Further Assessment of Nitrogen Dioxide for Bedford Borough Council

In fulfillment of Parts. 84(1) of the Environment Act 1995
Local Air Quality Management

November 2010

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Executive Summary

Section 84(1) of the Environment Act 1995 requires the Council to undertake the Further Assessment following the designation of the extended and consolidated air quality management area (AQMA) in Bedford. This Further Assessment report of nitrogen dioxide for the Bedford Borough Council ("the Council") follows previous Council air quality reports and thus fulfils this next step of the Local Air Quality Management (LAQM) process.

The report follows the guidance produced by the Department of Environment, Food and Rural Affairs (Defra) for LAQM purposes. New modelling predictions have been made for the areas within the Council's consolidated AQMA 5. The modelling incorporates a series of improvements over and above that undertaken previously (including revised emission factors). This report also incorporates the results of further monitoring undertaken by the Council within each of the extended parts of the AQMA investigated. The revised modelling predictions confirm the earlier findings that the annual mean nitrogen dioxide objective is exceeded in all of the areas.

The Defra guidance further requires the Council to: estimate the reduction in pollution necessary to meet the objective; estimate when the objective is likely to be met; and refine the knowledge of the sources of pollution so that the air quality action plan can be properly targeted.

Estimates of the reduction in oxides of nitrogen (NOx) to achieve the objective were derived from modelling and monitoring data. This is because NOx is predominantly emitted as the primary pollutant. These estimates indicate a median reduction of 14% for the areas exceeding the objective (although this proportion increases at some sites to around 25%).

A separate assessment using Defra guidance to determine an estimated year of compliance suggests that for these parts of the AQMA 5, the NO_2 objective will be met by 2011. However great care should be taken with these projections as monitoring in the Borough (and elsewhere) in recent years has shown little (if any) indication of an air quality improvement as forecast using the guidance.

Additional model runs were undertaken to understand and apportion the sources of pollution in the area. This was undertaken for specific vehicles groupings (i.e. cars, buses (and coaches), light goods vehicles (LGVs) and heavy goods vehicles (HGVs)). A contribution representing background sources was also incorporated. The source apportionment modelling was based on concentrations of oxides of nitrogen (NOx). The source apportionment was undertaken for specific sites within the areas relating to the diffusion tube monitoring sites.

The results confirm the importance of road traffic to air quality in the area and are based on the mean result of the locations investigated. The results indicated that Cars were the main emission sources in all the AQMAs. The individual contribution from LGVs, Buses and HGVs were smaller, however their combined contribution easily exceeded the Car total. The proportion from all background sources of NO_x was 20 to 50%. The background was however lowest in the most polluted sites closest to roads.

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

1) Retain its existing consolidated AQMA 5.

2) Use the results of the source apportionment work in this report to identify potential actions that will enable the Council to work towards improving air quality.

3) Maintain the current NO_2 monitoring capability within AQMA 5 and elsewhere in the Borough to check for improvements or otherwise in air quality.

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 the further assessment of air quality

1.1 Overview

This report provides the further assessment of air quality for the Bedford Borough Council ("the Council"). This forms part of the Council's duties under Local Air Quality Management (LAQM) process of the Environment Act 1995.

The report includes a revised modelling study of the Council's extended Air Quality Management Area (AQMA) for nitrogen dioxide (NO_2) for the following specific areas, which have not previously been re-assessed:

Ampthill Road (near the Hospital);
Goldington Road (near the University;
London Road (to the south of the Bedford town centre).

The assessments include comparisons with the government's annual mean air quality objective for NO_2 and the determination of the necessary reduction in oxides of nitrogen (NOx) to achieve compliance with the objective for each area. In addition predictions of expected year of compliance are provided (based on future predictions of air quality using Defra sponsored tools). Finally an apportionment of the pollution sources has also been undertaken. Thus the report fulfils this 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 (Defra, 2007) to achieve the air quality objectives under the Air Quality (England) Regulations 2000 and 2002. As part of its duties the Council has previously completed its reviews of local air quality and identified that the annual mean objective for NO_2 (see Table 1) has been exceeded after 2005 in parts of the Council's area.

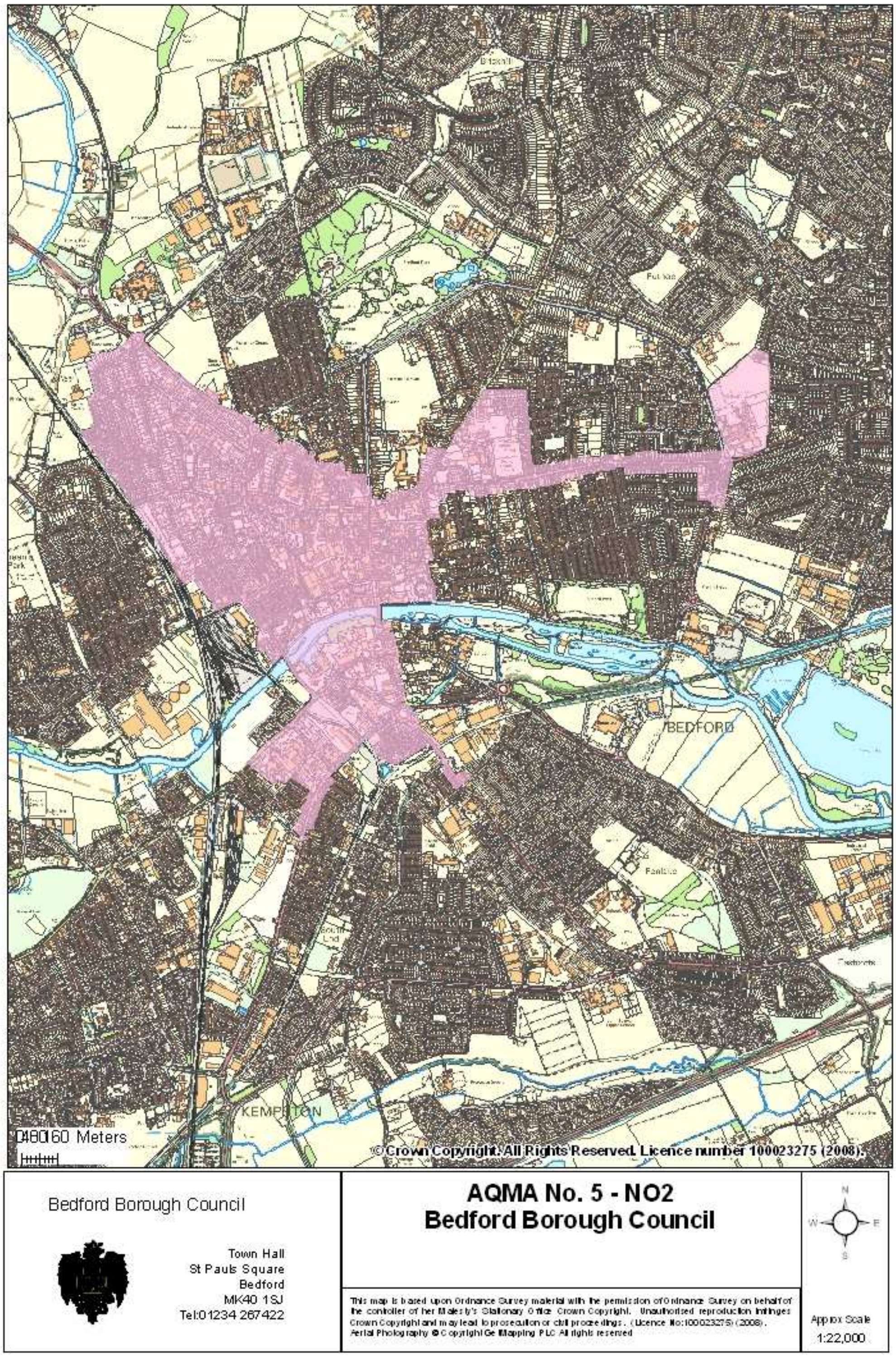
Table 1 Air quality objective relevant to this Further Assessment

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

This measured concentration of 40 µg m^{-3} as an annual mean is the same as that specified in the EU Limit Value for the UK government (although it has a later compliance date of 1 January 2010 from The Air Quality Standards Regulations 2007).

The Council designated several AQMAs within its area, including 2 AQMAs that have subsequently been revoked; near Stewartby and Great Barford. The AQMAs in the town of Bedford have also been extended and consolidated into one AQMA (AQMA 5). The AQMAs (2 and 3) previously designated within Bedford (High Street and Prebend Street) and incorporated into AQMA 5 were re-assessed in a previous Further Assessment. In view of this these parts of the consolidated AQMA are not discussed further in this report.

Figure 1 Consolidated AQMA in Bedford town centre (within shaded area)



Air Pollution Measurements in the Bedford AQMA

1.1 Continuous NO_2 monitoring

The Council operates two automatic chemiluminescent analysers to continuously monitor oxides of nitrogen (NOx) and NO_2 concentrations in the Borough near the town centre of the Bedford, although neither is located within the areas investigated in this report. One of these is located in Prebend Street (former AQMA 2). This site provides information on roadside air quality. The other site is located in a background location on Lurke Street, 100m east of the High Street (near former AQMA 3). Both sites are in the consolidated AQMA 5 and both sites were set up in recently: December 2008 for Prebend Street and May 2010 for Lurke Street.

Details of the site operation were provided previously in the Council's 2009 Updating and Screening Assessment. The results are sent to King's College London who rescale, validate and ratify the data. This section of the report provides an update of the most recent monitoring results. The Prebend Street is classified as a roadside site with the sample inlet located approximately 3.5 m from the kerb and 2.0m high. It is also 1.5m further from the road of the nearest building facade (It is located at easting 504491 and northing 249649).

The annual mean results for the continuous sites since 2009 are given below. Details of data capture are also provided. The results indicate that the annual mean concentration exceeded the annual mean objective for the period monitored at Prebend Street. The hourly standard of 200 $\mu g\ m^{-3}$ was exceeded once at the site during the year. The data capture exceeded the 90% recommended in the TG09 guidance (Defra, 2009) during 2009.

Table 2 NOx/ NO_2 Concentrations ($\mu g\ m^{-3}$) monitored at the Bedford continuous sites

	2009*	2010*
Prebend Street *(roadside)*		
Annual mean	**40.5**	*39.5*
Data capture %	96	*69*
Exceeds	1	*0*
NOx	111.7	*103.2*
Lurke Street *(background)*		
Annual mean		*26.7*
Data capture %		*37*
Exceeds		*0*
NOx		*57.8*

(Note – bold indicates exceeds objective; * data for year partially ratified; italics < 90% data capture)

2.2 Diffusion tube measurements in the AQMA

The Council also continued to extensively monitor NO_2 using diffusion tubes at 63 sites across the Borough and this chapter provides an update of the results of the monitoring in the relevant parts of the AQMA 5 only. In all fourteen sites are reported and all bar one, are located at roadside sites. The diffusion tubes used were analysed by Gradko International using a preparation method of 50% TEA in acetone.

All tubes are exposed singly at sites and are changed on a monthly basis. A co-location study has not been undertaken. In the most recent round of Annual Performance Criteria for NO_2 Diffusion Tubes used in LAQM (Defra, 2010), the laboratory demonstrated good performance in a QA/QC scheme for analysis of NO_2 diffusion tubes. Gradko International participates in the Workplace Analysis Scheme for Proficiency (WASP), which is an independent analytical performance testing scheme. The scheme is an important QA/QC exercise for laboratories supplying diffusion tubes to local authorities for use in the context of LAQM. The Health and Safety Laboratory (HSL) operate the WASP scheme independently and the cost of operation is borne by the laboratories.

The main disadvantage with monitoring using diffusion tubes is that the method is less precise and accurate than continuous monitoring. The recommended methods to reduce these errors include the use of good QA/QC practices and bias adjustment factors that are derived from co-location studies between continuous analysers and diffusion tubes.

The bias adjustment factors are specific to each year, analysing laboratory, method of analysis and location. The factors are therefore also limited to the data supplied. The Review and Assessment website advises that “in many cases, using an overall correction factor derived from as many co-location studies as possible will provide the ‘best estimate’ of the ‘true’ annual mean concentration, it is important to recognise that there will still be uncertainty associated with this bias adjusted annual mean. One analysis has shown that the uncertainty for tubes bias adjusted in this way is ± 20% (at 95% confidence level). This compares with a typical value of ± 10% for chemiluminescence monitors subject to appropriate QA/QC procedures.”

Earlier diffusion tube results were obtained from the Council’s previous reports. For these bias correction was undertaken using appropriate correction factors for 2007 to 2008 derived from the most recent (September 2010) default factor spreadsheet from Defra’s helpdesk. The default factors are based on statistical analyses of reported data provided by other local authorities (17 studies for 2007 and 19 for 2008). The factors used for 2007 to 2009 indicate that the diffusion tube results mostly slightly overestimate continuously monitored concentrations (see table below), whereas for 2006 the diffusion tube results underestimate the continuous results. The 2008 factor is also slightly different from the factor (in brackets) used in the 2009 USA report (which was based on an earlier default factor that used fewer studies).

Year	Bias factor	Type	
2006	1.01	Default	18 studies
2007	0.99	Default	17 studies
2008	0.94 *(0.93)*	Default	19 studies
2009	0.97	Default	16 studies

The results were also adjusted to a full calendar year where data were missing using TG09 methodology. The continuous sites used for this adjustment were part of the Herts and Beds Air Pollution Monitoring Network (namely the background sites in St. Albans, Luton and East Herts). The full set of diffusion tube results are given in the Appendix. The adjustment in each case was small (i.e. less than +/-7%).

2.2.1 Bias adjusted results

The two monitoring sites along Ampthill Road reported in the earlier Detailed Assessment are still monitored. The area around Goldington Road and Newnham Avenue however has been supplemented by a further six sites. Two additional sites have been added to London Road (although only one of these is reported due to a lack of data from one site). The site locations are shown in Figure 2 (Ampthill Road), Figure 3 (Goldington Road) and Figure 4 (London Road).

Figure 2 Diffusion tubes sites in Ampthill Road

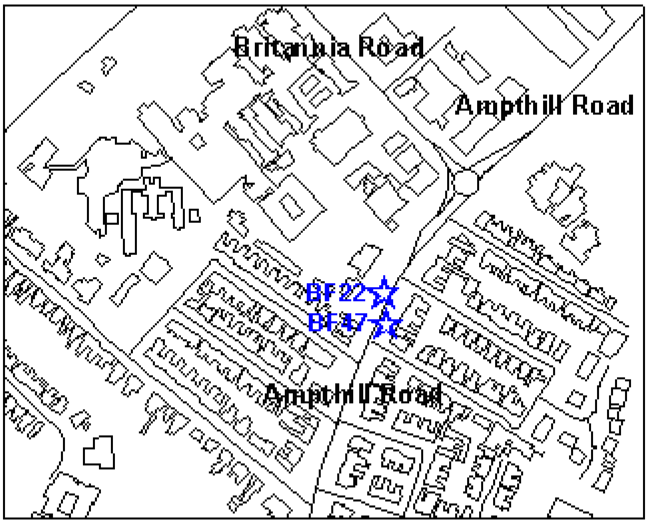


Figure 3 Diffusion tubes sites in Goldington Road

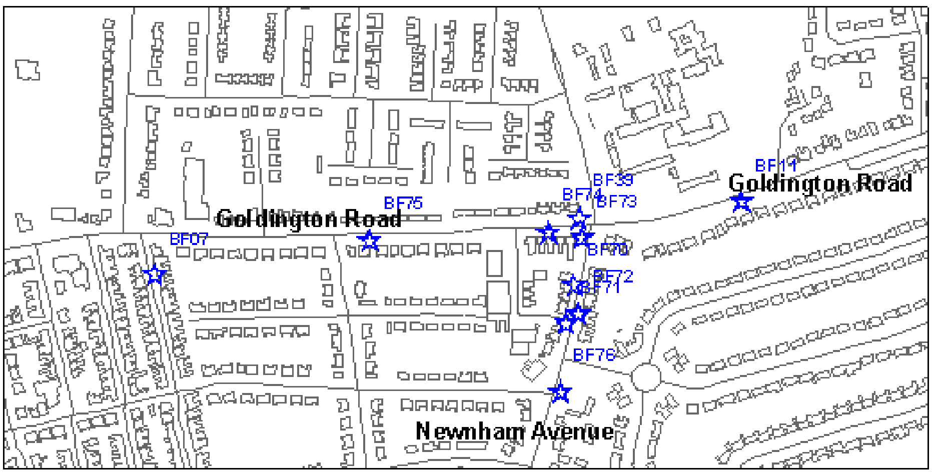


Figure 4 Diffusion tubes sites in London Road

The results presented in Table 3 are the bias adjusted results.

Table 3 Selected diffusion tube monitoring in AQMA 5 (2007 to 2008) (µg m^{-3})

Code	Location	Biased 2004	Biased 2005	Biased 2006	Biased 2007	Biased 2008	Biased 2009
BF22	Ampthill Road Bedford	36.5	34.7	34.4	29.8	36.8	39.3
BF47	Ampthill Rd Bedford (outside number 38)	39.9	**44.1**	**42.2**	**41.2**	**46.1**	**40.8**
BF35	London Rd Bedford (outside number 5)	**50.6**	**48**	**46.0**	**41.3**	**45.2**	**46.1**
BF11	Goldington Road Bedford	34.8	37.8	33.4	34.8	36.4	29.9
BF39	Goldington Rd (opposite university and shop)	**42.2**	**47.6**	**45.2**	**47.9**	**41.4**	**42.3**
BF07	George St Bedford (outside 135)	25.1	28.2	23.0	24.9	23.2	24.5
BF70	Newham Ave (outside 110)						36.3
BF71	Newnham Ave (road sign outside 96)						35.3
BF72	Newnham Ave (warning sign outside 117)						**42.9**
BF73	Newnham Ave (outside post office)						**46.2**
BF74	Goldington Road (outside 185)						34.5
BF75	Goldington Road (outside 139)						35.0
BF76	Newnham Avenue (outside BP)						38.2
BF78	London Road (outside 43)						34.6

(Notes – bold indicates exceeds AQS objective)

For 2009 the data capture at all sites reported was greater than 80%. Not all sites exceeded the objective in 2009, however at least one site did exceed in each of the three areas examined.

The highest concentrations of just over 46 µg m^{-3} arose at Newnham Avenue (BF73) and London Road (BF35). Both of these sites are close to road junctions. The lowest concentration arose at the background site BF07 on George Street (which is approximately 50m south of Goldington Road. The other sites in Newnham Avenue and Ampthill Road measured more than 35 µg m^{-3}.

The monitoring reported is for the six-year period from 2004 to 2009, for those sites that have been monitored for all this period there is some consistency. With three sites consistently meeting the objective and three sites exceeding the objective over this period. The sites however do not show any consistent reduction in concentrations over this period. Rather there is interannual variation, which may be due to differences in emissions, prevailing meteorology and the overall uncertainty of the measurement method.

2 Predictions of Nitrogen Dioxide (NO_2) in the Bedford AQMA

3.1 Outline of modelling developments

The Further Assessment incorporates:

- Roads on an exact geographic basis Ordnance Survey (OS), to allow an improved assessment of exposure;
- Verified predictions plotted on OS base maps;
- Incorporation of a direct NO_2 component;

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

The model has been empirically developed for urban areas and has been widely validated against a range of continuous monitoring sites in London and the southeast.

Revised traffic data are used for the modelling; these were obtained from the Department for Transport and are based upon the most recent traffic count sites for the road links. Traffic information details are given in Appendix D.

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[1], 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 to the background from the road. Only areas coloured yellow to orange exceed the air quality objective. The predictions were verified against the monitored data in accordance with TG09 (see later).

The rest of this chapter examines the three areas of AQMA 5 that are the subject of this report: Ampthill Road, Goldington Road and London Road.

[1] Note – Reproduction from/based upon the Ordnance Survey Mapping with the permission of the Controller of Her Majesty's Stationery Office © Crown Copyright. Unauthorised reproduction infringes Crown Copyright and may lead to prosecution or civil proceedings. Bedford Borough Council Licence No. LA100023275.

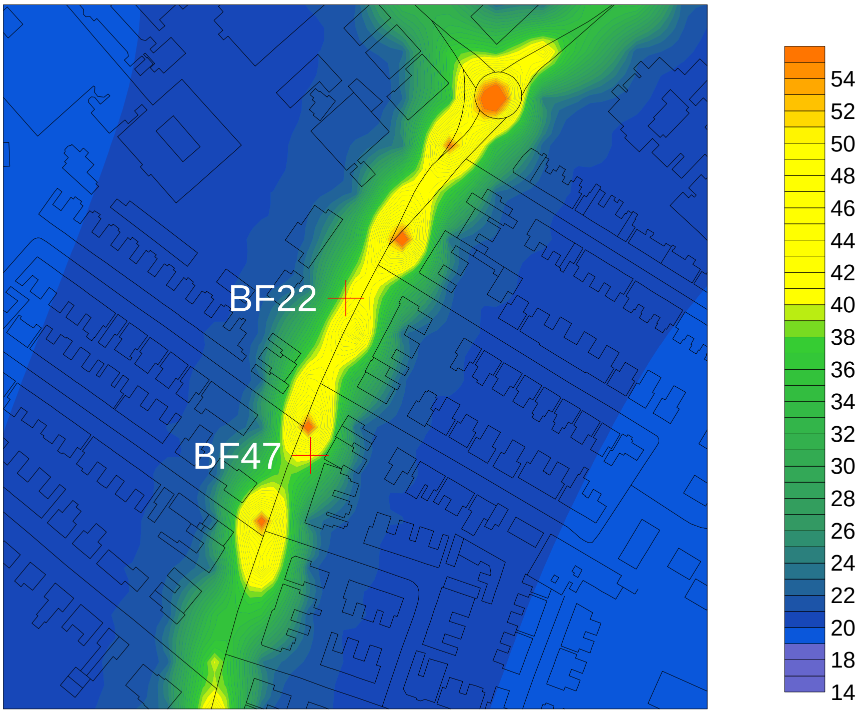
3.2 Ampthill Road

3.2.1 Modelled predictions

The predicted concentrations of the annual mean NO_2 for the 2009 base case are shown in Figure 5.

The modelled area includes Ampthill Road; close the hospital, extending south and north of the junction with Britannia Road. The area to the south includes residential areas either side of the road, whereas to the north of the junction there is an industrial area (with no relevant exposure). The predictions confirm that the air quality objective is exceeded close to the centre of roads and junction.

Figure 5 Modelled annual mean NO_2 in Ampthill Road (µg m^{-3})



(Note – the red crosses mark Bedford B.C monitoring sites)

3.2.2 Comparison with monitored results

The monitored results for the monitoring sites were given in the previous chapter. The 2009 results in the AQMA are compared below to the predicted results at the same sites using the 2009 base model.

Table 4 Monitored and modelled 2009 annual mean NO_2 concentrations (µg m^{-3})

Site	Modelled	Monitored
BF22	**40.1**	39.3
BF47	**41.4**	**40.8**

(Note – bold indicates exceeds AQS objective)

This comparison indicates an overall reasonable agreement, with the modelled result slightly exceeding the monitored result for both sites by less than 1 $\mu g\ m^{-3}$. In view of this agreement it was not necessary to apply a further verification factor.

3.2.3 Commentary on the Ampthill Road modelling

It is important to recognise that this area comprises a frequently congested street that is closely bounded by buildings on both sides of the road. Such conditions can limit the dispersion of pollution and can lead to locally high concentrations. Ampthill Road is a main route to the town centre, with a signalled traffic junction at the Britannia Road junction and consequently traffic queuing can arise at peak times. The modelled area also includes the minor junctions along the street that were not explicitly modelled.

Of the two monitoring sites the BF22 site was located on the northbound side, closer to the junction. The northbound side is two lanes wide, and the location of the monitoring site has a more open aspect. Despite being closer to the signalled junction with Britannia Road, any queuing traffic tends to be located in the middle lane rather than the lane closest to the monitoring point.

The BF47 site is on the southbound side, which is one lane wide. The 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. There is also a pelican crossing approximately 30m to the south of the site. As a result of the constricted conditions, the average speed of vehicles is low; with stop start driving during busy congested periods. A combination of these factors leads to higher emissions and consequently higher pollution.

These conditions are challenging to model using dispersion models. This is partly because of the situation as already described, but also because there is a very steep concentration gradient from roads to the background. This means that concentrations can change markedly over the distance of a few metres. This also partly explains why the model predicts some sites better than others.

Despite these limitations it is considered that the modelling in the report provides a reasonable approximation of the Ampthill Road area.

3.2.4 Comparison of modelling results with AQMA 5

A comparison of the area that exceeds the annual mean objective within AQMA 5 (shown in Figure 1) indicates that the area that exceeds the 40 $\mu g\ m^{-3}$ isopleth for this AQMA is slightly smaller than the area designated.

3.2.5 Estimated NOx reduction to achieve AQS objective in Ampthill Road

The model has been used to judge the scale of reduction in pollutants to attain the 40 $\mu g\ m^{-3}$ objective. The highest modelled concentration for 2009 based on

the two sites was 40.8 $\mu g\ m^{-3}$ at the BF47 site. This requires at least a 1.4 $\mu g\ m^{-3}$ reduction in nitrogen dioxide to meet the objective.
The NOx concentration from the model was 90 $\mu g\ m^{-3}$, of which 62 $\mu g\ m^{-3}$ is considered as road NOx. (The background NOx derived from national maps is estimated as 28 $\mu g\ m^{-3}$). To achieve the objective the estimated road NOx, based on the model, will need to be 85 $\mu g\ m^{-3}$, which is a reduction of 6 $\mu g\ m^{-3}$ and represents 7.5% of the road NOx.

The monitored 2008 concentration at the BF47 had a higher concentration than 2009. In this instance the measured NO_2 concentration was 46.1 $\mu g\ m^{-3}$, hence the required reduction in NO_2 is larger, as is the reduction in NOx. Based on the same understanding as above the predicted NOx is 105 $\mu g\ m^{-3}$, which requires a consequent 28% reduction of the road NOx to achieve the objective.

3.2.6 Estimated date that AQS objective will be achieved in Ampthill Road

The updated TG09 guidance (released 22 January 2010) provides adjustment factors that can be applied at roadside sites for future years. These factors are based on nationally modelled data and represent “best” estimates taking into account the changes in traffic activity, and emission factors for NOx and primary NO_2.

It is worth noting that some of the measured concentrations reported in the area earlier were either higher in more recent years or little changed over time. This is in contradiction to the expectation in the adjustment factors.

Based on the monitored 2008 measurement for the BF47 site (as a worst case) and use of the revised adjustment factors it is expected that there will sufficient reduction in NO_2 for the site to achieve the objective by 2011.

3.2.7 Conclusion of the re-assessment in Ampthill Road

The area that exceeds the annual mean objective for nitrogen dioxide almost overlaps the facades of buildings along the road close to BF47 monitoring site. This is consistent with the monitoring results, where one site exceeds and the other meets the objective. The 2008 monitoring results for the same site also showed concentrations that were 5 $\mu g\ m^{-3}$ higher, which further indicates that the facades of these buildings are within an area that exceeds the objective. In view of these findings the Council should:

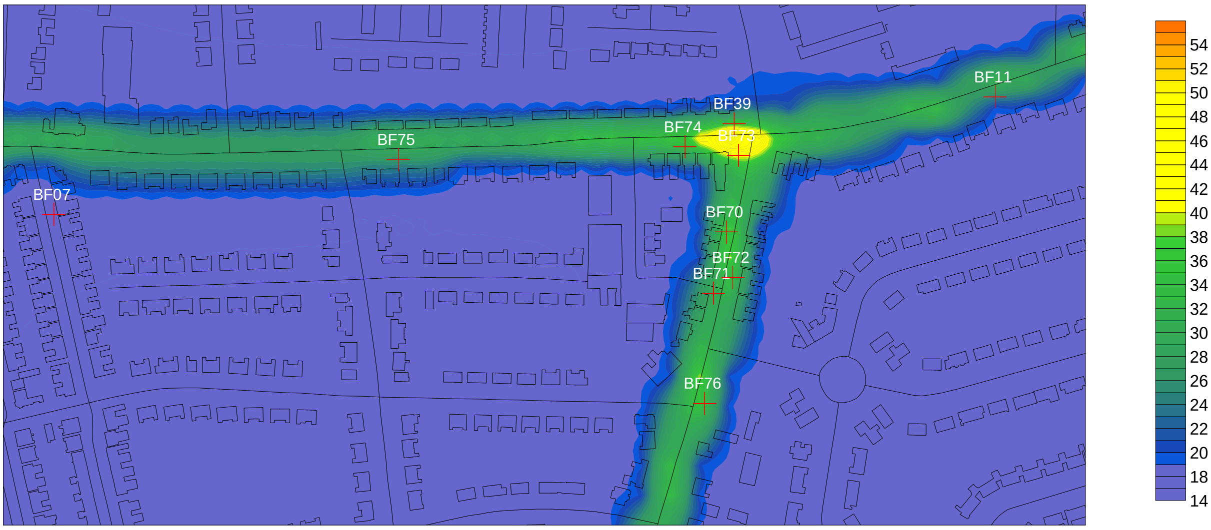
1) *Maintain the AQMA in this area and*
2) *Continue monitoring the area to check for future improvements in air quality.*

3.3 Goldington Road/ Newnham Avenue area

3.3.1 Modelled predictions

The predicted concentrations of the annual mean NO_2 for the 2009 base case are shown in Figure 6. The base case predictions confirm that the air quality objective is exceeded in the area close to the junction with Newnham Avenue only.

Figure 6 Modelled annual mean NO_2 in the Goldington Road area (µg m^{-3})



(Note – the red crosses mark Bedford B.C monitoring sites)

3.3.2 Comparison with monitored results

The monitored results for the monitoring sites were given in the previous chapter. The 2009 results in the area are compared below to the predicted results at the same sites using the 2009 base model. As with the monitored sites, there was a variation between sites and most of the sites in the area did not exceed the objective. The results indicate that the modelled results under predicted monitored concentrations at most sites (by an average of 5.1 µg m^{-3}).

Table 5 Monitored and modelled 2009 annual mean NO_2 concentrations (µg m^{-3})

Site	Modelled	Monitored
BF07	18. 4	24.5
BF11	25.0	29.9
BF39	36.6	**42.3**
BF70	35.4	36.3
BF71	30.1	35.3
BF72	32.7	**42.9**
BF73	**41.2**	**46.2**
BF74	34.1	34.5
BF75	26.4	35.0
BF76	33.9	38.2

(Note – bold indicates exceeds AQS objective)

Accordingly verification of the model was undertaken in line with TG09 methodology. The verified results are shown in Table 6. The verification factor used was 1.3.

Table 6 Monitored and verified modelled 2009 annual mean NO_2 concentrations ($\mu g\ m^{-3}$)

Site	Verified Model	Monitored
BF07	18.8	24.5
BF11	27.4	29.9
BF39	**42.8**	**42.3**
BF70	**40.4**	36.3
BF71	34.3	35.3
BF72	37.8	**42.9**
BF73	**48.8**	**46.2**
BF74	39.4	34.5
BF75	29.5	35.0
BF76	39.2	38.2

(Note – bold indicates exceeds AQS objective)

The verified results improve the predictions for most sites, however there are still some sites where agreement remains less good. For sites BF11, BF39, BF71, BF73 and BF76 there is reasonable agreement between verified and monitored results (with less 3 $\mu g\ m^{-3}$ difference). For these sites (other than BF73 and BF76) the predictions are slightly less than monitored concentrations.

Sites BF39 and BF73 both exceeded the objective for verified and monitored results. These sites are both close to the signalled junction between Goldington Road and Newnham Avenue, where there is often queuing traffic. The prediction for BF74 just to the east of this junction is less good, with the verified result 4 $\mu g\ m^{-3}$ higher than that monitored.

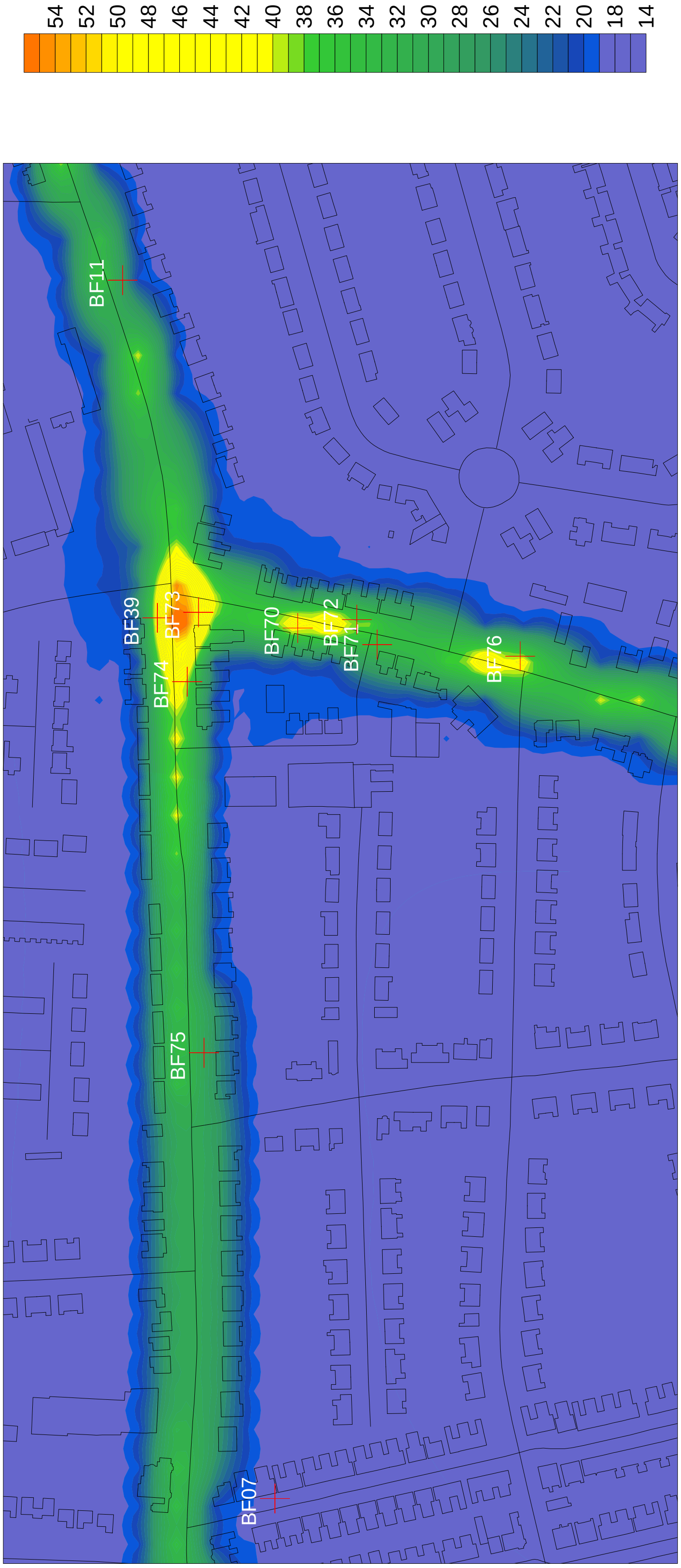
In Newnham Avenue, although there is good agreement at BF71, there is less good agreement for BF70 (which over predicts) and BF72 (which under predicts). Both variances are around 4 $\mu g\ m^{-3}$. This highlights the difficulty and uncertainty when determining air quality at the microenvironment level.

Site BF07 is furthest from the main source of emissions and closer to the background. However the monitored concentration easily exceeds the verified prediction. This may indicate that the predicted background concentration used from the national database is too low. There is also an influence from vehicles using George Street at this site, although this will be small as it is a minor road serving houses only.

Overall although there are differences between the sets of results it is considered that the verified predictions provide a reasonable assessment of air quality in this area, highlighting that the area where the objective is exceeded is close to the junction only.

The verified modelled results are shown in Figure 7.

Figure 7 Verified predictions of annual mean NO_2 in the Goldington Road area ($\mu g\ m^{-3}$)



3.3.3 Comparison of modelling results AQMA 5

A comparison of the area that exceeds the annual mean objective with the AQMA 5 (shown in Figure 1) indicates that the area that exceeds the 40 $\mu g\ m^{-3}$ isopleth for this Further Assessment is encompassed within the area designated as an AQMA.

3.3.4 Estimated NOx reduction to achieve AQS objective in the Goldington Road area

The model has been used to judge the scale of reduction in pollutants to attain the 40 $\mu g\ m^{-3}$ objective. The highest modelled concentration for 2009 in the AQMA was 48.8 $\mu g\ m^{-3}$ at the BF73 site. This requires almost a 9 $\mu g\ m^{-3}$ reduction in nitrogen dioxide to meet the objective.

The NOx concentration from the model was 118 $\mu g\ m^{-3}$, of which 94 $\mu g\ m^{-3}$ is considered as road NOx. (The background NOx derived from national maps is estimated as 24.1 $\mu g\ m^{-3}$). To achieve the objective the estimated road NOx, based on the model, will need to be 86 $\mu g\ m^{-3}$, which is a reduction of at least 32 $\mu g\ m^{-3}$ and represents 34% of the road NOx.

3.3.5 Estimated date that AQS objective will be achieved in the Goldington Road area

The modelling and monitored results indicate that the air quality objective is still being exceeded at locations with relevant exposure within this area (see Figure 7).

For the BF73 site, which exceeded in 2009, it is expected that there will sufficient reduction in NO_2 by 2011 for the site to achieve the objective using the updated TG09 guidance (released 22 January 2010).

3.3.6 Conclusion of the re-assessment of the Goldington Road area

The area that exceeds the annual mean objective for nitrogen dioxide overlaps the facades of buildings along Goldington Road, near the junction with Newnham Avenue. This is consistent with the monitoring results where the only sites that exceed are close to the road. In view of these findings the Council should:

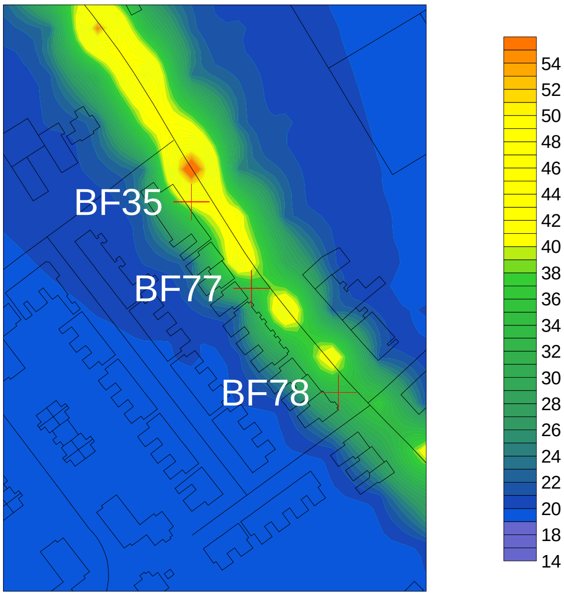
1) *Maintain the AQMA in this area and*
2) *Continue monitoring the area to check for future improvements in air quality.*

3.4 London Road

3.4.1 Modelled predictions

The predicted concentrations of the annual mean NO_2 for the 2009 base case are shown in Figure 8. The predictions confirm that the air quality objective is exceeded close to the centre of the road.

Figure 8 Modelled annual mean NO_2 in London Road (µg m^{-3})



(Note – the red crosses mark Bedford B.C monitoring sites)

3.4.2 Comparison with monitored results

The monitored results for the monitoring sites were given in the previous chapter (apart from BF77 which had insufficient data capture). The 2009 results in the area are compared below to the predicted results at the same sites using the 2009 base model.

The BF35 site exceeded the objective only; the result for BF78 however, which is a similar distance from the kerbside as BF35 was below the objective. In comparison with the monitored results there was reasonable agreement with the modelling, with both predictions lower than the monitored concentrations. In view of this agreement it was not necessary to apply a further verification factor.

Table 7 Monitored and modelled 2008 annual mean NO_2 concentrations (µg m^{-3})

Site	Modelled	Monitored
BF35	**41.8**	**46.1**
BF78	33.0	34.6

(Note – bold indicates exceeds AQS objective)

3.4.3 Comparison of modelling results for the London Road

A comparison of the area that exceeds the annual mean objective with the AQMA (shown in Figure 1) indicates that the area that exceeds the 40 $\mu g\ m^{-3}$ isopleth for this Further Assessment is similar to the area designated as the AQMA.

3.4.4 Estimated NOx reduction to achieve AQS objective in the London Road

The monitored result for 2009 has been used to judge the scale of reduction in pollutants to attain the 40 $\mu g\ m^{-3}$ objective. The highest modelled concentration for 2009 was 46.1 $\mu g\ m^{-3}$ at the BF35 site. This requires at least a 6.1 $\mu g\ m^{-3}$ reduction in nitrogen dioxide to meet the objective.

The NOx concentration from the model was 108 $\mu g\ m^{-3}$, of which 82 $\mu g\ m^{-3}$ is considered as road NOx. (The background NOx derived from national maps is estimated as 25.6 $\mu g\ m^{-3}$). To achieve the objective the estimated road NOx, based on the model, will need to be 85 $\mu g\ m^{-3}$, which is a reduction of almost 22 $\mu g\ m^{-3}$ and represents 26% of the road NOx.

3.4.5 Estimated date that AQS objective will be achieved in the London Road

Based on the updated TG09 guidance and use of the revised adjustment factors it is expected that there will sufficient reduction in NO_2 by 2011 for the site to achieve the objective. However as noted previously this is an idealistic forecast and measurements have varied between years previously across the Borough that are not in accordance with the forecasts.

3.4.6 Conclusion of the re-assessment of London Road

The area that exceeds the annual mean objective for nitrogen dioxide just overlaps the facades of buildings along the London Road. This agrees well with the monitoring results, which indicate that the results from the monitoring site nearby exceeds the air quality objective. In view of these findings the Council should:

1) *Maintain the AQMA in this area and*
2) *Continue monitoring the area to check for future improvements in air quality.*

3 Source Apportionment for NO_X in the Bedford AQMA

3.1 Methodology

To better understand the air quality improvement needed to achieve the annual mean NO_2 objective, it is necessary to determine the individual source emissions that contribute to the overall predicted pollution concentration. The factors that determine the pollution concentration in any given area are the pollutant emissions, location and atmospheric processes, including meteorology,

The pollutant under investigation in this stage of the LAQM process, i.e. NO_2, further complicates the understanding of source apportionment. For NO_2, the contribution that the different sources make to the predicted concentrations is 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 different proportions of NO_2 in the emissions of NOx from different sources additionally complicate this. 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. The uncertainty associated with the modelling undertaken is explained in Appendix E.

The source apportionment methodology used here is based on 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). The categories are Cars (i.e. all diesel and petrol cars, including taxis); Buses (i.e. all buses and coaches); HGVs (i.e. all rigid and articulated vehicles > 3.5 tonnes) and LGVs (including petrol and diesel vans, etc). Each category also includes within it all Euro and pre-Euro classifications.

In all instances the determination of the influences of the different sources is undertaken by modelling the sources independently of one another, then separately 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; these were based on the monitoring sites in the areas of AQMA 5 investigated. (See earlier chapter showing the locations of the monitoring sites).

3.2 Source apportionment at the identified locations within the Bedford AQMA

The understanding of NO_x is based on the 2009 predictions. 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:

- HGVs
- LGVs (both petrol and diesel)
- Cars (including all cars, taxis and motorcycles)
- Buses and coaches

A series of model runs for the base case were undertaken for each of the categories described above.

The results in terms of relative contributions of NO_x for these sites are shown in the tables below.

Table 8 Predicted relative mean NO_x contributions (%) for the different sources in the studied areas of the AQMA

Ampthill Road

Location	Buses	Cars	HGVs	LGVs	Background
BF22	17.7	23.6	17.5	8.2	32.9
BF47	18.1	24.1	17.9	8.4	31.3
Mean	17.9	23.9	17.7	8.3	32.1

Goldington Road/ Newnham Avenue

Location	Buses	Cars	HGVs	LGVs	Background
BF11	11.2	19.5	13.0	7.7	48.6
BF39	17.5	28.4	17.1	11.7	25.2
BF70	11.1	34.6	12.8	13.8	27.7
BF71	9.9	31.0	11.4	12.3	35.4
BF72	10.5	33.5	12.1	13.3	30.6
BF73	16.9	32.3	17.1	13.2	20.4
BF74	17.7	25.2	18.1	10.3	28.7
BF75	14.5	18.7	15.4	7.6	43.8
BF76	10.5	34.6	12.2	13.8	29.0
Mean	13.3	28.7	14.3	11.5	32.2

(Excluding background site BF07)

London Road

Location	Buses	Cars	HGVs	LGVs	Background
BF35	19.5	23.7	18.0	10.0	28.9
BF78	15.2	20.1	15.8	8.2	40.6
Mean	17.3	21.9	16.9	9.1	34.7

The results show the varying contributions between the different sources within the areas of AQMA 5 investigated. The results relate to the locations of the monitoring sites, especially proximity to the roadside and to the varying traffic activity.

As a consequence of this, the background proportion varies slightly between the locations examined, with the smallest proportion at the most polluted sites, i.e. close to the junction of Goldington Road and Newnham Avenue (BF39, BF70, BF73, BF74 and Bf76), and close to the road on London Road (BF35), all of which are less than 30%.

The Goldington Road sites (BF11 and BF75), plus London Road (BF78) have lower measured pollutant concentrations and hence have the highest background proportions of more than 40%. The mean background concentrations for all the sites are approximately 33 %. The background contribution comprises NO_x arising from other non-road vehicle emission sources, including domestic/ commercial (such as heating) and industrial sources, plus other roads in the area and rural sources.

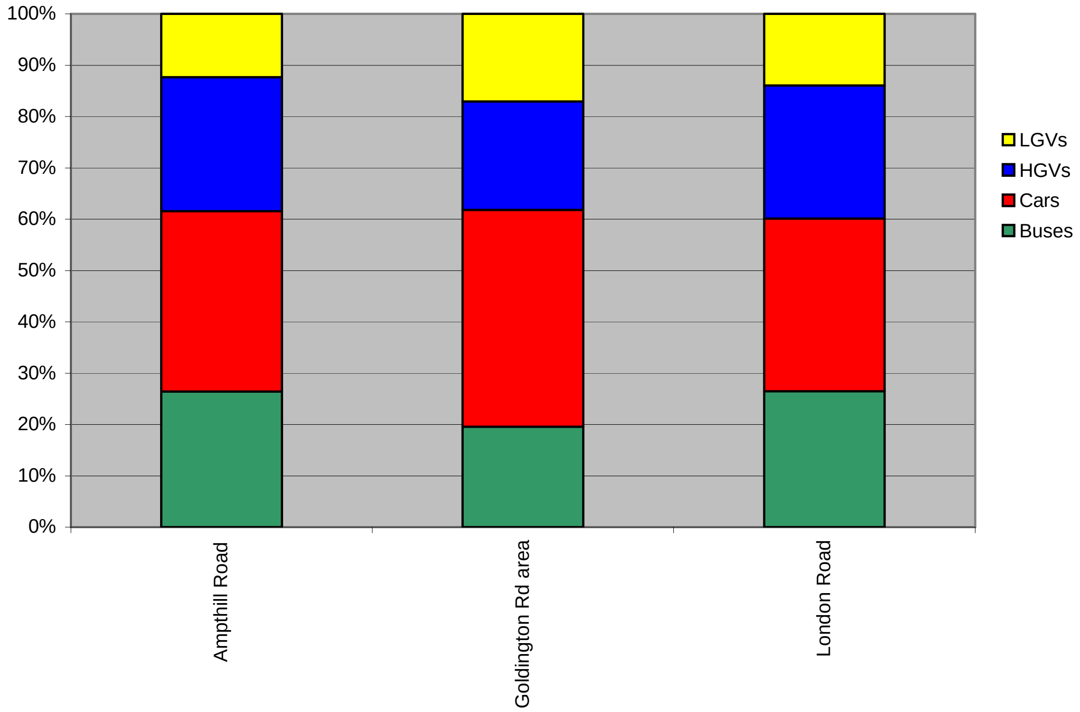
The Cars category provides the largest individual contribution of the road vehicle categories at all the locations examined. The mean contribution of Cars for all locations is approximately 25%, although at the most polluted sites around Goldington Road the proportion increases to almost 35%.

For the majority of sites the smallest individual contribution relates to LGVs, which total around 10% of the total contribution of NO_x at each site. The proportion from Buses is similar to LGVs along Newnham Avenue; whereas at Goldington Road, Buses exceed that of LGVs and approximate to that of HGVs. Similar proportions from both Buses and HGVs exist along Ampthill Road and London Road, with HGVs very slightly less; the mean overall contributions for both sources are slightly less than 20%.

The contribution of the road vehicles only to the individual locations is also shown in below. In this instance the road vehicle contributions only are counted and therefore the percentages indicated are relative to this total (excluding the background). The values are shown are the mean values for each of the areas investigated within AQMA 5.

This figure highlights more clearly some of the points made above, e.g. the similarity of the proportions between the areas; the small proportion of LGVs; the approximately equal proportions from buses and HGVs along Ampthill Road and London Road and the dominance of cars in all three areas.

Figure 9 Source contribution for the areas investigated in AQMA (excluding background sources)



4 Conclusion

This report fulfils the requirements of the Defra guidance for the Further Assessment and addresses relevant issues pertinent to the continuing LAQM process. The Further Assessment incorporates recent monitoring results and improved modelling techniques, plus an improved treatment of emissions using the most recent locally available traffic data. It also incorporates use of the most recent emission factors and TG09 tools released in 2010.

The monitoring results for the areas investigated in the report indicated that some of the locations monitored in those parts of AQMA 5 not previously assessed beyond the Detailed Assessment (i.e. Ampthill Road; Goldington Road and Newnham Avenue; and London Road) exceeded the annual mean nitrogen dioxide objective in 2009, although not all of the sites represented direct relevant exposure as outlined in the TG09 guidance (i.e. the building facades of residential properties, schools, hospitals and care homes).

New modelled predictions have been made for the areas for the base year of 2009. Overall these predictions compare well to the monitored results. The modelling confirms the extent of the area exceeding the objective in each area. The modelling predictions for Ampthill Road; Goldington Road and Newnham Avenue; and London Road indicate that the objective is exceeded at relevant facades.

Estimates of the reduction in NOx to achieve the objective were made following the Defra guidance. These indicated a median reduction of 14% is required for those areas exceeding the objective (although this proportion increases at some sites to just over 25%). A separate assessment to determine an estimated year of compliance in AQMA 5 was undertaken using TG09 tools. The results suggest that the NO_2 objective will be met by 2011. It is however considered that this represents an idealistic and consequently optimistic forecast. Monitoring in the Borough in recent years has shown little indication of air quality improvement.

Additional model runs were undertaken to understand and apportion the sources of pollution in the area. This was undertaken for specific vehicles groupings (i.e. cars, buses (and coaches), light goods vehicles (LGVs) and heavy goods vehicles (HGVs)). A contribution representing background sources was also incorporated. The source apportionment modelling was based on concentrations of oxides of nitrogen (NO_x) rather than NO_2, as NO_x is predominantly emitted as the primary pollutant. The source apportionment was undertaken for specific sites relating to the diffusion tube monitoring sites.

The results of the source apportionment indicated that Cars were the main emission sources in all the AQMAs. The individual contribution from LGVs, Buses and HGVs were smaller, however their combined contribution easily exceeded the Car total.

6 Recommendation

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

1. Retain the existing AQMA 5.

2. Use the results of the source apportionment work in this report to identify potential actions that will enable the Council to work towards improving air quality.

3. Maintain the current monitoring capability within AQMA 5 and elsewhere in the Borough to check for improvements or otherwise in air quality.

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

References:

Defra, 2007. Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Volume 1). Defra, London. Cm 7169.

Defra, 2009. Local Air Quality Management, Technical guidance LAQM.TG09. Defra, London.

Defra, 2010. WASP – Annual Performance Criteria for NO_2 Diffusion Tubes used in Local Air Quality Management (LAQM), 2008 onwards and Summary of Laboratory Performance in Rounds 103-107. AEA January 2010.

Bedford Borough Council, 2009. 2009 Air Quality Updating and Screening Assessment for Bedford Borough Council.

Appendix A

1 Model Development

1.1 Model Overview

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 Borough local authorities in Herts and Beds, Berkshire, Sussex, Surrey, Kent and Essex.

A receptor based approach was first developed by ERG through combining both modelling and measurement further. Separate modelling was undertaken of two categories of sources: 1) the road network close to measurement sites and 2) all sources, including roads further away. These were combined with a constant representing emission sources. A multiple regression analysis was then undertaken with the monitoring results from the London Air Quality Network and other regional networks in the southeast to establish the modelling relationship used.

This approach describes the balance between the local road contribution and the background since it provides a good comprise between the most robust aspects of both modelling and measurements.

1.2 NO_X and NO_2 Relationships

1.2.1 The Adopted Method

To determine the predicted NO_2 the ERG method builds on the approach described by Carslaw et al. (2001). In summary, the relationship between hourly NO_X and NO_2 can be described by plotting NO_2 against NO_X in different NO_X 'bins', for example 0-10 $\mu g\ m^{-3}$, 10-20 $\mu g\ m^{-3}$, etc. 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.

1.2.2 Roadside/ Background 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. 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 is summarised in Figure 10.

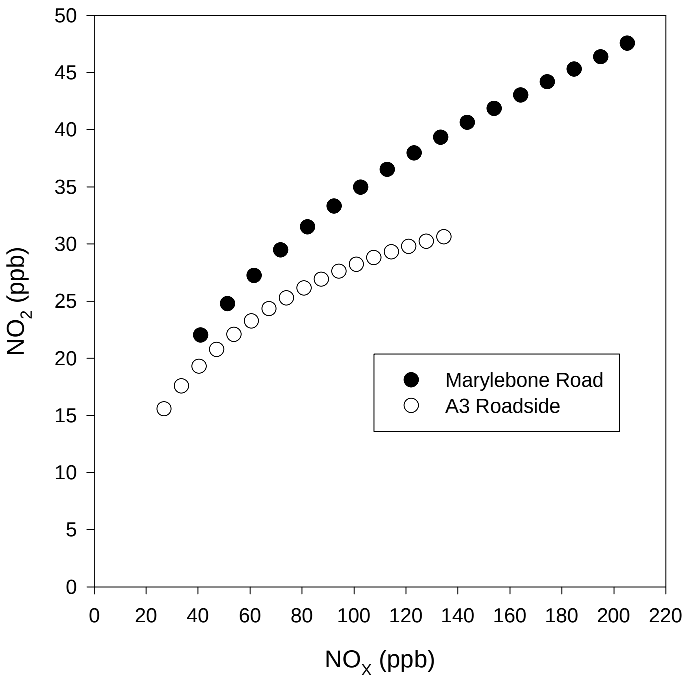


Figure 10 NO_X and NO_2 Relationships at Roadside Sites

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. The use of the roadside/ background curves is decided within the model itself by examination of the ratio of the other source NO_X contribution and local roadside NO_X contribution made at each prediction point.

Appendix B

1 Modelling Detailed Road Networks

1.1 Geographic Accuracy of Model Predictions

All major roads were split up into 10 m sections, as shown in Figure 11, 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.

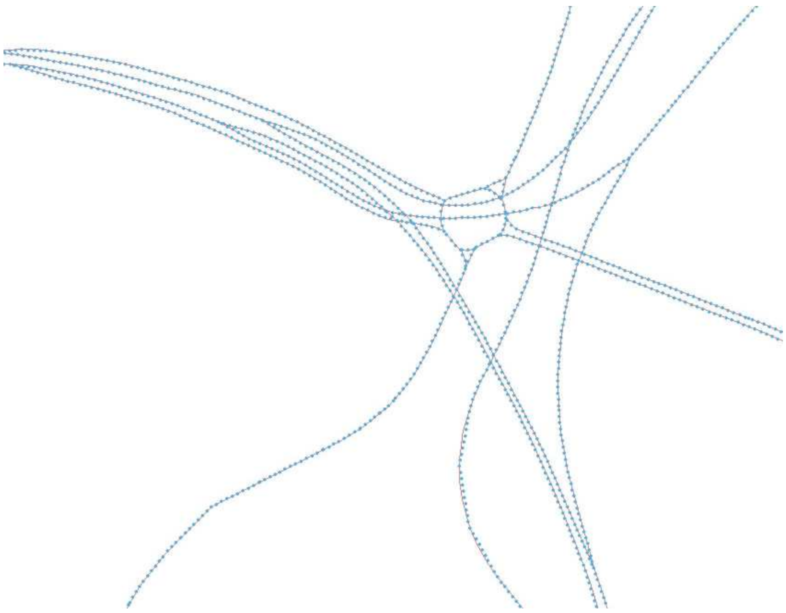


Figure 11 10m sections of road, showing complex junction details

This is further demonstrated in Figure 12 overleaf which show that features such as roundabouts and curved roads are accurately represented.

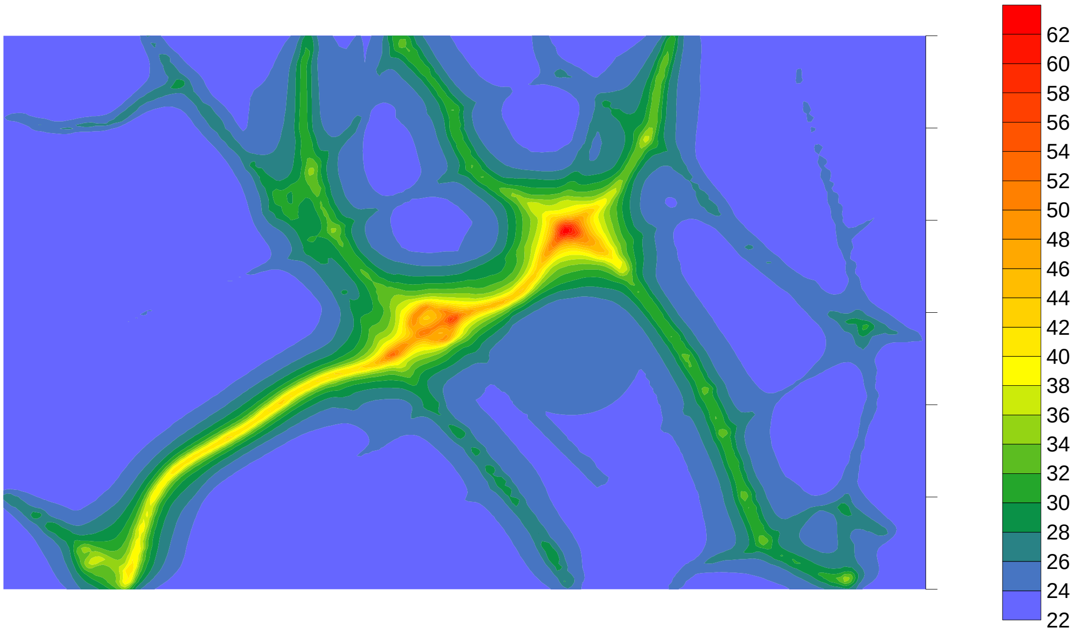


Figure 12 Modelled example showing concentrations near complex road junctions.

1.2 Treatment of emissions

The model has used the detailed emission factors mostly recently released by Defra in 2010. These are applicable down to a speed of 5 km/hr, although factors at this speed are highly uncertain.

Appendix C

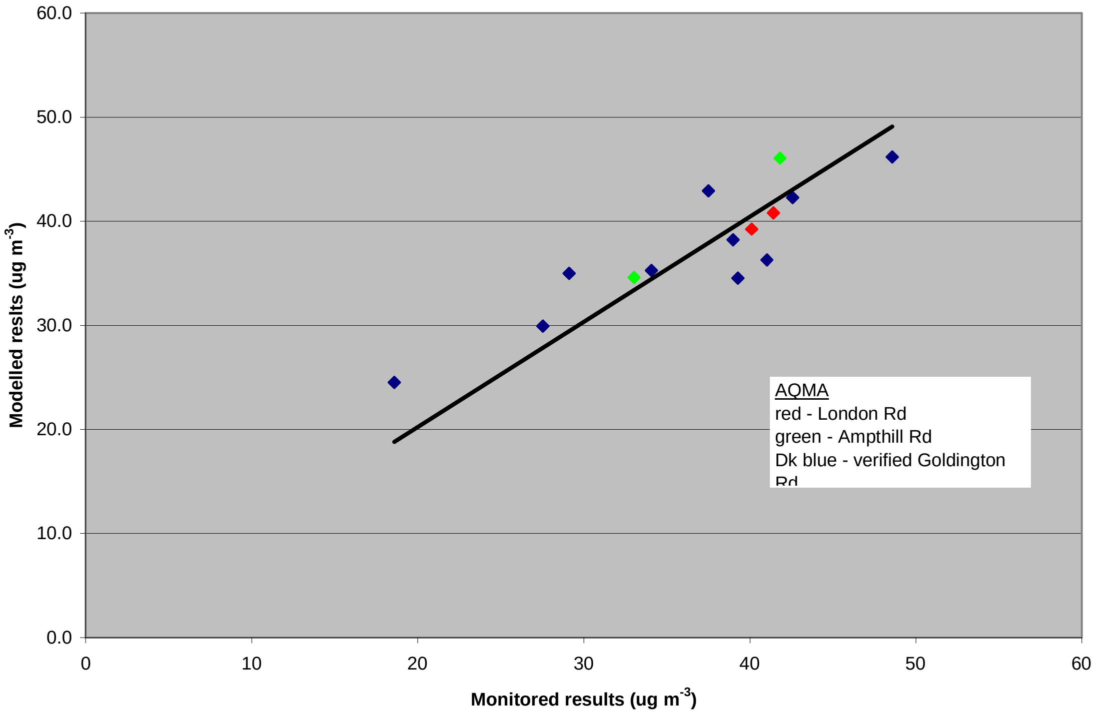
1 Model Verification

1.1 Model verification – AQMA 5

The TG09 guidance suggests where there is disparity between predicted and measured results an appropriate adjustment factor should be determined. For much of the modelling carried out the disparity was within acceptable limits (as outlined by TG09).

The comparison of modelled and monitored concentrations is shown in Figure 13 for the selected parts of AQMA 5.

Figure 13 Comparison of annual mean NO_2 concentrations for the Bedford AQMA



The range of the % difference for the sites is also provided in Table 9. This also shows the good overall agreement, with no sites outside the range of +/- 25%. Nine sites were within +/- 10 % difference and 5 others were within +/- 25 % difference. On this basis no further verification of these AQMAs was undertaken. The mean difference between sets of results was –2.7%.

Table 9 % Difference between modelled and monitored concentrations

Summary	
Within+10%	5
Within -10%	4
Within +/-10%	9
Within+10 to +25%	2
Within-10 to -25%	3
Within +/-10 to 25%	5
Over +25%	0
Under -25%	0
Within +/-25%	14
Greater +/-25%	0

1.2 Model verification – Goldington Road

To determine the applicability of the ERG model to this part of the AQMA a series of model tests were run for 2009. A comparison of the measured to final NOx modelled predictions indicated a reasonable agreement as an average, albeit with large differences (both under and over predictions) for many of the locations. In view of this finding the road the NOx results were left unadjusted. The final verification factor used and applied to the roads element only of the NO_2 modelling was 1.3 (see the results in Table 6).

Appendix D

1 Emissions from Road Transport in Bedford

1.1 Road traffic flows

Recent traffic counts for the area were obtained from the Department for Transport. These were based on 24-hour counts for the period 2000 to 2008. A comparison of these data indicated no little change in flows for many of the roads investigated, as a result traffic data from 2008 were used in the assessment.

1.2 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. Vehicle speeds were obtained from previous modelling and based on local knowledge.

Table 10 Roads modelled

Street	Road	M/C	CAR	BUS	LGV	HGVR2	HGVR3	HGVR4	HGVA3	HGVA5	HGVA6
Ampthill Road (S)	A6	193	17535	330	2647	504	67	42	38	54	81
Ampthill Road (N)	A6	117	13627	215	1895	308	62	50	17	23	80
Britannia Road	A5141	25	8951	107	1545	273	34	18	5	8	35
London Road	A600	171	15363	405	1988	250	31	32	31	40	23
Goldington Road (E)	A428	62	10052	210	1732	232	34	7	20	21	71
Goldington Road (W)	A428	106	18733	276	2351	308	39	30	40	81	54
Newnham Avenue	A5140	128	32705	153	2908	468	27	22	22	11	7