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The 10 Year Transport Plan. Site specific analyses of ambient NO_2 and PM_{10} concentrations

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

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Executive Summary

'Transport 2010: The Ten Year Plan' sets out the Government's strategy to tackle congestion and pollution and deliver better integrated, high quality, transport systems over the next decade. A background paper 'Transport 2010: The Background Analysis' has also been published which provides an overview of the modelling and analytical work that has informed the Plan. The Background Paper includes forecasts of emissions of oxides of nitrogen and particles from road and rail transport in England in 2010 under a number of different scenarios. It also includes an assessment of the impact of the measures in the Plan on ambient NO_2 and PM_{10} concentrations based on the methods described in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS) and supporting technical reports. These methods have been updated to incorporate more recent ambient air monitoring results, understanding of atmospheric chemistry and emissions estimates and projections.

NO_2 and PM_{10} are two important pollutants addressed in the AQS. They are pollutants for which the objectives set out within the Strategy and in recent EC Directives are likely to be the most challenging. This report describes these methods and presents the results of the site specific analyses of NO_2 and PM_{10} concentrations. Concentrations of NO_2 and PM_{10} in 2010 have been assessed for the road traffic emissions resulting from baseline and 'plan' scenarios and two illustrative scenarios of the impact of additional policy choices.

The background paper explains that the estimates of road traffic emissions and concentrations reductions should be treated with caution. DETR's strategic road traffic modelling work has necessarily had to make broad assumptions about how the key decision-makers, particularly local authorities and the Mayor of London, will choose to spend the funds being made available by the Plan. It is unlikely to represent accurately the decisions that those bodies will make in the context of their local transport strategies and air quality management plans. In practice expenditure might be more targeted on localised problems.

The Plan is estimated to reduce annual average NO_2 concentrations by, on average 3.1% (range 0.6–7.3%), compared to the baseline in 2010, with the biggest reductions predicted at roadside sites. The illustrative scenarios are estimated to produce reductions of, on average, 4.6 % (range 1.0-9.8%). On the basis of the assumptions underlying our air quality modelling, there would still be areas in London (centrally and near very busy roads) where the EC limit value and the Air Quality Strategy objective would not be attained, and possibly also near heavily trafficked roads in other large cities.

There are two sets of EC Directive limit values for PM_{10} concentrations: mandatory Stage 1 limit values for 2005, and more stringent non mandatory "indicative" Stage 2 limit values for 2010. Our analysis has focussed on the Plan's contribution to achievement of the indicative annual mean Stage 2 limit value in 2010 - the timeframe of the Plan. Analyses presented in the Air Quality Strategy showed that this indicative limit value is likely to be widely exceeded across the country in 2010, with highest levels generally occurring next to heavily trafficked roads. The estimated reductions in concentrations arising from the Plan and illustrative scenarios are small: on average 1.8 % (range 0.6-5.4%) compared to the baseline for the Plan scenario; and on average 2.4 % (range 1.0-6.2%) under the illustrative scenarios. The reductions will nonetheless contribute to the Government's broader strategy of reducing PM_{10} levels, which

involves addressing non-transport sources in the UK and emissions from the rest of Europe.

Contents

1 Introduction

'Transport 2010: The Ten Year Plan' (DETR, 2000a) sets out the Government's strategy to tackle congestion and pollution and deliver better integrated, high quality, transport systems over the next decade. A background paper 'Transport 2010: The Background Analysis' (DETR, 2000b) ('Background Paper') has also been published which provides an overview of the modelling and analytical work that has informed the Plan. The Background Paper includes forecasts of emissions of oxides of nitrogen and particles from road and rail transport in England in 2000 and in 2010 under a number of different scenarios. It also includes an assessment of the impact of the measures in the Plan on ambient NO_2 and PM_{10} concentrations based on the methods described in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (DETR et al, 2000) (AQS) and supporting technical reports (Stedman et al, 1998a, Stedman et al, 1998b). These methods have been updated to incorporate more recent ambient air monitoring results, understanding of atmospheric chemistry and emissions estimates and projections. This report describes these methods and presents the results of the site specific analyses of NO_2 and PM_{10} concentrations.

NO_2 and PM_{10} are two important pollutants addressed in the AQS. They are pollutants for which the objectives set out within the Strategy and in recent EC Directives are likely to be the most challenging. The AQS sets the following provisional objectives for NO_2, to be achieved by 31 December 2005:

- Annual mean: 40 μgm^{-3}
- Hourly mean: 200 μgm^{-3}, not to be exceeded more than 18 times a year.

The first EU air quality 'daughter directive' (AQDD) sets the same concentrations as limit values, to be achieved by 1 January 2010. The annual mean objective and limit value is expected to be the more stringent of the two.

The AQS sets the following objectives for PM_{10}, to be achieved by 1 January 2005:

- Annual mean: 40 μgm^{-3}
- 24-hour mean: 50 μgm^{-3}, not to be exceeded more than 35 times a year.

The AQS adopted the AQDD stage 1 limit values for PM_{10} as national objectives. The 24-hour mean objective and limit value is expected to be the more stringent of the two. Indicative stage 2 limit values have also been set at 20 μgm^{-3} as an annual mean and 50 μgm^{-3} as a 24-hour mean, not to be exceeded more than 7 times a year, to be achieved by 1 January 2010. Our analysis of the impacts of the Plan on PM_{10} concentrations has focussed on the achievement of the indicative annual mean Stage 2 limit value in 2010 - the timeframe of the Plan

The Government is currently considering the possibility of a more stringent AQS objective for PM_{10}. The 10 Year Plan provides an important input to this analysis as it will provide a basis on which the impact of possible additional measures on ambient concentrations can be assessed.

The emissions projections derived for the scenarios described in the Background Paper are set out in section 2. Sections 3 and 4 describe the methods that have been used to derive estimates of NO_2 and PM_{10} concentration in 2010 from a combination of ambient monitoring data and emissions information. Site specific projections have been calculated for both pollutants. This method has the advantage of not incorporating the additional uncertainty that would be introduced by the use of a dispersion model or mapping method. The site specific projection method involves separating the measured concentration into a number of component parts, projecting each of these parts forwards and recombining to derive an estimate of the concentration in 2010. The results of the analysis for the Plan are listed in sections 5 and 6 and discussed in section 7.

2 Emissions Projections for the 10 Year Transport Plan

As part of the analysis to inform the Plan, estimates were made of road and rail emissions of oxides of nitrogen (NO_x) and PM_{10} in 2000 and in 2010 for a number of different scenarios, from a base year of 1996. This work is described in the Background Paper. The scenarios for 2010 considered were as follows.

Firstly a **baseline**, which assumes that none of the increased investment and other measures in the Plan is implemented. Even in the absence of these measures, a significant decrease in emissions of these two pollutants is expected over this period due to the implementation of tighter standards for emissions from new vehicles and for fuel quality.

The second scenario is described as the '**Plan**' (see DETR (2000a) and DETR (2000b)) and includes:

- spending and outputs on local transport, London, railways and strategic roads:
- during the Plan period the Mayor introduces congestion charging in central London, and local authorities outside London introduce 8 congestion charging and 12 workplace parking levy schemes in the centres of most large urban areas the size of Blackpool and above. All net revenues are recycled into transport improvements in the urban areas concerned;
- the impacts on traffic volumes from land use policies, travel plans, sustainable distribution measures and local parking policies.

A number of illustrative scenarios were also considered. These examine the potential impact of some future changes and policy choices:

- **Constant motoring costs and additional investment scenario (Constant cost)**: assumptions as for Plan except it was assumed that motoring costs per car km remain constant in real terms through the Plan period, rather than falling by 20%, and that there is additional transport investment;

- **Wider take-up of local charging powers:** assumptions as for Plan, except it was assumed that by 2010 local charging is introduced in the centre of around 80 cities outside London the size of Winchester and above – congestion charging in central London and 8 other large urban areas, workplace parking levies elsewhere. All net revenues are recycled into transport improvements in the urban areas concerned;
- **Limited inter-urban charging scenario:** in addition to the Plan assumptions, it was assumed that by 2010 there are charges on the trunk road network, only at the times and places where congestion is highest;
- **All three illustrative scenarios combined (Combined)**

Estimates of emissions of NO_x and PM_{10} have been calculated for a total of four scenarios:

- Baseline
- Plan
- Illustrative constant motoring costs and additional transport investment (Constant cost)
- All three illustrative scenarios combined (Combined)

The Plan and illustrative scenarios are estimated to reduce traffic emissions of NO_x and PM_{10} relative to the baseline and produce a smaller increase in emissions from rail. Estimates of emissions from road transport and rail are listed in Table 1. A detailed analysis of the impact of reductions in traffic emissions on ambient concentrations has been carried out. The impact of increases in rail emissions on ambient concentrations in 2010 has not been included. The projected reductions in ambient concentrations therefore provide an upper limit on the impact of the Plan measures.

Table 1. 2010 road traffic and rail NO_x and PM_{10} emissions in England (kTonnes) (DETR, 2000b)

	NO_x			PM_{10}		
	Road	Rail	Total	Road	Rail	Total
Baseline	198	15.4	213	10.5	0.62	11.1
Plan	188	20.5	208	10.1	0.87	11.0
Constant cost	182	23.6	206	9.8	1.01	10.8
Combined	180	23.6	204	9.7	1.01	10.7

The projections of road traffic emissions for 2010 were derived using the National Road Traffic Forecasts (NRTF) modelling framework (see DETR, 2000b), incorporating an emissions module based on the National Atmospheric Emissions Inventory (NAEI, Goodwin et al, 1999). The network model in the NRTF framework divides the country into 11 different 'area types' and these are listed in Table 2. Emissions estimates for 1996 and projections for 2010 are listed in Table 3.

Table 2. National Road Traffic Forecast area types

Area Type	Description
1	Central London
2	Inner London
3	Outer London
4	Inner Conurbantions
5	Outer Conurbations
6	Other urban areas > 25 km^2 area
7	Urban areas 15 - 25 km^2 area
8	Urban areas 10 - 15 km^2 area
9	Urban areas 5 - 10 km^2 area
10	Urban areas < 5 km^2 area
11	Rural areas

Table 3. NO_x and PM_{10} road traffic emissions estimates for 1996 and projections for 2010 (kTonnes, England)

Area Type	1	2	3	4	5	6
NOx 1996	1.92	9.34	29.85	24.00	97.38	26.77
NOx 2010 Baseline	0.67	3.20	9.67	8.01	31.58	8.61
NOx 2010 Plan	0.58	2.73	9.20	7.53	29.09	8.26
NOx 2010 Constant cost	0.56	2.57	8.56	7.38	28.07	8.01
NOx 2010 Combined	0.56	2.57	8.56	7.37	27.36	7.99
PM10 1996	0.131	0.606	1.590	1.386	4.819	1.349
PM10 2010 Baseline	0.043	0.204	0.574	0.481	1.619	0.495
PM10 2010 Plan	0.033	0.164	0.539	0.441	1.491	0.468
PM10 2010 Constant cost	0.031	0.154	0.498	0.433	1.452	0.455
PM10 2010 Combined	0.031	0.154	0.498	0.433	1.417	0.453

Area Type	7	8	9	10	11	Total
NOx 1996	23.46	11.55	16.10	27.69	469.01	737.07
NOx 2010 Baseline	7.33	3.53	5.13	8.57	111.68	197.99
NOx 2010 Plan	7.12	3.42	5.06	8.47	106.87	188.34
NOx 2010 Constant cost	6.92	3.32	4.93	8.24	103.17	181.73
NOx 2010 Combined	6.85	3.30	4.89	8.24	102.40	180.08
PM10 1996	1.154	0.540	0.779	1.316	17.952	31.622
PM10 2010 Baseline	0.423	0.198	0.293	0.487	5.716	10.532
PM10 2010 Plan	0.406	0.191	0.288	0.480	5.593	10.093
PM10 2010 Constant cost	0.396	0.187	0.282	0.470	5.442	9.799
PM10 2010 Combined	0.390	0.186	0.281	0.470	5.411	9.725

The traffic and emissions projections for the Plan, constant cost and combined scenarios are built up from the results of different policy tests. This is to overcome the point that towns, grouped within the same area type for modelling purposes, may adopt different local transport strategies. For example, some local authorities in large urban areas will build light rail schemes and others guided bus schemes, each with different assumptions on how these schemes are

financed. The variations were modelled separately and the resulting projections for the Plan, constant cost and combined scenarios were based on a weighted result. In all, up to five different strategies were tested within an area type. The results of each individual run (for convenience labelled A-E) are presented alongside the weighted result in sections 5 and 6. This weighting process was not used for NRTF area types 1-3 (London). The impact of local policies in London was addressed using the London Transportation Studies (LTS) model, and a combined impact then incorporated in the NRTF model. For the London area types, the forecast emissions under the constant cost and combined scenarios are the same because the combined scenario assumes no increase in the intensity of application of local charging, or effect from limited inter-urban charging, in London.

3 Site Specific NO_2 Projections: Method

The methods used to calculate site specific projections of future annual mean NO_2 concentrations have been described in the AQS (DETR et al, 2000) and in some detail by Stedman et al (1998a) and Stedman (1999). Projections were based on measurements carried out at sites within the national automatic monitoring networks (see www.aeat.co.uk/netcen/airqual for details of the site locations and an archive of monitoring results). The following steps were required to project these measured concentrations forwards:

- The measured concentration was divided into component parts. A map of rural concentrations was subtracted from the measured concentration to determine the local source contribution to annual mean NO_x concentration. Emission inventory maps (Goodwin et al, 1999) for 1997 were used to split the local source contribution into four emissions sectors: road traffic, domestic and services, industry and other (a total of 25 1 km squares, centred on the monitoring site local were examined). For roadside monitoring sites there was assumed to be an additional contribution from emissions on the road adjacent to the monitoring site. Annual mean background concentrations for roadside sites were derived from mapping studies similar to those described in the AQS.
- Each component was then projected forwards from the measurement year to 2010 according to the projected change in emissions from each sector and added together to give an estimate of annual mean NO_x for 2010. Rural concentrations were projected on the basis of changes in UK total NO_x emissions.
- Non-linear relationships between annual mean NO_2 and NO_x concentrations were then used to calculate estimates of NO_2 concentration.

Estimates of road traffic emissions were taken from Table 3. Estimates of UK total non-traffic emissions of NO_x for 1998 and earlier years are available from the NAEI. Emissions from non-traffic sources for years between 1998 and 2010 have been derived from DTI (2000) and estimated within the NAEI. These estimates therefore incorporate an assumed growth in economic activity of about 2.5% per year and the continuation of current trends towards greater use of natural gas and cleaner technologies DTI (2000). The change in non-traffic emission of NO_x is expected to be small relative to the changes in emissions from road traffic. We have

estimated that non-traffic emissions in 2010 will be approximately 95% of those in 1998. These projections illustrate our best estimate of the likely result of current national and international policies.

The following non-linear relationships between annual mean concentrations were used. These have been derived from monitoring data from 1990 to 1999 inclusive and the graphs showing these relationships are reproduced in Appendix 1:

- Central London Background

$NO_2\,(ppb) = 1.750.NO_x\,(ppb)^{0.7}$

- Elsewhere Background

$NO_2\,(ppb) = 2.375.NO_x\,(ppb)^{0.6}$

- Roadside

$NO_2\,(ppb) = 1.8767.NO_x\,(ppb)^{0.6}$

Figures 1 to 3 show illustrative examples of site specific projections of NO_x and NO_2 concentrations for years between 1990 and 2010. Projected concentrations have been calculated from measured concentrations in 1996, 1997, 1998 and 1999. There is good agreement between the projections for years earlier than 1996 and the measured concentrations. This gives us confidence that the split into different sectors and the emissions estimates are reasonable. The inter-year changes in measured concentrations are also put into the context of changes in emissions, enabling the identification of years with unusually efficient or poor dispersion of primary pollutants. High concentrations due to poor dispersion conditions are evident at West London in 1997 and particularly in 1991, when there was a major episode of elevated concentrations. The projections also clearly illustrate the impact of emissions reductions on ambient NO_x concentrations and the correspondingly smaller changes in annual mean NO_2.

The projections of traffic emissions used to calculate the illustrative results shown in shown in Figures 1 to 3 are NAEI estimates (Murrells, 2000), which are based 1997 National Road Traffic Forecasts for Great Britain (DETR 1997). These projections pre-date the area type specific emissions projections for England listed in Table 3 and do not reflect any of the measures specified in the 10 Year Plan. The advantage of these NAEI projections is that they are available for all years from 1990 to 2010 and facilitate the comparison with measurement data (the 10 Year Plan emissions estimates are currently only available for 1996, 2000 and 2010). This enables the profile of projected concentrations changes to be compared with past trends an assessment of concentrations in years such as 2005 for which AQS objectives have been set. The NAEI projections for 2010 are similar to those for the baseline scenario within the 10 Year Plan. However the assumptions underlying the two are not the same. For example the NAEI estimates assumed that the previous policy of the fuel duty escalator would continue until 2002. The 10 year Plan baseline only includes the impacts of the fuel duty escalator to 1999, after which the policy was changed. In addition, the NAEI estimates also do not take into account the effect on road traffic volumes of the policies in the Government's Integrated Transport White Paper (DETR, 1998). More details on the Plan baseline can be found in the background document (DETR 2000b).

Figure 1. Site specific projections of annual mean NOx and NO2 at West London using NAEI national projections of traffic emissions (ugm-3)

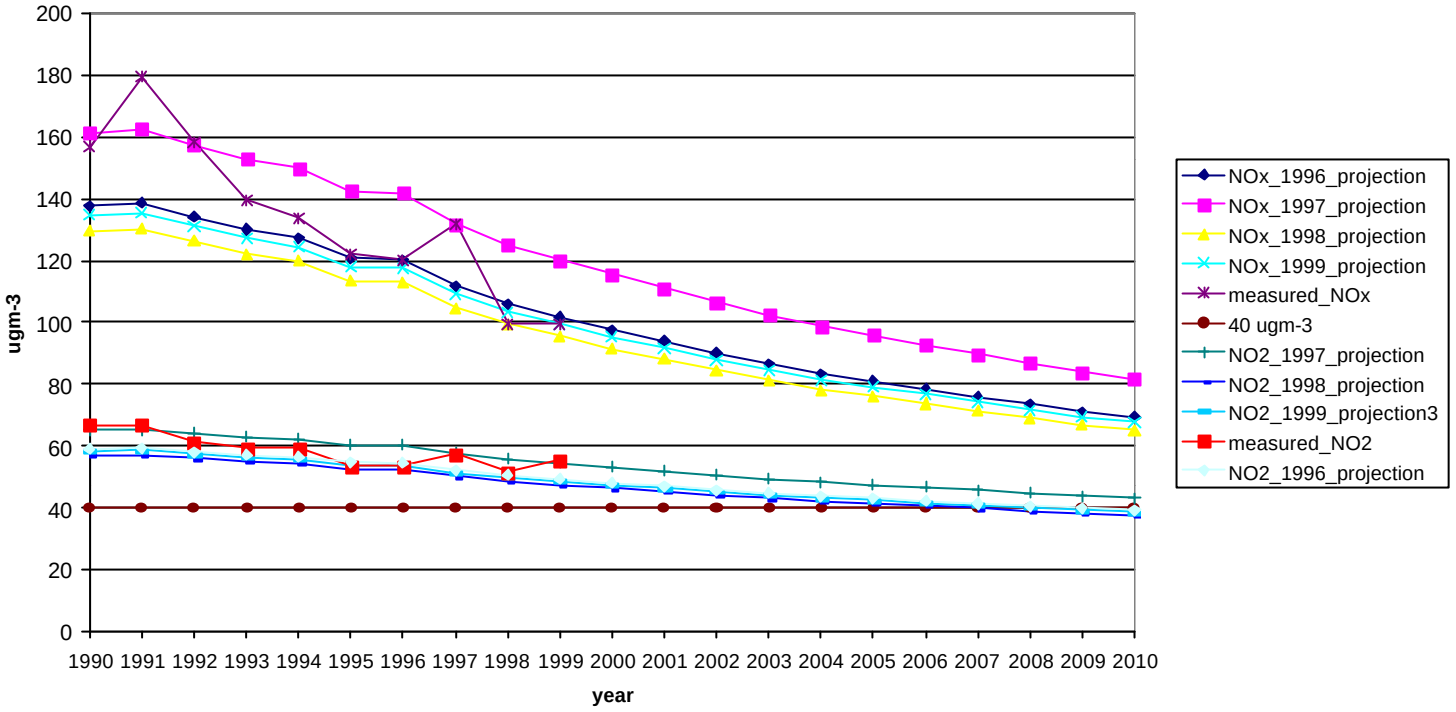


Figure 2. Site specific projections of annual mean NOx and NO2 at Birmingham Centre using NAEI national projections of traffic emissions (ugm-3)

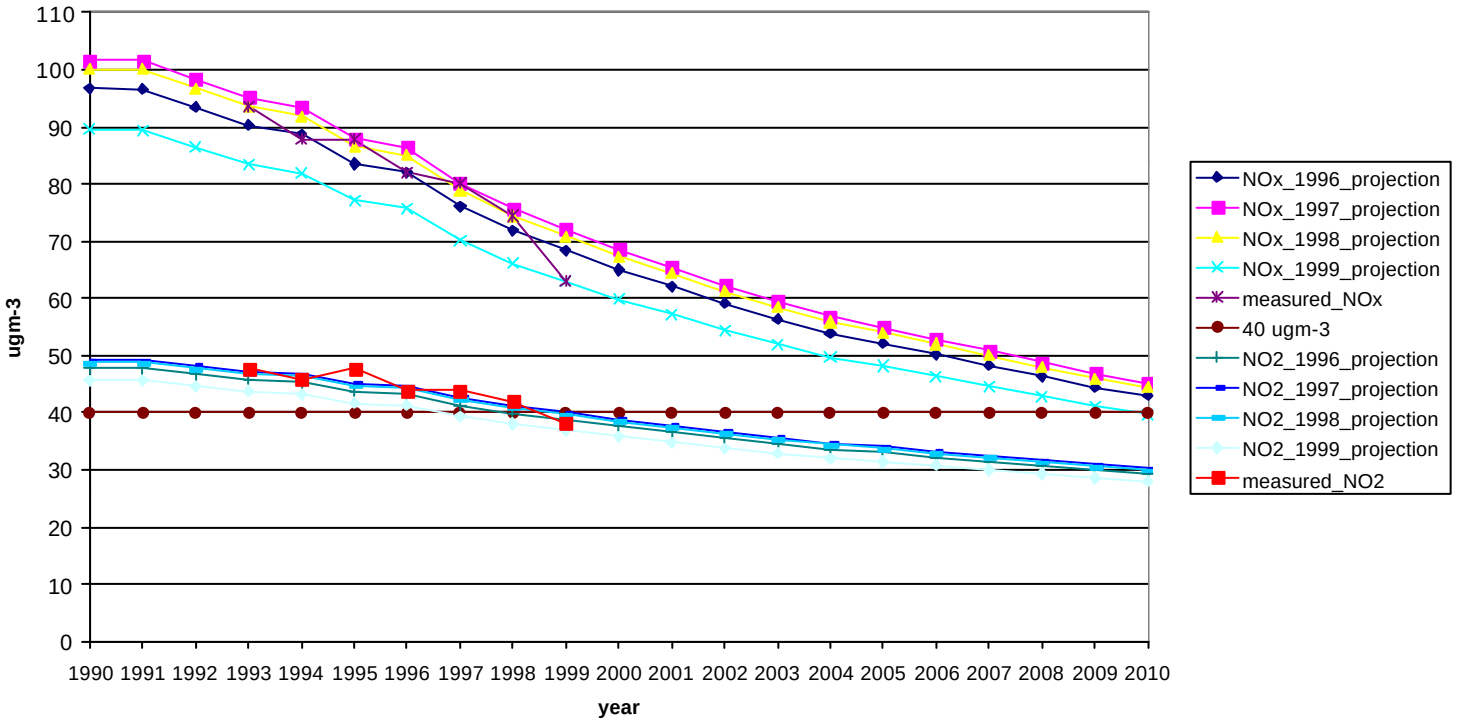
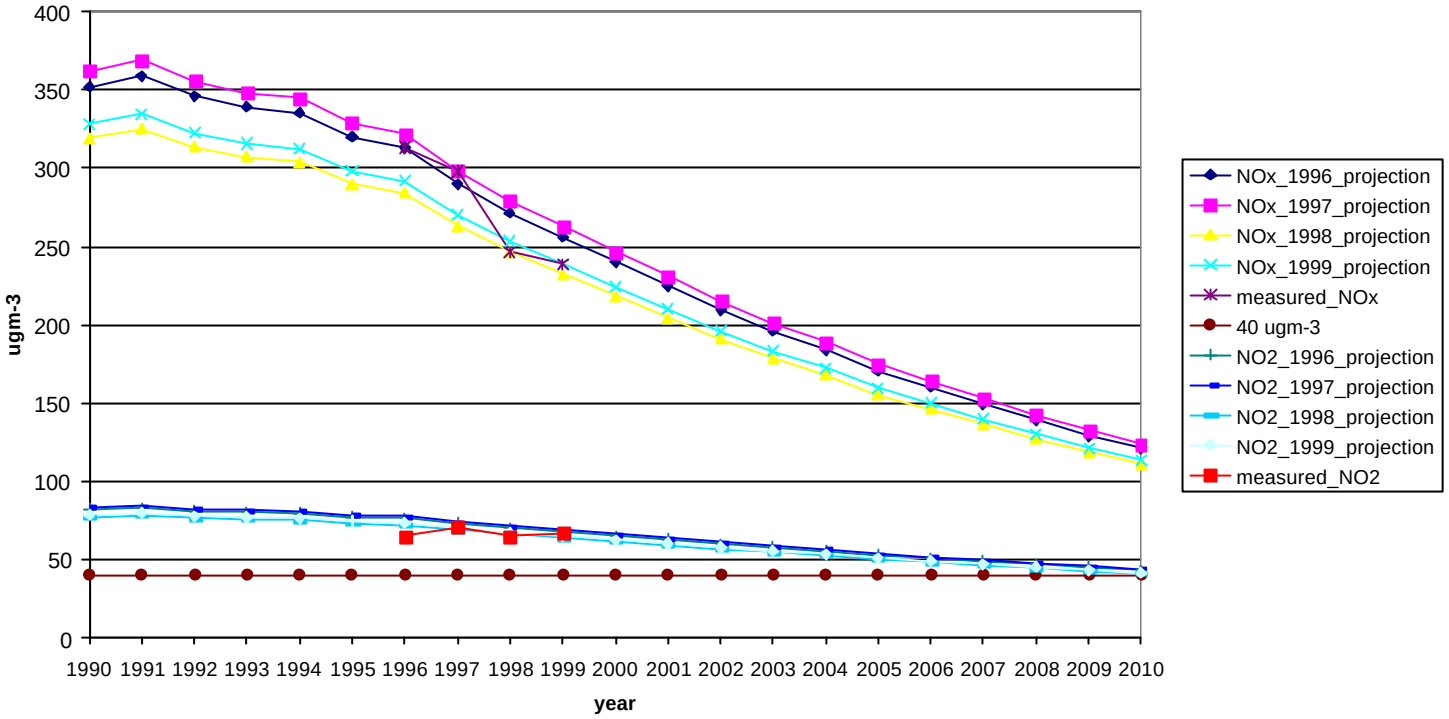


Figure 3. Site specific projections of annual mean NOx and NO2 at Tower Hamlets Roadside using NAEI national projections of traffic emissions (ugm-3)



4 Site Specific PM_{10} Projections: Method

4.1 THE APEG RECEPTOR MODEL

The site specific projections presented here were based on the receptor modelling methods that we developed within the framework of the Airborne Particles Expert Group (APEG, 1999, Stedman et al, 1998). A regression analysis has been carried out to divide measured daily average PM_{10} concentrations (as measured by TEOM or equivalent monitor) into three components:

- primary combustion PM_{10} (from co-located NO_x measurements)
- secondary PM_{10} (from rural sulphate measurements)
- 'other' PM_{10} (the residual)

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

$$[\text{measured } PM_{10} \text{ (mg m}^{-3})] = A.[\text{measured } NO_x \text{ (mg m}^{-3})] + B.[\text{measured sulphate (mg m}^{-3})] + C \text{ (mg m}^{-3})$$

These coefficients were then used to divide the measured concentration into the three components. This analysis has been completed for the years 1996 to 1999 inclusive at a range of UK national network monitoring sites.

4.2 PROJECTING CONCENTRATIONS

Each component of the daily average PM_{10} concentration was then projected from the measurements in 1996, 1997, 1998 and 1999 to provide estimates of concentrations in 2010.

Maps of primary PM_{10} emissions for 1997 from the NAEI (Goodwin et al, 1999) were used to determine the sectors (road traffic, domestic and services, industry, others) contributing to local primary combustion PM_{10} at each monitoring site location. Road traffic typically contributed about 75% of emissions in large urban areas in 1997. The emissions for each sector were projected forwards by reference to emissions for non-traffic sector for different years. Published emission estimates for each sector are available from the NAEI for the years up to and including 1998 (Goodwin et al, 1999). Emissions from non-traffic sources for years between 1998 and 2010 have been derived from DTI (2000) and estimated within the NAEI. These estimates therefore incorporate an assumed growth in economic activity of about 2.5% per year and the continuation of current trends towards greater use of natural gas and cleaner technologies DTI (2000). We have estimated that non-traffic emissions in 2010 will be approximately 70% of those in 1998. Estimates of road traffic emissions were taken from Table 3.

Secondary particle concentrations in previous years were derived from the network means of rural measurements of sulphate (at 8 sites) and nitrate (total inorganic nitrate at 2 sites). Concentrations of sulphate and nitrate in future years were derived from European scale modelling work for 1997 and 2010 carried out at Imperial College. The calculated values for 2010 incorporate the emissions reductions set out within the so-called 'Gothenburg Protocol' to Abate Acidification, Eutrophication and Ground-level Ozone. We have assumed a linear decline in concentrations from 1997 to 2010. Table 4 shows the measured and estimated sulphate and nitrate concentrations that we have used, normalised to 1997.

Table 4. UK annual mean sulphate and nitrate concentrations, 1997 = 1.

year	sulphate	nitrate
1993	1.182	1.151
1994	1.212	0.798
1995	1.182	0.824
1996	1.273	1.025
1997	1.000	1.000
1998	0.777	0.815
1999	0.702	0.951
2000	0.892	0.926
2001	0.855	0.902
2002	0.819	0.877
2003	0.783	0.852
2004	0.747	0.828
2005	0.711	0.803
2006	0.675	0.778
2007	0.639	0.754
2008	0.602	0.729
2009	0.566	0.705
2010	0.530	0.680

The split between sulphate and nitrate at each site for each year from 1996 to 1999 was derived from the receptor model coefficient B. This coefficient relates secondary PM_{10} concentrations to measured sulphate concentrations. If all of the measured secondary PM_{10} were ammonium sulphate, then this coefficient would be approximately 1.3. This coefficient was generally found to be in the range from 2 to 3, the remaining secondary PM_{10} was assumed to be nitrate.

We assumed that there will be no change in coarse particle concentrations.

Figure 4 shows illustrative site specific projections of annual mean PM_{10} concentrations for the London Bloomsbury site. It is clear that there is good agreement between the projections for the years 1993 to 1999 and the measured values for these years. The projections track both the year to year variability in concentrations due to changes in the meteorology that influences secondary particle concentrations and the changes in concentrations due to reductions in emissions. The projections based on 1996 monitoring data are the highest; projections based on 1998 and 1999 data are lower.

The site specific analysis for PM_{10} is of daily means, which allows us to estimate future daily concentrations directly, and thus the number of exceedences of 50 μgm^{-3}. The analysis is based on TEOM data, so we have applied a scaling factor of 1.3 to all data before comparing with the limit value (which is based on gravimetric measurement), as suggested by APEG (1999). Figure 5 shows illustrative site specific projections of the number of days with PM_{10} concentrations greater than or equal to 50 μgm^{-3} (gravimetric) at London Bloomsbury. The measured number of exceedences is relatively constant from 1992 to 1996, which 1996 having the largest number of exceedences. The number of days with concentrations greater than or equal to 50 μgm^{-3} then declined rapidly to about 20 in 1998 and 1999. The projected concentrations also show this decline, although projections based on 1996 or 1997 are consistently higher than those based on 1998 or 1999. High concentrations during 1997 were dominated by primary particle episodes, as demonstrated by the steep decline from 1993 to 1998 for projections based on 1997.

Figure 6 shows site specific projections of the number of days with PM_{10} concentrations greater than or equal to 50 μgm^{-3} (gravimetric) at Bristol Centre. Once again it is clear that the combination of the APEG receptor model and the emissions estimates and projections can be used to explain the trend in the measured concentrations.

The projections of traffic emissions used to calculate the illustrative results shown in shown in Figures 4 to 7 are NAEI estimates (Murrells, 2000), which are based 1997 National Road Traffic Forecasts for Great Britain (DETR 1997). These projections pre-date the area type specific emissions projections for England listed in Table 3 and do not reflect any of the measures specified in the 10 Year Plan. The advantage of these NAEI projections is that they are available for all years from 1990 to 2010 and facilitate the comparison with measurement data (the 10 Year Plan emissions estimates are currently only available for 1996, 2000 and 2010). This enables the profile of projected concentrations changes to be compared with past trends an assessment of concentrations in years such as 2004 for which AQS objectives have been set The NAEI projections for 2010 are similar to those for the baseline scenario within the 10 Year Plan. However the assumptions underlying the two are not the same. For example the NAEI estimates assumed that the previous policy of the fuel duty escalator would continue until 2002. The 10 year Plan baseline only includes the impacts of the fuel duty escalator to 1999, after which the policy was changed. In addition, the NAEI estimates also do not take into account the effect on road traffic volumes of the policies in the Government's Integrated Transport White Paper (DETR, 1998). More details on the Plan baseline can be found in the background document (DETR 2000b).

4.3 PROJECTIONS FOR ROADSIDE MONITORING SITES

Site specific projections for roadside monitoring sites have also been calculated. Daily averages of measured PM_{10} at a nearby background monitoring site have been subtracted from the concentrations measured at roadside monitoring sites in order to determine the roadside increment of daily PM_{10}. It is not possible to determine the split of the roadside increment between traffic exhaust emissions and re-suspended dusts from current network measurements. Analyses of PM_{10} and $PM_{2.5}$ monitoring data presented in the APEG report suggested that re-suspended component could be 50% of the total. It is likely that this is an overestimate because exhaust emission may include some particles of diameter greater than 2.5 μm. We have assumed that re-suspended dust contributed 25% of the roadside increment of PM_{10} concentrations in 1997. We have projected this roadside increment forward on the basis that this component will

not change in future years, unlike the remaining 75% of the roadside increment, which will decline in line with reductions in exhaust emissions.

Figure 7 shows projections for the Bury Roadside monitoring site. The projections closely mirror the steep decline in the measured numbers of exceedences.

Figure 4. Site specific projections of annual mean PM10 at London Bloomsbury using NAEI national projections of traffic emissions (ugm-3, gravimetric)

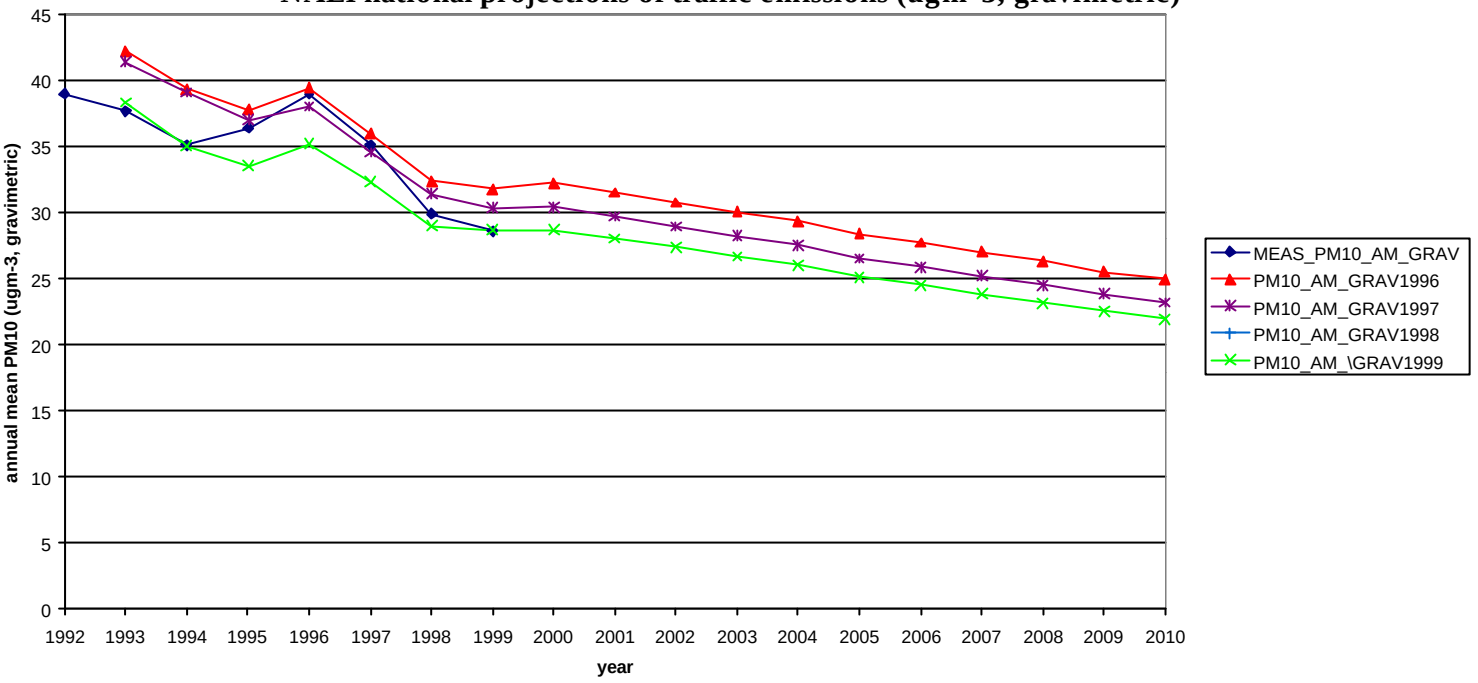


Figure 5. Site specific projections of PM10 days above 50 ugm-3 at London Bloomsbury using NAEI national projections of traffic emissions

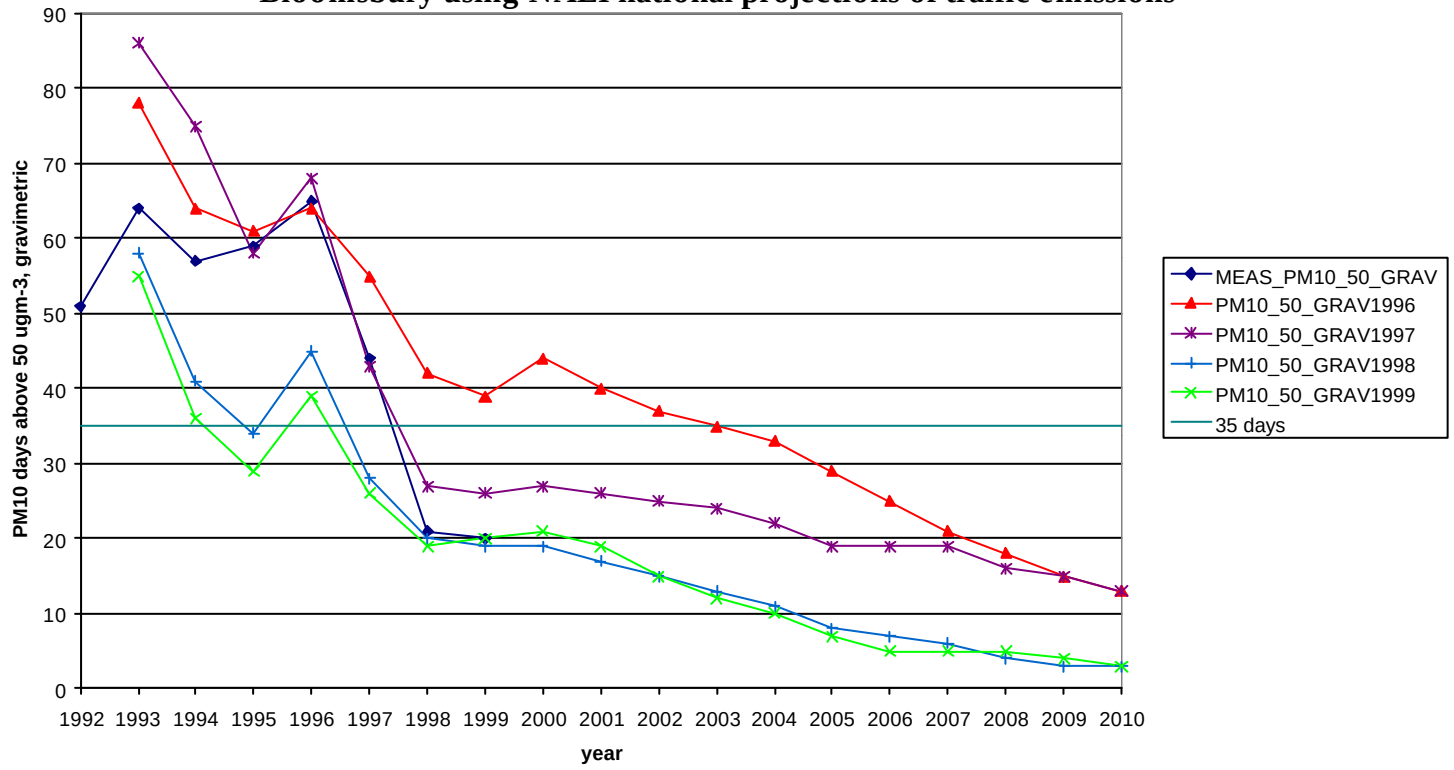


Figure 6. Site specific projections of PM10 days above 50 ugm-3 at Bristol Centre using NAEI national projections of traffic emissions

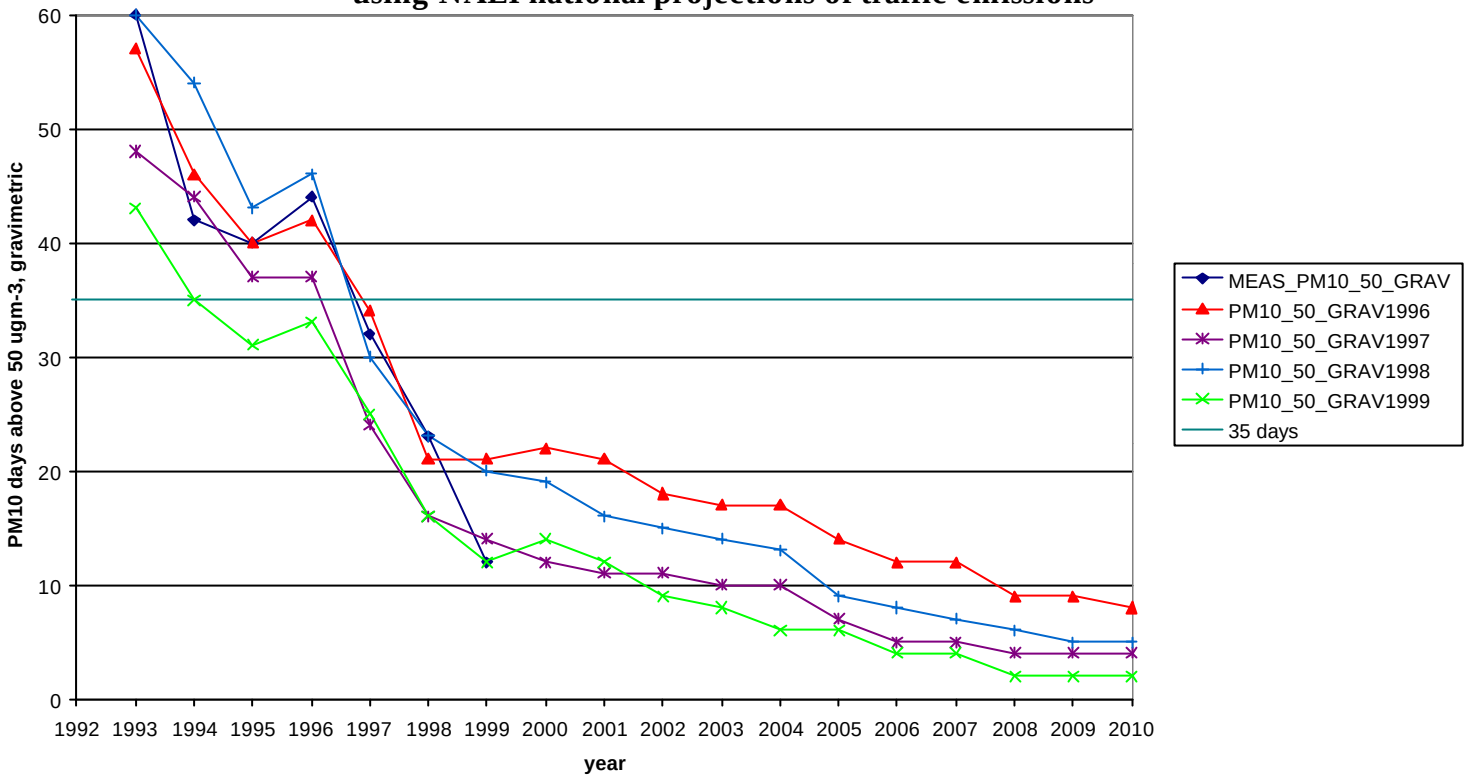
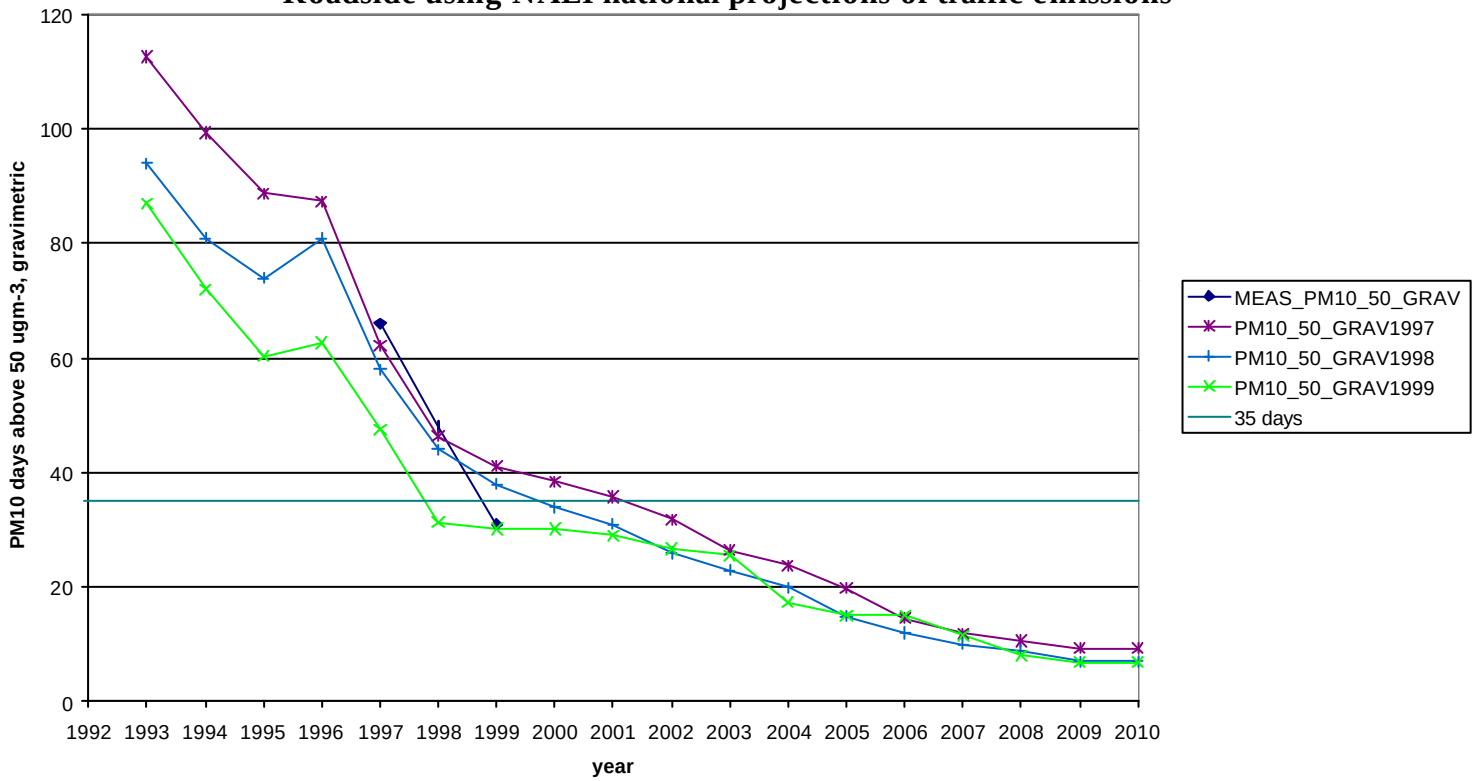


Figure 7. Site specific projections of PM10 days above 50 ugm-3 at Bury Roadside using NAEI national projections of traffic emissions



5 Site Specific NO_2 Projections for the 10 Year Plan

Site specific projections of annual mean NO_x and NO_2 concentrations, in μgm^{-3}, in 2010 for the baseline and plan scenarios are listed in Table 5. Projections for the illustrative constant cost and combined scenarios are listed in Tables 6 and 7. Projections have been derived from 1996, 1997, 1998 and 1999 monitoring data. Section 7 explains how these results have been drawn together to produce the estimates for the Background Paper. These tables also include projections based on the NAEI estimates of traffic emissions (Murrells, 2000), which are based on the 1997 National Road Traffic Forecasts (DETR, 1997), as discussed above. A blank entry in the tables indicates that projections have not been calculated because either the scenario is not applicable to a site in that area type (e.g. scenario D at Birmingham Centre), or monitoring data are not available for that year (e.g. 1996 at Marylebone Road).

Table 5. NO_x and NO_2 projections to 2010 based on emissions reductions by area type forecast in the Plan scenario

			NO_x Annual mean (μgm^{-3})				NO_2 Annual mean (μgm^{-3})			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
Birmingham Centre	4	NAEI	43.1	45.3	44.6	39.8	29.4	30.3	30.0	28.1
		Baseline	42.7	45.0	44.2	39.5	29.3	30.2	29.9	27.9
		Plan	41.7	43.9	43.1	38.6	28.8	29.7	29.4	27.5
		Scenario A	41.6	43.8	43.1	38.5	28.8	29.7	29.4	27.5
		Scenario B	41.7	43.9	43.2	38.6	28.8	29.7	29.5	27.5
		Scenario C	41.8	44.0	43.3	38.6	28.9	29.8	29.5	27.6
		Scenario D								
		Scenario E	42.0	44.2	43.5	38.9	29.0	29.9	29.6	27.7
Bridge Place	1	NAEI	76.3	83.3	68.7	72.8	44.2	47.0	41.0	42.7
		Baseline	77.0	84.1	69.3	73.5	44.5	47.3	41.3	43.0
		Plan	73.7	80.5	66.4	70.3	43.1	45.8	40.1	41.7
Bristol Centre	6	NAEI	59.0	69.9	54.8	50.2	35.5	39.3	34.0	32.3
		Baseline	57.6	68.2	53.5	49.0	35.0	38.8	33.5	31.8
		Plan	56.6	67.1	52.6	48.2	34.7	38.4	33.2	31.5
		Scenario A	56.3	66.6	52.3	47.9	34.5	38.2	33.1	31.4
		Scenario B	56.5	66.9	52.5	48.1	34.6	38.3	33.1	31.4
		Scenario C	56.7	67.1	52.7	48.3	34.7	38.4	33.2	31.5
		Scenario D	56.7	67.2	52.7	48.3	34.7	38.4	33.2	31.5
		Scenario E	56.9	67.4	52.9	48.4	34.8	38.5	33.3	31.6
Cromwell Road (Roadside)	1	NAEI	136.0		101.7	116.4	46.3		38.9	42.2
		Baseline	139.7		104.3	119.4	47.1		39.5	42.9
		Plan	123.0		92.3	105.4	43.6		36.7	39.8
Haringey Roadside	3	NAEI	66.9	78.5	65.8	63.6	30.3	33.3	30.0	29.4
		Baseline	64.5	75.5	63.4	61.3	29.6	32.6	29.3	28.7
		Plan	62.1	72.6	61.1	59.1	28.9	31.8	28.7	28.1
Hull Centre	6	NAEI	55.3	52.8	52.3	49.7	34.2	33.2	33.0	32.1
		Baseline	54.1	51.7	51.2	48.7	33.7	32.8	32.6	31.7
		Plan	53.3	51.0	50.4	47.9	33.4	32.5	32.3	31.4
		Scenario A	53.0	50.7	50.1	47.7	33.3	32.4	32.2	31.3
		Scenario B	53.2	50.9	50.3	47.9	33.4	32.5	32.3	31.3
		Scenario C	53.3	51.0	50.4	48.0	33.4	32.5	32.3	31.4
		Scenario D	53.4	51.0	50.5	48.0	33.5	32.6	32.4	31.4
		Scenario E	53.5	51.1	50.6	48.1	33.5	32.6	32.4	31.4
Leeds Centre	4	NAEI	58.8	68.4	59.3	54.1	35.4	38.8	35.6	33.7
		Baseline	58.3	67.8	58.8	53.6	35.3	38.6	35.5	33.6
		Plan	56.7	66.0	57.2	52.2	34.7	38.0	34.9	33.0
		Scenario A	56.6	65.9	57.2	52.1	34.7	38.0	34.9	33.0
		Scenario B	56.7	66.0	57.3	52.2	34.7	38.0	34.9	33.0
		Scenario C	56.8	66.2	57.4	52.4	34.7	38.1	34.9	33.1
		Scenario D								
		Scenario E	57.2	66.6	57.7	52.7	34.9	38.2	35.1	33.2
Liverpool Centre	4	NAEI	73.6	81.8	76.2	82.4	40.6	43.2	41.4	43.4
		Baseline	73.5	81.6	76.0	82.2	40.5	43.2	41.4	43.3
		Plan	72.9	81.0	75.4	81.5	40.3	43.0	41.2	43.1
		Scenario A	72.9	80.9	75.4	81.5	40.3	42.9	41.2	43.1
		Scenario B	72.9	81.0	75.4	81.5	40.3	43.0	41.2	43.1
		Scenario C	72.9	81.0	75.5	81.6	40.4	43.0	41.2	43.2

Table 5. NO_x and NO_2 projections to 2010 based on emissions reductions by area type forecast in the Plan scenario

			NO_x Annual mean (μgm^{-3})				NO_2 Annual mean (μgm^{-3})			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
		Scenario D								
		Scenario E	73.1	81.2	75.6	81.7	40.4	43.0	41.2	43.2
Manchester Town Hall	4	NAEI	63.3	67.9	58.0	55.8	37.1	38.7	35.2	34.4
		Baseline	63.0	67.6	57.7	55.6	36.9	38.6	35.1	34.3
		Plan	62.0	66.6	56.8	54.7	36.6	38.2	34.7	34.0
		Scenario A	61.9	66.5	56.8	54.6	36.6	38.2	34.7	33.9
		Scenario B	62.0	66.6	56.9	54.7	36.6	38.2	34.7	34.0
		Scenario C	62.1	66.7	56.9	54.8	36.6	38.2	34.8	34.0
		Scenario D								
		Scenario E	62.3	66.9	57.1	55.0	36.7	38.3	34.8	34.1
Marylebone Road (Roadside)	1	NAEI			173.2	188.4			53.6	56.3
		Baseline			177.7	193.4			54.4	57.2
		Plan			159.7	173.3			51.0	53.6
Sutton Roadside	3	NAEI	53.6	59.7	51.4	55.0	26.5	28.3	25.8	26.9
		Baseline	51.5	57.3	49.4	52.8	25.9	27.6	25.2	26.3
		Plan	49.4	54.9	47.4	50.7	25.3	26.9	24.6	25.6
Tower Hamlets (Roadside)	2	NAEI	121.4	124.3	111.4	114.1	43.3	43.9	41.1	41.7
		Baseline	122.2	125.2	112.2	114.9	43.5	44.1	41.3	41.9
		Plan	107.5	110.1	99.0	101.3	40.2	40.8	38.3	38.8
West London	2	NAEI	69.3	81.9	65.1	67.7	39.1	43.2	37.7	38.6
		Baseline	69.5	82.1	65.3	67.9	39.2	43.3	37.7	38.7
		Plan	66.1	78.0	62.0	64.6	38.0	42.0	36.6	37.5

Table 6. NO_x and NO_2 projections to 2010 based on emissions reductions by area type forecast in the Constant motoring costs scenario

			NO_x Annual mean (μgm^{-3})				NO_2 Annual mean (μgm^{-3})			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
Birmingham Centre	4	NAEI	43.1	45.3	44.6	39.8	29.4	30.3	30.0	28.1
		Baseline	42.7	45.0	44.2	39.5	29.3	30.2	29.9	27.9
		Constant cost	41.4	43.5	42.8	38.3	28.7	29.6	29.3	27.4
		Scenario A	41.3	43.4	42.7	38.2	28.7	29.6	29.3	27.4
		Scenario B	41.4	43.5	42.8	38.3	28.7	29.6	29.3	27.4
		Scenario C	41.5	43.6	42.9	38.4	28.8	29.7	29.4	27.5
		Scenario D								
		Scenario E	41.7	43.8	43.1	38.5	28.8	29.7	29.4	27.5
Bridge Place	1	NAEI	76.3	83.3	68.7	72.8	44.2	47.0	41.0	42.7
		Baseline	77.0	84.1	69.3	73.5	44.5	47.3	41.3	43.0
		Constant cost	72.8	79.4	65.5	69.4	42.7	45.4	39.7	41.3
Bristol Centre	6	NAEI	59.0	69.9	54.8	50.2	35.5	39.3	34.0	32.3
		Baseline	57.6	68.2	53.5	49.0	35.0	38.8	33.5	31.8
		Constant cost	55.9	66.2	52.0	47.6	34.4	38.1	32.9	31.2
		Scenario A	55.3	65.5	51.4	47.1	34.2	37.8	32.7	31.0
		Scenario B	55.9	66.2	51.9	47.6	34.4	38.1	32.9	31.2
		Scenario C	56.0	66.3	52.0	47.7	34.4	38.1	32.9	31.3
		Scenario D	56.0	66.4	52.1	47.7	34.4	38.1	33.0	31.3
		Scenario E	56.2	66.5	52.2	47.8	34.5	38.2	33.0	31.3
Cromwell Road (Roadside)	1	NAEI	136.0		101.7	116.4	46.3		38.9	42.2
		Baseline	139.7		104.3	119.4	47.1		39.5	42.9
		Constant cost	118.3		89.0	101.5	42.6		35.9	38.9
Haringey Roadside	3	NAEI	66.9	78.5	65.8	63.6	30.3	33.3	30.0	29.4
		Baseline	64.5	75.5	63.4	61.3	29.6	32.6	29.3	28.7
		Constant cost	58.8	68.6	57.9	56.0	28.0	30.7	27.8	27.2
Hull Centre	6	NAEI	55.3	52.8	52.3	49.7	34.2	33.2	33.0	32.1
		Baseline	54.1	51.7	51.2	48.7	33.7	32.8	32.6	31.7
		Constant cost	52.7	50.4	49.9	47.4	33.2	32.3	32.1	31.2
		Scenario A	52.2	49.9	49.4	47.0	33.0	32.1	31.9	31.0
		Scenario B	52.7	50.4	49.8	47.4	33.2	32.3	32.1	31.2
		Scenario C	52.8	50.4	49.9	47.5	33.2	32.3	32.1	31.2
		Scenario D	52.8	50.5	50.0	47.5	33.2	32.4	32.2	31.2
		Scenario E	52.9	50.6	50.1	47.6	33.3	32.4	32.2	31.2
Leeds Centre	4	NAEI	58.8	68.4	59.3	54.1	35.4	38.8	35.6	33.7
		Baseline	58.3	67.8	58.8	53.6	35.3	38.6	35.5	33.6
		Constant cost	56.2	65.4	56.8	51.8	34.5	37.8	34.7	32.9
		Scenario A	56.1	65.3	56.6	51.7	34.5	37.8	34.7	32.8
		Scenario B	56.2	65.4	56.8	51.8	34.5	37.8	34.7	32.9
		Scenario C	56.4	65.6	57.0	52.0	34.6	37.9	34.8	32.9
		Scenario D								
		Scenario E	56.7	65.9	57.2	52.2	34.7	38.0	34.9	33.0
Liverpool Centre	4	NAEI	73.6	81.8	76.2	82.4	40.6	43.2	41.4	43.4
		Baseline	73.5	81.6	76.0	82.2	40.5	43.2	41.4	43.3
		Constant cost	72.7	80.8	75.3	81.3	40.3	42.9	41.1	43.1
		Scenario A	72.7	80.7	75.2	81.3	40.3	42.9	41.1	43.1
		Scenario B	72.7	80.8	75.3	81.3	40.3	42.9	41.1	43.1
		Scenario C	72.8	80.8	75.3	81.4	40.3	42.9	41.1	43.1

Table 6. NO_x and NO_2 projections to 2010 based on emissions reductions by area type forecast in the Constant motoring costs scenario

			NO_x Annual mean (μgm^{-3})				NO_2 Annual mean (μgm^{-3})			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
		Scenario D								
		Scenario E	72.9	80.9	75.4	81.5	40.3	43.0	41.2	43.1
Manchester Town Hall	4	NAEI	63.3	67.9	58.0	55.8	37.1	38.7	35.2	34.4
		Baseline	63.0	67.6	57.7	55.6	36.9	38.6	35.1	34.3
		Constant cost	61.7	66.2	56.6	54.4	36.5	38.1	34.6	33.9
		Scenario A	61.6	66.2	56.5	54.4	36.5	38.1	34.6	33.8
		Scenario B	61.7	66.3	56.6	54.4	36.5	38.1	34.6	33.9
		Scenario C	61.8	66.4	56.7	54.5	36.5	38.1	34.7	33.9
		Scenario D								
		Scenario E	62.0	66.5	56.8	54.7	36.6	38.2	34.7	33.9
Marylebone Road (Roadside)	1	NAEI			173.2	188.4			53.6	56.3
		Baseline			177.7	193.4			54.4	57.2
		Constant cost			154.6	167.7			50.0	52.5
Sutton Roadside	3	NAEI	53.6	59.7	51.4	55.0	26.5	28.3	25.8	26.9
		Baseline	51.5	57.3	49.4	52.8	25.9	27.6	25.2	26.3
		Constant cost	46.6	51.7	44.7	47.7	24.4	25.9	23.8	24.7
Tower Hamlets (Roadside)	2	NAEI	121.4	124.3	111.4	114.1	43.3	43.9	41.1	41.7
		Baseline	122.2	125.2	112.2	114.9	43.5	44.1	41.3	41.9
		Constant cost	102.7	105.1	94.6	96.8	39.2	39.7	37.3	37.8
West London	2	NAEI	69.3	81.9	65.1	67.7	39.1	43.2	37.7	38.6
		Baseline	69.5	82.1	65.3	67.9	39.2	43.3	37.7	38.7
		Constant cost	64.9	76.6	61.0	63.5	37.6	41.6	36.2	37.1

Table 7. NO_x and NO_2 projections to 2010 based on emissions reductions by area type forecast in the combined scenario

			NO_x Annual mean (μgm^{-3})				NO_2 Annual mean (μgm^{-3})			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
Birmingham Centre	4	NAEI	43.1	45.3	44.6	39.8	29.4	30.3	30.0	28.1
		Baseline	42.7	45.0	44.2	39.5	29.3	30.2	29.9	27.9
		Combined	41.3	43.5	42.8	38.2	28.7	29.6	29.3	27.4
		Scenario A	41.3	43.4	42.7	38.2	28.7	29.6	29.3	27.4
		Scenario B	41.3	43.5	42.8	38.2	28.7	29.6	29.3	27.4
		Scenario C	41.5	43.6	42.9	38.3	28.7	29.6	29.3	27.4
		Scenario D								
		Scenario E	41.4	43.6	42.9	38.3	28.7	29.6	29.3	27.4
Bridge Place	1	NAEI	76.3	83.3	68.7	72.8	44.2	47.0	41.0	42.7
		Baseline	77.0	84.1	69.3	73.5	44.5	47.3	41.3	43.0
		Combined	72.8	79.4	65.5	69.4	42.7	45.4	39.7	41.3
Bristol Centre	6	NAEI	59.0	69.9	54.8	50.2	35.5	39.3	34.0	32.3
		Baseline	57.6	68.2	53.5	49.0	35.0	38.8	33.5	31.8
		Combined	55.9	66.2	51.9	47.6	34.4	38.1	32.9	31.2
		Scenario A	55.3	65.5	51.5	47.1	34.2	37.8	32.7	31.1
		Scenario B	55.8	66.1	51.9	47.5	34.4	38.0	32.9	31.2
		Scenario C	56.0	66.3	52.0	47.7	34.4	38.1	32.9	31.3
		Scenario D	56.0	66.3	52.0	47.7	34.4	38.1	32.9	31.3
		Scenario E	55.9	66.3	52.0	47.6	34.4	38.1	32.9	31.3
Cromwell Road (Roadside)	1	NAEI	136.0		101.7	116.4	46.3		38.9	42.2
		Baseline	139.7		104.3	119.4	47.1		39.5	42.9
		Combined	118.3		89.0	101.5	42.6		35.9	38.9
Haringey Roadside	3	NAEI	66.9	78.5	65.8	63.6	30.3	33.3	30.0	29.4
		Baseline	64.5	75.5	63.4	61.3	29.6	32.6	29.3	28.7
		Combined	58.8	68.6	57.9	56.0	28.0	30.7	27.8	27.2
Hull Centre	6	NAEI	55.3	52.8	52.3	49.7	34.2	33.2	33.0	32.1
		Baseline	54.1	51.7	51.2	48.7	33.7	32.8	32.6	31.7
		Combined	52.7	50.4	49.8	47.4	33.2	32.3	32.1	31.2
		Scenario A	52.2	49.9	49.4	47.0	33.0	32.1	31.9	31.0
		Scenario B	52.6	50.3	49.8	47.3	33.2	32.3	32.1	31.1
		Scenario C	52.8	50.4	49.9	47.5	33.2	32.3	32.1	31.2
		Scenario D	52.8	50.4	49.9	47.5	33.2	32.3	32.1	31.2
		Scenario E	52.7	50.4	49.9	47.4	33.2	32.3	32.1	31.2
Leeds Centre	4	NAEI	58.8	68.4	59.3	54.1	35.4	38.8	35.6	33.7
		Baseline	58.3	67.8	58.8	53.6	35.3	38.6	35.5	33.6
		Combined	56.2	65.4	56.7	51.8	34.5	37.8	34.7	32.8
		Scenario A	56.1	65.3	56.7	51.7	34.5	37.8	34.7	32.8
		Scenario B	56.2	65.4	56.7	51.7	34.5	37.8	34.7	32.8
		Scenario C	56.4	65.6	56.9	51.9	34.6	37.9	34.8	32.9
		Scenario D								
		Scenario E	56.3	65.5	56.8	51.9	34.5	37.8	34.7	32.9
Liverpool Centre	4	NAEI	73.6	81.8	76.2	82.4	40.6	43.2	41.4	43.4
		Baseline	73.5	81.6	76.0	82.2	40.5	43.2	41.4	43.3
		Combined	72.7	80.8	75.2	81.3	40.3	42.9	41.1	43.1
		Scenario A	72.7	80.7	75.2	81.3	40.3	42.9	41.1	43.1
		Scenario B	72.7	80.8	75.2	81.3	40.3	42.9	41.1	43.1
		Scenario C	72.8	80.8	75.3	81.4	40.3	42.9	41.1	43.1

Table 7. NO_x and NO_2 projections to 2010 based on emissions reductions by area type forecast in the combined scenario

			NO_x Annual mean (μgm^{-3})				NO_2 Annual mean (μgm^{-3})			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
		Scenario D								
		Scenario E	72.7	80.8	75.3	81.4	40.3	42.9	41.1	43.1
Manchester Town Hall	4	NAEI	63.3	67.9	58.0	55.8	37.1	38.7	35.2	34.4
		Baseline	63.0	67.6	57.7	55.6	36.9	38.6	35.1	34.3
		Combined	61.7	66.2	56.6	54.4	36.5	38.1	34.6	33.8
		Scenario A	61.6	66.2	56.5	54.4	36.5	38.1	34.6	33.8
		Scenario B	61.7	66.2	56.5	54.4	36.5	38.1	34.6	33.8
		Scenario C	61.8	66.3	56.7	54.5	36.5	38.1	34.7	33.9
		Scenario D								
		Scenario E	61.7	66.3	56.6	54.5	36.5	38.1	34.7	33.9
Marylebone Road (Roadside)	1	NAEI			173.2	188.4			53.6	56.3
		Baseline			177.7	193.4			54.4	57.2
		Combined			154.6	167.7			50.0	52.5
Sutton Roadside	3	NAEI	53.6	59.7	51.4	55.0	26.5	28.3	25.8	26.9
		Baseline	51.5	57.3	49.4	52.8	25.9	27.6	25.2	26.3
		Combined	46.6	51.7	44.7	47.7	24.4	25.9	23.8	24.7
Tower Hamlets (Roadside)	2	NAEI	121.4	124.3	111.4	114.1	43.3	43.9	41.1	41.7
		Baseline	122.2	125.2	112.2	114.9	43.5	44.1	41.3	41.9
		Combined	102.7	105.1	94.6	96.8	39.2	39.7	37.3	37.8
West London	2	NAEI	69.3	81.9	65.1	67.7	39.1	43.2	37.7	38.6
		Baseline	69.5	82.1	65.3	67.9	39.2	43.3	37.7	38.7
		Combined	64.9	76.6	61.0	63.5	37.6	41.6	36.2	37.1

6 Site Specific PM_{10} Projections for the 10 Year Plan

Site specific projections of PM_{10} concentrations in 2010 for the baseline and plan scenarios are listed in Table 8. Projections for the illustrative constant cost and combined scenarios are listed in Tables 9 and 10. These projections have been derived from 1996, 1997, 1998 and 1999 monitoring data. Section 7 explains how these results have been drawn together to produce the estimates for the Background Paper. These tables also include projections based on the NAEI estimates of traffic emissions (Murrells, 2000), which are based on the 1997 National Road Traffic Forecasts (DETR, 1997), as discussed above. All concentrations are expressed in μgm^{-3}, gravimetric, or equivalent, units. A blank entry in the tables indicates that projections have not been calculated because either the scenario is not applicable to a site in that area type (e.g. scenario D at Birmingham Centre), or monitoring data are not available for that year (e.g. 1996 at Marylebone Road).

Table 8. PM_{10} projections to 2010 based on emissions reductions by area type forecast in the Plan scenario (gravimetric units)

			Annual mean (μgm^{-3})				Days above $50\mu gm^{-3}$			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
Birmingham Centre	4	NAEI	20.5	18.9	20.0	18.4	14	1	7	1
		Baseline	20.7	19.1	20.3	18.6	14	1	7	1
		Plan	20.5	18.9	20.0	18.4	14	1	7	1
		Scenario A	20.5	18.9	20.0	18.4	13	1	7	1
		Scenario B	20.5	18.9	20.0	18.4	14	1	7	1
		Scenario C	20.5	18.9	20.0	18.4	14	1	7	1
		Scenario D								
		Scenario E	20.5	19.0	20.1	18.5	14	1	7	1
Bristol Centre	6	NAEI	20.7	21.1	21.3	21.4	8	4	5	2
		Baseline	21.1	21.6	21.6	21.7	8	4	5	2
		Plan	20.9	21.4	21.5	21.5	8	4	5	2
		Scenario A	20.9	21.3	21.4	21.5	8	4	5	2
		Scenario B	20.9	21.4	21.5	21.5	8	4	5	2
		Scenario C	20.9	21.4	21.5	21.5	8	4	5	2
		Scenario D	20.9	21.4	21.5	21.6	8	4	5	2
		Scenario E	20.9	21.4	21.5	21.6	8	4	5	2
Bury Roadside	5	NAEI		24.5	24.8	23.7		9	7	7
		Baseline		24.8	25.0	23.8		9	7	7
		Plan		24.3	24.6	23.5		9	7	7
		Scenario A		24.3	24.6	23.5		9	7	7
		Scenario B		24.3	24.6	23.5		9	7	7
		Scenario C		24.3	24.6	23.5		9	7	7
		Scenario D		24.4	24.7	23.5		9	7	7
		Scenario E		24.4	24.7	23.5		9	7	7
Camden Roadside	2	NAEI		29.1	25.5	26.4		21	4	8
		Baseline		29.3	25.7	26.5		22	4	8
		Plan		28.4	25.0	25.8		20	4	7
Liverpool Centre	4	NAEI	21.8	21.7	22.1	20.8	11	7	5	1
		Baseline	22.0	22.0	22.4	20.9	11	8	5	1
		Plan	21.8	21.7	22.1	20.7	11	7	5	1
		Scenario A	21.7	21.7	22.1	20.7	11	7	5	1
		Scenario B	21.8	21.7	22.1	20.7	11	7	5	1
		Scenario C	21.8	21.7	22.1	20.8	11	7	5	1
		Scenario D								
		Scenario E	21.8	21.8	22.2	20.8	11	7	5	1
London Bloomsbury	1	NAEI	25.0	23.2	23.0	21.9	13	13	3	3
		Baseline	25.0	23.3	23.0	22.0	13	13	3	3
		Plan	24.4	22.5	22.4	21.4	12	11	3	3
Haringey Roadside	3	NAEI		23.2	22.0	22.1		10	6	2
		Baseline		23.6	22.3	22.4		11	6	4
		Plan		23.3	22.1	22.3		11	6	3
Manchester Piccadilly	4	NAEI	21.2	20.7	20.4	20.6	10	2	7	0
		Baseline	21.4	21.0	20.6	20.8	10	2	8	0
		Plan	21.1	20.7	20.3	20.6	10	2	7	0
		Scenario A	21.1	20.7	20.3	20.6	10	2	7	0
		Scenario B	21.2	20.7	20.3	20.6	10	2	7	0

Table 8. PM_{10} projections to 2010 based on emissions reductions by area type forecast in the Plan scenario (gravimetric units)

			Annual mean (μgm^{-3})				Days above $50\mu gm^{-3}$			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
		Scenario C	21.2	20.7	20.4	20.6	10	2	7	0
		Scenario D								
		Scenario E	21.2	20.8	20.4	20.7	10	2	7	0
Marylebone Road	1	NAEI			30.0	33.2			13	20
		Baseline			30.0	33.2			13	21
		Plan			28.5	31.3			12	19
Newcastle Centre	5	NAEI	18.5	18.8	18.3	16.9	9	0	2	3
		Baseline	18.7	19.0	18.5	17.0	9	1	2	3
		Plan	18.5	18.8	18.3	16.9	9	0	2	3
		Scenario A	18.4	18.8	18.3	16.9	9	0	2	3
		Scenario B	18.5	18.8	18.3	16.9	9	0	2	3
		Scenario C	18.5	18.8	18.3	16.9	9	0	2	3
		Scenario D								
		Scenario E	18.5	18.8	18.3	16.9	9	0	2	3
Rochester	11	NAEI	19.5	19.7	18.3	17.0	9	5	1	1
		Baseline	19.5	19.6	18.3	17.0	9	5	1	1
		Plan	19.5	19.6	18.3	17.0	9	5	1	1
Sutton Roadside	3	NAEI		21.6	21.0	20.7		8	3	0
		Baseline		21.9	21.3	20.9		8	3	0
		Plan		21.7	21.1	20.8		8	3	0

Table 9. PM_{10} projections to 2010 based on emissions reductions by area type forecast in the Constant motoring costs scenario (gravimetric units)

			Annual mean (μgm^{-3})				Days above $50\mu gm^{-3}$			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
Birmingham Centre	4	NAEI	20.5	18.9	20.0	18.4	14	1	7	1
		Baseline	20.7	19.1	20.3	18.6	14	1	7	1
		Constant cost	20.4	18.9	19.9	18.3	13	1	7	1
		Scenario A	20.4	18.8	19.9	18.3	13	1	7	1
		Scenario B	20.4	18.9	19.9	18.3	13	1	7	1
		Scenario C	20.5	18.9	20.0	18.4	13	1	7	1
		Scenario D								
		Scenario E	20.5	18.9	20.0	18.4	14	1	7	1
Bristol Centre	6	NAEI	20.7	21.1	21.3	21.4	8	4	5	2
		Baseline	21.1	21.6	21.6	21.7	8	4	5	2
		Constant cost	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario A	20.7	21.2	21.3	21.4	8	4	5	2
		Scenario B	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario C	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario D	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario E	20.9	21.3	21.4	21.5	8	4	5	2
Bury Roadside	5	NAEI		24.5	24.8	23.7		9	7	7
		Baseline		24.8	25.0	23.8		9	7	7
		Constant cost		24.1	24.5	23.4		9	6	6
		Scenario A		24.1	24.5	23.4		9	6	6
		Scenario B		24.1	24.5	23.4		9	6	6
		Scenario C		24.2	24.5	23.4		9	7	7
		Scenario D		24.2	24.5	23.4		9	7	7
		Scenario E		24.2	24.5	23.4		9	7	7
Camden Roadside	2	NAEI		29.1	25.5	26.4		21	4	8
		Baseline		29.3	25.7	26.5		22	4	8
		Constant cost		28.2	24.9	25.6		19	4	7
Liverpool Centre	4	NAEI	21.8	21.7	22.1	20.8	11	7	5	1
		Baseline	22.0	22.0	22.4	20.9	11	8	5	1
		Constant cost	21.7	21.6	22.0	20.7	11	7	5	1
		Scenario A	21.7	21.6	22.0	20.7	11	7	5	1
		Scenario B	21.7	21.6	22.0	20.7	11	7	5	1
		Scenario C	21.7	21.6	22.1	20.7	11	7	5	1
		Scenario D								
		Scenario E	21.8	21.7	22.1	20.7	11	7	5	1
London Bloomsbury	1	NAEI	25.0	23.2	23.0	21.9	13	13	3	3
		Baseline	25.0	23.3	23.0	22.0	13	13	3	3
		Constant cost	24.3	22.4	22.4	21.3	12	10	3	3
Haringey Roadside	3	NAEI		23.2	22.0	22.1		10	6	2
		Baseline		23.6	22.3	22.4		11	6	4
		Constant cost		23.1	21.9	22.1		10	6	2
Manchester Piccadilly	4	NAEI	21.2	20.7	20.4	20.6	10	2	7	0
		Baseline	21.4	21.0	20.6	20.8	10	2	8	0
		Constant cost	21.1	20.6	20.3	20.6	9	2	7	0
		Scenario A	21.1	20.6	20.3	20.6	9	2	7	0
		Scenario B	21.1	20.6	20.3	20.6	9	2	7	0

Table 9. PM_{10} projections to 2010 based on emissions reductions by area type forecast in the Constant motoring costs scenario (gravimetric units)

			Annual mean (μgm^{-3})				Days above $50\mu gm^{-3}$			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
		Scenario C	21.1	20.7	20.3	20.6	9	2	7	0
		Scenario D								
		Scenario E	21.2	20.7	20.3	20.6	10	2	7	0
Marylebone Road	1	NAEI			30.0	33.2			13	20
		Baseline			30.0	33.2			13	21
		Constant cost			28.3	31.0			12	18
Newcastle Centre	5	NAEI	18.5	18.8	18.3	16.9	9	0	2	3
		Baseline	18.7	19.0	18.5	17.0	9	1	2	3
		Constant cost	18.4	18.7	18.2	16.8	9	0	2	3
		Scenario A	18.4	18.7	18.2	16.8	9	0	2	3
		Scenario B	18.4	18.7	18.2	16.8	9	0	2	3
		Scenario C	18.4	18.7	18.3	16.9	9	0	2	3
		Scenario D								
		Scenario E	18.5	18.8	18.3	16.9	9	0	2	3
Rochester	11	NAEI	19.5	19.7	18.3	17.0	9	5	1	1
		Baseline	19.5	19.6	18.3	17.0	9	5	1	1
		Constant cost	19.5	19.6	18.3	17.0	9	5	1	1
Sutton Roadside	3	NAEI		21.6	21.0	20.7		8	3	0
		Baseline		21.9	21.3	20.9		8	3	0
		Constant cost		21.5	20.9	20.6		8	3	0

Table 10. PM_{10} projections to 2010 based on emissions reductions by area type forecast in the combined scenario (gravimetric units)

			Annual mean (μgm^{-3})				Days above $50\mu gm^{-3}$			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
Birmingham Centre	4	NAEI	20.5	18.9	20.0	18.4	14	1	7	1
		Baseline	20.7	19.1	20.3	18.6	14	1	7	1
		Combined	20.4	18.9	19.9	18.3	13	1	7	1
		Scenario A	20.4	18.8	19.9	18.3	13	1	7	1
		Scenario B	20.4	18.9	19.9	18.3	13	1	7	1
		Scenario C	20.5	18.9	20.0	18.4	13	1	7	1
		Scenario D								
		Scenario E	20.5	18.9	20.0	18.4	13	1	7	1
Bristol Centre	6	NAEI	20.7	21.1	21.3	21.4	8	4	5	2
		Baseline	21.1	21.6	21.6	21.7	8	4	5	2
		Combined	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario A	20.7	21.2	21.3	21.4	8	4	5	2
		Scenario B	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario C	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario D	20.8	21.3	21.4	21.5	8	4	5	2
		Scenario E	20.9	21.3	21.4	21.5	8	4	5	2
Bury Roadside	5	NAEI		24.5	24.8	23.7		9	7	7
		Baseline		24.8	25.0	23.8		9	7	7
		Combined		24.0	24.4	23.3		9	6	6
		Scenario A		24.0	24.4	23.3		9	6	6
		Scenario B		24.0	24.4	23.3		9	6	6
		Scenario C		24.1	24.4	23.3		9	6	6
		Scenario D								
		Scenario E		24.1	24.4	23.3		9	6	6
Camden Roadside	2	NAEI		29.1	25.5	26.4		21	4	8
		Baseline		29.3	25.7	26.5		22	4	8
		Combined		28.2	24.9	25.6		19	4	7
Liverpool Centre	4	NAEI	21.8	21.7	22.1	20.8	11	7	5	1
		Baseline	22.0	22.0	22.4	20.9	11	8	5	1
		Combined	21.7	21.6	22.0	20.7	11	7	5	1
		Scenario A	21.7	21.6	22.0	20.7	11	7	5	1
		Scenario B	21.7	21.6	22.0	20.7	11	7	5	1
		Scenario C	21.7	21.6	22.1	20.7	11	7	5	1
		Scenario D								
		Scenario E	21.7	21.7	22.1	20.7	11	7	5	1
London Bloomsbury	1	NAEI	25.0	23.2	23.0	21.9	13	13	3	3
		Baseline	25.0	23.3	23.0	22.0	13	13	3	3
		Combined	24.3	22.4	22.4	21.3	12	10	3	3
Haringey Roadside	3	NAEI		23.2	22.0	22.1		10	6	2
		Baseline		23.6	22.3	22.4		11	6	4
		Combined		23.1	21.9	22.1		10	6	2
Manchester Piccadilly	4	NAEI	21.2	20.7	20.4	20.6	10	2	7	0
		Baseline	21.4	21.0	20.6	20.8	10	2	8	0
		Combined	21.1	20.6	20.3	20.6	9	2	7	0
		Scenario A	21.1	20.6	20.3	20.6	9	2	7	0
		Scenario B	21.1	20.6	20.3	20.6	9	2	7	0

Table 10. PM_{10} projections to 2010 based on emissions reductions by area type forecast in the combined scenario (gravimetric units)

			Annual mean (μgm^{-3})				Days above $50\mu gm^{-3}$			
	Area Type	Scenario	1996	1997	1998	1999	1996	1997	1998	1999
		Scenario C	21.1	20.7	20.3	20.6	9	2	7	0
		Scenario D								
		Scenario E	18.4	18.8	18.3	16.9	9	0	2	3
Marylebone Road	1	NAEI	21.1	20.7	20.3	20.6	10	2	7	0
		Baseline			30.0	33.2			13	21
		Combined			28.3	31.0			12	18
Newcastle Centre	5	NAEI	18.5	18.8	18.3	16.9	9	0	2	3
		Baseline	18.7	19.0	18.5	17.0	9	1	2	3
		Combined	18.4	18.7	18.2	16.8	9	0	2	3
		Scenario A	18.4	18.7	18.2	16.8	9	0	2	3
		Scenario B	18.4	18.7	18.2	16.8	9	0	2	3
		Scenario C	18.4	18.7	18.3	16.9	9	0	2	3
		Scenario D								
		Scenario E	18.4	18.8	18.3	16.9	9	0	2	3
Rochester	11	NAEI	19.5	19.7	18.3	17.0	9	5	1	1
		Baseline	19.5	19.6	18.3	17.0	9	5	1	1
		Combined	19.5	19.6	18.3	17.0	9	5	1	1
Sutton Roadside	3	NAEI		21.6	21.0	20.7		8	3	0
		Baseline		21.9	21.3	20.9		8	3	0
		Combined		21.5	20.9	20.6		8	3	0

7 Discussion

We have used the estimates of emissions reductions for specific types of area (including London) to estimate concentrations of NO_2 and PM_{10}. We have only modelled the impact of reductions in emissions from road traffic. Taking into account the impact of increases in rail emissions would partly offset the estimated reductions in concentrations.

DETR 2000b explains that the estimates of road traffic emissions and concentrations reductions should be treated with caution. This is because DETR's strategic road traffic modelling work has necessarily had to make broad assumptions about how the key decision-makers, particularly local authorities and the Mayor of London, will choose to spend the funds being made available by the Plan. It is unlikely to represent accurately the decisions that those bodies will make in the context of their local transport strategies and air quality management plans. In practice expenditure might be more targeted on localised problems.

The forecast average percentage reductions in annual average concentrations for the various scenarios are listed in Table 11 along with the range. The averages were calculated by calculating a 4-year average percentage reduction in annual mean concentration for each site for the weighted scenarios and then calculating an average value across all the sites for which analysis has been carried out. Similarly the ranges represent the maximum and minimum

reductions in the 4-year average results across the range of monitoring sites. A similar process was followed for the un-weighted scenarios (A to E) to give a better indication of the likely range of reductions across individual sites. DETR 2000b quotes (paragraphs 74-75) the average reductions in concentrations for each scenario and the range from the un-weighted scenario analysis.

Table 11 Summary of percentage reductions in annual mean concentrations in 2010 relative to the baseline scenario

	Plan	Constant cost	Combined
NO_x			
Average of weighted scenarios	3.1	4.6	4.6
Range of weighted scenarios	0.9 to 7.3	1.2 to 9.8	1.2 to 9.8
Range of scenarios A to E	0.6 to 7.3	1.0 to 9.8	1.1 to 9.8
PM_{10}			
Average of weighted scenarios	1.8	2.3	2.4
Range of weighted scenarios	0.7 to 5.4	1.2 to 6.2	1.2 to 6.2
Range of scenarios A to E	0.6 to 5.4	1.0 to 6.2	1.1 to 6.2

The Plan is estimated to reduce annual average NO_2 concentrations by, on average 3.1% (range 0.6–7.3%), compared to the baseline in 2010, with the biggest reductions predicted at roadside sites. The illustrative scenarios are estimated to produce reductions of, on average, 4.6 % (range 1.0-9.8%). On the basis of the assumptions underlying our air quality modelling, there would still be areas in London (centrally and near very busy roads) where the EC limit value and the Air Quality Strategy objective would not be attained, and possibly also near heavily trafficked roads in other large cities.

Projections of annual mean NO_2 concentrations have been calculated using monitoring data from 1996, 1997, 1998 and 1999. The results in terms of percentage reductions in 2010 annual mean concentrations relative to the baseline were found to be similar for all base years. The year to year variation in reductions for the plan scenario at each site (the difference between the highest and lowest projected reduction in concentrations for the different base years) was on average 0.03 % (range 0 to 0.05 %) of the 2010 baseline concentration at background sites and 0.2 % (range 0.2 to 0.3 %) at roadside monitoring sites. The fact that this variation from year to year is small reflects that while absolute concentrations measured at a monitoring site may show considerable variation due to changes in meteorology, and thus dispersion conditions, a change in emissions can be expected to have an approximately proportional effect on the measured concentration.

There are two sets of EC Directive limit values for PM_{10} concentrations: mandatory Stage 1 limit values for 2005, and more stringent non mandatory "indicative" Stage 2 limit values for 2010. Our analysis has focussed on the Plan's contribution to achievement of the indicative annual mean Stage 2 limit value in 2010 - the timeframe of the Plan. Analyses presented in the Air Quality Strategy showed that this indicative limit value is likely to be widely exceeded across the country in 2010, with highest levels generally occurring next to heavily trafficked roads. Although higher levels of PM_{10} are generally recorded next to roads, transport emissions are only one contribution to a relatively high background concentration, which is made up of a wide variety of sources. Because of this, reductions in transport PM_{10} emissions do not

necessarily lead to a proportionate reduction in overall PM_{10} concentrations. The estimated reductions in concentrations arising from the Plan and illustrative scenarios are small: on average 1.8 % (range 0.6-5.4%) compared to the baseline for the Plan scenario; and on average 2.4 % (range 1.0-6.2%) under the illustrative scenarios. The reductions will nonetheless contribute to the Government's broader strategy of reducing PM_{10} levels, which involves addressing non-transport sources in the UK and emissions from the rest of Europe.

Annual mean PM_{10} concentrations show considerable year to year variability. Changes in emissions of primary PM_{10} from traffic may not have the same percentage impact on annual mean PM_{10} concentrations for different base years due to variations in other important contributions to ambient PM_{10} concentrations, such as secondary and coarse particles. The percentage reduction in annual mean concentration in 2010, relative to the baseline, is generally greatest for projections based on 1997 monitoring data. Of the four years studied, 1997 was the year with the largest relative contribution to total PM_{10} from primary particles. The year to year variation in reductions for the Plan scenario at each site was on average 0.5 % (range 0.3 to 0.9 %) of the 2010 baseline concentration at background sites and 0.5 % (range 0.2 to 0.8 %) at roadside monitoring sites.

8 Acknowledgement

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APPENDIX 1

THE RELATIONSHIPS BETWEEN ANNUAL MEAN NO_x AND NO_2 CONCENTRATIONS

Figure A1. Comparison of annual mean NOx and NO2 concentrations, for background sites with at least 3 years of data in 1998 (1990-1998)

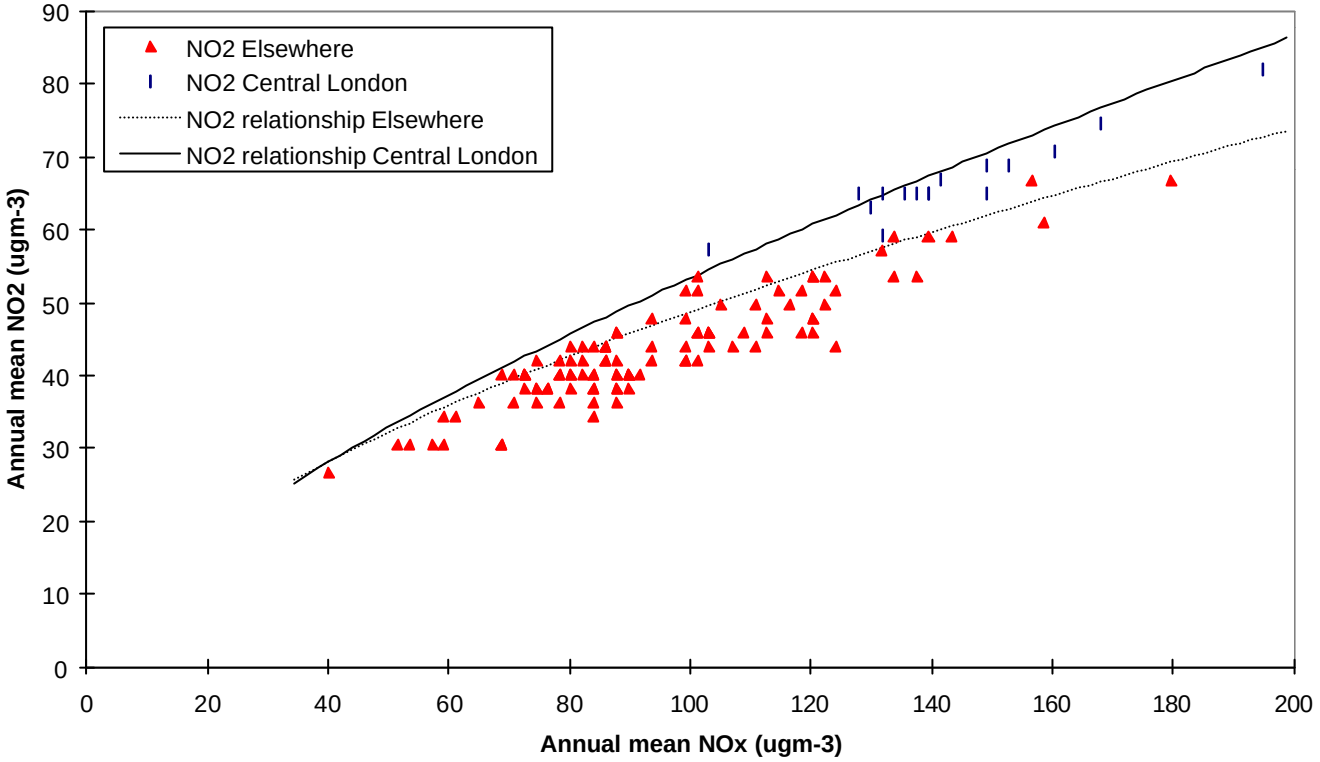

Figure A2. Comparison of annual mean NOx and NO2 concentrations, for roadside sites (1998-1999)