BEDFORD BOROUGH COUNCIL

Detailed Assessment of Nitrogen Dioxide in the Bedford Borough

September 2007

- Technical Services Group
- Environmental Health Service
- Pollution Control Section

PRIDE IN BEDFORD

YOUR AIR QUALITY

Bedford Borough Council

Introduction

Clean air is essential for a good quality of life and progress has been made since the smogs of the 1950s by regulating industry and introducing smoke control areas. However, there are still problems with certain pollutants, particularly from vehicles. In July 1995, the Environment Act 1995 received Royal assent. Part IV of the Act established a new framework for improving air quality, embracing the National Air Quality Strategy, and incorporating health based standards and systems for the management of air quality.

In keeping with the objectives of the Environment Act and as part of a commitment to sustainable development, Bedford Borough Council approved a Local Air Quality Strategy. A corner stone of this Strategy is the Review and Assessment of Bedford's air quality. The objective is to undertake monitoring and evaluation of air quality throughout the borough in a staged process in order to reduce pollution hot spots and integrate air quality into strategic decision making and policies on a local basis. Review and Assessments of local air quality are required every three years and, if necessary, Air Quality Management Areas (AQMA) declared where pollution levels are found likely to exceed national standards. This continual need to review air quality is because of the consequence of changing circumstances including new and expanding industry and increasing vehicular use which could all potentially impact on local air quality.

Air Quality Review & Assessment (2004-2005)

Two Detailed Assessments carried out as part of the second round of Review and Assessment confirmed that emissions of Nitrogen Dioxide from the traffic within three locations in Bedford (High Street, Prebend Street and the A421 running through the village of Great Barford) were such that the annual mean National Standard for Nitrogen Dioxide was likely to be exceeded by the objective date of 31st December 2005. In addition, it was concluded that the emissions from the Stewartby Brickworks were such that all three National Standards for Sulphur Dioxide were likely to be exceeded by their respective objective dates, the earliest being 31st of December 2004.

In 2005 the Borough Council declared four AQMA's and commenced two Further Assessments with which to inform the two Action Plans that will be needed to bring about the improvements in air quality necessary to ensure the National Standards are met. A Progress Report in 2005 provided further confirmation of the highlighted exceedances and also identified a need to expand the Nitrogen Dioxide passive air quality monitoring resources, particularly for those sites in London Road and Dame Alice Street. A commitment was also made to install new, more accurate, real time air quality monitoring stations in key locations to monitor both Sulphur Dioxide and Nitrogen Dioxide.

Air Quality Update and Screening Assessment (2006)

As part of it's continuing obligations under the Environment Act 1995, Bedford Borough Council commenced the third round of Review and Assessment in 2006 with an Update and Screening Assessment. The purpose being to re-examine the local air quality within the whole Borough to establish if there had been any changes since the second round of Review and Assessment which could threaten air quality elsewhere in the Borough other than those areas where AQMA's had been previously declared. This report incorporated the results of the newly expanded passive air quality monitoring resources for Nitrogen Dioxide. It concluded that, as a consequence of emissions from traffic, there may be a need to expand the existing AQMA's on the High Street and Prebend Street, Bedford. In addition, concerns were raised over the air quality on part of Goldington Road and Ampthill Road Bedford where again, emissions from traffic could threaten achievement of the annual mean National Standard for Nitrogen Dioxide.

Air Quality Further Assessment (2006)

Bedford Borough Council has now completed two Further Assessments in respect of the air quality situation in the previously declared AQMA's. These in depth studies have been conducted to characterise the sources of pollution so as to enable effective targeting within the Action Plans. The Further Assessment for Nitrogen Dioxide has supplemented information the Borough already had on the need to either designate further AQMA's or expand those already existing. The Further Assessment has outlined areas outside of the AQMA's where the National Standards are being exceeded. Following completion of the Detailed Assessments, Bedford Borough Council will identify if an AQMA needs to be declared for the whole town Centre, or if expansion of the existing areas is adequate to encompass the areas where exceedances are identified. The Further Assessment for Sulphur Dioxide has shown that the National Standards are still being exceeded in and around the Stewartby area. The existing AQMA incorporates the area of exceedance which the Action Plan will work towards improving in the future.

Air Quality Action Plan (2007)

The AQAP drawn up by Bedford Borough Council details the measures that the Borough and its partners are taking to help improve the Air Quality of Bedford. The AQAP reflects the results of previously declared AQMA's by introducing schemes and measures to reduce the pollution emitted from vehicles and Stewartby Brickworks. The AQAP is a working document and will be continually reviewed and updated in order to achieve each new target set. The AQAP details the need of a multidisciplinary approach, involving all partners in order to improve Bedford Air Quality.

Air Quality Detailed Assessment 2007

Bedford Borough Council has now completed a Detailed Assessment as part of the next step of the Local Air Quality Management process. The Detailed Assessment was also required as a result of the findings of the Council's 2006 Updating and Screening Assessment. The earlier screening assessment identified other parts of the Council which may exceed the government's annual mean. The purpose of this report was therefore to provide an accurate assessment of the likelihood of the objective being exceeded at locations with relevant exposure. The Detailed Assessment has identified that further AQMA's for London Road, Goldington Road and Newnham Avenue need to be declared. The report also identified the need to continue monitoring on Ampthill Road.

Moving Forward - Improving Local Air Quality

To inform the Detailed Assessment, Further Assessment and Action Plan processes, the real time air quality monitoring resources are to be expanded further. The Borough Council currently only operates one real time air quality monitoring station measuring Sulphur Dioxide in Stewartby though this has recently been upgraded and modernized to improve the quality of the data obtained. Funding has been secured to install two more stations. These will be placed in the existing AQMA's and will monitor Nitrogen Dioxide as appropriate. In addition, a local company who operates a station in Kempston, is now supplying the Borough Council with their Sulphur Dioxide data. There are also the two stations measuring Sulphur Dioxide operated by the owners of the Brickworks which are based in Stewartby and Kempston Hardwick. Therefore, in total there will be four monitoring stations measuring Sulphur Dioxide and two stations measuring Nitrogen Dioxide within the Borough. This is a significant achievement and will ensure a good spread of accurate air quality monitoring data be continually obtained for years to come.

Our Commitment to You

Bedford Borough Council's Corporate Plan identifies 6 key priorities to which the Council is fully committed, one of these is to provide a "Clean and Green Borough". As part of this commitment the Council strives for a continuing improvement of air quality within the Borough making it a safe and clean place to live, work, visit and enjoy. With this is mind the Council will use its best endeavours to secure the achievement of the National Standards.

David Logan
Head of Service (Environmental Health, Bedford Borough Council)

2007 Detailed Assessment of Air Quality for the Bedford Borough Council

Executive Summary

This is the Detailed Assessment of air quality for the Bedford Borough Council ("the Council"). This assessment fulfils the Council's next step of the Local Air Quality Management (LAQM) process and is required as a result of the findings of the Council's 2006 Updating and Screening Assessment report.

This earlier screening assessment identified that the government's annual mean nitrogen dioxide (NO_2) objective might be exceeded in part of the Council's area, specifically close to areas with public exposure on Ampthill Road, London Road and Goldington Road in Bedford. The purpose of this report is therefore to provide an accurate assessment of the likelihood of the objective being exceeded at locations with relevant exposure.

New modelling predictions have been made for this report, and these include both improved modelling methods and treatment of emissions. The report also incorporates the most recent monitoring results for the above areas. The report thus meets the requirements of the technical guidance LAQM. TG (03) produced by the Department of Environment, Food and Rural Affairs (DEFRA).

The Council's bias adjusted diffusion tube monitoring results for Ampthill Road, London Road and Goldington Road indicated that the 2005 annual mean objective for NO_2 was exceeded at roadside locations for 2005 and 2006. The objective was however not exceeded at other nearby monitoring sites on these roads in either 2005 or 2006.

The modelling predictions, using 2003 meteorology, for Ampthill Road, London Road and Goldington Road showed that the annual mean NO_2 objective was exceeded for 2005 close to the centre of the roads. This prediction was also verified against the 2005 diffusion tube results. Concentrations close to facades of houses on the west side of London Road (south of the junction with Elstow Road) and the south side of Goldington Road (near the junction with Newnham Avenue) had the highest predicted concentrations and these included areas with relevant exposure. For Ampthill Road the verified predictions did not include areas with relevant exposure. As a result an Air Quality Management Area should be designated in London Road, plus Goldington Road and Newnham Avenue area, but not Ampthill Road.

Bedfordshire County Council indicate that by 2010 it predicts zero growth in traffic over the 2005 base year of this study. Provided this is achieved and the expected improvements in engine technology have occurred then this would lead to reduced concentrations of NO_2 at the sites investigated in this study. Taking this into account, estimates based on these verified predictions for 2010 indicated that concentrations at the facades (in London Road, Goldington Road, Newnham Avenue and Ampthill Road) would not exceed the objective.

The Council is recommended to undertake the following actions, in respect of the findings for the statutory objective relating to annual mean nitrogen dioxide.

For the London Road, plus Goldington Road and Newnham Avenue areas, although improvements are anticipated, an AQMA (or separate AQMAs in each area) still needs to be designated due to the 2005 objective being exceeded:

1. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.

2. Confirm that there is relevant exposure in the area predicted to exceed and designate an AQMA.

3. Consider extending monitoring in the area to include Newnham Avenue to confirm the findings of the report.

For the Ampthill Road area examined in the report:

4. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.

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1 Introduction to Detailed Assessment of Nitrogen Dioxide

1.1 Overview to Detailed Assessment

This is the 2007 Detailed Assessment of nitrogen dioxide (NO_2) for the Bedford Borough Council. The report fulfils the statutory requirement for this, the Council's next step, of the Local Air Quality Management (LAQM) process.

1.2 Background

Local air quality management forms a key part of the Government's strategies to achieve the air quality objectives under the Air Quality (England) Regulations 2000 and 2002. As part of its duties the Council completed its third round Updating and Screening Assessment (USA) in 2006 for the seven LAQM pollutants. This report identified that there was a risk of the government's annual mean NO_2 objective being exceeded in part of the Borough not previously assessed as such. This assessment was based on results from the Council's diffusion tube monitoring programme. The conclusion of the 2006 USA report was that the Council needed to undertake a Detailed Assessment for NO_2 for Ampthill Road, London Road and Goldington Road close to the Bedford town centre only (see Figure 1).

The aim of the Council's Detailed Assessment is to determine with reasonable certainty whether or not there is a likelihood of the AQ objectives being achieved. The assumptions in the Detailed Assessment are therefore in depth and the data used are quality assured to a high standard. This allows the Council to have confidence in reaching its air quality management decisions. When carrying out its Detailed Assessment the Council applied its best estimates to all components used in producing estimated future concentrations.

Table 1 Air quality objective relevant to this Detailed Assessment

Pollutant	Concentration	Measured as	Date to be achieved by
Nitrogen dioxide (NO_2)	40 µg m^{-3}	Annual mean	31-Dec-05

1.3 Progress with Local Air Quality Management – Bedford Borough Council

The Council previously designated Air Quality Management Areas (AQMAs) in parts of its area for both NO_2 and sulphur dioxide (SO_2) during the second round review and assessment of air quality. Three AQMAs were declared for NO_2 where concentrations exceeded the annual mean objective. These were in the town centre of Bedford (along Prebend Street and the High Street, see Figure 1) and along the A421 in the village of Great Barford. A further AQMA was declared for SO_2 as concentrations exceeded the 15-minute mean objective around the village of Stewartby in the south west of the Borough.

The Council has also recently developed its Action Plan for these AQMAs and following consultation responses is due to consider approval of that Action Plan in October 2007.

Figure 1 Location of areas investigated within the Bedford town centre in relation to existing town centre AQMAs

2 Monitoring results

2.1 Updated NO_2 results

This section provides an update of the results of the Council's monitoring programme for the area under investigation. As reported in the 2006 Updating and Screening Assessment, the Council undertook an extensive programme of diffusion tube monitoring of NO_2, supplied and analysed by Gradko. The method of preparation was 50% triethanolamine (TEA) in acetone as absorbent.

The Council is also looking to install two continuous analysers in the Bedford town centre AQMAs and will undertake a local co-location study once the sites have been established. In the meantime default bias correction factors were used to adjust the measurements. These factors were obtained from the Review and Assessment website (http://www.uwe.ac.uk - March 2007 version). These indicated that the diffusion tubes measurements were less than continuously monitored concentrations at the same location. The figures in brackets are the default factors used in the 2006 USA from a previous version. These factors have changed as a result of further data being added to update the spreadsheet.

Year	Bias adjustment factor
2004	1.10 *(1.10)*
2005	1.10 *(1.18)*
2006	1.04

NO_2 monitoring was undertaken at the sites on Ampthill Road (A6), London Road (A600) and Goldington Road (A428) in Bedford.

Ampthill Road is one of the main routes into the Bedford town centre from the south, although access is constrained by the river Great Ouse and the three bridges that cross it near the town centre. There were two diffusion tube sites located on the Ampthill Road (BF22 and BF47). The BF22 site was located close to the kerbside, set approximately 1.5m from the kerb at a height of 2.5m. The BF47 site was located outside number 38, approximately 2m from the kerb edge. This site was started in late 2004 (when there was 3 months data capture), whereas the BF22 was in operation prior to 2000. The two locations were approximately 40m apart and there was a signalled junction approximately 100 m north of the BF22 (see Figure 2). There was also a bus stop located adjacent to the B47 site.

London Road is another major route into the Bedford town centre from the south and southeast. It meets the A6 at its northern end. The BF35 site was established on a lamppost 2m from the kerbside on the northbound lane. It is also located approximately 10m south of a signalled junction with Elstow Road. Cars often park along the road and slow the traffic. The site is therefore generally congested particularly during rush hours. The façade of houses are sited a further 2.5m behind the diffusion tube. The site is shown in Figure 3.

Goldington Road is a main route to the town centre from the eastern side of Bedford. There were two diffusion tube sites along Goldington Road and these are shown in Figure 4. The BF11 site was established prior to 2000 and the BF39 site in late 2004 (when there was 4 months data capture). Both sites were located at the kerbside and are about 75m apart. The BF39 site was located close to the junction with Newnham Avenue (A5140). (Also shown is the BF07 site, which was located at the roadside of a minor residential road in Bedford).

Figure 2 Diffusion tubes sites in Ampthill Road

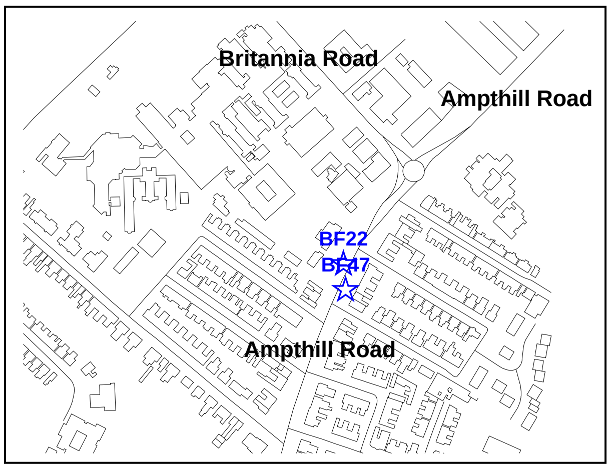


Figure 3 Diffusion tube site in London Road

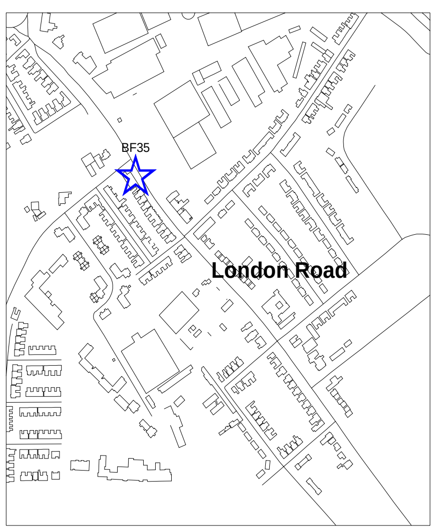
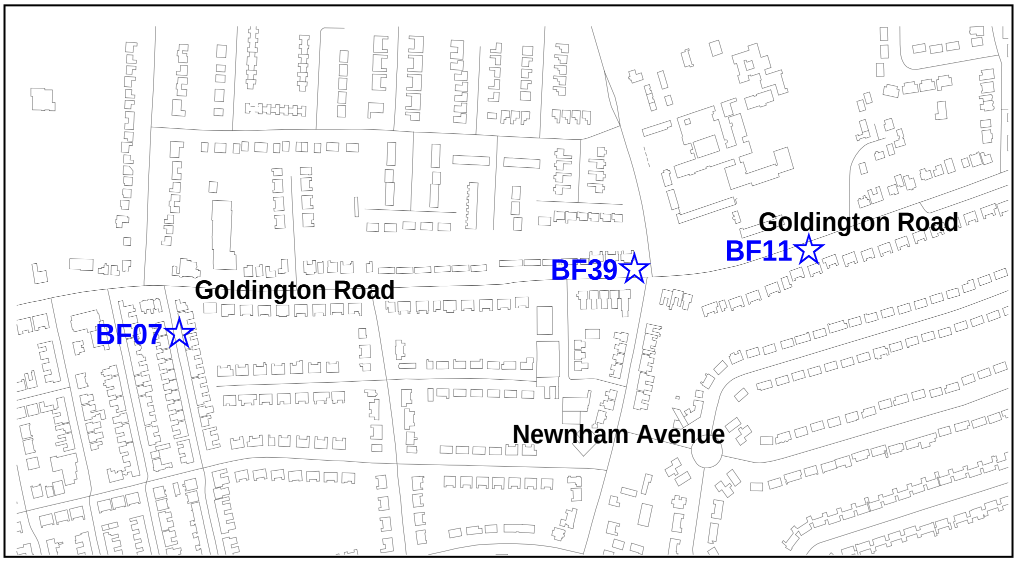


Figure 4 Diffusion tubes sites in Goldington Road



The biased adjusted results for the sites are given below and for all years reported there was more than 75% data capture (unless indicated). For 2006, the results were for the period from January to October only and these results were adjusted to 12 months using a factor of 1.0127, which was derived from the average of three background sites in the Herts and Beds Air Pollution Monitoring Network (see Appendix F).

Table 2 Diffusion tube monitoring at Ampthill Road, London Road and Goldington Road ($\mu g\ m^{-3}$)

Code	Road	Biased 2004	Biased 2005	Biased 2006
BF22	Ampthill St	36.5	34.7	36.4
BF47	Ampthill St	*39.9*	**44.1**	**43.6**
BF35	London Rd	*50.6*	**48.0**	**47.2**
BF11	Goldington Rd	34.8	37.8	35.0
BF39	Goldington Rd	*42.2*	**47.6**	**47.4**
BF07	George St	25.1	28.2	23.8

(Note: bold indicates exceeds objective; italics indicate < 75% data capture)

The results indicated that the annual mean objective was exceeded for 2005 and 2006 at the BF47, BF35 and BF39 sites only. (Note - the unbiased monthly results are given in Appendix F).

2.2 Commentary on diffusion tube results

The results indicated some inter annual variability, although overall they remained consistent between years, with BF39, BF35 and BF47 exceeding the annual mean objective for both 2005 and 2006. The measurements at the BF11 and BF22 sites achieved the objective for all three years reported (as did the BF07 background site).

3 Predictions of NO_2 at Ampthill Road, London Road and Goldington Road

3.1 Outline of modelling developments

The Detailed Assessment incorporates:

- Major roads on an exact geographic basis to allow an improved assessment of exposure;
- Predictions plotted on OS base maps;
- A best estimate of model uncertainty, using Monte Carlo techniques.

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

The model was empirically developed for urban areas and has been previously used for modelling assessments by the Council as part of its local air quality management responsibilities. Details of the model validation are given in Appendix C.

The traffic data are used for the modelling were obtained from the Department for Transport Rotating Census and are based upon the 2005 traffic counts for the road links. Traffic information details are given in Appendix D.

3.2 Annual mean NO_2 ($\mu g\ m^{-3}$) in 2005

The predicted annual mean concentrations for the 2005 base case, assuming that the meteorology of the year 2003 was repeated, are shown in Figure 5. Only areas coloured yellow to orange exceed the air quality objective.

The locations of the 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[1], which gives details of individual buildings 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 to the background from the road.

3.3 Predictions of NO_2 for Ampthill Road, Bedford

The base case predictions confirmed that the annual mean air quality objective was exceeded along the road modelled. The area that exceeded was mostly close to the centre of roads. The area that exceeded however did not overlap with the façades of nearby relevant buildings with public exposure.

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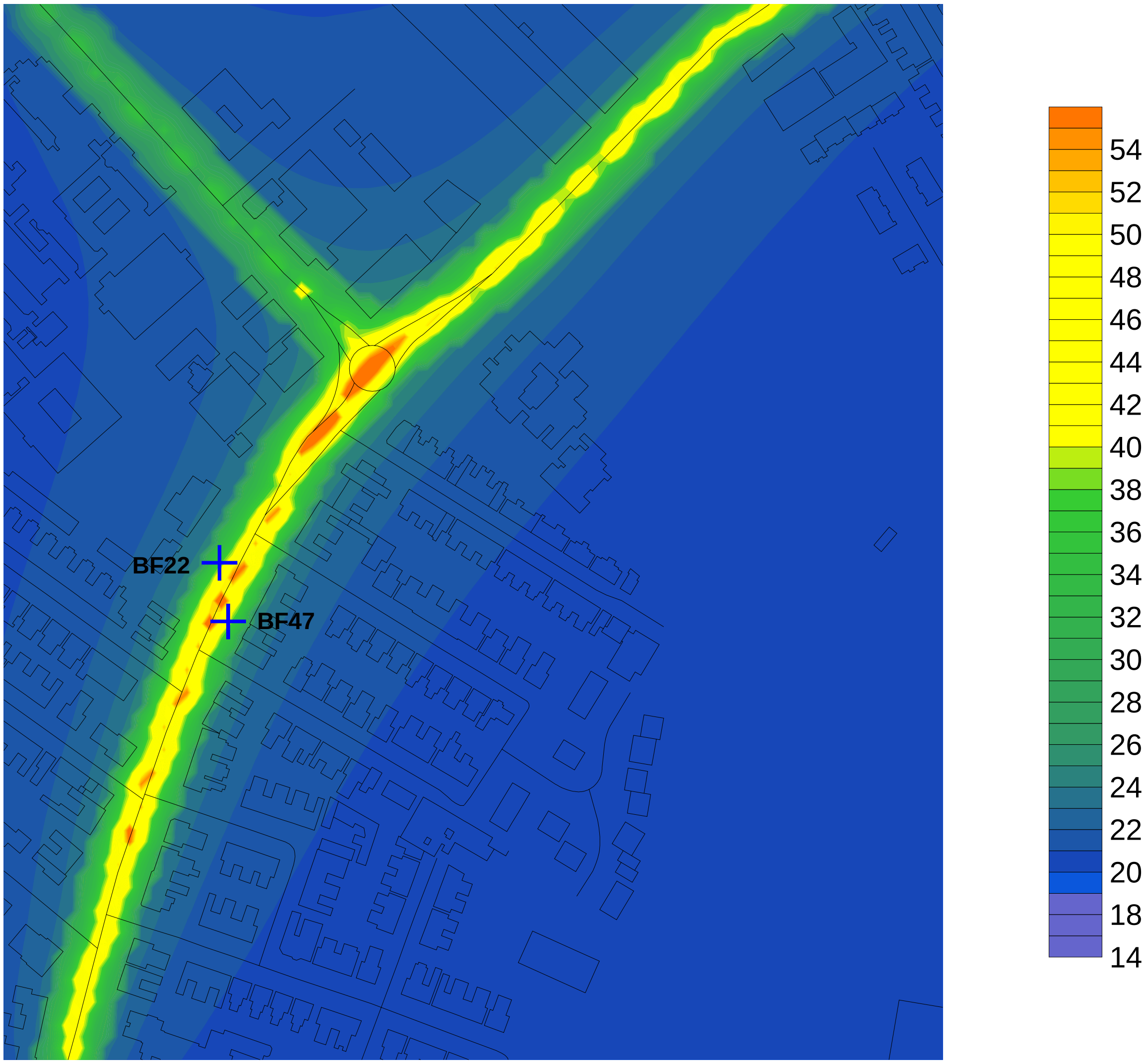
Figure 5 Predicted annual mean NO_2 ($\mu g\ m^{-3}$) at Ampthill Road, Bedford for 2005 base case (with 2003 meteorology)



(Note – blue crosses indicate diffusion tube sites)

3.4 Comparison with Ampthill Road monitored results

The annual mean NO_2 monitored results for the Ampthill Road diffusion tube sites were given in the previous section. The monitoring results indicated for the period 2005 and 2006 that the objective was exceeded at the BF47 monitoring location only. From Figure 4 above, it can be seen that the BF47 site is just within the area that exceeds, whereas the BF22 site is just outside.

Table 3 gives a comparison of the modelled and monitored results. These show a broad agreement with the one site (BF47) exceeding the objective and the other site (BF22) meeting it.

Table 3 2005 modelled and biased monitored annual mean NO_2 concentrations for Ampthill Road ($\mu g\ m^{-3}$)

Code	Easting	Northing	Class	Monitored	Modelled
BF47	504798	248751	Roadside	44.1	41.4
BF22	504794	248776	Roadside	34.7	37.3

There was a large difference of approximately 10 $\mu g\ m^{-3}$ between the bias adjusted monitored results of the two sites, despite their close proximity. The modelling prediction for the BF47 site exceeded the objective and was slightly lower than the monitoring result, whereas the BF22 result was the reverse, with the modelled result exceeding the monitored result. The modelled result for BF22 did not exceed the objective.

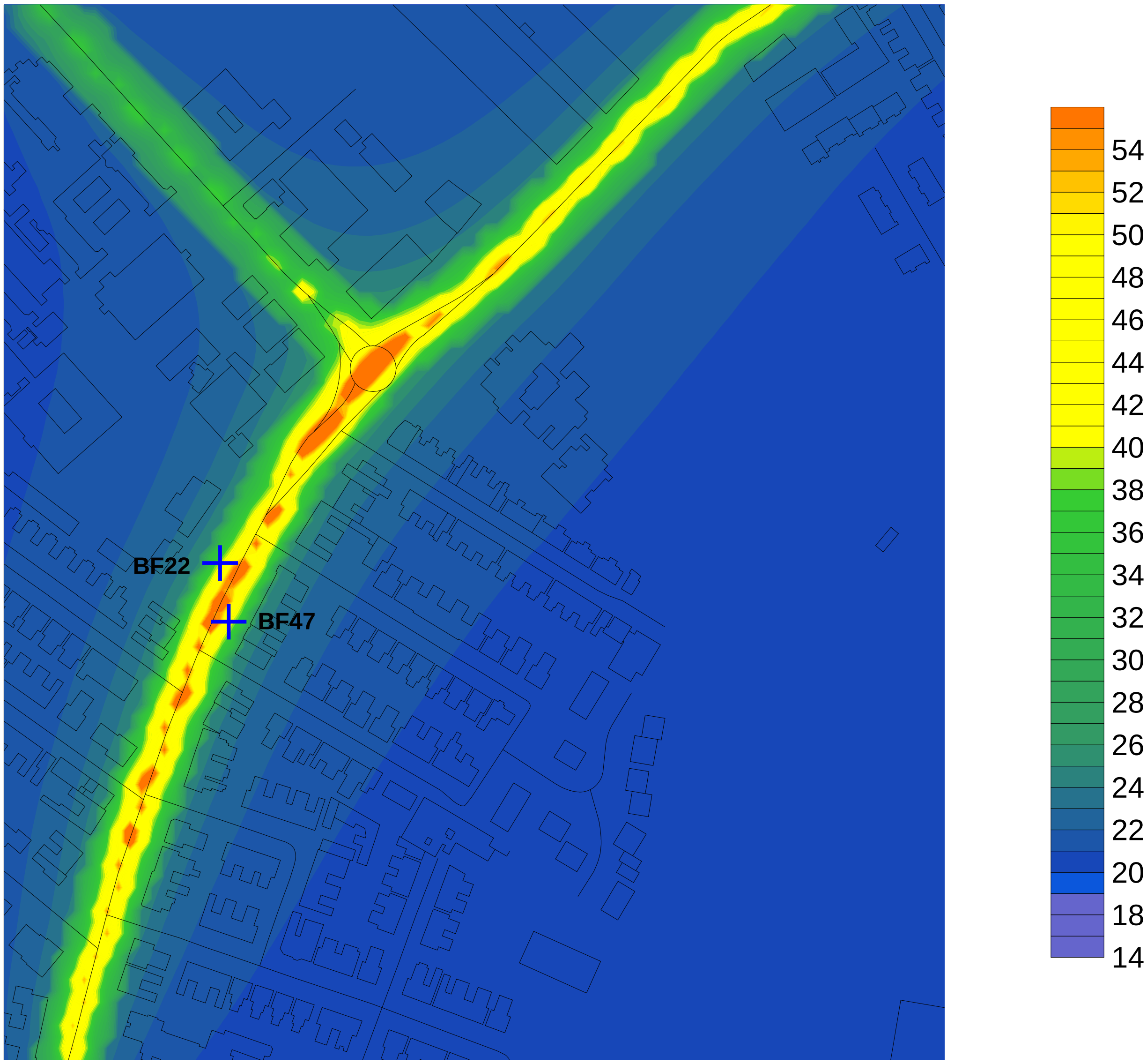
There were many uncertainties in both monitoring and modelling this section of road. The monitoring was undertaken by diffusion tube, which is more uncertain than continuous monitoring. In accordance with the TG03 guidance and to try to reduce this uncertainty, the diffusion tubes were corrected. In this instance default bias correction factors were used. These indicated that the diffusion tube measurements were less than measurements obtained using a continuous monitoring and therefore the measurements were biased upwards.

The location investigated was on a route to the town centre, with a signalled traffic junction nearby. Of the two sites the BF22 site was located closer to the junction at a more open roadside site than the BF47 site. As mentioned earlier the BF47 site was also located close to a bus stop, accordingly emissions were increased at the sections modelled close to this site, to represent both emissions from buses and other vehicles operating at slower speeds at this location.

The TG03 guidance suggests where there is disparity between predicted and measured results an appropriate adjustment factor should be determined. The guidance also highlights that this is not generally recommended based on solely on diffusion tubes. However in the absence of locally available high quality continuous monitoring data an adjustment factor was derived from the BF47 diffusion tube result for verification purposes. The derived factor applied to the roads element only in the modelling was 1.125. The verified model results are presented in Figure 6.

The verification was undertaken using 2005 monitored results. The concentrations measured in 2005 were the highest assessed and the verification can therefore be considered to provide a precautionary estimate of concentrations.

Figure 6 Verified annual mean NO_2 (µg m^{-3}) prediction at Ampthill Road for 2005 based on 2003 meteorology



(Note – blue crosses indicate diffusion tube sites)

The modelled plot in Figure 6, which is verified against the diffusion tube results, shows areas where concentrations exceed the annual mean objective along the road centre line. Thus the modelled concentration at BF47 equated to the monitored concentration, however at the BF22 monitoring location the prediction exceeded that monitored by 4.7 µg m^{-3} (but did not exceed the objective). This area extended outwards towards the facades of buildings along Ampthill Road, although the area did not overlap the facades, representing relevant exposure.

The estimated 2010 concentrations for these locations were obtained using the Year Calculator provided for the TG03 guidance. Future concentrations are expected to decrease into the future as a result of changes including the increased uptake of pollution abatement technology and the Year Calculator provides estimates for these changes at both roadside and background locations. The estimated 2010 concentrations for the above roadside sites are given in Table 4.

Table 4 Estimated 2010 annual mean concentrations (µg m^{-3}) from verified model results for Ampthill Road

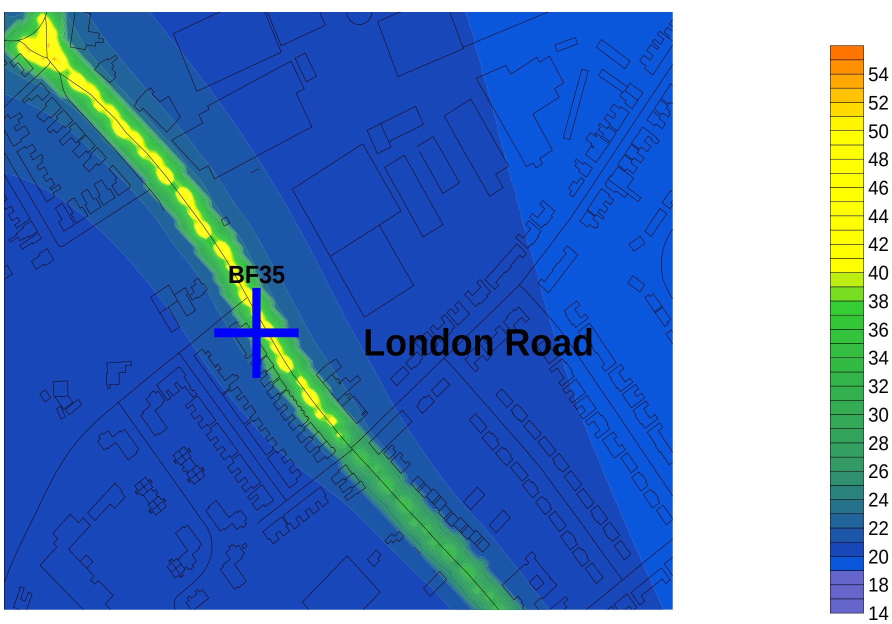
Location	2010 estimated
BF47	37.1
BF22	31.4

The estimated 2010 concentrations for the diffusion tube sites are below the 40 µg m^{-3} standard.

3.5 Predictions of NO_2 for London Road, Bedford

The base case predictions for London Road confirmed that the annual mean NO_2 objective was exceeded along the part of the road modelled, specifically closest to the town centre and junction with Elstow Road.

Figure 7 Predicted annual mean NO_2 (µg m^{-3}) at London Road, Bedford for 2005 base case (with 2003 meteorology)



(Note – blue cross indicates diffusion tube site)

The area that exceeded the objective for this base plot however did not overlap with the façades of relevant buildings with public exposure. The nearest houses with relevant exposure were located approximately 5m from the edge of the kerb (i.e. a further 3m beyond the monitoring location). The base case prediction is shown in Figure 7.

3.6 Comparison with London Road monitored results

The monitored annual mean NO_2 result for the London Road diffusion tube site was given in the previous chapter. This showed that the annual mean objective was easily exceeded at the BF35 kerbside site. In comparison the modelled prediction under predicted the monitored result at the BF35 site (see Table 5).

Table 5 2005 modelled and biased monitored annual mean NO_2 concentrations for the London Road site ($\mu g\ m^{-3}$)

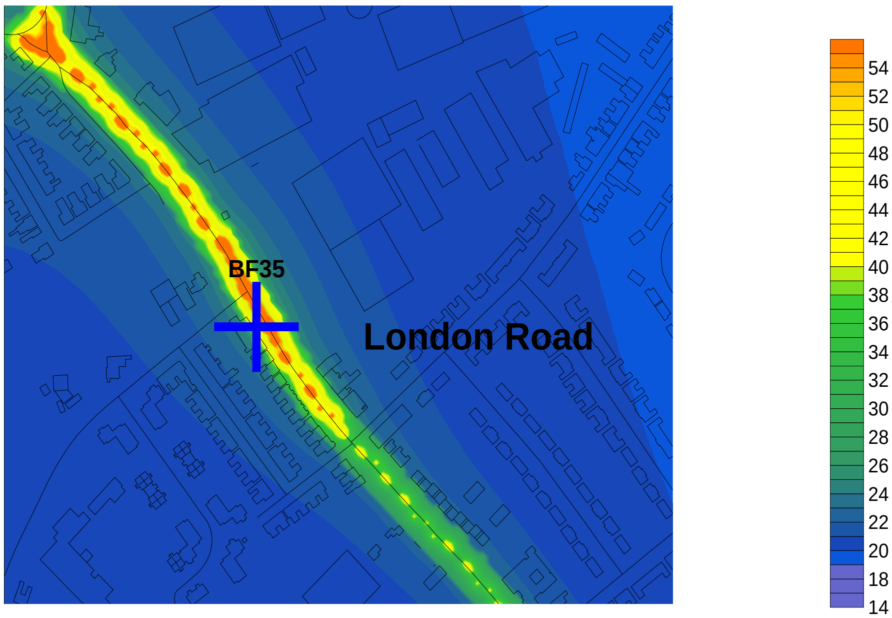
Code	Easting	Northing	Class	Monitored	Modelled
BF35	505380	248866	Kerbside	48.0	38.9

The BF35 diffusion tube site was located close to kerbside and was approximately 10m from a signalled road junction, with a left hand lane into Elstow Road. Turning counts for the junction were not available and the modelled assumption used was that one third of the total traffic flow of London Road turned left into Elstow Road.

Where there is disparity between predicted and measured results the TG03 guidance recommends that an appropriate adjustment factor should be determined. In the absence of locally available high quality continuous monitoring data an adjustment factor was derived from the BF35 diffusion tube result for verification purposes. The derived factor applied to the roads element only in the modelling was 1.48. The verified model results are presented in Figure 8.

The verification was undertaken using 2005 monitored results. The concentrations measured in 2005 were slightly higher than 2006 and the verification can therefore be considered to provide the most precautionary estimate of concentrations.

Figure 8 Verified annual mean NO_2 (µg m^{-3}) prediction at London Road for 2005 based on 2003 meteorology



The verified prediction shows that the area that exceeds the objective was increased further along London Road and that the facades of buildings with relevant exposure close to the junction with Elstow Road were within this area.

An estimate of 2010 concentrations at the BF35 site was made using the Year Calculator provided for the TG03 guidance. This estimate indicated at the monitoring site location that annual mean concentration will decrease to 40.4 µg m^{-3}, which still just exceeds the annual mean objective of 40 µg m^{-3}. However at the façade the predicted concentration was 47 µg m^{-3} indicating that the estimated 2010 concentration would be just below the objective (at 39.5 µg m^{-3}).

3.7 Predictions of NO_2 for Goldington Road, Bedford

The base case predictions for Goldington Road confirmed that the annual mean NO_2 objective was exceeded along the roads and junction modelled. The areas that exceeded the annual mean objective were however mostly close to the centre of roads, with the highest concentrations close to the Goldington Road junction with Newnham Avenue (see Figure 9).

Figure 9 Predicted annual mean NO_2 ($\mu g\ m^{-3}$) at Goldington Road, Bedford for 2005 base case (with 2003 meteorology)

(Note – blue crosses indicate diffusion tube sites)

3.8 Comparison with Goldington Road monitored results

The monitored annual mean NO_2 results for the Goldington Road diffusion tube sites were given in the previous chapter. These monitoring results indicated for 2005 and 2006 that the objective was exceeded at the BF39 monitoring location only. From Figure 9 above, it can be seen that the BF39 site is just within the area that exceeds, whereas the BF11 site furthest east along Goldington road is just outside.

Table 6 gives a comparison of the modelled and monitored results. These show some agreement with the one site (BF39) exceeding the objective and the other site (BF11) meeting it.

Table 6 2005 modelled and biased monitored annual mean NO_2 concentrations for Goldington Road ($\mu g\ m^{-3}$)

Code	Easting	Northing	Class	Monitored	Modelled
BF39	506623	250270	Roadside	47.6	40.8
BF11	506799	250288	Roadside	37.8	35.2

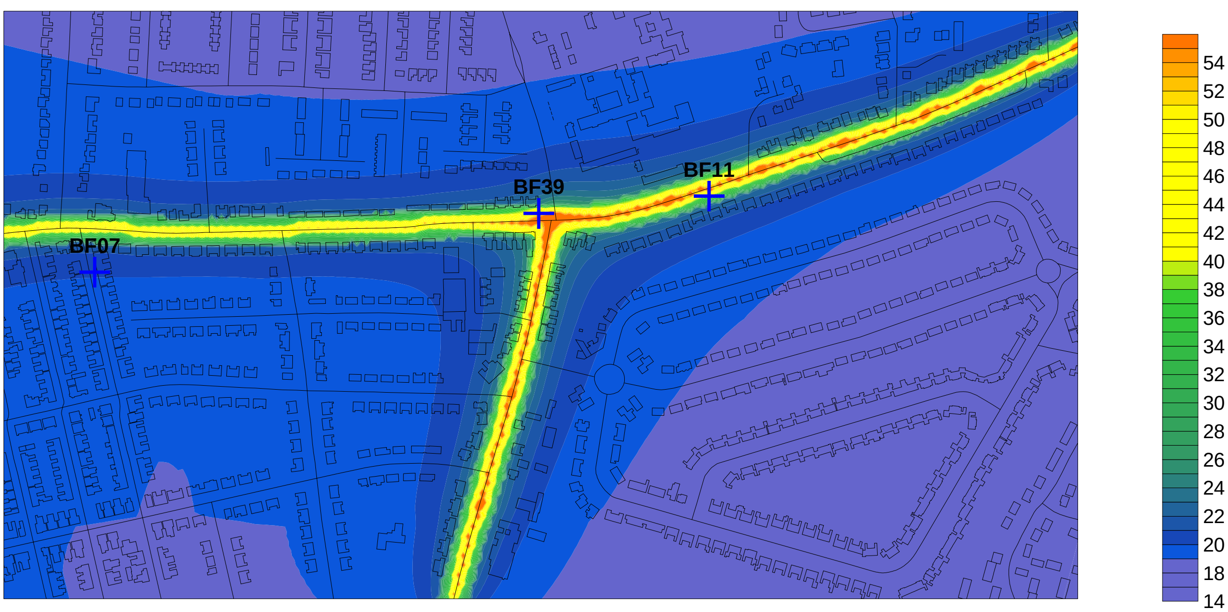
There was a large difference of almost 10 $\mu g\ m^{-3}$ between the bias adjusted monitored results of the two sites, despite their locations close to Goldington road. The modelled prediction for the BF39 site exceeded the objective and was lower than the monitoring result, whereas the BF11 result did not exceed the objective. For this site the modelled prediction also under predicted the monitored result.

The location investigated was a route to the town centre, with a signalled traffic junction nearby. Of the two sites the BF39 site was located closer to the junction than the BF11 site.

Based on the TG03 guidance where there is disparity between predicted and measured results an appropriate adjustment factor should be determined. In the absence of locally available high quality continuous monitoring data an adjustment factor was derived from the BF39 diffusion tube result for verification purposes. The derived factor applied to the roads element only in the modelling was 1.3. The verified model results are presented in Figure 10.

The verification was undertaken using 2005 monitored results. The concentrations measured in 2005 were slightly higher than 2006 and the verification can therefore be considered to provide the most precautionary estimate of concentrations.

Figure 10 Verified annual mean NO_2 ($\mu g\ m^{-3}$) prediction at Goldington Road for 2005 based on 2003 meteorology



(Note – blue crosses indicate diffusion tube sites)

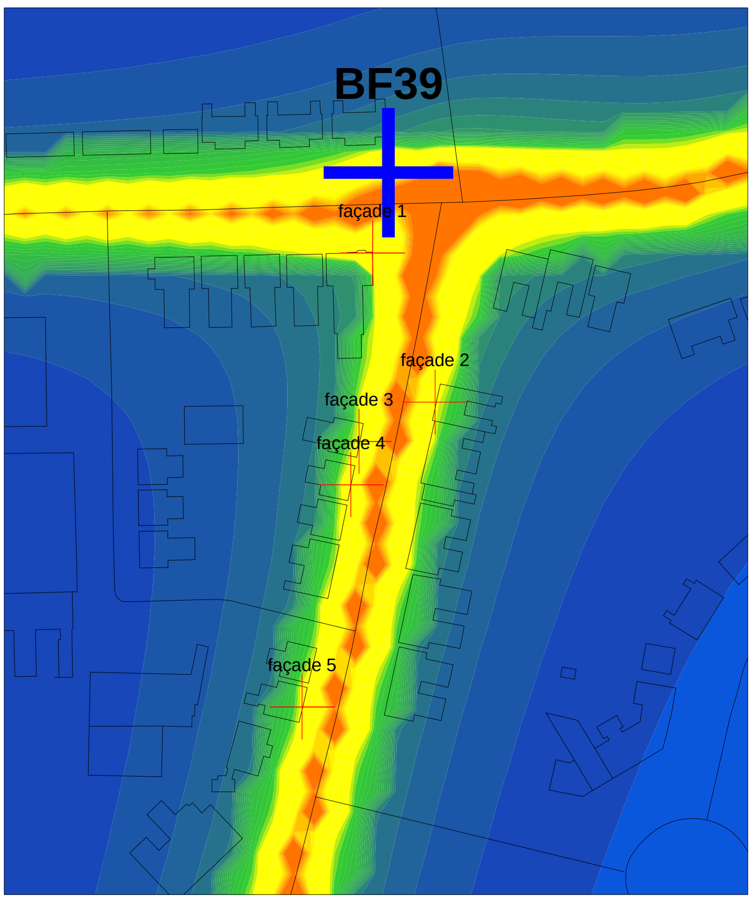
The modelled plot in Figure 10, which is verified against the diffusion tube results, shows areas where concentrations exceeded the annual mean objective along the road centre line and junction of Goldington Road and Newnham Avenue. This area extended outwards towards the facades of buildings along both roads and overlaps the facades of buildings, representing relevant exposure close to this junction (including houses in Goldington Road and Newnham Avenue).

These facades are shown more clearly in Figure 11. The modelled and estimated 2010 annual mean concentrations at the facades indicated are given in Table 7.

Table 7 Estimated annual mean concentrations (µg m^{-3}) from verified model results for Goldington Road/ Newnham Avenue

Location	Easting	Northing	2005	Estimated 2010
Façade 1	506619	250251	42.4	35.7
Façade 2	506634	250214	41.8	35.1
Façade 3	506616	250205	41.6	35.0
Façade 4	506614	250194	44.6	37.5
Façade 5	506602	250140	40.7	34.2

Figure 11 Close up verified annual mean NO_2 (µg m^{-3}) prediction at Goldington Road/ Newnham Avenue for 2005 based on 2003 meteorology



The verified model façade concentrations confirm that buildings fronting Goldington Road and Newnham Avenue exceeded the annual mean objective.

Estimates of 2010 concentrations were also derived using the Year Calculator provided for the TG03 guidance. These indicated that annual mean concentrations will decrease below the annual mean objective of 40 µg m^{-3}.

4 Conclusion

This report fulfils the requirements of the DEFRA guidance for the Detailed Assessment. The Detailed Assessment incorporates recent monitoring results and improved modelling techniques, plus an improved treatment of emissions using the most recent locally available traffic data.

The bias corrected NO_2 monitoring results indicated that roadside locations monitored on Ampthill Road, London Road and Goldington Road exceeded the annual mean objective for the years 2005 and 2006. Other roadside sites located nearby on the same road links however did not exceed the objective in either year.

Modelled predictions were made for the areas under investigation for 2005 and overall these agreed reasonably well with the biased monitored results, although they tended to under predict the monitored results. In view of this the modelling predictions were corrected using verification factors for each location (this was based on TG03 guidance). The verification factors were based on the 2005 bias adjusted results and this was considered to provide a conservative estimate.

The verified predictions indicated that concentrations exceeded the annual mean objective close to the road centres of Ampthill Road, London Road, Goldington Road and Newnham Avenue. The area predicted to exceed did not overlap the front facades of houses along Ampthill Road. However the area predicted to exceed close to the junction of London road and Elstow Road and the junction at Goldington Road and Newnham Avenue did overlap the front facades of houses, which represent the nearest relevant exposure.

An estimate of 2010 concentrations based on the verified predictions shows that concentrations at all the facades and the diffusion tube site will meet the objective.

Based on the above findings, it is considered that the objective was achieved in this area at facades representing relevant public exposure on Ampthill Road. In view of these findings the Council does not need to designate an AQMA in this area.

In the London Road area, plus the Goldington Road and Newnham Avenue area it is considered that the objective was not achieved at facades representing relevant public exposure. For each of these areas the Council should to designate an AQMA.

5 Recommendations

The Council is recommended to undertake the following actions, for the statutory objective relating to annual mean nitrogen dioxide:

For the London Road, plus Goldington Road and Newnham Avenue areas examined in the report:

1. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.

2. Confirm that there is relevant exposure in the area predicted to exceed and designate an AQMA.

3. Consider extending monitoring in the areas (to include Newnham Avenue) to confirm the findings of the report.

For the Ampthill Road area examined in the report:

4. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.

Appendix A

Model Development

The modelling approach adopted in this report is refined from that used by the ERG on behalf of local authorities in the southeast of England; including the Mayor of London, London Boroughs, plus Unitary, Borough and District local authorities in Herts and Beds, Sussex, Surrey, Kent, Essex and Berkshire.

Annual mean NO_2 vs. NO_X relationships

The modelling approach adopted in this report uses the approach described by Carslaw et al. (2001) and a summary of the key points is given here. The relationship between hourly NO_x and NO_2 has in the past been summarised 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.

NO_X and NO_2 Relationships, the Adopted Method

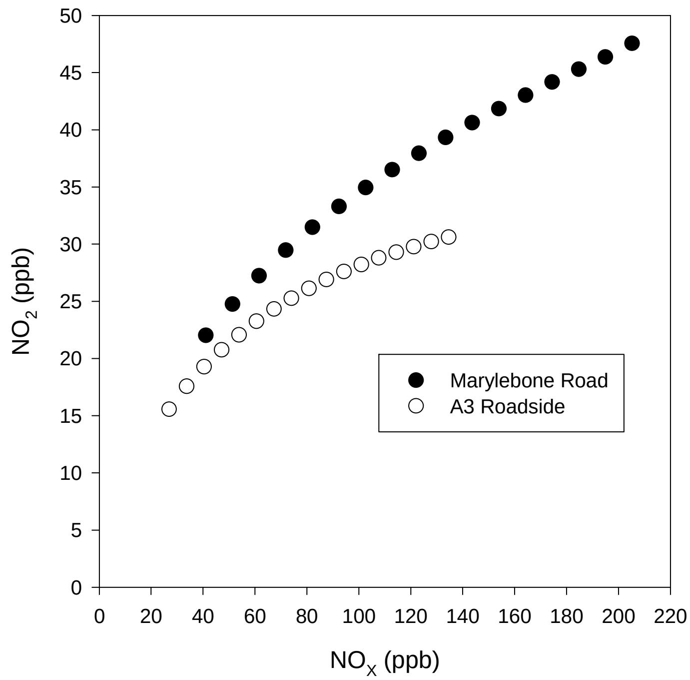
Roadside Concentrations

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 is 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 shows that the roadside concentrations of NO_2 for any NO_x concentration lies within a range of values and that this relates to location. The range is from a central London, busy street canyon, at Marylebone Road to an open road location, e.g. the A3 dual carriageway. The contrast between two such 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 is summarised in Figure 12 below.

Figure 12 NO_x and NO_2 Relationships at Roadside Sites across London



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.

Background Concentrations

Background concentrations for the area have been obtained from the UK Air Quality Archive (airquality.co.uk).

Appendix B

Modelling Detailed Road Networks

Geographic Accuracy of Model Predictions

To improve the geographic accuracy of predictions all roads have been split into 10 m sections, as shown in Figure 13. 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.

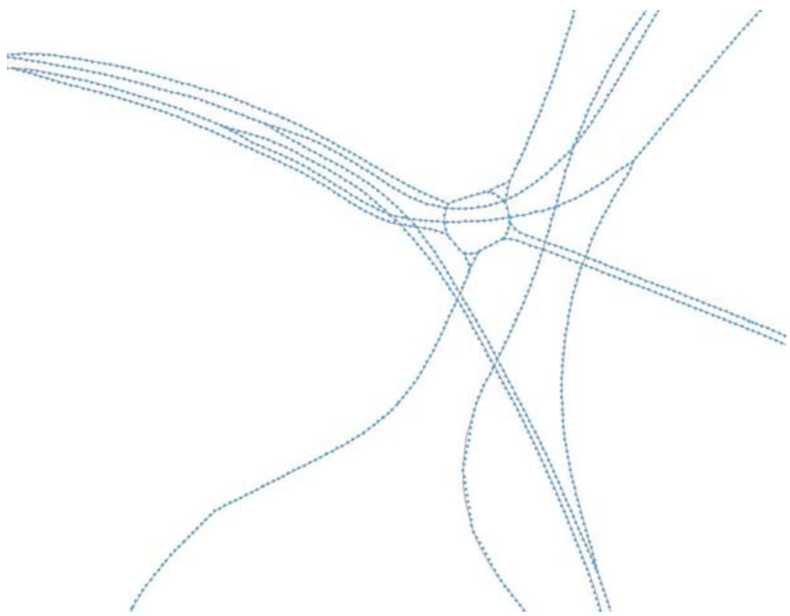


Figure 13 10m sections of road, showing complex junction details

This is further demonstrated in Figure 14 overleaf which shows that features such as roundabouts and curved roads are accurately represented.

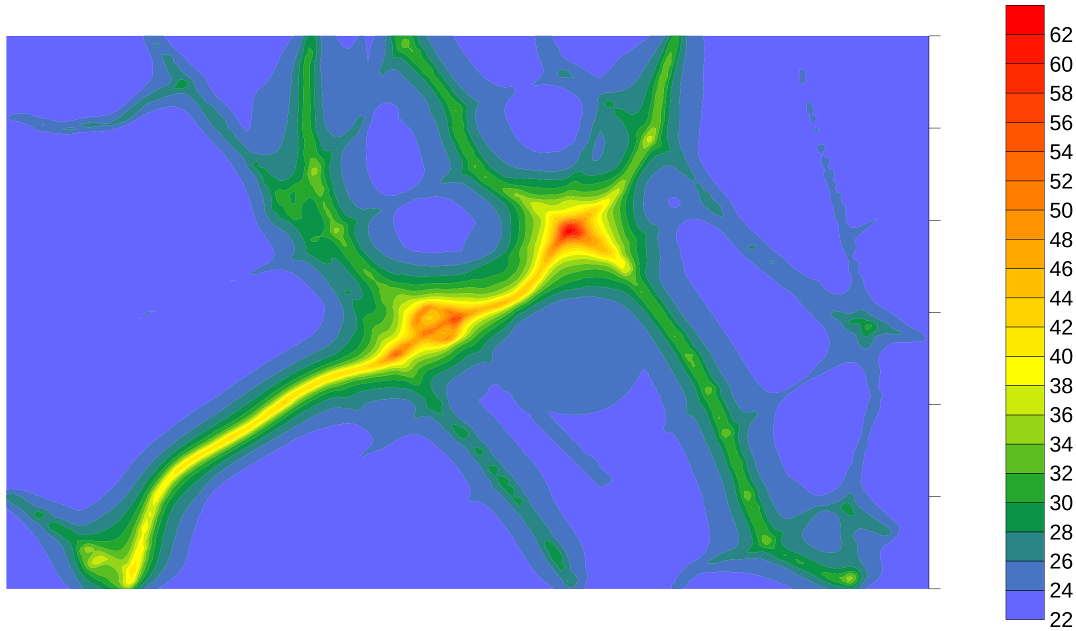


Figure 14 Modelled example showing concentrations near complex road junctions.

Treatment of Emissions

The model has used the latest detailed emission factors released by DEFRA. These are applicable down to a speed of 5 km/hr, although factors at this speed are highly uncertain.

It is therefore worth 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 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 15 below. 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 considered these effects when considering the results from the modelling.

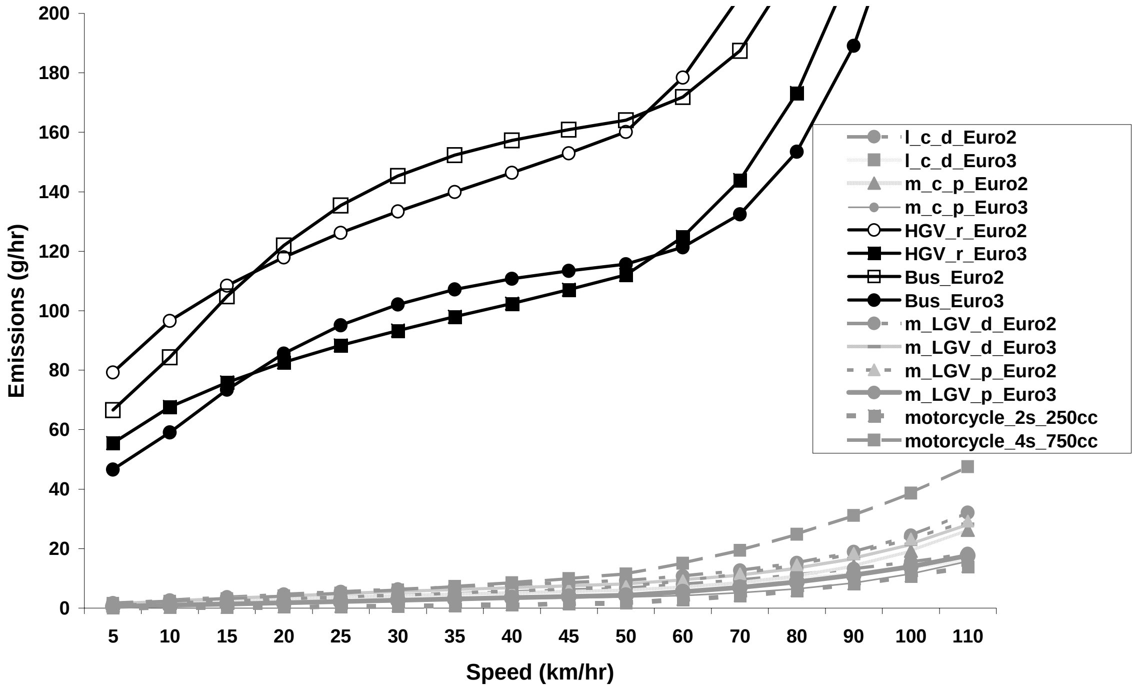


Figure 15 Emissions NO_X (g/hr) for Euro 2 and 3 Vehicles at different Average Speeds (km/hr)

Appendix C

Model Validation

A comprehensive validation exercise has been undertaken for the ERG models used at measurement sites in London and the southeast and this is presented below.

Sites used for model validation

A very extensive data set exists 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. However, Figure 16 summarises sites used during the validation exercise. The validation exercise encompasses all types of location. This is beneficial since it is only though a comparison with many sites types in different locations can the approaches used in this study be properly tested.

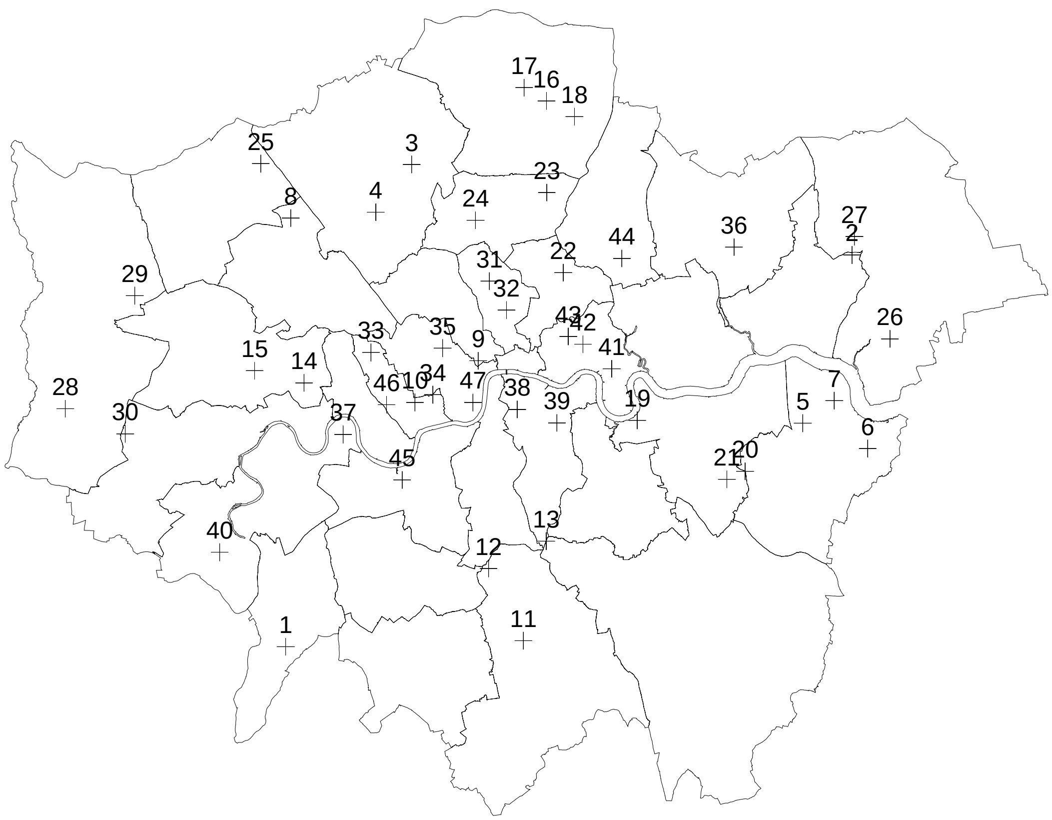


Figure 16 Sites used to validate model predictions (numbers are site references)

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 and poor site locations may lead to significant changes to the model performance.

Predictions of Annual Average NOx and NO_2

Table 8 provides the actual results and a summary of the overall model performance. Sites were not included with data capture rate of less than 90%.

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 9.

Table 8 Annual Mean NO_x and NO_2 (ppb) validation results for 2003

Reference	Site	NOx Measured	NOx Prediction	NO_2 Measured	NO_2 prediction
1	A3	97	71.6	38	31.4
2	Barking & Dagenham 1 - Rush Green	28	30.3	16	19.1
3	Barnet	98	105.1	39	41.0
4	Barnet 2 - Finchley	37	35.1	20	21.0
5	Bexley 5 - Bedonwell	27	29.2	18	18.7
6	Bexley1	35	31.4	20	19.4
7	Bexley2	33	29.4	19	18.7
8	Brent1	31	31.3	18	19.6
9	Camden 3 - Shaftesbury Avenue	83	106.5	36	42.4
10	Cromwell Road	100	117.0	39.2	45.3
11	Croydon 4 - George Street	64	70.1	29	31.3
12	Croydon 5 - Norbury	121	88.7	39	36.6
13	Crystal Palace 1 - C Palace Parade	60	73.1	26	31.8
14	Ealing 2	89	66.3	32	30.5
15	Ealing1	43	49.3	22	25.5
16	Enfield1	28	31.6	18	19.7
17	Enfield2	49	68.1	24	30.3
18	Enfield3	31	30.8	17	19.4
19	Greenwich 5 - Trafalgar Road	56	68.4	26	30.8
20	Greenwich Bexley 6 - A2 Falconwood	76	62.5	29	28.8
21	Greenwich4	31	32.3	20	19.9
22	Hackney4	56	48.7	26	25.0
23	Haringey	61	70.5	27	31.6
24	Haringey 2 - Priory Park	33	35.6	19	21.1
25	Harrow 1 - Stanmore	28	29.8	16	19.0
26	Havering	48	49.0	23	24.5
27	Havering 3	57	57.6	22	27.3
28	Hillingdon	73	76.8	28	33.3
29	Hillingdon 1 - South Ruislip	73	52.3	26	25.8
30	Hounslow 2 - Cranford	47	35.6	27	21.3
31	Islington 2 - Holloway Road	97	81.6	36	34.7
32	Islington1	42	45.7	25	24.4
33	KC1	39	45.7	23	24.5
34	Kens and Chelsea 3 -	126	135.0	49	50.2

	Knightsbridge				
35	Marylebone Road	164	139.5	56	51.2
36	Redbridge 1 - Perth Terrace	38	35.0	21	20.9
37	Richmond 1 - Castlenau	51	56.9	25	27.5
38	Southwark1	45	53.4	25	26.8
39	Southwark2	83	85.3	35	35.7
40	Teddington	23	30.1	15	19.0
41	Tower Hamlets 1	36	40.4	22	22.6
42	Tower Hamlets 2	95	80.4	35	34.3
43	Tower Hamlets 3 - Bethnal Green	37	42.8	23	23.4
44	WalthamF1	37	38.8	21	22.3
45	Wandsworth4	59	84.6	27	35.1
46	West London	48	44.6	29	24.2
47	Westminster - AURN	43	49.4	26	25.8

Table 9 All Site Average NO_x and NO_2 ($\mu g\ m^{-3}$)

	Predicted Average	Measured Average	Average difference (measured - predicted)	Standard Deviation (measured - predicted)
NO_x	58.99	58.64	-0.36	12.30
NO_2	27.93	26.64	-1.29	3.18

Appendix D

Emissions from Road Transport

Major Road Flows

Recent traffic counts for 2005 were obtained from the Department for Transport (DfT) for the identified roads in Bedford. The counts were undertaken for 24 hours. The Bedfordshire County Council provided traffic data for London Road.

Vehicle Classification, Age and Speed

The vehicle classification used for the roads was based on the vehicle split provided in the traffic counts undertaken. The breakdown of vehicle ages was based on the national model.

The following road links include the Ampthill Road links north and south of Britannia Road, London Road, plus the Goldington Road links east and west of Newnham Avenue.

Table 10 Traffic flows used in this assessment

Street	Road	M/C	CAR	BUS	LGV	HGVR2	HGVR3	HGVR4	HGVA3	HGVA5	HGVA6
Ampthill Road (S)	A6	197	18700	346	2281	521	63	35	55	71	75
Ampthill Road (N)	A6	147	14434	293	1737	345	63	46	30	39	91
Britannia Road	A5141	31	9481	146	1417	305	36	17	9	15	41
London Road	A600	138	10241	347	1727	266	17	15	15	16	44
Goldington Road (E)	A428	78	10648	287	1587	259	35	7	37	35	81
Goldington Road (W)	A428	136	19025	327	2109	401	45	22	81	121	93
Newnham Avenue	A5140	181	24809	236	2971	429	86	72	42	27	30

(Note: HGVR – rigid HGVs; HGVA – articulated HGVs)

Average vehicle speeds were assessed from previous discussions with the Bedfordshire County Council and evidence from visiting the town centre. These were estimated at 16kph towards the town centre, increasing to 24kph on road links at the periphery of the area modelled. For the sections of the Ampthill Road south adjacent to the BF47 site and the bus stop, and close to the London Road BF35 site, an average speed of 8kph was assumed.

Appendix E

Model Uncertainty Assessment

Note: This appendix contains extracts of a report written on behalf of the former Department of Environment, Transport and the Regions (DETR), entitled: *Estimating the Uncertainty of Model Predictions using a Monte Carlo Simulation*. Please note that although the DETR report addresses modelling in London, the same principles apply to the Council's report, as a similar methodology was used.

Predictions of the concentration of NO_2 at roadsides have shown a high sensitivity to the pass/fail standard of 40 µg m^{-3} (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 used 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 11 below shows how each input data or modelling method affects the final concentration, for the Marylebone Road example.

Table 11 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 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 12. 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 12 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.

APPENDIX F

Adjustment factor for short term monitoring in 2006

Table 13 NO_2 monitoring from HBAPMN sites for 2006

Top of Form Site Code	Site Name	Annual mean ($\mu g\ m^{-3}$)	Period mean ($\mu g\ m^{-3}$)	Ratio
NH4	N. Herts Breechwood Green (Background)	16.5	15.9	1.037736
SB1	South Beds Dunstable (Background)	31.5	32	0.984375
SA1	St. Albans Fleetville (Background)	25.3	24.9	1.016064

(Note – data capture > 90%)

Monthly NO_2 diffusion tube measurements

All results are unbiased and expressed in $\mu g\ m^{-3}$.

Table 14 Monthly monitoring results for Ampthill Road and Goldington Road (2004 to 2006)

Code	Address	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2004													
BF22	Ampthill Road Bedford		36	29		35		29	35	31	33	36	35
BF47	Ampthill Rd Bedford Outside number 38									29	36	42	38
BF35	London Rd Bedford outside number 5									42	44	50	48
BF11	Goldington Road Bedford	38	38	27	27	31	31	27	27	29	23	40	42
BF39	Goldington Rd Bedford Opp university and shop									29	42		44
BF07	135 George St Bedford	29	25		19	19	13	15	21	15	27	33	35
2005													
BF22	Ampthill Road Bedford	29	29	35	35	29	29	29	25	31	44	31	33
BF47	Ampthill Rd Bedford Outside number 38	38	46	44	44	35	40	38	36	38		38	44

BF35	London Rd Bedford outside number 5	42	48	44	46	40	38	36	46	44	48	50	42
BF11	Goldington Road Bedford	31	40	35	31	33	29	31	27	33	36	42	44
BF39	Goldington Rd Bedford Opp university and shop	40	44	46	40		36	40	42	42	50	50	46
BF07	135 George St Bedford	31	31	29	23	17	17	17	19	23	35	33	33
2006													
BF22	Ampthill Road Bedford	36	35	36	29	29	34	39	28	41	33		
BF47	Ampthill Rd Bedford Outside number 38	44	48	40	40	38		40	33		43		
BF35	London Rd Bedford outside number 5	48	48	40	40	43	40	49	40	53			
BF11	Goldington Road Bedford	40	36	33	31	29	28	33	29		35		
BF39	Goldington Rd Bedford Opp university and shop	46	52	38	44	39		46	39	48	46		
BF07	135 George St Bedford	33	31	19	21	19	16	17	18	24	24		

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