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UK air quality modelling for annual reporting 2006 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. Directive 2002/3/EC (the third Daughter Directive) sets targets and long-term objectives to be achieved for ozone.

2006 is the sixth year for which an annual air quality assessment for the first Daughter Directive pollutants is required and the fourth year for which an annual air quality assessment has been undertaken for the second Daughter Directive pollutants. 2006 is the third year for which an annual air quality assessment has been undertaken for the third Daughter Directive. 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 does not contain any supplementary modelling information on ozone. The accompanying technical report (Kent *et al.*, 2008) contains a summary of key results from the questionnaire for ozone (covered by the third Daughter Directive) and additional technical information on the modelling methods that have been used to assess ozone concentrations throughout the UK.

This report provides a summary of key results from the questionnaire for pollutants included in the first and second Daughter Directives and additional technical information on the modelling methods that have been used to assess SO_2, NO_2 and NO_X, PM_{10}, 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 comparisons with limit values.

Maps of background concentrations of SO_2, NO_2, PM_{10}, benzene and CO in 2006 on a 1km x 1km grid have been prepared. Maps of roadside concentrations of NO_2, PM_{10}, benzene and CO have been prepared for a total of 10027 urban major road links (A-roads and motorways) across the UK.

The dominant contributions to measured SO_2 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_2 from point sources were therefore modelled in some detail. Area sources have been modelled using a dispersion kernel approach. For NO_2, NO_X, PM_{10}, benzene and CO there are also important contributions to ambient concentrations from area sources, particularly traffic; therefore a slightly different modelling approach has 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_2, NO_X, PM_{10}, 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 E2 contains details of exceedences of old directives.

Table E1. Summary results of air quality assessment for 2006.

Pollutant	Averaging time	Number of zones exceeding limit value + margin of tolerance	Number of zones exceeding limit value[1]
SO_2	1-hour[3]	n/a	1 zone modelled (Eastern)
SO_2	24-hour[2]	n/a	1 zone modelled (Eastern)
SO_2	annual[3]	n/a	none
SO_2	winter[3]	n/a	none
NO_2	1-hour[4]	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)
NO_2	annual	38 zones (6 measured + 32 modelled)	39 zones (7 measured + 32 modelled)
NO_x	annual[3]	n/a	none
PM_{10}	24-hour (Stage 1)[3]	n/a	30 zones (5 measured + 25 modelled)
PM_{10}	annual (Stage 1)[3]	n/a	2 zones (1 measured + 1 modelled)
PM_{10}	24-hour (Stage 2)[5]	n/a	22 zones (22 measured)
PM_{10}	annual (Stage 2)[6]	36 zones (8 measured + 28 modelled)	42 zones (8 measured + 34 modelled)
Lead	annual[3]	n/a	none
Benzene	annual	none	1 zone modelled (Yorkshire & Humberside)
CO	8-hour[3]	n/a	none

[1] Includes zones exceeding LV + MOT
[2] No MOT defined, LV + MOT = LV
[3] No MOT. LVs are already in force in 2006
[4] No modelling for 1-hour LV
[5] Stage 2 indicative LV, no MOT defined for 24-hour stage 2 LV, no modelling for 24-hour stage 2 LV
[6] Stage 2 indicative LV

Table E2. Exceedences of old Directives

Pollutant	Directive	Averaging time	Concentration (µg m-3)
NO_2	85/203/EEC	1-hour 98%ile	244 (measured at London Marylebone Road)

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Appendices

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) 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) 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. Directive 2002/3/EC (the third Daughter Directive, AQDD3) sets target values and long-term objectives to be achieved for ozone.

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

The first and second Daughter Directives make provision for an annual air quality assessment for SO_2, NO_X, NO_2, PM_{10}, benzene and CO. A questionnaire has been completed for submission to the EU containing the results of this air quality assessment. A copy of the completed questionnaire can be found on the Central Data Repository of the European Environment Agency (CDR, 2007, http://cdr.eionet.europa.eu/gb/eu/annualair). 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 for SO_2, NO_X, NO_2, PM_{10}, benzene and CO and additional information on the modelling methods that have been used to assess concentrations throughout the UK.

The third Daughter Directive includes a requirement for an annual air quality assessment for ozone. The ozone air quality assessment is covered in a separate technical report (Kent *et al.*, 2008).

Sections 2 to 6 describe the modelling methods used for estimation of SO_2, NO_2, PM_{10}, benzene and CO. These include:

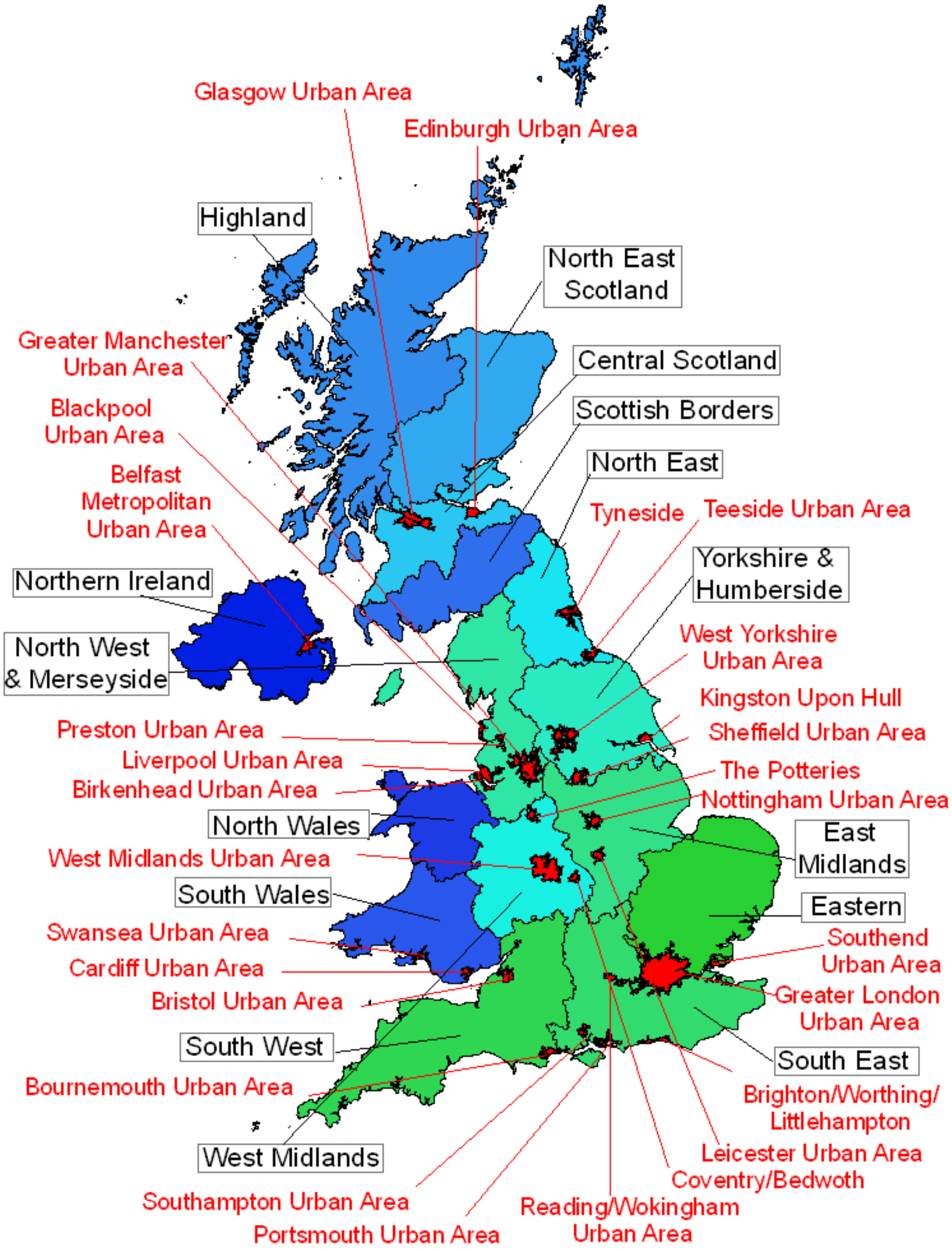
- Details of the modelling methods
- Information on the verification of the models used and comparisons with data quality objectives
- Detailed modelling results.

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 (CDR, 2007) 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 previous years (Kent *et al.*, 2007; Stedman *et al.*, 2006a; Stedman *et al.*, 2005; Stedman *et al.*, 2003; Stedman *et al.*, 2002).

1.3 Preliminary assessments and definition of zones

The preliminary assessment carried out for AQDD1 (Bush, 2000) defined a set of zones to be used for air quality assessment in the UK. Table 1.1 contains details of area, population (from 2001 census) and urban road length contained in each zone and agglomeration. The zones and agglomerations map for the UK is presented in Figure 1.1.

Figure 1.1. UK zones and agglomerations for 2006



Agglomeration zones (red)
Non-agglomeration zones (blue/green)

Table 1.1 Zones for AQDD1 reporting

Zone	Zone code	Ag or nonag*	Population	Area (km^2)	Number of urban road links	Length of urban road links (km)
Greater London Urban Area	UK0001	ag	8278251	1628	2024	1891.5
West Midlands Urban Area	UK0002	ag	2284093	594	407	560.8
Greater Manchester Urban Area	UK0003	ag	2244931	557	569	663.7
West Yorkshire Urban Area	UK0004	ag	1499465	363	291	423.1
Tyneside	UK0005	ag	879996	217	181	209.1
Liverpool Urban Area	UK0006	ag	816216	184	281	224.2
Sheffield Urban Area	UK0007	ag	640720	165	113	161.1
Nottingham Urban Area	UK0008	ag	666358	169	131	136.3
Bristol Urban Area	UK0009	ag	551066	142	122	118.7
Brighton/Worthing/Littlehampton	UK0010	ag	461181	97	56	84.3
Leicester Urban Area	UK0011	ag	441213	102	71	92.8
Portsmouth Urban Area	UK0012	ag	442252	91	54	72.6
Teesside Urban Area	UK0013	ag	365323	111	59	74.2
The Potteries	UK0014	ag	362403	91	113	130.0
Bournemouth Urban Area	UK0015	ag	383713	113	54	71.3
Reading/Wokingham Urban Area	UK0016	ag	369804	97	70	84.4
Coventry/Bedworth	UK0017	ag	336452	76	31	34.9
Kingston upon Hull	UK0018	ag	301416	80	40	52.3
Southampton Urban Area	UK0019	ag	304400	77	57	65.2
Birkenhead Urban Area	UK0020	ag	319675	88	69	69.3
Southend Urban Area	UK0021	ag	269415	64	33	49.8
Blackpool Urban Area	UK0022	ag	261088	63	49	65.7
Preston Urban Area	UK0023	ag	264601	58	35	45.8
Glasgow Urban Area	UK0024	ag	1168270	366	203	306.5
Edinburgh Urban Area	UK0025	ag	452194	117	61	103.2
Cardiff Urban Area	UK0026	ag	327706	72	43	53.9
Swansea Urban Area	UK0027	ag	270506	84	30	68.4
Belfast Metropolitan Urban Area	UK0028	ag	580276	193	27	199.4
Eastern	UK0029	nonag	4850132	19113	638	892.8
South West	UK0030	nonag	3980991	23506	476	680.8
South East	UK0031	nonag	6016677	18645	882	1347.4
East Midlands	UK0032	nonag	3084598	15491	441	690.6
North West & Merseyside	UK0033	nonag	2826622	13149	582	986.2
Yorkshire & Humberside	UK0034	nonag	2514947	14787	361	722.1
West Midlands	UK0035	nonag	2271650	12192	368	543.7
North East	UK0036	nonag	1269803	8282	219	291.9
Central Scotland	UK0037	nonag	1813314	9305	231	358.0
North East Scotland	UK0038	nonag	1001499	18587	137	233.5
Highland	UK0039	nonag	380062	38269	11	34.5
Scottish Borders	UK0040	nonag	254690	11145	38	59.9
South Wales	UK0041	nonag	1578773	12221	214	364.1
North Wales	UK0042	nonag	720022	8368	91	160.6
Northern Ireland	UK0043	nonag	1104991	13579	64	401.8
Total			59211755	242698	10027	13880.2

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

1.4 Monitoring sites

The monitoring stations operating during 2006 for the purpose of AQDD1 and AQDD2 are listed in Form 3 of the questionnaire which can be found at on the CDR (2007). Not all sites had sufficient data capture during 2006 for data to be reported. The data quality objective (DQO) for AQDD1 and AQDD2 measurements is 90% data capture. We have, however, 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 2006 for reporting purposes. Data capture statistics for sites operational during 2006 are also presented in Form 3 of the reporting questionnaire.

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_{10}. 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 2005 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. There is no applicable margin of tolerance for the hourly or 24-hourly SO_2 metric, the PM_{10} (Stage 1) 24-hour or annual metrics, the lead annual mean metric or the maximum daily 8-hour CO metric because these limit values all came into force in 2005. The stage 2 annual mean limit value + margin of tolerance for PM_{10} was 30 $\mu g\ m^{-3}$ from 2001 until 2005, declining by 2 $\mu g\ m^{-3}$ each year thereafter.

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_2

	Averaging period	LV	LV + MOT 2006	Date by which LV is to be met
1. Hourly LV for the protection of human health	1 hour	350 $\mu g\ m^{-3}$, not to be exceeded more than 24 times a calendar year	N/A	1 January 2005
2. Daily LV for the protection of human health	24 hour	125 $\mu g\ m^{-3}$, 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 $\mu g\ m^{-3}$	N/A	19 July 2001

Table 1.3. Limit values for NO_2 and NO_X

	Averaging period	LV	LV + MOT 2006	Date by which LV is to be met
1. Hourly LV for the protection of human health	1 hour	200 µg m^{-3} NO_2 not to be exceeded more than 18 times a calendar year	250 µg m^{-3}, NO_2 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^{-3} NO_2	48 µg m^{-3}, NO_2	1 January 2010
3. LV for the protection of vegetation	Calendar year	30 µg m^{-3} NO_X, as NO_2	N/A	19 July 2001

Table 1.4a. Limit values for PM_{10} (Stage 1)

	Averaging period	LV	LV + MOT 2006	Date by which LV is to be met
1. 24-hour LV for the protection of human health	24 hour	50 µg m^{-3} not to be exceeded more than 35 times a calendar year	N/A	1 January 2005
2. Annual LV for the protection of human health	Calendar year	40 µg m^{-3}	N/A	1 January 2005

Table 1.4b. Indicative limit values for PM_{10} (Stage 2)

	Averaging period	LV	LV + MOT 2006	Date by which LV is to be met
1. 24-hour LV for the protection of human health	24 hour	50 µg m^{-3} 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^{-3}	28 µg m^{-3}	1 January 2010

Table 1.5. Limit values for lead

	Averaging period	LV	LV + MOT 2006	Date by which LV is to be met
Annual LV for the protection of human health	Calendar year	0.5 µg m^{-3}	N/A	1 January 2005

Table 1.6. Limit values for benzene

	Averaging period	LV	LV + MOT 2006	Date by which LV is to be met
Annual LV for the protection of human health	Calendar year	5 µg m^{-3}	9 µg m^{-3}	1 January 2010

Table 1.7. Limit values for CO

	Averaging period	LV	LV + MOT 2006	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^{-3}	N/A	1 January 2005

1.6 Data quality objectives for modelling results and model verification

AQDD1 sets data quality objectives (DQOs) 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 first Daughter 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 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_2, NO_2 and NO_x. For PM_{10} and lead the DQO for annual averages is 50%. DQOs have not been defined for daily averages of PM_{10} at present. The second Daughter Directive 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 Form 3 of the reporting questionnaire. 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 AEA Energy & Environment under contract and not part of the national network, including Local Authority sites in the AEA Energy & Environment Calibration Club, Scottish Air Quality Archive monitoring sites, Welsh Air Quality Forum monitoring sites and sites from the Kent and Medway Air Quality Monitoring Network, 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 AEA Energy & Environment, are formally members of the Calibration Club. For 2006 we have also obtained monitoring data from the London Air Quality Network (LAQN) and Hertfordshire and Bedfordshire Air Quality Monitoring Network, courtesy of ERG. The monitoring sites used for this comparison are listed in Appendix 1. 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_2, NO_2, PM_{10}, benzene and CO have been prepared on a 1km x 1km grid for the 2006 calendar year. Emissions estimates used in calculating pollutant concentrations have been taken from the National Atmospheric Emissions Inventory (Dore *et al.*, 2007). Maps of roadside concentrations of NO_2, PM_{10} and benzene and CO have also been prepared for 10,027 urban major road links (A-roads and motorways). Emissions maps utilised in this modelling work are presented in the NAEI report (Dore *et al.*, 2007).

The dominant contributions to ambient SO_2 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_2 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.

For NO_2, NO_X, PM_{10}, 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_2, NO_X and secondary PM_{10}. Regional benzene concentrations have been estimated from rural NO_2 concentrations. The area source contribution to ambient NO_X, PM_{10}, 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_2, NO_X, PM_{10}, 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 (NAEI) (Dore *et al*., 2007). Emission maps from the 2005 NAEI have been used for the modelling work described here. Emission estimates for area sources have been scaled to values appropriate to 2006, using UK sector total emissions from 2005 and 2006.

There were notable revisions to the methodology for the 2006 modelling for PM_{10} and NO_2. The sea salt component of particulate matter is now derived from an interpolation of particle chloride measurements from 28 rural sites across the UK. Formerly this component was introduced into the model as a sea salt map produced by the Met Office. Secondary inorganic aerosol concentrations have been estimated using data from an expanded network of 28 rural sites which have been used to interpolate a 5km x 5km grid by Krigging. Modelling for 2006 has also included developments in the contribution to particulate matter from iron and calcium rich dusts, estimated from a combination of measurements made in Birmingham and surrogate variables for the spatial distribution of the emission associated with these dusts. The apportionment between fine and coarse nitrate PM has been revised for 2006.

The primary NO_2 inventory first used in the NO_x/NO_2 modelling for 2005 has been updated for 2006 to take account of findings from a recent European study of primary NO_2 emission fractions conducted by AEA for the European Commission (Grice *et al*., 2007). This inventory now incorporates this data in addition to the NAEI NO_X inventory. These developments are explained in detail in the following relevant sections.

1.8 Air quality in Gibraltar in 2006

Air quality monitoring is undertaken in Gibraltar and this data is submitted to the Commission each year via a separate questionnaire from the UK. Two continuous automatic monitoring stations were in operation in 2006 – Rosia Road (roadside site) and Bleak House (background site). The data from the monitoring campaigns are presented in Appendix 5, including tables of the relevant forms from the questionnaire and details of the monitoring sites.

2 SO_2

2.1 Introduction

Maps of annual mean, winter mean, 99.73 percentile of hourly mean SO_2 concentrations and 99.18 percentile of daily mean SO_2 concentrations have been calculated using methods based on those described by Abbott and Vincent (1999 and 2006). The percentile concentrations presented here correspond to the number of allowed exceedences of the 1-hour and 24-hour limit values for SO_2. Emissions from point and area sources have been modelled separately. Emissions from larger point sources (sources with emissions ≥500 tonnes per year) were modelled explicitly using the dispersion model ADMS 3.3 (CERC, 2005). Emissions from smaller point sources (< 500 tonnes) and area sources were modelled using 1km x 1km emission grids and a dispersion kernel approach, described more fully in Appendix 3. Emissions profiles and annual emissions for the power stations in England, Wales and Scotland were provided by either the Environment Agency or power generating companies. The emission profiles are derived using procedures agreed by the power generators and the Environment Agency. Emissions from power stations in Northern Ireland were modelled using emissions profiles typical of electricity generation in summer and winter. This information was provided from the National Grid Company and contained within the company's Seven Year Statement.

Emissions from non-power station point sources for 2006 were based upon data obtained from the Environment Agency's Pollution Inventory for the modelling in 2005. Emission estimates for area sources have been scaled to values appropriate to 2006, using UK sector total emissions from 2005 and 2006.

A number of receptor areas were defined, which together covered the UK. The size of the receptor areas varied but were typically 150km x 150km, 150km x 100km or 100km x 100km. For larger point sources all sources within the receptor area and extending out to 100 km of square's border were assumed to influence concentrations within the receptor area. Within each receptor area concentrations were calculated on a regular 5km x 5km grid using ADMS 3.3 and sequential meteorological data for 2006 from Waddington in Lincolnshire. This site was chosen as most representative of meteorology in the vicinity of the largest concentration of major point sources in the UK. 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_2 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 2. The contribution from area sources to annual mean SO_2 concentrations was also estimated using a dispersion kernel based approach. The derivation of the area source model kernels is described in Appendix 3. Dispersion kernels were calculated using ADMS 3.3 and hourly sequential meteorological data for 2006 from Waddington.

The contributions to annual mean and high percentile concentrations from the different sources were then summed as described below. The map of winter mean SO_2 concentrations was derived from the annual mean map using a factor of 1.29, which is the ratio between the average concentration measured at rural SO_2 monitoring sites during the 2005-2006 winter period and annual concentration for during 2006, respectively.

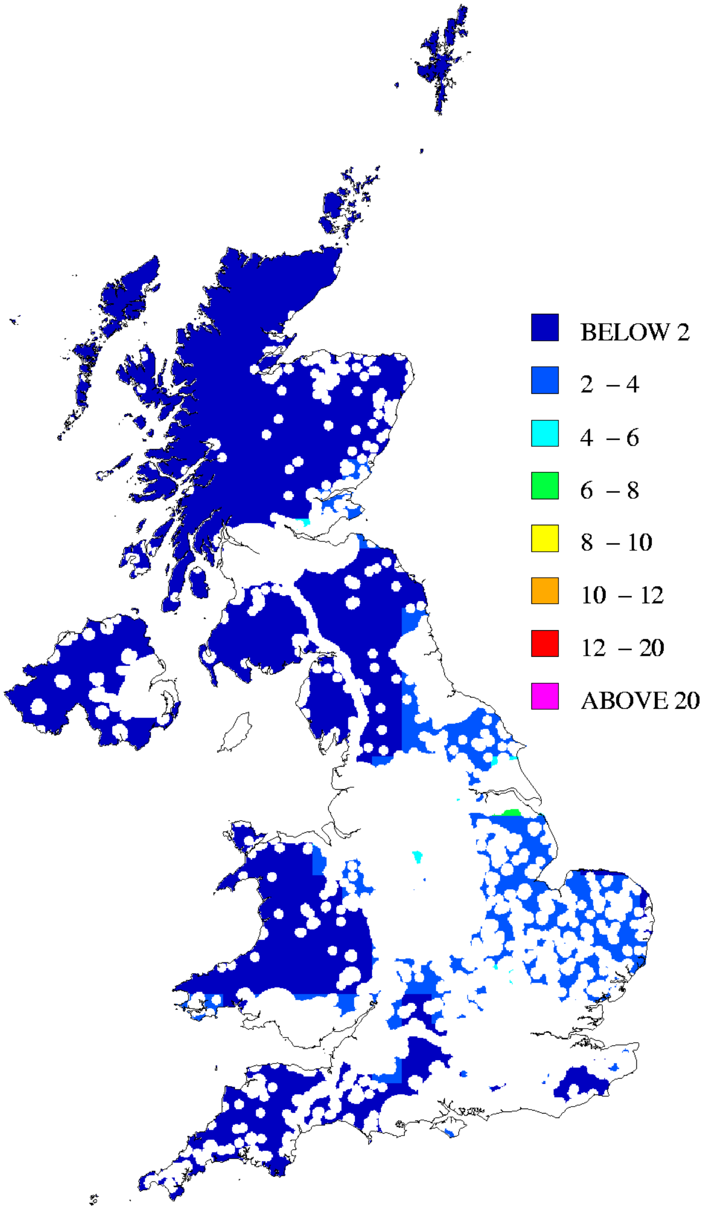
A different method was used to calculate the high percentile concentrations in Northern Ireland, where the dominant source for peak SO_2 concentrations is domestic emissions (see Section 2.3).

2.2 Maps of winter and annual mean concentrations

A map of annual mean SO_2 concentration for 2006 in ecosystem areas is shown in Figure 2.1. This map has been calculated by removing non-ecosystem areas from the background SO_2 map and calculating the zonal mean of the $1km^2$ grid squares for a $30km^2$ grid.

Mean concentrations on a 30km^2 grid have been used to prevent the influence of any urban area appearing unrealistically large on adjacent vegetation areas. Thus the modelled concentrations in vegetation areas should be representative of approximately 1000km^2 as specified in Directive 1999/30/EC for monitoring sites used to assess concentrations for the vegetation limit value.

Figure 2.1. Annual mean SO_2 concentration, 2006 (µg m^{-3}) in ecosystem areas



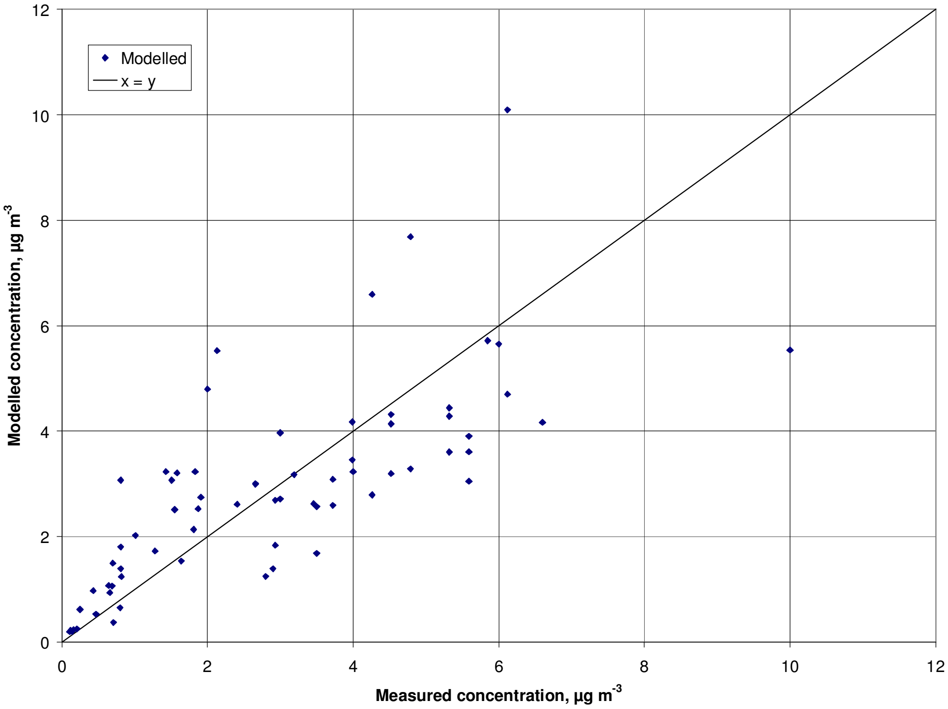
The factors used to combine the point source and area source contributions are shown in Table 2.1. A residual concentration of 0.19 µg m^{-3} was added. This residual was derived by a linear least squares fit between the measured and modelled concentrations. The residual is associated with contributions from more distant sources, for example, from continental European sources that are not explicitly modelled.

Table 2.1 Coefficients for annual mean model

	Points coefficient	Area coefficient	Constant µg m^{-3}
Annual mean	1	1	0.19

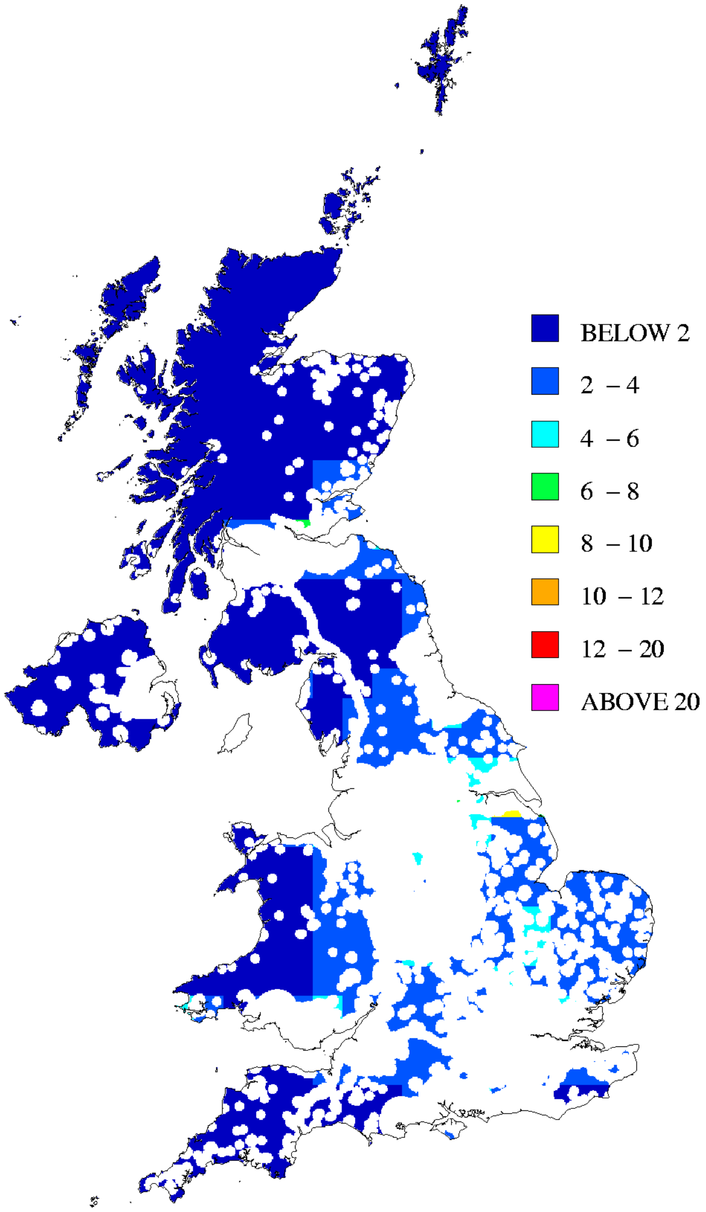
Measured concentrations from Rural SO_2 Monitoring Network sites (Lawrence, *pers comm.* 2007), rural, suburban and industrial sites in the national automatic monitoring networks and rural automatic monitoring sites maintained by the electricity generating companies were used to check the method used to combine the modelled components. A list of the sites maintained by the electricity generating companies is included in Appendix 1. The comparison plot for 2006 is shown in Figure 2.2.

Figure 2.2. Comparison plot for 2006 annual mean SO_2 concentration



A map of winter mean SO_2 concentrations for the period October 2005 to March 2006 has also been calculated and is shown in Figure 2.3. This map was calculated by multiplying the annual mean map for 2006 by 1.29, which is the ratio between the average concentration measured at rural SO_2 monitoring sites during the 2005-2006 winter period and annual concentration for during 2006.

Figure 2.3. Winter mean SO_2 concentration, 2005-2006 ($\mu g\ m^{-3}$) 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_2 concentration in 2006 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_2.

Figure 2.4. 99.73 percentile of 1-hour mean SO_2 concentration, 2006 ($\mu g\ m^{-3}$)

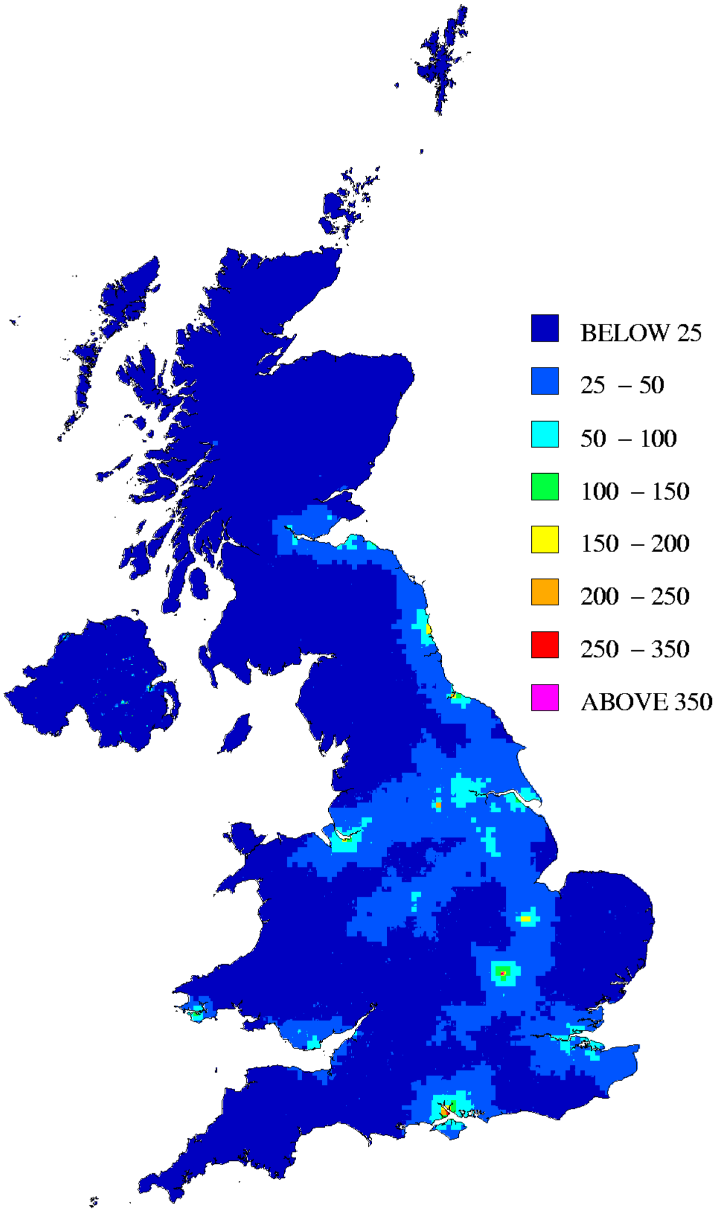
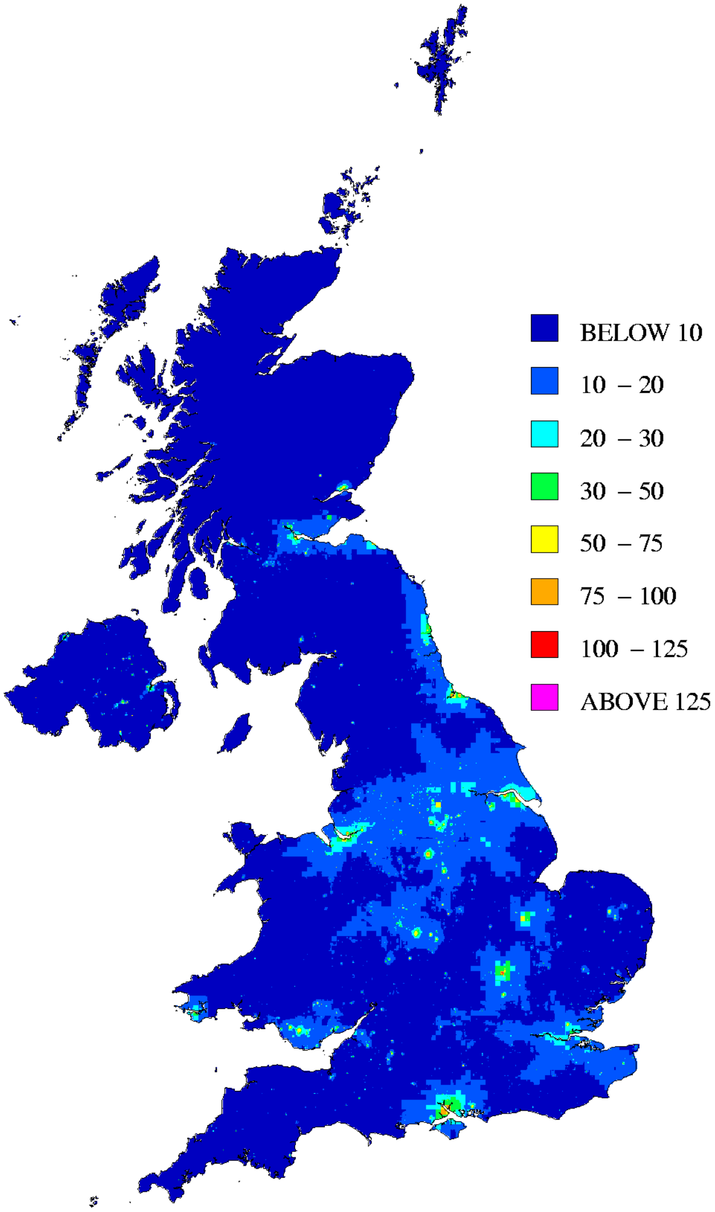


Figure 2.5. 99.18 percentile of 24-hour mean SO_2 concentration, 2005 ($\mu g\ m^{-3}$)



The methodology to produce the maps has been updated to include research on combining concentrations arising from area and industrial sources undertaken for the Environment Agency (Abbott and Vincent, 2006). This methodology aims to derive a better estimate of the percentile concentrations at locations distant from the industrial sources. A weighted regression analysis was carried out by Abbott and Vincent assuming that the variance of the residuals was proportional to the modelled concentration. The regression model was of the form:

$$c_{measured} = \max\begin{bmatrix} Ac_{\text{mod}elled\_industrial,\%ile} + 2(c_{\text{mod}elled\_area} + c_{long\_range})_{annual} \\ 2Ac_{\text{mod}elled\_industrial,annual} + k(c_{\text{mod}elled\_area} + c_{long\_range})_{annual} \end{bmatrix}$$

The constant A was obtained from the regression analysis. The background multiplier factor, k, was derived from monitoring data. The factor “2”, used to scale the $(c_{modelled\_area} + c_{long\_range})_{annual}$ and $c_{modelled\_industrial,annual}$ components, has been shown to be a robust factor that allows short-term average concentrations to be estimated from modelled annual mean concentrations arising from non-industrial or industrial sources (Abbott *et al.*, 2005). Table 2.2 presents the A and k factors used in the derivation of the maps.

Table 2.2 Factors for percentile models

Metric	Constant A	Background multiplier factor, k
99.73 percentile of 1-hour values	1.09	10.1
99.18 percentile of 24-hour values	1.23	3.3

The justification for treating industrial sources and area emissions separately is because peaks in high percentile modelled contributions may not coincide with peaks in high percentile background concentrations – a problem that is more pronounced in emissions from large industrial point sources because the meteorological conditions that give rise to high concentrations from tall stacks can be very different from those that produce high concentrations from emissions at low level.

Figures 2.6 and 2.7 provide an intermediate quality check at rural and suburban sites which form part of the national network and at sampling sites operated by the electricity supply companies.

Figure 2.6. Comparison plot for 2006 99.73 percentile of 1-hour mean SO_2 concentrations

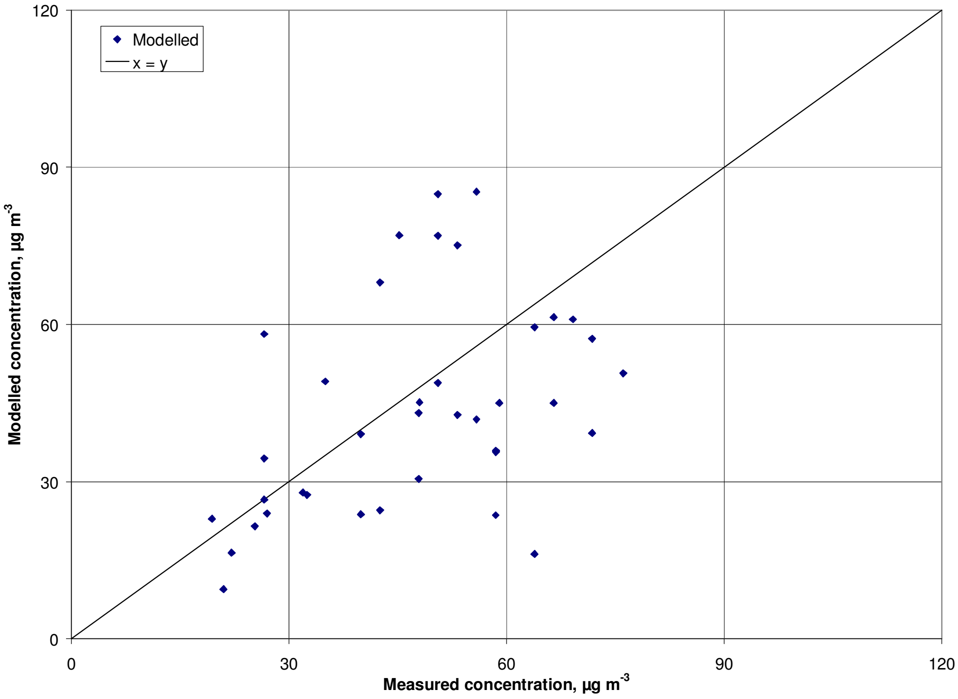
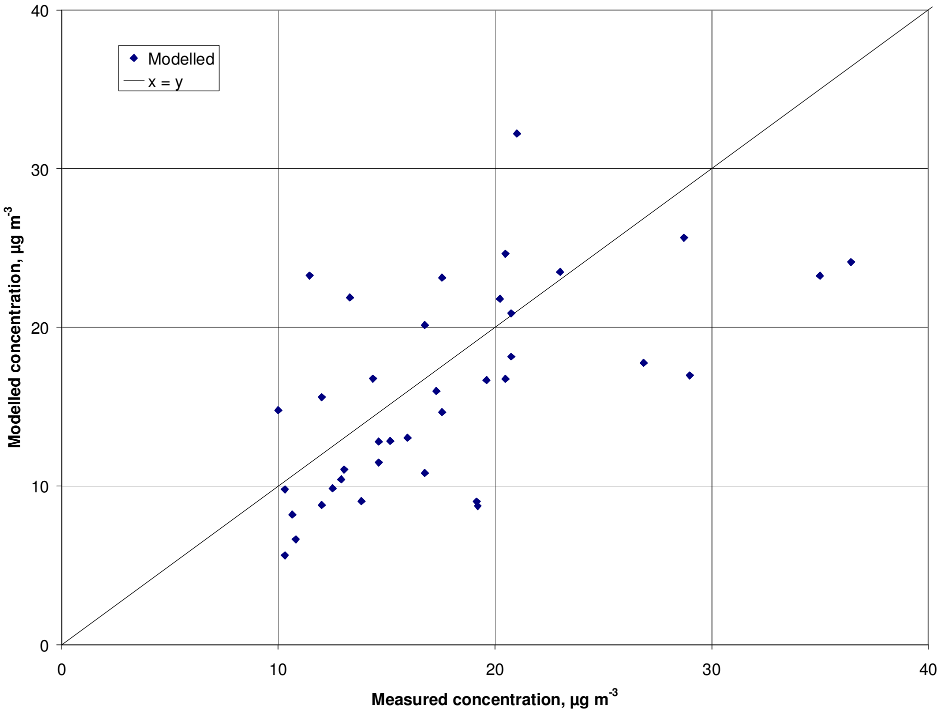


Figure 2.7. Comparison plot for 2006 99.18 percentile of 24-hour mean SO_2 concentrations



An alternative method was used to derive 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. Additionally, the smaller number of point sources in Northern Ireland means that these sources make a much 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_2 concentrations using a linear least squares fit between measured annual mean and measured high percentile concentrations in Northern Ireland during 2006 at national network and AEA Energy & Environment Calibration Club monitoring sites. Figures 2.8a and 2.8b show the relationship between the annual mean and the 99.73 percentile of 1-hour mean values and the 99.18 percentile of 24-hour mean values at the sampling sites in Northern Ireland.

The equations used to derive the high percentile maps are:

$$\textit{Predicted 99.73 \%ile in Northern Ireland} = 9.77 \times \textit{Modelled Annual Mean} + 3.3$$

$$\textit{Predicted 99.18 \%ile in Northern Ireland} = 4.74 \times \textit{Modelled Annual Mean} + 3.24$$

Figure 2.8a: Relationship between mean concentration and 99.73 percentile of 1-hour concentrations at sampling sites in Northern Ireland

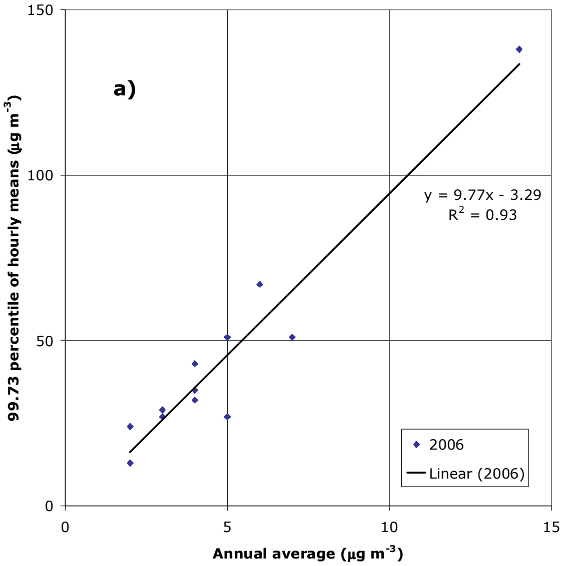
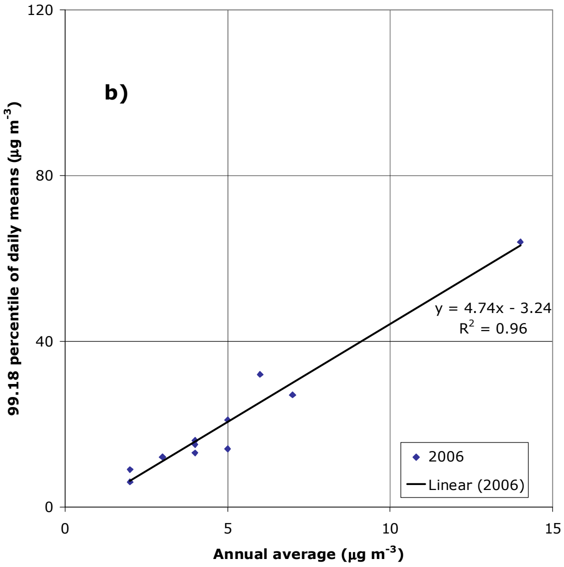


Figure 2.8b: Relationship between mean concentration and 99.18 percentile of 24-hour concentrations at sampling sites in Northern Ireland



A more detailed modelling study was carried out to estimate the ambient SO2 concentrations in the vicinity of the bickworks at Stewartby in Bedfordshire. Full details of this assessment are included in Appendix 4.

2.4 Verification of mapped values

Figures 2.8, 2.9 and 2.10 show comparisons of modelled and measured annual mean, 99.73 percentile of 1-hour means and 99.18 percentile of 24-hour means SO_2 concentrations in 2006 at monitoring site locations in the UK. Both the national network sites and the verification sites are shown. The ‘calibration sites’ include the electricity generating company sites and selected AURN sites. Urban background, centre and roadside AURN sites not used in the calibration process are also presented along with ‘verification sites’ that include ad-hoc monitoring sites and AEA Energy & Environment’s Calibration Club monitoring sites. A complete list of the AURN sites used are presented in Form 3 of the reporting questionnaire. Details of verification sites are presented in Table A1.1 of Appendix 1 and the sites maintained by the electricity generating companies are listed in Table A1.2. 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_2 concentrations respectively).

Figure 2.8. Verification of annual mean SO_2 model 2006

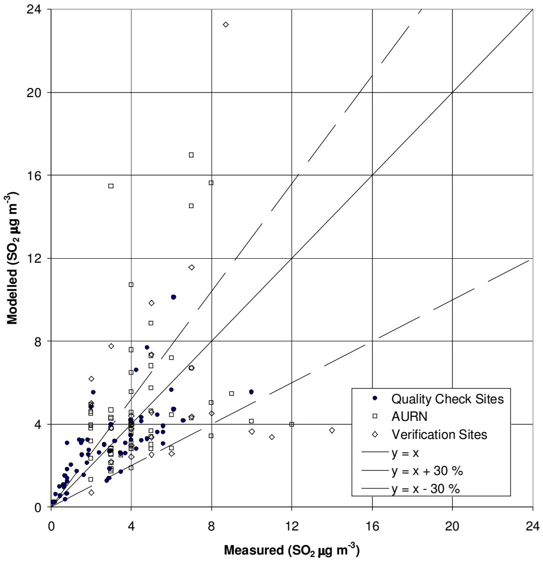


Figure 2.9. Verification of 99.73 percentile of 1-hour mean SO_2 model 2006

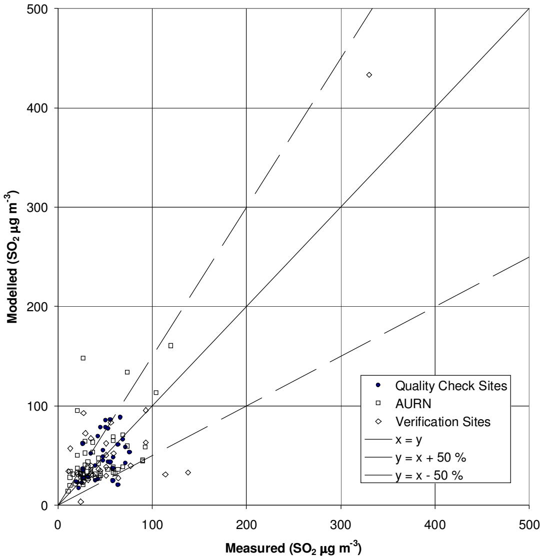
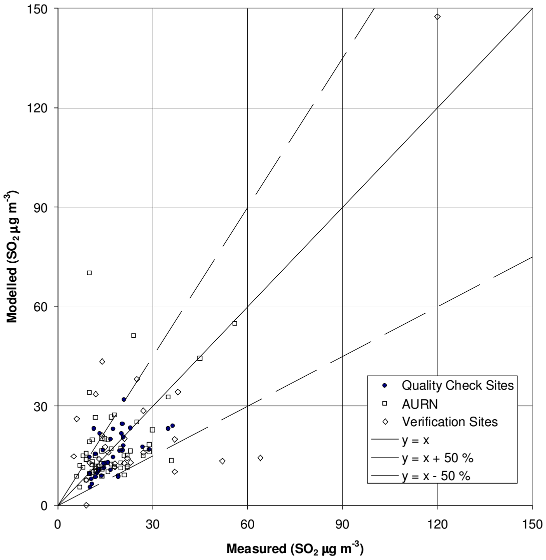


Figure 2.10. Verification of 99.18 percentile of 24-hour mean SO_2 model 2006



Summary statistics for modelled and measured SO_2 concentrations and the percentage of sites for which the modelled values are outside the data quality objectives (DQOs) and the total number of sites included in the analysis are listed in Tables 2.3, 2.4 and 2.5.

The mean measured and modelled concentrations for the each averaging time agrees reasonably well. For example, the annual mean measured concentration at the national network sites was 3.39 µg m^{-3}, whereas, the annual modelled concentration was 3.77 µg m^{-3}. The agreement between measured and modelled concentrations on a site-by-site basis (quantified using R^2) has historically been poor for all metrics both for sites in the national network at the verification sites. Note that the annual mean map is not compared directly with the annual mean limit value, the zonal mean of the 1km^2 grid squares in ecosystem areas has been calculated for a 30km^2 grid, as discussed above.

Reasons for the poor agreement include:

- Emissions from large industrial emission sources are decreasing. This will result in an increase in the relative contribution from other sources. The emission characteristics of these sources are less well known;
- The receptor grid used in the model predictions (concentrations are predicted at 5 km intervals) may be too coarse for the smaller emission sources;
- The modelling method does not explicitly model concentrations arising from non-UK sources.

The R^2 values in Tables 2.3 to 2.5 for national network sites were comparable to those reported in the 2005 SO_2 modelling. The R^2 values for the verification sites represent a reasonable model performance in the high percentile metrics but poor in the annual mean metric.

Methods to improve the prediction could include:

- Improve emission characteristics for smaller emission sources;
- Increase the resolution of the receptor area (5 km to 1 km or 2 km);
- Consider using region specific meteorological data;
- Use a long-range transport model to predict sulphur dioxide concentrations from non-UK sources.

Table 2.3. Summary statistics for comparison between modelled and measured annual mean concentrations of SO_2 at background sites

	Mean of measurements ($\mu g\ m^{-3}$)	**Mean of model estimates ($\mu g\ m^{-3}$)**	**r^2**	**% of sites outside DQO of ±30%**	**Number of sites in assessment**
National Network	3.39	3.77	0.29	67	98[a]
Verification Sites	5.36	5.31	0.04	67	27

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

Table 2.4 Summary statistics for comparison between modelled and measured 99.73 percentile of 1-hour mean concentrations of SO_2 at background sites

	Mean of measurements ($\mu g\ m^{-3}$)	**Mean of model estimates ($\mu g\ m^{-3}$)**	**r^2**	**% of sites outside DQO of ±50%**	**Number of sites in assessment**
National Network	41.22	36.32	0.28	22	68[b]
Verification Sites	60.81	59.97	0.72	33	27

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

Table 2.5 Summary statistics for comparison between modelled and measured 99.18 percentile of 24-hour mean concentrations of SO_2 at background sites

	Mean of measurements ($\mu g\ m^{-3}$)	Mean of model estimates ($\mu g\ m^{-3}$)	r^2	% of sites outside DQO of ±50%	Number of sites in assessment
National Network	17.25	14.05	0.22	24	68[c]
Verification Sites	25.41	23.10	0.57	37	27

c. 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 1-hour and 24-hour limit value for each zone, are summarised in Table 2.6. These data have also been presented in Form 19a of the questionnaire. The SO_2 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 2006. This limit value does not apply in agglomeration zones, according to the definition in the Directive (see Section 1.3). Method A in Table 2.6 refers to the modelling method described in this report. The modelled exceedences of the limit values in the Eastern Zone are associated with industrial emissions at the brickworks at Stewartby, which are further described in Appendix 4.

Table 2.6 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^2	*Method*	*Number*	*Method*	*km^2*	*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

Zone	*Zone code*	*Above LV for health (1hr mean)*				*Above LV for health (24hr mean)*			
		Area		*Population exposed*		*Area*		*Population exposed*	
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	4	A	867	A	1	A	59	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

3 NO_2/NO_X

3.1 Introduction

Two limit values concerning ambient NO_2 concentrations for the protection of human health have been specified in the First Daughter Directive: an annual mean of 40 µg m^{-3} and an hourly concentration of 200 µg m^{-3}, with 18 permitted exceedences each year. Additionally an annual mean limit value for NO_X of 30 µg m^{-3} (as NO_2) has been specified, which only applies for vegetation areas as defined in the directive. This section of the report describes modelling work carried out for 2006 to assess compliance with these limit values.

Annual mean concentrations of NO_X and NO_2 have been modelled for the UK for 2006 at background and roadside locations. Maps of annual mean NO_2 concentrations for these locations in 2006 are presented in Figures 3.1 and 3.2. The modelling methods for NO_X and NO_2 have been developed over a number of years (Stedman and Bush, 2000, Stedman *et al.*, 2001b, Stedman *et al.*, 2001c, Stedman *et al.*, 2002, Stedman *et al.*, 2003 Stedman *et al.*, 2005, Stedman *et al.*, 2006a, Kent *et al.*, 2007).

Figure 3.1. Annual mean background NO_2 concentration, 2006 (µg m^{-3})

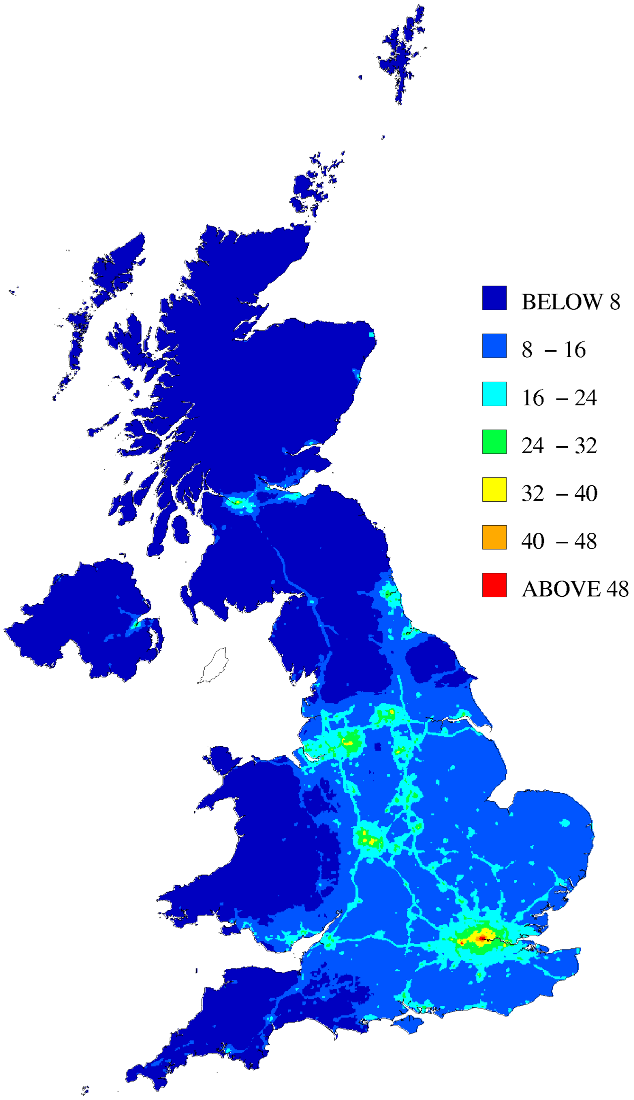
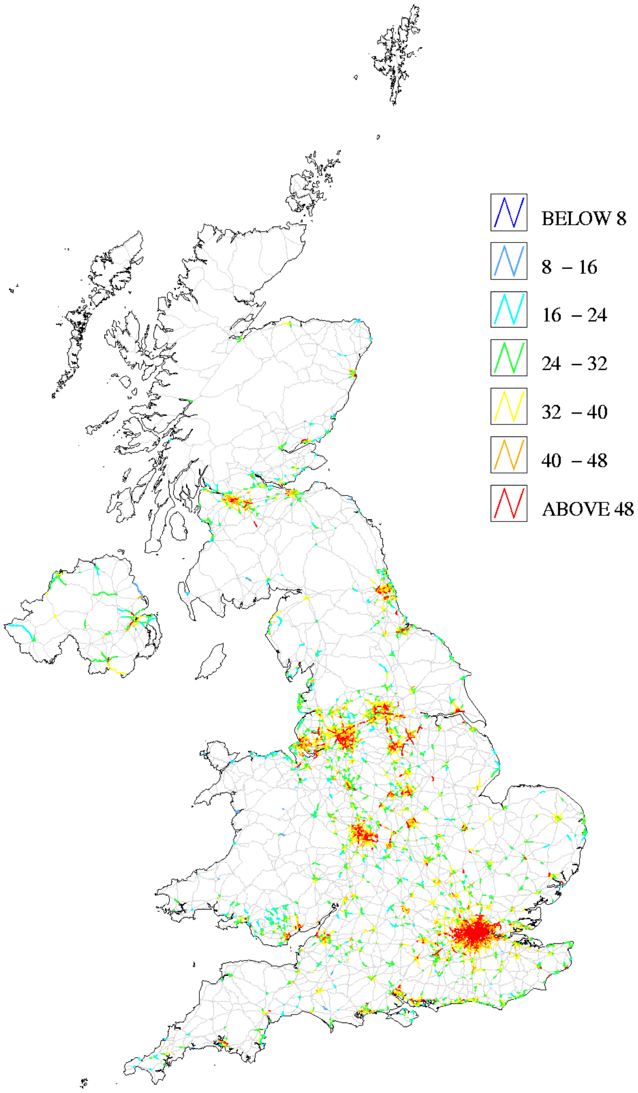
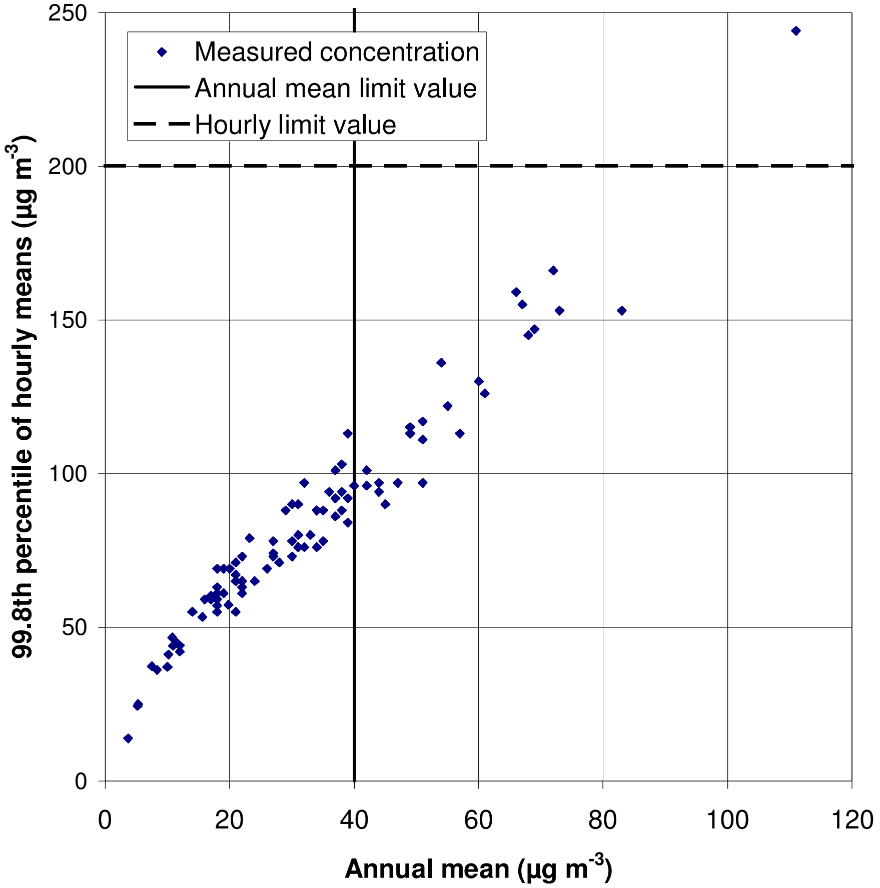


Figure 3.2. Urban major roads, annual mean roadside NO_2 concentration, 2006 (µg m^{-3})



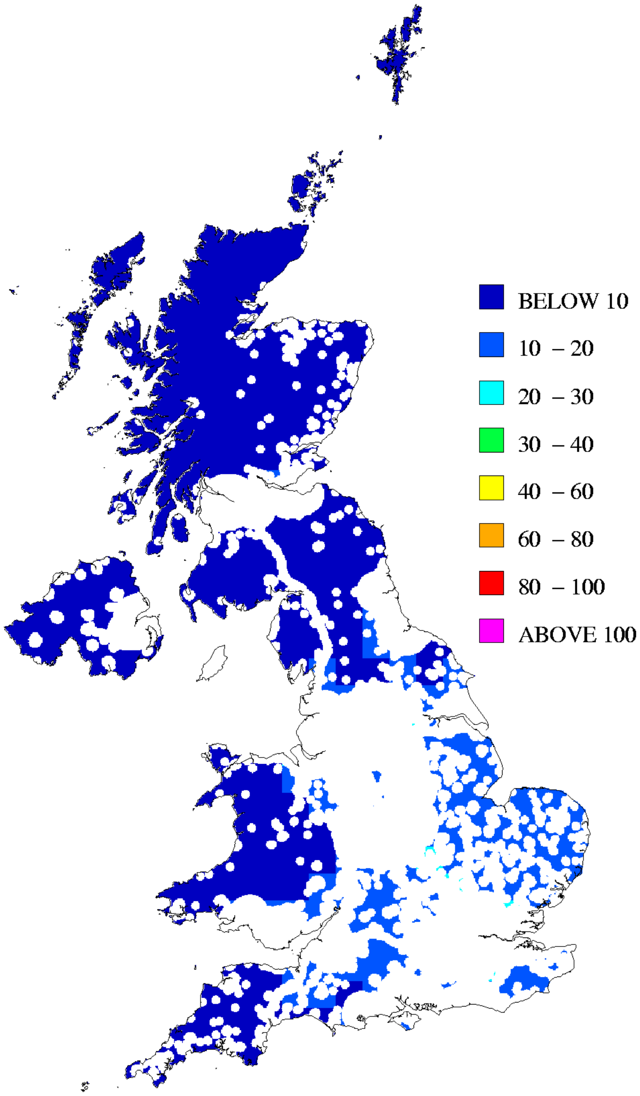
The modelling presented in this report for NO_X and NO_2 has been restricted to estimation of annual mean concentrations for comparison with the annual mean limit values. No attempt has been made to model hourly concentrations for comparison with the 1-hour limit value. This is due to the considerable uncertainties involved in modelling at such a fine temporal scale. The annual mean limit value is expected to be more stringent than the 1-hour limit value in the majority of situations (AQEG, 2004). This is illustrated in Figure 3.3 which is a scatter plot of the annual mean metric in 2006 against the 99.8th percentile (equivalent to 18 exceedences) hourly mean concentration in the same year. This plot shows a significantly higher number of sites exceeding the annual mean limit value of 40 µg m^{-3} than the 200 µg m^{-3} hourly limit value.

Figure 3.3. Plot of annual mean against 99.8th percentile hourly NO_2 concentrations in 2006



A map of NO_X concentrations from all sources has been calculated. This map is used to calculate a map of NO_2 concentrations for comparison with the limit values for the protection of human health and a map of NO_X concentrations in vegetation areas for comparison with the limit value for the protection of vegetation. The map of annual mean NO_X concentrations in vegetation areas is presented in Figure 3.4. This map has been calculated by removing non-vegetation areas from the background NO_X map and calculating the zonal mean of the 1km^2 grid squares for a 30km^2 grid. Mean concentrations on a 30km^2 grid have been used to prevent the influence of any urban area appearing unrealistically large on adjacent vegetation areas. Thus the modelled concentrations in vegetation areas should be representative of approximately 1000km^2 as specified in Directive 1999/30/EC for monitoring sites used to assess concentrations for the vegetation limit value.

Figure 3.4. Annual mean Rural NO_X concentration, 2006 ($\mu g\ m^{-3}$, as NO_2)



The annual mean background NO_X concentration map has been calculated by summing the contributions from:

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

The area source model has been calibrated using data from the national automatic monitoring networks for 2006. At locations close to busy roads an additional roadside contribution has been added to account for contributions to total NO_X from road traffic sources. The contributions from each of these components are described in sections 3.2-3.6.

In order to estimate the NO_2 concentrations, modelled NO_X concentrations derived from the approach outlined above are converted to NO_2 using an oxidant partitioning model which describes the complex inter-relationships of NO, NO_2 and ozone as a set of chemically coupled species (Jenkin, 2004). This approach provides additional insights into the factors controlling ambient levels of NO_2 (and ozone), and how they may vary with NO_X concentration. Details of the methods used to estimate ambient NO_2 from these estimates of NO_X are presented in Sections 3.7 and 3.8.

3.2 NO_X contributions from large point sources

Contributions to ground level annual mean NO_X concentrations from large point sources (those with annual emission greater than 500 tonnes) in the 2005 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model (ADMS 3.3) and sequential meteorological data for 2006 from Waddington. A total of 159 large point sources were modelled for NO_X. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100km x 100km square composed of a regularly spaced 5km x 5km resolution receptor grid. Each receptor grid was centred on the point source. 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 2005 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_2 point sources were also used to characterise the release of emission (Abbott and Vincent, 1999).

3.3 NO_X contributions from small point sources

Contributions from NO_X point sources with less than 500 tonnes per annum emissions in the 2005 NAEI were modelled using the small points model described in Appendix 2.

3.4 NO_X contribution from rural background concentrations

Rural annual mean background NO_X concentrations have been estimated using:

- NO_X measurements at 11 selected rural AURN sites
- NO_X estimated from NO_2 measurements at 16 rural NO_2 diffusion tube sites from the Acid Deposition Monitoring Network (Lawrence, *pers comm. 2007*)

Figure 3.5 shows the locations of these monitoring sites.

Figure 3.5. Monitoring sites used to interpolate rural background NO_X concentrations (annual mean NO_X concentrations for 2006 ($\mu g\ m^{-3}$, as NO_2) are shown below the site name)

Rural NO_x was estimated from rural NO_2 at diffusion tube sites by dividing by 0.7835. This factor, which is a typical NO_X/NO_2 ratio measured at rural automatic monitoring sites (Stedman *et al*, 2003), does not vary significantly between years or across the country. Measurements have then been corrected to remove the contribution from point source and local area sources to avoid double counting these contributions later in the modelling process. The correction procedure is as follows:

Corrected rural background (µg m^{-3}*) = Uncorrected rural background* (µg m^{-3}*) – (A + B + C)*

Where: A = an estimate of the contribution from area source components, derived using the area source model empirical coefficients from the 2005 modelling

B = sum of contributions from large point sources in 2006 modelling

C = sum of contributions from small point sources in 2006 modelling

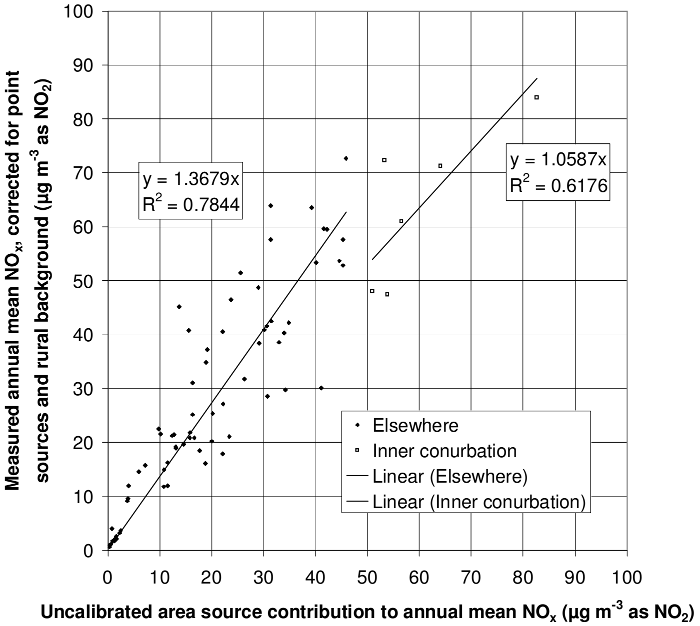
Automatic sites, where available have been used in preference to diffusion tubes as these are considered to be more accurate. A bi-linear interpolation of corrected rural measurement data has been used to map regional background concentrations throughout the UK.

3.5 NO_X contributions from local area sources

The modelled uncalibrated area source contribution has been calculated by applying an ADMS derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33km x 33km square surrounding each monitoring site. Hourly sequential meteorological data from Waddington in 2006 has been used to construct the dispersion kernels, as described in Appendix 3.

Figure 3.6 shows the calibration of the area source model. The modelled concentrations from all point sources and corrected rural NO_X concentrations have been subtracted from the measured annual mean NO_X concentration at background sites. This corrected background concentration is compared with the modelled area source contribution to annual mean NO_X to calculate the calibration coefficients used in the area source modelling.

Figure 3.6. Calibration of area source NO_x model, 2006 (µg m^{-3}, as NO_2)



The monitoring sites fall into two groups: ‘inner conurbations’ and ‘elsewhere’. ‘Inner conurbations’ includes central London (within the inner ring road) and central Birmingham, as defined by DfT (2003). The lower coefficients for the inner conurbations suggest that dispersion is more efficient in these locations due to increased turbulence resulting from variable urban topography.

Adjustment factors were applied to the emissions from selected transport sources. Emissions from aircraft were multiplied by 0.36, representing the diminishing influence of aircraft emissions on ambient air quality at the surface with increasing altitude. This factor was derived from specific dispersion modelling studies to determine the proportion of aircraft emissions released near the surface and fits well with the monitoring data. A factor of 0.25 was applied to emissions from ships to represent the diminishing influence of emissions on ambient air quality with increasing distance from the coast. This factor was empirically derived to fit monitoring data at coastal locations.

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 regional rural concentrations were then added, resulting in a map of background annual mean NO_x concentrations.

3.6 Roadside concentrations

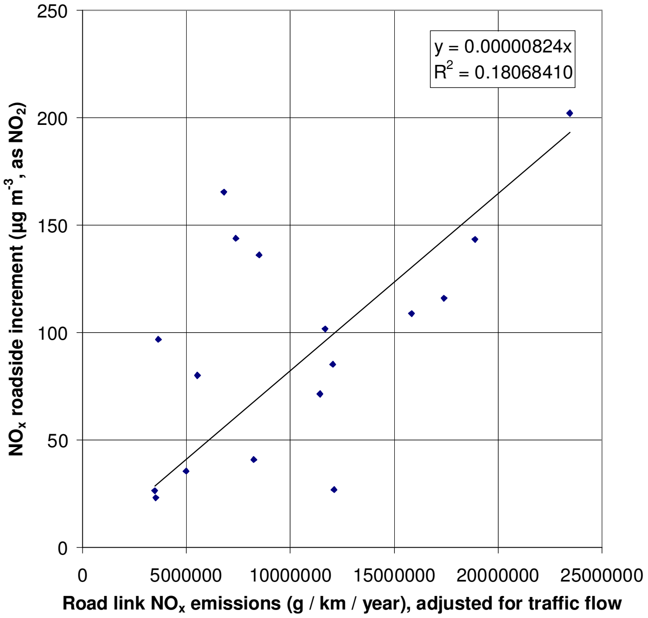
We have considered that the annual mean concentration of NO_X at roadside locations to be made up of two parts: the background concentration (as described above) and a roadside increment:

roadside NO_X concentration = background NO_X concentration + NO_X roadside increment

The NAEI provides estimates of NO_X emissions for major road links in the UK for 2005 (Dore *et al.*, 2007) and these have been adjusted to provide estimates of emissions in 2006. Figure 3.7 shows the roadside increment of annual mean NO_X concentrations (i.e. measured roadside NO_X concentration – modelled background NO_X concentration) at roadside or kerbside national automatic monitoring sites plotted against NO_X emission estimates adjusted for traffic flow for the individual road links alongside which these sites are located. The background NO_X component at these roadside monitoring sites is taken from the background map described in Section 3.5 above.

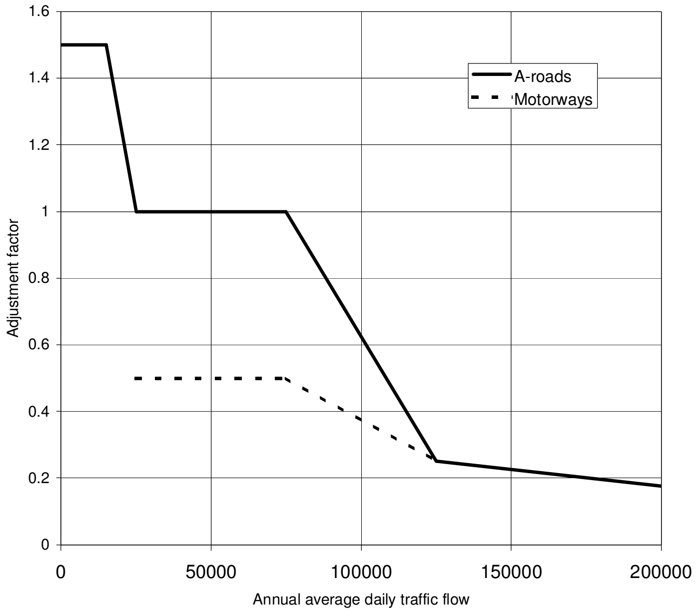
The calibration coefficient derived is then used to calculate the roadside increment on each road link by multiplying it with an adjusted road link emission (see figure 3.8). Roadside concentrations for urban major road links (A-roads and motorways) only are reported to the EU and included in this report.

Figure 3.7. Calibration of NO_X roadside increment model, 2006 (µg m^{-3}, as NO_2)



The dispersion of emissions from vehicles travelling along a road is influenced by a number of different factors including road width 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 3.8 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 3.8

Figure 3.8 The adjustment factors applied to road link emissions



3.7 Empirical relationships between NO_2 and NO_X concentrations

Maps of estimated annual mean NO_2 concentrations (Figure 3.1 and 3.2) have been calculated from modelled NO_X concentration using relationships presented in the oxidant-partitioning model (Jenkin, 2004). Using this method for predicting NO_2 offers a way of treating the NO_X to NO_2 relationship via representative expressions which account for the chemical coupling of O_3, NO and NO_2 within the atmosphere. In particular, this approach has the advantage of enabling the models to address emission scenarios by varying regional oxidant levels or primary NO_2 emissions, expressed as the proportion of NO_X emitted as primary NO_2 (f-NO_2).

NO_2 concentrations were calculated as the sum of local primary NO_2, which is estimated from the modelled NO_X concentrations, and a secondary NO_2 contribution, which is derived from an estimate of regional total oxidant as a function of modelled NO_X. The expression presented below has been used to describe the variation of annual mean $[NO_2]$ with $[NO_X]$ (in ppb, where 1 ppb NO_2 = 1.91 $\mu g\ m^{-3}$). Equation (i) being substituted for $f(NO_X)$ at locations directly influenced by roads and equation (ii) for $f(NO_X)$ at all other locations.

$$[NO_2] = (f\text{-}NO_2[NO_X] + B).f(NO_X)$$

$$[NO_2]/[OX] = (8.962 \times 10^{-2}) + (1.474 \times 10^{-2}\ [NO_X]) - (1.290 \times 10^{-4}\ [NO_X]^2) + (5.527 \times 10^{-7}\ [NO_X]^3) - (8.906 \times 10^{-10}\ [NO_X]^4) \qquad \text{(i)}$$

$$[NO_2]/[OX] = (1.015 \times 10^{-1}) + (1.367 \times 10^{-2}\ [NO_X]) - (6.127 \times 10^{-5}\ [NO_X]^2) - (4.464 \times 10^{-8}\ [NO_X]^3) \qquad \text{(ii)}$$

The appropriate values of regional oxidant (B, Oxidant [OX]) are given in Table 3.1. The values of f-NO_2 have been derived as described in Section 3.8.

Table 3.1 Summary of regional oxidant (OX) concentrations determined from an analysis of O_3 and NO_X in 13 UK areas (source Jenkin, 2004)

Region	Zones	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_X concentrations lower than 17 µg m^{-3}, as NO_2. At NO_X concentrations of less than 17 µg m^{-3} as NO_2, NO_2 concentrations have been estimated using the relationship previously suggested by Stedman *et al.* (2003) for rural locations:

$$[NO_2] = [NO_X] \times 0.7835$$

In calculating the annual mean NO_2 concentrations at background locations for 2004, 0.5 ppb was added to the regional oxidant concentrations presented in Jenkin (2004), who considered concentrations up to 2001, because regional oxidant is thought to be increasing with time at a rate of about 0.2 ppb yr^{-1} (Derwent *et al.*, 2005). As a result of indications of a recent reduction in the rate of regional oxidant increase, an increase of 0.1 ppb was added to regional oxidant for the 2005 mapping. For the same reason, in the 2006 modelling we have kept regional oxidant levels constant at the levels used in 2005.

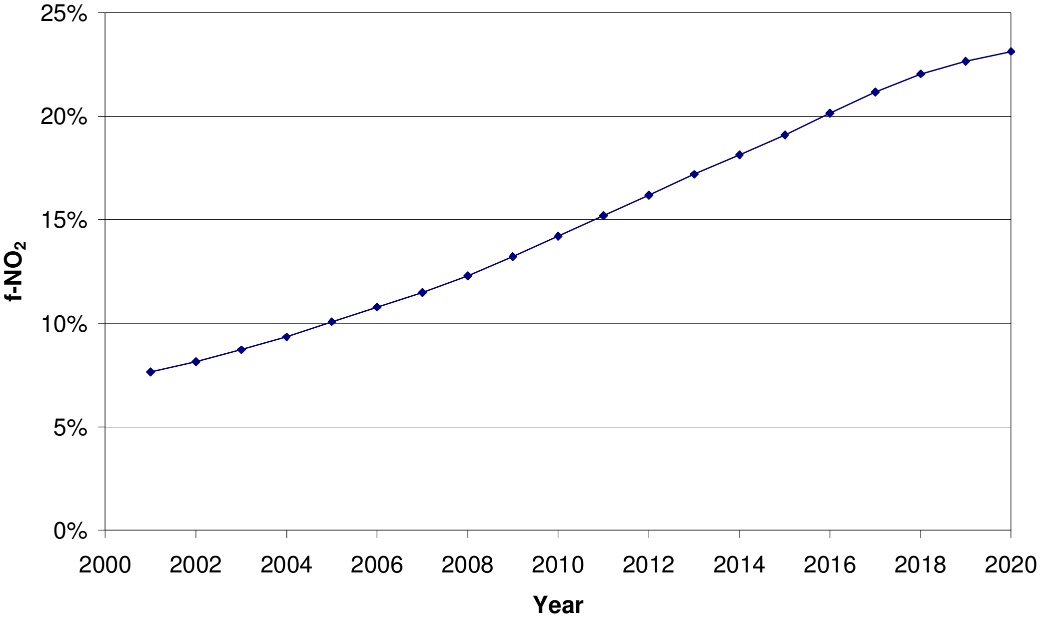
3.8 Primary NO_2 emission fractions

The primary NO_2 component (i.e. fraction of NO_X emitted directly as NO_2, referred to as *f*-NO_2) from road traffic sources is thought to be generally rising, although this trend displays considerable variation with location (AQEG, 2006, *in consultation*). This increase in *f*-NO_2 has implications for the ability of legislative controls on NO_X emissions to limit ambient NO_2 concentrations.

In order to represent these changes in *f*-NO_2 within the oxidant partitioning model used in this report to model NO_2 concentrations from the NO_X maps (see section 3.7), we have used an NO_2 specific inventory. This has been generated for the 2005 NAEI on the basis of the NO_X emissions inventory for traffic combined with *f*-NO_2 values taken from a review of *f*-NO_2 measurement studies presented in Grice *et al.* (2007). Average *f*-NO_2 values across different areas of the UK for urban roads and all roads have been then calculated as the ratio of NO_2/NO_X emissions for these areas. Figure 3.9 shows the resulting estimates of how the *f*-NO_2 across all the UK's urban roads has changed, and is predicted to change with time.

Details of how these *f*-NO_2 values have been incorporated into the roadside and background modelling are presented below in sections 3.8.1 and 3.8.2 respectively.

Figure 3.9 *f*-NO_2 on UK urban roads (2001-2020)



3.8.1 Roadside calculations

For the roadside modelling, an *f*-NO_2 value has been derived for each road link that we have modelled. To do this, we have generated average *f*-NO_2 values across the UK for different vehicle classes (cars, LGVs, rigid HGVs, articulated HGVs, buses and London buses) using the 2005 NAEI NO_X road transport emissions inventory combined with *f*-NO_2 values for specific vehicle classes taken from a review of values in the literature given in Grice *et al.*, (2007). This combines *f*-NO_2 values for vehicles with different fuels and compliant to different Euro emissions standards into one average UK value for each vehicle class. These average *f*-NO_2 values for different vehicle classes have been combined with traffic flow data by vehicle class for each road link to generate a road link specific *f*-NO_2 value.

In London, the NAEI does not incorporate data on taxis, which are predominantly diesel and therefore have a significantly higher *f*-NO_2 than petrol cars. This means that the national average *f*-NO_2 for cars under-predicts *f*-NO_2 in London and this under-prediction becomes greater towards central London as the proportion of taxis relative to other cars increases. To account for this in our modelling, we have used NO_X emission estimates for cars and taxis from the 2003 LAEI (GLA, 2006) to provide a new estimate of NO_X emissions from diesel and petrol cars. New road link specific *f*-NO_2 for cars was then calculated by taking the taxis into account. This *f*-NO_2 value for cars is then used instead of the nationwide *f*-NO_2 value for cars on road links in London in the calculations describe above.

3.8.2 Background calculations

A map of local oxidant for the background NO_2 calculations was calculated by splitting the background annual mean NO_X map into its three constituent components: NO_X from non-road traffic primary emissions, NO_X from road-traffic primary emissions and rural background NO_X concentrations. These components were then multiplied by the relevant *f*-NO_2 value presented in Table 3.2 (for rural background NO_X the non-road background *f*-NO_2 was used) to give a map of local oxidant.

Table 3.2 Local oxidant coefficients (*f*-NO_2) for background concentrations

Region	Non-road *f*-NO_2 for background calculations	Road *f*-NO_2 for background calculations
Central London	0.140	0.230
Inner London	0.128	0.192
Outer London	0.093	0.159
Elsewhere	0.093	0.108

The non-road *f*-NO_2 values used for background calculations in Table 3.2 have been taken directly from Jenkin (2004), as there is little evidence that this has changed significantly over the past few years.

The road traffic *f*-NO_2 value for background calculations everywhere outside London has been calculated using the NO_2 specific emissions inventory to calculate an *f*-NO_2 value as described above. For roads within London, this approach to calculating *f*-NO_2 values significantly under-predicted *f*-NO_2 compared with values suggested in other studies. This reflects significant differences between the average UK vehicle fleet used to derive the *f*-NO_2 values in this work and the vehicle fleet in London. Therefore we have adopted an alternative approach whereby we have calculated an average *f*-NO_2 from the major road links (see section 3.81) within each area of London and applied this in the background model equations. Thus the differences in *f*-NO_2 in London due to taxis and London buses were taken into account in the calculation of NO_2 for background locations.

3.9 Verification of mapped values

Figures 3.11 and 3.12 show comparisons of modelled and measured annual mean NO_X and NO_2 concentration in 2006 at background monitoring site locations. Figure 3.13 and 3.14 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_2 and NO_X concentrations). There is no requirement under AQDD1 to report modelled annual mean NO_X concentrations for comparison with limit values for the protection of human health (the NO_X limit value for the protection of vegetation only applies in vegetation areas). However, comparisons of modelled and measured NO_X concentrations and of the modelled NO_X concentrations with the data quality objectives are presented here alongside the comparisons for NO_2. This provides an additional check on the reliability of our modelled estimates of NO_2 because the non-linear relationships between NO_X and NO_2 tend to cause modelled NO_2 concentrations to be relatively insensitive to errors in the dispersion modelling of NO_X.

Figure 3.11. Verification of background annual mean NO_X model 2006

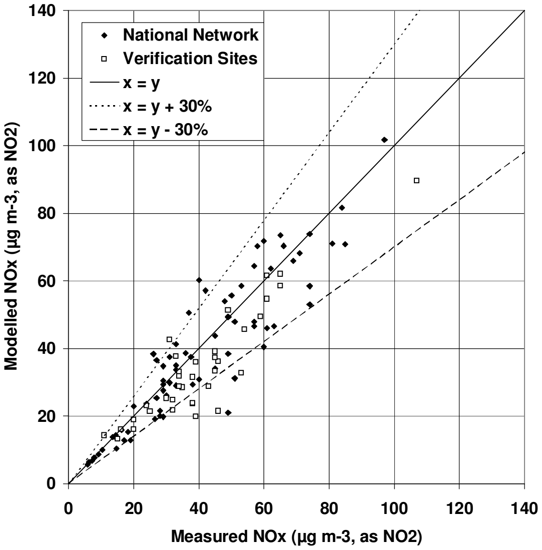


Figure 3.12. Verification of background annual mean NO_2 model 2006

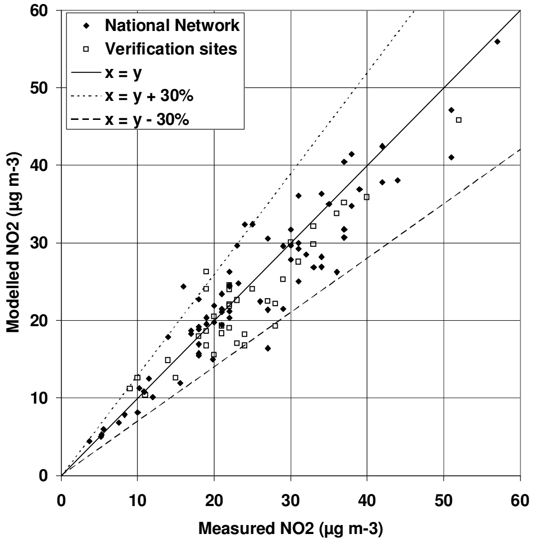


Figure 3.13. Verification of roadside annual mean NO_X model 2006

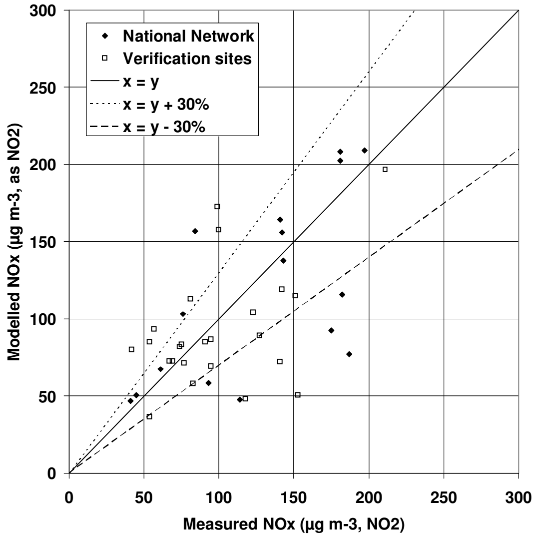
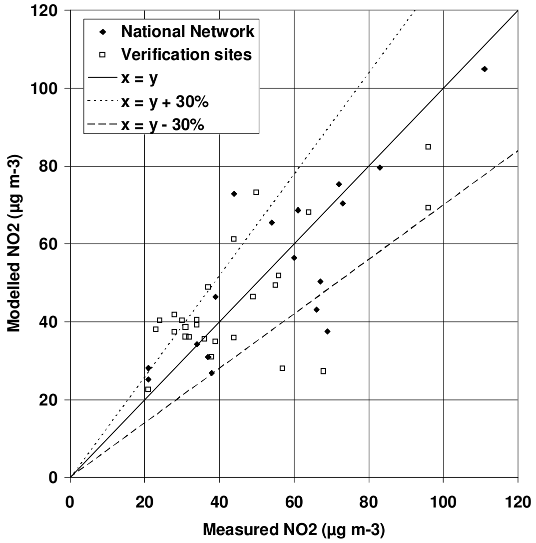


Figure 3.14. Verification of roadside annual mean NO_2 model 2006



Summary statistics for the comparison between modelled and measured NO_X and NO_2 concentrations are listed in Tables 3.4 and 3.5. The percentages of monitoring sites for which the modelled annual mean concentrations fall outside the data quality objectives is generally greater for NO_X than for NO_2, for the reasons discussed above.

Table 3.4. Summary statistics for comparison between modelled and measured NO_x and NO_2 concentrations at background sites (μg m^{-3}, as NO_2)

		Mean of measurements (μg m^{-3}, as NO_2)	Mean of model estimates (μg m^{-3}, as NO_2)	r^2	% outside data quality objectives	Number of sites in assessment
NO_X	National Network	40.5	38.7	0.841	13.5	74
	Verification Sites	40.6	34.3	0.830	22.2	36
NO_2	National Network	24.6	23.8	0.879	4.1	74
	Verification Sites	24.1	22.4	0.849	8.3	36

Table 3.5. Summary statistics for comparison between modelled and measured NO_x and NO_2 concentrations at roadside sites (μg m^{-3}, as NO_2)

		Mean of measurements (μg m^{-3}, as NO_2)	Mean of model estimates (μg m^{-3}, as NO_2)	r^2	% outside data quality objectives	Number of sites in assessment
NO_X	National Network	137.9	128.1	0.582	41.2	17
	Verification Sites	99.1	92.2	0.213	45.8	24
NO_2	National Network	55.9	53.9	0.670	23.5	17
	Verification Sites	44.0	44.5	0.444	38.5	26

3.10 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 3.6. These data have also been presented in Form 19b of the questionnaire. The NO_X annual mean limit value for the protection of vegetation was not exceeded in vegetation areas in any of the non-agglomeration zones in 2006. 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 3.6 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII(II))

Zone	Zone code	Above LV for health (annual mean)					
		Area		Road length		Population exposed	
		km^2	Method	km	Method	Number	Method
Greater London Urban Area	UK0001	86	A	1592.0	A	765443	A
West Midlands Urban Area	UK0002	0	A	346.8	A	0	A
Greater Manchester Urban Area	UK0003	1	A	382.5	A	308	A
West Yorkshire Urban Area	UK0004	2	A	164.6	A	2462	A
Tyneside	UK0005	0	A	75.9	A	0	A
Liverpool Urban Area	UK0006	0	A	120.9	A	0	A
Sheffield Urban Area	UK0007	0	A	104.4	A	0	A
Nottingham Urban Area	UK0008	0	A	52.1	A	0	A
Bristol Urban Area	UK0009	0	A	47.8	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	A	8.7	A	0	A
Leicester Urban Area	UK0011	0	A	46.5	A	0	A
Portsmouth Urban Area	UK0012	0	A	24.4	A	0	A
Teesside Urban Area	UK0013	0	A	21.6	A	0	A
The Potteries	UK0014	0	A	29.0	A	0	A
Bournemouth Urban Area	UK0015	0	A	8.5	A	0	A
Reading/Wokingham Urban Area	UK0016	0	A	20.9	A	0	A
Coventry/Bedworth	UK0017	0	A	20.1	A	0	A
Kingston upon Hull	UK0018	0	A	34.6	A	0	A
Southampton Urban Area	UK0019	0	A	21.4	A	0	A
Birkenhead Urban Area	UK0020	0	A	9.8	A	0	A
Southend Urban Area	UK0021	0	A	8.3	A	0	A
Blackpool Urban Area	UK0022	0	A	0.0	A	0	A
Preston Urban Area	UK0023	0	A	4.2	A	0	A
Glasgow Urban Area	UK0024	0	A	156.6	A	0	A
Edinburgh Urban Area	UK0025	0	A	31.3	A	0	A
Cardiff Urban Area	UK0026	0	A	16.0	A	0	A
Swansea Urban Area	UK0027	0	A	0.0	A	0	A
Belfast Urban Area	UK0028	0	A	46.5	A	0	A
Eastern	UK0029	0	A	134.6	A	0	A
South West	UK0030	0	A	78.5	A	0	A
South East	UK0031	0	A	238.0	A	0	A
East Midlands	UK0032	0	A	114.2	A	0	A
North West & Merseyside	UK0033	0	A	243.9	A	0	A
Yorkshire & Humberside	UK0034	0	A	237.4	A	0	A
West Midlands	UK0035	0	A	84.6	A	0	A
North East	UK0036	0	A	75.7	A	0	A
Central Scotland	UK0037	0	A	27.3	A	0	A
North East Scotland	UK0038	0	A	32.8	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	45.5	A	0	A
North Wales	UK0042	0	A	12.7	A	0	A
Northern Ireland	UK0043	0	A	24.2	A	0	A
Total		89		4744.6		768213	

4 PM_{10}

4.1 Introduction

Maps of annual mean PM_{10} in 2006 at background and roadside locations are shown in Figures 4.1 and 4.2. These maps have been calibrated using measurements from gravimetric instruments only. Measurements from gravimetric, TEOM and BAM monitors have been used to verify the mapped estimates by applying the appropriate scaling factors prior to comparison. The methods used to derive the maps for 2006 are largely the same as was adopted for the 2004 maps as described in detail by Stedman *et al*., 2006b. The main revisions to the method for 2006 are:

- The inclusion of an explicit treatment of the contribution from iron and calcium rich dusts
- Secondary inorganic aerosol concentrations have been estimated using data from an expanded network of rural monitoring sites
- The apportionment between fine and coarse nitrate PM has been revised
- Sea salt derived PM concentration has been estimated from chloride measurements at rural monitoring sites.

Figure 4.1. Annual mean background PM_{10} concentration, 2006 ($\mu g\ m^{-3}$, gravimetric)

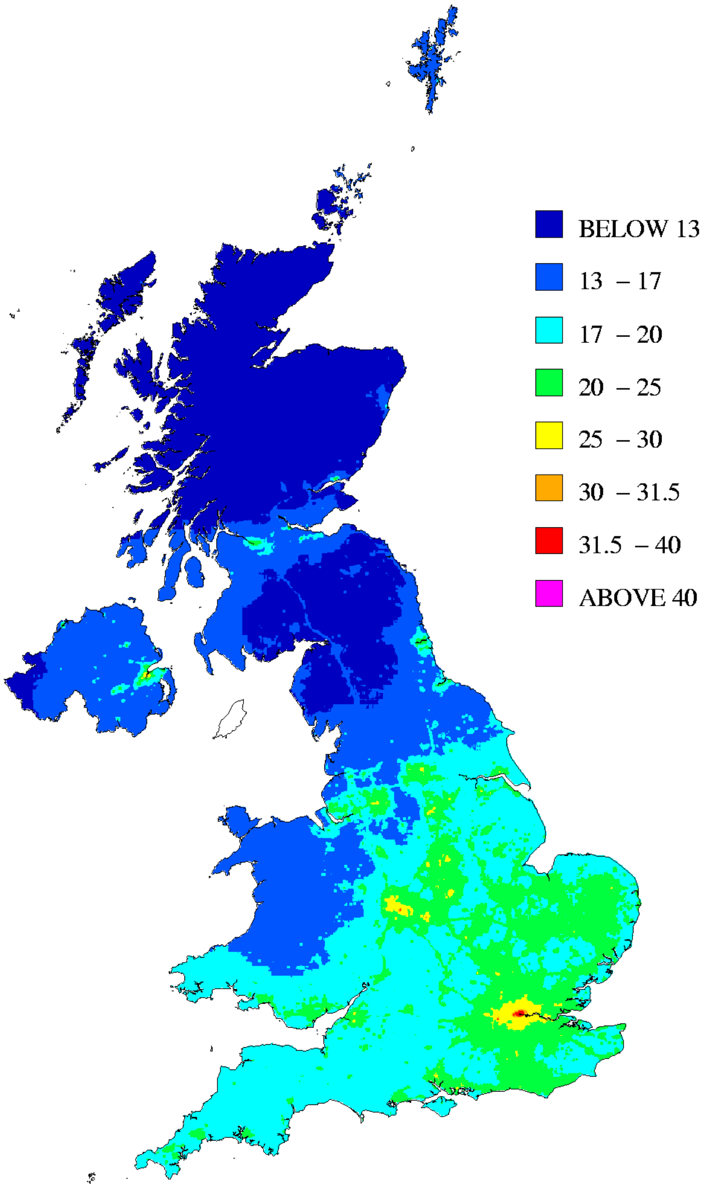
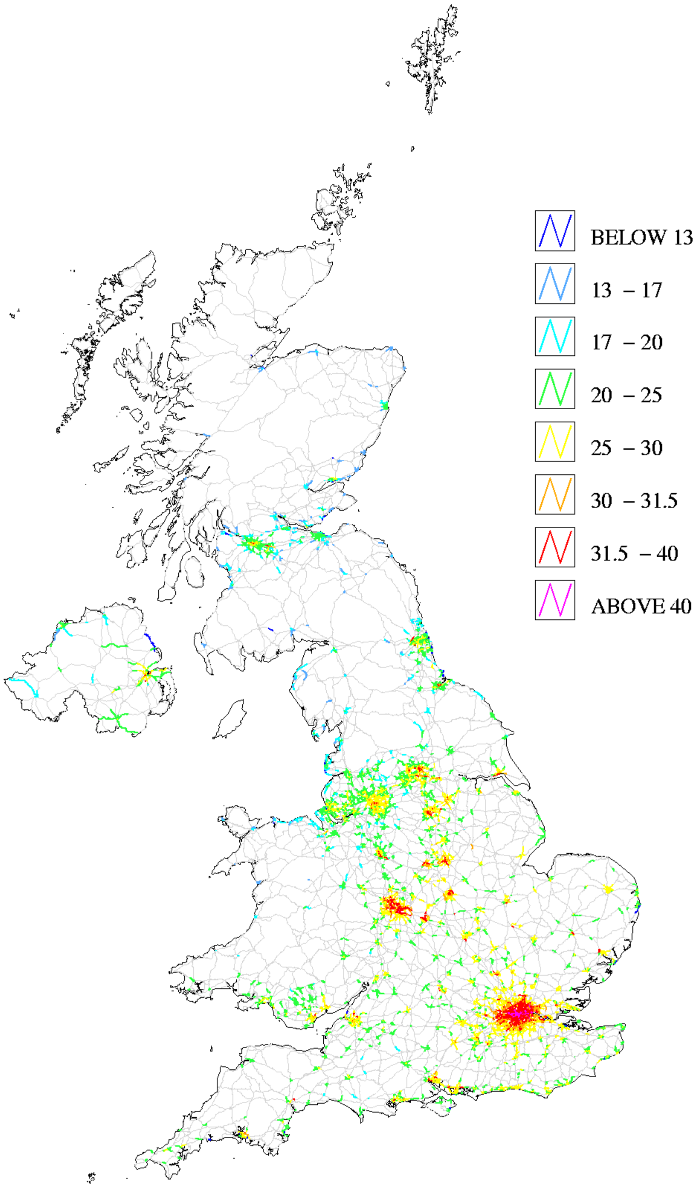


Figure 4.2. Urban major roads, annual mean roadside PM_{10} concentration, 2006 ($\mu g\ m^{-3}$, gravimetric)



The maps of background PM_{10} concentrations have been calculated by summing contributions from different sources:

- Secondary inorganic aerosol (derived by interpolation and scaling of measurements of SO_4, NO_3 and NH_4 at rural sites)
- Secondary organic aerosol (semi-volatile organic compounds formed by the oxidation of non-methane volatile organic compounds. Estimates derived from results from the HARM/ELMO model)
- Large point sources of primary particles (modelled using ADMS and emissions estimates from the NAEI)

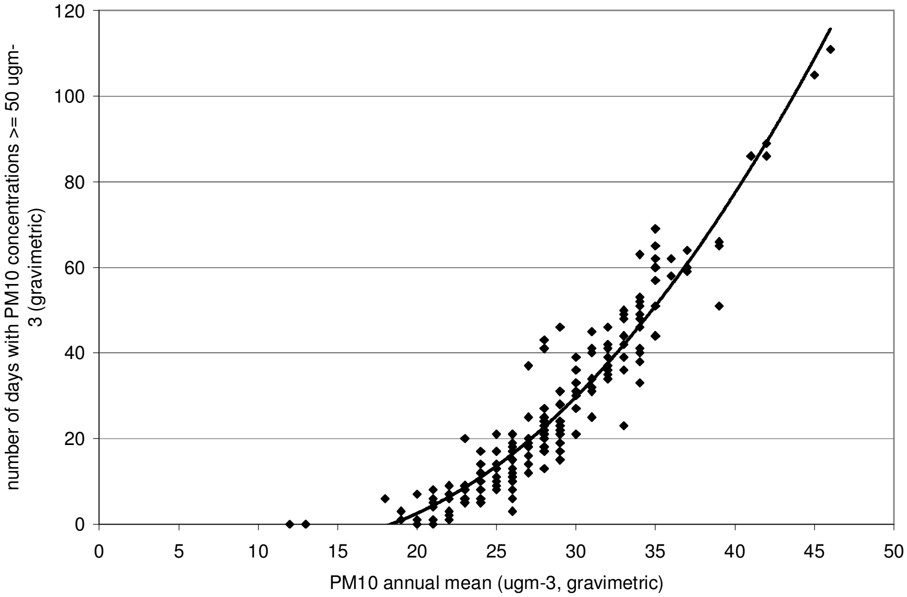
- Small point sources of primary particles (modelled using the small points model and emissions estimates from the NAEI)
- Regional primary particles (from results from the TRACK model and emissions estimates from the NAEI and EMEP)
- Area sources of primary particles (modelled using a dispersion kernel and emissions estimates from the NAEI)
- Iron and calcium rich dusts (estimated from a combination of measurements made in Birmingham and surrogate variables for the spatial distribution of the emission associated with these dusts)
- Sea salt (derived by interpolation and scaling of measurements of chloride at rural sites)
- Residual (assumed to be a constant value)

The concentrations of many of these components have been estimated separately for the fine and coarse fraction. This enables a consistent method to be adopted for estimation of PM_{10} (the sum of the fine and coarse fractions) and $PM_{2.5}$ (fine fractions only). These component pieces are then aggregated to a single 1x1 km background PM_{10} grid. An additional roadside increment is added for roadside locations.

Estimates of the emissions of primary PM from the 2005 UK National Atmospheric Emission Inventory (NAEI) have been used in this study (Dore, *et al*., 2007). Sector specific scaling factors have been used to scale the emissions to provide estimates for 2006. The NAEI provides emissions estimates and projections for a wide variety of different sources. Scaling factors for sectors such as road traffic, domestic combustion and processes were then derived by summing the emissions estimates for each source for 2005 and for the projection year (2006 in this case). The methods used to calculate ambient concentrations from the estimates of primary PM emissions are described below for point, area and regional sources.

24-hour mean concentrations have not been explicitly modelled for comparison with the 24-hour limit values. An annual mean concentration of 31.5 $\mu g\ m^{-3}$, gravimetric has been taken to be equivalent to 35 days with 24-hour mean concentrations greater than 50 $\mu g\ m^{-3}$ 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 Figure 4.3. Comparison with more recent monitoring data has confirmed that this relationship still holds (Stedman, *et al.* 2006b) and comparison against data obtained from Partisol instruments demonstrates that this relationship adequately describes genuine gravimetric data also (AQEG, 2005). The relationship between the number of days with concentrations greater than 50 $\mu g\ m^{-3}$, 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 $\mu g\ m^{-3}$, 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, 2005).

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



4.2 Contributions from secondary inorganic aerosol

Maps of secondary inorganic aerosol (SIA) concentrations across the UK have been calculated from rural measurements of sulphate, nitrate and ammonium concentrations by interpolation followed by the application of scaling factors derived from mass closure modelling. Measurements on a monthly basis are available for 27 rural monitoring sites for 2006 (Tang, *pers comm.* 2007). Concentration surfaces on a 5 km x 5 km grid were calculated from the measurement data using Krigging.

These secondary components were then split into fine and coarse fractions and non-volatile and volatile components using coefficients derived with reference to the detailed PM sampling carried out during the PUMA campaign at the University of Birmingham urban background monitoring site in June and July 1999 (Harrison *et al.*, 2006 and summarised by Kent *et al.*, 2007). The non-volatile secondary PM has been assumed to be sampled by a TEOM instrument, a gravimetric instrument should sample the sum of the non-volatile and volatile components. These secondary components were also scaled according to ‘bound water’ associated with the mass of water embedded within the particles (AQEG, 2005). Particle bound water is associated with the hygroscopic anions (Harrison *et al.*, 2006). This has been assumed to contribute to the fine and coarse components gravimetric but not the TEOM. Therefore a particle bound water scaling factor of 1.279 has been applied to the SIA components for the gravimetric maps (see Table 4.1). The scaling factors for bound water and counter ions (non-volatile) has not been used in this study but would be appropriate for mapping TEOM concentrations. The factor for coarse mode nitrate is higher as this includes the mass of the counter-ion (sodium or calcium).

The split between coarse and fine nitrate has been revised for 2006 with reference to measurement data from the TRAMAQ (Abdalmogith et al, 2006) and Birmingham (Harrison and Yin, 2006) studies. Fine PM is used to describe $PM_{2.5}$ and coarse PM is used to describe $PM_{2.5\text{-}10}$ in this report. The split between fine and coarse PM is simple to interpret for most PM constituents but is more complex for nitrate PM because there are two modes. The fine nitrate mode consists of ammonium nitrate, which is volatile, and is all in the fine $PM_{2.5}$ fraction. The coarse mode consists of sodium nitrate, which is split roughly half and half between fine $PM_{2.5}$ and coarse $PM_{2.5\text{-}10}$ fractions (Abdalmogith et al, 2006). Measurement data from the Birmingham study (Harrison and Yin, 2006) shows that the fine $PM_{2.5}$ nitrate to coarse $PM_{2.5\text{-}10}$ ratio was 3.5. Thus the fine mode nitrate to coarse mode nitrate ratio was 1.25. The factors for nitrate in Table 4.1 has been derived from a combination of this factor of 1.25 and the half and half split of the coarse mode nitrate into the fine $PM_{2.5}$ and coarse $PM_{2.5\text{-}10}$ fractions.

Table 4.1 Scaling factors for size fraction, bound water and counter ion mass for secondary inorganic and organic aerosol

Pollutant	Size fraction	Scaling factor for size fraction	Scaling factor for bound water and counter-ion mass	Scaling factor for bound water and counter-ion mass (non-volatile)
SO_4	Fine	0.94	1.279	1.00
	Coarse	0.06	1.279	1.00
NO_3	Fine mode	0.556	1.279	0.00
	Coarse mode fine	0.222	1.60	1.32
	Coarse mode coarse	0.222	1.60	1.32
NH_4	Fine	0.97	1.279	0.86
	Coarse	0.03	1.279	1.00
SOA	Fine	0.75	1.0	0.00
	Coarse	0.25	1.0	0.00

4.3 Contributions from secondary organic aerosol

Estimates of the secondary organic aerosol (SOA) concentrations on a 10km x 10km grid have been taken from the HARM/ELMO model (Whyatt *et al.*, 2007). This is a receptor oriented, Lagrangian statistical model, which tracks the changing composition of a series of air parcels travelling across the EMEP and UK areas towards designated receptor sites. SOA has been generated within the model through the photo-oxidation of terpenes and isoprene from natural emissions and anthropogenic emissions of toluene. SOA concentrations are not routinely measured but can be estimated from campaign measurements of elemental and organic carbon (EC and OC). Measured OC includes both primary and secondary components. EC and OC were measured at Bush Estate in Scotland from July 2002 to July 2003 (EMEP, 2005). The EC/OC campaign data exhibit seasonal variations at Bush that can be explained most simply by EC and primary OC contributions that peak in the winter and reach a minimum in the summer and a secondary OC contribution that peaks in the summer and is zero in the winter. More complicated explanations could and most certainly are operating. However, with the data available this is the simplest explanation of what is observed. Similar behaviour has been found at some sites in the EMEP EC/OC campaign but not at all sites. Hence we assume that the assumptions concerning the seasonal cycle in secondary OC work all across the UK, but not necessarily across Europe. Estimated peak summer time monthly concentrations of SOA were found to be 0.94 $\mu g\ m^{-3}$ and the model predicted peak summer time monthly concentrations of 0.4-0.5 $\mu g\ m^{-3}$. Since summer mean concentrations would be expected to be about double the annual mean, we consider that the modelled summer time value to provide a reasonable estimate of the annual mean and we have chosen not to scale the results. SOA is assumed to be volatile (Pankow, 1995) and thus contributes to gravimetric but not TEOM PM concentrations (Table 4.1).

4.4 Contributions from large and small point sources

Contributions to ground level annual mean primary PM concentrations from large point sources (those with annual emission greater than 200 tonnes) have been estimated by modelling each source explicitly using the atmospheric dispersion model (ADMS 3.3). Hourly sequential meteorological data for 2006 from Waddington was applied. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100km x 100km square composed of a regularly spaced 5km x 5km resolution receptor grid. Each receptor grid was centred on the point source. A total of 66 point sources were modelled explicitly.

Contributions from PM point sources with less than 200 tonnes per annum release were modelled using the ‘small points’ model described by Stedman *et al.* (2005) and summarised in Appendix 2. This model consists of separate ‘in-square’ and ‘out-of-square’ components, in which concentrations are estimated using dispersion kernels, which have been calculated by using ADMS 3.3 to model the dispersion of unit emissions from a central source to a grid of receptors at a spatial resolution of 1km x 1km squares.

4.5 Contributions from distant sources of primary particles

Contributions from long-range transport of primary particles on a 10km x 10km grid have been estimated using the TRACK receptor oriented, Lagrangian statistical model (Lee *et al*., 2000). Emissions of primary PM were taken from the NAEI for the UK sources and EMEP for sources in the rest of Europe. Primary PM was modelled as an inert tracer. All sources within 10km of the receptor point were excluded from the TRACK model to allow the area source model and the point source model to be nested within this long-range transport model without duplicating source contributions.

4.6 Iron and calcium rich dusts

A method for estimating the mass of iron (Fe) and calcium (Ca) rich dusts has been included in the modelling method for PM_{10} for the first time in 2006. Iron and calcium rich dusts were previously included in the constant residual PM concentration (Kent *et al*., 2007) because the emission of these dusts are not included in the NAEI, which precluded the use of a dispersion model to estimate ambient concentrations. A method has now been developed using the spatial distributions of vehicle km travelled and population as surrogates of the spatial distribution of the emissions of these components. Overall this has had the effect of reducing the mapped PM concentration in rural areas where the use of a constant residual tended to lead to a small overestimation in order to provide a good fit to measurements in urban areas.

The starting point for this new assessment is the measurements of a range of PM components including Fe and Ca reported by Harrison and Yin (2006) for three monitoring sites in the Birmingham area. Measurements were made and urban background site (BCCS) from May 2004 to May 2005, an urban roadside site (BROS) from May 2005 to November 2005 and at a rural site about 20km from the city (CPSS) from November 2005 to May 2006. Measurements were not made at the different sites simultaneously but the measurement periods were sufficiently long that they can be use to provide reasonable estimates of the urban and roadside increments of various PM components. The measurement data for Fe and Ca are summarised in Table 4.2

Table 4.2 Measured concentration of iron and calcium and derived estimates of iron and calcium rich dusts (µg m^{-3})

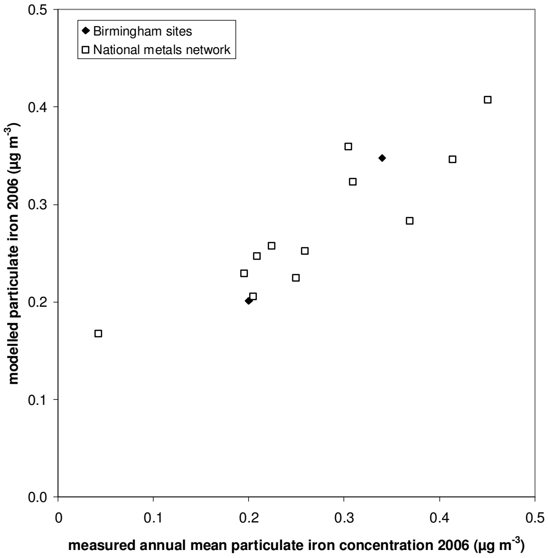
	CPSS (rural)	BCCS (urban)	conversion factor	rural x factor	Urban increment x factor
Fe fine	0.06	0.10	9.0	0.54	0.36
Fe coarse	0.14	0.24	9.0	1.26	0.89
Ca fine	0.03	0.09	4.3	0.13	0.26
Ca coarse	0.12	0.30	4.3	0.52	0.77

Table 4.2 also includes the conversion factors suggested by Harrison *et al*. (2006) for use within their pragmatic mass closure model. This factor converts to mass of elemental Fe to iron related dusts and the mass of elemental Ca to calcium related dusts. These factors have been applied to the measurement data from the rural CPSS site and the resulting PM masses have been assumed to apply across all rural areas of the UK. The urban increment in the table has been calculated by subtracting the data for CPSS from that for the urban BCCS site. It in clear that there is an urban increment for both fine and coarse iron and calcium rich dusts. Measurement data for the BROS roadside site indicates that there is a roadside increment on top of the urban increment for Fe but not for Ca. Thus it is reasonable to assume that urban increment for iron rich dusts is associated with emissions generated by road traffic but that the urban increment for calcium rich dusts is associated with urban emissions that are not related to traffic activity.

The NAEI does not include estimates of the urban emissions of iron or calcium rich dusts. Normalised distribution grid at a 1km x 1km are however available for vehicle km travelled and resident population. We have therefore used these distribution grids as surrogate emission grids within our area source model and have calculated calibration coefficients converting the values in the distribution grid (which add up to 1.0 for the whole of the UK) to surrogate emissions using the urban increments listed in Table 4.2.

The use of data from a single urban monitoring site to calibrate this model is clearly subject to considerable uncertainty. This revised method should, however, provide a more realistic estimate of the urban increments for these species. An indication that this method is providing reasonable estimates is provided by Figure 4.4, which shows a comparison of modelled Fe (the sum of rural and urban fine and coarse Fe) with ambient Fe measurements for 2006 from the national metals monitoring network. The modelled estimates are clearly of the correct magnitude and provide a reasonable description of the rural to urban gradients.

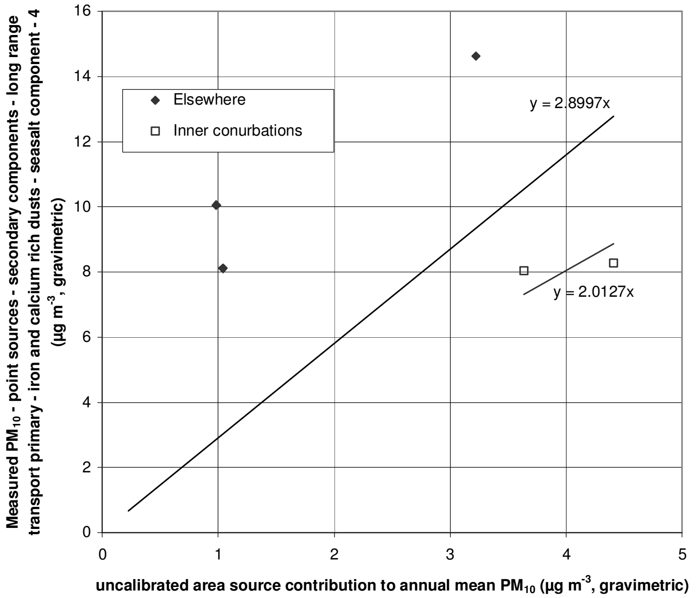
Figure 4.4. Comparison of modelled and measured annual mean elemental Fe concentrations 2006 (μg m^{-3})



4.7 Contributions from area sources

Figure 4.5 shows the calibration of the area source model. The modelled large point and small point source and mapped secondary PM_{10} have been subtracted from the measured annual mean PM_{10} concentration at background sites and compared with the modelled area source contribution to annual mean PM_{10} concentration. Calibration plots are shown in gravimetric μg m^{-3} because gravimetric measurements have been used to calibrate the model. An empirical method, utilising 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 33km x 33km square surrounding each monitoring site. Hourly sequential meteorological data from Waddington in 2006 was used to construct the dispersion kernels, as described in Appendix 3.

Figure 4.5. Calibration of PM_{10} area source model 2006 ($\mu g\ m^{-3}$, gravimetric)



The area source model has been calibrated using ambient PM monitoring data from the UK national networks. The modelled large point and small point source, SIA, SOA, iron and calcium rich dust, long range transport primary PM and the residual concentrations have been subtracted from the measured annual mean PM concentration at background sites and compared with the modelled area source contribution to annual mean PM concentration. The calibration coefficients used in the 2006 gravimetric background model are shown in Figure 4.5. The monitoring sites fall into two groups: 'inner conurbations' and 'elsewhere'. 'Inner conurbations' includes central London (within the inner ring road) and central Birmingham, as defined by DfT (2003). The lower coefficients for the inner conurbations suggest that dispersion is more efficient in these locations. This is a consistent finding in our modelling assessments (Stedman *et al.*, 2001a) including for TEOM PM_{10} in both 2004 and 2005 for which many more monitoring sites are available than for gravimetric PM_{10}. It is consistent with greater surface roughness and urban heat island effects in the city centres and the likelihood that some emissions sources are more elevated in city centres due to the greater building heights. Intermediate values of the calibration coefficient were used in an annulus of width 15km surrounding the central conurbation areas. It is clear that if more gravimetric monitoring data were available then the inclusion of more sites for the calibrations should increase the reliability of the estimates. There are however many more monitoring sites for NO_X and the modelling method has been shown to be reliable for NO_X (Stedman *et al.*, 2001a; 2006a and in this report). This gives confidence in the application of the method to both TEOM and gravimetric PM.

Special consideration was given to the relationship used for areas outside large conurbations (classified as 'elsewhere' in the plot) in 2006. This was because the relationship was being strongly influenced by data from Manchester Piccadilly, which was creating an unrealistically high coefficient based on a single point. When used in the model this coefficient resulted in exceedences far in excess of what would be expected and what has been measured in the past. As a solution in 2006, the 'elsewhere' calibration relationship was based on all 6 gravimetric points (including those for inner conurbations') in order to make the relationship more realistic. We recognise that the calibration of the area source component is subject to considerable uncertainties because there are very few gravimetric PM_{10} monitoring sites available for this calibration and there is considerable scatter on the plot. The calibration of the area source component is clearly highly dependent on the values estimated for all of the other components. Further support for the robustness of the final mapped concentrations is provided by the comparison with extensive measurements using different types of instruments presented below.

Adjustment factors were applied to the emissions from selected transport sources to represent the diminishing influence of emissions on air quality at the UK land surface, as described in Section 3.5. A factor of 0.5 was applied to aircraft emissions and a 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 area source contribution was then added to the contributions from secondary organic and inorganic particles, from small and large point sources, from regional primary particles, from sea salt and the residual, resulting in a map of background annual mean gravimetric PM_{10} concentrations.

4.8 Sea salt

Prior to 2005, contribution to ambient PM from sea salt was assumed to be constant across the UK. A modelled contribution from sea salt was included in 2005 (Kent *et al.*, 2007). The expansion of the rural monitoring network for 2006 (Tang, *pers comm*. 2007) means that it is now possible to estimate sea salt PM concentrations across the UK directly from measurements of particulate chloride. Data from 28 rural sites was interpolated by Krigging onto a 5km x 5km grid. A scaling factor of 1.648 was applied to convert elemental chloride mass to sodium chloride mass. 73% of the sea salt mass was assumed to be in the coarse fraction and 27% in the fine fraction. This split was derived from measurement data presented by APEG (1999) and Harrison and Yin (2006).

4.9 Residual (largely coarse particles)

Emissions of coarse particles from sources such as natural wind blown dusts and agricultural activities are not well characterised in emission inventories and have not been modelled explicitly. A constant residual concentration of 4 $\mu g\ m^{-3}$ (gravimetric) was therefore added as the final contribution to total particulate matter concentration. This value was chosen to provide the best fit to the measured total concentration. We consider this to be a genuine residual representing natural PM rather than an artefact of assumptions made in other aspects of the modelling.

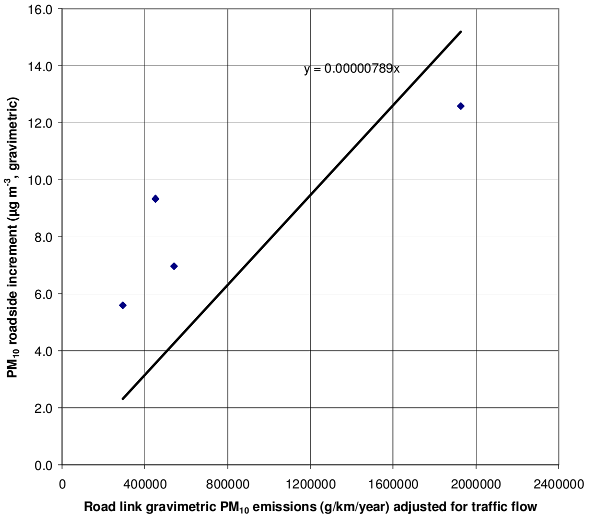
4.10 Roadside concentrations

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

roadside concentration = background concentration + roadside increment

The NAEI provides estimates of PM_{10} emissions for major road links in the UK for 2005 (Dore *et al.*, 2007) and these have been adjusted to provide estimates of emissions in 2006. Figure 4.6 shows a comparison of the roadside increment of annual mean PM_{10} concentrations at roadside or kerbside national automatic monitoring sites with PM_{10} emission estimates for the individual road links alongside which these sites are located. The line has been forced through zero to provide a reasonable model output without imposing an unrealistically high residual to the roadside increment. Emissions were adjusted for annual average daily traffic flow using the method described in Section 3.7. Roadside concentrations for urban major road links (A-roads and motorways) only are reported to the EU and included in this report.

Figure 4.6. Calibration of PM_{10} roadside increment model 2006 ($\mu g\ m^{-3}$, gravimetric)



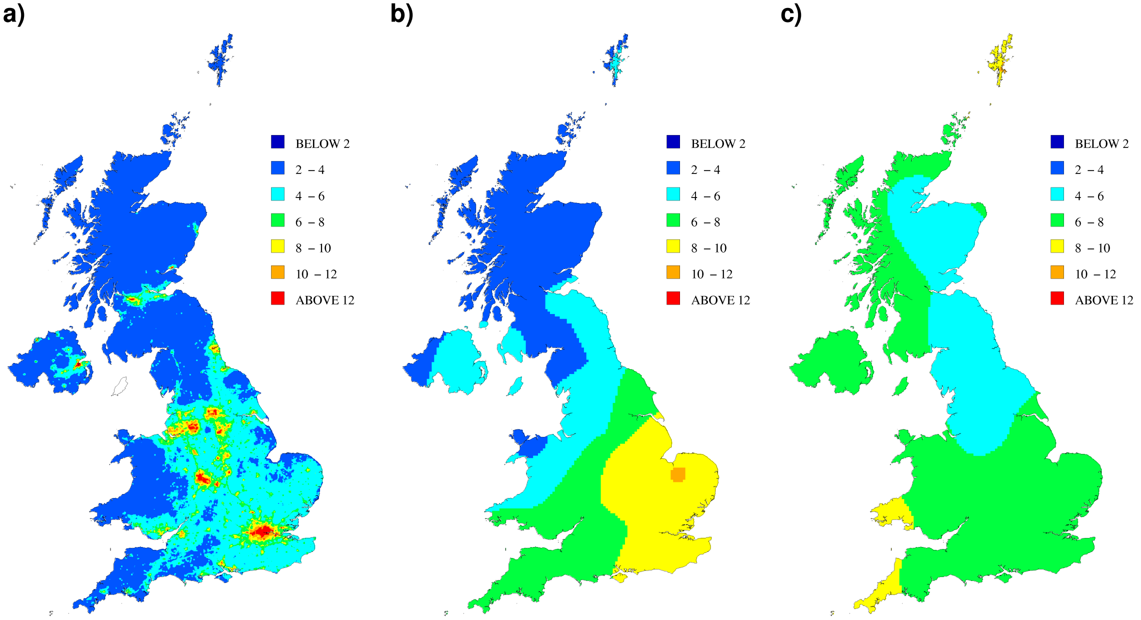
4.11 The spatial distribution of primary, secondary and other PM

The map of total PM_{10} concentration in 2006 is shown in Figure 4.1. PM_{10} includes a wide range of chemical species which can be usefully broken down into primary, secondary and other PM although it is important to realise that ambient particulate matter is processed in the atmosphere an individual particles generally include a range of components from a variety of sources. Figure 4.7a shows the contribution from primary PM, which is generally greatest in urban areas, close to emission sources. The sources of primary PM_{10} are diverse. Elemental and organic carbon is produced by combustion processes such as from motor vehicles, fuel burning and industrial processes. Mechanically generated particles are produced by building work and quarrying. Iron and calcium dust can also be considered as primary particles and are included in the figure.

A significant proportion of PM_{10} is secondary, formed by the reaction of gases in the air. Sulphates and nitrates are formed by chemical reactions in the atmosphere from emissions of SO_2 and NO_X. Secondary PM can therefore be produced considerable distances from the emission sources. Figure 4.7b shows the spatial distribution of secondary inorganic and organic aerosol. Secondary PM concentrations are generally greatest in the south and east of the UK, which are more often downwind of and closest to polluted areas of Northern Europe.

Figure 4.7c shows the contribution from remaining PM sources. This has been calculated as the sum of sea salt PM (derived from chloride measurements) and the constant residual non-modelled contribution of 4 $\mu g\ m^{-3}$. Sea salt PM concentrations are generally highest in the most exposed coastal areas of the UK. The map of total PM_{10} presented in Figure 4.1 is the sum of the three components: primary secondary and other PM.

Figure 4.7. The contribution to PM_{10} concentration from a) primary, b) secondary and c) other PM sources in 2006 ($\mu g\ m^{-3}$, gravimetric)



4.12 Verification of mapped gravimetric values

Figures 4.8 and 4.9 show comparisons of gravimetric PM_{10} modelled and measured annual mean PM_{10} concentration in 2005 at both background and roadside monitoring site locations. There were no genuine gravimetric monitoring data outside the AURN to use to verify the model so only the national network sites used to calibrate the models are shown along with verification data for the two sites with KFG instruments operating in 2006 (labelled as gravimetric sites in the verification). 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_{10} concentrations. Summary statistics for the comparison between modelled and measured PM_{10} concentrations are presented in Tables 4.3 and 4.4. All of the modelled values are within the data quality objectives.

The figures and tables also show a comparison between the modelled gravimetric PM_{10} concentrations and PM_{10} measurements made using TEOM and β attenuation instruments from the UK national monitoring networks and from other verification sites. Data from TEOM and β attenuation instruments with heated inlets have been multiplied by a factor of 1.3. Data from β attenuation instruments with unheated inlets have been multiplied by a factor of 0.8333. The agreement between the measured and modelled concentrations are generally very good at both background and roadside monitoring sites.

Figure 4.6. Verification of background annual mean PM_{10} (gravimetric) model 2006

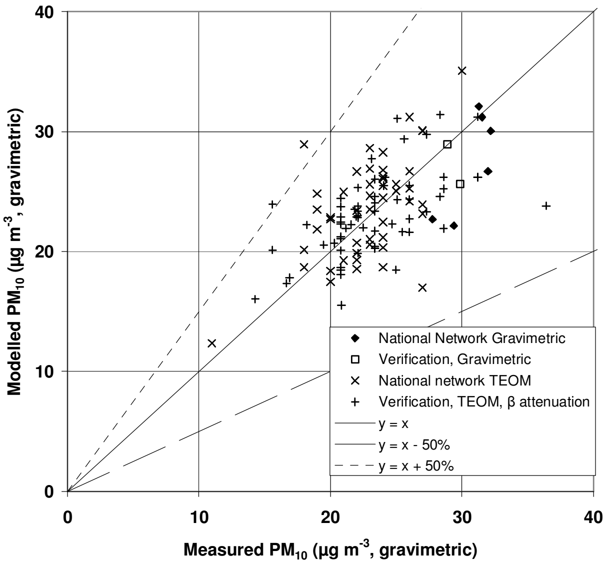


Figure 4.7. Verification of roadside annual mean PM_{10} (gravimetric) model 2006

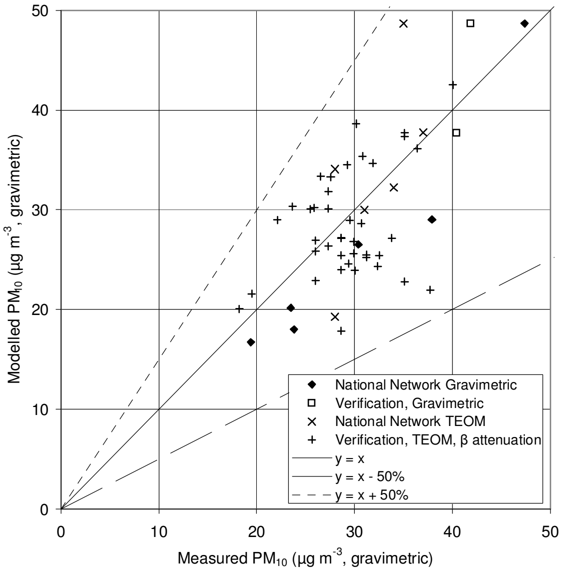


Table 4.3 Summary statistics for comparison between gravimetric modelled and measured concentrations of PM_{10} at background sites

	Mean of measurements ($\mu g\ m^{-3}$, grav)	Mean of model estimates ($\mu g\ m^{-3}$, grav)	r^2	% outside data quality objectives	Number of sites
National network gravimetric	28.1	27.5	0.62	0	6
Verification sites gravimetric	29.4	27.3	-	0	2
National network TEOM	22.8	23.6	0.32	2	48
Verification sites TEOM, β attenuation	23.3	23.0	0.34	2	63

Table 4.4 Summary statistics for comparison between gravimetric modelled and measured concentrations of PM_{10} at roadside sites

	Mean of measurements ($\mu g\ m^{-3}$, grav)	Mean of model estimates ($\mu g\ m^{-3}$, grav)	r^2	% outside data quality objectives	Number of sites
National network gravimetric	30.4	26.5	0.92	0	5
Verification sites gravimetric	41.1	43.2	-	0	2
National network TEOM	32.2	33.7	0.45	0	6
Verification sites TEOM, β attenuation	29.3	28.5	0.14	0	41

4.13 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 2 limit values by zone, are summarised in Tables 4.5 and 4.6 respectively. These data are also presented in Form 19c of the questionnaire. 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.

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 4.6 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)) - Results of and methods used for supplementary assessment for PM10 (Stage 1) Questionnaire Form 19c.1

Zone	*Zone code*	*Above LV (24hr mean)*						*Above LV (annual mean)*					
		Area		*Road length*		*Population exposed*		*Area*		*Road length*		*Population exposed*	
		km^2	*Method*	*km*	*Method*	*Number*	*Method*	*km^2*	*Method*	*km*	*Method*	*Number*	*Method*
Greater London Urban Area	UK0001	48	A	1012.6	A	402918	A	0	A	159.7	A	0	A
West Midlands Urban Area	UK0002	2	A	192.6	A	3713	A	0	A	3.5	A	0	A
Greater Manchester Urban Area	UK0003	0	A	18.0	A	0	A	0	A	0	A	0	A
West Yorkshire Urban Area	UK0004	0	A	32.7	A	0	A	0	A	0	A	0	A
Tyneside	UK0005	0	A	7.0	A	0	A	0	A	0	A	0	A
Liverpool Urban Area	UK0006	0	A	0.7	A	0	A	0	A	0	A	0	A
Sheffield Urban Area	UK0007	0	A	28.8	A	0	A	0	A	0	A	0	A
Nottingham Urban Area	UK0008	0	A	20.7	A	0	A	0	A	0	A	0	A
Bristol Urban Area	UK0009	0	A	5.1	A	0	A	0	A	0	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	A	0.0	A	0	A	0	A	0	A	0	A
Leicester Urban Area	UK0011	0	A	20.9	A	0	A	0	A	0	A	0	A
Portsmouth Urban Area	UK0012	0	A	7.9	A	0	A	0	A	0	A	0	A
Teesside Urban Area	UK0013	0	A	4.2	A	0	A	0	A	0	A	0	A
The Potteries	UK0014	0	A	13.6	A	0	A	0	A	0	A	0	A
Bournemouth Urban Area	UK0015	0	A	2.5	A	0	A	0	A	0	A	0	A
Reading/Wokingham Urban Area	UK0016	0	A	0.6	A	0	A	0	A	0	A	0	A
Coventry/Bedworth	UK0017	1	A	15.5	A	4205	A	0	A	0	A	0	A
Kingston upon Hull	UK0018	0	A	9.3	A	0	A	0	A	0	A	0	A
Southampton Urban Area	UK0019	0	A	8.2	A	0	A	0	A	0	A	0	A
Birkenhead Urban Area	UK0020	0	A	0.0	A	0	A	0	A	0	A	0	A
Southend Urban Area	UK0021	0	A	1.5	A	0	A	0	A	0	A	0	A
Blackpool Urban Area	UK0022	0	A	0.0	A	0	A	0	A	0	A	0	A
Preston Urban Area	UK0023	0	A	0.0	A	0	A	0	A	0	A	0	A
Glasgow Urban Area	UK0024	0	A	7.7	A	0	A	0	A	0	A	0	A
Edinburgh Urban Area	UK0025	0	A	0.0	A	0	A	0	A	0	A	0	A

Zone	*Zone code*	*Above LV (24hr mean)*						*Above LV (annual mean)*					
		Area		*Road length*		*Population exposed*		*Area*		*Road length*		*Population exposed*	
		km^2	*Method*	*km*	*Method*	*Number*	*Method*	*km^2*	*Method*	*km*	*Method*	*Number*	*Method*
Cardiff Urban Area	UK0026	0	A	0.0	A	0	A	0	A	0	A	0	A
Swansea Urban Area	UK0027	0	A	0.0	A	0	A	0	A	0	A	0	A
Belfast Urban Area	UK0028	0	A	20.7	A	0	A	0	A	0	A	0	A
Eastern	UK0029	0	A	42.3	A	0	A	0	A	0	A	0	A
South West	UK0030	0	A	4.5	A	0	A	0	A	0	A	0	A
South East	UK0031	0	A	27.5	A	0	A	0	A	0	A	0	A
East Midlands	UK0032	0	A	16.5	A	0	A	0	A	0	A	0	A
North West & Merseyside	UK0033	0	A	0.0	A	0	A	0	A	0	A	0	A
Yorkshire & Humberside	UK0034	0	A	18.6	A	0	A	0	A	0	A	0	A
West Midlands	UK0035	0	A	30.2	A	0	A	0	A	0	A	0	A
North East	UK0036	0	A	5.2	A	0	A	0	A	0	A	0	A
Central Scotland	UK0037	0	A	0.0	A	0	A	0	A	0	A	0	A
North East Scotland	UK0038	0	A	0.0	A	0	A	0	A	0	A	0	A
Highland	UK0039	0	A	0.0	A	0	A	0	A	0	A	0	A
Scottish Borders	UK0040	0	A	0.0	A	0	A	0	A	0	A	0	A
South Wales	UK0041	0	A	5.0	A	0	A	0	A	0	A	0	A
North Wales	UK0042	0	A	0.0	A	0	A	0	A	0	A	0	A
Northern Ireland	UK0043	0	A	0.0	A	0	A	0	A	0	A	0	A
Total		51		1580.5		410836.3		0		163.2		0	

Table 4.7 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)) - Results of and methods used for supplementary assessment for PM10 (Stage 2) Questionnaire Form 19c.2

Zone	*Zone code*	*Above LV (24hr mean)*						*Above LV (annual mean)*					
		Area		*Road length*		*Population exposed*		*Area*		*Road length*		*Population exposed*	
		km^2	*Method*	*km*	*Method*	*Number*	*Method*	*km^2*	*Method*	*km*	*Method*	*Number*	*Method*
Greater London Urban Area	UK0001							1628	A	1889.2	A	7781081	A
West Midlands Urban Area	UK0002							592	A	560.8	A	2081665	A
Greater Manchester Urban Area	UK0003							429	A	655.5	A	1523024	A
West Yorkshire Urban Area	UK0004							282	A	412.8	A	958722	A
Tyneside	UK0005							85	A	193.1	A	288262	A
Liverpool Urban Area	UK0006							114	A	223.6	A	483956	A
Sheffield Urban Area	UK0007							147	A	161.1	A	477056	A
Nottingham Urban Area	UK0008							169	A	136.3	A	558935	A
Bristol Urban Area	UK0009							139	A	118.7	A	485494	A
Brighton/Worthing/Littlehampton	UK0010							97	A	82.2	A	386373	A
Leicester Urban Area	UK0011							102	A	92.8	A	374314	A
Portsmouth Urban Area	UK0012							90	A	72.6	A	354312	A
Teesside Urban Area	UK0013							27	A	74.2	A	58824	A
The Potteries	UK0014							76	A	129.2	A	234457	A
Bournemouth Urban Area	UK0015							100	A	71.3	A	320197	A
Reading/Wokingham Urban Area	UK0016							97	A	84.4	A	305786	A
Coventry/Bedworth	UK0017							76	A	34.9	A	277475	A
Kingston upon Hull	UK0018							80	A	52.3	A	260201	A
Southampton Urban Area	UK0019							77	A	65.2	A	262379	A
Birkenhead Urban Area	UK0020							15	A	62.1	A	25750	A
Southend Urban Area	UK0021							64	A	49.8	A	217874	A
Blackpool Urban Area	UK0022							0	A	20.9	A	0	A
Preston Urban Area	UK0023							12	A	45.8	A	41946	A
Glasgow Urban Area	UK0024							60	A	255.8	A	233288	A
Edinburgh Urban Area	UK0025							0	A	70.5	A	0	A

Zone	*Zone code*	*Above LV (24hr mean)*						*Above LV (annual mean)*					
		Area		*Road length*		*Population exposed*		*Area*		*Road length*		*Population exposed*	
		km^2	*Method*	*km*	*Method*	*Number*	*Method*	*km^2*	*Method*	*km*	*Method*	*Number*	*Method*
Cardiff Urban Area	UK0026							66	A	52.8	A	249307	A
Swansea Urban Area	UK0027							64	A	68.4	A	157378	A
Belfast Urban Area	UK0028							161	A	199.4	A	469855	A
Eastern	UK0029							12734	A	876.0	A	4484375	A
South West	UK0030							1619	A	644.0	A	1661142	A
South East	UK0031							8493	A	1332.6	A	5151914	A
East Midlands	UK0032							5462	A	675.1	A	2474014	A
North West & Merseyside	UK0033							449	A	720.4	A	719227	A
Yorkshire & Humberside	UK0034							1395	A	637.9	A	1333684	A
West Midlands	UK0035							2022	A	518.2	A	1515301	A
North East	UK0036							46	A	173.4	A	71400	A
Central Scotland	UK0037							14	A	83.3	A	21536	A
North East Scotland	UK0038							13	A	62.0	A	52033	A
Highland	UK0039							0	A	0.0	A	0	A
Scottish Borders	UK0040							0	A	0.0	A	0	A
South Wales	UK0041							772	A	345.5	A	706880	A
North Wales	UK0042							7	A	42.2	A	3448	A
Northern Ireland	UK0043							85	A	256.9	A	135697	A
Total								37960		12303.2		37198558	

5 Benzene

5.1 Introduction

Maps of annual mean benzene concentrations at background and roadside locations in 2006 are presented in Figures 5.1 and 5.2. Benzene concentrations have been calculated using a similar approach to that adopted for NO_X 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, 2006 ($\mu g\ m^{-3}$)

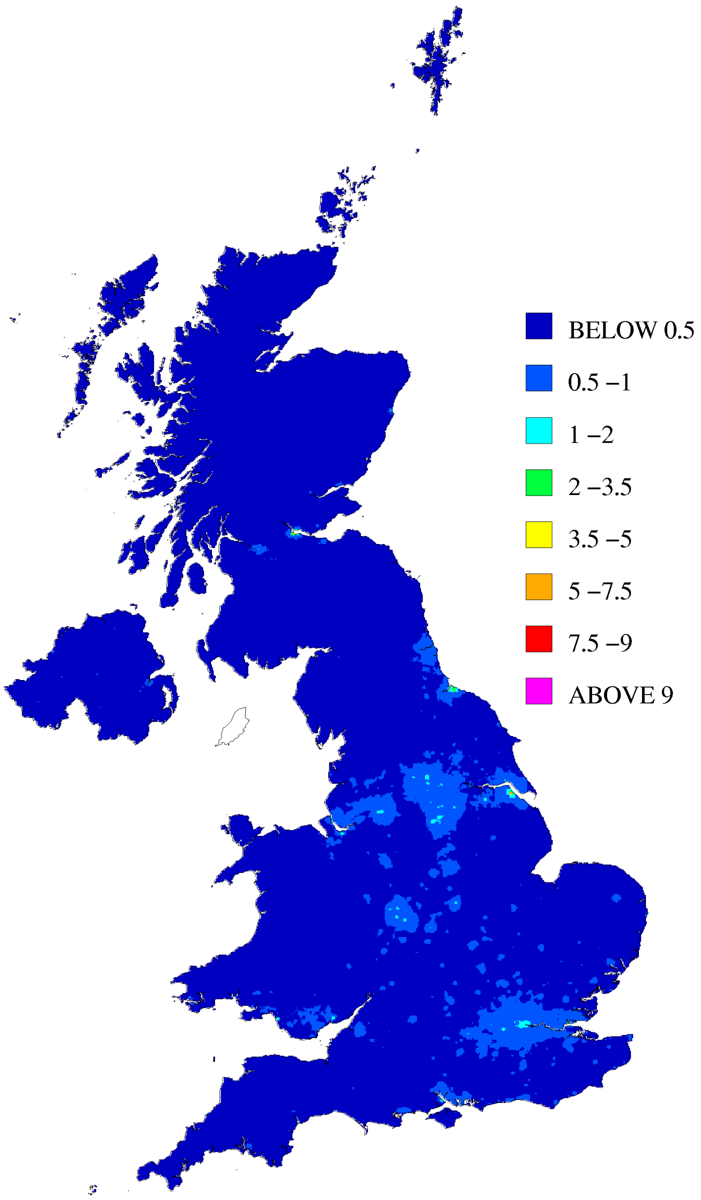
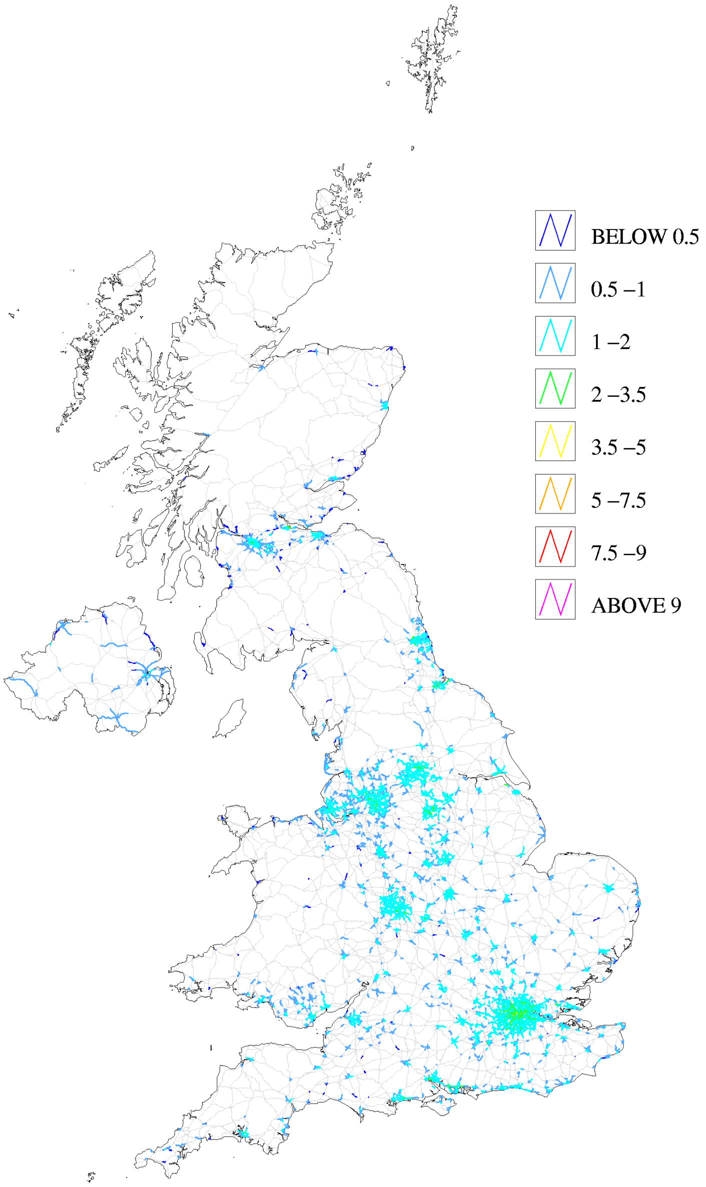


Figure 5.2. Urban major roads, annual mean roadside benzene concentration, 2006 (µg m^{-3})



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 2005 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model (ADMS 3.3) and sequential meteorological data for 2006 from Waddington. A total of 28 point sources were modelled. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100km x 100km square composed of a regularly spaced 5km x 5km 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 2. The emissions from these sources are not generally as well characterised in terms of exact location and release parameters as emissions from combustion sources. Separate models are used for the ‘in-square’ concentration (the concentration in the 1km x 1km grid square that includes the source) and the concentration in surrounding grid squares (‘the out-square concentration’). The method was revised in 2004 so that an in-square concentration has been estimated by assessing the concentration resulting from unit emissions released from a volume source of dimensions 200m by 200m and 30m high. The average concentration in the grid square has only been calculated for receptors outside an area 400m by 400m in the centre of the 1km x 1km square so that concentrations within the boundary fence of the process have been excluded. A dispersion kernel approach similar to that adopted for the area sources was used to calculate the out-square concentrations.

The results from this model were verified by comparison with benzene diffusion tube measurements made available by the local authorities at Killingholme (where only data from 2005 were available) and Scunthorpe. As expected, this generalised model was not able to provide a full description of the exact spatial pattern of measured concentrations close to each refinery but the overall patterns and, more importantly, the maximum modelled concentrations, were in good agreement.

5.4 Contributions from rural background concentrations

Regional rural benzene concentrations were estimated from the map of rural NO_X concentration described in Section 3.4. The rural NO_X map was scaled using the ratio of measured annual mean benzene and NO_X concentrations at the rural Harwell monitoring site in 2006.

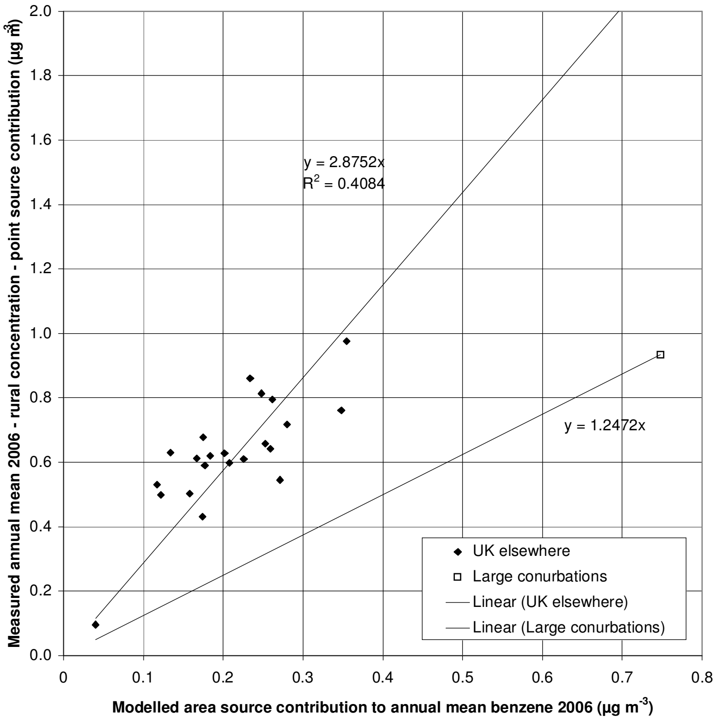
5.5 Contributions from area sources

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 33km x 33km square surrounding each monitoring site. Hourly sequential meteorological data from Waddington in 2006 has been used to construct the dispersion kernels, as described in Appendix 3. The calibration relationship used for large conurbations, for which there is only one point for benzene, was obtained by forcing the line through the origin.

Adjustment factors were applied to the emissions from selected transport sources to represent the diminishing influence of emissions on air quality at the UK land surface, as described in Section 3.5. A factor of 0.36 was applied to aircraft emissions and a 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 benzene concentrations.

Figure 5.3. Calibration of area source benzene model 2006 (µg m^{-3})

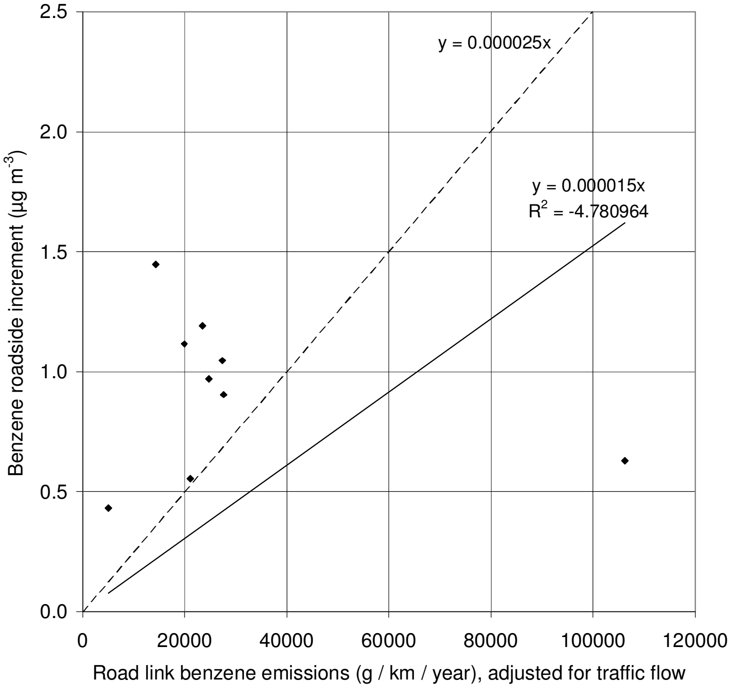


5.6 Roadside concentrations

Calibration of the benzene roadside increment model is shown in Figure 5.4. Roadside concentrations of annual mean benzene for 2006 have been modelled using a similar method to the NO_X modelling described in Section 3.6.

The relationship on this calibration plot is poor and it was decided that there was not an adequately meaningful relationship to ensure the model was robust. As a result, a coefficient was chosen (coefficient = 0.000025) that provided a reasonable representation of the measured concentration - i.e. resulted in the most modelled concentrations being located within the data quality objective range on the verification plot (see Figure 5.6 and Table 5.2). Using this coefficient, only 2 sites (20%) fell outside the data quality objectives range, one being overestimated and the other underestimated.

Figure 5.4. Comparison of benzene roadside increment and road link emission 2006 (µg m^{-3})



5.7 Verification of mapped values

Figures 5.5 and 5.6 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.

Figure 5.5. Verification of background annual mean benzene model 2006

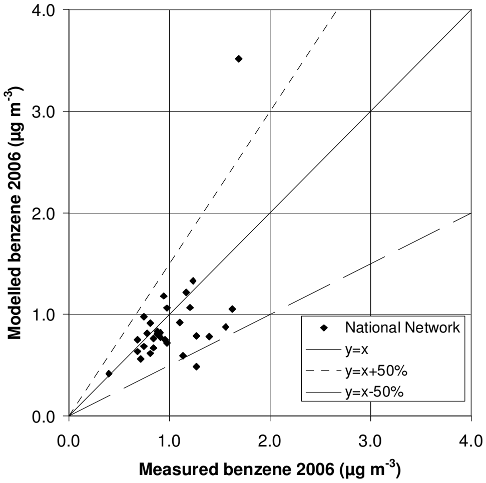
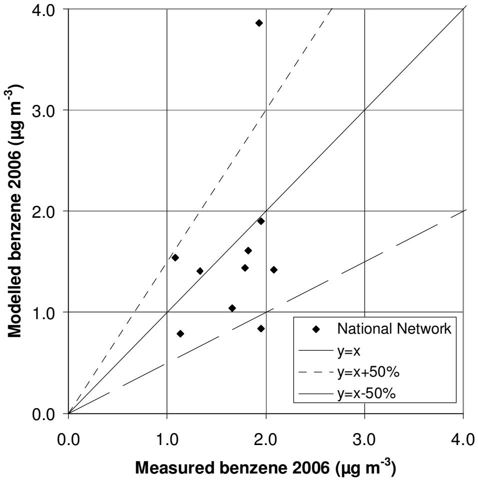


Figure 5.6. Verification of roadside annual mean benzene model 2006



Summary statistics for the comparison between modelled and measured benzene concentrations are listed in Tables 5.1 and 5.2. No monitoring sites were available to provide an independent verification of the background or roadside models.

Table 5.1 Summary statistics for comparison between modelled and measured benzene concentrations at background sites (µg m^{-3})

	Mean of measurements (µg m^{-3})	Mean of modelled (µg m^{-3})	r^2	%outside data quality objectives	Number of sites
National Network Sites	1.01	0.91	0.30	7%	30

Table 5.2 Summary statistics for comparison between modelled and measured benzene concentrations at roadside sites (µg m^{-3})

	Mean of measurements (µg m^{-3})	Mean of modelled (µg m^{-3})	r^2	%outside data quality objectives	Number of sites
National Network Sites	1.67	1.59	0.10	20%	10

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. 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))

Zone	*Zone code*	*Above LV*					
		Area		*Road length*		*Population exposed*	
		km^2	*Method*	*km*	*Method*	*Number*	*Method*
Greater London Urban Area	UK0001	0	A	0	A	0	A
West Midlands Urban Area	UK0002	0	A	0	A	0	A
Greater Manchester Urban Area	UK0003	0	A	0	A	0	A
West Yorkshire Urban Area	UK0004	0	A	0	A	0	A
Tyneside	UK0005	0	A	0	A	0	A
Liverpool Urban Area	UK0006	0	A	0	A	0	A
Sheffield Urban Area	UK0007	0	A	0	A	0	A
Nottingham Urban Area	UK0008	0	A	0	A	0	A
Bristol Urban Area	UK0009	0	A	0	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	A	0	A	0	A
Leicester Urban Area	UK0011	0	A	0	A	0	A
Portsmouth Urban Area	UK0012	0	A	0	A	0	A
Teesside Urban Area	UK0013	0	A	0	A	0	A
The Potteries	UK0014	0	A	0	A	0	A
Bournemouth Urban Area	UK0015	0	A	0	A	0	A
Reading/Wokingham Urban Area	UK0016	0	A	0	A	0	A

Zone	*Zone code*	*Above LV*					
		Area		*Road length*		*Population exposed*	
		km^2	*Method*	*km*	*Method*	*Number*	*Method*
Coventry/Bedworth	UK0017	0	A	0	A	0	A
Kingston upon Hull	UK0018	0	A	0	A	0	A
Southampton Urban Area	UK0019	0	A	0	A	0	A
Birkenhead Urban Area	UK0020	0	A	0	A	0	A
Southend Urban Area	UK0021	0	A	0	A	0	A
Blackpool Urban Area	UK0022	0	A	0	A	0	A
Preston Urban Area	UK0023	0	A	0	A	0	A
Glasgow Urban Area	UK0024	0	A	0	A	0	A
Edinburgh Urban Area	UK0025	0	A	0	A	0	A
Cardiff Urban Area	UK0026	0	A	0	A	0	A
Swansea Urban Area	UK0027	0	A	0	A	0	A
Belfast Metropolitan Urban Area	UK0028	0	A	0	A	0	A
Eastern	UK0029	0	A	0	A	0	A
South West	UK0030	0	A	0	A	0	A
South East	UK0031	0	A	0	A	0	A
East Midlands	UK0032	0	A	0	A	0	A
North West & Merseyside	UK0033	0	A	0	A	0	A
Yorkshire & Humberside	UK0034	6	A	0	A	872	A
West Midlands	UK0035	0	A	0	A	0	A
North East	UK0036	0	A	0	A	0	A
Central Scotland	UK0037	0	A	0	A	0	A
North East Scotland	UK0038	0	A	0	A	0	A
Highland	UK0039	0	A	0	A	0	A
Scottish Borders	UK0040	0	A	0	A	0	A
South Wales	UK0041	0	A	0	A	0	A
North Wales	UK0042	0	A	0	A	0	A
Northern Ireland	UK0043	0	A	0	A	0	A
Total		6		0		872	

6 CO

6.1 Introduction

Maps of maximum 8-hour mean CO concentrations at background and roadside locations in 2006 are presented in Figures 6.1 and 6.2.

Background and roadside maps of annual mean CO were calculated. These maps were then scaled using the relationship between measured annual mean CO concentrations and measured maximum of 8-hour concentrations from the national network. Only the maximum 8-hour mean maps are required for comparison with the AQDD2 limit value but annual mean maps are prepared as an intermediate step within the modelling exercise. The annual mean maps are not presented in this report but details of the calibration and the verification of the annual mean background and roadside models are presented because they are directly relevant to the model output of the maximum 8-hour metric.

CO concentrations have been calculated using a similar approach to that adopted for NO_X 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
- Regional background

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.

Figure 6.1. Maximum 8-hour mean background CO concentration, 2006 (mg m^{-3})

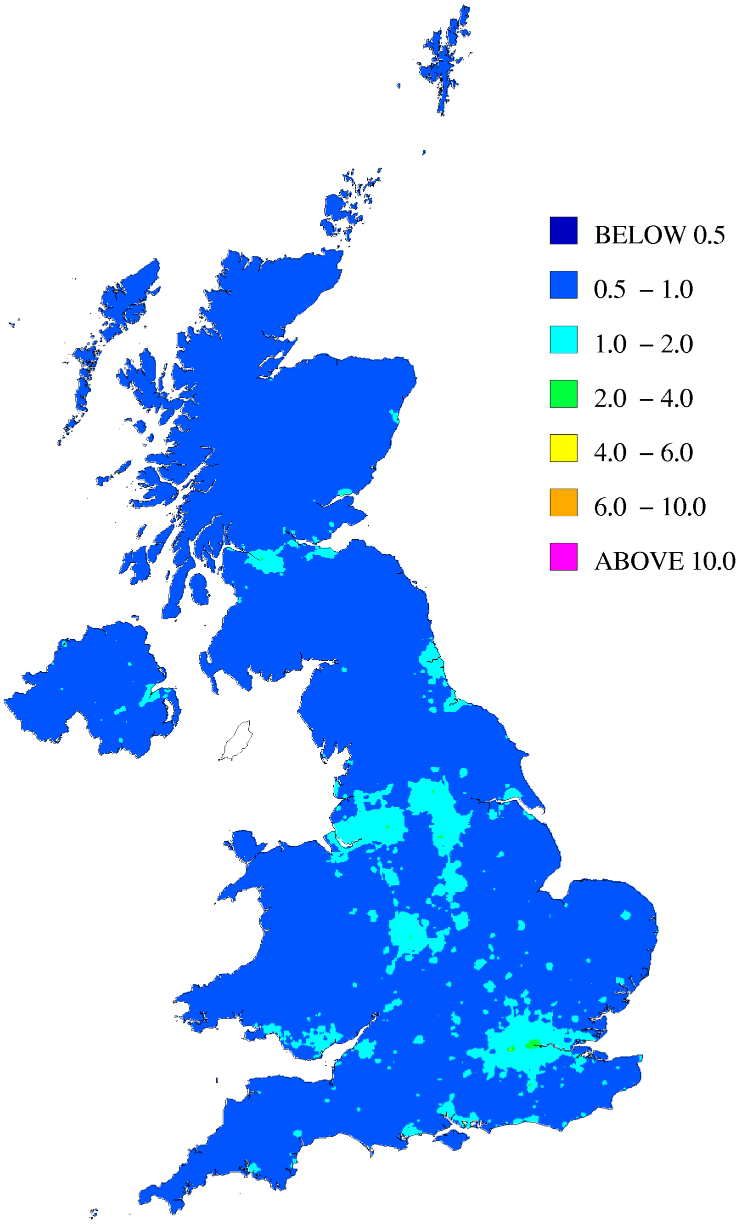
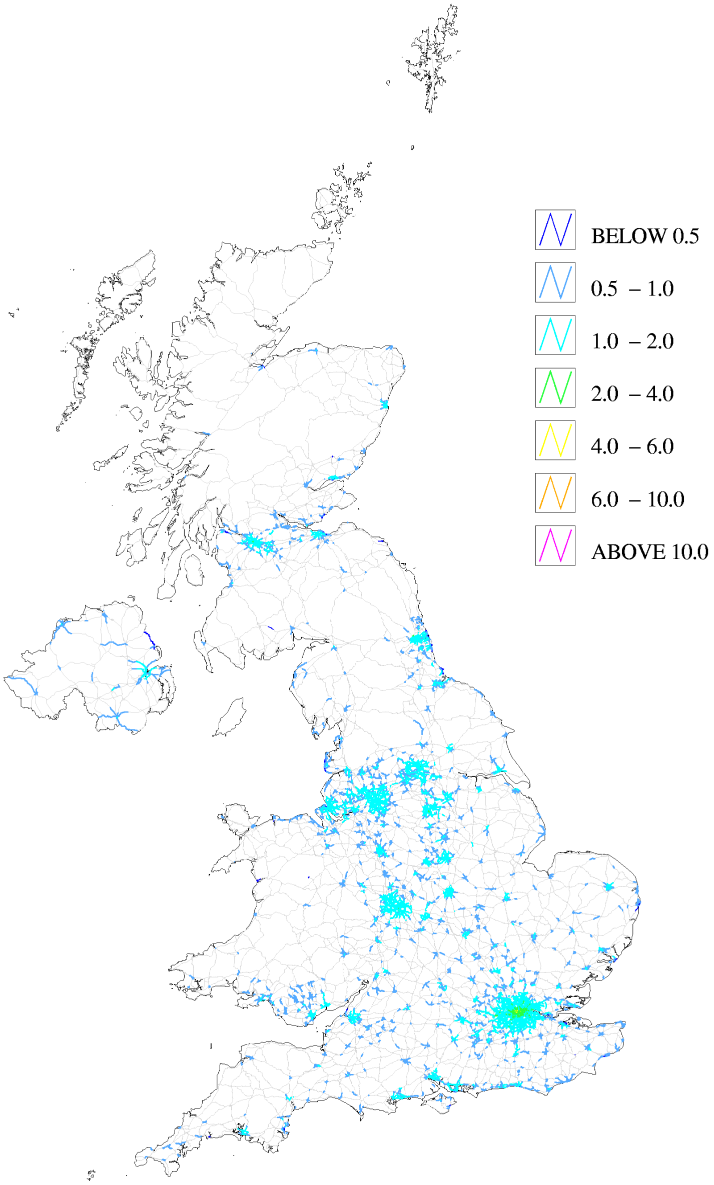


Figure 6.2. Urban major roads, maximum 8-hour mean roadside CO concentration, 2006 (mg m^{-3})



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 2005 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model (ADMS 3.3) and sequential meteorological data for 2006 from Waddington. A total of 50 large point sources were modelled. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100km x 100km square composed of a regularly spaced 5km x 5km resolution receptor grid. Each receptor grid was centred on the point source.

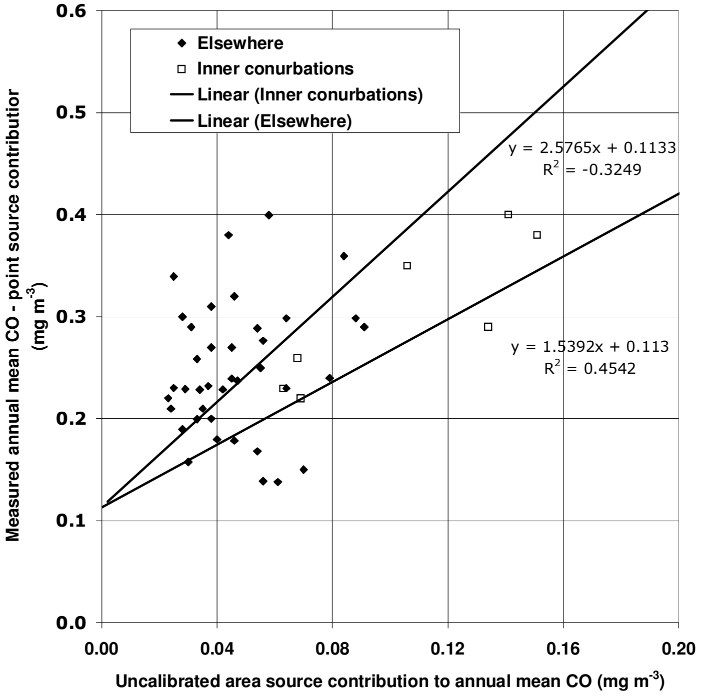
6.3 Contributions from small point sources

Contributions from CO point sources with less than 3000 tonnes per annum release were modelled using the small points model described in Appendix 2.

6.4 Contributions from area sources

Figure 6.3 shows the calibration of the annual mean area source CO model for background locations.

Figure 6.3. Calibration of 2006 background annual mean CO model (mg m^{-3})



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 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 33km x 33km square surrounding each monitoring site. Hourly sequential meteorological data from Waddington in 2006 has been used to construct the dispersion kernels, as described in Appendix 3.

Examination of Figure 6.3 shows that the monitoring sites fall into two groups:

- Inner conurbations
- Elsewhere

'Inner conurbations' includes Inner and Central London and central Birmingham. The intercept of 0.113 µg m^{-3} for the 'elsewhere' and 'inner conurbations' relationships was taken to represent regional rural annual mean CO concentrations in the UK. This intercept was assumed from the modelling performed for 2005 and described in Kent *et al*., 2007.

Adjustment factors were applied to the emissions from selected transport sources to represent the diminishing influence of emissions on air quality at the UK land surface, as described in Section 3.5. A factor of 0.36 was applied to aircraft emissions and a 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.

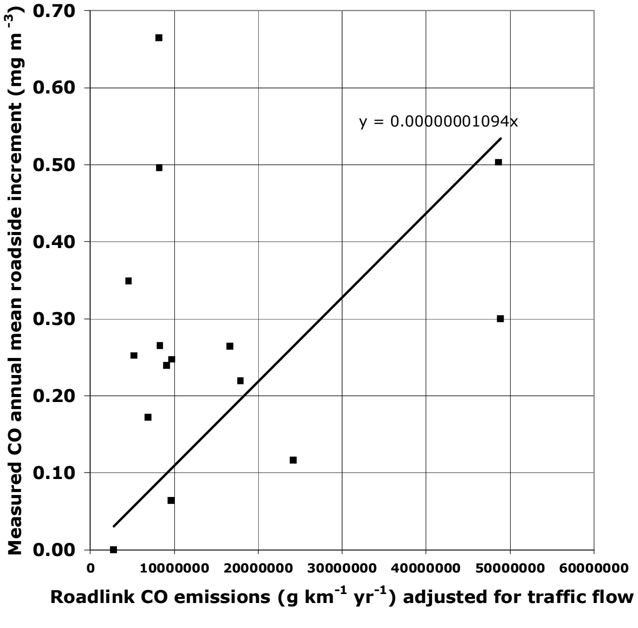
6.5 Roadside annual mean CO concentrations

Calibration of the CO annual mean roadside increment model is shown in Figure 6.4. 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:

roadside CO concentration = background CO concentration + CO roadside increment

The NAEI provides estimates of CO emissions for major road links in the UK for 2005 (Dore *et al*., 2007) and these have been adjusted to provide estimates of emissions in 2006. 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 6.4. The traffic flow adjustment factors used were the same as those applied in the roadside NO_X modelling (Section 3.6) and are presented in Figure 3.6. 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.

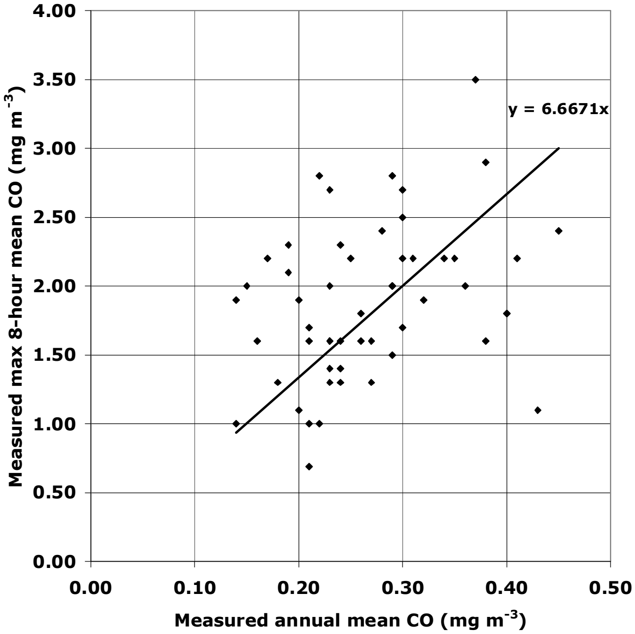
Figure 6.4. Calibration of 2006 roadside annual mean CO model (mg m^{-3})



6.6 Modelling the maximum 8-hour mean CO concentration

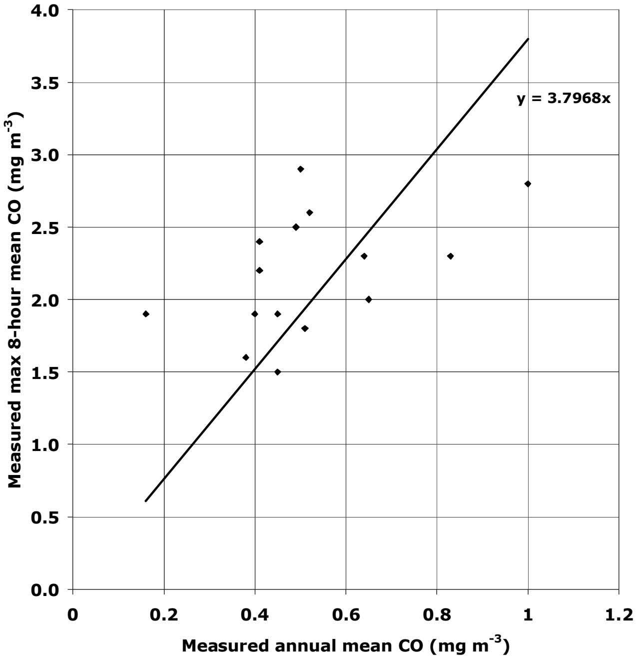
The map of maximum 8-hour mean CO concentrations at background locations shown in Figure 6.1 was calculated from the map of background annual mean CO concentrations by scaling annual mean map with the relationship between measured annual mean concentrations and the measured maximum 8-hour concentrations from the national network. Figure 6.5 shows this relationship.

Figure 6.5 Calibration of 2006 background maximum 8-hour mean CO model (mg m^{-3})



The map of maximum 8-hour mean CO concentrations at roadside locations shown in Figure 6.2 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 6.6. Roadside concentrations for urban roads only are reported to the EU and included in this report.

Figure 6.6. Calibration of 2006 roadside maximum 8-hour CO model (mg m^{-3})



6.7 Verification of mapped values

Figures 6.7 to 6.10 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 6.7. Verification of background annual mean CO model 2006

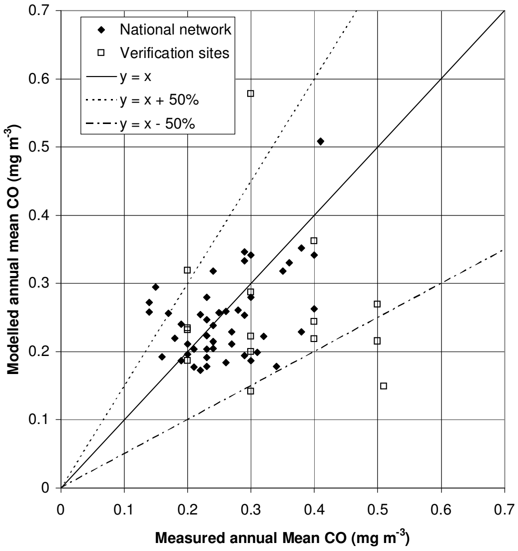


Figure 6.8. Verification of background maximum 8-hour mean CO model 2006

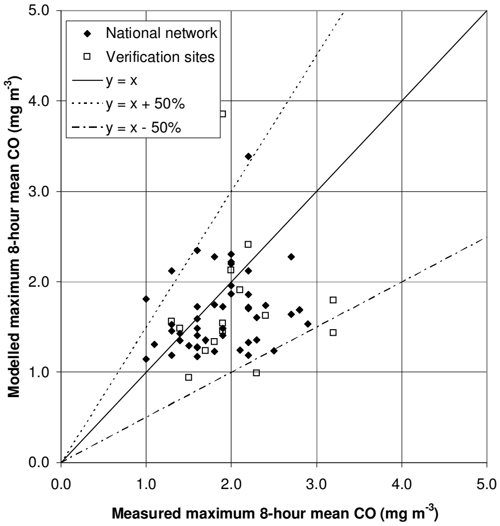


Figure 6.9. Verification of roadside annual mean CO model 2006

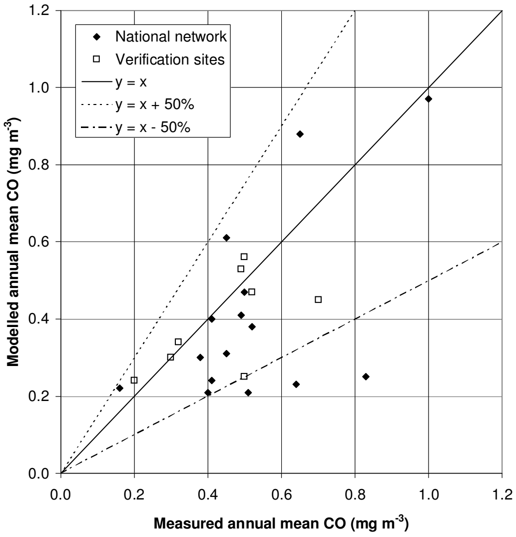


Figure 6.10. Verification of roadside maximum 8-hour mean CO model 2006

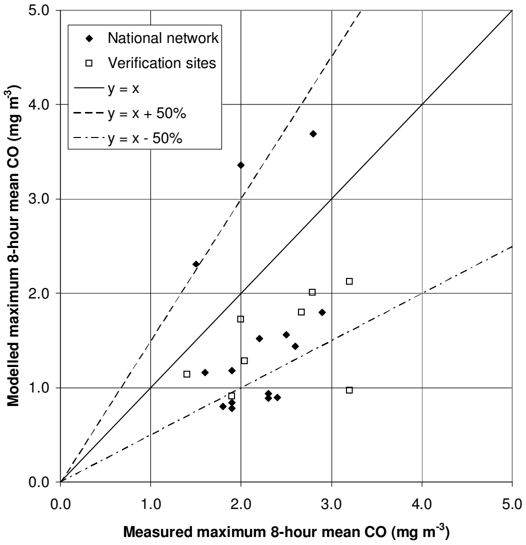


Table 6.1. Summary statistics for comparison between modelled and measured annual mean CO concentrations at background sites (mg m^{-3})

	Mean of measurements (mg m^{-3})	Mean of model estimates (mg m^{-3})	r^2	% outside data quality objectives	Number of sites
National Network	0.26	0.25	0.21	9	54
Verification Sites	0.30	0.26	0.01	20	15

Table 6.2. Summary statistics for comparison between modelled and measured maximum 8-hour mean CO concentrations at background sites (mg m^{-3})

	Mean of measurements (mg m^{-3})	Mean of model estimates (mg m^{-3})	r^2	% outside data quality objectives	Number of sites
National Network	1.90	1.66	0.06	7	54
Verification Sites	2.05	1.71	0.002	27	15

Table 6.3. Summary statistics for comparison between modelled and measured annual mean CO concentrations at roadside sites (mg m^{-3})

	Mean of measurements (mg m^{-3})	Mean of model estimates (mg m^{-3})	r^2	% outside data quality objectives	Number of sites
National Network	0.52	0.41	0.32	40	15
Verification Sites	0.44	0.39	0.37	0	8

Table 6.4. Summary statistics for comparison between modelled and measured maximum 8-hour mean CO concentrations at roadside sites (mg m^{-3})

	Mean of measurements (mg m^{-3})	Mean of model estimates (mg m^{-3})	r^2	% outside data quality objectives	Number of sites
National Network	2.17	1.54	0.06	60	15
Verification Sites	2.40	1.49	0.21	25	8

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 for 2006 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 2006

The tables included in this section are from Form 8 of the questionnaire. Exceedence (or otherwise) of the limit value (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 ≤LV + MOT; > LV indicates that modelled concentrations were higher than measured concentrations or on rare occasions that measurements were not available or not required for that zone (where the Article 5 Assessment illustrates that concentrations are lower than the Lower Assessment Threshold) 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 ≤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.

The results of the air quality assessments for SO_2, NO_2 and NO_X, PM_{10}, lead, benzene and CO are listed in Tables 7.1 to 7.6. The relationship between the number of days with PM_{10} concentrations greater than 50µg m^{-3} and annual means is less certain than the Stage 2 24-hour LV as discussed in Section 4.1. This is why we have not attempted to model exceedences of this LV. In Table 7.3, however we have assumed that a modelled exceedence of the Stage 1 24-hour LV implies an exceedence of the Stage 2 24-hour LV.

We have assessed that lead concentrations were below the LV in all zones where measurements have not been made on the basis of emission inventory results (objective estimation).

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) for SO_2 (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

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
West Midlands Urban Area	UK0002			y		y				n
Greater Manchester Urban Area	UK0003			y		y				n
West Yorkshire Urban Area	UK0004			y		y				n
Tyneside	UK0005			y		y				n
Liverpool Urban Area	UK0006			y		y				n
Sheffield Urban Area	UK0007			y		y				n
Nottingham Urban Area	UK0008			y		y				n
Bristol Urban Area	UK0009			m		m				n
Brighton/Worthing/Littlehampton	UK0010			y		y				n
Leicester Urban Area	UK0011			y		y				n
Portsmouth Urban Area	UK0012			y		y				n
Teesside Urban Area	UK0013			y		y				n
The Potteries	UK0014			y		y				n
Bournemouth Urban Area	UK0015			y		y				n
Reading/Wokingham Urban Area	UK0016			y		y				n
Coventry/Bedworth	UK0017			y		y				n
Kingston upon Hull	UK0018			y		y				n
Southampton Urban Area	UK0019			m		m				n
Birkenhead Urban Area	UK0020			y		y				n
Southend Urban Area	UK0021			y		y				n
Blackpool Urban Area	UK0022			y		y				n
Preston Urban Area	UK0023			y		y				n
Glasgow Urban Area	UK0024			y		y				n
Edinburgh Urban Area	UK0025			y		y				n
Cardiff Urban Area	UK0026			y		y				n
Swansea Urban Area	UK0027			y		y				n
Belfast Urban Area	UK0028			y		y				n
Eastern	UK0029	m			m			y		y
South West	UK0030			y		y		m		m

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
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		y		y
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) for NO_2 and NO_X (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

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			m	m				n
Liverpool Urban Area	UK0006			y	m				n
Sheffield Urban Area	UK0007			y	m				n
Nottingham Urban Area	UK0008			y	m				n
Bristol Urban Area	UK0009			y	y				n
Brighton/Worthing/Littlehampton	UK0010			y	m				n
Leicester Urban Area	UK0011			y	m				n
Portsmouth Urban Area	UK0012			y	m				n

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
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	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			y		n
Preston Urban Area	UK0023			y		m			n
Glasgow Urban Area	UK0024			y	y				n
Edinburgh Urban Area	UK0025			y	m				n
Cardiff Urban Area	UK0026			y	m				n
Swansea Urban Area	UK0027			y			y		n
Belfast Urban Area	UK0028			y	m				n
Eastern	UK0029			y	m				y
South West	UK0030			y	y				y
South East	UK0031			y	y				y
East Midlands	UK0032			y	m				y
North West & Merseyside	UK0033			y	m				m
Yorkshire & Humberside	UK0034			y	m				y
West Midlands	UK0035			y	m				m
North East	UK0036			y	m				m
Central Scotland	UK0037			y	m				y
North East Scotland	UK0038			y	m				m
Highland	UK0039			y			y		m
Scottish Borders	UK0040			y			y		y
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) for PM_{10} (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

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	m					y	y		y		
West Yorkshire Urban Area	UK0004	y					y	y		y		
Tyneside	UK0005	m					y	m		m		
Liverpool Urban Area	UK0006	m					y	y		m		
Sheffield Urban Area	UK0007	m					y	y		m		
Nottingham Urban Area	UK0008	m					y	y		m		
Bristol Urban Area	UK0009	m					m	m		m		
Brighton/Worthing/Littlehampton	UK0010	y					y	y		y		
Leicester Urban Area	UK0011	m					y	m		m		
Portsmouth Urban Area	UK0012	m					y	m		m		
Teesside Urban Area	UK0013	m					y	y		m		
The Potteries	UK0014	m					y	y		m		
Bournemouth Urban Area	UK0015	m					y	y		y		
Reading/Wokingham Urban Area	UK0016	m					y	m		m		
Coventry/Bedworth	UK0017	m					y	m		m		
Kingston upon Hull	UK0018	m					y	m		m		
Southampton Urban Area	UK0019	m					y	m		m		
Birkenhead Urban Area	UK0020			y			y		y		y	
Southend Urban Area	UK0021	m					y	m		m		
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			y			y		y		m	
Cardiff Urban Area	UK0026			y			y		y	m		
Swansea Urban Area	UK0027			y			y	y		y		
Belfast Urban Area	UK0028	m					y	m		m		
Eastern	UK0029	m					y	m		m		
South West	UK0030	m					m	m		m		
South East	UK0031	m					y	y		m		

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
East Midlands	UK0032	m					y	y		m		
North West & Merseyside	UK0033			y			y	y		m		
Yorkshire & Humberside	UK0034	y					y	y		y		
West Midlands	UK0035	m					y	y		m		
North East	UK0036	m					y	y		m		
Central Scotland	UK0037			y			y	m		m		
North East Scotland	UK0038			y			y		y	m		
Highland	UK0039			y			y		y			y
Scottish Borders	UK0040			y			y	y			y	
South Wales	UK0041	m					y	m		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) for lead (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

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			m
Bristol Urban Area	UK0009			y
Brighton/Worthing/Littlehampton	UK0010			m
Leicester Urban Area	UK0011			m
Portsmouth Urban Area	UK0012			m
Teesside Urban Area	UK0013			m
The Potteries	UK0014			m
Bournemouth Urban Area	UK0015			m
Reading/Wokingham Urban Area	UK0016			m
Coventry/Bedworth	UK0017			m
Kingston upon Hull	UK0018			m
Southampton Urban Area	UK0019			m
Birkenhead Urban Area	UK0020			m
Southend Urban Area	UK0021			m
Blackpool Urban Area	UK0022			m
Preston Urban Area	UK0023			m
Glasgow Urban Area	UK0024			y
Edinburgh Urban Area	UK0025			m
Cardiff Urban Area	UK0026			y
Swansea Urban Area	UK0027			y
Belfast Urban Area	UK0028			m
Eastern	UK0029			y
South West	UK0030			y
South East	UK0031			y
East Midlands	UK0032			m
North West & Merseyside	UK0033			y
Yorkshire & Humberside	UK0034			m
West Midlands	UK0035			m
North East	UK0036			m
Central Scotland	UK0037			y
North East Scotland	UK0038			y
Highland	UK0039			m
Scottish Borders	UK0040			y
South Wales	UK0041			y
North Wales	UK0042			m
Northern Ireland	UK0043			m

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) for benzene (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

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			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
Blackpool Urban Area	UK0022			m
Preston Urban Area	UK0023			m
Glasgow Urban Area	UK0024			y
Edinburgh Urban Area	UK0025			y
Cardiff Urban Area	UK0026			y
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		m	
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

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) for CO (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

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			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			m
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
Glasgow Urban Area	UK0024			y
Edinburgh Urban Area	UK0025			y
Cardiff Urban Area	UK0026			y
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			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 of Tolerance

Form 11 of the questionnaire requires reasons associated with the measured exceedences of the limit value and margin of tolerance to be documented. In most cases the reason is prescribed by the guidance documents for the questionnaire but there is scope to introduce bespoke reason for unique situations. Table 7.7 below presents the reason codes and associated explanations that were used in the compilation of the 2006 questionnaire.

Reasons for the specific exceedences submitted for 2006 are summarised for different pollutants in Tables 7.8 to 7.11 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_2 are listed in Table 7.8. Measured exceedences of the limit value and margin of tolerance for annual mean NO_2 are listed in Table 7.9. Measured exceedences of the limit value for 24-hour mean and annual mean PM_{10} are listed in Tables 7.10 and 7.11 (there is no margin of tolerance for PM_{10} in 2006 as the limit values are now in force).

Table 7.7 Reason codes for exceedences submitted to Commission

Code	Explanation
S1	Heavily trafficked urban centre
S2	Proximity to a major road
S3	Local industry including power production
S4	Quarrying or mining activities
S5	Domestic heating
S6	Accidental emission from an industrial source
S7	Accidental emission from a non-industrial source
S8	Natural source(s) or natural event(s)
S9	Winter sanding of roads
S10	Transport of air pollution from sources outside the Member State
S11	Local petrol station
S12	Parking facility
S13	Benzene storage
S14	Local building or demolition work

Table 7.8. Measured exceedences of the 1-hour mean NO_2 limit value plus margin of tolerance, 2006 (Form 11e). London Marylebone Road (Greater London Urban Area)

Month	Day of month	Hour	Level (µg/m^3)	Reason code(s) *
1	12	16	260	S2
1	12	18	241	S2
1	17	7	283	S2
1	19	7	243	S2
2	11	7	241	S2
2	15	8	244	S2
2	15	15	246	S2
2	16	18	241	S2
2	17	9	254	S2
3	2	16	269	S2
3	7	7	269	S2
3	7	8	248	S2
3	8	9	254	S2
3	8	10	273	S2
3	8	17	250	S2
3	8	18	252	S2

Month	Day of month	Hour	Level ($\mu g/m^3$)	Reason code(s) *
3	9	7	244	S2
3	9	8	260	S2
3	9	9	271	S2
3	9	13	248	S2
3	9	15	244	S2
3	9	16	241	S2
3	9	17	260	S2
3	14	9	250	S2
3	14	10	241	S2
3	14	11	256	S2
3	14	16	262	S2
3	14	17	241	S2
3	24	10	250	S2
3	24	11	258	S2
3	24	15	262	S2
3	28	8	252	S2
3	28	9	241	S2
3	28	14	243	S2
3	28	16	246	S2
3	29	6	262	S2
3	29	7	262	S2
3	29	8	267	S2
3	29	11	265	S2
3	29	12	285	S2
3	29	13	264	S2
4	6	6	260	S2
4	6	7	294	S2
4	6	8	273	S2
4	7	6	241	S2
4	7	7	264	S2
4	7	8	262	S2
4	7	9	258	S2
4	7	10	250	S2
4	7	12	262	S2
4	7	13	248	S2
4	7	14	300	S2
5	3	7	260	S2
5	12	11	260	S2
5	12	15	254	S2
5	12	16	296	S2
5	12	17	248	S2
6	8	6	271	S2
6	8	7	260	S2
6	12	13	243	S2
6	12	14	285	S2
6	12	15	275	S2
6	12	16	244	S2
6	30	14	243	S2
6	30	15	244	S2
7	4	15	244	S2
7	5	8	250	S2
7	5	10	248	S2

Month	Day of month	Hour	Level (µg/m^3)	Reason code(s) *
7	5	12	283	S2
7	5	13	292	S2
7	5	14	287	S2
7	5	15	265	S2
7	5	16	294	S2
7	6	14	258	S2
7	6	15	262	S2
7	6	16	248	S2
7	6	17	241	S2
7	12	16	256	S2
7	17	16	252	S2
7	19	13	241	S2
7	19	14	254	S2
7	19	15	309	S2
7	19	16	254	S2
7	19	17	241	S2
7	20	12	277	S2
7	20	13	264	S2
7	20	14	254	S2
7	20	15	262	S2
7	20	16	283	S2
7	20	17	243	S2
7	21	10	262	S2
7	21	16	244	S2
7	26	13	250	S2
7	26	14	319	S2
7	26	15	309	S2
7	26	16	403	S2
7	26	17	338	S2
7	27	15	264	S2
9	13	11	273	S2
9	19	7	248	S2
9	26	7	252	S2
9	27	7	243	S2
9	28	13	241	S2
10	2	15	250	S2
10	5	6	256	S2
10	11	8	246	S2
10	11	19	246	S2
10	12	7	283	S2
10	20	11	273	S2
10	20	12	265	S2
10	20	13	254	S2
10	20	14	248	S2
10	20	15	285	S2
10	24	17	264	S2
10	27	8	244	S2
10	27	15	243	S2
10	27	16	244	S2
11	6	7	250	S2
11	6	9	279	S2
11	6	10	262	S2

Month	Day of month	Hour	Level ($\mu g/m^3$)	Reason code(s) *
11	6	12	243	S2
11	6	13	296	S2
11	6	14	313	S2
11	6	15	319	S2
11	6	16	308	S2
11	6	17	302	S2
11	6	18	254	S2
11	7	7	248	S2
11	7	11	311	S2
11	7	13	265	S2
11	7	14	258	S2
11	7	15	271	S2
11	7	16	292	S2
11	7	17	277	S2
11	7	19	243	S2
11	8	7	264	S2
11	8	8	264	S2
11	8	10	296	S2
11	8	13	243	S2
11	8	14	260	S2
11	8	15	294	S2
11	8	16	290	S2
11	8	17	262	S2
11	8	20	246	S2
11	10	15	241	S2
11	10	16	275	S2
11	14	9	283	S2
11	14	13	264	S2
11	15	7	248	S2
11	16	15	265	S2
11	16	16	283	S2
11	16	17	273	S2
11	17	7	248	S2
11	20	12	243	S2
11	20	16	250	S2
11	20	17	267	S2
11	21	7	254	S2
11	21	8	254	S2
11	21	9	258	S2
11	22	7	275	S2
11	22	8	269	S2
11	22	9	260	S2
11	22	11	279	S2
11	22	12	252	S2
11	22	13	248	S2
11	22	14	264	S2
11	22	16	269	S2
11	22	17	243	S2
11	28	13	265	S2
11	28	14	250	S2
11	28	15	300	S2
11	28	16	279	S2

Month	Day of month	Hour	Level (μg/m^3)	Reason code(s) *
11	28	17	246	S2
11	29	7	254	S2
11	29	8	292	S2
11	29	12	256	S2
11	29	14	265	S2
11	29	15	275	S2
11	29	16	277	S2
12	4	8	248	S2
12	5	15	241	S2
12	5	16	250	S2
12	5	17	348	S2
12	6	8	250	S2
12	6	11	273	S2
12	6	14	313	S2
12	6	15	294	S2
12	6	16	243	S2
12	6	17	287	S2
12	7	8	241	S2
12	11	12	277	S2
12	11	14	269	S2
12	11	15	285	S2
12	11	18	256	S2
12	12	7	267	S2
12	12	8	243	S2
12	12	14	241	S2
12	14	16	243	S2
12	14	17	281	S2
12	14	18	273	S2
12	15	7	248	S2
12	20	12	248	S2
12	22	11	283	S2

* see Table 7.7 for details

Table 7.9. Measured exceedences of the annual mean NO_2 limit value plus margin of tolerance, 2006 (Form 11f)

Site	Zone	Level (μg m^{-3})	Reason code(s) *
Bath Roadside	UK0030	69	S2
Brentford Roadside	UK0001	54	S2
Bristol Old Market	UK0009	67	S2
Bury Roadside	UK0003	73	S2
Camden Kerbside	UK0001	72	S2
Glasgow Kerbside	UK0024	68	S2
London A3 Roadside	UK0001	60	S2
London Bloomsbury	UK0001	57	S1
London Cromwell Road 2	UK0001	83	S2
London Hackney	UK0001	49	S1
London Hillingdon	UK0001	49	S1
London Lewisham	UK0001	55	S1
London Marylebone Road	UK0001	111	S2
London Wandsworth	UK0001	51	S1

Site	Zone	Level ($\mu g\ m^{-3}$)	Reason code(s) *
London Westminster	UK0001	51	S1
Oxford Centre Roadside	UK0031	66	S2
Tower Hamlets Roadside	UK0001	61	S2
West London	UK0001	51	S1

* see Table 7.7 for details

Table 7.10. Measured exceedences of the 24-hour mean PM_{10} limit value, 2006 (Form 11h).

Site	Zone	Month	Day of month	Level ($\mu g\ m^{-3}$)	Reason code(s) *
Bradford Centre	UK0004	1	3	76	S7
Bradford Centre	UK0004	1	4	55	S7
Bradford Centre	UK0004	1	6	56	S7
Bradford Centre	UK0004	1	17	87	S7
Bradford Centre	UK0004	1	18	116	S7
Bradford Centre	UK0004	1	19	66	S7
Bradford Centre	UK0004	1	20	68	S7
Bradford Centre	UK0004	1	21	73	S7
Bradford Centre	UK0004	1	22	75	S7
Bradford Centre	UK0004	1	24	168	S7
Bradford Centre	UK0004	1	25	82	S7
Bradford Centre	UK0004	1	27	57	S7
Bradford Centre	UK0004	1	28	57	S7
Bradford Centre	UK0004	2	1	97	S7
Bradford Centre	UK0004	2	2	51	S7
Bradford Centre	UK0004	2	3	71	S7
Bradford Centre	UK0004	2	6	59	S7
Bradford Centre	UK0004	2	9	114	S7
Bradford Centre	UK0004	2	10	63	S7
Bradford Centre	UK0004	2	17	64	S7
Bradford Centre	UK0004	2	20	94	S7
Bradford Centre	UK0004	2	23	71	S7
Bradford Centre	UK0004	2	27	93	S7
Bradford Centre	UK0004	2	28	122	S7
Bradford Centre	UK0004	3	1	116	S7
Bradford Centre	UK0004	3	2	87	S7
Bradford Centre	UK0004	3	3	66	S7
Bradford Centre	UK0004	3	5	92	S7
Bradford Centre	UK0004	3	6	81	S7
Bradford Centre	UK0004	3	23	53	S7
Bradford Centre	UK0004	4	4	80	S7
Bradford Centre	UK0004	4	5	75	S7
Bradford Centre	UK0004	4	13	80	S7
Bradford Centre	UK0004	5	4	73	S7
Bradford Centre	UK0004	5	8	97	S10,S7
Bradford Centre	UK0004	5	9	62	S10,S7
Bradford Centre	UK0004	5	12	63	S7
Bradford Centre	UK0004	6	9	72	S7
Bradford Centre	UK0004	6	28	51	S7
Bradford Centre	UK0004	7	5	55	S10
Bradford Centre	UK0004	9	11	64	S10
Bradford Centre	UK0004	9	16	59	S10
Bradford Centre	UK0004	10	13	58	S10
Bradford Centre	UK0004	10	15	55	S10
Bradford Centre	UK0004	10	16	64	S10
Bradford Centre	UK0004	10	17	58	S10
Bradford Centre	UK0004	12	18	53	S1
Brighton Roadside PM10	UK0010	1	6	51	S2
Brighton Roadside PM10	UK0010	1	7	54	S2

Site	Zone	Month	Day of month	Level (µg m^{-3})	Reason code(s) *
Brighton Roadside PM10	UK0010	1	14	56	S2
Brighton Roadside PM10	UK0010	1	23	63	S2
Brighton Roadside PM10	UK0010	1	24	56	S2
Brighton Roadside PM10	UK0010	1	25	65	S2
Brighton Roadside PM10	UK0010	1	28	67	S2
Brighton Roadside PM10	UK0010	1	31	53	S2
Brighton Roadside PM10	UK0010	2	1	75	S2
Brighton Roadside PM10	UK0010	2	2	72	S2
Brighton Roadside PM10	UK0010	2	3	75	S2
Brighton Roadside PM10	UK0010	2	4	61	S2
Brighton Roadside PM10	UK0010	2	5	64	S2
Brighton Roadside PM10	UK0010	2	6	62	S2
Brighton Roadside PM10	UK0010	2	10	53	S2
Brighton Roadside PM10	UK0010	2	14	62	S2
Brighton Roadside PM10	UK0010	2	15	51	S2
Brighton Roadside PM10	UK0010	2	24	57	S2
Brighton Roadside PM10	UK0010	3	4	51	S2
Brighton Roadside PM10	UK0010	3	14	52	S2
Brighton Roadside PM10	UK0010	3	16	55	S2
Brighton Roadside PM10	UK0010	3	17	63	S2
Brighton Roadside PM10	UK0010	3	18	57	S2
Brighton Roadside PM10	UK0010	3	23	64	S2
Brighton Roadside PM10	UK0010	3	24	56	S2
Brighton Roadside PM10	UK0010	3	28	51	S2
Brighton Roadside PM10	UK0010	3	31	61	S2
Brighton Roadside PM10	UK0010	4	13	52	S2
Brighton Roadside PM10	UK0010	4	14	52	S2
Brighton Roadside PM10	UK0010	4	24	85	S2
Brighton Roadside PM10	UK0010	5	10	69	S10, S2
Brighton Roadside PM10	UK0010	5	12	52	S10, S2
Brighton Roadside PM10	UK0010	5	13	57	S10, S2
Brighton Roadside PM10	UK0010	5	18	51	S2
Brighton Roadside PM10	UK0010	5	20	61	S2
Brighton Roadside PM10	UK0010	6	9	53	S2, S10
Brighton Roadside PM10	UK0010	6	13	51	S2, S10
Brighton Roadside PM10	UK0010	6	18	61	S2
Brighton Roadside PM10	UK0010	6	25	57	S2
Brighton Roadside PM10	UK0010	7	19	52	S2, S10
Brighton Roadside PM10	UK0010	7	21	52	S2, S10
Brighton Roadside PM10	UK0010	7	26	51	S2, S10
Brighton Roadside PM10	UK0010	9	10	56	S2, S10
Brighton Roadside PM10	UK0010	9	16	69	S2, S10
Brighton Roadside PM10	UK0010	10	14	60	S2, S10
Brighton Roadside PM10	UK0010	10	15	70	S2, S10
Brighton Roadside PM10	UK0010	10	16	67	S2, S10
Brighton Roadside PM10	UK0010	11	4	105	S7
Brighton Roadside PM10	UK0010	11	5	86	S7
Brighton Roadside PM10	UK0010	11	6	74	S2
Brighton Roadside PM10	UK0010	12	22	57	S2
Camden Kerbside	UK0001	1	6	57	S2
Camden Kerbside	UK0001	1	7	52	S2

Site	Zone	Month	Day of month	Level ($\mu g\ m^{-3}$)	Reason code(s) *
Camden Kerbside	UK0001	1	9	59	S2
Camden Kerbside	UK0001	1	21	53	S2
Camden Kerbside	UK0001	1	23	77	S2
Camden Kerbside	UK0001	1	28	53	S2
Camden Kerbside	UK0001	1	30	52	S2
Camden Kerbside	UK0001	1	31	57	S2
Camden Kerbside	UK0001	2	1	74	S2
Camden Kerbside	UK0001	2	2	74	S2
Camden Kerbside	UK0001	2	3	97	S2
Camden Kerbside	UK0001	2	4	92	S2
Camden Kerbside	UK0001	2	5	73	S2
Camden Kerbside	UK0001	2	6	54	S2
Camden Kerbside	UK0001	2	9	75	S2
Camden Kerbside	UK0001	2	10	73	S2
Camden Kerbside	UK0001	2	11	67	S2
Camden Kerbside	UK0001	2	18	52	S2
Camden Kerbside	UK0001	2	27	63	S2
Camden Kerbside	UK0001	2	28	62	S2
Camden Kerbside	UK0001	3	3	70	S2
Camden Kerbside	UK0001	3	4	57	S2
Camden Kerbside	UK0001	3	6	66	S2
Camden Kerbside	UK0001	3	23	56	S2
Camden Kerbside	UK0001	4	24	51	S2
Camden Kerbside	UK0001	5	4	64	S2
Camden Kerbside	UK0001	5	10	54	S10, S2
Camden Kerbside	UK0001	5	12	57	S10, S2
Camden Kerbside	UK0001	6	8	54	S2
Camden Kerbside	UK0001	6	9	65	S10, S2
Camden Kerbside	UK0001	6	10	51	S10, S2
Camden Kerbside	UK0001	6	12	52	S2
Camden Kerbside	UK0001	6	25	51	S2
Camden Kerbside	UK0001	6	29	56	S10, S2
Camden Kerbside	UK0001	6	30	54	S10, S2
Camden Kerbside	UK0001	7	1	62	S10, S2
Camden Kerbside	UK0001	7	3	52	S10, S2
Camden Kerbside	UK0001	7	4	67	S10, S2
Camden Kerbside	UK0001	7	5	73	S10, S2
Camden Kerbside	UK0001	7	18	54	S10, S2
Camden Kerbside	UK0001	7	19	62	S10, S2
Camden Kerbside	UK0001	7	20	54	S10, S2
Camden Kerbside	UK0001	7	21	60	S10, S2
Camden Kerbside	UK0001	10	15	59	S10, S2
Camden Kerbside	UK0001	10	16	72	S10, S2
Camden Kerbside	UK0001	10	17	58	S10, S2
Camden Kerbside	UK0001	11	3	60	S2
Camden Kerbside	UK0001	11	4	85	S7
Camden Kerbside	UK0001	11	5	89	S7
Camden Kerbside	UK0001	11	6	67	S2
Camden Kerbside	UK0001	11	7	55	S2
Camden Kerbside	UK0001	12	19	60	S2
Glasgow Kerbside	UK0024	1	24	53	S2

Site	Zone	Month	Day of month	Level ($\mu g\ m^{-3}$)	Reason code(s) *
Glasgow Kerbside	UK0024	1	25	86	S2
Glasgow Kerbside	UK0024	1	26	76	S2
Glasgow Kerbside	UK0024	1	27	59	S2
Glasgow Kerbside	UK0024	1	28	73	S2
Glasgow Kerbside	UK0024	1	29	70	S2
Glasgow Kerbside	UK0024	2	1	66	S2
Glasgow Kerbside	UK0024	2	2	52	S2
Glasgow Kerbside	UK0024	2	18	62	S2
Glasgow Kerbside	UK0024	2	20	63	S2
Glasgow Kerbside	UK0024	2	21	75	S2
Glasgow Kerbside	UK0024	2	24	72	S2
Glasgow Kerbside	UK0024	2	25	105	S2
Glasgow Kerbside	UK0024	2	28	59	S2
Glasgow Kerbside	UK0024	3	1	51	S2
Glasgow Kerbside	UK0024	3	2	54	S2
Glasgow Kerbside	UK0024	3	3	95	S2
Glasgow Kerbside	UK0024	3	6	66	S2
Glasgow Kerbside	UK0024	3	9	54	S2
Glasgow Kerbside	UK0024	3	10	61	S2
Glasgow Kerbside	UK0024	3	11	52	S2
Glasgow Kerbside	UK0024	3	14	58	S2
Glasgow Kerbside	UK0024	3	15	95	S2
Glasgow Kerbside	UK0024	3	17	73	S2
Glasgow Kerbside	UK0024	3	18	72	S2
Glasgow Kerbside	UK0024	3	20	71	S2
Glasgow Kerbside	UK0024	3	21	59	S2
Glasgow Kerbside	UK0024	3	22	57	S2
Glasgow Kerbside	UK0024	3	23	83	S2
Glasgow Kerbside	UK0024	3	24	64	S2
Glasgow Kerbside	UK0024	3	30	55	S2
Glasgow Kerbside	UK0024	4	20	61	S2
Glasgow Kerbside	UK0024	4	21	70	S2
Glasgow Kerbside	UK0024	4	28	51	S2
Glasgow Kerbside	UK0024	5	4	79	S2
Glasgow Kerbside	UK0024	5	6	62	S2
Glasgow Kerbside	UK0024	5	7	60	S10, S2
Glasgow Kerbside	UK0024	5	8	101	S10, S2
Glasgow Kerbside	UK0024	5	9	67	S10, S2
Glasgow Kerbside	UK0024	5	10	63	S10, S2
Glasgow Kerbside	UK0024	5	11	62	S10, S2
Glasgow Kerbside	UK0024	5	12	59	S10, S2
Glasgow Kerbside	UK0024	6	5	55	S2
Glasgow Kerbside	UK0024	7	19	64	S2,S10
Glasgow Kerbside	UK0024	7	20	62	S2,S10
Glasgow Kerbside	UK0024	7	21	54	S2,S10
Glasgow Kerbside	UK0024	7	25	51	S2,S10
Glasgow Kerbside	UK0024	8	18	64	S2
Glasgow Kerbside	UK0024	9	9	51	S2
Glasgow Kerbside	UK0024	9	11	54	S2
Glasgow Kerbside	UK0024	9	16	63	S10,S2
Glasgow Kerbside	UK0024	9	21	57	S2

Site	Zone	Month	Day of month	Level ($\mu g\ m^{-3}$)	Reason code(s) *
Glasgow Kerbside	UK0024	9	22	58	S2
Glasgow Kerbside	UK0024	9	23	51	S2
Glasgow Kerbside	UK0024	10	13	70	S2
Glasgow Kerbside	UK0024	10	14	52	S10,S2
Glasgow Kerbside	UK0024	10	15	54	S10,S2
Glasgow Kerbside	UK0024	10	16	73	S2
Glasgow Kerbside	UK0024	10	17	72	S2
Glasgow Kerbside	UK0024	10	18	51	S2
Glasgow Kerbside	UK0024	10	19	54	S2
Glasgow Kerbside	UK0024	10	20	66	S2
Glasgow Kerbside	UK0024	10	21	51	S2
Glasgow Kerbside	UK0024	10	24	53	S2
Glasgow Kerbside	UK0024	11	3	59	S2
Glasgow Kerbside	UK0024	12	18	65	S2
London Marylebone Road	UK0001	1	9	67	S2
London Marylebone Road	UK0001	1	12	65	S2
London Marylebone Road	UK0001	1	13	52	S2
London Marylebone Road	UK0001	1	14	51	S2
London Marylebone Road	UK0001	1	16	53	S2
London Marylebone Road	UK0001	1	19	60	S2
London Marylebone Road	UK0001	1	23	66	S2
London Marylebone Road	UK0001	1	24	66	S2
London Marylebone Road	UK0001	1	31	51	S2
London Marylebone Road	UK0001	2	1	64	S2
London Marylebone Road	UK0001	2	2	51	S2
London Marylebone Road	UK0001	2	3	53	S2
London Marylebone Road	UK0001	2	6	53	S2
London Marylebone Road	UK0001	2	7	71	S2
London Marylebone Road	UK0001	2	11	79	S2
London Marylebone Road	UK0001	2	13	66	S2
London Marylebone Road	UK0001	2	14	63	S2
London Marylebone Road	UK0001	2	15	62	S2
London Marylebone Road	UK0001	2	16	63	S2
London Marylebone Road	UK0001	2	17	63	S2
London Marylebone Road	UK0001	3	2	58	S2
London Marylebone Road	UK0001	3	7	61	S2
London Marylebone Road	UK0001	3	8	52	S2
London Marylebone Road	UK0001	3	9	56	S2
London Marylebone Road	UK0001	3	14	75	S2
London Marylebone Road	UK0001	3	23	52	S2
London Marylebone Road	UK0001	3	24	58	S2
London Marylebone Road	UK0001	3	28	54	S2
London Marylebone Road	UK0001	3	30	55	S2
London Marylebone Road	UK0001	3	31	66	S2
London Marylebone Road	UK0001	4	7	51	S2
London Marylebone Road	UK0001	4	18	51	S2
London Marylebone Road	UK0001	4	24	59	S2
London Marylebone Road	UK0001	4	25	69	S2
London Marylebone Road	UK0001	5	2	53	S2
London Marylebone Road	UK0001	5	3	56	S2
London Marylebone Road	UK0001	5	4	71	S2

Site	Zone	Month	Day of month	Level ($\mu g\ m^{-3}$)	Reason code(s) *
London Marylebone Road	UK0001	5	5	57	S2
London Marylebone Road	UK0001	5	8	55	S2
London Marylebone Road	UK0001	5	9	52	S2
London Marylebone Road	UK0001	5	10	54	S10,S2
London Marylebone Road	UK0001	5	12	67	S10,S2
London Marylebone Road	UK0001	5	15	56	S2
London Marylebone Road	UK0001	5	16	55	S2
London Marylebone Road	UK0001	5	18	69	S2
London Marylebone Road	UK0001	5	19	53	S2
London Marylebone Road	UK0001	5	23	51	S2
London Marylebone Road	UK0001	6	7	54	S2
London Marylebone Road	UK0001	6	8	69	S2
London Marylebone Road	UK0001	6	9	69	S2
London Marylebone Road	UK0001	6	10	54	S10,S2
London Marylebone Road	UK0001	6	11	51	S10,S2
London Marylebone Road	UK0001	6	12	66	S2
London Marylebone Road	UK0001	6	17	61	S2
London Marylebone Road	UK0001	6	18	58	S2
London Marylebone Road	UK0001	6	19	52	S2
London Marylebone Road	UK0001	6	20	54	S2
London Marylebone Road	UK0001	6	23	58	S2
London Marylebone Road	UK0001	6	29	54	S2
London Marylebone Road	UK0001	6	30	54	S2
London Marylebone Road	UK0001	7	1	57	S10,S2
London Marylebone Road	UK0001	7	4	66	S10,S2
London Marylebone Road	UK0001	7	5	83	S2
London Marylebone Road	UK0001	7	6	70	S2
London Marylebone Road	UK0001	7	7	52	S2
London Marylebone Road	UK0001	7	10	59	S2
London Marylebone Road	UK0001	7	18	56	S2,S10
London Marylebone Road	UK0001	7	19	65	S2,S10
London Marylebone Road	UK0001	7	20	87	S2
London Marylebone Road	UK0001	7	21	94	S2
London Marylebone Road	UK0001	7	22	66	S2,S10
London Marylebone Road	UK0001	7	25	70	S2
London Marylebone Road	UK0001	7	26	72	S2
London Marylebone Road	UK0001	7	27	64	S2
London Marylebone Road	UK0001	7	31	51	S2
London Marylebone Road	UK0001	8	15	52	S2
London Marylebone Road	UK0001	8	18	53	S2
London Marylebone Road	UK0001	8	23	51	S2
London Marylebone Road	UK0001	9	5	59	S2
London Marylebone Road	UK0001	9	6	53	S2
London Marylebone Road	UK0001	9	11	77	S2
London Marylebone Road	UK0001	9	12	68	S2
London Marylebone Road	UK0001	9	13	64	S2
London Marylebone Road	UK0001	9	16	70	S10,S2
London Marylebone Road	UK0001	9	17	54	S10,S2
London Marylebone Road	UK0001	9	19	61	S2
London Marylebone Road	UK0001	9	20	60	S2
London Marylebone Road	UK0001	9	21	58	S2

Site	Zone	Month	Day of month	Level ($\mu g\ m^{-3}$)	Reason code(s) *
London Marylebone Road	UK0001	9	22	57	S2
London Marylebone Road	UK0001	9	25	55	S2
London Marylebone Road	UK0001	9	26	51	S2
London Marylebone Road	UK0001	9	27	58	S2
London Marylebone Road	UK0001	9	28	60	S2
London Marylebone Road	UK0001	9	29	53	S2
London Marylebone Road	UK0001	10	2	56	S2
London Marylebone Road	UK0001	10	5	54	S2
London Marylebone Road	UK0001	10	6	53	S2
London Marylebone Road	UK0001	10	9	63	S2
London Marylebone Road	UK0001	10	10	59	S2
London Marylebone Road	UK0001	10	11	64	S2
London Marylebone Road	UK0001	10	12	77	S2
London Marylebone Road	UK0001	10	13	61	S2
London Marylebone Road	UK0001	10	15	65	S10,S2
London Marylebone Road	UK0001	10	16	91	S2
London Marylebone Road	UK0001	10	17	74	S2
London Marylebone Road	UK0001	10	18	55	S2
London Marylebone Road	UK0001	10	19	64	S2
London Marylebone Road	UK0001	10	20	70	S2
London Marylebone Road	UK0001	10	21	53	S2
London Marylebone Road	UK0001	10	23	57	S2
London Marylebone Road	UK0001	10	24	52	S2
London Marylebone Road	UK0001	10	26	58	S2
London Marylebone Road	UK0001	10	27	72	S2
London Marylebone Road	UK0001	10	28	52	S2
London Marylebone Road	UK0001	10	30	62	S2
London Marylebone Road	UK0001	11	4	93	S7
London Marylebone Road	UK0001	11	5	97	S7
London Marylebone Road	UK0001	11	6	91	S2
London Marylebone Road	UK0001	11	7	83	S2
London Marylebone Road	UK0001	11	8	67	S2
London Marylebone Road	UK0001	11	14	63	S2
London Marylebone Road	UK0001	11	15	64	S2
London Marylebone Road	UK0001	11	16	57	S2
London Marylebone Road	UK0001	11	17	54	S2
London Marylebone Road	UK0001	11	18	57	S2
London Marylebone Road	UK0001	11	20	57	S2
London Marylebone Road	UK0001	11	21	56	S2
London Marylebone Road	UK0001	11	22	68	S2
London Marylebone Road	UK0001	11	23	65	S2
London Marylebone Road	UK0001	11	24	61	S2
London Marylebone Road	UK0001	11	27	55	S2
London Marylebone Road	UK0001	11	28	64	S2
London Marylebone Road	UK0001	11	29	71	S2
London Marylebone Road	UK0001	11	30	63	S2
London Marylebone Road	UK0001	12	1	54	S2
London Marylebone Road	UK0001	12	2	52	S2
London Marylebone Road	UK0001	12	4	55	S2
London Marylebone Road	UK0001	12	5	59	S2
London Marylebone Road	UK0001	12	6	64	S2

Site	Zone	Month	Day of month	Level (μg m^{-3})	Reason code(s) *
London Marylebone Road	UK0001	12	7	61	S2
London Marylebone Road	UK0001	12	8	52	S2
London Marylebone Road	UK0001	12	12	59	S2
London Marylebone Road	UK0001	12	14	53	S2
London Marylebone Road	UK0001	12	15	63	S2
London Marylebone Road	UK0001	12	18	55	S2
London Marylebone Road	UK0001	12	19	61	S2
London Marylebone Road	UK0001	12	20	64	S2
London Marylebone Road	UK0001	12	27	52	S2
London Marylebone Road	UK0001	12	28	54	S2
Scunthorpe Town	UK0034	1	24	61	S3
Scunthorpe Town	UK0034	3	15	67	S3
Scunthorpe Town	UK0034	3	23	80	S3
Scunthorpe Town	UK0034	3	24	82	S3
Scunthorpe Town	UK0034	5	4	124	S3
Scunthorpe Town	UK0034	5	8	121	S10, S3
Scunthorpe Town	UK0034	5	9	57	S3
Scunthorpe Town	UK0034	5	11	56	S3
Scunthorpe Town	UK0034	6	7	52	S3
Scunthorpe Town	UK0034	6	8	87	S3
Scunthorpe Town	UK0034	6	9	107	S3
Scunthorpe Town	UK0034	6	10	130	S3
Scunthorpe Town	UK0034	7	2	60	S3
Scunthorpe Town	UK0034	7	3	64	S3
Scunthorpe Town	UK0034	7	4	51	S3
Scunthorpe Town	UK0034	7	5	72	S3
Scunthorpe Town	UK0034	7	6	51	S3
Scunthorpe Town	UK0034	7	16	52	S3, S10
Scunthorpe Town	UK0034	7	17	57	S3, S10
Scunthorpe Town	UK0034	7	18	91	S3, S10
Scunthorpe Town	UK0034	7	19	97	S3,S10
Scunthorpe Town	UK0034	7	21	55	S3,S10
Scunthorpe Town	UK0034	7	22	52	S3,S10
Scunthorpe Town	UK0034	7	25	90	S3,S10
Scunthorpe Town	UK0034	7	26	57	S3,S10
Scunthorpe Town	UK0034	8	17	59	S3
Scunthorpe Town	UK0034	9	9	57	S3
Scunthorpe Town	UK0034	9	11	56	S3
Scunthorpe Town	UK0034	9	16	60	S10
Scunthorpe Town	UK0034	9	21	69	S3
Scunthorpe Town	UK0034	10	11	51	S3
Scunthorpe Town	UK0034	10	14	51	S3
Scunthorpe Town	UK0034	10	15	77	S3
Scunthorpe Town	UK0034	10	16	80	S3,S10
Scunthorpe Town	UK0034	10	17	65	S10,S3
Scunthorpe Town	UK0034	12	18	56	S3
Scunthorpe Town	UK0034	12	22	51	S3

* see Table 7.7 for details

Table 7.11. Measured exceedences of the annual mean PM_{10} limit value plus margin of tolerance (Stage 1), 2006 (Form 11i)

Site	Zone	Level ($\mu g\ m^{-3}$)	Reason code(s) *
London Marylebone Road	UK0001	47	S2

* see Table 7.7 for details

7.3 Comparison with previous years

Tables 7.12 and 7.13 provide a comparison of the monitoring and modelling results for 2006 with the results of the air quality assessments reported to the EU for 2001, 2002, 2003, 2004 and 2005 (Stedman, *et al.,* 2002, Stedman, *et al.,* 2003, Stedman, *et al.,* 2005, Stedman, *et al.,* 2006a, Kent, *et al.*, 2007). 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 and 24-hour LV for SO_2 have been reported for 2006. As in 2004 and 2005 these exceedences were limited to Stewartby in Eastern zone. The modelling analysis indicates that these exceedences were associated with emissions from a brick works (see Appendix 4). A plan or programme is now in place to address these exceedences. There were no reported exceedences of the annual or winter mean limit values for SO_2 in ecosystem areas.

An exceedence of the 1-hour LV + MOT for NO_2 has been reported for the first time in 2003 and was repeated in 2004, 2005 and 2006 in London. The reasons for this exceedence at the London Marylebone Road site remain under investigation and appear to be related to an increase in primary NO_2 emissions (Abbott, 2005). Increasing contributions to ambient NO_2 from primary NO_2 directly emitted from road traffic sources have been the focus of research by the Air Quality Expert Group (AQEG, 2006). Reasons may include changes in traffic management and fleet emission characteristics. The number of zones in which there were modelled exceedences of the annual mean LV + MOT increased from 2005 to 2006 although the number of measured exceedences remained the same. Exceedences of the annual mean LV in 2006 remained similar to 2005. There were no reported exceedences of the annual mean LV for NO_X in vegetation areas.

Exceedences of ‘old’ directives are listed in Table 7.14. Directive 85/203/EEC was exceeded at one monitoring site, Marylebone Road, in 2006 as in the previous 3 years.

A similar number of zones exceeded the Stage 1 24-hour limit value for PM_{10} in 2006 as in 2005. A larger number of zones exceeded the Stage 2 indicative limit values than in 2005, although exceedences were not as widespread as in 2003.

There were no exceedences for Lead in 2001, 2002, 2003, 2004, 2005 or 2006.

One exceedence of the benzene LV were modelled in 2006 but there were no modelled exceedences of the LV + MOT. These exceedences were modelled in close proximity to a large oil refinery at Killingholme.

CO concentrations were below the LV in all zones in 2006.

Table 7.12 Exceedences of limit values plus margins of tolerance for 1st and 2nd Daughter Directives

Pollutant	Averaging time	2006	2005	2004	2003	2002	2001
SO_2	1-hour[3]	n/a	n/a	1 zone modelled (Eastern)	1 zone modelled (Eastern)	none	none
SO_2	24-hour[2]	n/a	n/a	none	1 zone modelled (Eastern)	none	1 zone measured (Belfast Urban Area)
SO_2	annual[3]	n/a	n/a	n/a	n/a	n/a	n/a
SO_2	winter[3]	n/a	n/a	n/a	n/a	n/a	n/a
NO_2	1-hour[4]	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)	none	none
NO_2	annual	38 zones (6 measured + 32 modelled)	35 zones (6 measured + 29 modelled)	34 zones (6 measured + 28 modelled)	35 zones (5 measured + 30 modelled)	19 Zones (5 measured + 14 modelled)	21 Zones (4 measured + 17 modelled)
NO_x	annual[3]	n/a	n/a	n/a	n/a	n/a	n/a
PM_{10}	24-hour (Stage 1)[3]	n/a	n/a	19 zones (1 measured + 18 modelled)	18 zones (2 measured + 16 modelled)	1 zone modelled (Greater London Urban Area)	1 zone modelled (Greater London Urban Area)
PM_{10}	annual (Stage 1)[3]	n/a	n/a	1 zone modelled (Greater London Urban Area)	10 zones (1 measured + 9 modelled)	1 zone modelled (Greater London Urban Area)	1 zone modelled (Greater London Urban Area)
PM_{10}	24-hour (Stage 2)[5]	n/a	n/a	n/a	n/a	n/a	n/a
PM_{10}	annual (Stage 2)[6]	36 zones (8 measured + 28 modelled)	32 zones (3 measured + 29 modelled)	32 zones (3 measured + 29 modelled)	36 zones (8 measured + 28 modelled)	22 zones (3 measured + 18 modelled)	not assessed
Lead	annual[3]	n/a	n/a	none	none	none	none
Benzene	annual	none	none	none	none	not assessed	not assessed
CO	8-hour[3]	n/a	n/a	none	none	not assessed	not assessed

[1] Includes zones exceeding LV + MOT
[2] No MOT defined, LV + MOT = LV
[3] No MOT. LVs are already in force in 2005
[4] No modelling for 1-hour LV
[5] Stage 2 indicative LV, no MOT defined for 24-hour stage 2 LV, no modelling for 24-hour stage 2 LV
[6] Stage 2 indicative LV

Table 7.13 Exceedences of limit values for 1st and 2nd Daughter Directives

Pollutant	Averaging time	2006	2005	2004	2003	2002	2001
SO_2	1-hour	1 zone modelled (Eastern)	1 zone modelled (Eastern)	1 zone modelled (Eastern)	1 zone modelled (Eastern)	none	none
SO_2	24-hour[1]	1 zone modelled (Eastern)	1 zone modelled (Eastern)	none	1 zone modelled (Eastern)	none	1 Zone measured (Belfast Urban Area)
SO_2	Annual[2]	none	none	none	none	none	none
SO_2	Winter[2]	none	none	none	none	none	not assessed
NO_2	1-hour[3]	1 zone measured (Greater London Urban Area)	2 zones measured (London, Bristol)	1 zone measured (Greater London Urban Area)	3 zones measured (London, Glasgow, South East)	1 zone measured (Glasgow Urban Area)	4 zones measured
NO_2	Annual	39 zones (7 measured + 32 modelled)	38 zones (8 measured + 30 modelled)	39 zones (9 measured + 30 modelled)	42 zones (10 measured + 32 modelled)	36 zones (6 measured + 30 modelled)	38 zones (6 measured + 32 modelled)
NO_x	Annual[2]	none	none	none	none	none	None
PM_{10}	24-hour (Stage 1)	30 zones (5 measured + 25 modelled)	29 zones (3 measured + 26 modelled)	27 zones (2 measured + 25 modelled)	33 zones (10 measured + 23 modelled)	18 zones (1 measured + 17 modelled)	26 zones (5 measured + 21 modelled)
PM_{10}	annual (Stage 1)	2 zones (1 measured + 1 modelled)	4 zones (1 measured + 3 modelled)	2 zones (1 measured, London + 1 modelled, West Midlands Urban Area)	15 zones (1 measured + 14 modelled)	2 zones (Greater London Urban Area measured, Eastern modelled)	2 zones (London measured, Manchester modelled)
PM_{10}	24-hour[4] (Stage 2)	22 zones (22 measured)	13 zones (13 measured)	15 zones (15 measured)	36 zones (36 measured)	21 zones (21 measured)	25 zones (25 measured)
PM_{10}	annual[5] (Stage 2)	42 zones (8 measured + 34 modelled)	40 zones (26 measured + 14 modelled)	41 zones (26 measured + 15 modelled)	43 zones (35 measured + 8 modelled)	42 zones (16 measured, 26 modelled)	43 zones (28 measured, 15 modelled)
Lead	Annual	none	none	none	none	none	none
Benzene	Annual	1 zone modelled (Yorkshire & Humberside)	2 zones modelled (Yorkshire & Humberside, Central Scotland)	none	1 zone modelled (Greater London Urban Area)	not assessed	not assessed
CO	8-hour	none	none	none	none	not assessed	not assessed

[1] No MOT defined, LV + MOT = LV

[2] Applies to vegetation and ecosystem areas only. No MOT defined, LVs are already in force

[3] No modelling for 1-hour LV
[4] Stage 2 indicative LV, no modelling for 24-hour Stage 2 LV
[5] Stage 2 indicative LV

Table 7.14 Exceedences of old Directives

Pollutant	Directive	Averaging time	2006 concentration ($\mu g\ m^{-3}$)	2005 concentration ($\mu g\ m^{-3}$)	2004 concentration ($\mu g\ m^{-3}$)	2003 concentration ($\mu g\ m^{-3}$)	2002 concentration ($\mu g\ m^{-3}$)	2001 concentration ($\mu g\ m^{-3}$)
NO_2	85/203/EEC	1-hour 98%ile	244 (measured at London Marylebone Road)	256 (measured at London Marylebone Road)	233 (measured at London Marylebone Road)	235 (measured at London Marylebone Road)	No exceedences	No exceedences

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Appendices

Appendix 1: Monitoring sites used to verify the mapped estimates

Appendix 2: Small point source model

Appendix 3: Dispersion kernels for area source model

Appendix 4: Model assessment of SO_2 concentrations at Stewartby brick works

Appendix 5: Air Quality monitoring data from Gibraltar in 2006

Appendix 1 Monitoring sites used to verify the mapped estimates

Table A1.1. Monitoring sites used to verify the mapped estimates (PM_{10} measurements by gravimetric and TEOM instruments were used in the verification)

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
Aberdeen Anderson Dr	ROADSIDE	Aberdeen City Council		y	y	
Aberdeen Market St	ROADSIDE	Aberdeen City Council		y	y	
Aberdeen Union St	ROADSIDE	Aberdeen City Council		y	y	
Antrim Greystone Estate	URBAN BACKGROUND	Antrim BC				y
Ards	URBAN BACKGROUND	Ards BC			y	y
Armagh Lonsdale Road	KERBSIDE	Armagh City DC		y	y	
Gatwick LGW3	AIRPORT	BAA	y	y	y	
Heathrow Bedfont Court	AIRPORT	BAA			y	
Heathrow Green Gates	AIRPORT	BAA		y	y	
Heathrow LHR2	AIRPORT	BAA	y	y	y	
Heathrow Main Road	AIRPORT	BAA	y	y	y	y
Heathrow Moorbridge	AIRPORT	BAA			y	
Heathrow Oaks Road	AIRPORT	BAA		y	y	
Stansted 3	AIRPORT	BAA	y	y	y	
Stansted 4	AIRPORT	BAA		y		
Ballymena North Road	KERBSIDE	Ballymena BC		y		
Ballymena Ballykeel	URBAN BACKGROUND	Ballymena BC			y	y
Ballymoney	URBAN BACKGROUND	Ballymoney BC			y	
Barnsley A628 Roadside	ROADSIDE	Barnsley MBC		y		
Barnsley Old Mill Lane Roadside	ROADSIDE	Barnsley MBC		y	y	
Barnsley Royston	ROADSIDE	Barnsley MBC		y	y	
Basingstoke Eastrop	URBAN BACKGROUND	Basingstoke & Deane DC		y	y	
Belfast Westlink	KERBSIDE	Belfast City Council		y	y	
Belfast Roadside	ROADSIDE	Belfast City Council		y		
Birmingham Airport	AIRPORT	Birmingham International Airport	y	y	y	y
Boston Haven Bridge Road	ROADSIDE	Boston BC		y		
Bracknell Yorktown Road Sandhurst	ROADSIDE	Bracknell Forest BC		y	y	
Bracknell Foxhill	URBAN BACKGROUND	Bracknell Forest BC		y	y	
Caerphilly Ton-y-Felin Roadside	ROADSIDE	Caerphilly County BC		y	y	

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
Cambridge Gonville Place	ROADSIDE	Cambridge City Council		y	y	
Cambridge Newmarket Road	ROADSIDE	Cambridge City Council		y	y	
Cambridge Parker Street	ROADSIDE	Cambridge City Council		y	y	
Cambridge Silver Street	ROADSIDE	Cambridge City Council		y	y	
Carrickfergus Rosebrook Avenue	URBAN BACKGROUND	Carrickfergus BC			y	y
Castlereagh Lough View Drive	ROADSIDE	Castlereagh BC		y	y	
Castlereagh Espie Way	URBAN BACKGROUND	Castlereagh BC			y	y
Chesterfield Whittington Roadside	ROADSIDE	Chesterfield BC		y	y	
Chesterfield Birdholme School	URBAN BACKGROUND	Chesterfield BC		y	y	y
Craigavon Castle Lane	ROADSIDE	Craigavon BC		y		
Craigavon Lord Lurgan Park	URBAN BACKGROUND	Craigavon BC			y	y
Derry Dale's Corner	KERBSIDE	Derry City Council		y		
Derry Brandywell	URBAN BACKGROUND	Derry City Council			y	y
Derry Claudy	URBAN BACKGROUND	Derry City Council			y	
Dundee Seagate	KERBSIDE	Dundee City Council		y		
Dundee Union Street	KERBSIDE	Dundee City Council		y	y	
Dundee Whitehall Street	KERBSIDE	Dundee City Council		y		
Dundee Broughty Ferry Road	ROADSIDE	Dundee City Council			y	
Dundee Lochee Road	ROADSIDE	Dundee City Council		y		
Dundee Mains Loan	URBAN BACKGROUND	Dundee City Council			y	
BT5	INDUSTRIAL	ERG		y	y	
BX4	INDUSTRIAL	ERG		y		
EA8	INDUSTRIAL	ERG			y	
NF1	INDUSTRIAL	ERG			y	
ST5	INDUSTRIAL	ERG		y		
BN1	KERBSIDE	ERG		y	y	
CR5	KERBSIDE	ERG		y		
CT2	KERBSIDE	ERG		y	y	
KC5	KERBSIDE	ERG			y	
LB4	KERBSIDE	ERG		y		
RB3	KERBSIDE	ERG		y		
ST4	KERBSIDE	ERG		y		
SU1	KERBSIDE	ERG	y	y	y	

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
SU2	KERBSIDE	ERG	y	y	y	
SX9	KERBSIDE	ERG	y	y	y	
BB1	ROADSIDE	ERG		y	y	
BH6	ROADSIDE	ERG		y		
BH7	ROADSIDE	ERG		y		
BT3	ROADSIDE	ERG		y		
BT4	ROADSIDE	ERG		y		
BT6	ROADSIDE	ERG		y		
BX7	ROADSIDE	ERG		y		
BX8	ROADSIDE	ERG		y		
BY7	ROADSIDE	ERG	y	y		
CD3	ROADSIDE	ERG		y		
CI1	ROADSIDE	ERG		y	y	
CR2	ROADSIDE	ERG		y		
CR4	ROADSIDE	ERG		y	y	
CT4	ROADSIDE	ERG		y	y	
CY1	ROADSIDE	ERG	y	y	y	
EA2	ROADSIDE	ERG	y	y		
EA6	ROADSIDE	ERG		y		
EA9	ROADSIDE	ERG		y		
EH3	ROADSIDE	ERG		y	y	
EN2	ROADSIDE	ERG	y	y		
EN4	ROADSIDE	ERG		y		
EN5	ROADSIDE	ERG			y	
GB6	ROADSIDE	ERG		y	y	
GN0	ROADSIDE	ERG		y		
GN3	ROADSIDE	ERG		y		
GR5	ROADSIDE	ERG		y	y	
GR7	ROADSIDE	ERG		y	y	
GR8	ROADSIDE	ERG		y	y	
GR9	ROADSIDE	ERG		y		
HF1	ROADSIDE	ERG		y	y	
HI1	ROADSIDE	ERG		y	y	

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
HI2	ROADSIDE	ERG		y	y	
HI3	ROADSIDE	ERG		y	y	
HK6	ROADSIDE	ERG		y	y	
HO2	ROADSIDE	ERG		y	y	
HR2	ROADSIDE	ERG		y	y	
HS4	ROADSIDE	ERG		y	y	
HS5	ROADSIDE	ERG	y	y	y	
HT1	ROADSIDE	ERG		y		
HV1	ROADSIDE	ERG		y		
HV3	ROADSIDE	ERG		y	y	
IS2	ROADSIDE	ERG	y	y	y	
KC2	ROADSIDE	ERG			y	
KC3	ROADSIDE	ERG		y		
KC4	ROADSIDE	ERG		y		
LB1	ROADSIDE	ERG		y		
LB5	ROADSIDE	ERG		y		
LS1	ROADSIDE	ERG		y	y	
LS2	ROADSIDE	ERG		y	y	
LW2	ROADSIDE	ERG		y	y	
MD3	ROADSIDE	ERG		y		
NF4	ROADSIDE	ERG		y	y	
NF5	ROADSIDE	ERG		y		
OX1	ROADSIDE	ERG		y		
OX2	ROADSIDE	ERG		y		
RB4	ROADSIDE	ERG	y	y		
RB5	ROADSIDE	ERG	y	y		
RI1	ROADSIDE	ERG		y	y	
RIS	ROADSIDE	ERG	y	y	y	
SE1	ROADSIDE	ERG		y	y	
TH4	ROADSIDE	ERG		y		
TK2	ROADSIDE	ERG		y		
TK3	ROADSIDE	ERG		y		
WA4	ROADSIDE	ERG	y	y		

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
WF1	ROADSIDE	ERG		y		
WL3	ROADSIDE	ERG		y	y	
ZV2	ROADSIDE	ERG		y		
RG3	RURAL	ERG		y		
BG1	SUBURBAN	ERG		y		
BG2	SUBURBAN	ERG			y	
BX2	SUBURBAN	ERG		y		
CR6	SUBURBAN	ERG		y		
EN1	SUBURBAN	ERG		y		
HG2	SUBURBAN	ERG		y		
HS2	SUBURBAN	ERG		y	y	
MV2	SUBURBAN	ERG		y		
RG1	SUBURBAN	ERG		y	y	
RG2	SUBURBAN	ERG		y		
RI2	SUBURBAN	ERG		y	y	
ST3	SUBURBAN	ERG		y		
BN2	URBAN	ERG		y		
BW1	URBAN	ERG		y		
CA2	URBAN	ERG		y		
CP1	URBAN	ERG		y		
CT1	URBAN	ERG		y		
CT3	URBAN	ERG		y		
DC2	URBAN	ERG		y	y	
EA1	URBAN	ERG		y		
EA7	URBAN	ERG		y	y	
EB1	URBAN	ERG		y	y	
EH2	URBAN	ERG		y	y	
EN3	URBAN	ERG	y	y		
GN2	URBAN	ERG		y		
HF2	URBAN	ERG		y	y	
HM4	URBAN	ERG		y	y	
HR1	URBAN	ERG		y		
IS1	URBAN	ERG		y		

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
IS4	URBAN	ERG			y	
LB3	URBAN	ERG		y		
LN1	URBAN	ERG	y	y	y	
MV3	URBAN	ERG		y	y	
NH4	URBAN	ERG		y	y	
PO1	URBAN	ERG	y	y	y	
RB1	URBAN	ERG		y		
SA1	URBAN	ERG	y	y		
SB1	URBAN	ERG		y	y	
SK1	URBAN	ERG			y	
TH1	URBAN	ERG		y		
TH3	URBAN	ERG		y		
TR1	URBAN	ERG		y	y	
WH1	URBAN	ERG		y		
WL1	URBAN	ERG		y	y	
ZV1	URBAN	ERG	y	y	y	
Glasgow Battlefield Road	ROADSIDE	Glasgow City Council		y	y	
Glasgow Byres Road	ROADSIDE	Glasgow City Council	y	y	y	
Glasgow Waulkmillglen Reservoir	RURAL	Glasgow City Council		y	y	
Glasgow Anderston	URBAN BACKGROUND	Glasgow City Council	y	y	y	y
Guildford Gyratory	ROADSIDE	Guildford BC		y	y	
Ipswich Piper's Court	ROADSIDE	Ipswich BC		y		
Dartford St Clements	KERBSIDE	Kent & Medway Air Quality Network		y	y	
Maidstone Roadside	KERBSIDE	Kent & Medway Air Quality Network	y	y	y	
Ashford Roadside	ROADSIDE	Kent & Medway Air Quality Network		y	y	
Canterbury Roadside	ROADSIDE	Kent & Medway Air Quality Network		y		
Chatham Roadside	ROADSIDE	Kent & Medway Air Quality Network		y	y	
Dartford Roadside	ROADSIDE	Kent & Medway Air Quality Network		y	y	
Dartford Town Centre	ROADSIDE	Kent & Medway Air Quality Network		y	y	
Dover Roadside 1	ROADSIDE	Kent & Medway Air Quality Network		y		
Dover Roadside 2	ROADSIDE	Kent & Medway Air Quality Network			y	
Gravesham Roadside	ROADSIDE	Kent & Medway Air Quality Network		y	y	
Swale Roadside	ROADSIDE	Kent & Medway Air Quality Network		y	y	

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
Swale Roadside 2	ROADSIDE	Kent & Medway Air Quality Network		y		
Thanet Roadside	ROADSIDE	Kent & Medway Air Quality Network		y	y	
Tunbridge Wells Roadside	ROADSIDE	Kent & Medway Air Quality Network		y	y	
Maidstone Rural	RURAL	Kent & Medway Air Quality Network		y	y	y
Folkestone	SUBURBAN	Kent & Medway Air Quality Network		y	y	y
Dover Background 1	URBAN BACKGROUND	Kent & Medway Air Quality Network				y
Dover Background 2	URBAN BACKGROUND	Kent & Medway Air Quality Network				y
Gravesham Northfleet	URBAN BACKGROUND	Kent & Medway Air Quality Network		y	y	
Luton Background	URBAN BACKGROUND	Kent & Medway Air Quality Network	y	y	y	y
Swale Background	URBAN BACKGROUND	Kent & Medway Air Quality Network		y	y	y
Thanet Airport	URBAN BACKGROUND	Kent & Medway Air Quality Network		y		
Thanet Background	URBAN BACKGROUND	Kent & Medway Air Quality Network		y		
Tunbridge Wells Background	URBAN BACKGROUND	Kent & Medway Air Quality Network		y		
Dover Docks	URBAN INDUSTRIAL	Kent & Medway Air Quality Network		y		y
King's Lynn South Quay	URBAN BACKGROUND	Kings Lynn & West Norfolk BC			y	
Larne Craigyhill	URBAN BACKGROUND	Larne BC			y	y
Lisburn Lagan Valley Hospital	ROADSIDE	Lisburn City Council		y	y	
Lisburn Dunmurry High School	URBAN BACKGROUND	Lisburn City Council			y	y
Lisburn Island Civic Centre	URBAN BACKGROUND	Lisburn City Council			y	y
Liverpool Islington	ROADSIDE	Liverpool City Council		y	y	
Newham Cam Road	ROADSIDE	London Borough of Newham	y	y	y	
Newham Wren Close	URBAN BACKGROUND	London Borough of Newham	y	y	y	y
Macclesfield Disley	ROADSIDE	Macclesfield BC		y	y	
Chepstow	ROADSIDE	Monthmouthshire CC		y	y	
Newport Malpas Depot	URBAN BACKGROUND	Newport County BC		y		
Newport St Julians Comp School	URBAN BACKGROUND	Newport County BC		y	y	
Newry Trevor Hill	KERBSIDE	Newry and Mourne DC		y	y	
Newry Kilkeel	URBAN BACKGROUND	Newry and Mourne DC			y	
Newry Monaghan Row	URBAN BACKGROUND	Newry and Mourne DC		y	y	y
Newtownabbey Sandyknowes	ROADSIDE	Newtownabbey Borough Council		y		
Newtownabbey Shore Road	ROADSIDE	Newtownabbey Borough Council		y		
Newtownabbey Ballyclare	URBAN BACKGROUND	Newtownabbey Borough Council			y	y
North Down Holywood A2	ROADSIDE	North Down BC		y	y	

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
North Down Bangor	URBAN BACKGROUND	North Down BC			y	y
Scunthorpe Allanby Street	ROADSIDE	North Lincolnshire Council			y	
Scunthorpe Gallagher Retail Park	ROADSIDE	North Lincolnshire Council		y		
Scunthorpe Kingsway House	ROADSIDE	North Lincolnshire Council		y		
North Lincs Broughton	URBAN BACKGROUND	North Lincolnshire Council			y	
Scunthorpe East Common Lane	URBAN BACKGROUND	North Lincolnshire Council			y	
Scunthorpe Lincoln Gardens	URBAN BACKGROUND	North Lincolnshire Council			y	
North Lincs Killingholme	URBAN INDUSTRIAL	North Lincolnshire Council		y	y	y
North Lincs Santon	URBAN INDUSTRIAL	North Lincolnshire Council		y	y	y
Scunthorpe Town NOx and CO	URBAN INDUSTRIAL	North Lincolnshire Council		y		
Oldham West End House	URBAN BACKGROUND	Oldham MBC	y	y	y	y
Oxford High St	ROADSIDE	Oxford City Council		y	y	
Oxford St Ebbes	URBAN BACKGROUND	Oxford City Council		y	y	
Perth	ROADSIDE	Perth & Kinross Council		y	y	
Perth 2	ROADSIDE	Perth & Kinross Council		y	y	
Ribble Valley Lillands	URBAN BACKGROUND	Ribble Valey BC		y	y	y
Ribble Valley Chatburn	URBAN INDUSTRIAL	Ribble Valey BC		y	y	y
Salford M60	ROADSIDE	Salford MBC	y	y	y	
Slough Chalvey	ROADSIDE	Slough BC		y		
Slough Town Centre A4	ROADSIDE	Slough BC		y	y	
Slough Colnbrook	URBAN BACKGROUND	Slough BC		y	y	
South Bucks Gerrards Cross	ROADSIDE	South Bucks DC		y	y	
S Cambs Bar Hill	ROADSIDE	South Cambridgeshire DC		y	y	
S Cambs Impington	ROADSIDE	South Cambridgeshire DC		y	y	
S Cambs Barrington Fruit Farm	RURAL	South Cambridgeshire DC				y
South Holland	RURAL	South Holland DC		y	y	
Spalding Monkhouse School	URBAN BACKGROUND	South Holland DC		y	y	
Stockport Hazel Grove	ROADSIDE	Stockport MBC		y	y	
Stockport Bredbury	URBAN BACKGROUND	Stockport MBC		y	y	
Strabane Springhill Park	URBAN BACKGROUND	Strabane DC			y	y
Tameside Two Trees School	URBAN BACKGROUND	Tameside MBC	y	y	y	y
Trafford A56	ROADSIDE	Trafford MBC		y	y	
Trafford	URBAN BACKGROUND	Trafford MBC		y	y	y

Site name/site code	Site type	Local Authority/Network	CO	NO_2	PM_{10}	SO_2
Abingdon	URBAN BACKGROUND	Vale of White Horse DC		y	y	y
Marchlyn Mawr	REMOTE	Welsh Air Quality Forum		y		
Fife Cupar	ROADSIDE	Welsh Air Quality Forum		y	y	
Fife Kincardine	ROADSIDE	Welsh Air Quality Forum		y		
Rhondda Broadway	ROADSIDE	Welsh Air Quality Forum	y	y	y	
Rhondda Tylorstown	ROADSIDE	Welsh Air Quality Forum		y		
Rhondda-Cynon-Taf Nantgarw	ROADSIDE	Welsh Air Quality Forum			y	
Swansea Morfa Roadside	ROADSIDE	Welsh Air Quality Forum	y	y	y	
Swansea Morriston Roadside	ROADSIDE	Welsh Air Quality Forum	y	y	y	
V Glamorgan Penarth	ROADSIDE	Welsh Air Quality Forum		y		
West Dunbartonshire Balloch	ROADSIDE	Welsh Air Quality Forum		y		
V Glamorgan Fonmon	RURAL	Welsh Air Quality Forum		y	y	y
Cardiff Briardene	URBAN BACKGROUND	Welsh Air Quality Forum	y	y	y	y
West Dunbartonshire John Knox St	URBAN BACKGROUND	Welsh Air Quality Forum		y	y	
Wrexham Isycoed	URBAN INDUSTRIAL	Welsh Air Quality Forum		y		y
Wigan Leigh 2	URBAN BACKGROUND	Wigan Metropolitan Borough Council		y	y	
Wokingham Woodward Close	ROADSIDE	Wokingham DC		y	y	
Wokingham Winnersh	URBAN BACKGROUND	Wokingham DC		y	y	
Wycombe Stokenchurch	URBAN BACKGROUND	Wycombe District Council		y		

Data were collected from the following sources: AEA Energy & Environment’s Calibration Club, the Welsh Air Quality Forum, the Scottish Air Quality Archive, the Kent and Medway Air Quality Monitoring Network and monitoring data held by ERG.

Table A1.2. Additional monitoring sites maintained by the electricity generating companies used to calibrate the SO_2 models.

Site	Company
Bentley Hall Farm	EON
Bexleyheath	RWE
Blair Mains	RWE
Bottesford	EON
Carr Lane (Drax)	RWE
Didcot South	RWE
Downes Ground Farm	RWE
East Tilbury	RWE
Font-y-gary	RWE
Gainsborough Cemetery	EON
Gillingham	EON
Grove Reservoir	EON
Hemingbrough	RWE
Longniddry West	RWE
Marton School	EON
North Featherstone	RWE
Northfleet	RWE
Rosehurst Farm	RWE
Ruddington Field	EON
Smeathalls Fm	RWE
Stile Cop Cemetery	EON
Telford Aqueduct	EON
Telford School	EON
Thorney	EON
West Bank	RWE
West Thurrock	RWE
Weston On Trent	EON

Appendix 2 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 3.3 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 3rd 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^{-3} 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^{-3}
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 3rd edition of the Chimney Heights Memorandum for very low sulphur fuels:

$$U = 1.36Q^{0.6}\left(1 - 4.7\times10^{-5}Q^{1.69}\right)$$

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^{-3} at reference conditions. A value of 300 mg 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, PM_{10}

The stack heights and diameters used for oxides of nitrogen were also used to provide the kernels for particulate matter PM_{10}. This will provide a conservative assessment of 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 mg m^{-3} at reference conditions. The emission limit for total particulate matter includes but is not limited to the contribution from PM_{10}.

DISPERSION MODELLING

The dispersion model ADMS 3.3 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 , µg 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, $\mu g\ m^{-3}$ 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, $\mu g\ m^{-3}$	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 A4.1 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 A4.1 does not include results for the 1 km source square.

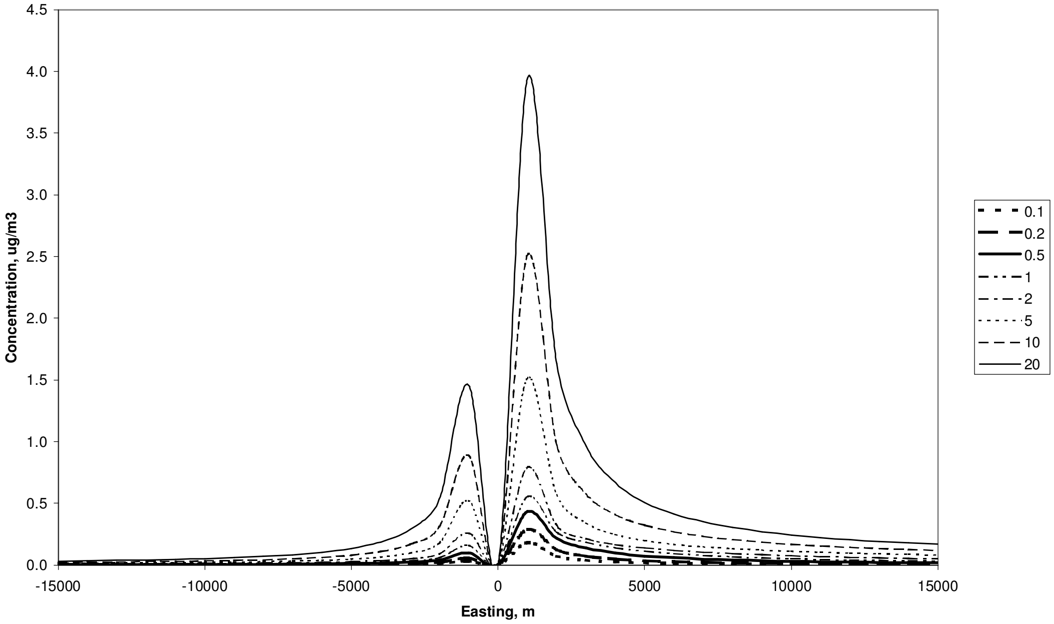


Figure A4.1 Sulphur dioxide concentration on east-west axis, 2000 meteorological data

Figure A4.2 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.

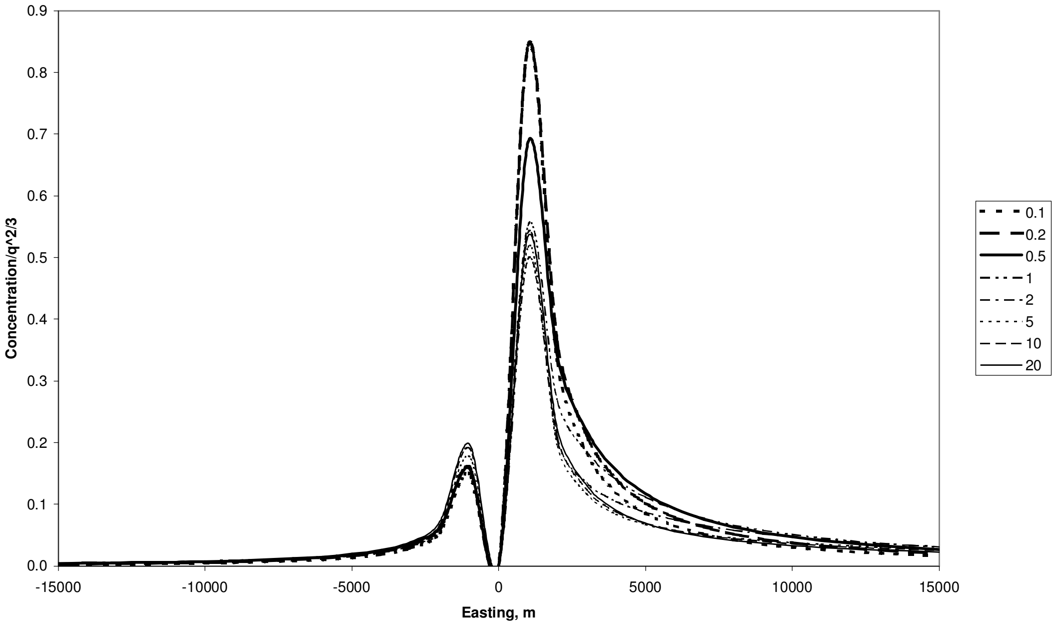


Figure A4.2 Reduced sulphur dioxide concentrations on the east-west axis, 2000 meteorological data

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 A3.5 In-square oxides of nitrogen concentrations, 2000

Emission rate, g/s	In square concentration, µg 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, µg 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 µg 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, µg 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).

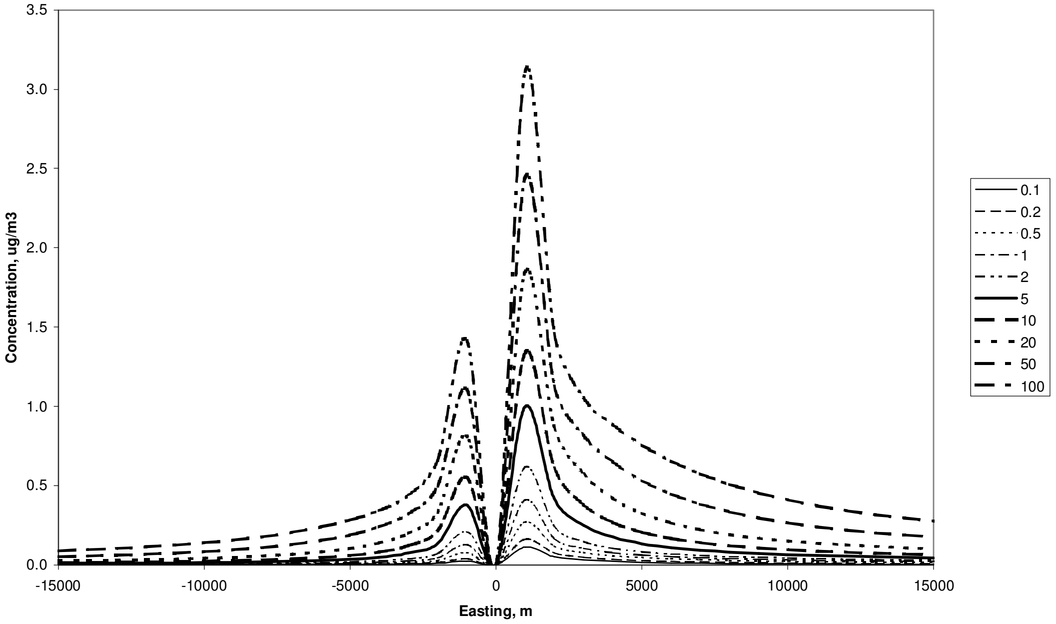


Figure A3.3 Oxides of nitrogen concentration on east-west axis, 2000 meteorological data

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.

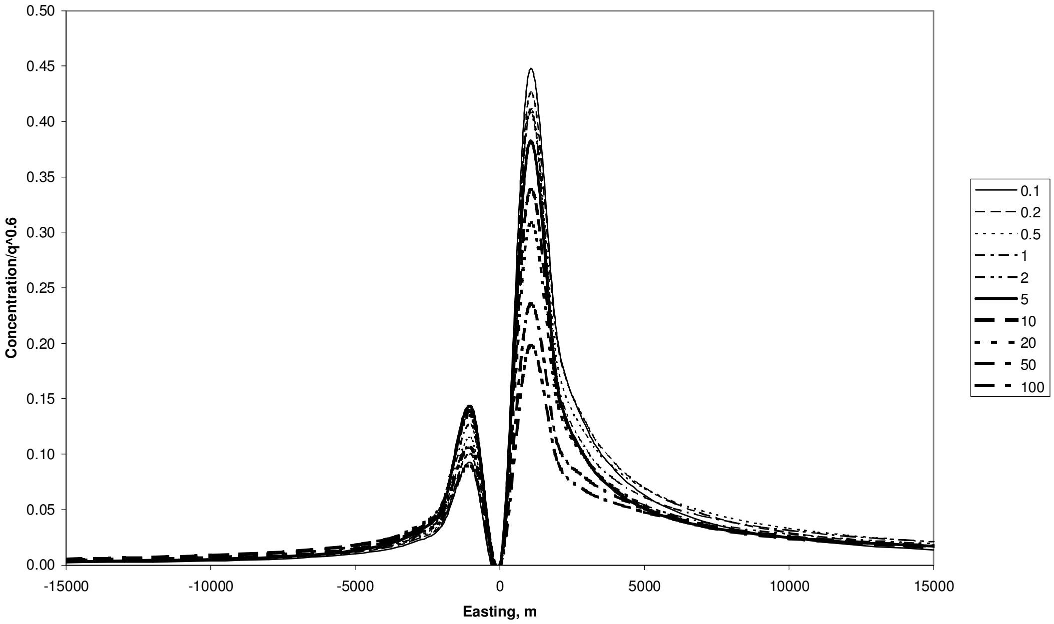


Figure A3.4 Reduced oxides of nitrogen concentrations on the east-west axis, 2000 meteorological data

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, $\mu g\ m^{-3}$ 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:

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

where C is the in-square concentration, $\mu g\ m^{-3}$ 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:

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

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_{10}

The method for PM_{10} was the same as for NO_x, 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_x, 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 3 Dispersion kernels for area source model

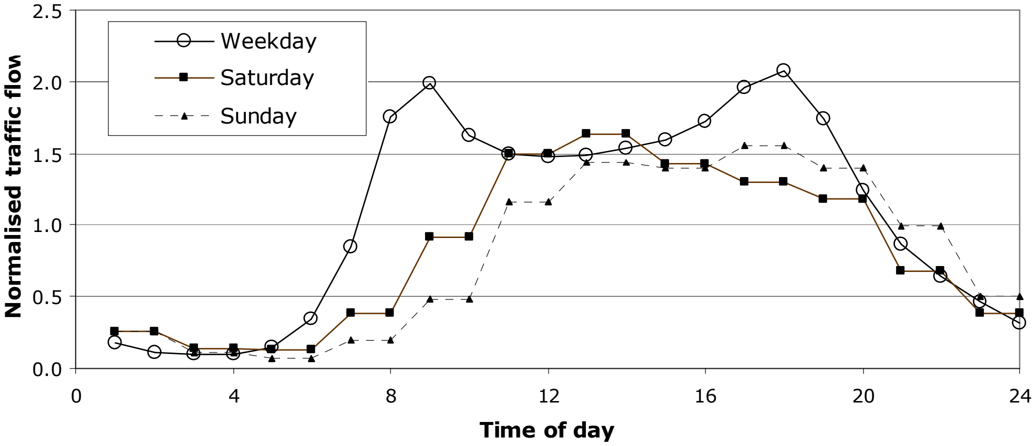
DISPERSION KERNELS FOR AREA SOURCE MODEL

Dispersion kernels for calculating the annual mean contribution of emissions from area sources to ambient annual mean concentrations were calculating 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 2005 using sequential meteorological data from Waddington. 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^{-1}	1 g s^{-1}
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_x and PM_{10}. A comparison of the fit between modelled and measured concentrations of NO_x 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_x and PM_{10}, benzene and CO. 1 km x 1 km kernels were used for SO_2.

Appendix 4 Model assessment of SO_2 concentrations at Stewartby brick works

Comparing modelled and measured sulphur dioxide concentrations at Stewartby in 2006

Our modelling of ambient SO_2 concentrations was informed by a report prepared for the process operator (Hanson) and forwarded to us by the Environment Agency. This report (Report Reference C12-P030R15) provided a review of the air quality management plan at Stewartby Brick works. This Appendix describes how information presented in the report was used to provide a more detailed assessment of emissions from the plant.

The approach to produce the national maps of SO_2 concentrations is necessarily coarse – for example, only one meteorological station is used in model emissions for all GB sources. Also, there is no consideration of terrain, a relatively coarse grid for large sources (5 km) and there are only emission profiles for power stations.

There are occurrences, though, when the modelled concentration predicted by the national scale mapping could be improved by more detailed modelling. Until the current years mapping (2006) concentrations at Stewartby were predicted like all other large point source with concentrations predicted on a 5 km x 5 km grid. This year concentrations were predicted at 1 km resolution in an effort to improve the representativity of the assessment.

The Hanson report presented measured and modelled concentrations at a number of sensitive receptors and at monitoring locations. The concentrations were predicted using two dispersion models- ADMS and AERMOD.

To make a comparison with the measured and modelled concentrations presented in the Hanson report, concentrations were predicted, as part of the national air quality assessment, at the continuous ambient monitoring station (CAMS) at Broadmead.

Model input parameters were obtained from Table 4.2 of the Hanson report.

Table 1 compares the measured concentration for each averaging time with the concentrations predicted by the modelling carried out as part of the sulphur dioxide mapping work (labelled 'AEA, PCM') as well as the modelling reported in the Hanson report.

For annual average, all modelled concentrations are more than two times the measured annual mean concentration. For the 99.18th percentile of daily concentrations all modelled results are above the 125 $\mu g\ m^{-3}$ threshold.

Table 1: A comparison of modelled and measured sulphur dioxide concentrations in 2006 at the Broadmead continuous analyser measurement system (CAMS).

Receptor location		Source within Hanson report, µg m^{-3}	Annual average, µg m^{-3}	99.9 percentile of 15 minute means, µg m^{-3}	99.73 Percentile of hourly concentrations, µg m^{-3}	99.18 percentile of daily values, µg m^{-3}	Measured or modelled used
Broadmead CAMS	Hanson report	Table 2.3	8.7	430	330	120	Measured
Broadmead CAMS	AEA, PCM		22.6	572	486	166	ADMS
Broadmead CAMS	Hanson report	Table 4.11	28.8	456	380	159	ADMS
		Table 4.12	26.9	389	286	157	Aermod

Note:
The Ordnance Survey coordinates for the Broadmead CAMS were obtained from an Ordnance Survey map presented in the Hanson report.

Our modelling used meteorological data collected at Waddington in Lincolnshire. The Hanson Brick works were modelled using met data collected from Bedford and Heathrow.

Monitoring results

It is unlikely that the monitor at Broadmead is a truly independent monitor. It is prevented from measuring high concentrations because of the dilution system that becomes active when concentrations above a certain threshold are detected at the monitor's location. The dilution system will cause the plume to ground somewhere else- an unknown distance but not likely to be far from the monitor.

That the monitor was unrepresentative was also recognised within the Hanson report also- see Note (a) within Table 4.13 and Table 4.14 "The use of the Kiln Management Plan may affect measured concentrations at the Kempston and Broadmead CAMS".

Although continuous emission monitoring data is collected at the brick works, the data is considered inappropriate for use in modelling emissions on an hourly basis.

Implications for sulphur dioxide modelling

Using a 1 km receptor grid reduces the area of exceedence compared to the modelling carried out for 2005 - exceedences of the EU limit values were predicted for the 5 km x 5 km square where the brick works is located. The 2006 modelling results indicate exceedence at one 1 km x 1 km square and four 1 km x 1 km squares, for the daily and hourly values, respectively. Figures 1 and 2 present the location of the squares exceeding the respective EU Limit Values.

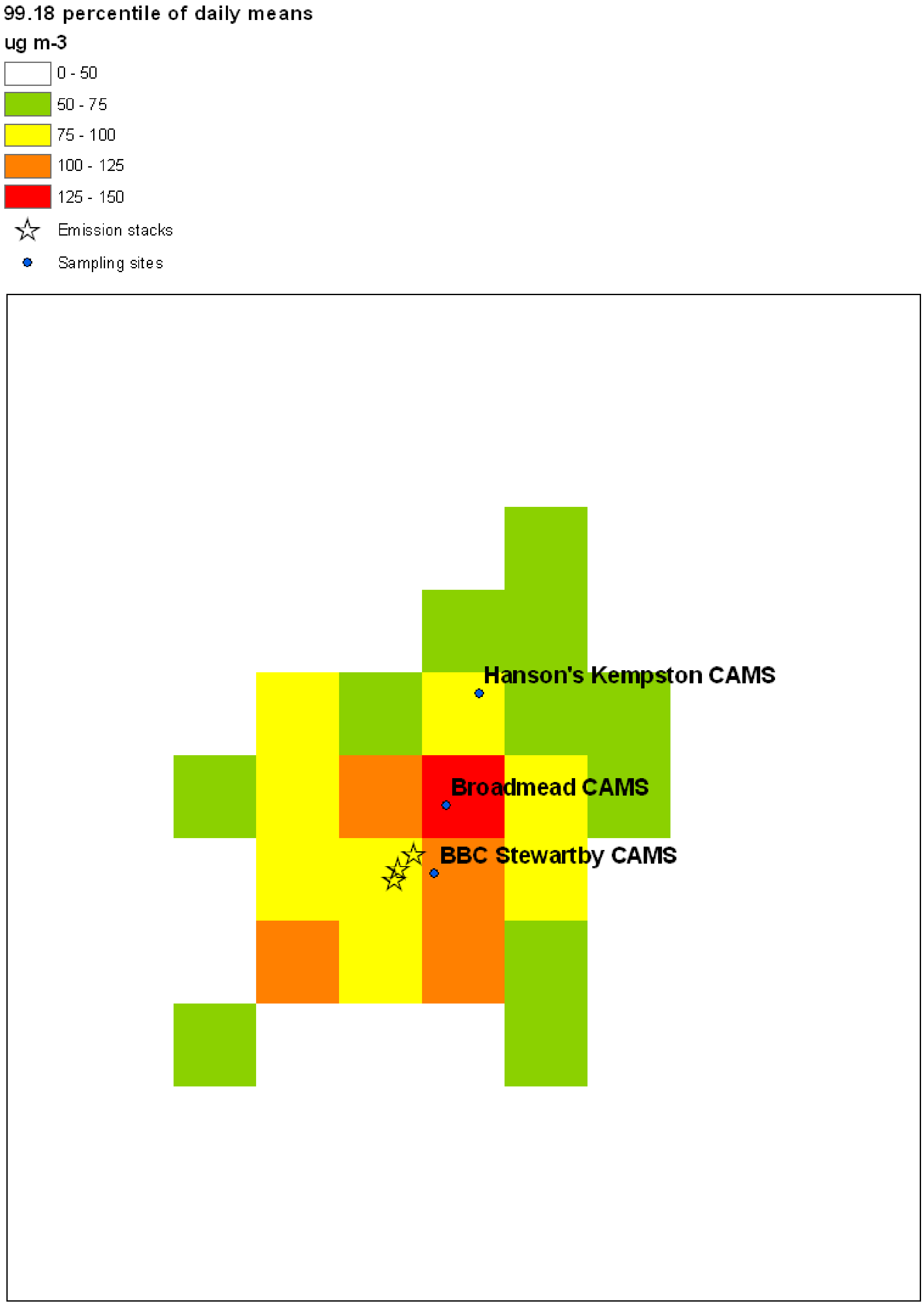


Figure 1: 99.18 percentile of daily concentrations

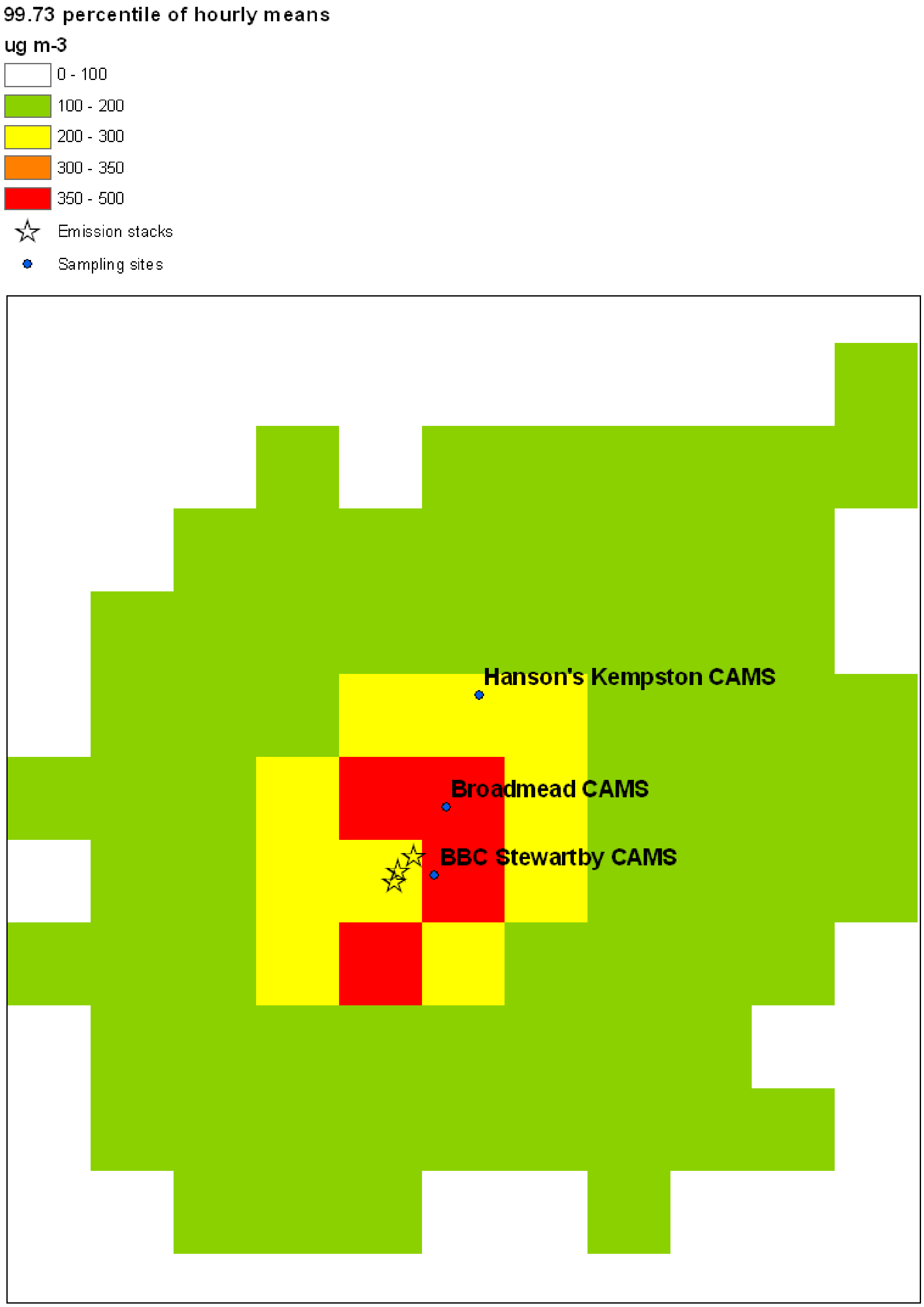


Figure 2: 99.73 percentile of hourly concentrations

Appendix 5 Air Quality monitoring data from Gibraltar in 2006

Introduction

Gibraltar is subject to the same European environmental legislation as the UK. Gibraltar is comprised of a single non-agglomeration zone for which no modelling assessment has been undertaken but data from an automatic monitoring campaign is presented in this report. The exceedence status of the Gibraltar zone has been determined from monitoring data only. This Appendix summarises ambient air quality concentrations reported in 2006 by the Gibraltar monitoring campaign and places it in the context of the Daughter Directive Limit Values as Section 7 did for the UK. The ozone air quality assessment for Gibraltar is covered in a separate technical report (Kent *et al.*, 2008).

Table 1 Gibraltar Air Quality Monitoring Network site details

Site	Site type	Latitude	Longitude	Altitude	Pollutants
Gibraltar Rosia Road	ROADSIDE	36 08 00N	05 21 11W	15m	Benzene, CO, NO_2, PM_{10}, $PM_{2.5}$, SO_2, Lead
Gibraltar Bleak House	URBAN BACKGROUND	36 06 46N	05 21 01W	50m	NO_2, O_3

Annual summary

Table 2 (Rosia Road) and Table 3 (Bleak House) show summary concentrations for different metrics for all pollutants reported at the two Gibraltar air quality monitoring stations. Data capture statistics are also provided.

Table 2 Gibraltar Rosia Road monitoring data, 2006

POLLUTANT	BENZ	CO	PM_{10}*	$PM_{2.5}$	NO_2	SO_2
Maximum 15-minute mean	-	9.5 mg m^{-3}	-	-	241 µg m^{-3}	247 µg m^{-3}
Maximum hourly mean	56.8 µg m^{-3}	6.7 mg m^{-3}	-	-	189 µg m^{-3}	149 µg m^{-3}
Maximum running 8-hour mean	25.1 µg m^{-3}	3.1 mg m^{-3}	-	-	119 µg m^{-3}	74 µg m^{-3}
Maximum running 24-hour mean	14.2 µg m^{-3}	1.9 mg m^{-3}	-	-	88 µg m^{-3}	50 µg m^{-3}
Maximum daily mean	13.8 µg m^{-3}	1.7 mg m^{-3}	92 µg m^{-3}	48 µg m^{-3}	84 µg m^{-3}	41 µg m^{-3}
Annual average	2.8 µg m^{-3}	0.6 mg m^{-3}	40 µg m^{-3}	19 µg m^{-3}	42 µg m^{-3}	13 µg m^{-3}
Data capture	97.9 %	97.6 %	97.8 %	95.9 %	98.3 %	97.1 %

Table 3 Gibraltar Bleak House monitoring data, 2006

POLLUTANT	NO_2	O_3
Maximum 15-minute mean	151 µg m^{-3}	168 µg m^{-3}
Maximum hourly mean	132 µg m^{-3}	164 µg m^{-3}
Maximum running 8-hour mean	101 µg m^{-3}	159 µg m^{-3}
Maximum running 24-hour mean	75 µg m^{-3}	145 µg m^{-3}
Maximum daily mean	63 µg m^{-3}	140 µg m^{-3}
Annual average	24 µg m^{-3}	62 µg m^{-3}
Data capture	97.4 %	98.7 %

* PM_{10} and $PM_{2.5}$ in gravimetric units
All mass units are at 20'C and 1013mb

Table 4 Rosia Road Lead data

Start Date	End Date	Lead (µg m^{-3})
03/01/2006	30/01/2006	0.02
31/01/2006	27/02/2006	0.02
28/02/2006	27/03/2006	0.01
28/03/2006	24/04/2006	0.01
25/04/2006	22/05/2006	0.01
23/05/2006	19/06/2006	0.01
20/06/2006	17/07/2006	0.01
18/07/2006	14/08/2006	0.01
15/08/2006	11/09/2006	0.01
12/09/2006	09/10/2006	0.01
10/10/2006	06/11/2006	0.01
07/11/2006	04/12/2006	0.02
05/12/2006	01/01/2007	0.01

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

The tables presented below are from Form 8 of the questionnaire and are equivalent tables for Gibraltar as those shown for the UK in Section 7.1. Exceedence (or otherwise) of the limit value (LV) and limit value plus margin of tolerance (LV + MOT) where this exists are indicated by a 'y' for measured exceedences.

The results of the air quality assessments in Gibraltar for SO_2, NO_2 and NO_X, PM_{10}, lead, benzene and CO are listed in Tables 5 to 10.

Table 5 Exceedence situation in Gibraltar showing whether levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) for SO_2 (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

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
Gibraltar Zone	UK(GIB)			y		y		n		n

Table 6 Exceedence situation in Gibraltar showing whether levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) for NO_2 and NO_X (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

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
Gibraltar Zone	UK(GIB)			y		y			n

Table 7 Exceedence situation in Gibraltar showing whether levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) for PM_{10} (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

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
Gibraltar Zone	UK(GIB)	y					y	y		y		

Table 8 Exceedence situation in Gibraltar showing whether levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) for lead (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

Zone	Zone code	LV		
		>LV+MOT	≤LV+MOT; >LV	≤LV
Gibraltar Zone	UK(GIB)			y

Table 9 Exceedence situation in Gibraltar showing whether levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) for benzene (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

Zone	Zone code	LV		
		>LV + MOT	≤LV+MOT; >LV	≤LV
Gibraltar Zone	UK(GIB)			y

Table 10 Exceedence situation in Gibraltar showing whether levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV + MOT) for CO (96/62/EC Articles 8, 9 and 11, 1999/30/EC Annexes I, II, III and IV, 2000/69/EC Annexes I and II)

Zone	Zone code	LV		
		>LV + MOT	≤LV + MOT; >LV	≤LV
Gibraltar Zone	UK(GIB)			y

Measured exceedences of Limit Values + Margins of Tolerance

Individual exceedences of Limit Values and Limit Values + Margin of Tolerance are presented in the questionnaire in Form 11. Form 11h is presented below in Table 11, showing individual exceedences of the 24-hour PM_{10} limit value. Forms 11a, 11b, 11e, 11f, 11i, 11j, 11k and 11l have not been presented here because there were no recorded exceedences in Gibraltar of the Limit Values and Limit Values + Margin of Tolerance that they pertain to in 2006. Forms 11c, 11d and 11g remained blank in the questionnaire as they relate to NO_X and SO_2 Limit Values applicable in vegetation and ecosystem areas only, of which none exist in Gibraltar.

Table 11 Measured exceedences of the 24-hour mean PM_{10} limit value, 2006 (Form 11h)

Site	Zone	Month	Day of month	Level (μg m^{-3})	Reason code(s)*
Gibraltar Rosia Road	UK(GIB)	1	19	60	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	2	15	53	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	3	27	61	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	3	31	63	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	4	52	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	11	59	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	12	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	25	52	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	26	59	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	27	65	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	28	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	4	29	53	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	5	8	53	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	5	10	55	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	5	17	64	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	5	18	68	S8;S10;S3;S1

Site	Zone	Month	Day of month	Level ($\mu g\ m^{-3}$)	Reason code(s)*
Gibraltar Rosia Road	UK(GIB)	5	24	51	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	5	29	53	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	5	30	59	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	5	31	61	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	1	51	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	12	54	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	13	67	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	14	71	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	20	51	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	21	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	22	74	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	6	23	82	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	10	52	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	11	56	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	19	58	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	20	53	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	21	55	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	24	51	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	25	55	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	7	26	60	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	8	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	12	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	13	62	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	14	58	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	24	51	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	25	52	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	29	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	30	56	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	8	31	53	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	9	7	58	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	9	8	53	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	9	26	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	10	2	59	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	10	11	51	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	10	28	65	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	10	30	78	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	10	31	92	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	11	1	72	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	11	2	57	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	11	10	54	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	11	14	52	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	11	20	58	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	11	28	54	S8;S10;S3;S1
Gibraltar Rosia Road	UK(GIB)	11	29	59	S8;S10;S3;S1

* see Table 7.7 of the main report for details