Stage 4 Review and Assessment for the Thurrock Council

King's College London

University of London

October 2003

ERG, King's College, London
Block 9, St. Thomas' Medical School,
Lambeth Palace Road, London
SE1 7EH

Tel: 0207 960 5511

This page had been left blank intentionally

Executive Summary

This is the Stage 4 report for the Thurrock Council, which fulfils the next step of the Local Air Quality Management (LAQM) process. Section 84(1) of the Environment Act 1995 requires the Council to undertake the Stage 4 assessment following the designation of its air quality management area (AQMA). The earlier Stage 3 report produced by the Council identified areas where the annual mean nitrogen dioxide and daily mean PM10 concentrations were predicted to exceed government objectives.

The report follows the guidance produced by the Department of Environment, Food and Rural Affairs (DEFRA) and this allows the Council to:

- confirm the original assessment of air quality against the prescribed objectives and thus to ensure that they were right to designate the AQMA in the first place;

- calculate more accurately how much of an improvement in air quality would be needed to deliver air quality objectives within the AQMA;

- refine the knowledge of the sources of pollution so that air quality action plans can be properly targeted;

- take account of any new national policy developments, which have come to light since the AQMA declaration and the Stage 3 report, were prepared;

- take account as far as possible of any new local policy developments which are likely to affect air quality by the relevant date, and which were not fully factored into the stage 3 report;

- respond to comments from statutory consultees in respect of the Stage 3 report;

- check the other assumptions previously made on which the designation of the AQMA has been based and to check that the designation is still correct;

- carry out further monitoring in problem areas to check earlier findings.

New modelling predictions have been made for the Stage 4, and these incorporate a series of improvements over and above that undertaken in Stage 3. These improvements include both improved modelling methods and treatment of emissions.

The Stage 4 modelling predictions confirm the Stage 3 findings that the Air Quality Strategy (AQS) Objective will be exceeded within most of the Council's 20 designated Air Quality Management Areas. The area where the 24-hour PM10 AQS objective is predicted to exceed however is smaller than the area where the annual mean NO_2

objective is predicted to exceed. Thus the modelling confirms that the annual mean NO_2 is the more stringent of the objectives that need to be met.

A series of locations have been chosen by the Council across its area to help understand the source contribution of oxides of nitrogen, (NO_x) and PM10. This assessment is for NO_x rather than nitrogen dioxide because the latter is mostly a secondary pollutant formed as a result of complicated atmospheric chemistry from the oxides of nitrogen. Based on the median façade result, approximately 44% of the total contribution is derived from background sources of NO_x and 56% from local road transport. The range of contributions related to background however varies greatly, and is between 16 and 76%, dependant on location. A significant proportion (i.e. approximately two thirds) of the background contribution also arises from roads including roads outside the Council's area.

A series of scenarios produced by the Council were also tested using the same modelling techniques. These were based on changes including new roads and other traffic flow alterations. The different scenarios produce improvements (i.e. reductions in pollutant concentrations) at some locations and also in one instance produce an increase in pollutants at one location.

Table of Contents

List of Figures

List of Tables

1 Introduction to Stage 4 – further assessment of air quality

~~1.1~~1.1 Overview to Stage 4

This is the Stage 4 report for the Thurrock Council. This report is intended to fulfil the statutory requirement for this, the Council's next step, of the Local Air Quality Management (LAQM) process.

~~1.2~~1.2 Background – national perspective

Section 84(1) of the Environment Act 1995 requires local authorities to undertake a further assessment, where the local authority has designated an air quality management area (AQMA); this is now termed the Stage 4 assessment. The Council designated twenty small Air Quality Management Areas by order across its area, following the production of its Stage 3 report. That report confirmed that areas across the borough were likely to exceed relevant future AQS objectives.

Under the Act local authorities are required to report the results of this assessment within 12 months of the designation by order of the AQMA. Section 84(1) requires the local authority to undertake the Stage 4 to supplement the information it has on the AQMA.

The Department of Environment, Food and Rural Affairs (DEFRA) has produced specific guidance on the Stage 4 assessment for local authorities (see www.defra.gov.uk/environment/airquality/laqm/stage4/index.htm).

The following provides a check list of the requirements for the Stage 4, as given in the DEFRA guidance:

- To allow the Council to confirm the original assessment of air quality against the prescribed objectives and thus to ensure that they were right to designate the AQMA in the first place;
- To calculate more accurately how much of an improvement in air quality would be needed to deliver air quality objectives within the AQMA;
- To refine the knowledge of the sources of pollution so that air quality action plans can be properly targeted;
- To take account of any new national policy developments, which have come to light since the AQMA declaration and the Stage 3 report, were prepared;

- To take account as far as possible of any new local policy developments which are likely to affect air quality by the relevant date, and which were not fully factored into the Stage 3 report;
- To respond to comments from statutory consultees in respect of the Stage 3 report;
- To check the other assumptions previously made on which the designation of the AQMAs has been based and to check that the designation is still correct;
- To carry out further monitoring in problem areas to check earlier findings.

1.3 Background – Thurrock Council perspective

The Council has undertaken the earlier stages of review and assessment of the Local Air Quality Management (LAQM) process within its area (see the individual Stage 1, 2 and 3 reports prepared between 1998 and 2000). These reports present the staged approach whereby the seven air pollutants in the Government's Air Quality Strategy (AQS) related to LAQM, were assessed and screened as to their relative importance to air quality within the Council's area.

The Stage 3 report assessed air quality across the whole of the Council's area in accordance with DEFRA (formerly DETR) guidance. The findings of the Stage 3 report were that the statutory objectives (see Table 1) for both nitrogen dioxide (NO_2) and PM10 were exceeded, specifically the annual mean objective for NO_2 and the 24-hour mean objective for PM10. The area predicted to exceed relates mainly to areas adjacent to major roads across the borough.

The other five AQS pollutants (benzene, 1,3 butadiene, carbon monoxide, lead and sulphur dioxide) were only considered at earlier stages of the review and assessment. The finding for all these pollutants was that none were found likely to lead to the AQS objectives being exceeded and therefore no further action was required in respect of these pollutants.

Table 1 Table of air quality objectives relevant to Stage 4

	Concentration	Measured as	Date to be achieved by
Nitrogen dioxide (NO_2)	40µg/m^3 (21ppb)	Annual mean	31-Dec-05
	200µg/m^3 (105ppb) not be exceeded more than 18 times a year	1 hour mean	31-Dec-05
Particles (PM10)[1]	40 µg/m^3	Annual mean	31-Dec-04
	50 µg/m^3 not to be exceeded more than 35 times a year	24 hour mean	31-Dec-04

The nitrogen dioxide objectives are routinely reported in ppb within this report as the modelling process evaluates the impact of changing meteorological conditions on the concentration of the gas in the atmosphere. A volumetric concentration is the most accurate means of describing the concentration of gaseous pollution in the atmosphere at any one time. The objectives are routinely referred to in the guidance as gravimetric concentrations, assuming that the conditions are equivalent to a set temperature and pressure of 20^{o}C and 101.3 kPa. In order to compare the modelling results presented within this report, to the national air quality objectives as reported in the guidance the formula below is used for converting ppb to µg/m^3 for nitrogen dioxide and nitric oxide.

Nitric oxide	1 ppb =	1.25 µg/m^3
Nitrogen dioxide*	1 ppb =	1.91 µg/m^3

*NOx in µg/m^3 is expressed as NO_2 i.e. (NOppb+NO_2ppb)*1.91 = NOx µg/m^3

Where comparison to the national air quality objectives is drawn, tables show values as ppb and µg/m^3.

1.4 National Policy Developments

There are a number of key developments that have taken place since the Stage 3 report was first produced.

The government released its revised Air Quality Strategy in January 2000. This revision included a reappraisal of the objective pollutants (DETR, 2000). As a result many of these were changed to reflect both the UK's commitments to the EU and also that the objectives for many of the pollutants were already being met or close to being met. One principal change however was the amendment of the previous PM10 objective to equate with both the EU Daughter Directive and an

[1] PM10 to be measured using the European gravimetric system or equivalent

improved scientific understanding. The effect of this was to make this objective far less stringent and therefore easier to meet than the previous objective.

Both the NO_2 and PM10 objectives however remained provisional, with the PM10 objective subject to a further review. The Environment Minister subsequently announced in January 2001 that the PM10 objective would remain to give local authorities a period of stability (ENDS, 2001), however consultation on a new objective for the longer term is already underway, following release of the latest Air Quality Strategy consultation for: particles, benzene, carbon monoxide and PAHs (polycyclic aromatic hydrocarbons) (DEFRA, 2001).

The latest health evidence shows that particles are likely to have significant long-term effects on health: probably many times more severe than the short-term effects on which policy has previously concentrated. The above mentioned consultation document explains the changes that the government proposes for the Strategy's objectives to take account of the latest health evidence. The proposals also seek to set a longer-term focus to the Strategy to reflect recent developments at the European Union (EU) level and to influence the development of wider policies that impact on air quality.

Of key importance to the Council are the proposals to strengthen substantially the AQS objectives for particles by supplementing the present objectives with new provisional objectives. These are:

- for all parts of the UK, except London and Scotland, a 24-hour mean of 50$\mu g/m^3$ not to be exceeded more than 7 times per year and an annual mean of 20$\mu g/m^3$, both to be achieved by the end of 2010;

- for London, a 24-hour mean of 50$\mu g/m^3$ not to be exceeded more than 10-14 times per year and an annual mean of 23-25$\mu g/m^3$, both to be achieved by the end of 2010.

In addition the government's Expert Panel on Air Quality Standards (EPAQS) separately reported on an appropriate measurement upon which to base the airborne particle standard. The Panel concluded that the metric PM10 should remain, although it should be kept under active review due to the likelihood of important advances in the understanding of particles and health in the next few years (EPAQS, 2001).

The government also revised the road traffic emission factors at the end of February 2002 and required their use by local authorities when reviewing and assessing local air quality. These are discussed further in the next section.

1.5 Use of New Emission Factors

On initial inspection the new factors as released appear to be quite different from the previous factors. Briefly, these cover:

- Petrol cars (small, medium and large) Euro I, Euro II and Euro III.
- Diesel cars: (small and large) Euro I, Euro II and Euro III.
- LGVs (petrol and diesel) Euro I
- HGVs (rigid and articulated) Euro I and Euro II.
- Buses: Euro I and Euro II

To provide a complete breakdown of Euro classes it is necessary to use the old factors for pre-Euro I vehicles. As a result the new factors for NO_X and PM10 were considered in detail.

By way of an example, initial calculations were made of the total road transport emissions in London based on the new factors for NO_X and PM_{10}. These have been based on the same flows and vehicle stock, with only the emissions factors changed.

For NO_X, the following observations can be made:

- Total emissions for 1999 have increased by over 25 %.
- All vehicle types show an increase in NO_X except motorcycles.
- The most significant increase is for HGV emissions.
- LGV are also significantly higher than previous estimates
- Re-calculated 2005 total emissions have increased significantly.

In summary the outcome is that there are increases in emissions of both pollutants.

These findings therefore have important implications for dispersion modelling and the management of emissions from road traffic sources. The application of the new factors would be expected to increase predicted concentrations for the future, although detailed modelling is required to quantify the magnitude of this increase. The effect on individual links could be large. For example, the increase in emissions for HGVs is likely to have a larger impact where the flows of HGVs are highest. Another important aspect is the allocation of emissions between the different vehicle classes. Compared with the previous inventory there are marked differences between the shares of emissions for different vehicle classes, particularly for PM10.

This page had been left blank intentionally

2 Predictions of Nitrogen Dioxide (NO_2) and Particles (PM10)

~~2.1~~2.1 Outline of modelling developments

The Stage 4 review represents significant progress beyond the Stage 3 report. As a summary the developments include:

- Major roads on an exact geographic basis Ordnance Survey (OS), to allow an improved assessment of exposure;
- Predictions plotted on OS base maps;
- Improved modelling methods;
- A best estimate of model uncertainty, using Monte Carlo techniques;
- Detailed estimates of effects of traffic management scenarios;
- Additional monitoring data for assisting the modelling.

A detailed explanation of the methods used, including the developments undertaken is given in the appendices.

2.2 Annual mean (ppb) in 2005

The predicted concentrations of annual average NO_2 for the 2005 base case, assuming that the meteorology of the year 1999 was repeated, are shown in Figure 1 below. The areas coloured yellow to red are those that exceed the AQS objective of 21 ppb. The predictions confirm the Stage 3 findings that the AQS objective will be exceeded adjacent to major roads across the borough. The predicted concentrations at specific locations are given in the next section.

It is clearly illustrated by Figure 1 that the major roads provide the most important contribution to concentrations of NO_2. It is also important to note that the locations of the major roads are modelled to a high degree of accuracy and in this case it is within 1m. This enables the concentration contours to be plotted with OS Landline data[2], which gives details of individual houses and allows easy estimation of the exposure of the local population to concentrations above the AQS objective. The pollution contours also show the rapid fall off in concentration from the road and the effect of increased concentrations close to road junctions, where the emissions of two or more roads combine and where slow moving, congested traffic is more likely to occur.

The one-hour mean has not been modelled in this report, as the predictions in the Stage 3 report were below the objective level. This previous analysis is further confirmed by the most recent monitoring results from the London Air Quality Monitoring Network sites, which are presented in Appendix F.

[2] Note – these are reproduced from the Ordnance Survey map with the permission of Her Majesty's Stationery Office, Crown Copyright reserved. Unauthorised production infringes Crown Copyright and may lead to prosecution or civil proceedings. Licence No LA 079766.

Specific areas, which exceed the AQS objective and are associated with major roads include:

- The M25 motorway which crosses the Council's area in a north south direction;
- The A13 trunk road which crosses the Council's area in an east west direction;
- Other roads including the A1306 Arterial Road, A13 Arterial Road Purfleet, A1090 (Stonehouse Lane, London Road Purfleet, Tank Hill Road), Purfleet by-pass, A1089 (Dock Approach Road, St. Andrews Road), and A126 London Road
- Parts of roads include the southern part of A1012 Hogg Lane and B1335 Aveley by pass.

2.3 Daily mean PM10 Concentrations in 2004

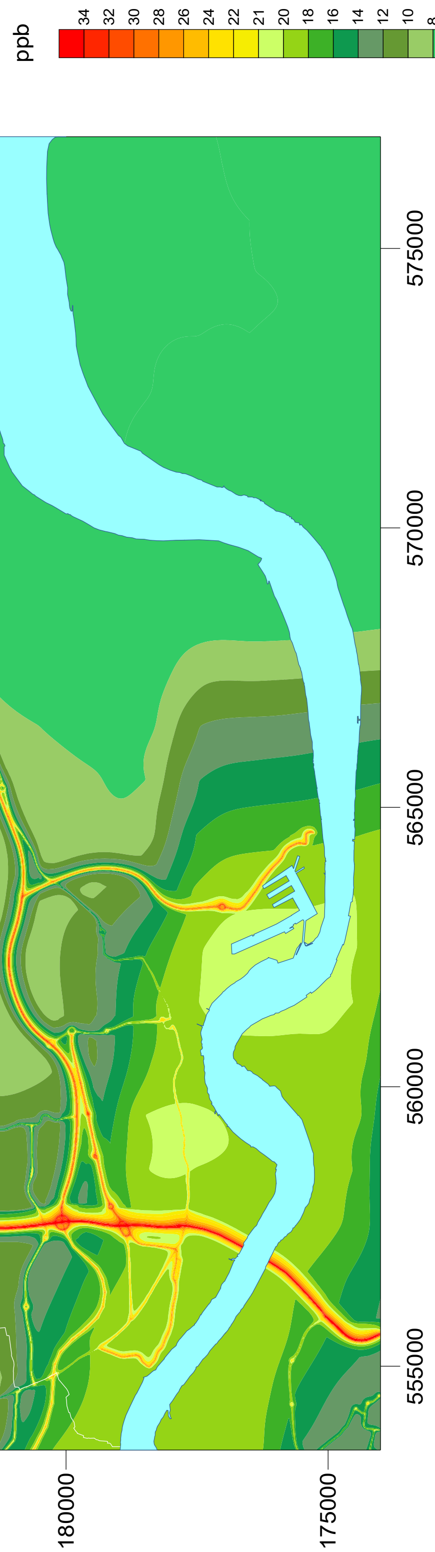
The prediction for the number of days exceeding the 24 hour mean of 50 $\mu g/m^3$ for 2004, assuming that the meteorology of the year 1996 was repeated, are given in Figure 2 below. The areas coloured yellow to red exceed the AQS objective, in this case where PM10 concentrations greater than 50 $\mu g/m^3$ occur for more than 35 days each year. Once again it is clear that major roads provide a significant proportion of PM10 concentrations in the Council's area although the PM10 concentrations differ markedly from that of NO_2, with the areas predicted to exceed being much smaller. The main predicted areas are associated with:

- The M25 motorway which crosses the Council's area in a north south direction;
- The A13 trunk road which crosses the Council's area in an east west direction;
- Other roads including the A1306 Arterial Road, A13 Arterial Road Purfleet, A1090 (Stonehouse Lane, London Road Purfleet, Tank Hill Road), A1089 (Dock Approach Road, St. Andrews Road).

The hourly mean objective for NO_2 has not been modelled in this report as modelling confirms that the annual mean NO_2 is the more stringent of the objectives that need to be met.

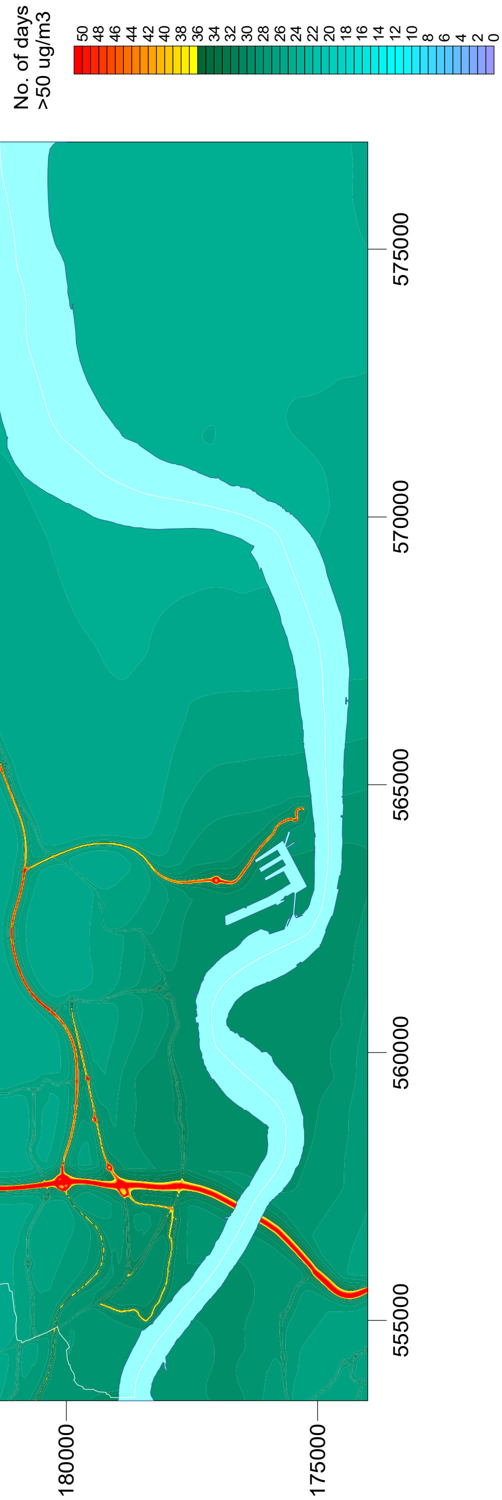
The annual mean concentration for PM10 has also not been modelled in this report, as the predictions in the Stage 3 report were below the objective level.

Figure 1 Annual mean nitrogen dioxide (ppb) for 2005 (based on 1999 meteorology.)



This page had been left blank intentionally

Figure 2 Number of days with daily mean PM10 >50(μg/m^3) for 2004 (based on 1996 meteorology.)



~~3~~*This page had been left blank intentionally*

2.4 Source Apportionment for NO_X and PM10 in Thurrock

2.4.1 Methodology

To better understand the improvement needed at a location, to achieve the AQS objectives, it is necessary to determine the individual source emissions that contribute to the overall predicted pollution concentration. Both pollutant emissions and atmospheric processes, including meteorology, determine the pollution concentration at any given location. Traditionally pollution is determined only from an understanding of emissions derived from local sources and background influences. This however provides only a simplistic understanding, as the pollution climate is further complicated by the presence of emissions from London nearby and the huge numbers of varying activities contributing to the source of emissions.

The pollutants under investigation in this stage of the LAQM process, i.e. PM10 and NO_2, further complicate the understanding of source apportionment. For NO_2, the contribution that the different sources make to the predicted concentrations can only be understood by examining the contribution of NO_x sources as the primary emission. This reflects the fact that the relationship between NO_2 and NO_x is non-linear and determined by photochemistry that is highly location dependent. The modelling undertaken to derive the predictions of NO_2 reflect this aspect and this is explored more fully in the model description given in Appendix A.

For PM10 it is necessary to understand the influence of the primary, secondary and coarse components, which contribute to the total concentration. It is the 24-hour mean objective, which is predicted to be exceeded. However the source apportionment undertaken is based on annual mean PM10, which is averaged over a longer timescale and therefore less affected by specific events.

The source apportionment methodology used here is based on both:

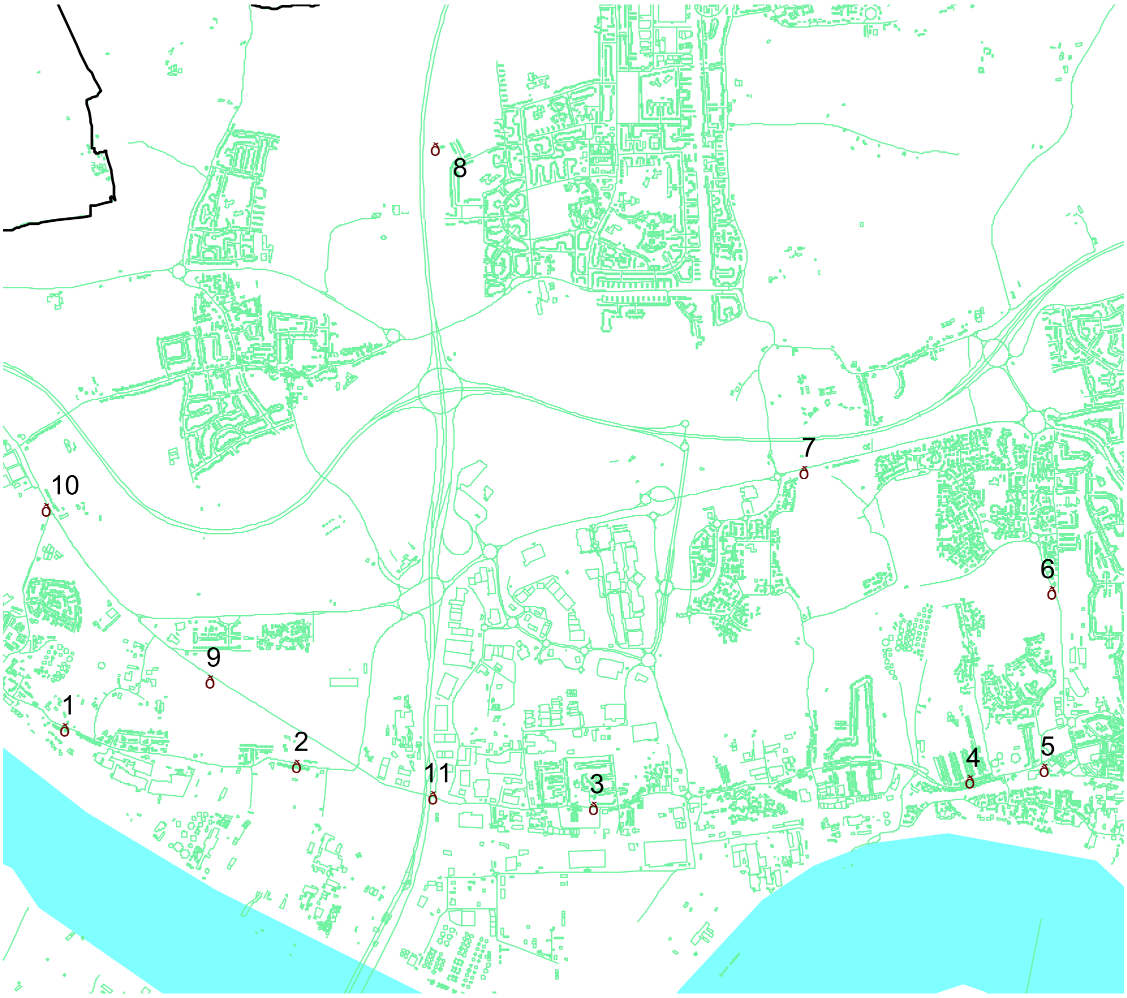
a) Determining the source apportionment for individual categories of the vehicle fleet, which of course recognises the major influence of road transport (as the dominant local source) and

b) Further determining the source apportionment in relation to the so called background sources, this recognises that this is influenced by both near and far sources, including road transport beyond the immediate location, which is therefore not considered as a local source. This contribution is determined by deriving the pollution from all roads outside the Council's area, but within the M25 area for those locations to the west of the motorway. A more simplistic approach was taken for those locations to the east of the motorway; this was based on the National Atmospheric Emissions Inventory.

In all instances the determination of the influences of the different sources is undertaken by modelling sources independently of one another and establishing the predicted concentration at a given point. This is necessary since the influence of the different sources varies between locations due to their proximity to the sources; hence the apportionment is location dependent.

A series of specific point locations were selected for investigation to provide a representative understanding. The selection of these locations was undertaken by the Council, with the points chosen considered to be those representative of areas with predicted high concentrations of pollution. Many of these are in the Council's AQMAs. The specific locations are shown in Figure 3 below and listed in Table 2.

Figure 3 The location of facades identified within Thurrock



(Note the numbered points refer to the locations given in Table 2)

Table 2 Location of sites used for source apportionment

Number	Location	Easting	Northing
1	AQMA No. 11 Purfleet Rail Station	555420	178130
2	AQMA No. 10 Jarrah Cottages	556760	177920
3	London Road - West Thurrock	558470	177680
4	AQMA No. 2 London Road - South Stifford	560640	177830
5	AQMA No. 1 Poison Store (incorporating new road layout)	561065	177900
6	AQMA No. 3 Hogg Lane	561110	178920
7	AQMA No. 5 Arterial Road - North Stifford	559690	179615
8	AQMA No. 15 M25	557560	181475
9	Purfleet Bypass	556260	178410
10	AQMA No. 13 facing changes to junction	557550	177740

~~3.1~~2.4.2 Annual mean NO_2 at identified locations within Thurrock

To calculate more accurately how much improvement in air quality would be needed to deliver the air quality objective within an AQMA; it is necessary first to confirm the concentration of NO_2 at specific sites. This can be established from the modelling undertaken above and the concentrations are given in Table 3 below.

Table 3 Predicted NO_2 concentration (ppb) at identified locations within the AQMA

Number	Base case	*Base case as μg/m³*
1	25.0	*47.8*
2	27.7	*52.9*
3	22.0	*42.0*
4	20.1	*38.4*
5	19.2	*36.7*
6	19.3	*36.9*
7	25.9	*49.5*
8	23.3	*44.5*
9	22.0	*42.0*
10	30.7	*58.6*

The predicted results for the 2005 base year (from Table 3 above) show that for those locations exceeding the objective, the amount is between approximately 0.3 and 10 ppb. Locations 4, 5 and 6 however are predicted to meet the AQS objective in 2005 based on existing proposed changes in the vehicle fleet.

2.4.2 Source apportionment of NO_x at the identified locations

The understanding of NO_x is undertaken for the base case of 1999 (for which accurate traffic estimates are available, including; vehicle flows and stock information. This is described more fully in Appendix D). The method for calculating the emissions incorporates the many different categories in the vehicle fleet using the road, however for the purposes of understanding source contributions more straightforwardly the following grouping has been applied to the sources:

- HGV (i.e. all HGVs and LGVs other than cars, taxis and motorcycles)
- Cars (including all cars, taxis and motorcycles) and
- Buses and coaches.

A series of model runs for the base case were undertaken for each of the components described above, plus a separate run to determine the gross background contribution. The individual contribution for each category is given in Table 4 below.

Table 4 Predicted NO_x concentration (ppb) for the different sources

Location	Base case	Buses	Cars	HGVs	Background
1	89.7	1.5	13.2	40.3	34.7
2	125.9	2.3	21.4	69.3	32.8
3	59.2	0.0	4.2	19.3	35.7
4	49.5	0.0	6.6	9.6	33.3
5	43.5	0.0	5.2	5.4	33.0
6	53.4	0.0	18.9	11.1	23.4
7	111.7	2.1	20.7	70.6	18.2
8	85.7	0.4	22.1	49.2	14.0
9	61.4	0.0	4.0	23.9	33.5
10	191.5	2.1	50.2	106.1	33.1

The results highlight that the vehicle related contributions vary by location, with the background contribution between 14 and almost 36 ppb. The Car and HGV categories together dominate for all locations apart from 3, 4, 5 and 9. For locations 1, 2, 6, 7, 8 and 10 this contribution also exceeds the background. The dominance of the background can be more clearly seen in Table 5 and, as can be seen from Table 3, the locations with the greatest contribution from background also have the lowest total concentrations. The most polluted locations (2, 7 and 10) are close to the London Road, Purfleet (A1090), A1306 Arterial Road and M25 respectively.

The Car contribution dominates the HGV category on the A1012 only (i.e. location 6), reflecting the small numbers of HGV using this road. However for locations (1, 2, 7, 8 and 10) there are a significantly higher proportion of emissions from the HGV category. Even for those locations where the background is most significant the contribution from HGVs still dominates that of cars.

Buses and coaches form only a minor contribution (approximately 0.7 to 2.3 ppb) at some locations, although for five of the locations the bus contribution is insignificant (i.e. less than 0.1ppb).

For those locations furthest from the main urban centres (7 and 8) the background contribution is lowest. Table 5 below, gives the relative proportions in percentage terms. (It should be noted there is a slight rounding effect with these figures.)

Table 5 Proportions of source contributions (%)

Location	Buses	Cars	HGVs	Background
1	1.6	14.8	45.0	38.6
2	1.8	17.0	55.1	26.1
3	0.0	7.1	32.6	60.3
4	0.0	13.4	19.5	67.1
5	0.0	11.9	12.4	75.7
6	0.0	35.3	20.8	43.9
7	1.9	18.5	63.2	16.3
8	0.5	25.8	57.4	16.3
9	0.0	6.6	38.9	54.5
10	1.1	26.2	55.4	17.3

The background component comprises emissions from the following sectors:

- Domestic (including heating and cooking)
- Commercial/ industrial sources (termed industrial for both gas and oil)
- Other transport sources (Railways, airports and shipping)
- Part B industrial processes (which are authorised by the Council)
- Background roads

The method for deriving this contribution is also more fully explained in Appendix A on the model development. It is dependent on the availability of highly detailed emission information. This is available within the M25 perimeter as part of the London Atmospheric Emissions Inventory, beyond that area the emissions information is more coarsely aggregated. The source apportionment here is based on the proportion of emissions within the National Atmospheric Emissions Inventory (NAEI) for the relevant area.

For the roads to the west of the M25 the background roads category includes the contribution to the total pollutant concentration, which is derived from roads beyond those modelled as directly influencing the location. This includes those roads that are outside the Council's area, which contribute to the overall background concentration within the M25 perimeter. In addition a separate contribution termed "Other background" is also included. This is the contribution which is that derived from natural/ rural emissions outside of this area. This contribution is considered constant for all locations in the southeast.

Part A sources are included within the categories rather than specifically included as a separate category. The predicted NO_x contribution in the Council's area for all Part A sources was predicted as being less than 1 ppb for 2005 and therefore can be considered as a minor source (Carslaw, Beevers and Hedley, 2000).

Table 6 below gives the individual contributions for the 4 identified locations within or on the M25 motorway.

Table 6 Predicted NO_x concentration (ppb) for the different background sources within or on the perimeter of the M25 motorway

Location	Background roads	Domestic	Industrial Gas	Industrial Oil	Railways	Ships	Part Bs	Other Background
1	20.7	0.8	0.5	0.2	0.2	1.9	0.3	10.0
2	19.1	0.9	0.5	0.1	0.8	0.2	0.1	10.0
9	21.2	0.4	0.3	0.1	0.9	0.1	0.5	10.0
10	19.7	0.4	0.3	0.1	1.6	0.1	1.1	10.0

The contribution to the background component from domestic, commercial/ industrial, other transport and Part B sources for all locations is small (less than 5 ppb) compared to the contributions from the Other background and Background roads.

Table 7 provides the relative importance within the background component of NO_x from road transport and non-road transport related sources for these same locations.

Table 7 Predicted NO_x contributions (%) for the different background sources for locations within or on the perimeter of the M25 motorway

Location	% Non-road related	% Road related
1	40.2	59.8
2	39.8	60.2
9	36.6	63.4
10	40.5	59.5

The above proportions indicate that for all locations, almost two thirds of the background component is from road transport related sources. This is obviously in addition to the road transport related sources modelled locally to the identified locations and therefore this absolutely confirms the major influence of this sector in the Council's area.

The findings for those locations outside the M25 are given below in Table 8 and these are based on the NAEI as explained above.

Table 8 Predicted NO_x contributions (%) for the different background sources for locations outside the perimeter of the M25 motorway

Number	% Non-road related	% Road related
3	40.8	59.2
4	27.8	72.2
5	59.4	40.6
6	18.9	81.1
7	15.0	85.0
8	16.3	83.7

For these locations the breakdown indicates again that the road related contribution is very significant for all locations. However at location 5 the road contribution is less than the non-road related contribution. An examination of the inventory used for this area indicates a comparatively high proportion of emissions from the domestic sector. This is not surprising, when you consider that this location is approximately 30 m from the roadside and thus demonstrates the reduction in nitrogen dioxide concentrations attributed to traffic with increasing distance from the roadside.

2.4.3 Source apportionment of PM10 at the identified locations

The source apportionment for PM10 has been derived using the same methodology as that described earlier (section 2.4.1). The locations given in the following tables are therefore those identified in Table 2 and Figure 3.

Table 9 provides the results for the 1999 base case with the relative contributions for the road transport source categories, plus background. In this instance the road transport sources provide the major proportion of the primary component, the background contribution includes the remainder of the primary, plus secondary and coarse components. The background contribution remains almost constant for all the locations investigated (between 22.6 and 25.1 $\mu g/m^3$).

The most polluted locations are 2, 7 and 10 (all approximately 32-7 $\mu g/m^3$), on the A1090 London Road, Purfleet, A1306 Arterial Road and the M25. These same locations also exhibit the highest contributions from the HGV category (which also includes all LGVs other than cars, taxis and motorcycles), thus reflecting the relatively higher proportion of HGVs on these roads.

For all locations the HGV category contribution exceeds that of cars. The contribution from buses is minimal and is also less than that from cars at all locations.

Table 9 Predicted annual mean PM10 concentration (µg/m^3) for different sources

Location	Base case	Buses	Cars	HGVs	Background
1	29.8	0.1	0.6	4.1	25.0
2	33.0	0.2	0.9	7.1	24.8
3	28.0	0.0	0.2	2.7	25.1
4	26.7	0.0	0.4	1.5	24.8
5	25.9	0.0	0.3	0.8	24.8
6	26.1	0.0	0.8	1.6	23.7
7	31.3	0.2	1.0	7.1	23.1
8	27.7	0.0	0.9	4.2	22.6
9	27.8	0.0	0.1	2.8	24.8
10	37.3	0.1	2.0	10.3	24.8

Table 10 provides the same information in relative terms for the sites, however, as previously explained the variation between proportions can be partly explained by both the contributions themselves, i.e. proximity of the individual locations, as well as by the actual magnitude of the local sources investigated.

Table 10 Proportions of source contributions (%)

Location	All road transport	Background
1	16.0	84.0
2	25.0	75.0
3	10.4	89.6
4	7.1	92.9
5	4.4	95.6
6	9.4	90.6
7	26.3	73.7
8	18.5	81.5
9	10.5	89.5
10	33.5	66.5

In all instances it can be clearly seen that the Background contribution greatly dominates even when compared with the All Road Transport total. The most polluted locations are also those most influenced by the contribution from road transport (i.e. locations 2, 7 and 10).

The proportion of vehicle category contributions to the total for All Road Transport can be seen below in Table 11. This highlights the expected dominance of the HGV category (even excluding buses) for all locations. At location 6, the proportion of Cars is the highest reflecting the lower numbers of HGVs using A1012 Hogg Lane.

Table 11 Proportion (%) of vehicle contributions to predicted PM10 concentrations

Location	Buses	Cars	HGVs
1	2.1	12.3	85.6
2	1.9	11.5	86.6
3	0.0	8.5	91.5
4	0.0	20.4	79.6
5	0.0	26.4	73.6
6	0.0	34.3	65.7
7	1.8	11.9	86.3
8	0.4	17.0	82.5
9	0.0	5.1	94.9
10	1.0	16.3	82.8

The background component for PM10 varies from that of NO_x as it includes both secondary and coarse components. These are in addition to the other primary components, which also include the influence of traffic beyond the Council's boundary. The background contribution is split into two based on the those within the M25 perimeter which are included within the London Atmospheric Emissions Inventory (LAEI) and those outside which relates to the less detailed national inventory NAEI. Within the M25 the background contribution comprises emissions from the following sectors:

- Commercial/ industrial sources (termed industrial for both gas and oil)
- Other transport sources (Railways, airports and shipping)
- Part B industrial processes (which are authorised by the Council)
- Background roads
- Rural background primary
- Secondary and coarse

It should also be noted that other sectors were considered including contributions from the domestic sector, however these found to comprise very small proportions (i.e. less than 0.01 $\mu g/m^3$). As a consequence these contributions have not been included in Table 12 of the predicted contributions to background PM10.

Background roads include the contribution to the total pollutant concentration, which is derived from those roads beyond those modelled as directly influencing the location. This includes those roads that are outside the Council's area, which contribute to the overall background concentration. In addition separate contributions termed "Secondary/ Coarse" and "Rural background primary" are also included. These are the contributions that are derived from natural/ rural emissions outside the area of the M25 (including transboundary contributions).

These contributions are therefore considered constant for all locations within the M25.

Table 12 Predicted PM10 concentration (µg/m^3) at the identified locations within or on the M25 for the different background sources

Location	Background roads	Ships	PartBs	Rural Background primary	Secondary/ coarse
1	1.4	0.1	0.8	1.2	20.9
2	2.5	0.1	0.4	1.2	20.9
9	2.3	0.0	0.4	1.2	20.9
10	2.2	0.1	0.5	1.2	20.9

It can be seen from that the secondary/ coarse contributions are of greatest significance, totally dominating the overall background contribution. This apportionment was based on 1999 meteorology and therefore it would be expected to be even greater for the worst-case meteorology scenario i.e. for 1996. The PM10 measurements for that year were dominated by the transboundary secondary episodes, due to the higher than normal frequency of easterly winds from Europe during the year.

The relative proportions for the above categories are given in Table 13. In this instance the local commercial/ industrial and other transport categories have been combined. The second most significant contribution to the background is that from the Background roads, these approximate to about 6-10% of the total for all locations. The Other transport/ commercial contribution approximates to 1.8- 4% for all locations. As indicated above the secondary/ coarse component greatly dominates at all locations (about 85% of the total).

Table 13 Proportion (%) of source category contributions for locations within the M25

Location	Background roads	Other transport/ commercial	Rural Background primary	Secondary/ coarse
1	5.8	3.8	4.8	85.6
2	9.9	1.8	4.7	83.6
9	9.2	1.8	4.7	84.3
10	8.7	2.1	4.7	84.4

The proportions of the source category contributions for those locations outside of the M25 are given in Table 14. It should be noted that the categories within the inventories do not quite match one another, however they still represent a reasonable comparison. The same rural background secondary and coarse component contributions as above are used.

Table 14 Proportion (%) of source category contributions for locations outside the M25

Number	Road Transport	Other transport/ commercial	Rural background primary	Secondary/ coarse
3	7.1	4.9	4.8	83.2
4	7.9	3.0	4.8	84.2
5	4.4	6.4	4.8	84.3
6	5.4	1.3	5.1	88.3
7	3.6	0.6	5.2	90.6
8	1.7	0.3	5.3	92.6

In comparative terms the contributions are dominated to a similar degree by the secondary and coarse components (83-93%). With the second most important category being that from roads, apart from location 5 where, as with the NO_x contributions above, this category is reduced. As for NO_x this is attributed to the distance of 30 m between location 5 and the roadside. Both locations 7 and 8 have very low contributions from the other transport/ commercial category and this relates to these locations being located furthest from the main urban centres.

This page had been left blank intentionally

3 Air Quality Action Plan Scenarios

~~1.1~~3.1 Overview to Air Quality Action Plans

The Council having declared AQMAs is required to produce an action plan following the production of its Stage 4 report. The purpose of the action plan is to allow it to work towards the AQS objectives that have been identified as being likely to be exceeded for the relevant years.

To test the effectiveness of possible measures to improve air quality within the AQMA a series of scenario tests have been considered. These reflect the fact that road transport is the main source of emissions (as discussed above in section 2).

There are 3 separate air quality action plan scenarios being implemented by the Council. These can be summarised as follows:

- *Grays Town Centre Regeneration Scheme*, which is already in progress and includes the building of Grays Western by-pass;
- *West Thurrock Marshes Relief Road*, which will link London Road through Oliver Road to Stoneness Road. The scheme is expected to be completed by 2002/3;
- *The Hedley Avenue Extension*, which will by-pass part of London road linking Wouldham Road with Hedley Avenue and is expected to be completed by 2004/5.

~~1.2~~3.2 Road Traffic Information for the Action Plans

Traffic information on those roads affected by the action plan scenarios was provided by the Council and is given in Table 15 below.

Table 15 AADT Traffic flows for Cars, LGV's and HGV's

Road Name	Vehicle Flow as AADT	Grays Town Centre Regeneration Scheme		West Thurrock Marshes Relief Road	Hedley Avenue Extension
	Vehicle Type	Do nothing	With Development	With Development	With Development
London Road Grays	Cars	11768	7554	7554	7554
	LGV	3894	569	569	569
	HGV	1328	365	365	365
London Road South Stifford	Cars	11768	11768	11768	5884
	LGV	3894	3894	3894	1947
	HGV	1328	1328	1328	664
London Road West Thurrock	Cars	5297	5297	2649	2649
	LGV	3080	3080	1540	1540
	HGV	2286	2286	1143	1143
Grays Western by Pass	Cars	N/A	11698	11698	11698
	LGV	N/A	2512	2512	2512
	HGV	N/A	568	568	568
Eastern Way	Cars	12938	12938	12938	12938
	LGV	974	974	974	974
	HGV	626	626	626	626
West Thurrock Marshes Relief Road	Cars	N/A	N/A	8536	8536
	LGV	N/A	N/A	3473	3473
	HGV	N/A	N/A	4331	4331
Hedley Avenue Extension	Cars	N/A	N/A	N/A	11893
	LGV	N/A	N/A	N/A	3524
	HGV	N/A	N/A	N/A	4405
Purfleet by-pass	Cars	3800	3800	3800	11215
	LGV	2558	2558	2558	4706
	HGV	3484	3484	3484	7614
London Road –Purfleet	Cars	2604	2604	2604	2604
(Jar rah Cottages)	LGV	1269	1269	1269	1269
	HGV	3323	3323	3323	3323
Elizabeth road	Cars	19526	22971	22971	22971
	LGV	2803	2803	2803	2803
	HGV	1140	1140	1140	1140
Hogg lane	Cars	19526	11229	11229	11229
	LGV	2803	330	330	330
	HGV	1140	579	579	579
Orsett Road	Cars	13773	17097	17097	17097
	LGV	1037	1287	1287	1287
	HGV	665	826	826	826

The traffic data was incorporated into the model scheme in exactly the same way as for other roads in Thurrock, for which traffic information already exists. The effect of each scheme was modelled separately for both annual average NO_2 and days > 50 $\mu g/m^3$ for PM_{10}.

3.3 The effect of the air quality action plan scenarios

The effect of the air quality action plan scenarios is summarised in Table 16 and Table 17 below. For the sake of clarity the changes in air pollution are associated with three of the source apportionment locations. These are locations 3 (London Road, West Thurrock), 9 (Purfleet by-pass) and 10 (AQMA No.13 facing changes to junction). These locations can all be seen in Figure 2 earlier.

Contour maps of NO_2 and PM_{10} concentrations arising from these scenario actions are also given in Figures 4 to 9. At location 3, the "do nothing" and Grays development scenarios indicate an exceedence of the annual average NO_2 objective of 21 ppb. The implementation of the West Thurrock Marshes Relief Road and the Hedley Avenue Extension, have the effect of meeting the objective at this location.

The Purfleet by-pass (location 9) exceeds the 21 ppb objective for all three of the action plans and a significant increase occurs for the final phase, that of the Hedley Avenue extension, because of generation of additional LGV and HGV traffic. The point positioned close to the M25 and London road (location 10) exceeds the 21 ppb annual average NO_2 objective throughout each phase of the action plan scenarios, by a considerable margin.

Table 16 Annual Average NO_2 concentration, ppb, in 2005 (99 meteorology)

Location	Do Nothing	Grays Development	West Thurrock Marshes Relief Road	Hedley Avenue Extension
London Road - West Thurrock (3)	22.0	22.0	20.3	20.3
Purfleet By-pass (9)	22.0	22.0	22.0	25.5
AQMA No. 13 facing changes to junction (10)	30.7	30.7	30.5	30.7

Table 17 Annual Average NO_2 concentration, $\mu g/m^3$, in 2005 (99 metrology)

Location	Do Nothing	Grays Development	West Thurrock Marshes Relief Road	Hedley Avenue Extension
London Road - West Thurrock (3)	42.0	42.0	38.8	38.8
Purfleet By-pass (9)	42.0	42.0	42.0	48.7
AQMA No. 13 facing changes to junction (10)	58.6	58.6	58.3	58.6

The concentration of PM_{10} (days > 50 $\mu g/m^3$) exhibits a similar response to that of annual average NO_2 for each of the three action plan phases. However along London Road the objective of 35 days is not exceeded during any phase and similarly along the Purfleet by-pass the objective is not exceeded except for the Hedley Avenue extension phase, where once again the considerable LGV and HGV traffic generated creates an exceedence of the 35 day objective. The point positioned close to the M25 and London Road will continue to exceed the PM_{10} objective through all the development phases.

Table 18 The Number of Days with PM_{10} greater than 50 μg/m^3

Location	Do Nothing	Grays Development	West Thurrock Marshes Relief Road	Hedley Avenue Extension
London Road - West Thurrock	32.4	32.4	30.9	30.9
Purfleet By-pass	33.3	33.3	33.3	39.9
AQMA No. 13 facing changes to junction	50.3	50.3	49.3	50.1

3.4 Contour Plots of NO_2 and PM_{10} concentration

These figures are given at the end of the report.

Figure 4 Annual mean nitrogen dioxide (ppb) for 2005 (based on 1999 meteorology.) Grays Development

Figure 5 Number of days with daily mean PM10 >50(μg/m^3) for 2004 (based on 1996 meteorology.) Grays Development

Figure 6 Annual mean nitrogen dioxide (ppb) for 2005 (based on 1999 meteorology.) West Thurrock Marshes Relief Road

Figure 7 Number of days with daily mean PM10 >50(μg/m^3) for 2004 (based on 1996 meteorology.) West Thurrock Marshes Relief Road

Figure 8 Annual mean nitrogen dioxide (ppb) for 2005 (based on 1999 meteorology.) Hedley Avenue Extension

Figure 5 Number of days with daily mean PM10 >50(μg/m^3) for 2004 (based on 1996 meteorology.) Hedley Avenue Extension

4 Conclusion

This report fulfils the requirements of the DEFRA guidance for Stage 4 and permits the Council to review and update its Stage 3 report and address relevant issues as part of the continuing LAQM process. The Stage 4 has used both improved modelling techniques and also an improved treatment of emissions.

The predictions for the 2005 base case take into account a predicted vehicle growth, improvement in vehicle technology leading to lower emission releases and changes to the background. These result in predicted concentrations that will still exceed the objectives. In the case of NO_2 the area predicted as likely to exceed is greater than the equivalent area for PM10. This confirms that the annual mean nitrogen dioxide objective is more stringent than the daily mean objective for PM10.

The extent by which the predictions exceed the objective has been derived from a selection of locations identified within the AQMA and all (bar 3) of these are predicted to exceed the NO_2 objective in the modelled 2005 base case.

For the first time an accurate source apportionment has been undertaken within the Council's area. To determine the separate contributions from the road and background sources a series of detailed tests were run, based on NO_x as the primary pollutant rather than NO_2. These confirm that approximately 24 - 82% of the concentrations relate to the road transport with the remainder relating to the background sources. However the tests further confirm that the background can also be partly ascribed to road transport sources, such as those outside the Council's area. For NO_x approximately two thirds the background contribution arises from such road transport sources.

For PM10 the proportions vary from that of NO_x as a result of the different components that contribute to total PM10. In this instance the contribution from the background sources is most significant (between 66 – 95%), whereas road transport as a primary emission varies between 5 – 34%. Of the latter again as expected, it is HGVs that predominate as the main source. Of the total background sources, road transport contribute between 2 and 10%, with the remainder arising mostly from secondary and coarse components, which are beyond the control of local authorities.

The Council is also required to consider actions that might be undertaken to reduce pollutant concentrations in order to work towards the prescribed objectives. To aid this process an agreed set of scenarios were tested. The result for PM10 was that no location was predicted to exceed the AQS objective except for two locations. One of these adjacent to the M25 exceeded for all scenarios, whilst the other (near the Purfleet by pass exceeded with the Hedley Avenue extension. For NO_2 however an improvement, which meets the objective areas, arises with the West Thurrock Marshes Relief Road and also the Hedley Avenue extension scenarios on the London Road location. For the other locations investigated the predicted concentrations exceeded the objective. Therefore to ensure complete compliance across the Council's area additional pollution reduction measures would be required.

Appendix A

1 Model Development

1.1 Annual mean NO_2 vs. NO_X relationships

The modelling approach adopted in this Stage 4 report builds on the approach described by Carslaw et al. (2001). In summary, the relationship between hourly NO_x and NO_2 has previously been described by plotting NO_2 against NO_x in different NO_x 'bins', for example 0-10 ppb, 10-20 ppb etc, (Derwent and Middleton, 1996). The resulting NO_x to NO_2 relationship describes the main features of NO_x chemistry, first the NO_x -limited regime where NO_2 concentrations increase rapidly with NO_x and second the O_3-limited regime where a change in NO_x concentration has little effect on the concentration of NO_2. A third and final regime also exists where, once again NO_x and NO_2 increase pro-rata, related to extreme wintertime episodes. In all cases, the precise relationship is always both year and site dependent.

~~1.2~~1.2 NO_X and NO_2 Relationships, the Adopted Method

~~1.2.1~~1.2.1 Background Concentrations

The ERG has adopted a revised approach to estimating background emissions to more fully describe the continued decrease of NO_x (for example) away from a background site, for example in London's green areas where NO_x concentrations are likely to reduce towards their centre.

This approach better describes the balance between the local road contribution and the background since it provides a good compromise between the most robust aspects of both modelling and measurements. Importantly it permits all background emission sources to be identified accurately within the modelling e.g. this means that if any emission source becomes less significant over time, it will feature less prominently in the final predictions and thus reflect the actuality of measurements.

The new approach uses a derived relationship, established by modelling all sources (apart from roads) in a 30x30km grid (to a depth of 10m). The areas close to roads (i.e. within 500m of their centre line) were removed from the dataset. These results were replaced with results from the separate modelling of road sources (see next section). The combined predictions for all NO_x sites were then plotted against the measurements. Based on a multiple regression analysis of results the relationship can be described as:

Concentration = a.[road cont] + b.[background cont] + const.

This new approach provides improved predictions and produces a continuous and smooth fall-off in NO_x away from roads. This permits monitoring sites to be better described in terms of background and roadside concentrations, further improving the understanding of the NO_x - NO_2 relationship for the sites.

~~1.2.2~~1.2.2 Roadside Concentrations

Of more use than the hourly relationship discussed earlier is the relationship between the annual mean NO_x and NO_2 concentrations. The construction of these curves described in Carslaw et al. (2001) and is both site and year specific. The relationship for a site relates annual mean concentrations of NO_x to NO_2 whilst implicitly including the full distribution of concentrations measured each hour of the year.

When using these relationships it is important to differentiate between those applicable to background locations and those applicable to roadside locations for any given predicted year.

The NO_x and NO_2 relationships described above are year and site dependent. However, analysis of 1999, the year for which there are most sites shows that the roadside concentrations of NO_2 for any NO_X concentration lies within a range of values that can be related to location. The range is from a central London, busy street canyon, at Marylebone Road to an outer London suburb with an open road location, i.e. the A3 dual carriageway. The contrast between the two locations relates specifically to the background concentration of NO_x and NO_2, with Marylebone Road (70,000 vehicles per day) in a region of very high background concentration and the A3 site (120,000 vehicles per day) in an area with a low background concentration of NO_X and NO_2, and thus it is similar to a rural motorway. For all years Marylebone Road provides the upper limit of NO_2 concentrations and A3, the lower limit for any given concentration of NO_x. The hierarchy of NO_x and NO_2 relationships, for 1999, is summarised in Figure 6, below.

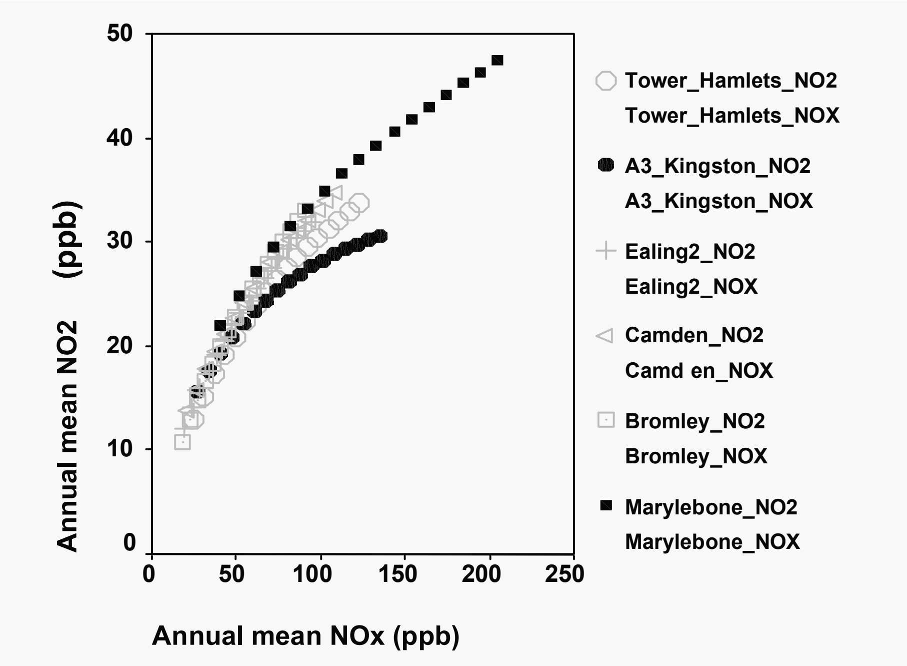


Figure 6 NO_x and NO_2 Relationships at Roadside Sites across London (1999)

The range of NO_2 concentrations, for a given NO_x concentration at the roadside are much larger than for background locations. This is because of a number of factors, including the relative contribution of the road to total NO_x concentrations, the rapid fall-off in concentration away from a road and the rapid reaction between NO and O_3 to form NO_2.

It is recognised that the approaches developed here are new and perhaps unfamiliar. However, confidence can be gained in their application through comprehensive validation, which is described in Appendix C.

~~1.3~~1.3 The ERG PM10 Model

~~1.3.1~~1.3.1 Model Description

A new PM10 model has been developed specifically for the Stage 4 modelling study (Fuller et al., 2002). It uses the comprehensive PM10, PM2.5 and NO_x measurements to derive a model to predict daily concentrations of PM10. The model splits PM10 into 4 component parts and relates each to the likely source/s of the particles. To achieve this, regression analysis of NO_x with PM10 has been employed. Stedman (2000, 2001) and APEG (1999) used a similar analysis, however the ERG model has extended this to include PM2.5. The four component parts are summarised as:

- PM2.5 that is related to NO_X
- PM2.5 that is not related to NO_X
- Coarse particles that are related to NO_X
- Coarse particles that are not related to NO_X.

~~1.3.2~~1.3.2 Measurements used in the PM10 Model

To determine the relationship between NO_x and PM10, regression analysis has been undertaken for co-located rolling annual mean concentrations of NO_x, PM10 and PM2.5 at monthly intervals. Rolling annual means have been chosen to test the stability of the derived relationships over time. A total of over 10 million, 15 minute mean measurements from November 1995 to March 2000 have been averaged to produce the rolling annual means at each site. Data have been used from all site types: kerbside, roadside, urban background, suburban and rural. A maximum of 22 sites have been used for PM10 and maximum of 5 sites for PM2.5. The sites used in each regression are not consistent and depend on the operational start date for each site and at least 75% annual data capture.

~~1.3.3~~1.3.3 Modelling Daily Particle Concentrations

Since the EU Limit values refer to daily mean concentration it is necessary to model and understand the particle concentrations with a daily time resolution. Time series of daily means for each of the components were calculated by applying the factors derived from regression analysis, to the daily mean NO_x, PM10 and PM2.5 measured at each of the sites with co-located measurements. This allowed the calculation of the NO_x dependent components. The non-NO_x dependent components can be calculated by subtraction. Time series of each of the components has been calculated for the four years 1996 to 1999, inclusive. An example of the relationship between annual mean NO_x and number of days greater than 50 $\mu g/m^3$ for 1999 (using the TEOM to gravimetric scaling factor of 1.3), is summarised in Figure 7 below.

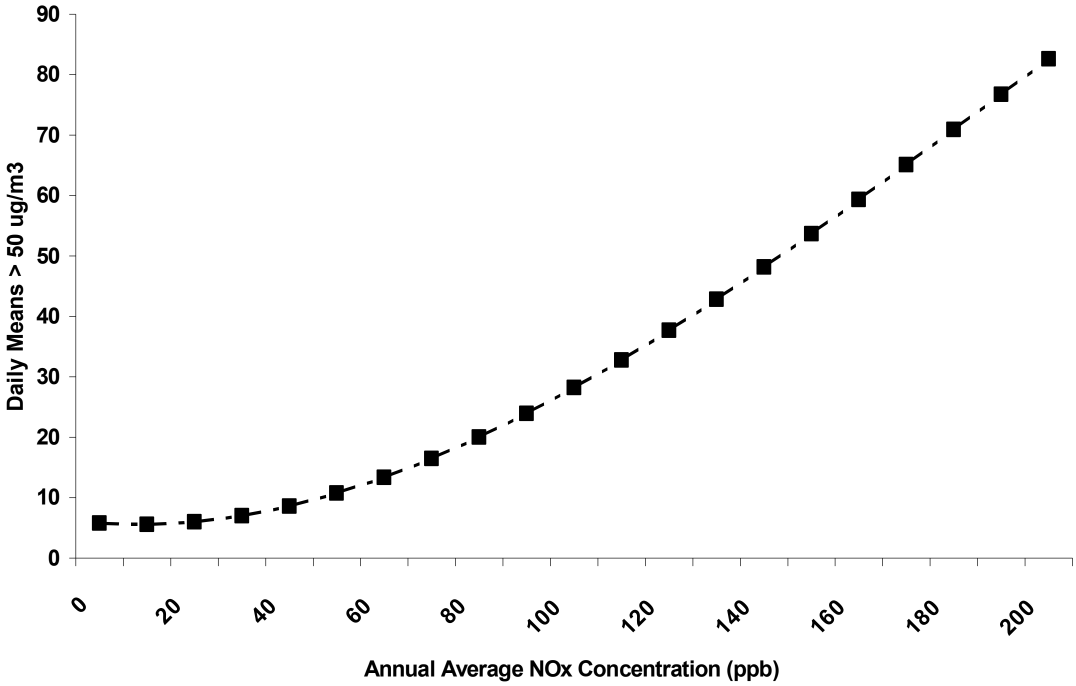


Figure 7 The relationship between annual mean NO_X and days where PM10 > 50 $\mu g/m^3$

1.3.4 Background concentrations

The predicted concentrations of PM10 at background locations are determined using the same method as for NO_x, described earlier in section 1.2.1 of this Appendix.

For predictions in future years each part of the emissions information used can be changed independently. For example, in 2004 it has been assumed that the rural PM10 concentration reduces in line with national predictions for the primary and secondary components.

1.3.5 Roadside concentrations

The determination of concentrations of PM10 at the roadside is described in the next Appendix.

Appendix B

1 Modelling Detailed Road Networks

~~1.1~~1.1 Geographic Accuracy of Model Predictions

Significant progress has been made towards improving the geographic accuracy of predictions. All major roads have been split up into 10 m sections, as shown in Figure 8, below. There are several benefits, which result from this development. First, each 10 m point can act as a source of emissions, thus allowing emissions to be varied along each link. This approach allows, for example, emissions near junctions where vehicle idling is important to be increased. Second, the emissions sources are geographically accurate, enabling roundabout and complex road junctions be modelled thoroughly. Third, maps of concentration will also be geographically accurate allowing more accurate assessments to be made of population exposure.

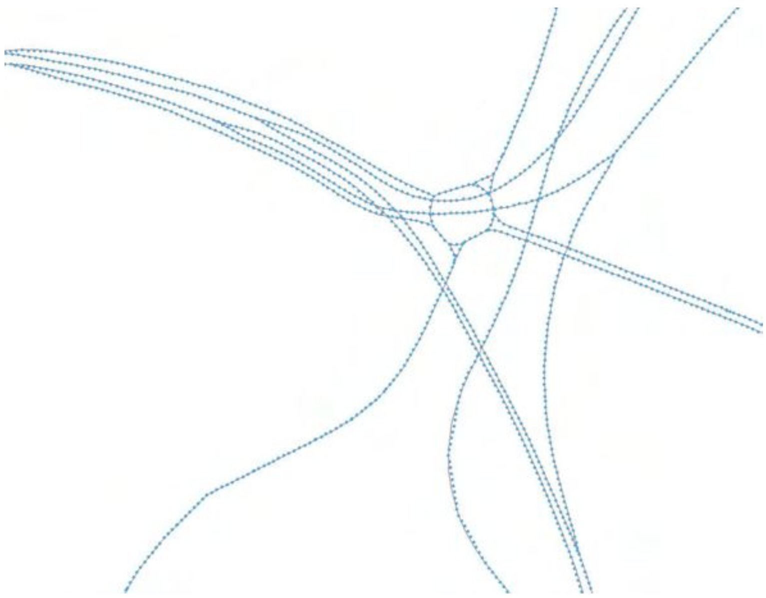


Figure 8 10m sections of road, showing complex junction details

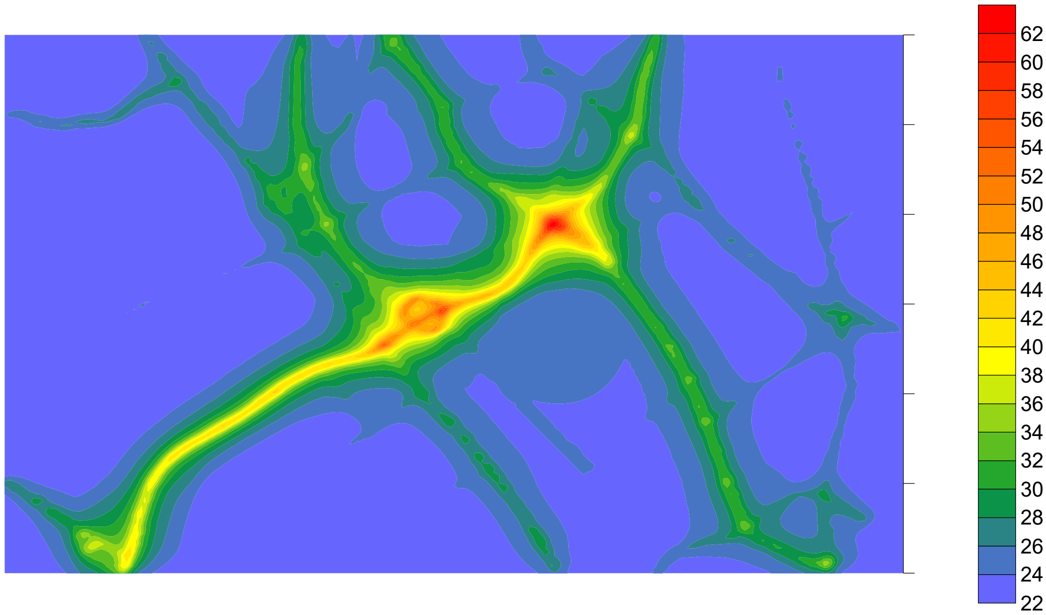


Figure 9 Modelled example showing concentrations near complex road junctions.

Figure 9 shows that features such as roundabouts and curved roads are accurately represented and therefore this is ideal for the purposes of exposure assessment.

~~1.2~~1.2 Roadside modelling method

The ADMS dispersion model is used to predict the fall-off in air pollution concentrations away from roads. Each 10 m point is modelled as a small road link using the ADMS Urban model run using hourly sequential meteorological data for each relevant year from the London Heathrow site. A roughness length of 1 m was assumed. This approach ensures that the effects of converging roads are correctly represented.

Each 10 m section of road is modelled separately over an area of 300 x 300 m, at 5 m intervals.

The predictions from each of the sources are then added together, where their contributions overlap and are combined onto a master grid of NO_X concentrations. Up to the facades of buildings the fall-off in concentration is assumed to be the same as a “typical urban road” in the CAR model. This correction was made based on the results of a validation exercise described in Appendix C. This approach refers back to the method by which CAR was developed i.e. it is based on extensive wind tunnel modelling experiments, which are the most appropriate way of assessing flow around complex street configurations in urban areas.

To reflect the effects of anthropogenic heating of London (urban heat island effect), the meteorological data were pre-processed to take account of the additional heat input. An additional 15 Wm^{-2} of sensible heat flux was added, based on model sensitivity tests, comparisons with measurements and a review of available literature. The additional heat input had the effect of generating additional thermal turbulence, which also affected the minimum boundary layer height that was rarely predicted to be less than 100 m.

It should be noted that the fall-off in concentration predicted across each road was assumed to be symmetrical about the road centreline. This assumption was based on the observation from near-road, roadside and kerbside monitoring sites, considered in Appendix C. This observation, will in some part, be explained by the effects of vehicle-generated turbulence. No explicit modelling was made of street canyons, since the "typical urban road" fall-off in concentration worked equally well for a wide range of site types and site locations. Although it might be expected that these effects are important, it is likely that the uncertainties in the base traffic data, traffic speed and speed-dependent emissions factors are more significant.

In a complex urban area with many buildings it can be difficult to apply a full street canyon model with confidence. Furthermore, street canyon models, such as the Operational Street Pollution Model (OSPM), only consider the dilution effects between building facades. Beyond building facades the fall-off in concentration is the same as that for the case with no buildings. In a densely populated urban area, it is very unlikely that mixing between street canyons is properly represented. For example, for two parallel roads separated by buildings it is likely that only a fraction of the emissions from one street will mix down into the neighbouring street. The approach used here is therefore pragmatic and is consistent with the level and quality of information available and the capability of the models used to make the predictions.

The NO_X master grid is then used within the NO_X to NO_2 relationships (see Appendix A) to predict annual average NO_2 or within the PM10 model to predict the daily concentrations of PM10 for the year in question. The final step is to test the results over all suitable measurement sites; including street canyons and open road locations. The results of the validation are reported in detail in Appendix C.

The method of applying the dispersion calculations to each of the 10 m sources separately and then combining them into a master grid has the additional benefit of accounting for the effect of increased concentrations at road junctions.

~~1.3~~1.3 Emissions at Major Road Junctions

The new approach of separating road links into 10 m sections allows emissions near to junctions to be explicitly accounted for. Within a short distance of each junction it is assumed that vehicle idling is increased and the average speed of vehicle is reduced significantly. The assumption~~s~~ used in the model predictions ~~are~~ is that 30 m[3] from a major road junction vehicles travel on average at 5 km/hr and that this includes significant periods of idling. Having made significant improvements in the predictions of average link speed, using 'floating car' data, care was taken to keep the link emissions constant, by increasing the emissions at the ends of the links and reducing the emissions elsewhere on the link. In summary the effect of junctions is accounted for through a redistribution of the emissions along each of the road links.

A further set of assumptions is required for the application of such a scheme. First, the road junctions are assumed to be congested on one side of the road only and second, that there is a combination of periods of free flowing traffic and traffic travelling at 5 km/hr. The assumption for the proportion of time spent at the average link speed was assumed to be 50 % on the side of the road affected by the queue. The application of the emissions redistribution was taken only on roads that were greater than 150 m in length as it is assumed that the congested nature of such short links would be well reflected in the measured average speed. Motorways were further exempted as the simplistic assumptions were not thought applicable.

The assumptions used in the emission model are a first estimate and it is accepted that individual road links should be treated independently, for example, using detailed traffic models. Furthermore, emission factors of the type used to develop large-scale emissions inventories are not a suitable method by which to represent emissions for specific driving characteristics (idling, acceleration/deceleration), which are unique to each junction separately.

[3] 30 m was assumed as being a typical length for queuing traffic. In practice, road traffic activity is more variable and there is a lack of quality data available from which to improve the predictions made here.

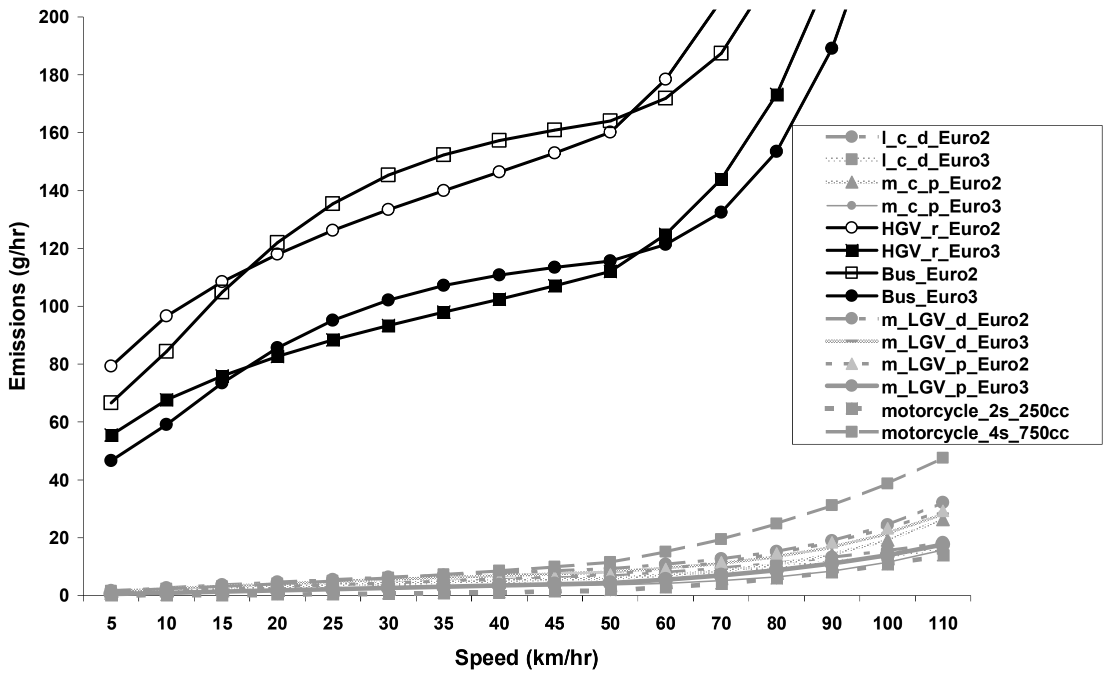


Figure 10 Emissions NO_X (g/hr) for Euro 2 and 3 Vehicles at different Average Speeds (km/hr)

The detailed DMRB emission factors are applicable down to a speed of 5 km/hr, although factors at this speed are highly uncertain. These data were employed in the redistribution of junction emissions described above. It is worth therefore investigating the effect of low speeds on the emissions of, in this case NO_X, from different vehicle types. By multiplying the g/km results for different average speeds by the speed the emissions may be expressed in g/hr. A sample of the g/hr vehicle emissions for Euro 2 and 3 vehicles is summarised in Figure 10 above. It shows that as LGV (petrol and diesel), cars (petrol and diesel) and motorcycles increase their speed so the emissions increase steadily and are at a maximum at 110 km/hr. This increase in emissions is related to the additional work, which is being done by the engine. It is important to note however, that for these vehicle types the g/hr emissions approaches zero at 5 km/hr. Also plotted in black are rigid HGVs, and buses in the Euro 2 and 3 technology categories. These vehicles contrast significantly with the cars, LGVs and motorcycles by showing emissions up to a factor 40 times greater than for smaller vehicles at very slow speeds. It is therefore these specific vehicle types, which provide the majority of the emissions close to road junctions. Since comparatively little work has been carried out on emissions from heavy vehicles, the emission factors derived at such slow speeds should be treated with considerable caution. It is important to appreciate these effects when considering the results from the modelling.

Appendix C

1 Model Validation

A comprehensive validation exercise has been undertaken for the NO_x-NO_2 and PM10 models at measurement sites in London. A very extensive data set exists for the years 1996, 1997, 1998 and 1999 and these were used in the exercise. Comparisons were made with sites located at roadside and kerbside in both open locations and street canyons, as well as in background locations. All sites were not available for every year and for NO_X, NO_2 and PM10. However, Figure 11 below summarises those sites used during the validation exercise as a whole. The validation exercise goes beyond the sites available in the Council's area. This is beneficial since it is only through a comparison with many sites types in different locations can the approaches used can be properly tested.

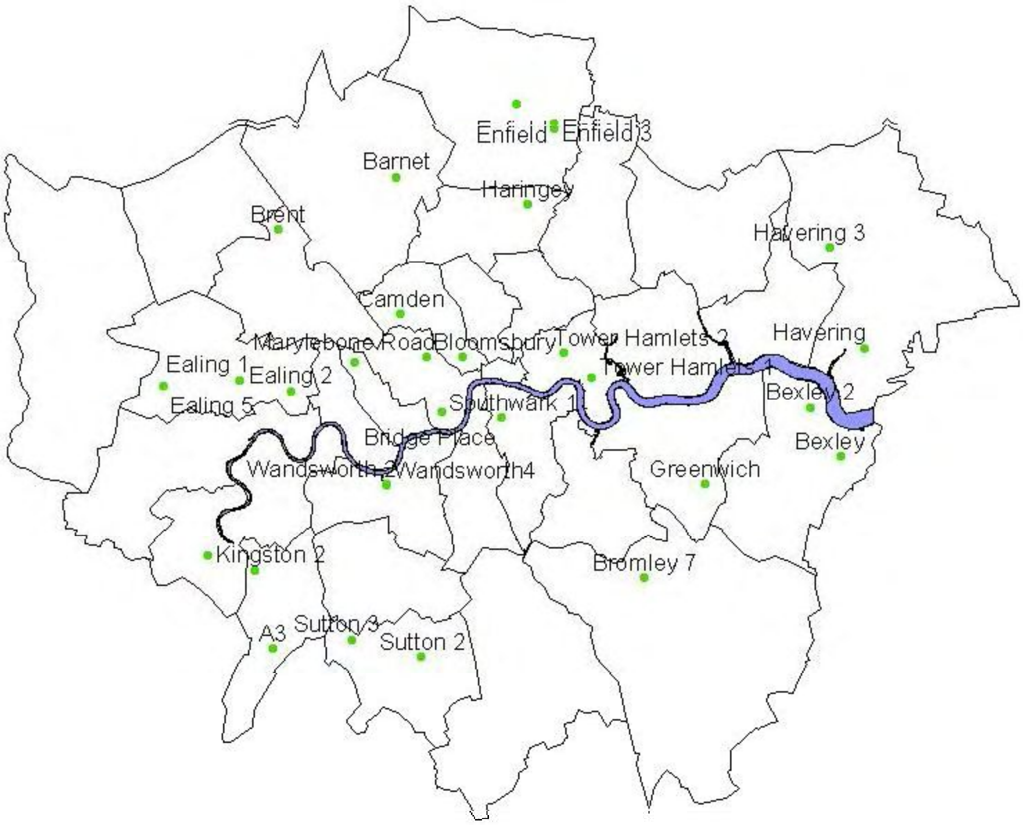


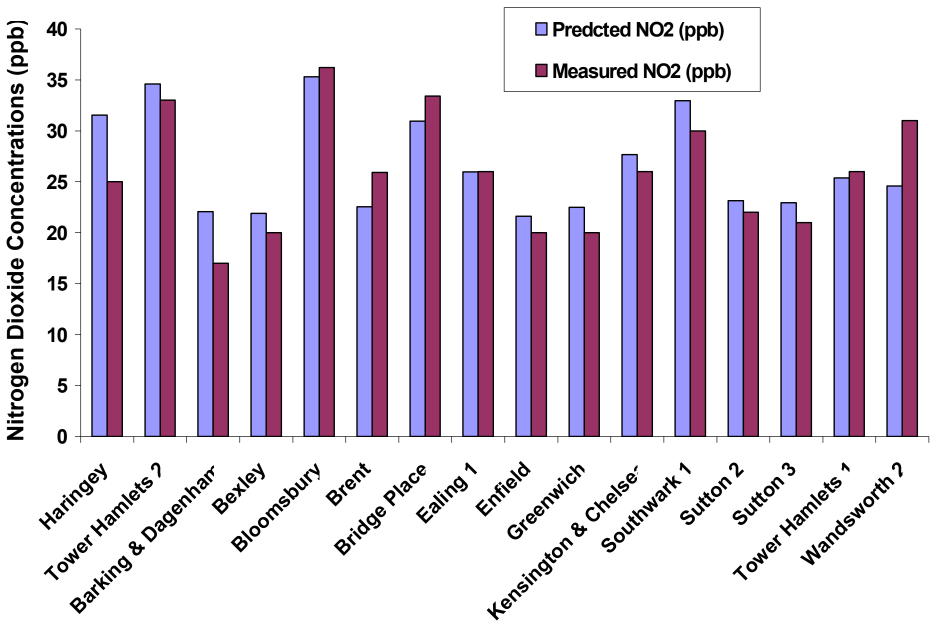
Figure 11 Sites used to Validate Model Predictions

To ensure the validity of the exercise care was taken to locate the site locations as accurately as possible, particularly in relation to roadside sites, where a steep concentration gradient exists. Poorly identified site locations could lead to significant changes to the model performance.

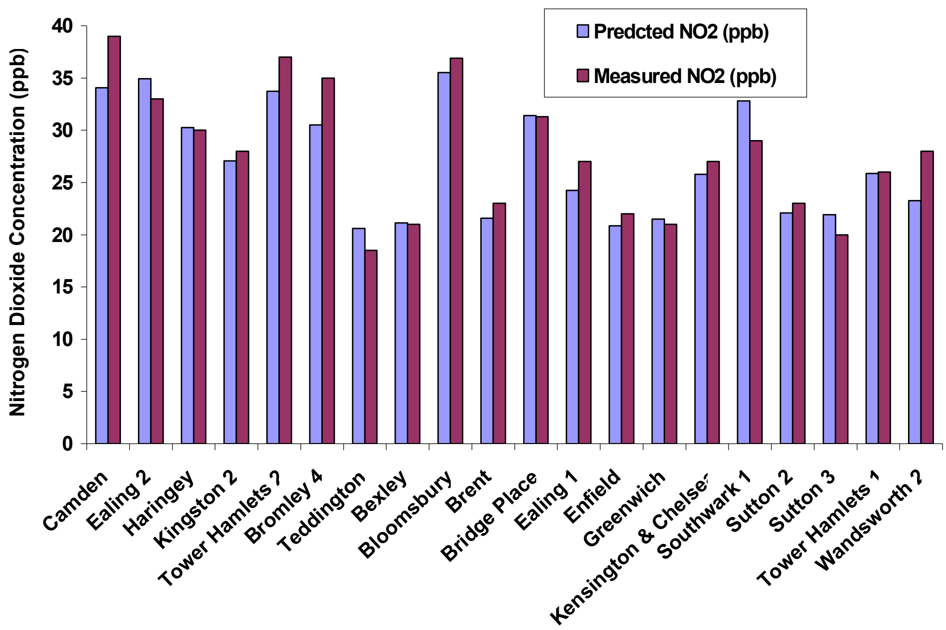
~~1.1~~1.1 Predictions of Annual Average NO_2 in London

The column plots in Figure 12 show predicted against measured concentrations of NO_2 for 1996 (first plot) to 1999 (last plot). Additionally Table 19 and Table 20 provide the actual results and a summary of the overall model performance. The average for all sites used was 94 % for 1999 and those sites with low data capture rates were not included.

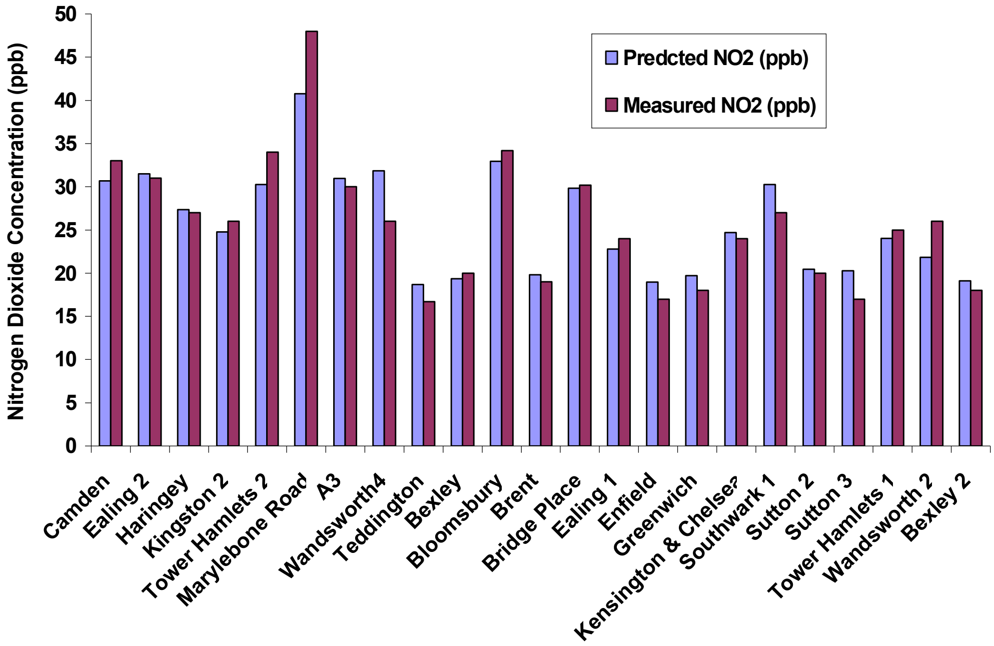
1996



1997



1998



1999

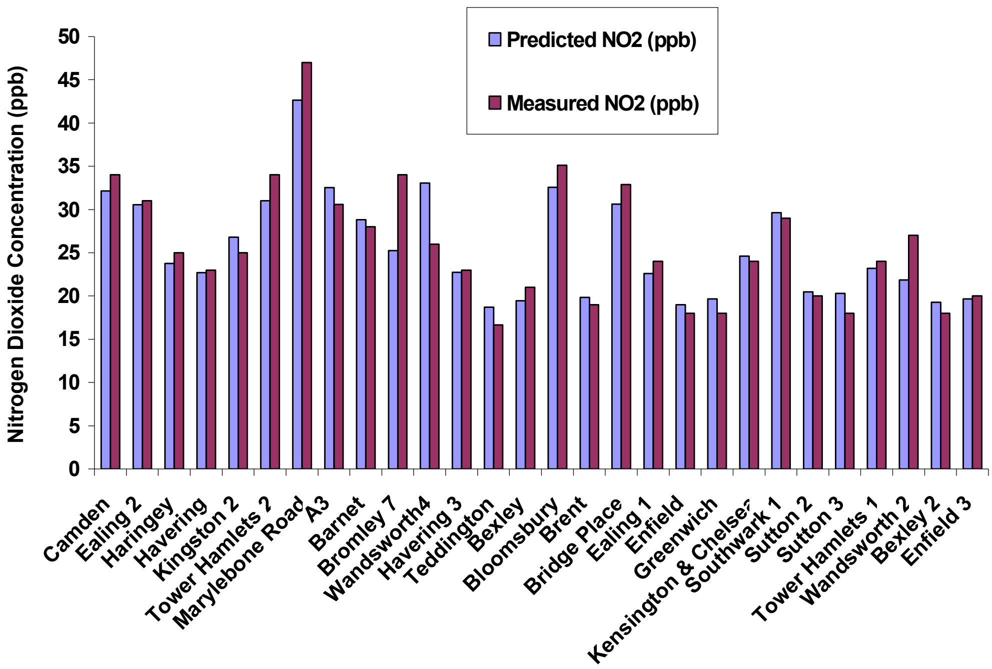


Figure 12 Predicted and Measured Annual Average NO_2 for 1996, 1997, 1998 and 1999

Overall the model performed very well with the average modelled and measured predictions showing close agreement. A summary of the overall performance of the model is given in Table 20, which gives the standard deviation of the measured minus the predicted NO_2 concentrations as 12 % (1996), 9 % (1997), 11 % (1998), and 11 % (1999). The percentages were calculated by dividing the standard deviation by the all site average measured NO_2 concentration.

Table 19 Annual Mean NO_x and NO_2 (ppb) Validation Results for 1999

Site	Predicted NO_X	Measured NO_X	Predicted NO_2	Measured NO_2
A3	160.4	134	32	31
Barnet	78.7	95	27.8	27.6
Bexley 1	36.4	35	20.5	19.1
Bloomsbury	73.7	71	34	35
Brent 1	32	34	18.9	19.4
Bridge Place	60	55	30.3	31
Bromley 7	77.9	94	27.3	34
Camden 1	110.7	109	33.4	34.2
Cromwell Road	151	134	38.2	48
Croydon 2	107.6	91	29.7	20.3
Ealing 1	44.9	47	23.4	24.1
Ealing 2	82.4	91	28.9	31.1
Ealing 5	90.1	88	27.3	33.8
Enfield 1	32.4	32	19.2	17.6
Enfield 2	61.8	51.8	25.2	23.6
Enfield 3	35.2	37	20.3	19.7
Greenwich	36.4	33	21	18.5
Hackney 4	58.9	70	28.4	31.2
Haringey	53.6	70.2	25.8	26.6
Havering	50.6	70.6	25.8	22.9
Havering 3	53.7	66	24.4	23.2
Hillingdon	110.7	86.8	28.9	26.3
Islington	48.9	50	27.2	25.6
Kensington	46.9	42	25.1	23.8
Kingston 2	78.4	66	26.9	25.4
Marylebone Road	188.3	205	42.2	47.5
Southwark 1	64.9	62	32	29.1
Sutton 2	40.3	39	21.9	19.8
Teddington	31.1	26	18.6	16.7
Tower Hamlets 1	55.2	39	29	23.8
Tower Hamlets 2	88.2	124	31.6	36.4
Waltham Forest	42.9	41	23.9	22.8
West London	62.7	52	29.7	28.6

This level of accuracy does not apply to all sites and certain roadside sites are not as well predicted. The most obvious example of this is the Croydon 2, which is poorly predicted for all years and has not been included in the summary above. This site exhibits a very low NO_2 to NO_x ratio, which is more typical of a rural motorway site, as thus the model over predicts by a large margin, typically 10 ppb.

Other sites, included in the summary above, that also identify poor model performance are Bromley 7, which is under predicted by 9 ppb and Wandsworth 4, which is over predicted by 7 ppb. The first full year of operation of Bromley 7 was during 1999 and so it is difficult to draw firm conclusions from this result alone. Over prediction at Wandsworth 4 occurred in both 1998 and 1999, which might be a result of the very low vehicle speeds at this site (approximately 10 km/hr throughout the day) and the uncertainty in emission factors at this speed, as described in Appendix E.

Table 20 All Site Average NO_2 (ppb)

Year	Predicted Average (ppb)	Measured Average (ppb)	Average difference (measured - predicted) (ppb)	Standard Deviation (measured - predicted) (ppb)
1996	26.6	25.8	-0.8	3.2
1997	27.0	27.8	0.8	2.4
1998	25.7	25.7	0.0	2.7
1999	25.5	25.9	0.4	2.9

~~1.2~~1.2 Predictions of the 24 hour mean AQS PM10 Objective

The map in Figure 13 shows the sites used to validate the model, these include sites both in London and the other surrounding areas.

Table 21 and Table 22 provide the results and a summary of the overall model performance. Those sites with low data capture rates were not included and by way of example, the all site 1999 data capture rates averaged 96 %. The insistence of a very high data capture rate for measurements is essential in this case, as the PM10 pollution is episodic in nature and therefore loss of data can lead to a bias in the measured results. In addition, sites with instruments other than the TEOM were not included in the analysis as the relationship between the measurements and European gravimetric standards are not well understood at present.

Furthermore, care should be taken to avoid very localised particle effects, which are not covered in the inventory or the model calculations. One such example is Marylebone Road. This site was removed from the comparison in 1999 due to localised building works, which increased the days greater than 50 $\mu g/m^3$ significantly and invalidated any model comparison made.

Overall the model performed well with the average modelled and measured predictions showing close agreement. A summary of the overall performance of the model is given in Table 23, which gives the standard deviation of the measured minus the predicted PM10 days greater than 50 $\mu g/m^3$ as 16 % (1996), 21 % (1997), 24 % (1998), and 22 % (1999). The percentages were calculated by dividing the standard deviation by the all site average measured PM10 days greater than 50 $\mu g/m^3$.

Much of the inaccuracy of the PM10 predictions is associated with the error in predicting annual average NO_x correctly, and highlights the difficulty in dispersion calculations in urban areas as well as the error in estimating emissions of NO_x themselves. With this in mind only those sites, which have a complete dataset of NO_x measurements for the year, were chosen for prediction of PM10. The results given above indicate that overall the predictions for 1996 represent the best model performance and those for 1998, the worst. Care should be taken interpreting the results in this way as there are relatively few site predictions in 1996, although it is reasonable to assume that the existence of a large source of secondary particles during many of the PM10 episodes in 1996 would reduce the model sensitivity to NO_x predictions, thereby improving the overall performance.

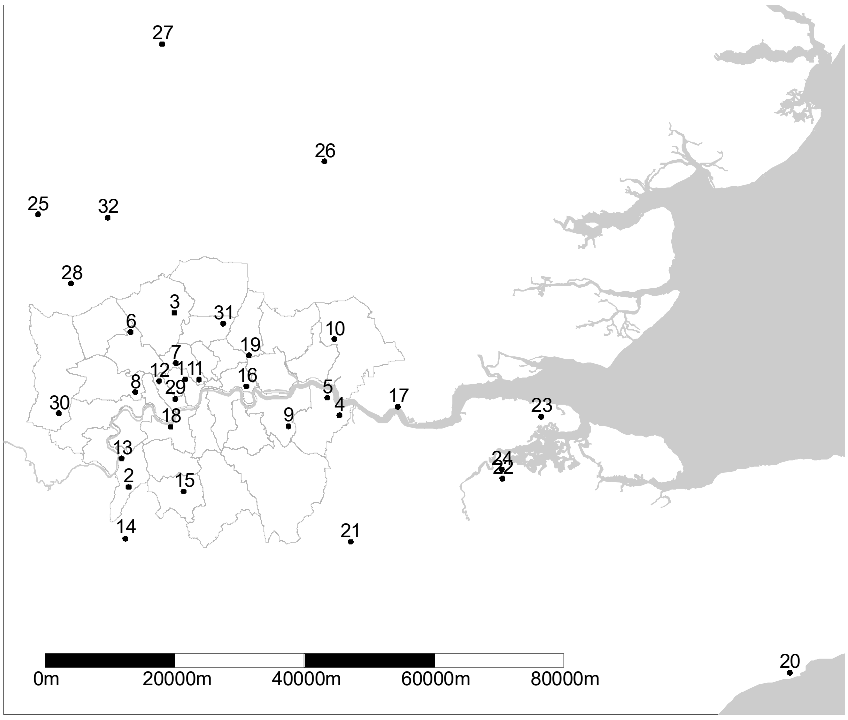


Figure 13 Monitoring sites in used to derive the model.

Several sites in the PM10 validation are not well predicted. First is the Wandsworth 4 site, which the model over predicts by 24 days (i.e. those extra days greater than 50 µg/m^3). This is consistent with the difficulty in predicting for NO_x at this location, which is assumed to be due to the effect of low vehicle speeds. Second is the A3 site, which is predicted well for NO_X and should show good performance for PM10. However, the PM10 model relationships calculated from the London sites do not perform well at the A3 site and here too the PM10 model over predicts the days greater than 50 µg/m^3 by approximately 27.

Table 21 Predicted and measured number of days where PM10 > 50 µg/m³ (TEOM*1.3)

Site code	Site name	Site type	Annual Mean NO_X (ppb)	Annual mean PM_{10} µg m^{-3} TEOM *1.3			Daily means >50 µg m^{-3} TEOM *1.3		
				Measured	Modelled	Difference	Measured	Modelled	Difference
1996									
9	Greenwich 4	U	41	23	24	1	38	46	8
31	Haringey 1	R	89	29	28	-1	67	63	-4
12	Kens & Chelsea 1	U	53	25	25	0	46	54	8
15	Sutton 1	R	79	27	28	1	50	60	10
16	Tower Hams 1	U	50	27	25	-2	61	51	-10
1	Bloomsbury	U	80	30	28	-2	65	63	-2
1997									
6	Brent	U	46	22	22	0	26	30	4
4	Bexley 1	S	48	23	23	0	32	30	-2
7	Camden 1	K	153	32	31	-1	86	78	-8
9	Greenwich 4	U	43	21	22	1	24	29	5
31	Haringey 1	R	96	26	26	0	50	46	-4
12	Kens & Chelsea 1	U	57	24	23	-1	33	32	-1
13	Kingston 2	R	90	27	26	-1	48	44	-4
15	Sutton 1	R	77	24	25	1	34	37	3
16	Tower Hams 1	U	54	25	25	0	36	31	-5
17	Thurrock	U	40	23	22	-1	31	29	-2
24	Medway Chatham	R	53	22	23	1	23	22	-1
22	Medway Luton	U	30	18	21	3	16	22	6
23	Medway Stoke	RU	19	19	20	1	19	18	-1
1998									
2	A3	R	153	24	28	4	38	62	24
31	Haringey 1	R	75	22	22	0	22	24	2
12	Kens & Chelsea 1	U	42	20	20	0	16	13	-3
11	Marylebone Road	K	197	32	32	0	83	89	6
15	Sutton 3	S	62	21	21	0	13	19	6
6	Brent	U	32	18	19	1	8	10	2
4	Bexley 1	S	36	19	19	0	18	12	-6
5	Bexley 2	S	31	19	19	0	19	10	-9
8	Ealing 2	R	96	23	24	1	22	33	11
13	Kingston 2	R	71	23	22	-1	28	22	-6
14	Mole Valley 2	S	26	17	18	1	8	8	0
32	St Albans	S	36	18	19	1	4	10	6
16	Tower Hams 1	U	43	21	20	-1	23	14	-9
17	Thurrock	U	37	19	19	0	14	11	-3
18	Wandsworth 4	R	56	19	21	2	12	18	6
24	Medway Chatham	R	51	21	20	-1	15	15	0
22	Medway Luton	U	25	14	18	4	2	8	6
23	Medway Stoke	RU	16	17	17	0	3	7	4
21	Sevenoaks 2	U	23	19	18	-1	10	8	-2

Key to Site Types: K= Kerbside, R = Roadside, U = Urban Background, S = Suburban, RU = Rural.

Table 22 Comparison of measurements and modelled results for 1999 to EU Limit Values

Site code	Site name	Site type	Annual Mean NO_X (ppb)	Annual mean PM_{10} µg m^{-3} TEOM *1.3			Daily means >50 µg m^{-3} TEOM *1.3		
				Measured	Modelled	Difference	Measured	Modelled	Difference
1999									
2	A3	R	134	23	27	4	22	45	23
7	Camden 1	K	110	26	25	-1	33	33	0
9	Greenwich 4	U	33	17	19	2	5	10	5
31	Haringey 1	R	71	22	22	0	17	16	-1
12	Kens & Chelsea 1	U	42	20	20	0	16	12	-4
11	Marylebone Road	K	206	35	33	-2	111	88	-23
15	Sutton 3	S	61	19	21	2	4	15	11
1	Bloomsbury	U	71	22	22	0	21	25	4
3	Brent	S	96	22	24	2	16	26	10
6	Barnet 1	K	32	18	19	1	6	6	0
4	Bexley 1	S	38	19	19	0	17	11	-6
5	Bexley 2	S	31	18	19	1	17	8	-9
25	Dacorum	U	30	16	19	3	2	6	4
8	Ealing 2	R	92	23	23	0	25	26	1
26	East Herts 2	U	22	16	18	2	6	6	0
10	Havering 3	R	67	22	21	-1	22	16	-6
29	Kens & Chelsea 2	R	134	30	27	-3	51	45	-6
13	Kingston 2	R	66	22	21	-1	15	16	1
30	Heathrow	U	71	22	22	0	27	25	-2
14	Mole Valley 2	S	26	17	18	1	1	6	5
27	North Herts	R	61	22	21	-1	8	15	7
16	Tower Hams 1	U	39	21	19	-2	21	7	-14
17	Thurrock	U	37	19	19	0	3	11	8
18	Wandsworth 4	R	63	20	21	1	17	15	-2
28	Watford	R	54	20	20	0	7	13	6
19	Waltham Forest	U	41	19	20	1	12	12	0
24	Medway Chatham	R	51	19	20	1	7	12	5
20	Folkestone	S	19	21	18	-3	15	6	-9
22	Medway Luton	U	27	14	18	4	1	6	5
23	Medway Stoke	RU	16	18	17	-1	6	6	0
21	Sevenoaks 2	U	24	17	18	1	2	6	4

Key to Site Types: K= Kerbside, R = Roadside, U = Urban Background, S = Suburban, RU = Rural.

Table 23 All Site Average Number of Days where PM10 > 50 μg/m^3 (TEOM*1.3)

Year	Predicted Average (days)	Measured Average (days)	Average difference (measured - predicted) (days)	Standard Deviation (measured - predicted) (days)
1996	61.6	55.4	6.2	8.7
1997	39.2	42.2	-3.0	8.8
1998	24.6	24.2	0.4	5.7
1999	15.5	17.8	2.6	3.9

This page had been left blank intentionally

Appendix D

~~1~~1 Emissions from Road Transport in Thurrock

1.1 Overview of the London Atmospheric Emissions Inventory

The revised London Atmospheric Emissions Inventory for road traffic (LAEI) uses a considerable number of data sources available across the area up to and including the M25 motorway. This therefore enables the dependence upon modelled transport vehicle flow and speed data to be reduced. The use of the activity data in the inventory follows a hierarchy, which is summarised as follows:

- Data available from DTLR/LT/TfL;
- Data from local authorities;
- Data from transport models.

The total vehicle km represented by each category for this area per annum is: DTLR manual counts 20.75 billion vehicle km (bvkm), LTS 4.48 bvkm, minor roads 2.47 bvkm. The DTLR manual counts therefore account for an estimated 75 % of total traffic activity in this Greater London area.

1.2 Base Year and Pollutants Covered

The base year for the inventory is 1999, but includes predictions for 2004 and 2005.

The pollutants covered include:

- Benzene;
- 1-3 Butadiene;
- Carbon dioxide CO_2;
- Carbon monoxide CO;
- Hydrocarbons HC[4];
- Oxides of nitrogen NO_X;
- Particles PM10;
- Sulphur dioxide SO_2;

The km^2 emissions have been calculated over the same geographic area as the previous inventory i.e. the area bounded by the M25 (see Figure 14). Details of individual road flows and emissions cover all local authorities within this area.

[4] Note, any reference to hydrocarbons excludes methane.

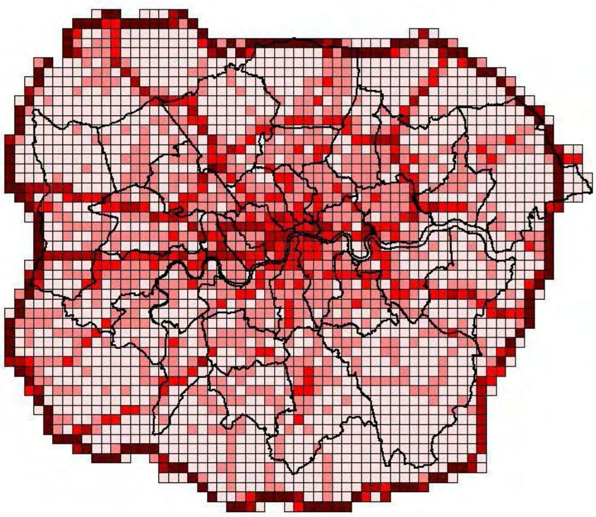


Figure 14 NO_x Emissions for 2005 (tonnes/annum), showing area covered by new LAEI

~~1.3~~1.3 Major Road Flows

Use has been made of manual count data for all “A” and “M” roads from the DTLR rotating census programme. Two principal data sources are available: hourly variation for 12 hours between 7 am and 7 pm for weekdays and annual average daily flows (AADF). In total 11 vehicle types are considered:

Table 24 Vehicle Categories on Major Roads

Vehicle Category
Pedal cycles (not used)
Motorcycles
Cars
Light Goods Vehicles (LGV)
Buses
Taxis (derived)
Rigid HGVs with 2 axles
Rigid HGVs with 3 axles
Rigid HGVs with >=4 axles
Articulated HGVs with 3 & 4 axles
Articulated HGVs with 5 axles
Articulated HGVs with >=6 axles

Expansion factors have been derived to determine vehicle flows for each hour of the day. These factors have been derived from an assessment of continuous count data from fixed traffic counters. The DTLR operates 56 such sites in the area and the TfL operate approximately another 30. It should be noted that the TfL sites are mostly in central and inner London on "A" roads.

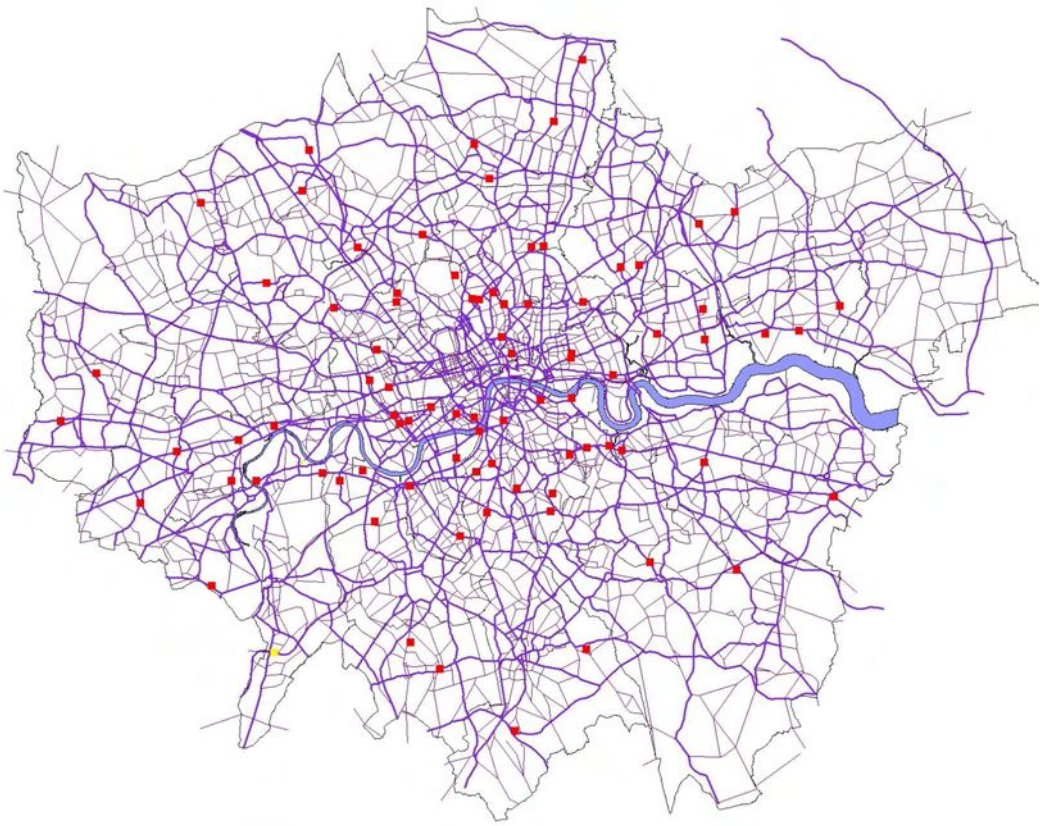


Figure 15 Map showing road network and the locations of the automatic traffic counters[5]

Data from the automatic traffic counters (ATC) have been used to derive the profiles of vehicles throughout each day. An analysis of the data from ATC sites showed that there were differences between inner and central London compared with outer London areas. The ATC data serves two main purposes: i) to calculate the 12 to 24 hour expansion factors by vehicle type and ii) to derive realistic hourly profiles by vehicle type. These profiles have been applied in two different ways:

- Where 12 hourly data were available, the factors were used to "fill-in" the non-peak hours i.e. after 7pm to 7 am.
- Where an AADF has already been calculated by the DTLR, the profiles were used to estimate the hourly flow by vehicle type.

[5] Bold lines show the principal road network (A and M roads); thin lines show the LTS roads

~~1.4~~1.4 Local Authority Traffic Counts

The Council supplied specific information to supplement that mentioned above. In addition a request was made to all 33 London local authorities for traffic count data. Table 4 shows that 21 authorities responded to the request and of those 15 were used in the inventory development. It should be noted that data were only used for non A and M roads, since DTLR manual count data were available for these roads and it was considered important to maintain consistency.

Table 25 Responses to Request for Local Authority Traffic Count Data

LA	Data Available?
Barking and Dagenham	Sent Count data
Barnet	Sent Count data
Bexley	Sent Count data
Brent	Saturn Data
Bromley	Sent Count data
Camden	Sent Count data
City of London	Sent Count data
Croydon	No Data Sent
Ealing	Sent Count data
Enfield	No Data Sent
Greenwich	No Data Sent
Hackney	No Data Sent
Hammersmith	Sent Count data
Haringey	No Data Sent
Harrow	No Data Sent
Havering	Sent Count data
Hillingdon	No Data Sent
Hounslow	Sent Count data
Islington	Count Data Unavailable
Kensington and Chelsea	Sent Count data
Kingston	No Data Sent
Lambeth	Sent Count data
Lewisham	Sent Count data
Merton	Sent Count data
Newham	No Data Sent
Redbridge	Sent Count data
Richmond	Sent Count data
Southwark	Sent Count data
Sutton	Sent Count data
Tower Hamlets	No Data Sent
Waltham Forest	Sent Count data
Wandsworth	Sent Count data
Westminster	Count Data Unavailable

~~1.5~~1.5 LTS Road Flows

LTS version B1.5 has been obtained from MVA (via TfL) for base years 1996 and 2011. All "A" and "M" roads were removed from the output using the LTS definition of road number. A later examination of the remaining links suggested that around 150 links out of 4200 were misclassified or could not be adequately identified. These links were also removed. Checks were also made on the remaining links to ensure that none contained anomalous flows.

LTS provides the split between light, HGV and buses. These were summed to give a 12 hour flow and expanded to 24 hour flows as described in the previous section. Most remaining LTS roads are either "B" roads or unclassified. The rotating census data for "B" roads was used to derive the breakdown of 11 vehicle types.

Table 26 Vehicle breakdown assumed for LTS roads

Vehicle	%
Motorcycles	1.8
Cars	84.1
Bus and coaches	1.3
LGV	10.7
Rigid 2 axle	1.4
Rigid 3 axle	0.2
Rigid >=4 axle	0.2
Artic 3 & 4 axle	0.1
Artic 5 axle	0.2
Artic >=6 axle	0.1

~~1.6~~1.6 Minor Road Flows

Minor roads are those for which there are no individual road link details and are represented as total vehicle km in grid squares. The original LRC inventory estimated the total vehicle km by vehicle type. The current inventory uses the same total vehicle km estimates, but apportions the vehicle km differently. Use has again been made of the rotating census data, for "unclassified roads". These roads typically have very little HGV or bus traffic, as shown in the table below.

Table 27 Vehicle breakdown assumed for minor roads

Vehicle type	%
Motorcycles	1.20
Cars	86.5
Bus and coaches	0.97
LGV	9.79
Rigid 2 axle	1.15
Rigid 3 axle	0.13
Rigid >=4 axle	0.10
Artic 3 & 4 axle	0.05
Artic 5 axle	0.07
Artic >=6 axle	0.03

~~1.7~~1.7 Vehicle Age By Road Type

The analysis of DTLR on road vehicle age data highlights significant variations in vehicle age by road type across the Greater London area. These data are from 20 sites, from motorways to rural B roads and total approximately 200,000 vehicles. This agrees well with the conclusions drawn from the manual counts, which suggest that the mix of traffic varies from place to place, and from hour to hour. The DTLR data therefore supports the idea of developing methods of estimating vehicle stock in a more spatially disaggregated way.

A comparison was made of the breakdown of vehicle ages in the national model with those described above. It was found that there is a slightly newer vehicle stock on motorways on average and older vehicle stock on minor roads compared with national data. A small correction has therefore been made to motorway traffic and minor road traffic to account for this effect. The effect is more apparent on minor roads, however, these roads only account for 8.9 % of the total estimated vehicle km. Overall the effect is therefore very small.

~~1.8~~1.8 Vehicle Speed Estimates

With the use of speed-dependent vehicle emission factors, it is essential that realistic speeds be used in the inventory. The previous inventory used vehicle speed estimates directly from the LTS model for three periods of the day (am peak, inter-peak and pm peak). The current inventory uses data from actual measurements of speed. Vehicle speed estimates are derived from the "floating-car" technique (Roland, 1998). The technique involves the use of an instrumented car driven at the prevailing traffic speed in such a way as to make equal the number of vehicles overtaken and the number of vehicles overtaken by the car itself. Journey times between successive junctions are recorded, and the speed calculated by weighting the speed against vehicle flow. Surveys are conducted throughout the year but are timed to avoid holiday periods or periods of particularly adverse weather. Each road link is surveyed in both directions on four separate occasions: once in the morning peak period between 7.45 am and 9.15 am, one in the morning off-peak period between 10 am and 12 noon, once in the afternoon off-peak period between 2 pm and 4 pm, and one in the evening peak period between 4.45 pm and 6.15 pm. The estimated speed on an individual link is subject to wide sampling variation. On average the 7.45 am to 6.15 pm speed on a single link has a 95 per cent confidence interval of about ± 10 kmh^{-1}. Compared with fixed measurements of speed in one location, the floating-car technique should produce representative *mean* vehicle speeds.

The floating car data does not cover all major road links in the inventory. Mean am peak, inter-peak and pm-peak speeds have therefore been calculated by area of London (central, inner and outer). Neither does the database consider speeds from 7pm to 7am. For these hours the inter peak speed has been applied.

The speed estimates provided in the LTS model have been used for all remaining LTS links by 3 periods of the day.

For minor roads and local authority roads, a constant speed of 30 km/h has been assumed.

~~1.9~~1.9 Bus Data and Assumptions

A summary of the key assumptions for the estimate of emissions from buses in London is as follows:

- Data for the study were provided by:
    - ***DTLR:*** Manual count information, split by hour of day (7am-7pm) for all major roads in London. Total number of roads is 1992;
    - ***TfL:*** LTS model data, split for three period of the day am peak, inter peak and pm peak;
    - ***TfL and DTLR:*** automatic count data for 86 sites throughout London;
    - ***LT Buses:*** Information from environmental audit 2000 and through personal communication with Mike Weston and Simon Thomas of LT buses;
- Bus and coach numbers were taken from the rotating census of traffic counts from 7am to 7pm;
- Other periods of the day were factored from the automatic count data;
- The remaining bus numbers were taken from LTS B1.5, although these were a small proportion of the total bus vehicle km and applied to minor roads only;

- The bus vehicle stock was broken into two parts, central London (defined by LTS) and other London stock representing all other locations in London. LT bus services are assumed to represent 90 % of the bus vehicle km in London (personal communication, LT Buses);

- The outer London bus stock is given in Table 28 below;

- The emission reduction factors summarised in Table 29 are applied to the vehicle emission according to the Euro class and whether an oxidation catalyst or particle trap has been fitted. For example for emissions of particles a factor of 0.11 is applied to the particle emissions of a Euro 2 bus if it is fitted with a particle trap.

Table 28 Outer London Bus Vehicle stock by Euro Class (1999)

	pre Euro 1	Euro 1	Euro 2
	18 %	14 %	68 %
Catalyst fitted	17 %	7 %	11 %
RPT fitted	0 %	0 %	23 %

Table 29 Emission Reduction Factors by Euro Class and Technology

	CO	HC	NO_X	PM
Pre Euro 1 with Catalyst fitted	0.08	0.19	0.72	0.46
Euro 1 with Catalyst fitted	0.16	0.25	0.88	0.3
Euro 2 with Catalyst fitted	0.22	0.37	1	0.33
Euro 1/2 with Particle Trap Fitted[6]	0.10	0.10	0.90	0.10

[6] Factors supplied by GLA for 2005 BAU case.

Appendix E

1 Model Uncertainty Assessment

~~1.1~~1.1 Introduction

This appendix describes the application of Bayesian Monte Carlo (BMC) analysis to the ERG model developed to predict present and future concentrations of annual average NO_2. Model uncertainties arise because of limited scientific knowledge, limited ability to assess the uncertainty of model inputs, for example, emissions from vehicles, poor understanding of the interaction between model and/or emissions inventory parameters, sampling and measurement error associated with NO_X and PM10 sites across the south east and whether the model itself completely describes all the necessary atmospheric processes. The application of the BMC technique here results in the reduction in uncertainties predicted through the additional information provided by the measurements themselves.

~~1.2~~1.2 Uncertainty Assumption in Model Input Parameters

Selection of the uncertainty of input variables are obtained through access to published literature, the opinions of experts in the field, and through the assessment of relationships used within the model. A summary of the assumptions made for the model are given in the table below:

Table 30 Uncertainty Assumptions (1 σ) use for the Uncertainty Predictions

	(%)
Road Traffic Emissions	30
Other Emissions	50
London + Rural NO_X Contribution	10
Pollution Climate Mapping (NO_X)	11
NOx-NO2 Relationship	10
Roadside Dispersion	20

~~1.3~~1.3 Bayesian Monte Carlo Analysis

In Monte Carlo analysis, the model is run with the input variables varied simultaneously and independently of each other and a resulting probability distribution of the output information, obtained. Bayes' theorem is then applied to derive a final uncertainty estimate, by assigning a high probability to those predictions that agree with the measurements and a low or zero probability to those, which do not. The application of probabilities to the model prediction uses the likelihood function (Equation 1) and results in the best estimate of overall model uncertainty.

$$L(Y_k \mid O) = \frac{1}{\sqrt{2\pi\sigma_e}} \exp\left(-\frac{1}{2}\left[\frac{O - Y_k}{\sigma_\varepsilon}\right]^2 \right) \quad (1)$$

A mathematical summary of BMC is given below. From Bayes' theorem the final probability of model output is defined by equation 2 as

$$p(Y_k \mid O) = \frac{L(Y_k \mid O)\, p(Y_k)}{\sum_{j=1}^{N} L(Y_j \mid O)\, p(Y_j)} \quad (2)$$

~~1.4~~1.4 Results at Background

A BMC uncertainty analysis was carried out for annual average NO_2 concentration throughout London.

The prior and posterior distributions for an average of the measurement sites in London are included in Table 31. The application of BMC analysis reduces the final uncertainty giving a standard deviations in this case are 2.0 ppb (8.5 %).

The BMC analysis was then applied for 5 sites individually and the results summarised in Table 32. Again BMC analysis results in a significant reduction in σ providing a reduction in uncertainty. The average σ for the 5 sites was 1.8 ppb.

Table 31 Final uncertainty and measured annual mean NO_2 concentrations (ppb) at all sites for 1998

Average Model Prediction (ppb)	σ (ppb)	Uncertainty %	Measured Result (ppb)
23.6	2.0	8.5	23.2

Table 32 Final uncertainty and measured annual mean NO_2 Concentrations for separate sites for 1998

Site Location	Final Model Prediction (ppb)	σ (ppb)	Uncertainty %	Measured Results (ppb)
Bridge Place	30.6	2.2	7.2	30.2
Bexley 2	19.1	1.5	7.8	18
Tower Hamlets 1	24.1	1.8	7.5	24.6
West London	26.8	2.0	7.5	26.8
Sutton 2	18.6	1.4	7.5	19.8

~~1.5~~1.5 Results at Roadside

Predictions of the concentration of NO_2 at roadsides throughout London have shown a high sensitivity to the pass/fail standard of 21 ppb. These predictions are crucial to the development of air pollution control, through local authority action plans, and it is therefore essential to completely understand the uncertainty associated with them. Only then will the strengths and weaknesses of the predictive process be understood enough for decision-makers to make informed policy judgements. It is the uncertainties associated with these predictions, which are the subject of this appendix.

Monte Carlo modelling techniques have been used to calculate the uncertainties associated with roadside NO_2 predictions. It also includes a full sensitivity analysis to determine the most important input variables to the model. Specific tests include the uncertainties associated with flows and emissions from LGVs, HGVs and buses, vehicle speed, the dispersion model, and the pollution climate mapping technique, used for calculating background concentrations.

In *Monte Carlo* analysis, the input variables are varied simultaneously and independently of each other, and the effect on important outputs assessed. The model uncertainty, relating to the input parameters, is calculated by treating them as random variables. By studying the resulting probability distribution of the output (i.e. the concentration or emission estimate), information is obtained regarding the model uncertainty.

The original study has focused on Marylebone Road for a base year of 1997 for meteorology and atmospheric chemistry and uses the London Transportation Studies (LTS) traffic model. Further uncertainty assessments have also been undertaken for an "average road' in central and outer London, as well as a 'Motorway' in outer London.

The sensitivity analysis revealed that roadside NO_x predictions are mostly sensitive to the assumptions regarding HGV emissions and flows and the dispersion model used to predict roadside concentrations. For the prediction of NO_2, the NO_x-NO_2 relationship used is the most important factor. Table 33 below shows how each input data or modelling method affects the final concentration, for the Marylebone road example.

Table 33 The Relative Importance of Model Parameters in Predicting NO_2 at Marylebone Road

Model Parameter	Relative Importance 2005 (% of mean at 2σ)	Relative Importance 1997 (% of mean at 2σ)
NO_X-NO_2 relationship	13.9	11.9
HGV emissions	7.9	8.1
Dispersion model	7.3	6.8
HGV flow	5.5	5.5
LGV emissions	4.2	4.7
LGV flow	4.2	4.7
Vehicle speed	3.6	2.1
Background mapping	1.8	1.7
Bus emissions	1.2	0.9
Bus flow	0.6	0.4

For 1997, NO_x was predicted to be 258 +/- 83 ppb and NO_2 47 +/- 10 ppb, at two standard deviations – equivalent to the 95 % confidence interval. These statistics assume that the resultant distribution is normal.

The overall uncertainty of NO_2, which corresponds to 22 %, is less than that for NO_X (32 %). This feature is a result of the non-linear NO_2 relationship, which is quite insensitive to NO_x concentrations, implying that a stated NO_X uncertainty is a better indication of the quality of a prediction.

Measurements for the Marylebone Road site for NO_x and NO_2 are within the uncertainty limits calculated here. NO_x was between 213 and 229 ppb and NO_2 between 44 and 48 ppb for 1997. The range reflects the two different monitoring techniques used at the Marylebone site.

Similarly, for 2005, NO_x is estimated to be 117 +/- 35 ppb and NO_2 33 +/- 7 ppb, at two standard deviations – equivalent to the 95 % confidence interval. It can therefore be concluded that with a probability of 95 % the true value lies within the ranges given above. This would indicate that, despite the calculation of uncertainty associated with the 2005 predictions, the NO_2 concentration always exceeds 21 ppb and therefore Marylebone Road will exceed the AQS objective. This may not always be the case however and with a prediction whose range straddles 21 ppb, a decision must be made concerning the approach to be taken. For example, a prediction of 20 +/- 2 ppb could be considered a pass or a fail.

It is further concluded that the prediction of NO_2 concentrations in London depend most on the NO_x-NO_2 relationship used and the traffic data for HGVs. It is flows of, and emissions from, HGVs and buses that become more important in the future, as emissions from these vehicles will make up a greater proportion of the total.

The results from the analysis of a further three roads is given in Table 34. These represent an average road at a central and outer location and an average motorway in outer London. The flow and percent HGV for the average road was derived from all 10,000 roads in the LTS 91 network.

Table 34 NO_2 Uncertainty Estimates for Typical Roads in 2005

Road Type/Location	Total vehicle flow	Percent HGV	Uncertainty (% of mean at 2σ)
Average road (central London)	17,000	9	16
Average road (outer London)	17,000	9	18
Motorway (outer London)	80,000	9	21

Our best estimate of the uncertainty in annual mean NO_2 predictions is therefore +/- 16-21 % at two standard deviations.

It has not been possible to quantify the uncertainty of PM10 predictions in the same way as NO_2. This is because the uncertainty of the measurement techniques themselves and the sources and sinks of particles has not been well established. *However, it is reasonable to expect that the uncertainty in PM10 predictions is larger than NO_2.*

This page had been left blank intentionally

Appendix F

~~1~~1 Air Pollution Measurements in Thurrock and across London

~~1.1~~1.1 Monitoring Update

Details of the monitoring undertaken at comparable sites across the LAQN, as well as the Government's AURN were provided in the Stage 3 report. At the time of the preparation of that report, ratified data were only available up to 1997. These data can now be supplemented with more recent results.

~~1.2~~1.2 Nitrogen dioxide

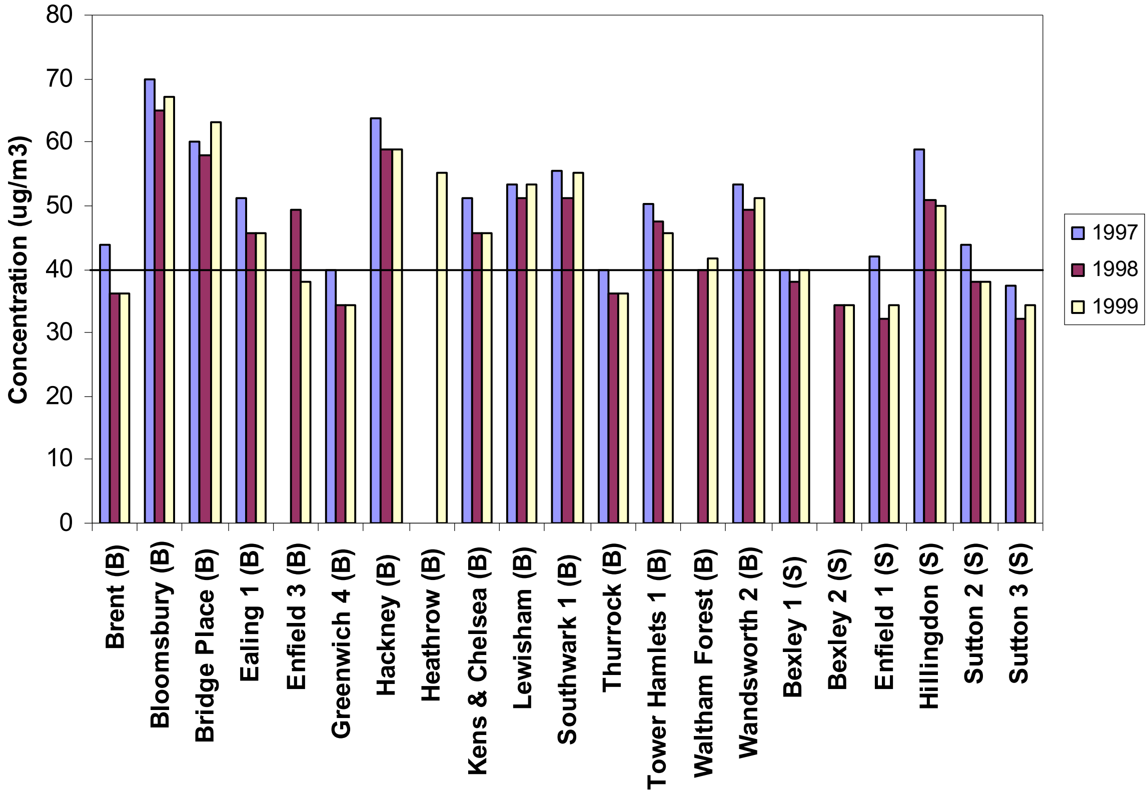


Figure 16 Annual average NO_2 means for background and suburban sites (1997-9)

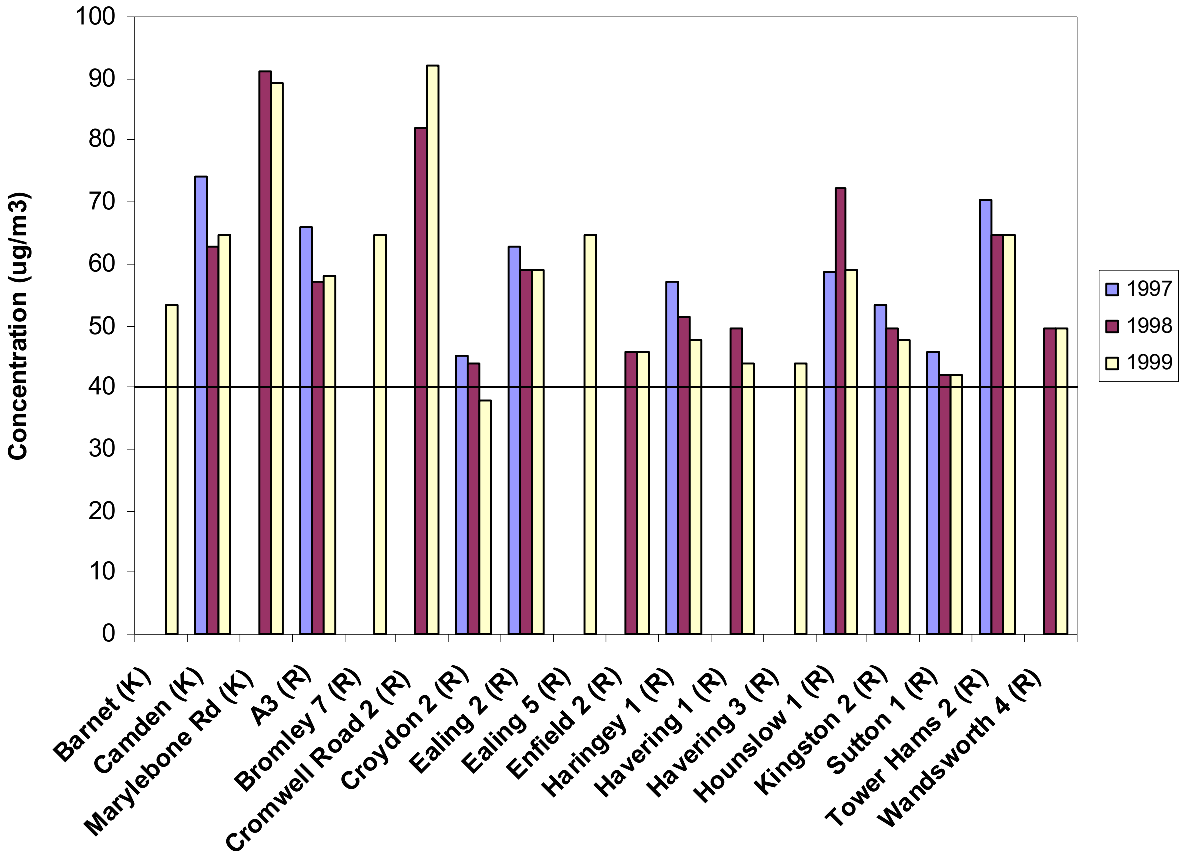


Figure 17 Annual average NO_2 means for kerbside and roadside sites (1997-9)

These figures update the information in the Stage 3 report and highlight that exceedences of the NO_2 annual mean objective have continued at all kerbside (K) and roadside sites (R) (apart from Croydon, which if monitoring uncertainty is taken into account will exceed the objective). Similarly the majority of background sites (B) also exceed the objective apart from some sites in outer London (e.g. the Brent, Greenwich and Thurrock sites). The suburban sites (S) mostly do not exceed the objective, with the exception of Hillingdon and Bexley.

The figures suggest that the pollution for 1999 was marginally better than 1997, which was considered the worst-case year for NO_2. However it is not possible to conclude without further investigation, whether this was from either an emissions reduction (of NO_x) or as a result of the meteorology or a combination of these factors.

It is also worth noting that during 1999 there was an absence of the major pollution incidents seen in previous years. For example, during 1994 and 1997 London experienced significant winter pollution incidents, a prolonged secondary particulate episode occurred during 1996 and the hot summer of 1995 produced substantial photochemistry. However, the summer of 1999 was characterised by a series of moderate photochemical episodes.

To further understand the effect of changing pollution climates over time it is possible to start to consider the relative results from 1995 to 1999. Data from November 1995 to September 2000 have been analysed to place the results from 1999 in context. Rolling annual means from November 1996 have been calculated in an attempt to eliminate seasonal effects. Note that the mean value for a particular date represents that for the preceding year e.g. the value calculated for November 1996 represents the mean between November 1995 and November 1996. To provide a perspective across the network as a whole, the rolling means from each of the long term sites have been averaged to produce a LAQN rolling mean, normalised to 100 % for each pollutant as at November 1996 to illustrate relative change. Measurements from roadside and background sites have been used. However, due to data availability, a different set of sites has been used for each pollutant. Twelve sites have been used for the rolling NO_X and NO_2 calculation. (NO_x is the sum of NO and NO_2). It should be noted that data from summer 2000 are still subject to ratification.

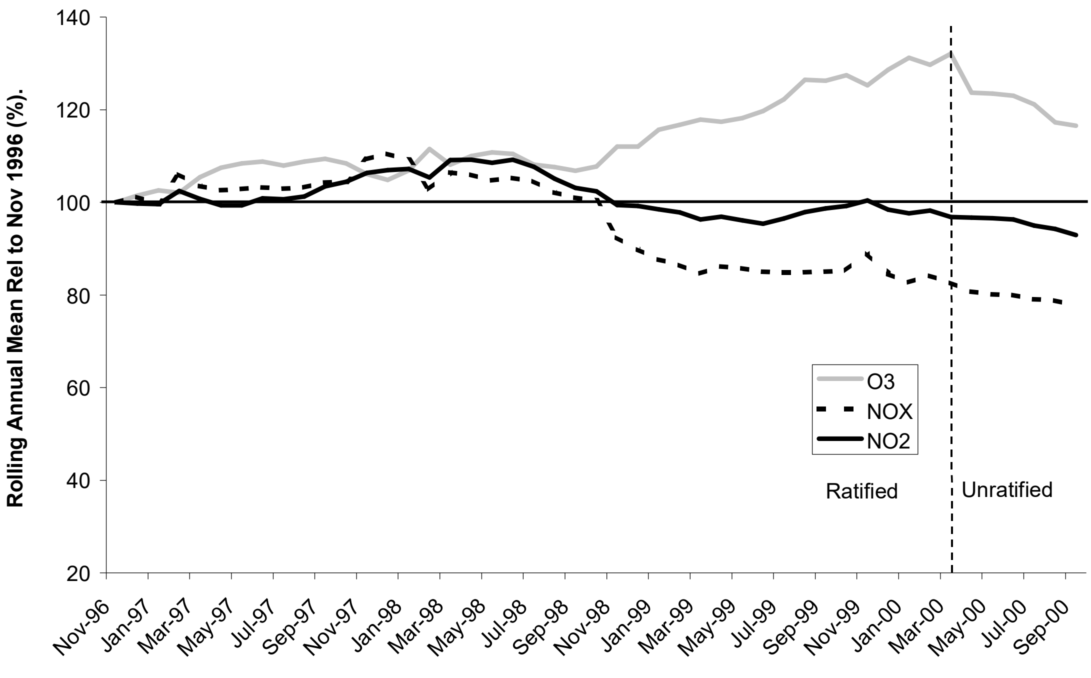


Figure 18 Relative Rolling Annual LAQN Means for O_3, NO_X and NO_2

Figure 18 shows a fall of around 23 % in the NO_X concentration over the period November 1996 to September 2000. This is very likely the result of reduced NO_X emissions due to technological changes in the vehicle fleet. The effects of pollution incidents during autumn 1997 can also be clearly seen in the NO_X concentration, causing a rise in concentration at this time and a consequential fall during autumn

1998 as this incident drops from the rolling annual mean. The overall fall in NO_X concentrations has not been matched by those of NO_2, which show little change over the period, although data that are yet to be ratified suggested a decline during the summer of 2000. This decrease might be linked to the relatively poor summer weather rather than being part of a long-term trend. The overall stability of NO_2 concentrations, in the face of NO_X reductions, is of profound importance to air quality management strategies.

The behaviour of NO_2 over the period begs the question whether the rate of decline is sufficient to achieve the objective by 2005. Clearly the required reduction in NO_2 concentrations is different at each site, dependent on its annual mean at the start of the period of analysis. To illustrate this, target rates of reduction have been derived for four sites in London. For illustrative purposes these are assumed to be constant. The rolling annual LAQN mean NO_2 is shown compared to these target reduction rates in Figure 19.

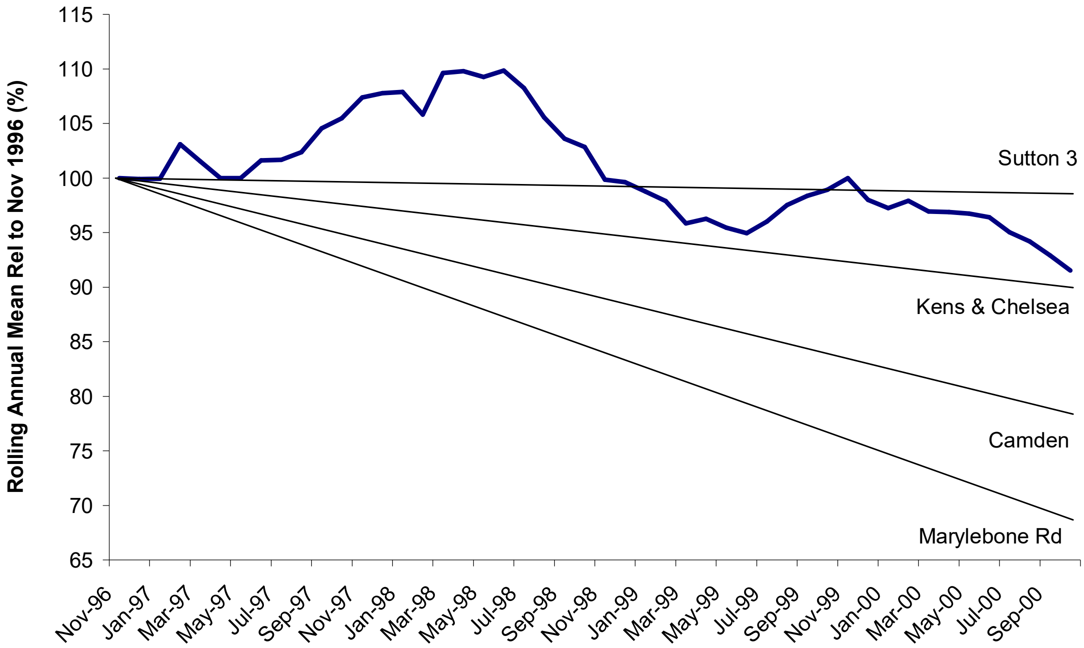


Figure 19 Relative Rolling Annual LAQN Means for NO_2 and target reduction rates for 4 sites.

Figure 19 suggests that the rate of change in NO_2 concentration seen over the previous 4 years may be sufficient to achieve the AQS objective at outer London suburban sites such as Sutton 3. The rate of change is approaching the rate at which inner London background sites will achieve the objective. The background site at Kensington & Chelsea illustrates this. It is evident that a greater rate of reduction will be required if inner and central kerbside sites, such as Camden and Marylebone Road, are to meet the objective by 2005.

1.31.3 Particles (PM10)

The following figure updates the PM10 concentrations monitored at London sites for the period 1997 to 1999. These measurements indicate that the objective levels of PM10 are reducing at most sites. The only site, which exceeded the objective in 1999, was the Marylebone Road site. The Marylebone Road site also exceeded in 1998 as did the A3 roadside site. Background sites exceeded the objective in 1997 only (apart from Kensington and Chelsea and Brent), as did the roadside and kerbside sites.

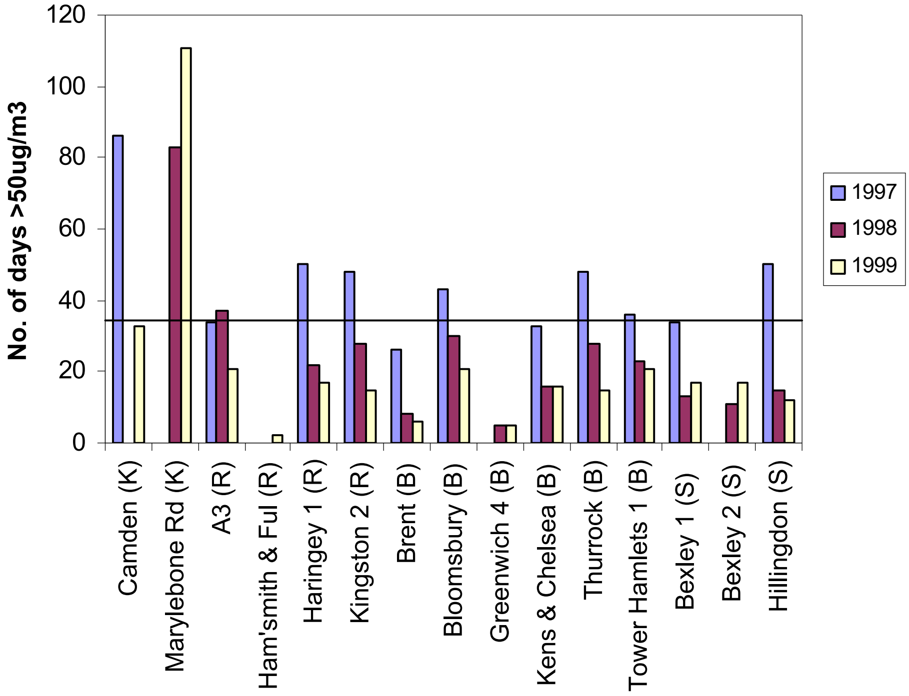


Figure 20 Days exceeding 50µg/m^3 for sites (1997-9)

The reduction in PM10 can also be seen to fall in the following graph, which shows approximately a 30% in the rolling annual mean for PM10 since 1996. Four sites have been used for the rolling PM10 calculation.

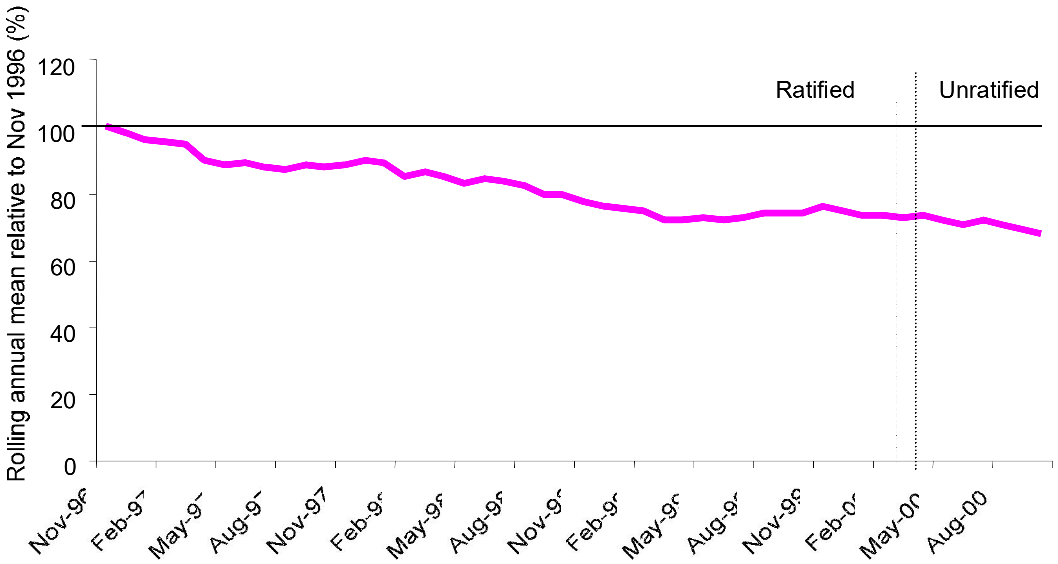


Figure 21 Relative Rolling Annual LAQN Means for PM10

References:

Airborne Particles Expert Group (APEG), 1999. Source apportionment of particulate matter in the United Kingdom. HMSO.

Carslaw D, Beevers S 1999. Estimating the Uncertainty of Model Predictions using a Monte Carlo Simulation, Department of the Environment, Transport and the Regions, April 99

Carslaw, D., C., Beevers, S., D., Fuller, G., 2001. An Empirical Approach for the Prediction of Annual Mean Nitrogen Dioxide Concentrations in London. Atmospheric Environment 35-8, 1505-1515.

Carslaw, D., C., Beevers, S., D., Hedley, S.D., 2000. Air quality assessment in London and the East Thames Corridor – a report for the Environment Agency. Environmental Research Group, King's College, London, November 2000.

Derwent, R.G. and Middleton D.R., 1996. An Empirical Function for the Ratio NO_2:NO_X. Clean Air 26, No. ¾, National Society for Clean Air, Brighton.

DEFRA, 2001. Air Quality Strategy for England, Scotland, Wales and Northern Ireland - Consultation document on proposals for air quality objectives for particles, benzene, carbon monoxide and polycyclic aromatic hydrocarbons. DEFRA, London

DETR, 2000. Review and Assessment: pollutant specific Guidance. LAQM.TG4 (00) London: The Stationery Office. ISBN 1 85112 387 3.

DETR, 2000. Air Quality Strategy for England, Scotland, Wales and Northern Ireland. London: The Stationery Office. ISBN 010 145482 1.

EPAQS, 2001. Expert Panel on Air Quality Standards, Airborne Particles. London: The Stationery Office.

ENDS, 2001. The ENDS Report. Environmental Data Services Ltd 313, 34

Fuller, G., Carslaw, D., Lodge H. 2001. An Empirical Approach for the Prediction of Daily Mean PM10 Concentrations. Atmospheric Environment 36-9.

Green, D., C., Fuller, G., Barratt, B., 2001. Evaluation of TEOM™ Correction Factors' for assessing the EU Stage 1 limit values for PM10. Atmospheric Environment 35-14, 2589-2593.

Quality of Urban Air Review Group, 1996. Airborne particulate matter in the United Kingdom. Third Report of the Quality of Urban Air Review Group.

SEIPH, 1997. The AIM Project and Air Quality in London 1996. South East Institute of Public Health, ISBN 1 87 42 5742 6, July 1997.

Stedman, J., R., Vincent, K., J., Campbell, G., W., Goodwin, J., W., L., Downing, C., E., H., 1997. New High Resolution Maps of Estimated Background Ambient NO_X and NO_2 Concentrations in the U.K. Atmospheric Environment 31, 3591-3602.

Figure 4 Annual mean nitrogen dioxide (ppb) for 2005 (based on 1999 meteorology.) Grays Development

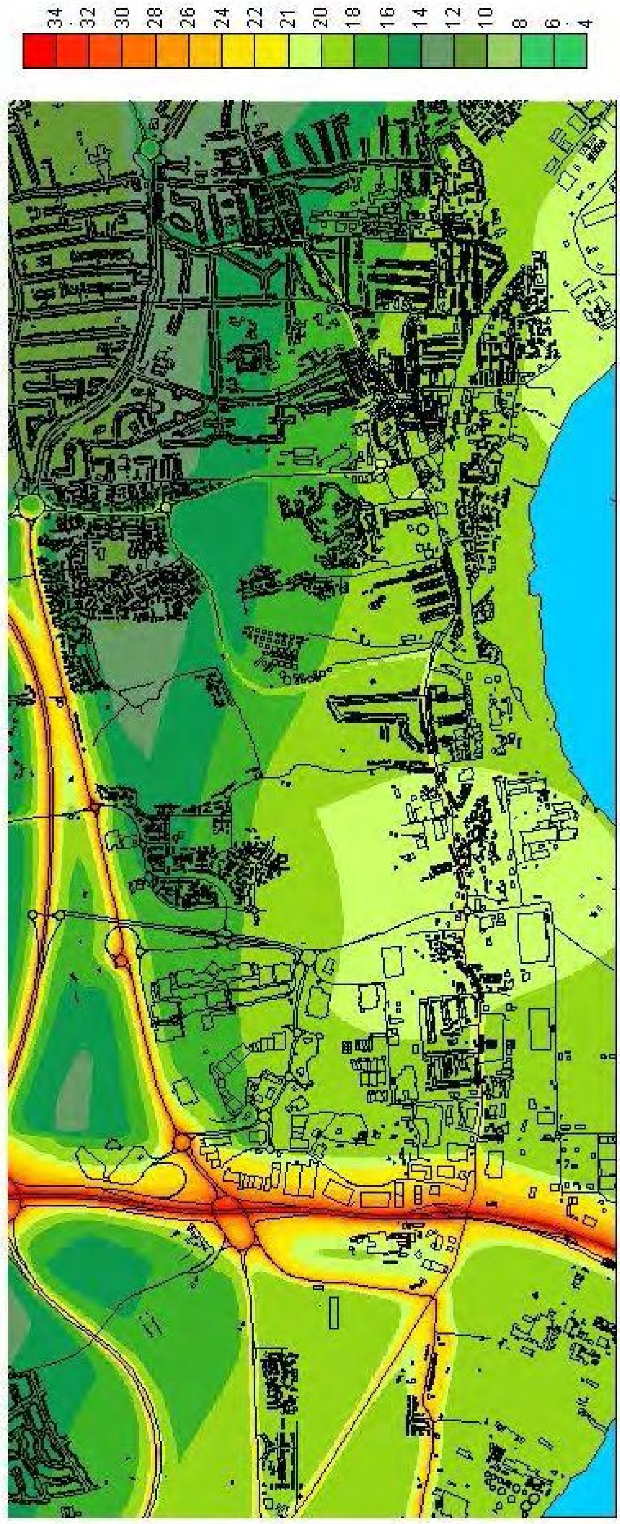


Figure 5 Number of days with daily mean PM10 >50(μg/m^3) for 2004 (based on 1996 meteorology.) Grays Development

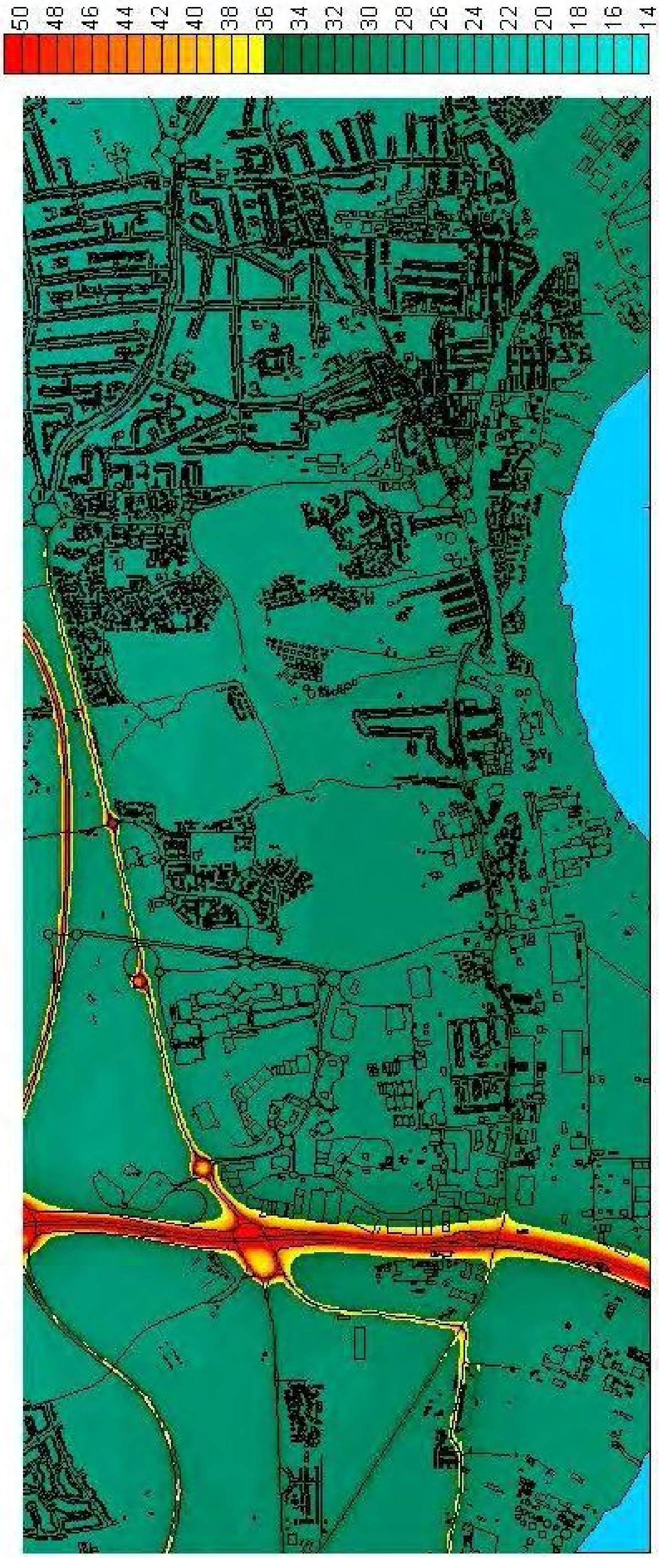


Figure 6 Annual mean nitrogen dioxide (ppb) for 2005 (based on 1999 meteorology.) West Thurrock Marshes Relief Road

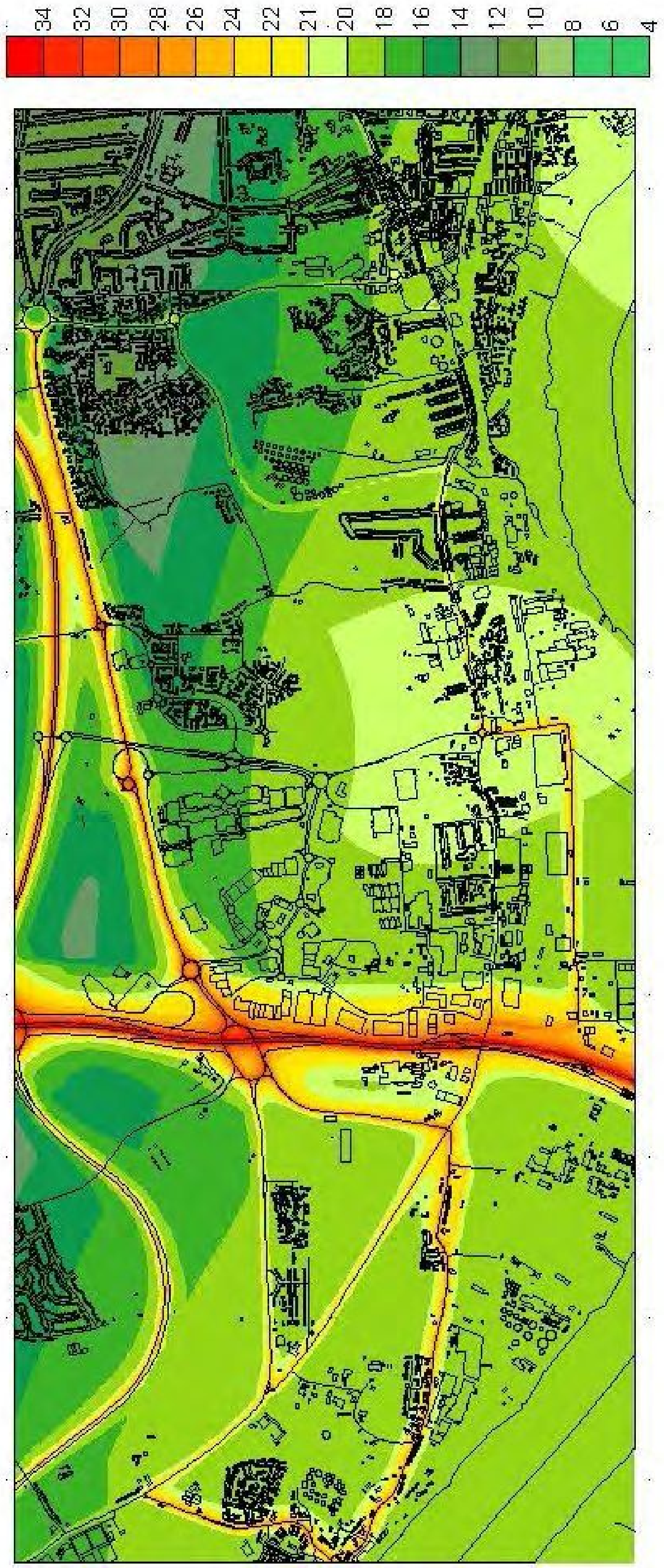


Figure 7 Number of days with daily mean PM10 >50(μg/m^3) for 2004 (based on 1996 meteorology.) West Thurrock Marshes Relief Road

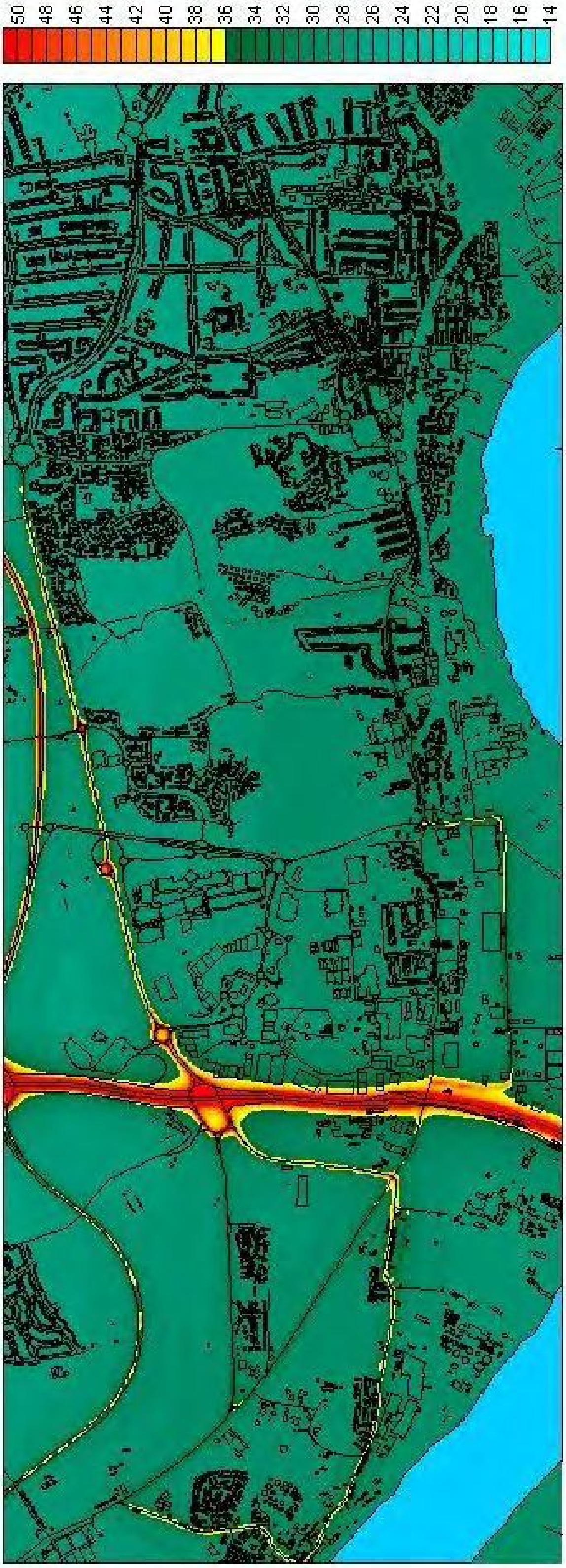


Figure 8 Annual mean nitrogen dioxide (ppb) for 2005 (based on 1999 meteorology.) Hedley Avenue Extension

Figure 9 Number of days with daily mean PM10 >50(μg/m^3) for 2004 (based on 1996 meteorology.) Hedley Avenue Extension