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An empirical model for estimating roadside nitrogen dioxide concentrations in the UK

A report produced for The Department of the Environment, Transport and the Regions

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Executive Summary

Introduction

The UK National Air Quality Strategy (NAQS) gives the following objectives for nitrogen dioxide (NO_2) to be achieved by the end of 2005:

- Annual mean: The annual mean must not exceed 21 ppb.
- Hourly mean: The hourly mean must not exceed 150 ppb.

The European Union (EU) 'Daughter Directive' gives the following limit values for NO_2 to be achieved by 1 January 2010:

- Annual mean limit value of 40 μgm^{-3} (21 ppb).
- 1-hour limit value of 200 μgm^{-3} (104.6 ppb), not to be exceeded more than 18 times a year.

This report focuses on the annual mean objective and annual mean limit value, since these are likely to be the most stringent of the targets, particularly at the roadside. Projections of annual mean concentrations of NO_2 have therefore been calculated for both 2005 and 2009 for comparison with the NAQS objective and EU limit value. National measures are likely to deliver significant reductions in the emissions of oxides of nitrogen (NO_x, the sum of NO and NO_2) from road traffic sources between now and 2005. It is likely, however, that there will still be significant exeedances of the annual mean objective in 2005 if national measures are considered in isolation. This 'policy gap' can be addressed by implementing local air quality management to reduce concentrations in locations that are at risk of exceeding the objective. One of the first stages in this process is to identify those areas that are most at risk of exceeding the objective annual mean NO_2 concentration in 2005.

Method

This report describes an empirical model for annual mean roadside NO_2 concentrations, which has been used to estimate concentrations for 1996, 2005 and 2009. Concentrations within roughly 5 m of a major road have been considered as the sum of two components:

roadside concentration = background concentration + 'roadside enhancement'

The model builds on previously published maps of annual mean background NO_2 and NO_x concentrations, to which the roadside enhancement is added. The relationship between the roadside enhancement of NO_x concentrations and individual road link NO_x emissions has been derived from an analysis of automatic monitoring data for roadside sites.

Current policies are likely to deliver a reduction of urban road traffic NO_x emissions to about 50% of 1996 levels by 2005 and annual mean roadside concentrations of NO_x are therefore likely to fall to approximately 50% of 1996 levels. Annual mean roadside NO_2 concentrations are likely to see a less dramatic reduction, because current NO_2 concentrations are limited by the availability of oxidant. We have assumed that annual mean NO_2 concentrations will fall to about 70% of 1996 levels by 2005.

Results

Annual mean urban background NO_2 concentrations in 2005 are likely to be below 21 ppb in all areas except for inner London, where current national policies are expected to lead to concentrations in the range 21 - 29 ppb.

Roadside NO_2 concentrations in urban areas in 2005 are expected to be significantly higher, with a total of 761 road links likely to have concentrations higher than the annual mean objective of 21 ppb. This represents about 10% of the total number of urban major road links with a total length 670 km. The majority of these links (495, representing 387 km) are in the Greater London area. The remainder are generally confined to the most heavily trafficked roads in other big cities.

Annual mean roadside NO_2 concentrations have also been predicted for 2009, for comparison with the European Union 'Daughter' Directive limit value, which is also 21 ppb. The continuing downward trend in traffic emissions is likely to further reduce the number of links exceeding this value by 2009, only about 2% of urban major road links are predicted to have concentrations higher than 21 ppb.

Roadside NO_2 concentrations in 2005 and 2009 have also been estimated for several alternative emission reduction scenarios. Many fewer road links are expected to have concentrations greater than 21 ppb if additional NO_x emission reductions of the order of 30% compared with business as usaul can be achieved.

The objectives for 2005 within the NAQS (DoE, 1997) apply to non-occupational near-ground level outdoor locations where a person might reasonably be expected to be exposed over the relevant averaging period. The annual mean NO_2 objective of 21 ppb therefore only applies at the facade of buildings where people actually live. Many of the road links in cities other than London with estimated concentrations greater than 21 ppb are unlikely to have people living close to the road, although there are a number of roads with houses present.

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APPENDIX 1 MEASUREMENT SITES

Introduction

The UK National Air Quality Strategy (NAQS) gives the following objectives for nitrogen dioxide (NO_2) to be achieved by the end of 2005:

- Annual mean: The annual mean must not exceed 21 ppb.
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The European Union (EU) 'Daughter Directive' gives the following limit values for NO_2 to be achieved by 1 January 2010:

- Annual mean limit value of 40 μgm^{-3} (21 ppb).
- 1-hour limit value of 200 μgm^{-3} (104.6 ppb), not to be exceeded more than 18 times a year.

This report focuses on the annual mean objective and annual mean limit value, since these are likely to be the most stringent of the targets, particularly at the roadside. Projections of annual mean concentrations of NO_2 have therefore been calculated for both 2005 and 2009 for comparison with the NAQS objective and EU limit value.

Concentrations of both NO_2 and oxides of nitrogen (NO_x, the sum of NO and NO_2) are currently monitored at a wide range of automatic monitoring sites around the UK (Broughton *et al*, 1998). Annual mean NO_2 concentrations are currently higher than 21 ppb at the majority of urban background sites and almost all of the roadside or kerbside monitoring sites. Emissions of NO_x from road traffic sources make an important contribution to urban background NO_2 concentrations and will clearly dominate concentrations at the roadside. National measures are likely to deliver significant reductions in road traffic NO_x emissions between now and 2005 (Murrells, *pers comm*). It is likely, however, that there will still be significant exeedances of the annual mean objective in 2005 if national measures are considered in isolation, particularly at the roadside. Concentrations of NO_2 in some locations may also still be higher than 21 ppb in 2009. It is envisaged that this 'policy gap' will be addressed by implementing local air quality management to reduce concentrations in locations that are at risk of exceeding the objective. One of the first stages in this process is to identify those areas that are most at risk of exceeding the objective annual mean NO_2 concentration in 2005.

Automatic monitoring sites within the UK national monitoring networks are classified according to site type and this classification distinguishes between kerbside (within 1 m of the road) and roadside (1 - 5 m). In this report we have considered all locations within 5 m of a road as roadside. This enables a larger number of monitoring sites to be considered as a single group and our analysis does not show any systematic difference between these two site types.

An empirical model for estimating annual mean roadside NO_2 concentrations has been developed and used to estimate concentrations for 1996, 2005 and 2009. The expected changes in urban road traffic emissions of NO_x are discussed in section 2 and the methods that are used to predict NO_2 concentrations from NO_x concentrations are discussed in section 3. Concentrations within roughly 5 m of a major road have been considered as the sum of two components:

roadside concentration = background concentration + 'roadside enhancement'

The model builds on previously published maps of annual mean background NO_2 and NO_x concentrations, to which the roadside enhancement is added. Section 4 describes the derivation of the maps of background concentrations. Section 5 shows how the relationship between the roadside enhancement of NO_x concentrations and individual road link NO_x emissions has been derived from an analysis of automatic monitoring data for roadside sites. The roadside enhancement is then added to background concentrations to produce estimates of roadside concentrations for individual road links for 1996, 2005 and 2009.

The roadside NO_2 concentrations that are likely to result from a range of alternative traffic emissions reduction scenarios are listed in section 6. A preliminary investigation of the likely presence of housing at the roadside of the roads with the highest predicted concentrations is described in section 7.

Emission projections

It is reasonable to assume that road traffic emissions of NO_x will determine the roadside enhancement of NO_x and NO_2 concentrations. Similarly, we have assumed that traffic emissions contribute 90 % of the total low level NO_x emissions in areas with the highest urban background concentrations. We have also assumed that the remaining 10% of emissions will remain unchanged between now and 2005 or 2009.

The National Atmospheric Emissions Inventory (NAEI) road transport model has been used to calculate estimates of urban road traffic NO_x emissions for 1996 and for future years (Murrells, *pers comm*). The emissions estimates listed in Table 2.1 show that urban road traffic emissions of NO_x are expected to fall to about 44% of 1996 levels by 2005. If the remaining 10% of emissions contributing to background concentrations NO_x remain at 1996 levels in 2005, then this leads to a reduction in 'background' emissions to 50% of current levels. Urban road traffic emissions are expected to fall to about 33% of 1996 levels by 2005, leading to a reduction in 'background' emissions to 40% of current levels.

Table 2.1 UK urban road traffic emissions of NO_x and emission reduction factors relative to 1996

	1996	2005	2009
UK urban road traffic emissions (kTonnes per year)	370	162	123
urban road traffic (roadside enhancement), relative to 1996	-	0.44	0.33
background, relative to 1996	-	0.50	0.40

Predicting NO_2 from NO_x

INTRODUCTION

Nitrogen dioxide is often described as a secondary pollutant because the majority of ambient NO_2 is formed by oxidation of NO that has been emitted into the atmosphere. An understanding the oxidation processes that lead to the current measured concentrations of NO_2 and how these processes are likely to be influenced by changes in future emissions are therefore essential for predicting future concentrations of NO_2.

One of the main mechanisms by which NO is oxidised to NO_2 is by reaction with O_3. If NO_x emissions are reduced and O_3 concentrations remain approximately unchanged then this will increase the proportion of NO_x emissions that will be rapidly converted to NO_2. The trimolecular reaction of NO with O_2 is thought to be one of the dominant oxidation routes on rare winter smog episode days (Bower *et al*, 1994). The rate of this reaction depends on the square of the NO concentration and a reduction in NO_x emissions to about half of the current values on these types of days will therefore tend to significantly reduce the efficiency of this pathway. Winter smog episode concentrations of NO_2 are therefore expected to be much reduced in 2005 and 2009 and this is the reason why predictions in this report are focused on annual means.

Methods for predicting future NO_2 concentrations from predictions of NO_x are currently the subject of considerable research, because of the importance of these predictions within the review of the NAQS. The methods that have been used to predict background concentrations of NO_2 in this report are not fully consistent with the methods that have been applied at the roadside. Projections of background NO_2 for 2005 and 2009 have been derived from maps of 1996 NO_2 concentrations. Projections of roadside NO_2 concentrations for 2005 and 2009 have been derived from projections of roadside NO_x concentrations for these years. This inconsistency will be fully addressed in future national modelling studies.

BACKGROUND LOCATIONS

Figure 3.1 shows a comparison of measured annual mean concentrations of NO_x and NO_2 for both background and roadside monitoring locations in 1997.

Estimates of NO_x emissions from low levels sources have been used to derive the local source contribution to current annual mean background concentrations of both NO_x and NO_2 (see section 4). Background NO_2 concentrations in urban areas are determined by a combination of the availability of NO_x and the efficiency of the oxidation process. Our coefficient (k_m) for the relationship between ambient concentrations and local emissions for NO_2 has been derived from a combination of urban NO_2 measurements and NO_x emissions estimates for 1996. The efficiency of the oxidation process has therefore been implicitly included within the coefficient. The resulting implied linear relationship between annual mean NO_x and NO_2 concentrations is shown by the dotted line on figure 3.1. It is clear, however, that this relationship between NO_x emissions and NO_2 concentration is unlikely to remain unchanged as NO_x emissions are reduced.

Table 3.1 shows the reductions in annual mean NO_2 concentrations that have been used to calculate the maps of concentrations in 2005 and 2009 from the 1996 maps.

Table 3.1 Factors used to estimate annual mean background NO_2 concentrations in 2005 and 2009 from 1996 values

	2005	2009
background NO_2, relative to 1996	0.70	0.62

These factors have been derived from the results of a detailed modelling study of the effect of NO_x emission reductions on NO_2 concentrations in London (Derwent, *pers comm*). Hourly average NO_2 concentrations for 2005 were modelled by assuming that NO_x emissions will reduce to 50% of current levels. The key results of this study were that annual mean NO_2 concentrations are likely to fall to 70% of current values but winter peak NO_2 concentrations are likely to fall to less than 50% of current values.

In summary, background NO_2 concentrations in 2005 and 2009 have been calculated by applying effective reduction factors for NO_2 relative to 1996, to maps for 1996, which were calculated by assuming a linear relationship between NO_2 concentrations and local NO_x emissions. The solid line on Figure 3.1 shows an alternative non-linear function that has been fitted to the measurement data for background sites. This curve predicts lower NO_2 concentrations at high NO_x. The advantage of using this type of non-linear curve is that future NO_2 concentrations can be directly predicted from NO_x predictions by assuming that the curve will remain the same in future years. Further work will be carried out to validate this approach and is likely to lead to estimates of lower background concentrations in areas such as central London. The dotted line on figure 3.1 indicates that the approach we have adopted in the current work provides a worst case (or slightly worse than worst case) estimate of current NO_2 concentrations, which have then been projected forwards to 2005 and 2009.

ROADSIDE LOCATIONS

Figure 3.1 shows that roadside NO_2 concentration are generally lower than background concentrations for the same measured NO_x concentration. This is because of the limited time that is available for NO to be oxidised to NO_2 at the roadside and the limited amount of ozone that may be available in the roadside environment. The dashed line shows the non-linear function that has been fitted to current roadside measurement data. This function can then be used to estimate annual mean NO_2 concentrations from annual mean NO_x concentrations for 1996, 2005 and 2009. The function has been chosen to be consistent with the modelling work of Derwent (*pers comm*) in that a 50% reduction in NO_x emissions and concentrations from 1996 values will lead to an reduction in NO_2 concentrations to approximately 70% of 1996 values.

Mapping background NO_2 and NO_x concentrations

CURRENT ANNUAL MEAN CONCENTRATIONS

Maps of estimated annual mean background NO_2 and NO_x concentrations for 1996 are presented in Figures 4.1 and 4.2. These maps are from our earlier report on background concentration maps (Stedman, 1998), where more details of the mapping methods can be found. Our general approach to mapping background concentrations has been described in Stedman (1998) and Stedman *et al* (1997).

Measured annual mean background concentrations have been considered to be made up of two parts:

- A contribution from relatively distant major point and area sources such as power stations or large conurbations. Measurements from monitoring sites well away from local sources, from sites within the Department of the Environment, Transport and the Regions' (DETR) rural networks, for example, provide good indications of the spatial variation of concentrations due to distant sources.
- A contribution from more local emissions. We have found that estimates of low level emissions in an area of 25 km^2 centred on an urban background monitoring site location can be used to derive this local contribution.

The difference, *diff*, between measured ambient NO_x and NO_2 concentrations at urban automatic monitoring sites (not roadside or industrial sites) and an underlying rural concentration field is calculated where monitoring data are available.

diff = measured annual mean urban concentration - mapped rural concentration

A regression analysis is then performed to find coefficients, k_m, for the relationship between *diff* and estimated NO_x emissions in the vicinity of the monitoring sites taken from the National Atmospheric Emissions Inventory (NAEI) (Salway *et al*, 1997, Goodwin *et al*, 1997):

$$diff = k_m . emissions$$

This coefficient, which is the equivalent of an empirical box model coefficient, can then be used to derive a map of annual mean concentrations from a combination of a rural map and emissions inventory estimates. Thus automatic monitoring data is used to calibrate the relationship between ambient air quality and emissions inventories.

estimated concentration (ppb) = rural map (ppb) + k_m*. emissions (Tonnes* NO_x *as* NO_2 *per 25* km^2 *per year)*

A map of rural NO_2 concentrations has been interpolated from monthly measurements of NO_2 by diffusion tubes at DETR Acid Deposition Secondary Network sites (Vincent *et al*, 1998). A map of rural NO_x concentration has been derived from this NO_2 map by multiplying by 1.2 (the measured ratio at the Lullington Heath monitoring site, which is very similar to that found at other rural automatic monitoring sites). The empirically derived coefficients used to calculate the maps of background NO_x and NO_2 concentrations for 1996 are listed in Table 4.1.

Table 4.1 Coefficients used to calculate 1996 background annual mean maps

	k_m
NO_2	5.920
NO_x	17.349

The highest estimated background concentrations are in the centres of the large cities. The maximum concentrations are 43 ppb for NO_2 and 97 ppb for NO_x. Areas strongly influenced by emissions from busy motorways are also evident.

PREDICTING ANNUAL MEAN CONCENTRATIONS FOR 2005 AND 2009

Maps of estimated background concentrations for 2005 and 2009 are also shown in Figures 4.1 and 4.2. Annual mean background NO_2 concentrations in the centres of large cities, other than London, in 2005 are expected to be in the range from 15 to 21 ppb, within the NAQS objective. Concentrations in inner London are expected to be in excess of 21 ppb; 29 ppb is the maximum concentration represented on the map. Concentrations will be lower still in 2009 but the maximum predicted concentration in inner London is 26 ppb, still well above the EU annual mean limit value.

Predicted concentrations in inner London are, however, extremely sensitive to the NO_x to NO_2 conversion assumptions within the mapping, as discussed in section 3. Preliminary results from a non-linear model suggest that maximum predicted background concentrations of NO_2 in 2009 in inner London will be lower than 21 ppb. Concentrations in 2005 are, however, expected to be greater than 21 ppb in inner London. It is likely that the projections of background NO_2 concentrations presented here represent a worst case analysis, as discussed in section 3.2.

PREDICTING BACKGROUND NO_2 CONCENTRATIONS FOR INDIVIDUAL MONITORING SITES

The emissions projections that have been used to calculate the maps of estimated background NO_2 concentrations for 2005 and 2009 can also be applied to individual site measurements for 1996 or 1997 to provide projections which do not have the uncertainty associated with the mapping methods. Projections based on 1996 and 1997 measured annual mean NO_2 concentrations at background sites are listed in Tables 4.2 and 4.3. Projections based on data for both years are presented in order to give an indication of the influence of the year to year variability of concentrations on the projected concentrations.

Measured NO_2 concentrations at background sites were higher than 21 ppb at most sites in 1996 and 1997. Business as usual values for 2005 are lower than 21 ppb for all sites except those in central London, which is consistent with the mapping analysis for 2005. Projected concentrations for 2005 at London Hillingdon and London Hackney are also greater than 21 ppb but these are not typical background sites. Both of these sites are influenced by nearby major road: London Hillingdon is 30 m from the M4 and London Hackney is 20 m from the A107.

Table 4.2. Projected annual mean NO_2 concentrations for background (non-roadside) sites based on 1996 measurements for the business as usual scenario (ppb).

Site	Site type	1996	2005	2009
West London	URBAN BACKGROUND	28	20	17
Glasgow City Chambers	URBAN BACKGROUND	27	19	17
Manchester Town Hall	URBAN BACKGROUND	28	20	17
Walsall Alumwell	URBAN BACKGROUND	24	17	15
Billingham	URBAN INDUSTRIAL	19	13	12
Sheffield Tinsley	URBAN INDUSTRIAL	25	18	16
London Bridge Place	URBAN BACKGROUND	33	23	20
London Bloomsbury	URBAN CENTRE	36	25	22
Edinburgh Centre	URBAN CENTRE	25	18	16
Cardiff Centre	URBAN CENTRE	21	15	13
Belfast Centre	URBAN CENTRE	20	14	12
Birmingham Centre	URBAN CENTRE	23	16	14
Newcastle Centre	URBAN CENTRE	21	15	13
Leeds Centre	URBAN CENTRE	27	19	17
Bristol Centre	URBAN CENTRE	25	18	16
Liverpool Centre	URBAN CENTRE	25	18	16
Birmingham East	URBAN BACKGROUND	21	15	13
Hull Centre	URBAN CENTRE	22	15	14
Leicester Centre	URBAN CENTRE	22	15	14
Southampton Centre	URBAN CENTRE	24	17	15
London Bexley	SUBURBAN	23	16	14
Swansea	URBAN CENTRE	23	16	14
Middlesbrough	URBAN INDUSTRIAL	16	11	10
Manchester Piccadilly	URBAN CENTRE	28	20	17
Sheffield Centre	URBAN CENTRE	24	17	15
Wolverhampton Centre	URBAN CENTRE	21	15	13
London Brent	URBAN BACKGROUND	21	15	13
London Wandsworth	URBAN CENTRE	27	19	17
London Sutton	SUBURBAN	20	14	12
London N. Kensington	URBAN BACKGROUND	23	16	14
London Eltham	SUBURBAN	19	13	12

Table 4.3. Projected annual mean NO_2 concentrations for background (non-roadside) sites based on 1997 measurements for the business as usual scenario (ppb).

Site	Site type	1997	2005	2009
West London	URBAN BACKGROUND	30	22	19
Glasgow City Chambers	URBAN BACKGROUND	26	19	17
Manchester Town Hall	URBAN BACKGROUND	27	20	17
Walsall Alumwell	URBAN BACKGROUND	25	18	16
Billingham	URBAN INDUSTRIAL	19	14	12
Sheffield Tinsley	URBAN INDUSTRIAL	26	19	17
London Bridge Place	URBAN BACKGROUND	31	23	20
London Teddington	URBAN BACKGROUND	18.5	14	12
London Bloomsbury	URBAN CENTRE	37	27	24
Edinburgh Centre	URBAN CENTRE	25	18	16
Cardiff Centre	URBAN CENTRE	20	15	13
Belfast Centre	URBAN CENTRE	20	15	13
Birmingham Centre	URBAN CENTRE	23	17	15
Newcastle Centre	URBAN CENTRE	21	15	13
Leeds Centre	URBAN CENTRE	27	20	17
Bristol Centre	URBAN CENTRE	23	17	15
Liverpool Centre	URBAN CENTRE	23	17	15
Birmingham East	URBAN BACKGROUND	20	15	13
Hull Centre	URBAN CENTRE	21	15	13
Leicester Centre	URBAN CENTRE	21	15	13
Southampton Centre	URBAN CENTRE	23	17	15
London Bexley	SUBURBAN	22	16	14
Swansea	URBAN CENTRE	20	15	13
Middlesbrough	URBAN INDUSTRIAL	16	12	10
Manchester Piccadilly	URBAN CENTRE	22	16	14
Sheffield Centre	URBAN CENTRE	24	18	15
Wolverhampton Centre	URBAN CENTRE	20	15	13
London Brent	URBAN BACKGROUND	21	15	13
London Wandsworth	URBAN CENTRE	28	20	18
London Sutton	SUBURBAN	19	14	12
London N. Kensington	URBAN BACKGROUND	26	19	17
London Eltham	SUBURBAN	21	15	13
London Hillingdon	SUBURBAN	31	23	20
Glasgow Centre	URBAN CENTRE	23	17	15
Leamington Spa	URBAN BACKGROUND	16	12	10
Nottingham Centre	URBAN CENTRE	25	18	16
Thurrock	URBAN BACKGROUND	19	14	12
Stockport	URBAN BACKGROUND	24	18	15
Manchester South	SUBURBAN	13	10	8
London Hackney	URBAN CENTRE	33	24	21
Port Talbot	URBAN BACKGROUND	13	10	8
Bolton	URBAN BACKGROUND	19	14	12
Coventry Centre	URBAN CENTRE	12	9	8

London Southwark	URBAN CENTRE	28	20	18
Salford Eccles	URBAN INDUSTRIAL	23	17	15

Mapping roadside NO_2 and NO_x concentrations

OUR APPROACH

We have considered that the annual mean concentration of NO_x at a roadside location is made up of two parts: the background concentration (as described in section 4) and a roadside enhancement.

There are several stages to mapping roadside NO_2 concentrations in 2005 and 2009:

- Derive a relationship between the roadside enhancement of NO_x and annual road link NO_x emissions estimates;
- Add the roadside enhancement to the background NO_x concentration to get an estimate of the 1996 annual mean roadside NO_x concentration;
- Apply an appropriate emissions reduction factor to calculate a map of annual mean roadside NO_x concentration in 2005 or 2009 from the 1996 map of roadside NO_x;
- Convert the predicted NO_x concentration to NO_2 using the non-linear function for roadside sites shown in Figure 3.1

THE RELATIONSHIP BETWEEN ROADSIDE NO_x CONCENTRATIONS AND EMISSIONS

The NAEI provides estimates of NO_x emissions for a total of 15226 major road links in the UK (Goodwin *et al*, 1997). Figure 5.1 shows a comparison of the roadside enhancement of NO_x concentrations at ten automatic monitoring sites with NO_x emission estimates for the individual road links alongside which these monitoring sites are located (roadside enhancement = measured roadside concentration - mapped background concentration). The sites used in the analyses presented in this report are listed in Appendix 1. The identification numbers on the scatter plots can be used to identify each site. The sites chosen for this analysis are those that are in built up areas and there is clearly a strong dependence of the roadside enhancement of concentration with NO_x emission at these sites.

roadside enhancement of NO_x (ppb) = k_{NOx} . NO_x emission from road link (kg NO_2 m^{-1} y^{-1})

The value of k_{NOx} is 3.0 (or 5.73 if the roadside enhancement of NO_x is expressed in μgm^{-3}).

Roadside NO_x monitoring sites at locations with a more open aspect, such as those adjacent to motorways or major roads in rural areas, do not conform to this relationship. The NO_x emissions from vehicles travelling on these roads are generally more effectively dispersed than the emissions on built up urban roads. We have therefore restricted our mapping to urban major roads (a total of 7508 road links), where the relationship is reliable.

Figure 5.2 shows the good agreement between the measured and estimated total roadside NO_x concentrations at the ten roadside sites (mean of measurements = 142 ppb, mean of estimates = 138, $r^2 = 0.89$)

CURRENT ROADSIDE NO_2 CONCENTRATIONS

We have calculated the annual mean roadside NO_2 concentration in 1996 by applying the non-linear function for roadside sites shown in Figure 3.1. The use of this function to convert from NO_x to NO_2 clearly introduces an additional uncertainty to our estimates but the agreement between the estimates and measurements of annual mean NO_2 at automatic monitoring sites shown in Figure 5.3 is still reasonably good (mean of measurements = 35 ppb, mean of estimates = 34 ppb, $r^2 = 0.64$). The resulting maps of estimated roadside NO_2 concentrations in 1996 are shown in Figure 5.4. Additional detail is shown in Figures 5.5 (London) and 5.6 (Birmingham and Manchester).

PREDICTING ANNUAL MEAN NO_2 CONCENTRATIONS FOR 2005

We have derived estimates of annual mean roadside NO_2 concentration in 2005 from the estimates of roadside NO_x concentrations for 2005. The estimates of roadside NO_x concentration in 2005 were derived from estimates for 1996 by applying the NO_x emission reduction factors listed in Table 2.1.

Figures 5.7 to 5.9 show the estimated annual mean urban roadside NO_2 concentrations for 2005. The links for which the estimated concentration is above 21 ppb are highlighted. Figure 5.7 shows all of the 761 road links with concentrations higher than 21 ppb. This represents about 10% of the total number of urban major road links and a total length 670 km. Only 10% (76 road links) are estimated to have concentrations greater than 26 ppb. The majority of these links (495, representing 387 km) are in the Greater London area. Figure 5.8 shows these links, with the lower map showing the central area in more detail. The remainder are generally confined to the most heavily trafficked roads in other big cities and Birmingham and Manchester are shown in Figure 5.9.

PREDICTING ANNUAL MEAN NO_2 CONCENTRATIONS FOR 2009

Roadside NO_2 concentrations have also been estimated for 2009, in order to assess compliance with the EU ‘Daughter Directive’ limit value for annual mean concentration. The limit value is 40 μgm^{-3}, which is essentially the same value as the NAQS objective of 21 ppb. We have estimated the NO_2 concentrations in 2009 for comparison with this limit value, which will come into force on 1 January 2010.

Figures 5.10 to 5.12 show the estimated annual mean urban roadside NO_2 concentrations for 2009. Fewer urban road links are expected to have a concentration greater than 21 ppb in 2009 than in 2005. A total of 170 links representing 120 km of road will have concentrations greater than the limit value. Only 10% (18 road links) are estimated to have concentrations greater than

25 ppb. 121 of the links with projected concentrations greater than 21 ppb (representing 83 km) are in the London area.

PREDICTING ROADSIDE NO_2 CONCENTRATIONS FOR INDIVIDUAL MONITORING SITES

The emissions projections that have been used to calculate the maps of estimated roadside NO_2 concentrations for 2005 and 2009 can also be applied to individual site measurements for 1997 (or most of 1998) to provide projections which do not have the additional uncertainty associated with the mapping methods. Projections based on measured annual mean NO_x concentrations at roadside sites are listed in Table 5.1.

An annual mean NO_2 concentration of 21 ppb is currently exceeded at most roadside monitoring sites. Projected concentrations in 2005 at sites on smaller roads are lower than 21 ppb but not for the more heavily trafficked roads. Projected concentrations for 2009 are still higher than 21 ppb for the busiest roads in London. This is fully consistent with the results of the mapping analysis.

Table 5.1. Projected annual mean NO_2 concentrations for roadside sites based on 1997 (or 1998) measurements for the business as usual scenario (ppb).

Site	1997			2005		2009	
	NO_x	NO_2 [1]	NO_2 [2]	NO_x	NO_2	NO_x	NO_2
Sutton Roadside	77	26	25	39	17	30	15
Tower Hamlets Roadside	156	37	36	78	25	60	22
Haringey Roadside	98	31	28	50	20	39	17
Camden Roadside	145	37	35	72	24	56	21
Exeter Roadside	79	23	25	39	17	30	15
Bristol Old Market	123	32	32	61	22	47	19
Bath Roadside	137	33	34	66	23	51	20
Glasgow Kerbside	162	37	37	80	25	62	22
Lincoln Roadside	149	35	35	72	24	55	21
Norwich Roadside	43	19	18	23	13	18	12
London Marylebone Road	202	49	42	100	29	78	25
Hove Roadside	62	19	22	31	15	24	14

[1] measured NO_2 concentration

[2] NO_2 concentration estimated from measured NO_x concentration

Alternative emissions scenarios

NATIONAL TRAFFIC EMISSION REDUCTION MEASURES

Roadside NO_2 concentrations have also been estimated for several alternative emission reduction scenarios in order to examine the impact of additional reductions in NO_x emissions from traffic on the likely extent of exceedance of the annual mean objective and limit value for NO_2. We have estimated the roadside NO_2 that would be likely to result from two national emissions reduction scenarios and two scenarios for which emission reductions are targeted to London (DETR, 1999).

Tables 6.1 and 6.2 show the NO_x emission reduction factors for the two national emission reduction scenarios that we have examined (Murrells *pers comm*). The 30% reductions are relative to the 2005 (or 2009) business as usual emissions.

Table 6.1. Urban road traffic NO_x national emissions reduction scenarios, factors relative to 1996.

	scenario	2005	2009
Business as usual	a	0.44	0.33
30% less emissions from traffic	h	0.31	0.23
30 % less emissions from cars (other traffic as business as usual)	i	0.37	0.29

Table 6.2. Background NO_x national emissions reduction scenarios, factors relative to 1996.

	scenario	2005	2009
Business as usual	a	0.50	0.40
30% less emissions from traffic	h	0.38	0.31
30 % less emissions from cars (other traffic as business as usual)	i	0.44	0.36

Tables 6.3 and 6.4 show the number of major road links with estimated concentrations greater than 21 ppb for these two scenarios along with the number of links for business as usual. We have estimated concentrations for a total of 7508 urban road links, of which 705 are in Inner London and 785 are in Outer London.

It is clear that the number of road links with concentrations above the annual mean objective is significantly reduced for these scenarios. It is likely, however, that many of the links with high concentrations in cities other than London may not have housing at the roadside and concentrations do not need to be less than 21 ppb for this links. This is discussed further in section 7.

Table 6.3. Number of built up major road links with estimated annual mean concentrations greater than 21 ppb in 2005.

scenario	UK	Inner London	Outer London	Other cities
a	761	395	100	266
h	116	66	13	37
i	360	206	40	114

Table 6.4. Number of built up major road links with estimated annual mean concentrations greater than 21 ppb in 2009.

scenario	UK	Inner London	Outer London	Other cities
a	170	102	19	49
h	21	13	4	4
i	87	54	10	23

TRAFFIC EMISSION REDUCTION MEASURES IN LONDON

We have also estimated the roadside NO_2 concentrations that would be likely to result from two scenarios (hl and il) in which additional emission reductions are targeted to London.

Tables 6.5 and 6.6 show the NO_x emission reduction factors for the two London emission reduction scenarios that we have examined (Murrells *pers comm*). Scenario hl has a 30% reduction in traffic emissions in inner London and a 10% reduction in outer London. Scenario il has a 30% reduction in emissions from cars in inner London and a 10% reduction in outer London. NO_x emissions in the rest of the UK are assumed to be the same as the business as usual scenario.

Table 6.5. Urban road traffic NO_x London emissions reduction scenarios, factors relative to 1996.

	scenario	Inner London		Outer London	
		2005	2009	2005	2009
Business as usual	a	0.44	0.33	0.44	0.33
30%/10% less emissions from traffic	hl	0.31	0.23	0.40	0.30
30%/10% less emissions from cars (other traffic as business as usual)	il	0.37	0.29	0.42	0.32

Table 6.6. Background NO_x London emissions reduction scenarios, factors relative to 1996.

	scenario	Inner London		Outer London	
		2005	2009	2005	2009
Business as usual	a	0.50	0.40	0.50	0.40
30%/10% less emissions from traffic	hl	0.38	0.31	0.46	0.37
30%/10% less emissions from cars (other traffic as business as usual)	il	0.44	0.36	0.48	0.39

Tables 6.7 and 6.8 show the number of major road links with estimated concentrations greater than 21 ppb for these two scenarios along with the number of links for business as usual. The numbers of links with concentrations greater than 21 ppb is obviously the same as the business as usual scenario for all road links outside London.

Maps of annual mean background NO_2 concentrations for 2005 and 2009 can also be calculated for these two scenarios.

Table 6.7. Number of built up major road links with estimated annual mean concentrations greater than 21 ppb in 2005.

scenario	UK	Inner London	Outer London	Other cities
a	761	395	100	266
hl	388	66	56	266
il	549	206	77	266

Table 6.8. Number of built up major road links with estimated annual mean concentrations greater than 21 ppb in 2009.

scenario	UK	Inner London	Outer London	Other cities
a	170	102	19	49
hl	74	13	12	49
il	118	54	15	49

ALTERNATIVE EMISSIONS SCENARIOS FOR CONCENTRATIONS FOR INDIVIDUAL ROADSIDE MONITORING SITES

Predicted NO_2 concentrations for individual roadside monitoring sites for the alternative emissions reductions scenarios are listed in Table 6.9. Estimated concentrations for 1997 and predicted concentrations for the business as usual scenario are shown in Table 5.1.

Table 6.9. Projected annual mean NO_2 concentrations for roadside sites based on 1997 (or 1998) measurements for alternative emission reduction scenarios (ppb).

Scenario	h				i				hl				il			
Year	2005		2009		2005		2009		2005		2009		2005		2009	
	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2
Sutton Roadside	28	15	22	13	33	16	27	14	36	17	27	14	37	17	29	15
Tower Hamlets Roadside	57	21	44	19	67	23	54	21	57	21	44	19	67	23	54	21
Haringey Roadside	37	17	29	15	43	18	35	16	37	17	29	15	43	18	35	16
Camden Roadside	53	20	41	18	63	22	50	20	53	20	41	18	63	22	50	20
Exeter Roadside	28	15	21	13	33	16	26	14	39	17	30	15	39	17	30	15
Bristol Old Market	44	19	34	16	53	20	42	18	61	22	47	19	61	22	47	19
Bath Roadside	47	19	36	17	57	21	45	19	66	23	51	20	66	23	51	20
Glasgow Kerbside	58	21	45	19	69	24	54	21	80	25	62	22	80	25	62	22
Lincoln Roadside	52	20	40	18	62	22	49	20	72	24	55	21	72	24	55	21
Norwich Roadside	17	11	14	10	20	12	16	11	23	13	18	12	23	13	18	12
London Marylebone Road	73	24	57	21	87	27	69	24	73	24	57	21	87	27	69	24
Hove Roadside	23	13	18	12	27	14	21	13	31	15	24	14	31	15	24	14

The locations of the road links with the highest predicted concentrations

The objectives for 2005 within the NAQS (DoE, 1997) apply to non-occupational near-ground level outdoor locations where a person might reasonably be expected to be exposed over the relevant averaging period. The annual mean NO_2 objective of 21 ppb therefore only applies at the facade of buildings where people actually live. NO_2 concentrations are expected to fall rapidly as the distance from the road increases reaching levels similar to background at distances greater than 20-30 metres (QUARG, 1993). The modelled estimates of roadside NO_2 concentrations presented in this report have been calibrated by reference to automatic monitoring sites within the national monitoring networks. The estimated concentrations are therefore representative of concentrations at distances up to about 5 m from the edge of the road. We have carried out a preliminary assessment of the likely presence of housing at the roadside of the links with the highest estimated concentrations in 2005.

Table 7.1 lists the top 50 or so road links outside London with the highest estimated roadside NO_2 concentrations in 2005. The roads are sorted by city and ranked by concentration within each city. Estimated concentrations for the business as usual (a) and 30% less traffic emissions (h) and 30% less emissions from cars (i) are shown. The likelihood of housing within about 10 m the roadside was assessed by contacting local authority representatives and studying maps. Many of the road links listed in Table 7.1 are unlikely to have people living close to the road, although there are a number of roads with houses present. It should be emphasised that this is only a preliminary assessment and this should be addressed in detail by local authorities carrying out a review and assessment for roadside NO_2.

The built-up road links with estimated concentrations in excess of 21 ppb in 2005 are almost exclusively confined to cities in England. Two of the four links in Scotland have concentrations high enough to be included in Table 7.1. Stobcross street is a largely commercial area, with a few flats at an unknown distance from the road. The Clydeside Expressway looks like a commercial area on the map. The other two road links are the A739 Clyde Tunnel and the A725, which is a by-pass near Hamilton. Neither of these links are expected to have housing within 10 m. The only road link in Wales with estimated concentration greater than 21 ppb is the A4051 in Malpas near Newport. This road has been by-passed by a new road which avoids the urban area since the road links database was compiled and is therefore unlikely to present a problem in 2005. Detailed information on the split between built-up and non-built-up road links is not available for the major roads in Northern Ireland. The only non-motorway links with estimated concentrations greater than 21 ppb in 2005 are the A12 West Link and A55 University Road/Malone Road in Belfast. The likelihood of housing close to these roads has not been assessed.

We have not assessed road links in London for the presence of housing but it is likely that people will be living close to many links with estimated concentrations greater than 21 ppb in 2005.

Background concentrations in inner London are also expected to be at risk of exceeding 21 ppb in 2005 for the business as usual scenario, so the presence or absence of housing close to a particular road is less important. Details of the locations of the roads with the highest estimated concentrations in Inner and Outer London are given in Tables 7.2 and 7.3. Concentrations for scenarios a, h and i are listed for each link. The London specific scenarios hl and il are the same as scenarios h and i for Inner London, estimates for scenarios hl and il are listed separately for Outer London.

Table 7.1. Major built-up road links outside London with the highest estimated annual mean NO_2 concentration in 2005.

Road Number	Length (m)	NO_2 2005 scenario a	NO_2 2005 scenario h	NO_2 2005 scenario i	City	Road name	Comment on likelihood of houses close to the roadside
A4400	800	28	23	26	Birmingham	St Chads Queensway	No housing, only shops
A38	782	27	23	25	Birmingham	St Chads Queensway, Copr Street	No housing, only shops
A4400	650	27	23	25	Birmingham	Bristol Road	Some housing along the roadside within 10m
A38	1742	26	22	24	Birmingham	Tyburn Road	Housing along the roadside within 10m
A38	847	26	21	24	Birmingham	Bristol Road	Housing along the roadside within 10m
A4400	500	25	21	23	Birmingham	Moor Street Queensway	No housing, only shops
A4540	812	25	21	23	Birmingham	Belgrave Middleway	Houses, but may not be within 10m
A41	405	24	20	22	Birmingham	Bull Ring, Digbeth	No houses
A4540	419	24	20	22	Birmingham	Dartmouth Middleway	Houses, but may not be within 10m
A4400	800	24	20	22	Birmingham	Moor Street Queensway	No housing, only shops
A452	1400	24	20	22	Birmingham	Chester Road	Houses, some as close as 5m. Very built up in places
A4044	1100	26	22	24	Bristol	Western inner ring road (Colston Ave, Lweins Mead etc)	No houses
A4044	700	26	21	24	Bristol	Temple Way	Houses, some closer than 10m.
A4032	1100	25	21	23	Bristol	Newfoundland Street	Houses, some closer than 10m.
A4	347	25	21	23	Bristol	Temple Gate / Bath Bridge	No houses
A370	500	25	21	23	Bristol	Brunel Way?	No houses
A4044	500	24	20	22	Bristol	Bond Street	No houses
A4044	347	24	20	22	Bristol	Bond Street	No houses
A638	853	24	20	22	Doncaster	A638 in City Centre	Probably industrial area
A814	700	26	21	24	Glasgow	Stobcross Street	A few flats. Distance from road unknown. Mostly commercial district
A814	3500	24	21	23	Glasgow	Clydeside Expressway	Looks like commercial district on map
A63	965	26	22	24	Hull	Hedon Rd and Castle St	Houses, some with gardens and some without
A63	658	25	21	23	Hull	Hedon Rd and Castle St	Houses, some with gardens and some without
A58	600	30	25	28	Leeds	Wellington Road	Not Known
A58	500	28	24	26	Leeds	Wellington Road	Not Known
A58	300	28	23	25	Leeds	West Street?	Not Known
A58	476	28	23	25	Leeds	West Street?	Not Known
A64	500	28	23	25	Leeds	York Road	Not Known

Road Number	Length (m)	NO_2 2005 scenario a	NO_2 2005 scenario h	NO_2 2005 scenario i	City	Road name	Comment on likelihood of houses close to the roadside
A4400	800	28	23	26	Birmingham	St Chads Queensway	No housing, only shops
A38	782	27	23	25	Birmingham	St Chads Queensway, Copr Street	No housing, only shops
A4400	650	27	23	25	Birmingham	Bristol Road	Some housing along the roadside within 10m
A58	300	27	23	25	Leeds	Gelderd Street	Not Known
A64	2800	27	22	25	Leeds	A64 in Burmantofts	Not Known
A643	1200	25	21	23	Leeds	A643 in Holbeck	Not Known
A64	500	25	21	23	Leeds	York Road	Not Known
A64	2800	24	20	22	Leeds	A64 in Harehills	Not Known
A46	400	28	23	26	Leicester	Burleys Way	Commercial area. Factories shops and offices.
A46	600	26	22	24	Leicester	Burleys Way	Commercial area. Factories shops and offices.
A46	500	24	20	22	Leicester	Burleys Way	Commercial area. Factories shops and offices.
A5038	341	25	21	23	Liverpool	Lime Street	University non residential buildings only
A59	1300	25	21	23	Liverpool	A59 near University	University non residential buildings only
A5080	227	25	21	23	Liverpool	New Islington	Houses within 10m of roadside
A580	372	25	21	23	Liverpool	link prior to M62	Houses within 10m of roadside
A59	638	25	21	23	Liverpool	A59 near University	University non residential buildings only
A580	500	25	21	23	Liverpool	Brunswick Road	Some houses within 10m of roadside
A580	800	24	20	22	Liverpool	Erskine Street	Houses within 10m of roadside
A5036	621	24	20	22	Liverpool	Strand Street	Shops only
A59	300	24	20	22	Liverpool	A59 near University	University non residential buildings only
A56	600	26	22	24	Manchester	Old Trafford	Some flats, mostly shops and offices
A5103	1400	26	22	24	Manchester	junction of M63	Housing estate nearby, but > 100m from junction.
A6	1000	24	20	22	Manchester	A6 in Salford	Not Known
A34	700	24	20	22	Manchester	Old Trafford	Houses 10m of roadside
A56	792	24	20	22	Manchester	A34 in Gatley	Not Known
A57	895	24	20	22	Manchester	Regent Road	Commercial area
A665	127	24	20	22	Manchester	Great Ancoats St	Commercial area
A6	748	24	20	22	Manchester	Crescent Chapel	Not Known
A1	1500	28	23	25	Newcastle	A1 in Lemington	No houses within 10m
A167	800	26	22	24	Newcastle	A167 Tyne Bridge	No housing on bridge
A3	447	26	22	24	Portsmouth	A3 junction with M27	No houses close to junction
A533	2158	29	24	27	Runcorn	Bridge across River Mersey	No housing on bridge
A61	800	24	20	22	Sheffield	Sheaf Street	Not Known

Table 7.2. Major built-up road links in Inner London with the highest estimated annual mean NO_2 concentration in 2005.

Road Number	Length (m)	NO_2 2005 scenario a	NO_2 2005 scenario h	NO_2 2005 scenario i	Location	Road name
A4202	1200	33	28	31	Mayfair	Park Lane
A302	600	30	25	27	Green Park	Grosvenor Place
A4	1100	29	25	27	Hammersmith	Great West Road
A40	1626	29	25	27	East Acton	Westway
A4	829	29	24	27	Hammersmith	Hammersmith Flyover
A4	400	29	24	27	West Kensington	West Cromwell Road
A4	406	29	25	27	Knightsbridge	Knightsbridge
A501	400	29	24	27	Paddington	Marylebone Rd
A501	200	29	24	27	Baker St	Marylebone Rd
A4	1300	29	24	27	Hammersmith	Talgarth Road
A3	225	29	24	26	Kennington	Kennington Park Road
A3211	400	29	24	26	Blackfriars	Embankment
A4	1700	29	24	26	Hammersmith	Hammersmith Flyover
A4	300	28	24	26	South Kensington	Cromwell Rd
A501	400	28	24	26	Warren Street	Euston Road
A501	400	28	24	26	Marylebone	Marylebone Rd
A4	200	28	23	26	Hyde Park Corner	Knightsbridge
A40	138	28	23	26	Marble Arch	Marble Arch
A3211	854	27	23	25	Embankment	Embankment
A4	600	27	23	25	Hyde Park Corner	Hyde Park Corner Underpass
A40	306	27	23	25	Marble Arch	Cumberland Gate
A501	900	27	23	25	Baker St	Marylebone Rd
A3211	1300	27	23	25	Monument	Upper / Lower Thames St
A404	600	27	23	25	Paddington	Harrow Road
A301	500	27	23	25	Waterloo Bridge South	Waterloo Bridge South
A301	337	27	23	25	Waterloo Bridge North	Waterloo Bridge North
A202	526	27	23	25	Vauxhall	Vauxhall Bridge
A13	1700	27	23	25	Canning Town	Newham Way
A13	600	27	23	25	Canning Town	Eat India Dock Road
A3211	204	27	23	25	Tower Hill	Tower Hill
A3212	800	27	23	25	Westminster	Whitehall
A501	157	27	22	25	Kings Cross	Euston Road
A4	700	27	22	25	Mayfair	Piccadilly
A3220	511	27	22	25	Chelsea	Cheyne Walk

A3211	304	26	22	24	Blackfriars	Embankment
A5	600	26	22	24	Marble Arch	Edgware Road
A40	200	26	22	24	Notting Hill	Notting Hill Gate
A3	300	26	22	24	Newington	Newington Butts
A5201	300	26	22	24	Old Street	Old Street
A3205	1824	26	22	24	Vauxhall	Nine Elms Lane
A4	900	26	22	24	Knightsbridge	Brompton Road
A10	122	26	22	24	Tottenham	High Road
A3217	230	26	22	24	Victoria	Bressenden Place
A4	300	26	22	24	Trafalgar Square	Trafalgar Square
A4	200	26	22	24	Aldwych	Aldwych
A501	400	26	22	24	Euston Station	Euston Road
A501	600	26	22	24	Kings Cross	Euston Road
A3220	715	26	22	24	Kensington	Holland Road
A3212	500	26	22	24	Chelsea	Chelsea Embankment
A501	200	26	22	24	Old Street	City Road

Table 7.3. Major built-up road links in Outer London with the highest estimated annual mean NO_2 concentration in 2005.

Road Number	Length (m)	NO_2 2005 scenario a	NO_2 2005 scenario h	NO_2 2005 scenario i	NO_2 2005 scenario hl	NO_2 2005 scenario il	Location	Road name
A406	1939	32	27	29	30	31	London, West Hendon	North Circular Road
A406	900	31	26	28	29	30	London, Hendon	North Circular Road
A406	2100	29	24	27	28	28	London, Church End	North Circular Road
A4	600	29	24	27	27	28	London, Hammersmith	Great West Road
A4	1849	28	24	26	27	28	London, Chiswick	Ellesmere Road
A406	2400	28	23	26	26	27	London, Neasdon	North Circular Road
A102	2300	28	23	25	26	27	London, Poplar	Blackwall Tunnel
A1	206	27	23	25	26	26	London, Hendon	Henleys Corner
A10	400	27	22	25	25	26	London, Enfield	Cambridge Road near M25
A40	1200	27	22	25	25	26	London, Acton	Western Avenue
A40	1867	26	22	24	24	25	London, Park Royal	Western Avenue
A104	202	25	21	23	24	25	London, Walthamstow	Woodford New Road
A406	721	25	21	23	24	25	London, Hendon	North Circular Road at Staples Corner
A118	129	25	21	23	23	24	London, Ilford	Chapel Road
A1	500	25	21	23	23	24	London, Hendon	Henleys Corner
A406	300	24	21	23	23	24	London, Hendon	North Circular Road
A41	1400	24	20	23	23	24	London, Hendon	Hendon Way
A312	1900	24	20	22	23	24	London, Northolt	Church Road, The Parkway
A406	940	24	20	22	23	24	London, Finchley	North Circular Road
A3	1738	24	20	22	23	24	London, Roehampton	Kingston Road
A406	200	24	20	22	23	23	London, Park Royal	Hanger Lane Junction
A212	1007	24	20	22	23	23	London, Croydon	Wellesley Road
A2	208	24	20	22	23	23	London, New Cross	Blackheath Road
A4	192	24	20	22	23	23	London, Hounslow	Great West Road
A406	1700	24	20	22	23	23	London, Walthamstow	Southend Road
A10	3500	24	20	22	23	23	London, Enfield	Cambridge Road
A106	700	24	20	22	23	23	London, Hackney	Ruckholt Road
A12	1200	24	20	22	22	23	London, Redbridge	Eastern Avenue

Conclusions

Annual mean urban background NO_2 concentrations in 2005 are likely to be below 21 ppb in all areas except for inner London, where current national policies are expected to lead to concentrations in the range 21 - 29 ppb.

Roadside NO_2 concentrations in urban areas in 2005 are expected to be significantly higher, with a total of 761 road links likely to have concentrations higher than the annual mean objective of 21 ppb. This represents about 10% of the total number of urban major road links with a total length 670 km. The majority of these links (495, representing 387 km) are in the Greater London area. The remainder are generally confined to the most heavily trafficked roads in other big cities.

Annual mean roadside NO_2 concentrations have also been predicted for 2009, for comparison with the European Union 'Daughter' Directive limit value, which is also 21 ppb. The continuing downward trend in traffic emissions is likely to further reduce the number of links exceeding this value by 2009, with about 2% of urban major road links predicted to have concentrations higher than 21 ppb

Roadside NO_2 concentrations in 2005 and 2009 have also been estimated for several alternative emission reduction scenarios. Many fewer road links are expected to have concentrations greater than 21 ppb for additional NO_x emission reductions of the order of 30% compared with business as usual.

The objectives for 2005 within the NAQS (DoE, 1997) apply to non-occupational near-ground level outdoor locations where a person might reasonably be expected to be exposed over the relevant averaging period. The annual mean NO_2 objective of 21 ppb therefore only applies at the facade of buildings where people actually live. Many of the road links in cities other than London with estimated concentrations greater than 21 ppb are unlikely to have people living close to the road, although there are a number of roads with houses present.

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Appendix 1
Monitoring sites

Table A1. Roadside Automatic Monitoring sites.

id	site	Network
1	Haringey Roadside	DETR
2	Camden Roadside	DETR
3	Marylebone Road	DETR
4	Cromwell Road	DETR
5	Tower Hamlets Roadside	DETR
6	Brighton Roadside	DETR
7	Bristol Old Market	DETR
8	Bath Roadside	DETR
9	Southwark Roadside	DETR
10	Croydon 2	LAQN

Annual mean concentrations where calculated for 1997 where data are available. An annual mean covering part of 1997 and part of 1998 was calculated for Marylebone Road, 1995 data was used for Cromwell Road and 1996 was used for Croydon 2.