C is the in-square concentration,  $\mu\text{g m}^{-3}$  and q is the emission rate, g/s. A is a proportionality factor (2.07 in 2000)

Table A3.4 shows the predicted in-square concentration for an emission rate of 10 g/s for meteorological years 1993-2002. Table A3.4 also shows the inter-annual variation in the factor A.

**Table A3.4 In-square concentrations for 10 g/s emissions**

Year	In-square concentration, $\mu\text{g m}^{-3}$	Factor A
1993	6.21	1.96
1994	6.01	1.90
1995	6.12	1.94
1996	6.23	1.97
1997	6.10	1.93
1998	6.18	1.95
1999	6.49	2.05
2000	6.56	2.07
2001	6.32	2.00
2002	6.51	2.06

Figure A3.1 shows the predicted "outer-grid" concentration along the east-west axis through the source for 2000 meteorological data for a range of rates of emission (in g/s). Figure A3.1 does not include results for the 1 km source square.

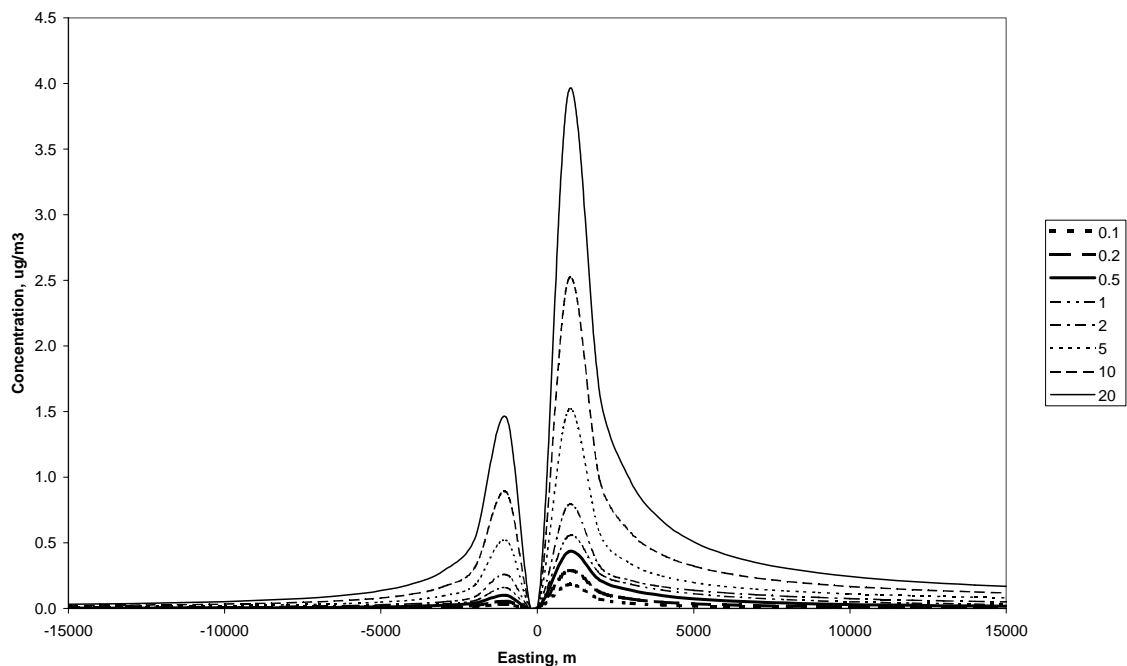


Figure A3.1 Sulphur dioxide concentration on east-west axis, 2000 meteorological data

Figure A3.2 shows the same model results plotted as  $C/q^{2/3}$ . The spread of the model results is greatly reduced so that as a reasonable approximation all the model results may be reduced to a single line.

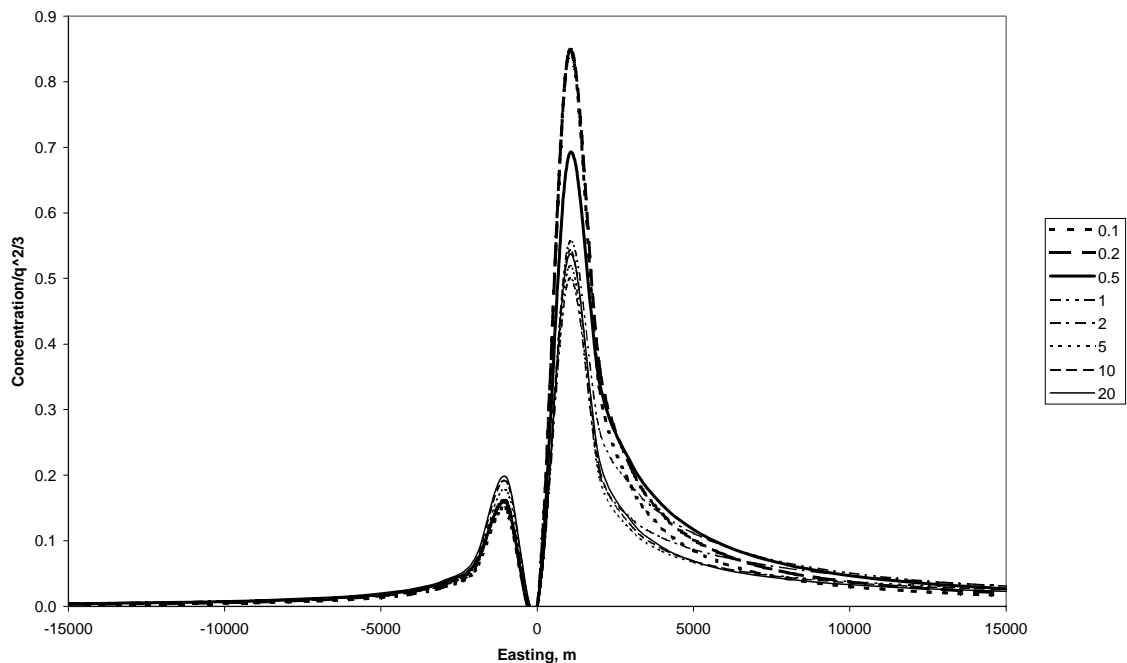


Figure A3.2 Reduced sulphur dioxide concentrations on the east-west axis, 2000 meteorological data

Thus it is proposed to use the results for an emission rate of 10 g/s for all emission rates in the range 0.1-20 g/s in the preparation of dispersion kernels for industrial sulphur

dioxide emissions. The dispersion kernel will be multiplied by  $10.(q/10)^{2/3}$  to provide estimates of the impact of emission  $q$  g/s at each receptor location. Separate kernels have been created from each meteorological data year 1993-2002.

### Oxides of nitrogen

Table A3.5 shows the predicted "in-square average" concentration for the 1 km square centred on the emission source for 2000 meteorological data.

**Table 3.5 In-square oxides of nitrogen concentrations, 2000**

Emission rate, g/s	In square concentration, $\mu\text{g m}^{-3}$
0.1	0.464
0.2	0.764
0.5	1.37
1	1.97
2	2.6
5	3.31
10	3.58
20	4.34
50	3.745
100	4.3

The results shown in Table A3.5 may be approximated in the range 0.1-20 g/s by the relationship

$$C = B \log_{10}(10q) + 0.464$$

where  $C$  is the in-square concentration,  $\mu\text{g m}^{-3}$  and  $q$  is the emission rate, g/s. and  $B$  is a numerical constant, 1.68 in 2000.

For emission rates in the range 20-100 g/s, the in-square concentration is approximately  $4 \mu\text{g m}^{-3}$ .

Table A3.6 shows the predicted in-square concentration for an emission rate of 20 g/s for meteorological years 1993-2002. Table A3.6 also shows the inter-annual variation in the factor  $B$ .

Table A3.6 Inter annual variation in in-square oxides of nitrogen concentration

Year	In-square concentration, $\mu\text{g m}^{-3}$	Factor B
1993	3.62	1.37
1994	3.88	1.48
1995	3.74	1.42
1996	4.3	1.67
1997	3.66	1.39
1998	3.64	1.38
1999	4.14	1.60
2000	4.34	1.68
2001	4.02	1.55
2002	4.68	1.83

Figure A3.3 shows the predicted "outer-grid" oxides of nitrogen concentration along the east-west axis through the source for a range of rates of emission (in g/s).

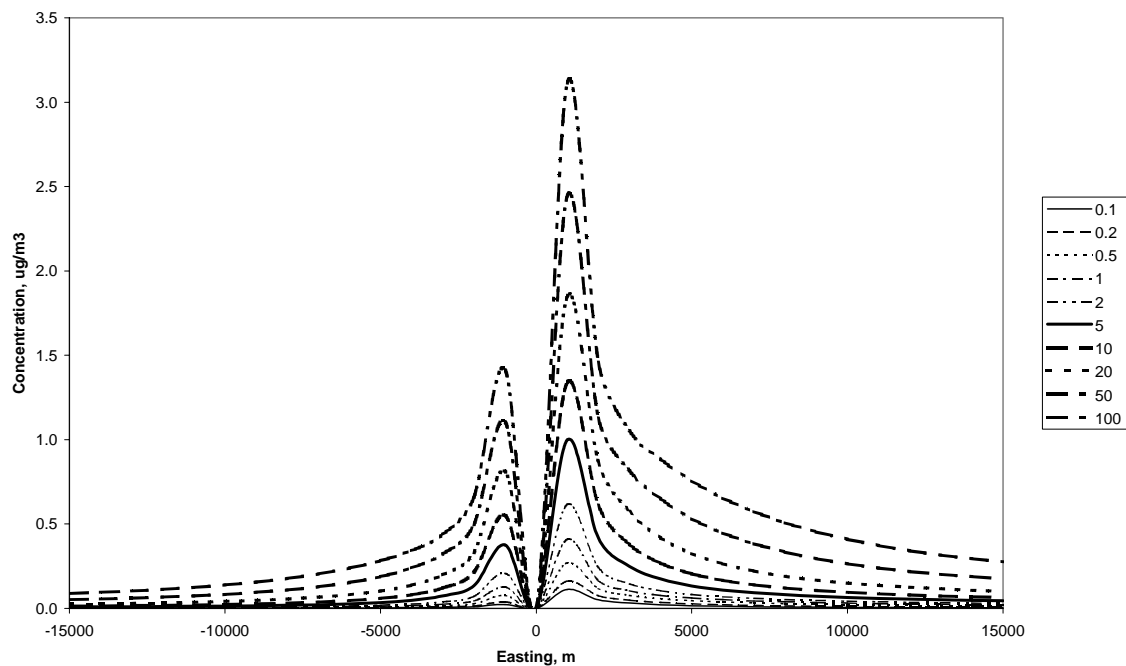


Figure A3.3 Oxides of nitrogen concentration on east-west axis, 2000 meteorological data

Figure A3.4 shows the same model results plotted as  $C/q^{0.6}$ . The spread of the model results is greatly reduced so that as a reasonable approximation all the model results may be reduced to a single line.

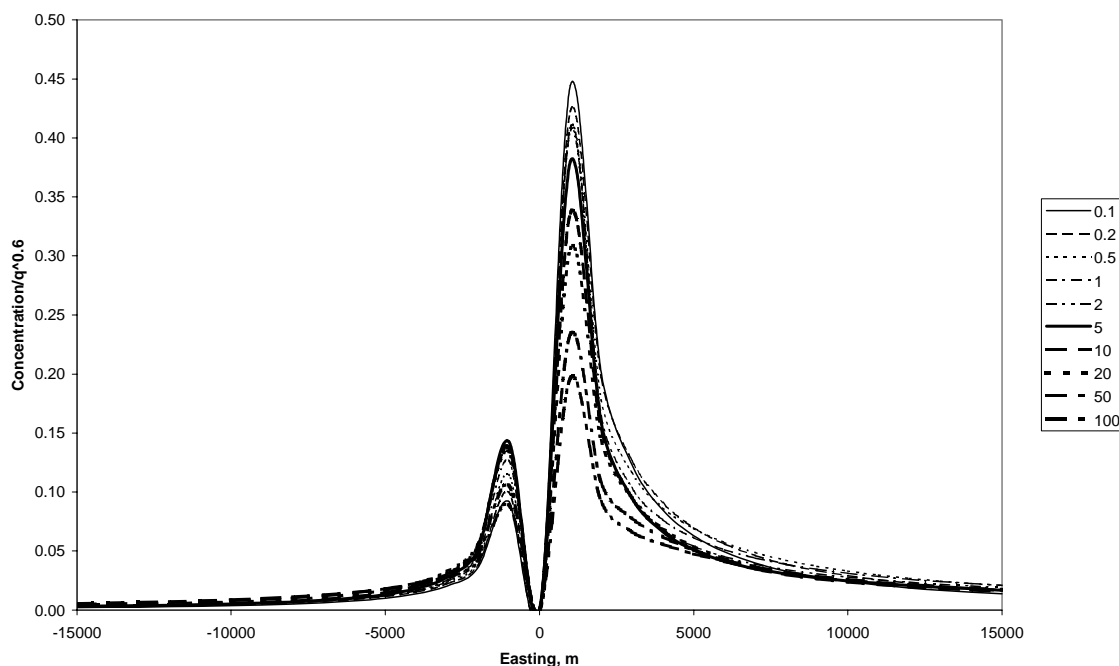


Figure A3.4 Reduced oxides of nitrogen concentrations on the east-west axis, 2000 meteorological data

Thus it is proposed to use the results for an emission rate of 20 g/s for all emission rates in the range 0.1-100 g/s in the preparation of dispersion kernels for oxides of nitrogen emissions. The dispersion kernel will be multiplied by  $20.(q/20)^{0.6}$  to provide estimates of the impact of emission  $q$  g/s at each receptor location. Separate kernels have been created for each meteorological data year 1993-2002.

## METHOD

### Sulphur dioxide

Point sources with emissions greater than or equal to 500 tonnes per year (15.85 g/s) have been modelled explicitly using ADMS. Point sources with emissions less than 500 tonnes per year have been modelled using the small points model. This model has two components.

The in-square concentration for each source has been calculated using the following function:

$$C=1.98.q^{0.5}$$

where  $C$  is the in-square concentration,  $\mu\text{g m}^{-3}$  and  $q$  is the emission rate, g/s and 1.98 is a numerical constant, calculated as the average value over the years 1993-2002 for met data at Heathrow.

The outer-grid concentration has been calculated by adjusting the emissions for each source using the function:

$$Q = 10.(q/10)^{0.667}$$

where  $q$  is the emission rate, g/s and  $Q$  is the adjusted emissions. The sum of the adjusted emission was then calculated for each grid square and the outer-grid

concentration calculated using a small points dispersion kernel (which was calculated as the average over the years 1993-2002 for met data at Heathrow).

The in-square and outer-grid concentrations were then summed to calculate the total contribution to ambient annual mean concentrations from these small point sources.

### Oxides of nitrogen

Point sources with emissions greater than or equal to 500 tonnes per year (15.85 g/s) have been modelled explicitly using ADMS. Point sources with emissions less than 500 tonnes per year have been modelled using the small points model. This model has two components.

The in-square concentration for each source has been calculated using the following function:

$$C = 1.54 \cdot \log_{10}(10q) + 0.464$$

where C is the in-square concentration,  $\mu\text{g m}^{-3}$  and q is the emission rate, g/s and 1.54 is a numerical constant, calculated as the average value over the years 1993-2002 for met data at Heathrow.

The outer-grid concentration has been calculated by adjusting the emissions for each source using the function:

$$Q = 20 \cdot (q/20)^{0.6}$$

where q is the emission rate, g/s and Q is the adjusted emissions. The sum of the adjusted emission was then calculated for each grid square and the outer-grid concentration calculated using a small points dispersion kernel (which was calculated as the average over the years 1993-2002 for met data at Heathrow).

The in-square and outer-grid concentrations were then summed to calculate the total contribution to ambient annual mean concentrations from these small point sources.

### PM<sub>10</sub>

The method for PM<sub>10</sub> was the same as for NO<sub>x</sub>, except that point sources with emissions greater than or equal to 200 tonnes per year (6.34 g/s) have been modelled explicitly using ADMS. Point sources with emissions less than 200 tonnes per year have been modelled using the small points model.

### CO

The method for CO was the same as for NO<sub>x</sub>, except that point sources with emissions greater than or equal to 3000 tonnes per year (95.1 g/s) have been modelled explicitly using ADMS. Point sources with emissions less than 3000 tonnes per year have been modelled using the small points model.

### Benzene

The method for benzene was the different. Point sources with combustions emissions greater than or equal to 5 tonnes per year (0.16 g/s) have been modelled explicitly using ADMS. Fugitive and process point sources have been modelled using a different small points model, as described in section 5.3.

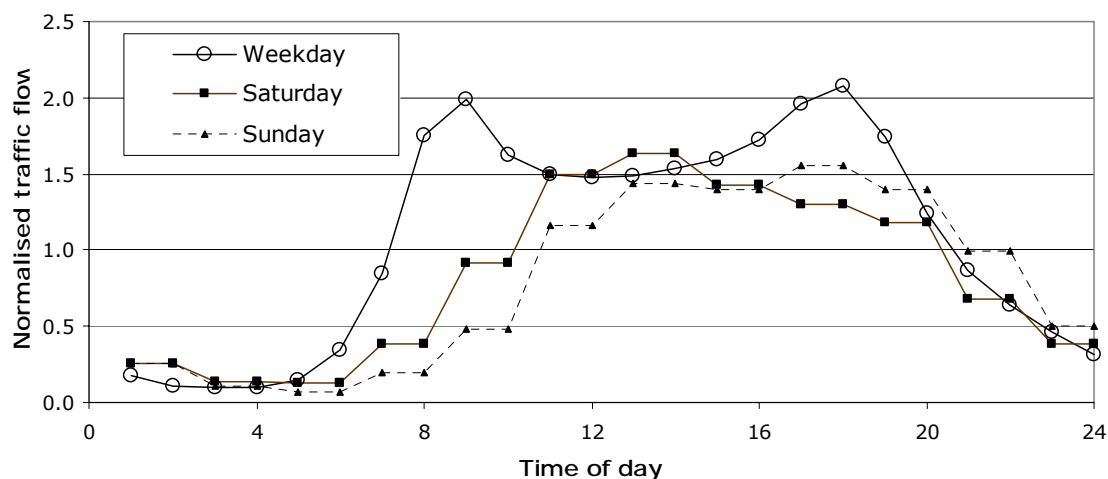
## APPENDIX 4. DISPERSION KERNELS FOR AREA SOURCE MODEL

Dispersion kernels for calculating the annual mean contribution of emissions from area sources to ambient annual mean concentrations were calculated using ADMS. Separate kernels were calculated for traffic and other area sources (which were assumed to have a constant temporal profile of emissions). Kernels were generated for 2003 using sequential meteorological data from Heathrow. The dispersion parameters used to calculate the kernels are listed in Table A4.1. The emission profile used to represent traffic emissions for the traffic kernels is shown in Figure A4.1. This was obtained from a distribution of all traffic in the United Kingdom by time of day (Road Traffic Statistics, 1999, Department of Transport).

Table A4.1 Dispersion parameters used to calculate area source kernels

	Traffic kernel	Constant kernel
Surface roughness	1 m	1 m
Emission factors	Varying (see below)	Constant
Height of well mixed source	10 m	30 m
Hourly sequential meteorological data	Yes	Yes
Monin-Obukhov height	30 m	30 m
Emission from each volume source	1 g s <sup>-1</sup>	1 g s <sup>-1</sup>
Number of receptor grids (model extent):		
1 km area source model	31 (31 km)	31 (31 km)
3 km area source model	11 (33 km)	11 (33 km)
5 km area source model	7 (35 km)	7 (35 km)

Figure A4.1 Temporal profile of traffic emissions



Dispersion kernels were calculated at spatial resolutions of 1 km x 1 km, 3 x 3 km and 5 km x 5 km, representing the size of emission and receptor squares modelled. Previous modelling studies (Stedman et al, 2002) used kernels at a resolution of 5 km x 5 km for NO<sub>x</sub> and PM<sub>10</sub>. A comparison of the fit between modelled and measured concentrations of NO<sub>x</sub> for the three different kernel resolutions showed that the 3 km x 3 km kernels provided the most robust calibration plots for the area source model. These kernels were therefore used for NO<sub>x</sub> and PM<sub>10</sub>, benzene and CO. 1 km x 1 km kernels were used for SO<sub>2</sub>.



