Chesterfield
BOROUGH COUNCIL

Additional fine scale modelling of selected roadside exposure sites within Chesterfield, with a view to examining possible actions to reduce air pollution.

In part fulfillment of Part IV of the Environment Act 1995

Local Air Quality Management

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Local Authority Officer	Steve Payne

Department	Environment
Address	Town Hall Rose Hill Chesterfield Derbyshire S40 1LP
Telephone	01246 345741
e-mail	steven.payne@chesterfield.gov.uk

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EXECUTIVE SUMMARY

There are at least two locations in Chesterfield where the annual air quality objective for nitrogen dioxide (NO_2) was exceeded in 2010 and in previous years. This is based on a single diffusion tube measurement of NO_2 concentration at each of the two locations, one in Church Street, Brimington and the other at Whittington Hill. Chesterfield Borough Council (CBC) are therefore concerned that despite improvements in vehicle emissions and reduction in background concentrations, the two locations in question might be genuine pollution "hot spots", and if confirmed, action would be required to improve air quality at these locations.

CBC therefore commissioned this dispersion modelling study to confirm the findings from the limited diffusion tube data, and to define the extent of the problem, that is, to determine the size of the area affected at each of the two locations. In addition, the study was aimed at predicting current and future NO_2 concentrations at these locations, and at examining the effectiveness of possible measures to reduce pollution at the two hot spots. At the same time the Council embarked on a program to increase the number of diffusion tubes at the hot spots so that additional monitoring data can be obtained to aid in defining the area affected.

Anecdotal evidence suggests that queuing traffic due to narrow roads and other local factors are responsible for the elevated levels of nitrogen dioxide at both locations. Unfortunately, little data is available on local traffic flows and road conditions at these two locations. Prior to starting the new modelling work therefore, CBC undertook a brief program of traffic monitoring to obtain traffic data at the hot spots and at two other key locations within Chesterfield. The other locations were in Chatsworth Road close to an AURN affiliated continuous monitoring station, and at Jawbones Hill where the Council recently embarked on a four-month continuous monitoring campaign to obtain data at a key roadside location for comparison with that from the Chatsworth Road site.

The two other locations (Chatsworth Road and Jawbones Hill) were also included in the present modelling study as they provided valuable data in their own right as well as aided the model verification process.

Four separate areas were therefore modelled in detail; these included the two areas of concern, namely, Church Street, Brimington; and Whittington Hill, and the two locations with continuous monitoring data, namely Chatsworth Road and Jawbones Hill. All of these areas were modelled in a previous study, but the work reported herein differs from those conducted previously because it took account of the local knowledge of traffic flows and speeds obtained from the traffic monitoring program. In addition, it was conducted using a fine resolution so that local effects (hills, bus stops, traffic lights, road restrictions etc.) could be taken in to account.

Dispersion modelling was conducted using version 3 of ADMS Urban as held by Chesterfield Borough Council and all modelling was conducted in accordance with DEFRA's guidance on modelling for Local Air Quality Reviews and Assessments. As such, the model was first verified by comparing the modelled data for 2010 with monitoring data for the same period. Reasonably good agreement was obtained between the modelled results and those obtained from the monitoring. In addition, the modelled results were compared with those from Chesterfield's AURN site in Chatsworth Road and with data from another continuous monitor in Jawbones Hill, and reasonably good agreement was found in both cases. The model was therefore found to be performing well and no adjustments were made to the modelled results.

The model predicts that the annual objective for NO_2 will be met along Chatsworth Road and at Jawbones Hill in 2011, and in the future unless traffic flows increase significantly and / or congestion increases. This is consistent with the findings from the previous dispersion modelling studies. No action is therefore required at these locations at present, but monitoring of NO_2 should continue to ensure that there is no significant change in pollution levels.

In contrast, the modelling results indicate that the annual objective for NO_2 will be exceeded along parts of Church Street, Brimington in 2011 but are likely to be just met in 2012 and in future years, providing traffic growth is small and congestion does not increase. The reason for the marginal improvement in future is due to the expected reduction in future vehicle emissions. However, given that past experience has shown that vehicle emissions in future do not always meet expectations, it is recommended that additional measures be taken to ensure that air quality along Church Street improves in future.

One possible measure is to reduce congestion and encourage free flowing traffic along Church Street. This has been confirmed by the dispersion model which showed that an increase in vehicle speeds of just 5 kph along Church Street can produce noticeable reductions in NO_2 concentrations. The practicality of achieving such an increase in vehicle speed should therefore be investigated; this could include measures to encourage both lanes of the road to be used rather than just one lane being used while the other is used by parked vehicles. It should be noted, however, that any means to increase traffic flow along Church Street will have to include consideration of traffic approaching and leaving the gyratory system. This should include an examination of the impact of bus stops, traffic lights, and feeding traffic from Devonshire Street on congestion along Church Street.

Another possible measure to improve air quality along Church Street would be the reduction in HGV traffic. This was also borne out by the model which showed that even with the same degree of congestion, a 10% reduction in HGV traffic could have a notable reduction in NO_2 concentrations.

A similar situation was found in Whittington Hill, where the annual objective for NO_2 was predicted to be exceeded along some sections of the road in 2011 but will be just met in 2012 and in future years. Here again, this was dependent on traffic growth being relatively small and on vehicle emissions reducing in line with expectations. As in Brimington, it is therefore also recommended that for Whittington Hill, rather than rely solely on possible vehicle emission reduction and small traffic growth, additional steps be taken to ensure that the objectives will be met in future.

At Whittington Hill, it appears that the increased levels of NO_2 concentrations arise because engines of HGV's and buses tend to be working very hard as they travel up the relatively steep hill, but since there is only one lane of traffic in both directions, all other vehicles are forced to follow at the same speed. The result is that emissions rates are at their highest over this section of the road.

Unfortunately, the only feasible means of improving air quality along this stretch of the road appears to be to reduce the amount of traffic, however, modelling has shown that a reduction in HGV traffic by 10% will only produce a small reduction in NO_2 concentrations. A detailed investigation will therefore be required to examine measures to reduce traffic, and hence pollution along Whittington Hill. In the meantime, diffusion tube monitoring should continue.

1. INTRODUCTION.

The 2011 Progress Report[1] prepared by Chesterfield Borough Council (CBC) as part of their responsibilities for Local Air Quality Management, indicated two locations where the air quality objectives were exceeded in 2010 and in previous years. The implication is that despite the improvement in vehicle emissions over the years, these locations seem to be genuine pollution “hot spots”. The two locations are Church Street, Brimington and Whittington Hill. At both locations, queuing traffic due to narrow roads and other local factors appear to be responsible for the elevated levels of nitrogen dioxide (NO_2).

CBC are keen to improve air quality at these locations, and are therefore considering various options to reduce pollution at these locations, but have recognised that before viable solutions can be developed, it is important to clearly define the extent of the problem and to check the effectiveness of the proposed measures. The Council has therefore commissioned a dispersion study to confirm the findings from the diffusion tubes, define the extent of the problem and to predict current and future conditions at these hot spots. The Council has also embarked on a programme to increase the number of diffusion tubes at the hot spots so that additional monitoring data can be obtained to aid in defining the area affected.

Dispersion modelling was conducted on two previous occasions; first by Bureau Veritas in 2007[2] as part of a detailed assessment and more recently in 2010 by Enstec Services[3] as part of a further detailed assessment. Neither of these studies indicated a problem at these areas and it is believed that this was largely due to a lack of appropriate information on local traffic flows and road conditions at these two locations.

Prior to starting the new modelling work, CBC undertook a brief programme of traffic monitoring to obtain traffic data at these hot spots and at two other key locations within Chesterfield. The other locations were on Chatsworth Road close to an AURN affiliated continuous monitoring station, and at Jawbones Hill where the Council recently embarked on a four-month continuous monitoring campaign to obtain data at a key roadside location for comparison with that from the Chatsworth Road site. The results from the brief program of traffic monitoring were compared with available data including data from Derbyshire County Council (DCC) which became available shortly after the traffic monitoring was completed. The data obtained from the brief monitoring program was largely consistent with that from DCC, but in general, traffic flows tended to be slightly higher. It should also be mentioned that the brief programme of traffic monitoring also provided valuable information on traffic speeds and queuing especially in Brimington and along Whittington Hill.

The two other locations (Chatsworth Road and Jawbones Hill) were also included in the present modelling study as they provided valuable data in their own right as well as aided the model verification process. Although all of the areas modelled were included in the previous modelling study, the work reported herein differs from those conducted previously because it takes account of the local knowledge of traffic obtained from the traffic monitoring program. In addition, the new study was conducted using a fine resolution so that local effects (hills, bus stops, traffic lights, road restrictions etc.) could be taken in to account.

The modelling methodology and procedures were conducted largely in accordance with the recommendations in TG(09)[4]; as such the model was first verified using data for 2010 before being used to predict current and future concentrations and hence define the extent of the problem. This report presents details of the modelling methodology together with the salient results obtained.

2. MODELLING METHODOLOGY

2.1 Introduction

The model used during this study was version 3 of ADMS-URBAN. The model is widely used by Local Authorities during detailed assessments conducted in fulfilment of their requirements as part of Local Air Quality Management and for the modelling or air pollution within large areas. Here, the model was used by Chesterfield Borough Council's staff with the assistance of Enstec Services to examine pollution levels at two hot spots within the Borough. The model has been widely validated by its developers, however, as is the usual practice when conducting detailed modelling, site specific verification was carried out by comparing the model results with the monitoring data. Verification of these two models was done using data for 2010. Two additional areas were, however, also modelled; these were areas in Chatsworth Road and in Jawbones Hill, where continuous NO_X analyser data were available. This model verification process was conducted in accordance with the recommendations for verification as given in TG09[4] and is reported in this section, together with other pertinent modelling details.

It should be noted that the work conducted herein was in fact an extension and refinement of modelling study conducted earlier as part of a detailed assessment[3]. Here, however, areas deemed as hot spots or key areas have been re-modelled at a finer scale with account taken of recent traffic data. As a result, four separate models have been produced and this section presents the input data used during the modelling, the methodology adopted, and the verification conducted.

2.2 The ADMS-URBAN Model and the data input

The ADMS-URBAN model has been designed specifically for assessing the dispersion of emissions from major road networks such as those within large cities. As such, it includes features specific to the modelling of roads, such as canyon effects, the modelling of chemical reactions involving NO, NO_2 and ozone and the calculation of emissions from traffic flow data. The ability to take into account time varying emission factors is also included, by entering a time varying traffic flow factor which enables the diurnal traffic flow to be modelled. In addition it retains much of the physics of the boundary layer characterisation used in the original ADMS programs.

The model calculates both the NO_x and NO_2 concentrations, but the conversion of NO_x to NO_2 is dependent on a number of factors, and in particular the amount of available ozone. Additional complexities also arise regarding the treatment of existing or background values of NO_x. The conversion of NO_x is based on a semi-empirical model of a simplified set of chemical reactions and requires the use of background concentrations of NO_x, NO_2 and O_3 (ozone). Relevant background O_3 concentrations were not available so the model was not used to convert NO_X to NO_2. Instead, as recommended in section 2.26 of TG09[4] ,the NO_x to NO_2 conversion spreadsheet tool[5] was used. This uses default values of the regional ozone, oxides of nitrogen and nitrogen dioxide concentration above the surface layer for the Chesterfield area. In using this spreadsheet it was assumed that the traffic mix in Chesterfield was best characterised as an “other urban UK traffic”, i.e., urban traffic mix outside of London.

The model was run with a roughness length (z_o) of 0.3m and a minimum Monin-Obukhov length scale (L_o) of 10m. These are parameters that characterise the depth of the atmospheric boundary layer and its turbulence characteristics, and are therefore important to the calculation of the dispersion of pollutants. As part of the model verification process these parameters were varied and the values used are believed to be appropriate to the site having been found to provide the best match to the monitoring data.

2.3 The Modelled Areas

The two hot spots that were modelled were Whittington Hill and Brimington. These areas are shown in Figure 2.1 in relation to one of the areas previously modelled and in detail in Figures 2.2 and 2.3 respectively. These figures show all major roads and heavily trafficked or congested roads in the area that were modelled. Chesterfield also has two air quality monitoring stations which are affiliated to the national Automatic Urban and Rural Network. One of these is located in Chatsworth Road; the area around this air quality station was therefore also modelled. Continuous monitoring data was also available for a limited period at another key site within Chesterfield; this was at Jawbones Hill. This area was therefore also modelled. Figures 2.4 and 2.5 show these two additional areas and the roads that were modelled.

Where necessary, each road was split into several convenient sections to accommodate changes in the road width, its elevation, traffic flow or speed. Steep gradients or known areas of queuing traffic were also taken into account by including additional segments. Further, sections of roads with hills were modelled using separate uphill and downhill links with emissions of modified in accordance with section A2.19 of TG09. This resulted in 28 separate road segments being used for the Whittington Hill model, 30 for the Brimington and Chatsworth Road models and 20 for the Jawbones Hill model. These sections are listed below in Tables 2.1 to 2.4 to show the traffic flow and speed data used for each of the four modelled areas. Additional details of the traffic data used are presented below.

Regardless of the area being modelled, the grid size used was such that the spatial resolution was 10 metres or less.

Table 2.1. Traffic data used with the Whittington Hill model

Road Segment	LDV (Veh/hr)	HDV (Veh/hr)	LDV Spd (kph)	HGV Spd (kph)
Station Road to Whittington Way	632	28	40	30
Station Road to Whittington Valley	632	28	40	30
Station Road to the green	632	28	35	25
Whittington Hill - North bound to Jnct with lights	301	14	25	20
Whittington Hill -South bound to jnct with lights	345	14	40	30
Whittington Hill - NB to Holland Road	301	14	20	15
Whittington Hill - SB to Holland Road	345	14	40	30
WH: Junction with Holland Road NB	301	14	20	15
WH: Junction with Holland Road SB	345	14	40	30
WH: Between Holland and Prospect Rd NB	301	14	15	15
WH: Between Holland and Prospect Rd SB	345	14	40	30
WH: Junction with Prospect Rd NB	301	14	15	15
WH: Junction with Prospect Rd SB	345	14	40	30
WH: To Newbridge Rd NB	301	14	15	15
WH: To Newbridge Rd SB	345	14	35	30
WH: Newbridge Rd Junct NB	301	14	15	15
WH: Newbridge Rd Junct SB	345	14	35	30
WH: To Broomhill Rd NB	301	14	20	20
WH: To Broomhill Rd SB	345	14	40	30
WH: Broomhill Rd Jnct	632	28	40	30
Newbridge Rd Junct	20	0	20	20
Broomhill Rd	47	3	40	30
WH: To Station Lane	632	28	40	30
High St continues from Station Lane	632	28	40	30
Prospect Rd Jnct with Whittington Hill	40	3	25	20
Prospect Road	40	3	40	30
Holland Rd Jnct with Whittington Hill	40	3	25	20
Holland Road	40	3	40	30

Table 2.2 Traffic data used with the Brimington model

Road Segment	LDV (Veh/hr)	HDV (Veh/hr)	LDV Spd (kph)	HGV Spd (kph)
A619: From Wikeley way to Brier Way - EB	345	14	40	35
A619: From Wikeley way to Brier way - WB	396	15	40	35
A619: To Diffusion Tube 10	741	30	40	35
A619: To Bradley Way - EB	345	14	35	30
A619: To Bradley way - WB	396	15	35	30
A619: EB to Junction	345	14	30	25
A619: WB to Junction	396	15	30	25
Entering Church St Gyratory	345	14	20	15
Exiting Hall Rd into Chesterfield Rd	395	16	20	15
Church St Devonshire Way Junct	515	22	15	15
Church St to Zebra crossing	515	22	20	15
Church St to the Hall	515	22	20	20
Church St - Canyon section	515	22	20	20
Church St - to lane split	515	22	20	20
Church St - To exit of gyratory	515	22	20	20
Exit Church Road	464	19	20	15
Enter High St	51	3	20	15
High Street	464	19	30	25
Hight St - approaching Hall Rd	464	19	25	20
Hall Road to Jnct with Cotterhill Lane	464	19	30	25
Hall Rd - Cotterhill Lane Jnct	464	19	30	25
Hall Road - NW section	464	19	35	30
Hall Rd to church St	70	3	20	15
Devonshire Street Junct	101	4	25	20
Devonshire Street	101	4	30	20
Ringwood Road East bound to Tube 22	464	19	30	25
Ringwood Rd west Bound to Junct	413	17	30	25
Ringwood Rd WB - to lights	413	17	35	30
Ringwood Rd WB - To Tube 22	413	17	40	35
Ringwood Rd	877	37	40	35

Table 2.3. Traffic data used with the Chatsworth Road model

Road Segment	LDV (Veh/hr)	HDV (Veh/hr)	LDV Spd (kph)	HGV Spd (kph)
Chatsworth Rd 1	664	38	40	30
Chatsworth Rd 2	664	38	30	25
Chatsworth Rd 3	664	38	30	25
Chatsworth Rd 4	664	38	30	25
Chatsworth Rd 5 - EB	332	19	25	20
Chatsworth Rd 5 - WB	332	19	25	20
Walton Rd / Chatsworth Rd Roundabout	664	38	20	15
Chatsworth Rd 6 - EB	332	19	25	20
Chatsworth Rd 6 - WB	332	19	25	20
Chatsworth Rd 7	664	38	25	25
Chatsworth Rd 8	664	38	25	25
Chatsworth Rd 9	664	38	25	25
Chatsworth Rd 10 - EB	332	19	25	20
Old Hall Road -1	371	5	40	35
Old Road east	500	20	50	45
Old Road West	500	20	50	45
Chatsworth Rd 10 - WB	332	19	30	25
Old Hall Road -2	371	5	25	20
Old Hall Road -3	371	5	40	35
Old Hall Road -4	371	5	25	20
Walton Rd 1 -NB	186	3	20	15
Walton Rd 2 -NB	186	3	25	20
Walton Rd 1 -SB	186	3	25	20
Walton Rd - Mini Rdbt	371	5	20	15
Walton Rd 3	371	5	30	25
Walton Rd 4	371	5	25	20
Walton Rd 5	371	5	45	30
Walton Rd 6	371	5	50	45
Walton Rd 2 -SB	186	3	25	20
Old Rd /Hall Rd - Jnct	500	20	30	20

Table 2.4 Traffic data used with the Jawbones Hill model

Road Segment	LDV (Veh/hr)	HDV (Veh/hr)	LDV Spd (kph)	HGV Spd (kph)
Derby Road - south of Storforth Lane	1071	42	35	30
Derby Rd - Storforth Lane Junct	1071	42	25	15
Derby Rd between Storforth Ln and Lincoln rd	1071	42	35	30
Derby Rd Junct with Lincoln Rd	1071	42	25	15
Derby Road - Lincoln Rd to St. Augustine's	1071	42	35	30
Derby Rd Junction with St. Augustine's	1071	42	25	15
Derby Rd to Crescent	1071	42	35	30
Derby Rd - Junction with Crescent	1071	42	25	15
Jawbones Hill	1071	42	30	20
Junction with Baden Powell Rd	1071	42	30	20
Derby Rd - north of Baden Powell Rd	1071	42	35	30
Derby Road - junction with Sherwood St	1071	42	25	15
Jawbones Hill - main link NB	536	21	20	15
Derby Road - Herriot Drive	1071	42	35	30
Derby Road - junction with Trevor Crescent	1071	42	25	15
Derby Road - to Byron St	1071	42	35	30
Derby Road	1071	42	35	30
Derby Rd - NB approaching Roundabout	536	21	20	15
Derby Rd - SB approaching Roundabout	536	21	35	30
Jawbones Hill - main link SB	536	21	30	20

2.4 Traffic flows

The traffic data listed above in Tables 2.1 to 2.4 were obtained from a number of sources including the Department of Transport website[6] , the NAEI data warehouse[7] and Derby County Council. The available traffic data were supplemented by a brief program of traffic counting at each of the four locations modelled. This was done to check the validity of the data obtained from the other sources that were not always close to the sites of interest. Generally, the local traffic counts (conducted in July 2011) produced slightly higher data than those derived from the other sources, but the diurnal variation and the percentage of HGV's were largely consistent with the available data. Local knowledge was also employed for the minor roads, and for the estimation of traffic speeds and to indicate areas of queuing traffic.

Finally, since there is a strong diurnal pattern in traffic flows which clearly affects emissions, this effect was modelled by using the time varying emission factor facility in the model. This essentially scales the average traffic flow input to the model so that the diurnal variation is replicated.

2.5 Background Concentrations

Input data to the model also included background concentrations. These were obtained from the national air quality archive which provides background data for each Local Authority District in 1 km x 1 km grid squares. As mentioned above, the model was configured to produce concentrations of NO_X only (and this was later converted to NO_2 using the conversion tool as explained in section 2.2.2 above), so only background NO_X concentrations were input to the model. The available background NO_X concentrations for the Whittington Hill and Brimington areas in 2010 are shown in Figure 2.6. This information was used together with the tabulated data to ensure that double counting was avoided (i.e the contribution from sources within the modelled area were excluded form the background values used in the model). The values used for each of the modelled areas for the periods modelled were as summarised below.

Table 2.5 Background NO_X concentrations (in ug/m^3)

Year	Whittington Hill model	Brimington model	Chatsworth Road model	Jawbones Hill model
2010	30	21	22	22
2011	29	20	21	21
2012	28	19	20	20

2.6 Meteorological Data

The nearest meteorological station to Chesterfield that has recent complete meteorological data necessary to run ADMS Roads is that at Nottingham Watnall. This station, managed by the UK Meteorological Office, is some 30 km south, southeast of Chesterfield. Data for 2009 and the two previous years (2008 and 2007) were available from the earlier study, but data for 2010 and for the period August 2010 to July 2011 were also obtained. The latter data was obtained so that a comparison could be made of the modelled results with data from a continuous station at Jawbones Hill which was installed in April through to July this year.

Figure 2.7 shows the wind roses for the two data sets used (2010 and 2010/11). Not surprisingly, this shows that in common with most of the country, the predominant winds were from the south west. It is interesting, however, to note that in 2010, even though winds from the south west were still the most prevalent, there were a higher percentage of winds from some of the other directions compared to that observed in the 2010/11 data set.

2.7 Model Verification

Model verification was essentially carried out by comparing the results form the model with that obtained during the monitoring study. The approach adopted was that suggested in TG(09)[4] . The model was used to predict concentrations in 2010 using the 2010 meteorological data and traffic flow and speed data as believed to be relevant to 2010. Results from the model were then compared with those obtained from the continuous analysers and from the bias corrected diffusion tubes.

The first part of the verification was done by comparing the modelled and monitored NO_2 concentrations as outlined in Example 1 of the verification process given in Annex 3 of TG09 [4] . The results are as summarised below in table 2.6 where the modelled NO_2 concentrations are compared with those obtained from monitoring. As explained above, four areas were modelled in detail rather than using a single coarse model. Table A2.6 therefore shows the results for all models. It should be noted that results from all four models were used as the same results would have been obtained if the data were combined and input into a single model; the only difference is that that the run would have taken much longer.

TG09 recommends that if there is no obvious bias in the data (i.e that the model does not consistently over-predict or under-predict concentrations, and if the differences are within $\pm$ 25%, no adjustment of the model is necessary. These data are therefore shown graphically in Figure 2.8 where the $\pm$ 10% and $\pm$ 25% spread are also shown. It is clear from this figure and from the above table, that all of the modelled data lie within $\pm$ 25% of the monitored results. On this basis, it would appear that the model is performing well and no adjustment is necessary.

TG09 also recommends that the road contribution to NO_X concentrations obtained from the model and the monitoring should be compared as part of the verification process. Further, paragraph A3.240 recommends that both continuous monitoring and diffusion tube data be used for model verification. For the diffusion tube data, the recommendation is that the NO_X to NO_2 conversion spreadsheet tool [5] be used to derive the NO_X concentrations. This process was therefore adopted and the results obtained are as summarised below in table 2.7. The modelled and monitored road contribution to NO_X are also shown graphically in Figure 2.9 where the best fit straight line through all data points are shown together with the $\pm$ 25% variation.

It is evident from Figure 2.8 that there is some scatter in the data but generally the modelled NO_X concentrations were within 25% of those derived from the diffusion tube data. In a few cases, however, the model tended to over-predict NO_X concentrations significantly. This was most noticeable at tube 31, where NO_2 concentrations were also over-predicted by the model.

Table 2.6 Comparison of modelled and monitored NO_2 concentrations in ug/m^3

Receptor name	Monitor Type	Background NO_2	Monitored Total NO_2	Modelled Total NO_2	Percent Difference
6	DT	15.1	38.9	33.3	-14.4
10	DT	15.1	20.5	23.83	16.2
22	DT	15.1	30.4	28.46	-6.4
11	DT	19.5	37.8	35.74	-5.4
25	DT	14.6	19	21.44	12.8
30	DT	14.6	32.1	28.15	-12.3
34	DT	14.6	27.4	25.15	-8.2
A	CM	14.6	20.53	23.03	12.2
31	DT	15.6	24.1	29.63	22.9
8	DT	15.6	31.4	28.97	-7.7
3	DT	15.6	20.2	17.71	-12.3
4	DT	15.6	21.1	21.88	3.7
9	DT	15.6	32.1	32.83	2.3
14	DT	15.6	35.9	36	0.3

N.B: CM = Continuous analyser; DT = Diffusion tube.

Table 2.7. Comparison of modelled and monitored NO_X concentrations in ug/m^3

Receptor name	Monitor Type	Monitored Total NO_x	Modelled Total NO_x	Monitored Road NO_x	Modelled Road NO_x	Percent Difference
6	DT	79.77	63.62	58.77	42.62	-27.5
10	DT	32.41	39.91	11.41	18.91	65.7
22	DT	55.92	51.00	34.92	30.00	-14.1
11	DT	74.5	68.84	44.49	38.84	-12.7
25	DT	31.2	34.43	9.2	12.43	35.1
30	DT	62.56	50.13	40.56	28.13	-30.6
34	DT	50.5	42.91	28.5	20.91	-26.6
A	CM	45.0	37.99	23.0	15.99	-30.6
31	DT	40.43	53.82	18.43	31.82	72.7
8	DT	58.37	52.16	36.37	30.16	-17.1
3	DT	31.69	26.39	9.69	4.39	-54.7
4	DT	33.67	35.41	11.67	13.41	14.9
9	DT	60.21	62.19	38.21	40.19	5.2
14	DT	70.67	70.99	48.67	48.99	0.7

N.B: CM = Continuous analyser; DT = Diffusion tube.

Finally, the modelled results are compared with monitoring data obtained in 2011 for Chesterfield's AURN site at Chatsworth Road and with data obtained from a program of monitoring between April and July 2011at Jawbones Hill. In these cases, the background NO_X data from Chesterfield's urban background site at Queens Park was used as a background file of concentrations in the model. However, the Queens Park background data was scaled to produce an average of 21 g/m^3 as this is the background NO_X value appropriate to these sites (see Table 2.5 above).

Figures 2.10 and 2.11 show the NO_X and NO_2 concentrations respectively from the AURN site at Chatsworth Road between January 2010 to July 2011 compared with those from the model. Therese results for the period between January and February 2011are also shown in Figures 2.12 and 2.13 to show the comparisons in closer detail. Similarly, Figures A2.7 and A2.8 show the NO_X and NO_2 concentrations respectively, from the model with those obtained during the monitoring campaign at Jawbones Hill. In both cases, the comparisons are reasonably good and give confidence in the modelling methodology. The modelled concentrations are therefore considered as being verified.

2.8 Model Uncertainty

TG(09) also discusses the uncertainty in modelling and suggests that three statistical measures can be used to assess the uncertainty n the model. These are :- the correlation coefficient, the root mean square error (RMSE) and the fractional bias. These parameters have therefore been calculated for the results obtained for the NO_2 concentrations obtained from the models. As mentioned above, the results from four models are used, as the same results would have been obtained if the data used in these models were input to a single model. This is because the same input parameters were used; the only difference was that different road sources and corresponding traffic data were used.

The results of the uncertainty parameters are presented below in Table 2.8. Based on these results, it is clear that the modelled results can be used with a fair degree of confidence. It is especially worth noting that the RMSE is 3.01 ug/m^3; this means that one way of being confident in areas not exceeding the objectives is to ensure that all concentrations at relevant receptors are less than 36.9 ug/m^3.

Table 2.8 Uncertainty parameters

Statistical Parameter	Value	Comments
Correlation Coefficient	0.90	Reasonably close to 1.0
Root Mean Square Error (RMSE) in ug/m^3	3.01	Well within expectations for modelling and less than 10% of the objective (4 in ug/m^3)
Fractional Bias	0.014	Sufficiently close to 0.0 and showing a slight under-prediction by the model

3. RESULTS AND DISCUSSION

3.1 Introduction

Results for the four areas modelled, i.e the two hot spots (Brimington and Whittington Hill) and the two other key areas modelled (Chatsworth Road and Jawbones Hill) are presented in separate sections below for 2010, the current year and for 2012. It should be noted that in each case results are presented to show the annual mean ground level NO_2 concentrations only as this is the pollutant that was exceeded at the hot spots. Note that the 1 hour objective was in no danger of being exceeded and results for this are not presented.

It should also be noted that in presenting the contours of concentration, the annual objective of 40 ug/m^3 is shown as a shaded area outlined in red, and the 37 ug/m^3 contour is also highlighted, as a shaded area outlined in blue. This practice is adopted in order to allow for the uncertainty of 3 ug/m^3 that is present in the modelling results. In other words, outside of the 37 ug/m^3 contour, it is fairly certain that the objectives will be met, but in areas between the 37 and 40 ug/m^3 contours, there is a chance that the objectives will be exceeded. Obviously, within the 40 ug/m^3 contours, the annual objective will be exceeded, if there are any relevant receptors within this area.

3.2 Conditions in Brimington – the do nothing case

Figure 3.1 shows the annually averaged ground level NO_2 concentrations that were estimated for 2010. It is clear that the objectives (outlined in red) were exceeded along parts of Church Street, but this was on the street where no receptors were present. The area outlined in blue, which takes account of the uncertainty in the model, does however, indicate that the objectives may have been exceeded along Nos. 4 to 18 Church Street in 2010, but elsewhere, the objectives were met. It should be noted that the single diffusion tube on Church Street which recorded a concentration of 43.2 ug/m^3 in 2010 (when annualised) was located at the corner of the last building on a block (see Figure 3.2) and would have been subjected to enhanced wind speeds and turbulence. It was therefore less than ideal for siting diffusion tubes. This has since been re-located. The modelled concentrations in 2010 is therefore believed to be a reasonably accurate representation of conditions at the time.

Turning to the current year, Figure 3.3 shows that the situation is predicted to improve compared to 2010, as the area outlined in red (the 40 ug/m^3 contour) is now located firmly in the middle of the road. However, based on the 37 ug/m^3 contour, it is likely that the objectives will be exceeded along the facade of Nos. 6 to 12 Church Street. The objectives are likely to be met at all other locations.

If no action is taken, the NO_2 concentrations predicted in 2012 are likely to be as shown in Figure 3.4; this indicates that the objectives are unlikely to be exceeded at any location where receptors are likely to be present. The improvement between 2011 and 2012 is due to the reduction in vehicle emissions, however the same traffic data was used in 2012 as was used for 2011 because the traffic growth factors predicted (between 2011 and 2012) were relatively small. Given that experience from the last few years has shown that the improvement in vehicle emissions has not been as good as expected, and given the uncertainty in prediction in future traffic growth, it is believed that the results shown in Figure 3.4 may not necessarily be achieved. Further, since the improvements in 2012 is such that the objectives will only just be met, it would be prudent to develop measures to reduce NO_2 concentrations along Church Street. The following therefore examines such possible measures.

3.3 Examination of possible measures to reduce air pollution in Brimington.

The aim here was to examine the effectiveness of possible measures without consideration of costs or ease of implementation. The first measure examined was that of increasing traffic speeds along Church Street only by 5kph. Figure 3.5 shows that such a measure would ensure that the objectives are met along the entire street in 2012. The feasibility of improving traffic speeds along Church Street should therefore be examined as a possible solution.

Another possible measure would be to attempt to reduce the amount of heavy goods vehicles through Brimington. Figure 3.6 therefore shows the effect of reducing HGV traffic through Brimington by 10% with all other parameters remaining the same as in the original run for 2012. Here again, it is clear that such a measure would ensure that the annual objective for NO_2 will be met in 2012. Further, any combination of the two approaches, i.e reducing HGV traffic and increasing through flow along Church Street will be even more beneficial.

3.4 Conditions in Whittington Hill – the do nothing case

Results obtained for 2010 in Whittington Hill are as shown in Figure 3.7. These results show that there was a strong likelihood that the annual objective for NO_2 was exceeded in 2010 along both sides of a substantial portion of Whittington Hill. This was due to the slow speeds of vehicles (especially HGV's) as they proceeded up the hill. Turning to the current situation, Figure 3.8 shows that although there is some improvement, it is still likely that there will be some areas along Whittington Hill where the annual objective for NO_2 will be exceeded (areas outlined in blue). This includes the facades of a few houses. If no action is taken, the annually averaged NO_2 concentrations in 2012 is likely to be as shown in Figure 3.9; this indicates that the annual objective is likely to be just met. However, as explained above, the uncertainty in future emissions and in traffic growth are such that in order to ensure that the objectives for NO_2 will be met in future, action will be required.

3.5 Examination of possible measures to reduce air pollution along Whittington Hill.

As mentioned above, the reason for the relative high NO_2 concentrations along Whittington Hill appear to be due to the slowly moving traffic which results because of HGV's traversing the hill. Since there is little that can be dome to increase the speed of the HGV's, the only measure examined was that of reducing the number of HGV's by 10%. Figure 3.10 shows the impact of such a reduction in 2012, with all other conditions remaining the same. Evidently, although there is some reduction in concentrations compared with the "do-nothing" approach, the improvements are marginal as can be seen by comparing Figures 3.9 and 3.10. Additional measures will therefore be required.

3.6 Conditions in Jawbones Hill

Results for the Jawbones Hill area are as shown in Figure 3.11 for 2010. It is clear that the annual objective for NO_2 was unlikely to have been exceeded in 2010 along Jawbones Hill. For the current year, Figure 3.12 shows that the annual objective is even less likely to be exceeded. Similarly, Figure 3.13 shows that due to the reduction in vehicle emissions, the annually averaged NO_2 concentrations will decrease further in 2012 such that unless traffic or other conditions change dramatically, the annual objective for NO_2 will be met. No further action is necessary in Jawbones Hill, but diffusion tube monitoring should continue especially towards the northern section of the modelled area to check that conditions do improve over time.

3.7 Conditions in Chatsworth Road

Figure 3.14 shows the annually averaged NO_2 concentrations along Chatsworth Road in the vicinity of the AURN site that were estimated for 2010. Not surprisingly, the highest concentrations, were obtained on the road and at the roundabout with Walton road, however, it is clear that the annual objective was unlikely to have been exceeded along this stretch of the road in 2010. For the current year, Figure 3.15 shows that the NO_2 concentrations are likely to be reduced and it is therefore less likely that the annual objective for NO_2 will be exceeded. The continuing reduction in vehicle emissions over time means that even lower concentrations are predicted in 2012 and as illustrated in Figure 3.16, the annual will not be exceeded along this stretch of Chatsworth Road. No further action is necessary in this area, but monitoring should continue to confirm that conditions do not deteriorate over time.

3.8 Summary and Discussion

These results confirm that unless traffic flows or other conditions change dramatically in future, the annual objective for NO_2 will be met along Chatsworth Road (in the vicinity of the AURN station). Relatively high concentrations are likely but these tend to occur at roundabouts due to slowly moving traffic, but no receptors are present at such locations. Similarly, the annual objective for NO_2 is unlikely to be exceeded at Jawbones Hill, as the peak concentrations were on the road itself (generally at busy junctions) where no receptors are present. The improvement in air quality at these two locations is due to the expected reduction in vehicle emissions and the reduction in background concentrations, which is greater than the estimated small increase in traffic growth. Should the traffic growth be greater than expected and / or should vehicle emissions not be reduced in line with expectations, air quality could deteriorate at these locations.

At Brimington, these results indicate that for the current year, the annual objective for NO_2 will be exceeded along parts of Church Street. If no action is taken, conditions will improve and the objectives might only just be met in 2012. However, the reduction in NO_2 concentrations will only occur if traffic growth is small and if emissions from vehicles are reduced as expected. Past experience has shown that emissions from vehicles have not always been as predicted and action will therefore be required to ensure that air quality along Church Street improves.

The reasons for the poor air quality along Church Street is due to traffic congestion along a relatively narrow street resulting in queuing traffic at peak times. Any measure that increases the flow of traffic will therefore be beneficial; in fact, these modelling results show an increase in vehicle speeds of just 5 kph produces a noticeable reduction in NO_2 concentrations. Such measures could include the use of both lanes for traffic (as opposed to one lane being used for parking – see Figure 3.2). It is likely, however, that any means to increase traffic flow along Church Street will have to include consideration of traffic approaching and leaving the gyratory system. This should include an examination of the impact of bus stops, traffic lights, and feeding traffic from Devonshire Street on congestion along Church Street.

Another possible measure that can be considered, is the reduction in HGV traffic along Church Street. These results have shown that a 10% reduction in HGV traffic, even with the same degree of congestion, would also have a notable reduction in NO_2 concentrations.

It is also predicted that the annual objective for NO_2 will be exceeded in 2011 along certain sections of Whittington Hill. However, it is predicted that the objective will only just be met in 2012 if no action is taken, but only if emissions of vehicles are reduced as expected and provided that traffic growth is small. As mentioned earlier, based on past experience of vehicle emission projections, it would seem prudent to take additional steps to ensure that the annual objective for NO_2 will be met at Whittington Hill in future. However, before such steps can be devised, it is worth examining the reasons for the increased NO_2 concentrations along Whittington Hill.

Based on the observations made during the traffic monitoring programme, it appears that the prime reason for the relatively high NO_2 concentrations is HGV's and buses as they traverse the relatively steep hill. HGV's , especially if they were heavily laden, tended to travel very slowly up the hill, and it was obvious that their engines worked very hard to negotiate the hill. In addition, given that it was a single lane road, all other traffic had to follow at the same speed. The result is that along this section of the road vehicle emissions tend to be at their highest.

There is little that can be done to increase vehicle speeds up the hill, so the only feasible means of improving air quality along this stretch of the road is to reduce the amount of traffic. However, unlike Brimington, a reduction in HGV traffic by 10% was only marginally beneficial. Other measures will therefore need to be devised to reduce NO_2 concentrations along Whittington Hill.

4. CONCLUSIONS AND RECOMMENDATIONS

Chesterfield Borough Council (CBC) commissioned this study to model concentrations of nitrogen dioxide (NO_2) at selected locations within Chesterfield. The work was prompted by the fact that there are two locations within Chesterfield where, based on the 2010 Progress Report, the annual objective for NO_2 appear to have been exceeded. At both locations, the finding is based on data from a single diffusion tube and this data suggests that the annual objective was either exceeded or was only just met in previous years. Thus, despite the improvement in vehicle emissions over the years, these locations seem to be genuine pollution hot spots.

The Council is keen to confirm these findings and, if required, develop measures to improve air quality at these locations. This dispersion study was therefore commissioned to confirm the findings from the diffusion tubes, define the extent of the problem, predict current and future conditions at these hot spots, and to examine the effectiveness of possible measures. However, since there was limited traffic flow data at these hot spots, CBC undertook a brief programme of traffic counting at these hot spots and at two additional locations. The other locations were in Chatsworth Road close to an AURN affiliated continuous monitoring station, and at Jawbones Hill where the Council recently embarked on a four-month monitoring campaign to obtain data at a key roadside location for comparison with that from the Chatsworth Road site. Traffic counting was conducted at the two additional locations because it was decided to model these locations also because they provided valuable data in their own right as well as aided the model verification process.

Four separate areas were therefore modelled in detail; these included the two hot spots, namely, Church Street, Brimington and Whittington Hill, and the two locations with continuous monitoring data, namely Chatsworth Road and Jawbones Hill. All of these areas were modelled in a previous study, but the work reported herein differs from those conducted previously because it took account of the local knowledge of traffic flows and speeds obtained from the traffic monitoring program. In addition, it was conducted using a fine resolution so that local effects (hills, bus stops, traffic lights, road restrictions etc.) could be taken in to account. The main findings and recommendations from this new dispersion study were as follows.

Dispersion modelling was conducted using version 3 of ADMS Urban as held by Chesterfield Borough Council. The model was verified by comparing the modelled data for 2010 with monitoring data for the same period. Reasonably good agreement was obtained between the modelled results and those obtained from the monitoring with a root mean square error of 3.01 $\mu g/m^3$ in the modelled concentrations. In addition, time histories of NO_X and NO_2 concentrations obtained from the model were compared with data from Chesterfield's AURN site in Chatsworth Road and with data from another continuous monitor in Jawbones Hill, and reasonably good agreement was found in both cases. The model was therefore found to be performing well and no adjustments were made to the modelled results.

In spite of the confidence in the model, the uncertainty of 3ug/m^3 was taken into account when assessing the likelihood of the annual objective for NO_2 being exceeded. As a result, the annual objective for NO_2 was considered to be achieved only when NO_2 concentrations were less than 37ug/m^3. Areas where the concentrations were between 37 and 40 ug/m^3 were considered to be areas where the objective was likely to be exceeded.

Based on these criteria, it was found that the annual objective for NO_2 will be met along Chatsworth Road in 2011 and in future unless traffic flows increase significantly and / or congestion increases. No action is therefore required at present, but monitoring of NO_2 should continue to ensure that there is no significant change.

The annual objective for NO_2 is also unlikely to be exceeded at Jawbones Hill in 2011 and in future unless traffic growth is greater than expected and / or should vehicle emissions not be reduced in line with expectations. Diffusion tube monitoring of NO_2 levels should, however, continue as a means of ensuring that conditions do not deteriorate at this location.

In contrast, results indicate that for the current year, the annual objective for NO_2 will be exceeded along parts of Church Street, Brimington. The expected reduction in future vehicle emissions means that the annual objectives are likely to be just met in 2012 if traffic growth is small. It is therefore recommended that rather than rely on vehicle emission reductions and low traffic growth, additional measures be taken to ensure that air quality along Church Street improves in future.

It has been shown that an increase in vehicle speeds of just 5 kph along Church Street can produce a noticeable reduction in NO_2 concentrations. Any scheme that reduces congestions and promotes free flowing traffic along Church Street should therefore be investigated. This could include measures to encourage both lanes of the road to be used rather than just one lane being used while the other is used by parked vehicles. Another possible measure to improve air quality along Church Street could be the reduction in HGV traffic. This was also borne out by the model which showed that even with the same degree of congestion, a 10% reduction in HGV traffic could have a notable reduction in NO_2 concentrations.

The annual objective for NO_2 is also predicted to be exceeded in 2011 along some sections of Whittington Hill, but due to the expected reduction in future vehicle emissions and small traffic growth, the objective might just be met in future. Here again, rather than rely solely on possible vehicle emission reduction and small traffic growth, additional steps should be taken to ensure that the objectives will be met in future.

At Whittington Hill, relatively high NO_2 concentrations appear to be due largely to HGV's and buses as they travel up the relatively steep hill.   The only feasible means of improving air quality along this stretch of the road is therefore, to reduce the amount of traffic, however, modelling has shown that a reduction in HGV traffic by 10% will only result in a small reduction in NO_2 concentrations. A detailed investigation should therefore be undertaken to examine measures to reduce traffic, and hence pollution along Whittington Hill. The whole situation is further complicated by the location of the industrial estate on Station Lane, Old Whittington, and this being the predominantly used route to, and from, the businesses operating on the estate.

The works to mitigate the impact of existing traffic flows, and to ensure the further improvement in traffic pollution, will involve close liaison with Derbyshire County Council, as the local highways authority. In the meantime, diffusion tube monitoring is continuing, and has increased with 4 additional monitoring tubes being located along Whittington Hill, and a further 4 at Brimington (3 on Church St, and 1 on High St), in order to continue to monitor the actual exposure of the public to traffic pollution at the modelled sites.

5. REFERENCES

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FIGURES

Please note the figures are large documents, and are available on request. Please see the second page of this document, for contact details