AIR QUALITY DETAILED ASSESSMENT

BROXTOWE BOROUGH COUNCIL

Acknowledgements

The assistance of the Highways Agency and Arup Consultants for providing the continuous monitoring results at the monitoring site in the Borough is gratefully acknowledged. The assistance of the researchers working at Kings College London is appreciated for the modelling undertaken within this report.

Executive Summary

This is the Detailed Assessment of air quality for the Broxtowe 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 recent monitoring reports.

The purpose of this report is to provide an updated 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 (09) produced by the Department of Environment, Food and Rural Affairs (Defra).

The Council's bias adjusted diffusion tube monitoring results for AQMAs 1 and 4 indicated that the 2005 annual mean objective for nitrogen dioxide (NO_2) was exceeded at roadside locations between 2005 and 2009. The objective was however not exceeded between 2005 and 2009 for AQMAs 2 and 3. The continuous monitoring (undertaken by the Highways Agency) in AQMA 1 did not exceed the objective in 2007 and 2008.

Modelling predictions were undertaken for 2009, using 2002 meteorology. These showed that the annual mean NO_2 objective was exceeded for 2009 close to the centre of the roads and also close to those roads that cross the motorway in the four AQMAs. The predictions were verified against the 2009 diffusion tube results and found to agree well for both NO_2 and oxides of nitrogen, as a result further adjustment was not required.

The area predicted to exceed did not overlap the facades of houses in AQMA 2 and 3. However the area predicted to exceed did overlap the front facades of houses, which represent the nearest relevant exposure in both AQMA 1 and 4.

Based on the above findings, it is considered that the objective was achieved in AQMAs 2 and 3 at the facades of locations representing relevant public exposure. In view of these findings the Council can revoke these AQMAs in Trowell.

For the AQMAs 1 and 4 (in Trowell and Nuthall) it is considered that the objective was not achieved at facades of buildings representing relevant public exposure. This was based on both modelled predictions monitored results. For each of these areas the Council will retain these AQMA(s) (pending the results of future years' monitoring).

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 AQMA 2 and 3 areas examined in the report:

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

2. Revoke these AQMAs based on the findings of the report.

For the AQMAs 1 and 4 areas examined in the report:

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

2. Maintain and review monitoring in these areas to confirm that the areas with the highest concentrations and relevant exposure are monitored

3. Review future years' monitoring with a view to revoking the AQMAs if the measured concentrations go below the objective for several years and also if national trends in emissions confirm these findings.

Contents

1 Introduction to Detailed Assessment of Nitrogen Dioxide

1.1 Overview to Detailed Assessment

This is the 2010 Detailed Assessment of nitrogen dioxide (NO_2) for Broxtowe Borough Council. The report fulfils the statutory requirement for this, the Council's next step, of the Local Air Quality Management (LAQM) process.

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 within the existing AQMAs. 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 has applied its best estimates to all components used in producing estimated concentrations.

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 and as required, the Council completed the previous Review and Assessment rounds of air quality.

As a result of the findings from the 2005 Detailed Assessment, the Council designated four Air Quality Management Areas (AQMAs) along the M1 corridor due to an exceedence of the annual mean nitrogen dioxide (NO_2) objective. The predominant source of pollution was from vehicles travelling along the motorway. These AQMAs were subsequently maintained following the 2006 Updating and Screening Assessment.

For the 2005 Detailed Assessment, real time monitoring was carried out (in the Borough near the M1) for the period 2004/05 along with predictive modelling for both 2005 and 2010. This found that whilst there was an exceedence of NO_2 in 2005, the AQMAs should fall below the prescribed standard prior to 2010 without any active intervention. The purpose of this report is to re-assess air quality within the AQMAs using similar methods to those used in the 2005 report.

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 December 2005

Nitrogen dioxide (NO_2) and nitric oxide (NO) are both oxides of nitrogen, and are collectively referred to as nitrogen oxides (NO_x). All combustion processes produce NO_x emissions, largely in the form of nitric oxide, which is then converted to nitrogen dioxide, mainly as a result of reaction with ozone in the atmosphere. It is nitrogen dioxide that is associated with adverse effects upon human health. At high concentrations NO_2 causes inflammation of the lung. Long-term exposure is also considered to affect lung function and exposure to NO_2 is particularly important for people with asthma and related diseases. NO_x is also important in the formation of ozone and secondary particle formation.

The dominant source of NO_x in the UK remains road transport (around 40% of UK emissions in 2003) (Defra, 2005). Although in urban areas this proportion is higher, up to 70%. Combustion sources also emit significant amounts of NOx; however such sources only make a small contribution to NO_2 levels. Significant emissions reductions have occurred over time primarily as a consequence of abatement measures in road transport and power stations and the increased use of other fuels for power generation. Since 1989, total NO_x emissions are estimated to have declined by 45%.

Despite the above reductions, monitoring results from across the UK continue to indicate that sites, particularly at roadside, exceed the annual mean objective. The hourly objective tends only to be exceeded close to the busiest urban roadside sites.

Further improvements are projected to 2010. These reductions arise as tougher Euro standards enter into force for new vehicles, and as the older vehicle fleet is retired. Further emissions reductions are also projected to occur post 2010.

As a result of high concentrations arising post 2005 more than 150 AQMAs were declared across the UK during the first and second rounds of Review and Assessment for the annual mean objective. These AQMAs ranged from small areas to whole Boroughs.

1.3 Progress with Local Air Quality Management – Broxtowe Borough Council

The Council previously designated Air Quality Management Areas (AQMAs) in parts of its area for NO_2 and during the second round review and assessment of air quality. Four small AQMAs were declared for NO_2 where concentrations exceeded the annual mean objective. These were:

AQMA 1 - M1/A6007 including the closest houses to east of M1 in Iona Drive and Tiree Close, Trowell Park Estate, Trowell

AQMA 2 - **M1/A609** including houses on Derbyshire Avenue closest to the M1, Trowell

AQMA 3 - M1/A609 including a house on Nottingham Road closest to the M1, Trowell

AQMA 4 - M1/B600 including houses on the Nottingham Road and Watnall Road closest to the M1, Nuthall

Maps of the areas are as follows:

Figure 1 : AQMA 1 encompassing twenty properties on parts of Iona Drive and Tiree Close next to the M1 motorway and the Trowell Park estate (boundary marked in red)

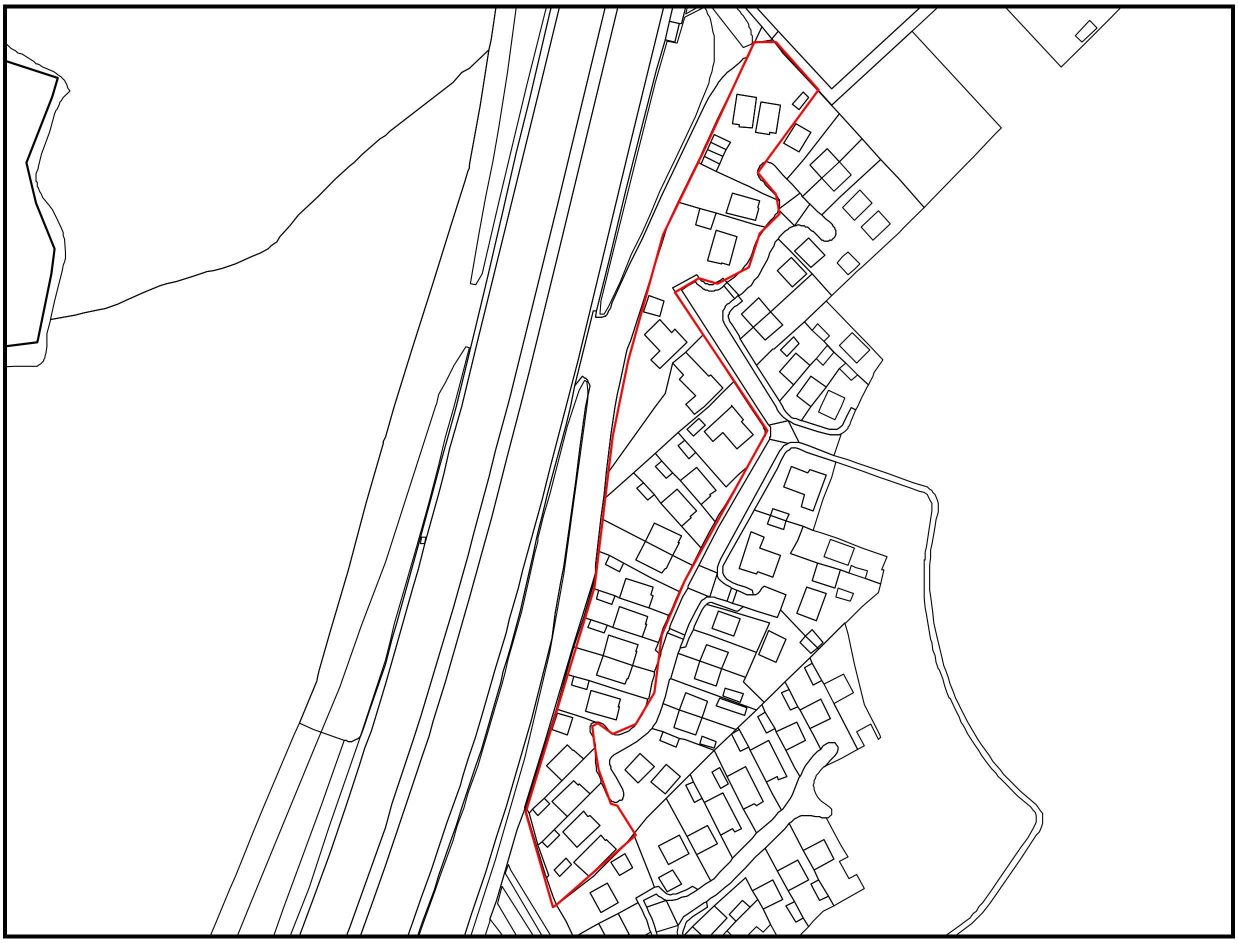


Figure 2 : AQMA 2 encompassing two properties on Derbyshire Avenue next to the M1 motorway in Trowell, Nottingham (boundary marked in red)

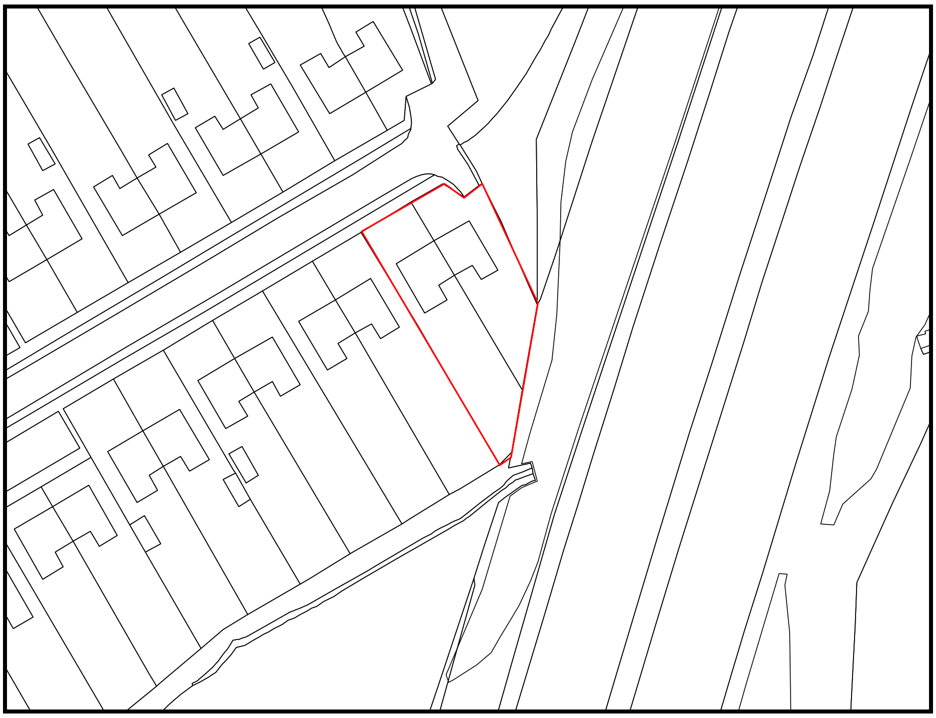


Figure 3 : AQMA 3 encompassing a single property on Nottingham Road next to the M1 motorway in Trowell, Nottingham (boundary marked in red)

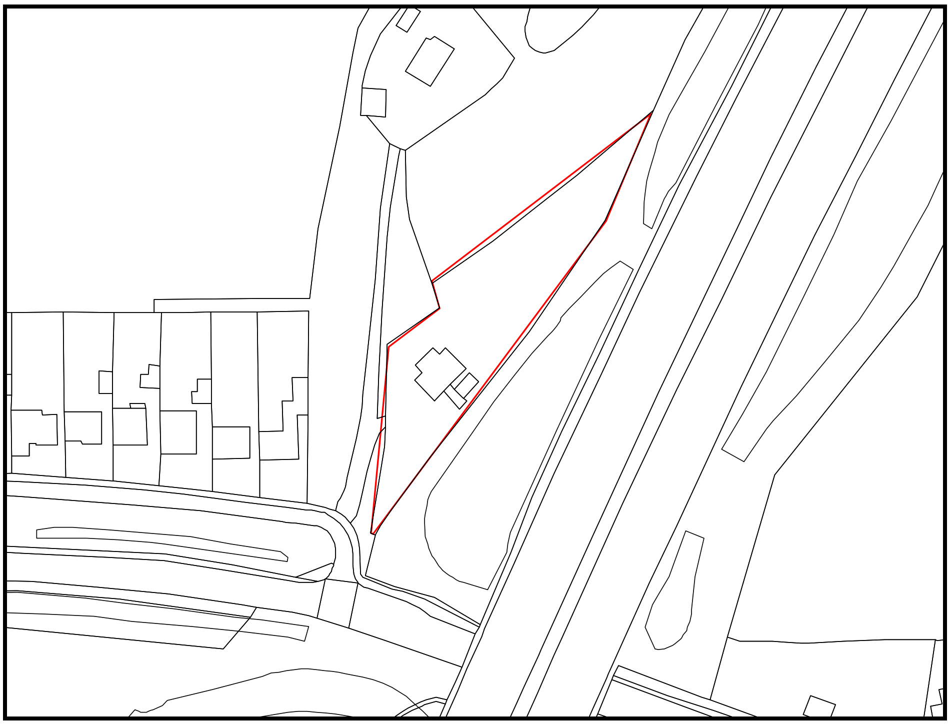
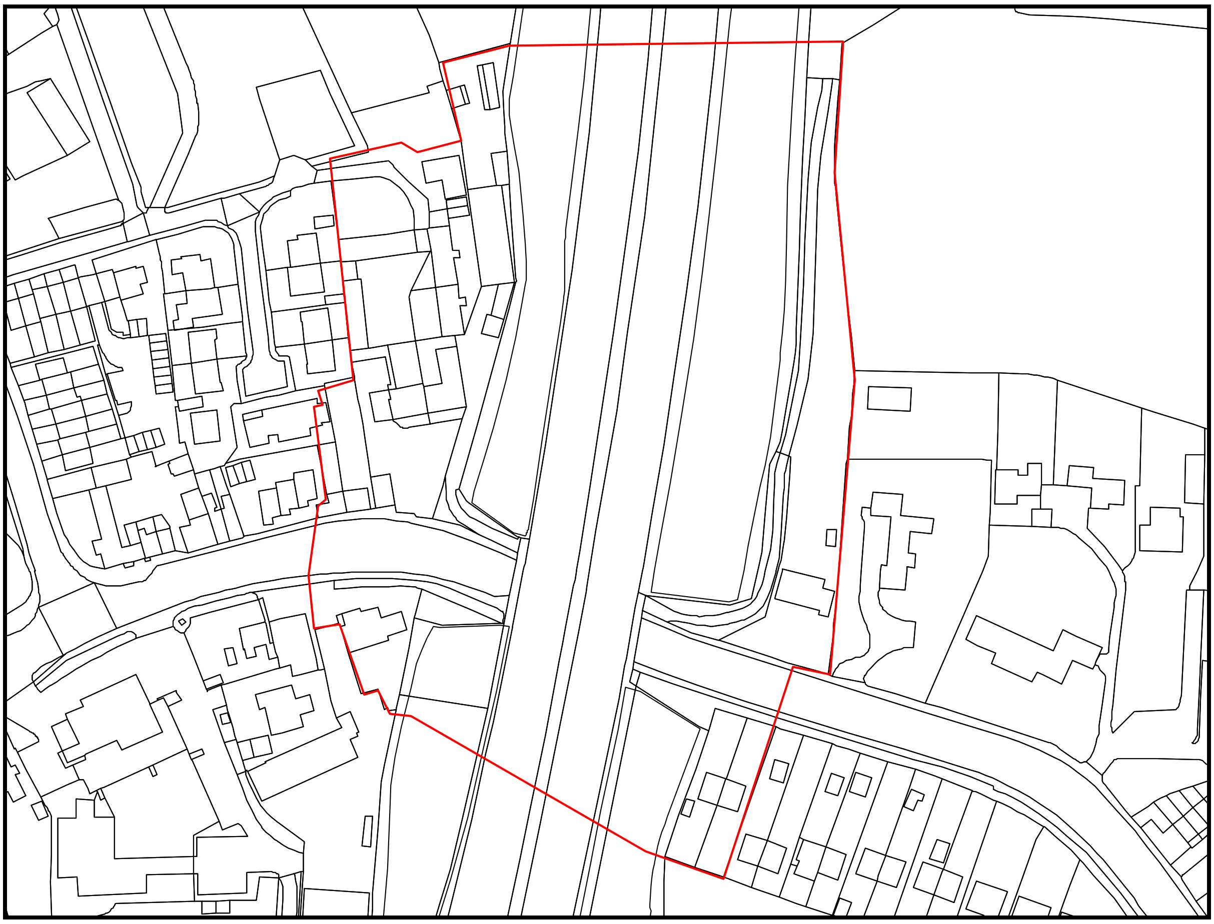


Figure 4 : AQMA 4 encompassing fourteen properties next to the M1 motorway on parts of Nottingham Road, Nottingham, and Nottingham Road and Back Lane, Nuthall (boundary marked in red).



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 areas under investigation. As reported in the 2006 Updating and Screening Assessment, the Council undertook an extensive programme of diffusion tube monitoring of NO_2, supplemented by continuous monitoring at one site (undertaken on behalf of the Highways Agency).

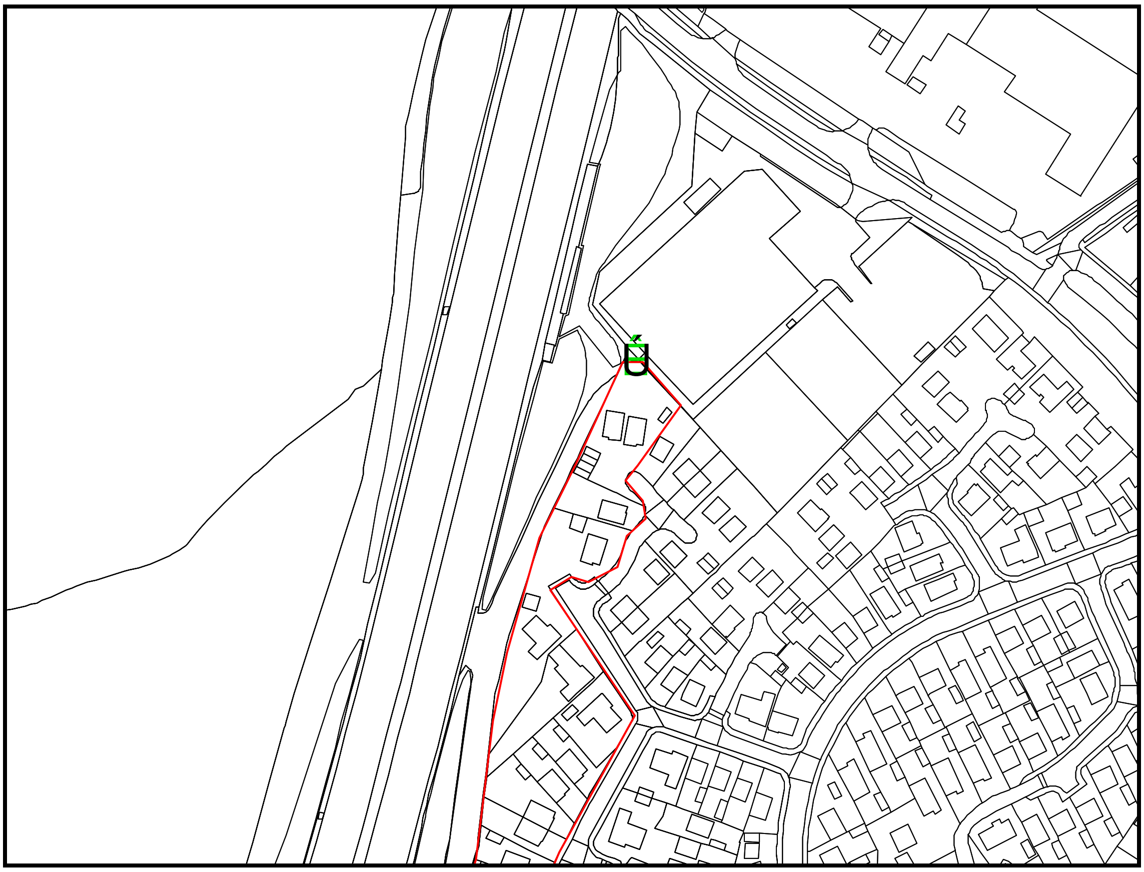
2.2 Automatic Monitoring

The Highways Agency (using Arup consultants) undertook the automatic monitoring of NO_2 with an API M400E chemiluminescent analyser. The analyser was located at a roadside site adjacent to the M1 motorway, at the same location as the real-time monitor used for Broxtowe's 2005 Detailed Assessment i.e. off the A6007 Stapleford Road, Trowell Park estate and at the rear of an industrial site (Martyn Barratt Transport). The monitoring site faced the M1 southbound carriageway (OS grid reference 448628, 339122) and was approximately equidistant from the carriageway and the nearby houses in Iona Drive in the AQMA (see Figure 2.2.)

Arup undertook installation of the equipment, site audits, checking of calibration data and quality control and scaling of the real time results. AEA ratified the data.

The monitoring site is considered representative of similar locations along the M1 within the Borough.

Figure 2.2 Location of continuous monitoring site near the M1 and Trowell Park Estate



(Green star indicates location of continuous monitoring site)

The results for the continuous site are shown in Table 2.2. The monitoring started in September 2006 and the results are reported for the part year 2006 and full years 2007 and 2008 inclusive. The results include details relating to the annual mean objective and data capture. There were no periods when the daily mean standard was exceeded. (Note - the daily mean objective is reported here only for the sake of completeness. The AQMAs were designated for the annual mean only and the daily objective is considered less stringent than the annual mean). All the data reported are fully ratified apart from 2008, part of which is still provisional.

Table 2.2 Results of continuous monitoring near the M1 and Trowell Park Estate

	2004/5*	2006	2007	2008
Annual mean NO_2 (µg m^{-3})	**40.3**	*38.7*	36.3	38.9
Data capture %	86.5	25.1	99.6	99.3
Annual mean NOx (µg m^{-3})	N/A	*93.4*	74.2	82.7
Data capture %	N/A	25.1	99.3	97.6

Note – italics indicates < 75% data capture; * from 2005 DA)

The results show for the full years of 2007 and 2008, plus part year of 2006 that the annual mean objective was not exceeded at the monitoring site, although the monitoring at the site undertaken previously for the 2005 Detailed Assessment which indicated that the objective was just exceeded. (Note - this monitoring was for the period from 1st April 2004 until the end of April 2005).

The monitoring also shows a slightly higher annual mean concentration in 2008 than 2007. This inter annual variability may be as a result of differing meteorological conditions and or changes in local emissions.

2.3 Non-Automatic Monitoring

Broxtowe Borough Council participates in the UK NO_2 diffusion tube network and has diffusion tubes sited at a number of locations, primarily monitoring the M1 corridor. Tubes are exposed in and near the 4 AQMA's.

Most of the tubes are placed on building facades of residential properties at sites mainly classified as 'roadside'. The tubes are exposed for a month before being sent for laboratory analysis. The diffusion tubes used were analysed by Gradko International using a preparation method of 20% TEA in water.

Monitoring using diffusion tubes has advantages over continuous monitoring in that it is far cheaper and therefore more sites can be established and assessed. The main disadvantage 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.

Default bias adjustment factors have been obtained from the Government's Review and Assessment website (based on Spreadsheet 03/10). The default factor is based on statistical analyses of reported data provided by other local authorities. The default factors for the inclusive period from 2005 to 2009 indicate that the diffusion tube results slightly over estimate continuously monitored concentrations. For all years there was predominantly good precision, with each year based on more than 10 studies.

See Appendix A for:

- Details of the tube type and the laboratory that supplies and analyses the tubes
- Details of the bias adjustment factor that has been applied to the annual mean NO_2 diffusion tube data
- Details of diffusion tube QA/QC

Table 2.3.1 Results of Nitrogen Dioxide Diffusion Tubes in AQMA 1

Site ID	Location	Within AQMA?	Data Capture 2009 (%)	Annual Mean Concentrations 2009 (µg/m3) Adjusted for bias
BX11	34 Iona Drive, Trowell	Y	100	36.32
BX31	18 Tiree Close, Trowell	Y	100	32.72

Table 2.3.2 Results of Nitrogen Diffusion Tubes in AQMA 2

Site ID	Location	Within AQMA?	Data Capture 2009 (%)	Annual Mean Concentrations 2009 (µg/m3) Adjusted for bias
BX32	30 Derbyshire Avenue, Trowell	Y	100	31.04

Table 2.3.3 Results of Nitrogen Diffusion Tubes in AQMA 3

Site ID	Location	Within AQMA?	Data Capture 2009 (%)	Annual Mean Concentrations 2009 (µg/m3) Adjusted for bias
BX33	81 Nottingham Road, Trowel	Y	91.6	30.21

Table 2.3.4 Results of Nitrogen Diffusion Tubes in AQMA 4

Site ID	Location	Within AQMA?	Data Capture 2009 (%)	Annual Mean Concentrations 2009 (µg/m3) Adjusted for bias
BX01	19 Nottingham Road, Nuthall	Y	100	34.54
BX05	19 Nottingham Road, Nuthall	Y	100	32.71
BX13	20 Nottingham Road, Nuthall	y	100	35.27

* Co-located

All diffusion tubes within Air Quality Management Areas meet the requirements for the Air Quality Annual Objective for NO_2 of 40µg/m^3 in 2009. Each Air Quality Management Area will now be considered in the table below to show the trend over the previous 5 years

Table 2.3.5 Results of Nitrogen Dioxide Diffusion Tubes within all AQMA's over the last 5 years

Site ID	Location	Within AQMA?	Annual mean concentrations (µg/m^3) Adjusted for bias (default)				
			2005	2006	2007	2008	2009
BX11	AQMA 1	Y	**44.29**	39.66	**40.67**	38.42	36.32
BX31	AQMA 1	Y	-	38.90	38.72	37.99	32.72
BX32	AQMA 2	Y	-	34.24	30.67	32.78	31.04
BX33	AQMA 3	Y	-	34.06	28.44	30.66	30.21
BX01	AQMA 4	Y	38.22	37.19	33.05	32.16	34.54
BX05	AQMA 4	Y	38.6	37.65	33.80	33.53	32.71
BX13	AQMA 4	Y	**41.53**	**40.36**	38.62	35.60	35.27

* Data does not exist for tubes BX31, BX32 and BX33 during 2005 as tubes were not in these locations.

The diffusion tube data shows a decline in the annual mean of NO_2 in all of the AQMA's over the last 5 years. AQMA 2 and AQMA 3 have shown no exceedences of the annual objective for NO_2 over the last 4 years, however, AQMA 1 and AQMA 4 showed exceedences in 2007 and 2006 respectively.

In the same time period, the real time monitor showed a decline in the levels of NO_2 during 2006 and 2007 which corresponds with the diffusion tubes whilst it showed a marginal increase in the level of NO_2 during 2008. However, the overall levels of NO2 has shown a reduction than when the AQMA's were first declared.

3 Predictions of NO_2 of Broxtowe AQMAs

3.1. Outline of Modelling Developments

This section of the Detailed Assessment incorporates modelling of:

- 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.

Modelling was undertaken by the Environmental Research Group (ERG), Kings College, London on behalf of Broxtowe Borough Council. A detailed explanation of the methods used, including the developments undertaken is given in Appendix B.

The model was empirically developed for local air quality management and has been previously used for modelling assessments by other local authorities in England. Details of the model validation are given in Appendix C.

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

3.2 Annual mean NO_2 (µg m^{-3}) in 2009

The predicted annual mean concentrations for 2009 are based on the assumption of similar metrological conditions to that recorded in 2002. 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 from the road to the background.

3.3 Predictions of NO_2 for AQMA1

The base case predictions confirmed that the annual mean air quality objective was exceeded along the roads modelled. The area that exceeded was mostly close to the centre of the M1 motorway and A6007 road, where it crosses the motorway. The area predicted to exceed overlapped with the façade of one nearby house in Iona Drive. The 40 µg m^{-3} threshold also

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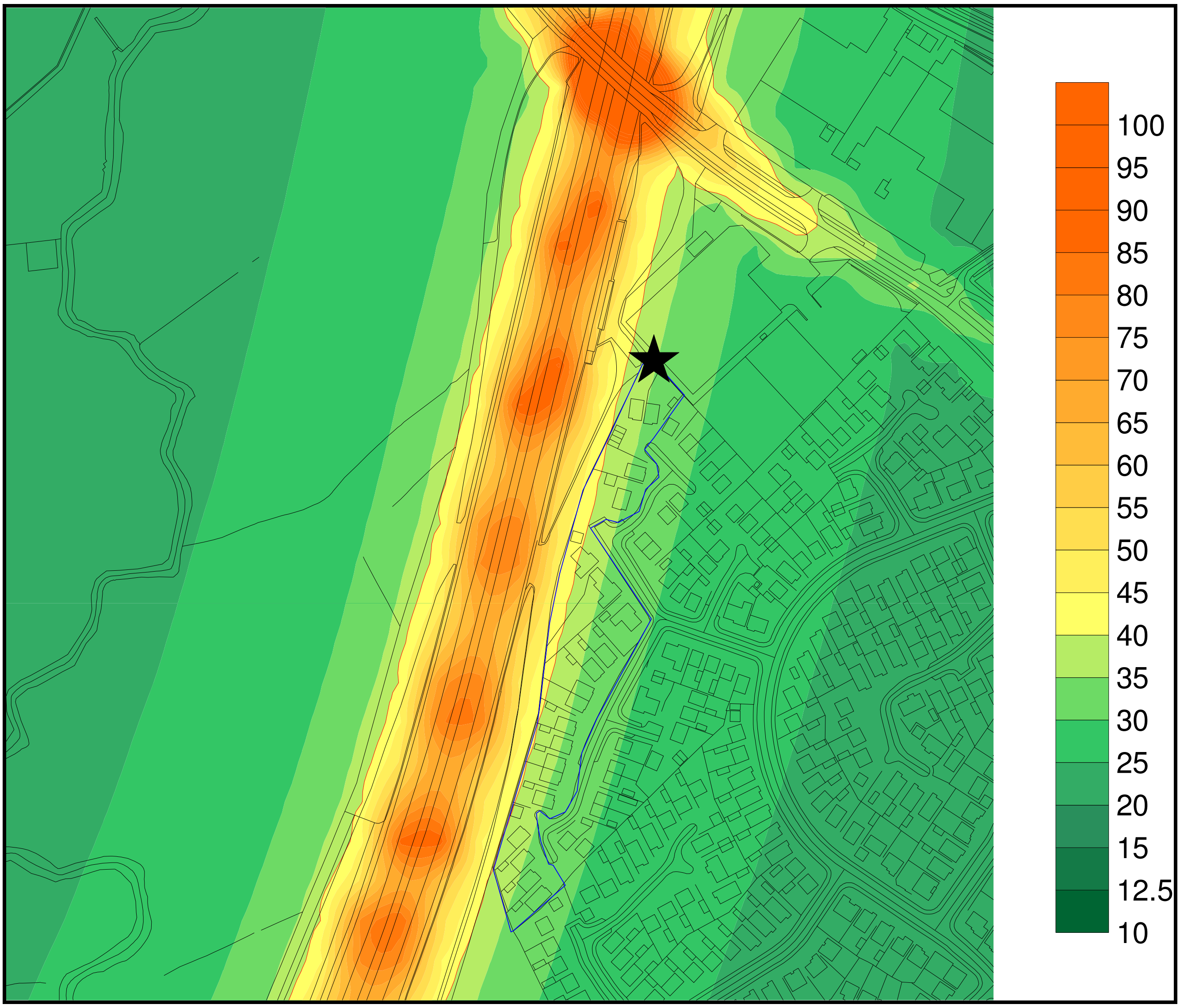
approached within 2-3 metres of the facades of several other houses in Tiree Close also shown in Figure 3.3.

Figure 3.3 Predicted annual mean NO_2 ($\mu g\ m^{-3}$) at Broxtowe AQMA 1 for 2009 base case (with 2002 meteorology)



(Notes – black star indicates continuous monitoring site; blue line indicates AQMA boundary)

Comparison with AQMA 1 monitored results

The annual mean NO_2 monitored results for the AQMA 1 diffusion tube sites were given in the previous section. The monitoring results for the BX11 site in Iona Drive indicated that the objective was exceeded in 2005 and 2007 (based on default factor correction). However, it met the objective in both 2006, 2008 and 2009, although the air quality objective was approached.

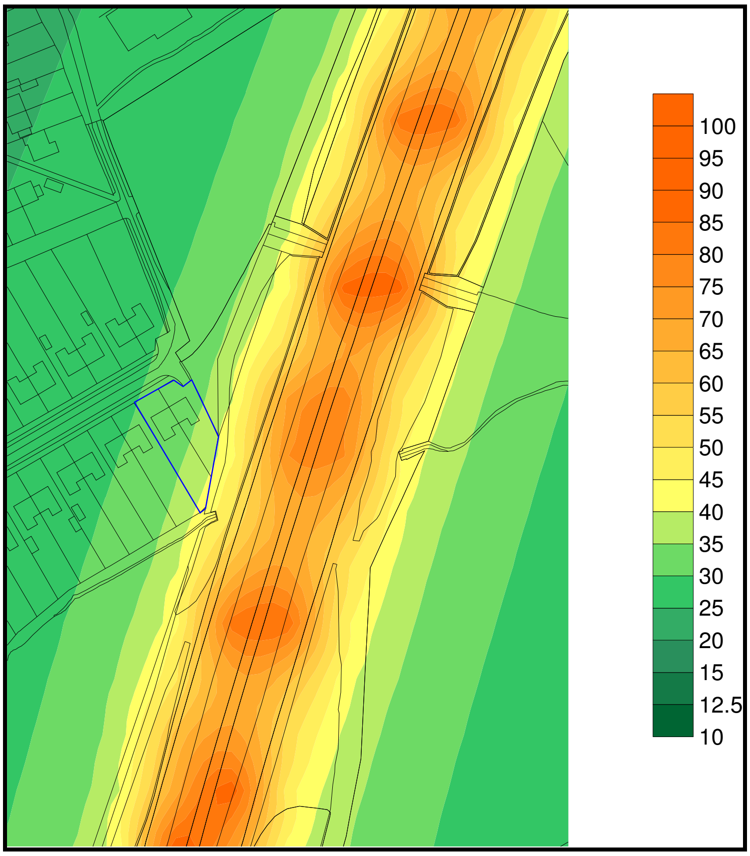
At the BX 31 site in Tiree Close the objective has been met since 2006 when the diffusion tube was situated at the site. From Figure 3.3 above, it can be seen that the continuous site is just outside the area that exceeds and gives a comparison of the modelled and monitored results for the site.

The two diffusion sites (BX11 and BX31) are located at the nearest houses to the M1 motorway, with the BX31 site in Tiree Close located approximately 5m further from the centre of the nearest part of the carriageway than the BX11 site (which is approximately 25m from the centre of the nearest carriageway). This increased distance is reflected in the difference in monitored concentrations between the sites, with the BX31 site having slightly lower concentrations than the BX11 site for all years reported. The continuous site is also located approximately 10m further from the nearest equivalent part of the motorway than the BX11 site. Again the monitored results for the continuous site indicate a reduction in concentration, as expected with greater distance from the motorway.

3.4 Predictions of NO_2 for AQMA 2

The base case predictions confirmed that the annual mean air quality objective was exceeded along the road modelled, however the area that exceeded was mostly close to the centre of the motorway. The area that exceeded also did not overlap with the façade of the houses in Derbyshire Avenue i.e. with AQMA 2 (see Figure 3.4).

Figure 3.4 Predicted annual mean NO_2 ($\mu g\ m^{-3}$) at Broxtowe AQMA 2 for 2009 base case (with 2002 meteorology)



(Note – blue line indicates AQMA boundary)

Comparison with AQMA 2 monitored results

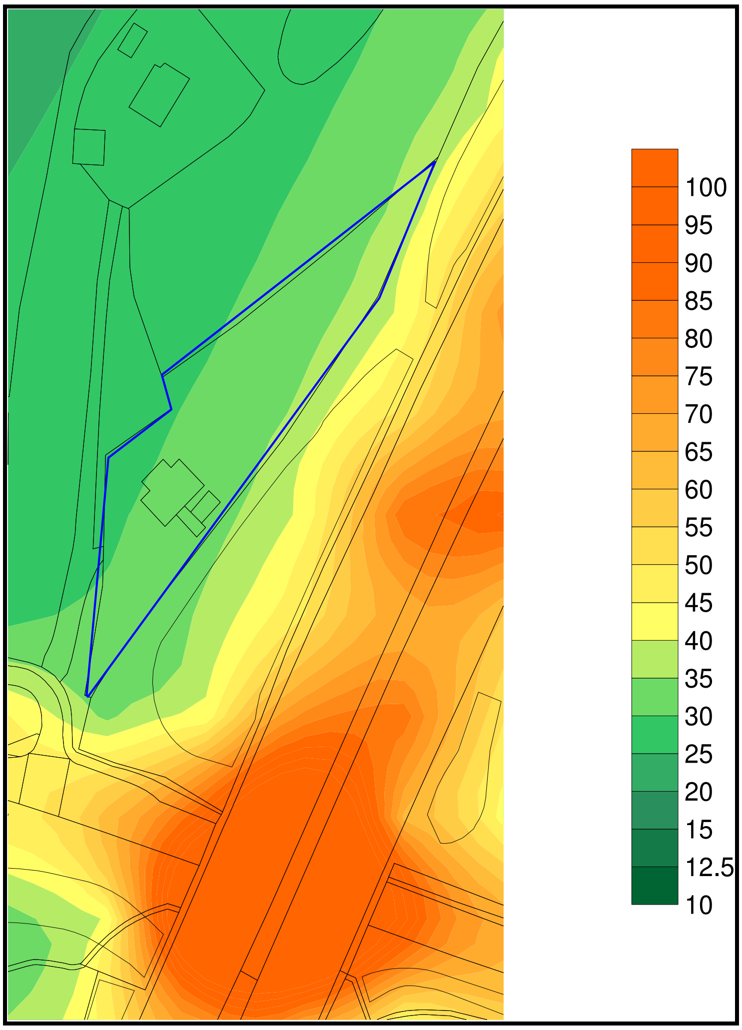
The monitoring site at BX32 was located at the façade of a house in Derbyshire Avenue. The bias adjusted results for the period of monitoring from 2006 to 2009 indicated that annual mean concentrations did not exceed 35µg m^{-3}. This agrees well with the prediction shown above for this area. It again confirms that the annual mean NO_2 concentration at the location of relevant exposure within this AQMA did not exceed the objective.

3.5 Predictions of NO_2 for AQMA 3

The base case predictions for AQMA 3 (shown in Figure 3.5) confirmed that the annual mean NO_2 objective was exceeded along the nearest part of the M1 motorway and near the A609 road, close to where it crosses the motorway.

The area that exceeded the objective for this base plot however did not overlap with the façades of the building with relevant exposure in AQMA 3.

Figure 3.5 Predicted annual mean NO_2 (µg m^{-3}) at Broxtowe AQMA 3 for 2009 base case (with 2002 meteorology)



(Note – blue line indicates AQMA boundary)

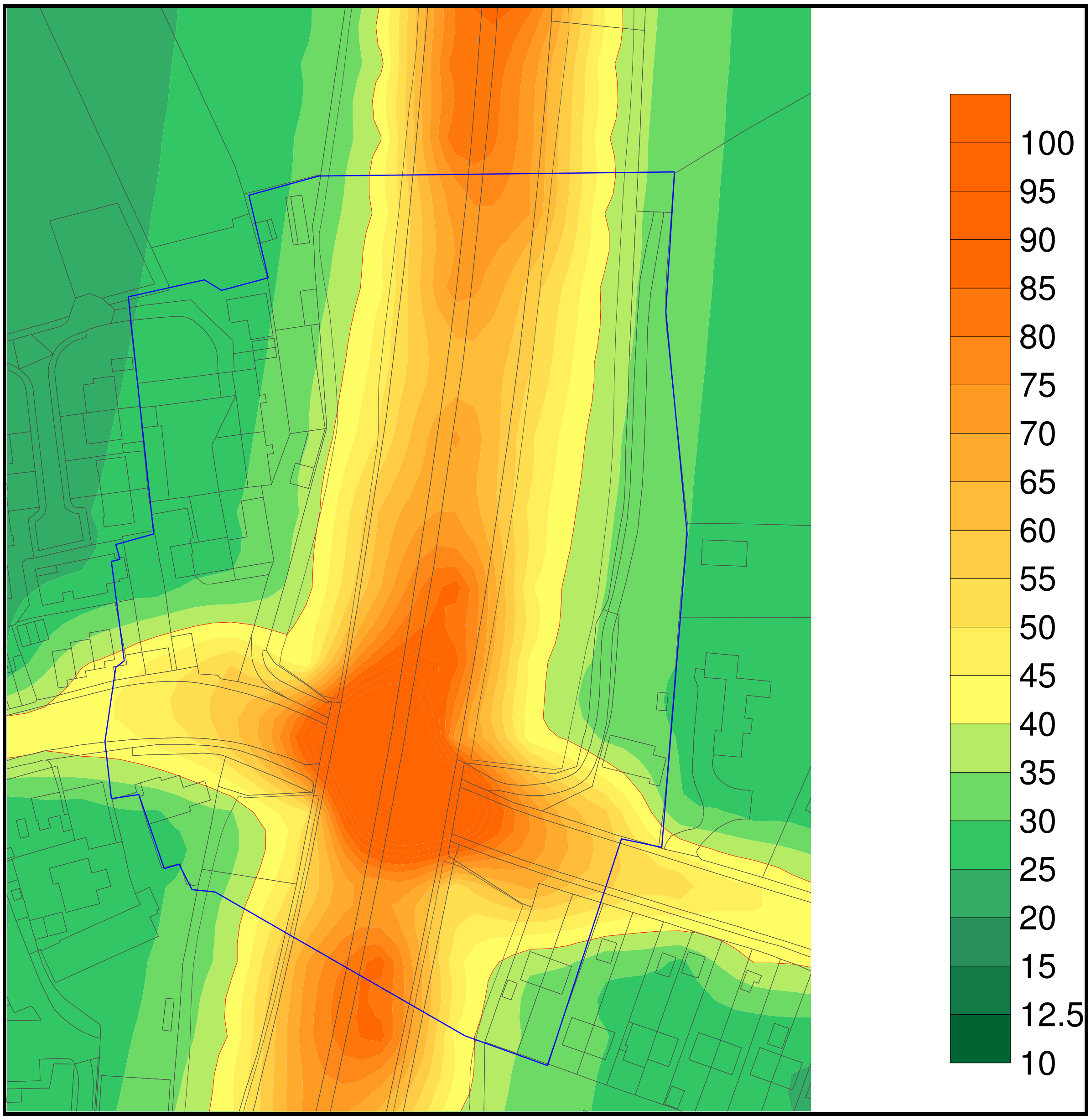
Comparison with AQMA 3 monitored results

The monitored annual mean NO_2 result for the AQMA 3 diffusion tube site was given in the previous chapter. This showed that the annual mean objective was easily met at the BX33 site, which is located at the façade of the only house within AQMA 3. In comparison the modelled 2009 prediction for the same location also predicted for that the annual mean concentration did not exceed 35 µg m^{-3}.

3.6 Predictions of NO_2 for AQMA 4

The base case predictions for AQMA 4 confirmed that the annual mean NO_2 objective was exceeded along the roads modelled, i.e. the M1 motorway and B600, close to where it crosses the motorway in 2006. The areas that exceeded the annual mean objective were mostly close to the centre of both roads (see Figure 3.6). It can also be seen that several facades with relevant exposure within the AQMA were just within the area that exceeds.

Figure 3.6 Predicted annual mean NO_2 (µg m^{-3}) at Broxtowe AQMA 4 for 2009 base case (with 2002 meteorology)



(Note – blue line indicates AQMA boundary)

Comparison with AQMA 4 monitored results

The monitored annual mean NO_2 results for the AQMA 4 diffusion tube sites were given in the previous chapter. The monitoring results at the BX13 monitoring location indicated for 2005 and 2006 that the objective was exceeded, whereas for 2007, 2008 and 2009, the objective was met.

3.7 Improvements in Air Quality within the AQMAs

The modelling corresponds well with the diffusion tube data and gives an indication into the dispersion of the levels of NO_2 generated from vehicles utilising the M1. As a rule, the further away the properties are from the motorway, the better the improvements in air quality.

The monitoring and modelling for AQMA 2 and 3 shows these areas meet the air quality objective for the annual mean of NO_2. Furthermore the historical data shows that these areas have never exceeded the air quality objective since monitoring began in 2006. It is therefore arguable that the areas never exceeded the air quality objective and that the modelling contained within the Detailed Assessment (2005) did not take into consideration the topography (the 3 properties contained within AQMA 2 and 3 are below the motorway) and therefore the dispersion of pollutants.

In AQMA 1 and 4, air quality has improved. However, the reductions in the level of NO_2 have not improved as anticipated within the Detailed Assessment (2005) which suggested that the air quality standards would be met prior to 2010 without any active intervention. The reasons for this could be that the modelling techniques used within this report are more accurate or that the air quality objectives (nationally) have not seen the reductions as expected.

4 Recommendations

The Council recommends undertaking the following actions, for the statutory objective relating to annual mean nitrogen dioxide:

For the AQMA 2 and 3 areas examined in the report:

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

2. Revoke these AQMAs based on the findings of the report.

For the AQMAs 1 and 4 areas examined in the report:

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

2. Maintain and review monitoring in these areas to confirm that the areas with the highest concentrations and relevant exposure are monitored

3. Review future years' monitoring with a view to revoking the AQMAs if the measured concentrations go below the objective for several years and also if national trends in emissions confirm these findings.

5 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.

Diffusion tube monitoring was undertaken at locations within the AQMAs for the period 2005 to 2009 inclusive. The bias corrected NO_2 monitoring results indicated that some locations monitored in the AQMAs exceeded the annual mean objective for some of the years reported. All the sites reported included more than one year where the annual mean objective was met and all the AQMAs also included a monitoring site that met the annual mean objective for all years reported.

For the 2007 and 2008 period, continuous monitoring was also undertaken at the Trowell Park estate close to the M1 motorway. This monitoring was undertaken on behalf of the Highways Agency and the results used to correlate the trend in the level of NO_2 along the M1 corridor. The monitoring results indicated that the annual mean objective was not exceeded for these years at this site, although previously monitoring undertaken in 2004 for the Council's 2005 Detailed Assessment the annual mean just exceeded the objective.

Modelled predictions were undertaken for 2009, partly as a result of the above findings. The predictions made agreed very well with the continuously monitored NO_2 and NOx results from the Highways Agency site in AQMA 1; hence no further verification of the results was needed.

The predictions indicated that concentrations exceeded the annual mean objective close to the M1 motorway and also close to those roads that cross the motorway in the four AQMAs. The area predicted to exceed did not overlap the facades of houses in AQMA 2 and 3. However the area predicted to exceed did overlap the front facades of houses, which represent the nearest relevant exposure in both AQMA 1 and 4.

Based on the above findings, it is considered that the objective was achieved in AQMAs 2 and 3 at the facades of locations representing relevant public exposure. In view of these findings the Council can revoke these AQMAs in Trowell.

For the AQMAs 1 and 4 (in Trowell Park estate and Nuthall) it is considered that the objective was not achieved at facades of buildings representing relevant public exposure. This was based on both modelled predictions and the monitored results. For each of these areas the Council should to retain an AQMA (pending the results of future years' monitoring).

Appendices

Appendix A: Nitrogen Dioxide Diffusion Tube Adjustment Information

Broxtowe Borough Council's diffusion tubes are supplied and analysed by Gradko International, Hampshire. The tubes are prepared using a 20% solution of triethanolamine (TEA) in de-ionised water. The tubes are exposed for one month before being returned for laboratory analysis.

Diffusion Tube Bias Adjustment Factors

2009 Figures

The R&A Helpdesk Database 2008 bias adjustment factor for Gradko 20% TEA in water tubes = 0.90. This figure is the average of 33 studies and was taken from Spreadsheet Version Number: 03/10.

Diffusion tube precision was good for 25 of the 33 studies used to derive the national bias adjustment factor. Tube precision is categorised as "good" where the coefficient of variation (CV) of triplicate diffusion tubes for eight or more periods during the year is less than 20%, and the average CV of all monitoring periods is less than 10% (LAQM.TG(09)).

2008 Figures

The R&A Helpdesk Database 2008 bias adjustment factor for Gradko 20% TEA in water tubes = 0.90. This figure is the average of 18 studies and was taken from Spreadsheet Version Number: 05/09.

Diffusion tube precision was good for 16 of the 18 studies used to derive the national bias adjustment factor. Tube precision is categorised as "good" where the coefficient of variation (CV) of triplicate diffusion tubes for eight or more periods during the year is less than 20%, and the average CV of all monitoring periods is less than 10% (LAQM.TG(09)).

2007 Figures

The R&A Helpdesk Database 2007 bias adjustment factor for Gradko 20% TEA in water tubes = 0.89. This figure is the average of 22 studies and was taken from Spreadsheet Version Number: 05/09.

Diffusion tube precision was good for 21 of the 22 studies used to derive the national bias adjustment factor. Tube precision is categorised as "good" where the coefficient of variation (CV) of triplicate diffusion tubes for eight or more periods during the year is less than 20%, and the average CV of all monitoring periods is less than 10% (LAQM.TG(09)).

2006 Figures

The R&A Helpdesk Database 2006 bias adjustment factor for Gradko 20% TEA in water tubes = 0.98. This figure is the average of 10 studies and was taken from Spreadsheet Version Number: 05/09.

Diffusion tube precision was good for 9 of the 10 studies used to derive the national bias adjustment factor. Tube precision is categorised as "good" where the coefficient of variation (CV) of triplicate diffusion tubes for eight or more periods during the year is less than 20%, and the average CV of all monitoring periods is less than 10% (LAQM.TG(09)).

2005 Figures

The R&A Helpdesk Database 2008 bias adjustment factor for Gradko 20% TEA in water tubes = 0.97. This figure was derived from Spreadsheet Version Number: 03/10. No information is available regarding the number of studies used to derive the national bias adjustment factor.

QA/QC Data for Non-Automatic Sites

Gradko International (diffusion tube supplier and analyst) is UKAS accredited; is assessed annually for compliance to ISO 17025 and participates in other proficiency schemes.

Gradko International confirms that:

- Their procedures have been amended to follow the guidance issued on behalf of DEFRA (AWA Energy & Environment, Feb 2008) relating to the preparation, extraction, analysis and calculation procedures for passive NO_2 diffusion tubes. And
- That most of these procedures were in force before the guidance was introduced and any amendments necessary in achieving compliance were minimal

Gradko International also participates in a number of QA/QC monitoring systems to demonstrate satisfactory performance:

- The Workplace Analysis Scheme for Proficiency (WASP) programme to ensure uniformity of data throughout the year. Only laboratories that are in the WASP scheme are used for analysing tubes from the National Nitrogen Dioxide Diffusion Tube Network.
- The monthly field inter-comparison exercise with other laboratories to enable assessment of bias and precision undertaken by AEA Energy & Environment
- An external QC scheme to check solutions run by AEA Energy & Environment

WASP (Workplace Analysis Scheme for Proficiency)

This involves monthly analysis of doped tubes, allowing assessment of overall uniformity of data throughout the year. Performance scores i9.e. Z-score are assigned to the reported analysis results, on the basis of their difference form the known concentration of the analyte and the actual standards deviations.

Z-score results are classified as follows:

Satisfactory	< +/- 2
Questionable (warning)	> +/- 2 - < +/- 3
Unsatisfactory	> +/- 3

Each participating laboratory's results are analysed by AEA Energy & Environment and combined to give an annual relative standard deviation. If this value is greater than + 15% of the Performance Target then the laboratory's performance for the year in the WASP scheme will be deemed unsatisfactory. Only laboratories that remain in the WASP scheme are used for analysing tubes form the National NO_2 diffusion tube non-automatic network.

Table A:1 below shows 2008 WASP performance results.

Table A:1 GRADKO 2008 WASP NO_2 Diffusion Tube Performance Results

All data supplied by GRADKO International April 2008

Date	WASP Round Number	NO_2 Reference Value µg NO_2	NO_2 Measured Value µg NO_2	Z Score	Laboratory Performance
Jan 2008	100	1.36	1.34	-0.1	Satisfactory
		1.47	1.50	0.2	Satisfactory
Mar 2008	101	0.92	0.95	0.2	Satisfactory
		1.86	1.85	0	Satisfactory
July 2008	102	1.37	1.42	0.3	Satisfactory
		2.28	2.21	-0.2	Satisfactory
Jan 2009	104	2.02	1.85	-0.7	Satisfactory
		1.22	1.21	-0.1	Satisfactory

Appendix B

Model Development

The modelling approach adopted in this report is refined from that used by the ERG on behalf of local authorities; 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

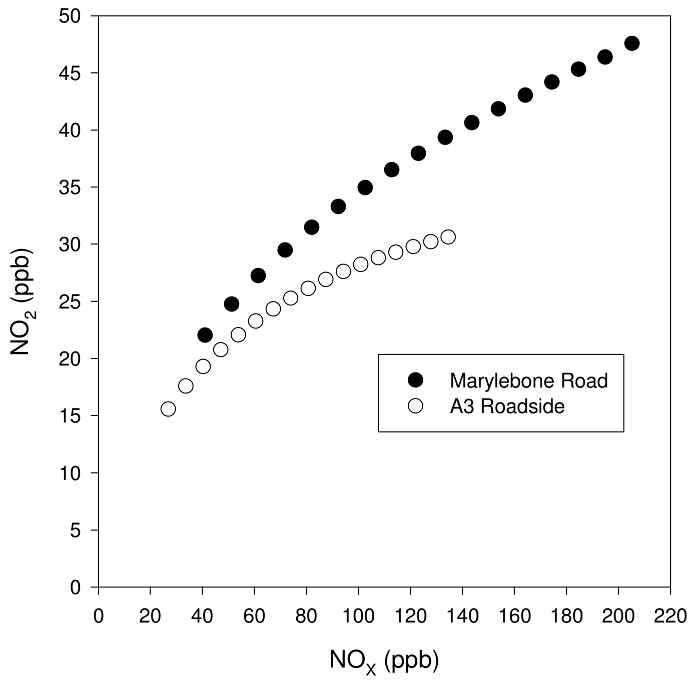
Roadside Concentrations

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 B:1 below.

Figure B:1 NO_x and NO_2 Relationships at Roadside Sites across London



The range of NO_2 concentrations at the roadside, for a given NO_x concentration is 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

2007 background concentrations for the area were obtained from the UK Air Quality Archive (airquality.co.uk). The background NOx concentrations adjusted in accordance with TG(09) methodology.

Appendix C

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 C:1. 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.

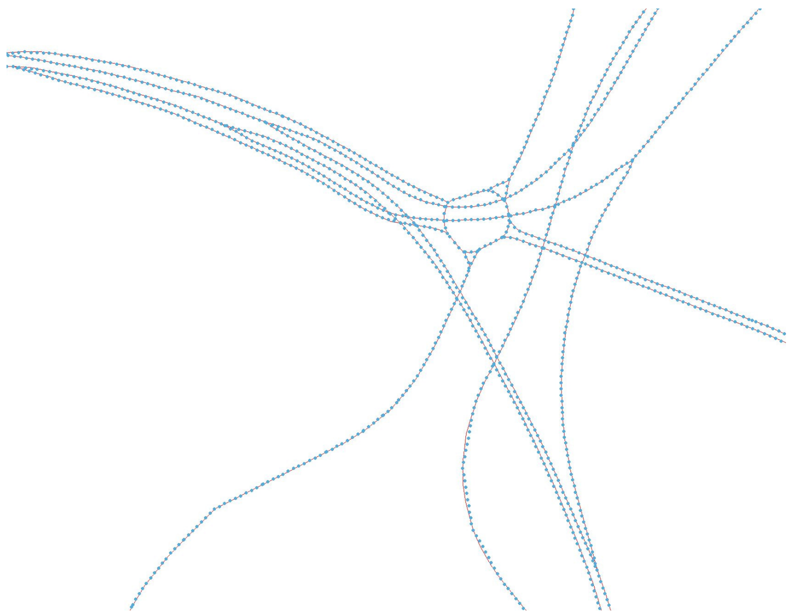


Figure C:1 10m sections of road, showing complex junction details

This is further demonstrated in Figure C:2 overleaf which shows that features, such as roundabouts and curved roads, are accurately represented.

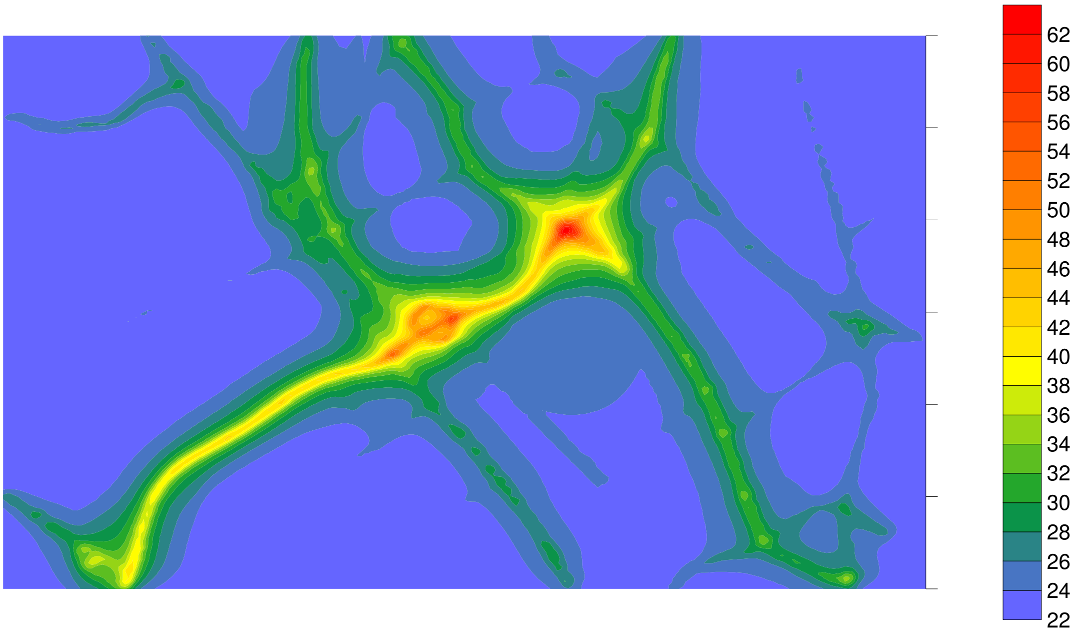


Figure C:2 Modelled example showing concentrations near complex road junctions.

Treatment of Emissions

The model has used the 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 **Error! Reference source not found.** 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.

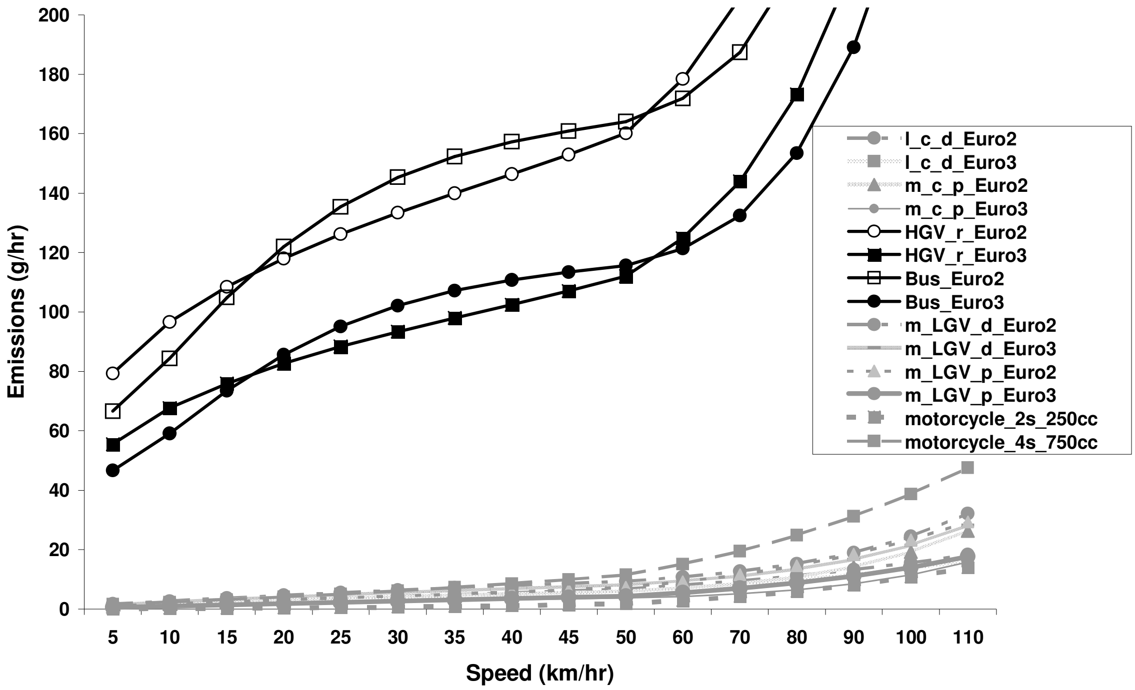


Figure C:3 Emissions NO_X (g/hr) for Euro 2 and 3 Vehicles at different Average Speeds (km/hr)

Appendix D

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 D:1 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.

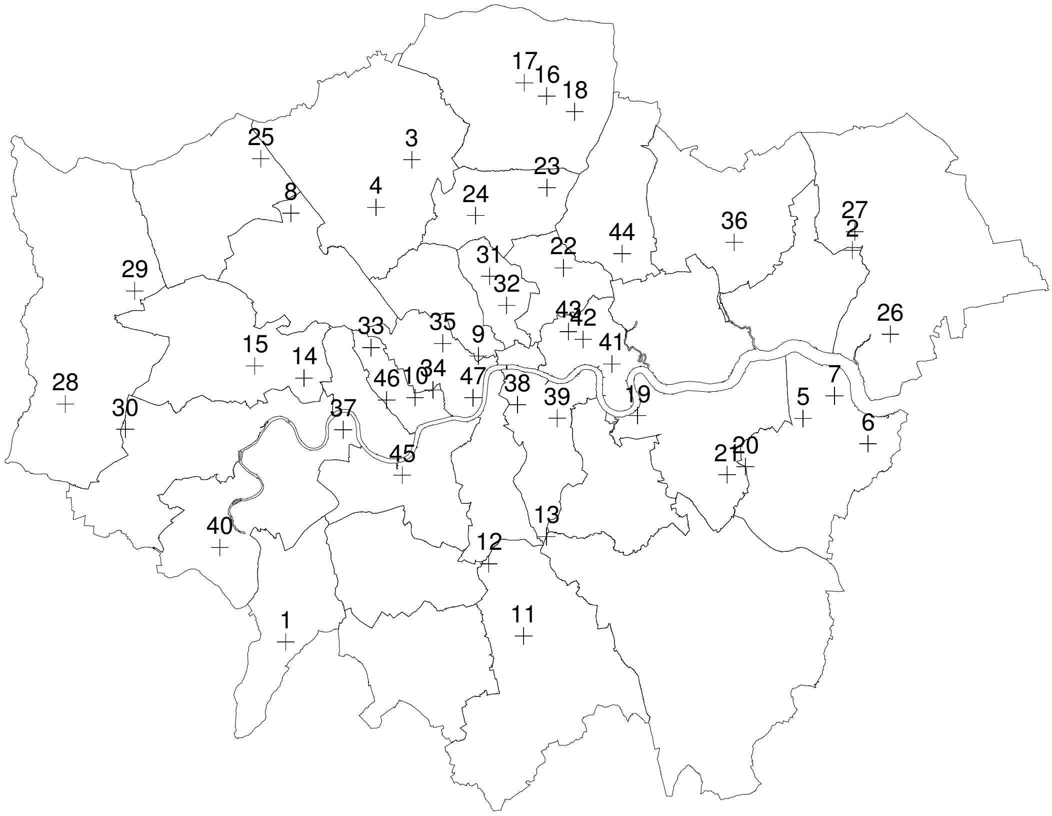


Figure D:1 Sites used to validate model predictions (numbers are site references)

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 NO_x and NO_2

Table D:2 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 D:3.

Table D:2 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	97	81.6	36	34.7

	Road				
32	Islington1	42	45.7	25	24.4
33	KC1	39	45.7	23	24.5
34	Kens and Chelsea 3 - Knightsbridge	126	135.0	49	50.2
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 D:3 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 E

Emissions from Road Transport

Major Road Flows

Recent traffic counts for 2007 were obtained from the Department for Transport (DfT) for the identified roads in Broxtowe. The counts were undertaken for 24 hours.

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.

Table E:1 Traffic flows used in this assessment

Street	Road	M/C	CAR	BUS	LGV	HGVR2	HGVR3	HGVR4	HGVA3	HGVA5	HGVA6
Nottingham Road	B600	0	17167	43	3004	730	0	0	0	515	0
Stapleford Road	A6007	0	7649	120	1468	263	39	11	11	22	33
Nottingham Road	A609	248	11893	108	1778	303	50	22	58	54	44
M1	Link J25 to 26	316	95160	397	18481	4812	681	421	1569	6070	5781

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

Average vehicle speeds were assessed from discussions with the Broxtowe Borough Council and based on speed limits. These were 112 kph for the M1 and 48 kph for the other roads links.

Appendix F

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 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 F:1 below shows how each input data or modelling method affects the final concentration, for the Marylebone Road example.

Tabel F:1 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 F:2. 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 F:2 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.