SECOND AND THIRD STAGE REVIEW AND ASSESSMENT OF AIR QUALITY

Technical Annex 1: Air Quality Modelling in York

CITY OF YORK COUNCIL
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Summary

Under Part IV of the Environment Act 1995, all local authorities are required to review and assess air quality in their areas against health based objectives prescribed by Central Government. Where it is found that the objectives are unlikely to be met, local authorities must declare Air Quality Management Areas and draw up Action Plans for improving air quality.

In December 1998 the City of York Council published it's First Stage Review and Assessment of Air Quality in York. The report concluded that the air quality objectives for benzene, 1,3 butadiene, lead and carbon monoxide would be met in the City of York through existing national policies, and that no further action by the City of York Council was required for these pollutants. For three other pollutants, sulphur dioxide, PM_{10} and nitrogen dioxide, it was recommended that the City of York Council carried out a more detailed Review and Assessment.

The City of York Council has now completed it's Second and Third Stage Review and Assessment of Air Quality in York which has been published as a separate document. The report concludes that for sulphur dioxide and $PM_{10,}$ the current air quality objectives should be met in the City of York by the relevant compliance dates. However, for nitrogen dioxide, four 'relevant' locations have been identified on or near to the Inner Ring Road where it can not be certain that the annual average nitrogen dioxide objective will be met.

Where the City of York Council can not be certain that the annual average nitrogen dioxide objective will be met it must declare Air Quality Management Areas and draw up an Action Plan for improving air quality in these areas. In York it is considered that there are two options for the declaration of Air Quality Management Area(s).

Option 1

The declaration of four separate Air Quality Management Areas covering only those areas where potential technical breaches of the annual average nitrogen dioxide objective have currently been identified.

Option 2

The declaration of a single Air Quality Management Area with a boundary large enough to encompass the four areas of technical breach, and which would include some of the other heavily trafficked roads on, and around, the Inner Ring Road.

The City of York intends to consult on these two options before formally declaring the Air Quality Manangement Area(s).

The purpose of this document is to provide further technical information about the Air Pollution Dispersion Modelling undertaken for the purpose of the Second and Third Stage Review and Assessment of Air Quality in York. It should be read in conjunction with the Second and Third Stage Review and Assessment Report.

This document consists of three parts:

- **Section A** - The reasons for using an Air Pollution Dispersion Model
- **Section B -** A report by Cambridge Environmental Research Consultants Ltd detailing the preparation of the City of York Council's Emissions Inventory and the modelling work undertaken on behalf of the City of York Council
- **Section C -** Model Validation

In planning and carrying out it's air pollution modelling work the City of York Council has taken into consideration guidance provided in the following documents:

- LAQM(TG2)(00) Review and Assessment: Estimating Emissions.
- LAQM(TG3)(00) Review and Assessment: Selection and Use of Dispersion Models.
- National Society for Clean Air Toolkit – Air Quality Management Areas: Turning Reviews into Action (2000).

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Glossary of Terms

Air Quality Objectives

Targets set by the Government for air quality which are considered to be achievable in terms of cost, benefit and technical feasibility.

Air Quality Standards

Optimistic targets for air quality, which represent the minimum or no significant risk to health levels. They take no account of cost, benefit and technical feasibility.

Review

The consideration of current and future concentrations of air pollutants for which objectives have been set.

Assessment

The consideration of whether or not the air quality objectives will be met by the relevant compliance dates.

Relevant Location

Outdoor, non-occupational, locations where members of the public are likely to be regularly exposed to pollutants over the averaging time of the air quality objectives.

Air Quality Management Area (AQMA)

An area formally designated by a local authority where one or more of the air quality objectives are unlikely to be met.

Air Quality Action Plan

A plan of action drawn up by a local authority for improving air quality in an Air Quality Management Area.

Emissions Inventory

A database of emission sources in an area.

Point Source

A single emission point, such as an industrial stack, for which detailed emissions data can be obtained.

Line Source

A linear emission source, such as a road, for which emissions can be estimated.

Area Source

A collection of low level sources, such as domestic chimneys, for which total emissions in a 1km by 1km area can be estimated.

Air Pollution Dispersion Model

A mathematical method of predicting air pollution concentrations at a particular location.

ADMS - Urban

A complex computer based Air Pollution Dispersion Model developed by Cambridge Environmental Research Consultants Ltd (CERC). The model is capable of simultaneously modelling emissions from point, line and area sources.

SATURN - Simulation and Assignment of Traffic to Urban Road Networks

A complex computer based model for predicting and analysing traffic flows on an urban road network

Bias

A measure of the systematic error arising in a monitoring or modelling technique.

Uncertainty

A measure of the random error arising in a monitoring or modelling technique.

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List of Abbreviations

ppb - parts per billion

ppm - parts per million

µg/m^3 - microgrammes per cubic metre

mg/m^3 - milligrammes per cubic metre

Mt - mega tonnes

TEOM - Tapered Element Oscillating Microbalance

LAQM - Local Air Quality Management

AQMA - Air Quality Management Area

PM_{10} - Particulate Matter with an aerodynamic diameter of less than 10 Microns

NO_2 - Nitrogen dioxide

NO_x - Oxides of nitrogen

NO - Nitric Oxide

SO_2 – Sulphur dioxide

RMS – Root Mean Square

SECTION A

THE REASONS FOR USING AN AIR POLLUTION DISPERSION MODEL

1.0 Air Pollution Dispersion Modelling

1.1 What is an Air Pollution Dispersion Model?

An Air Pollution Dispersion Model is a method of calculating air pollution concentrations based on information about pollutant emissions and the nature of the atmosphere. There are many types of model available ranging from simple paper based systems to complex computer programmes.

1.2 Why Use an Air Pollution Dispersion Model?

The most reliable way of determining information about air quality is to carry out accurate air pollution monitoring using complex automatic monitoring equipment. Details of the air pollution monitoring carried out in York can be found in Technical Annex 2 – Air Quality Monitoring in York.

Although air pollution monitoring can provide useful and valuable information about air quality it has two main disadvantages:

1. Automatic monitoring equipment is expensive to acquire and run such that the number of locations that can be monitored is often limited by financial constraints.

2. It can only provide a “snapshot” of the situation at a particular location at a particular time. It therefore can not provide information about future pollutant concentrations or the behaviour of pollutants over a wide area.

Dispersion models can offer considerable advantages over monitoring when the following types of information are required:

- Predictions of future air pollution concentrations.

- Details of pollutant concentrations over a wide area.

- Information about the impact on air quality of different planning policies and proposals.

All these types of information are needed in the Review and Assessment process. The City of York Council has therefore used the ADMS-Urban Air Pollution Model alongside automatic monitoring data to complete the Second and Third Stage Review and Assessment of Air Quality in York.

1.3 Limitations of Dispersion Models

Although dispersion models play an important role in the Review and Assessment process they are subject to considerable uncertainties. The designers of air pollution dispersion models have to make many simplifying assumptions about extremely complex atmospheric conditions and chemical processes which can not be modelled exactly.

In addition to the assumptions made within the model, there are also assumptions made with respect to the data put into the model.

Collecting the necessary information about emission sources to input into an air pollution model is time-consuming and difficult. Often the type of data required is not available and estimates have to be made. For example, operators of some large boiler plant are under no legal obligation to monitor emissions from their plant. In these cases emissions have to be estimated using information about the types and quantity of fuels used.

When modelling traffic emissions often the only information available about traffic flows on a particular road is that which has been calculated using a transport model. If the transport model is inaccurate then these inaccuracies are transferred to the air pollution model.

It is therefore important to recognise that the output from any type of model is only as good as the design of the model and the quality of the input data.

Section B of this document provides further details about the ADMS-Urban Air Pollution Model used to predict air pollution concentrations in the City of York. In particular it outlines the main assumptions made in the model and gives details of the emissions data used in the model.

Section C of this document addresses the issue of model uncertainty. It outlines the model validation work under taken by the City of York Council and provides information about the accuracy of the model predictions when compared to air pollution monitoring data.

SECTION B

SUPPORTING MODELLING DATA

CAMBRIDGE ENVIRONMENTAL RESEARCH CONSULTANTS LTD

SECTION C

MODEL VALIDATION

1.0 Introduction

As outlined in Section B, the ADMS-Urban Air Pollution Model has been used by CERC Ltd to predict concentrations of sulphur dioxide, PM_{10} and nitrogen dioxide and in the City of York. As with any model there will always be a degree of error associated with the model predictions due to the large number of assumptions which are made in the modelling process. There are generally two main types of errors associated with models:

1. ***Systematic Errors (Bias)***

   Systematic errors (or bias) occur when the model shows the same trend error at all times. For example, the model may tend to consistently under or over predict when compared to a true measured value. Systematic errors can be quantified and corrected for by comparing model results against measurements in order to calculate a correction factor.

2. ***Random Errors (Uncertainty)***

   Random errors are those which occur even after the model results have been corrected for bias. A measurement of the uncertainty in a model can be made by measuring the '*root mean square error*' between modelled and monitored results

There are currently no clear guidelines on exactly what methods should be used to validate models for the purpose of Air Quality Reviews and Assessments. In carrying out the validation work associated with the Second and Third Stage Review and Assessment of Air Quality in York, the City of York Council has taken into consideration guidance provided in the following documents:

- LAQM.TG3(00) – Review and Assessment: Selection and Use of Dispersion Models.

- National Society for Clean Air Toolkit – Air Quality Management Areas: Turning Reviews into Action (2000).

The City of York Council has also consulted extensively with the Pollutant Specific Review and Assessment help-line before submitting this validation work. This help-line is operated by the University of West of England on behalf of the DETR. Specific advice on model validation was obtained from Dr Duncan Laxen of Air Quality Consultants Ltd, via the help-line scheme.

2.0 Model Validation – Sulphur Dioxide

CERC Ltd were commissioned by the City of York Council to carry out modelling of the 99.9^{th} percentile of 15 minute sulphur dioxide concentrations in the City of York.

The 99.9^{th} percentile is the value which is approximately equivalent to the 35^{th} highest 15 minute sulphur dioxide concentration predicted in any one year. If this value is less than the 100ppb (266ug/m^3) objective (not to be exceeded more than 35 times in any one year) then the 15 minute sulphur dioxide objective should be met.

As shown in the CERC Report (Section B), the maximum 99.9^{th} percentile of 15 minute means calculated for any point within the City of York for 1999 was 32ppb (85µg/m^3). Modelling was not undertaken for 2005 as both the monitoring and modelling results for 1999 indicated that the objective was already being met in the City of York.

To validate the model the following steps were undertaken

1. The sulphur dioxide model was run using meteorological data for the period March 1999 to February 2000.

2. The results from this model run were compared with real time monitoring data collected from the real time monitoring sites at Bootham Hospital and the City Centre during the period March 1999 to February 2000.

Comparing the modelled and monitored results directly showed that the model was under predicting the 99.9^{th} percentile of 15 minute means at both monitoring sites by approximately 54%.

This large degree of error in predicting a 15-minute mean was not unexpected. It is always very difficult to predict short-term concentrations of pollutants accurately with a dispersion model due to the large fluctuations in meteorological conditions, and emissions, which occur on an hour by hour basis. Predictions of annual average concentrations are usually much more accurate. If an annual mean concentration lies within $\pm$ 50% of the measured value a model is generally not considered to have behaved badly[1]. The large error in predicting a 15-minute average is therefore not surprising.

When modelling the 99.9^{th} percentile of 15-minute means the model predictions of greatest interest are the top 35 readings as these are the ones which determine whether of not a breach of the 15-minute objective is predicted. The ability of the model to accurately predict the highest concentrations was therefore investigated further.

The top 100 15-minute average modelled results and the top 100 15-minute average monitored results for the Bootham Hospital and City Centre sites were

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1 DETR, LAQM.TG3(00) Local Air Quality Management Guidance Notes: Selection and Use of Dispersion Models. (May 2000).

plotted on a scattergraphs – Figure 1 and Figure 2. A ***y=mx*** line of best fit was then drawn through the scatterplots and the value of **m** determined. All plots and regression lines were drawn automatically using Microsoft Excel 5 software.

Figure 1: Top 100 Modelled v Top 100 Monitored 15- Minute Sulphur Dioxide Concentrations – Bootham Hospital (1/03/99 to 29/02/00)

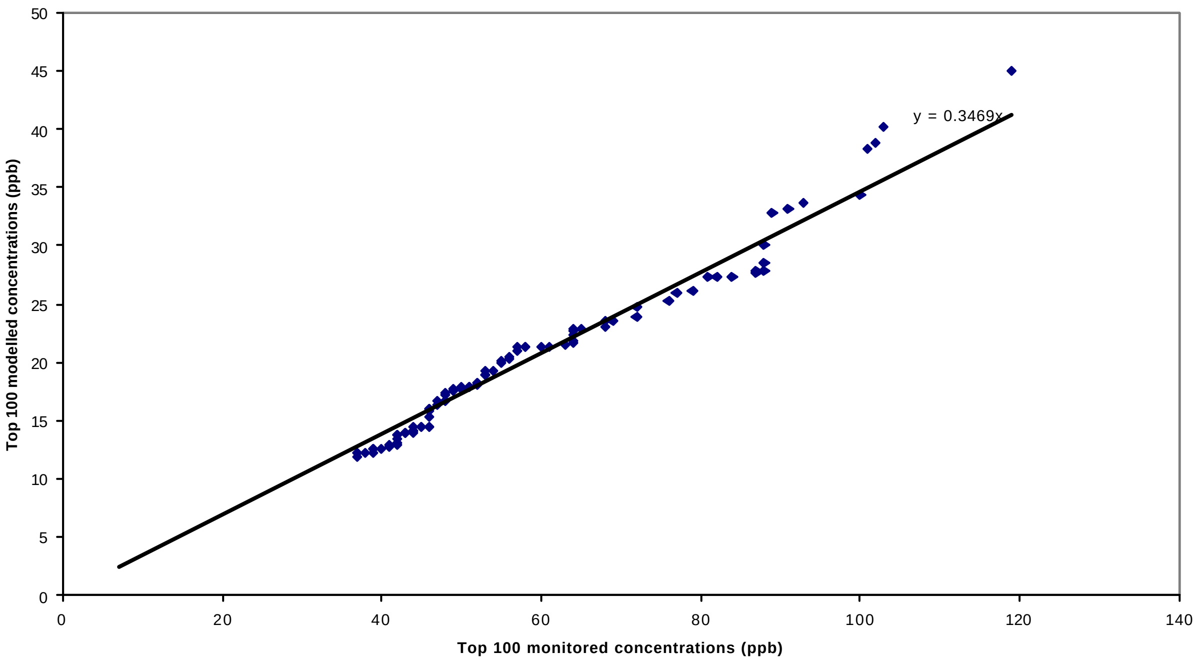
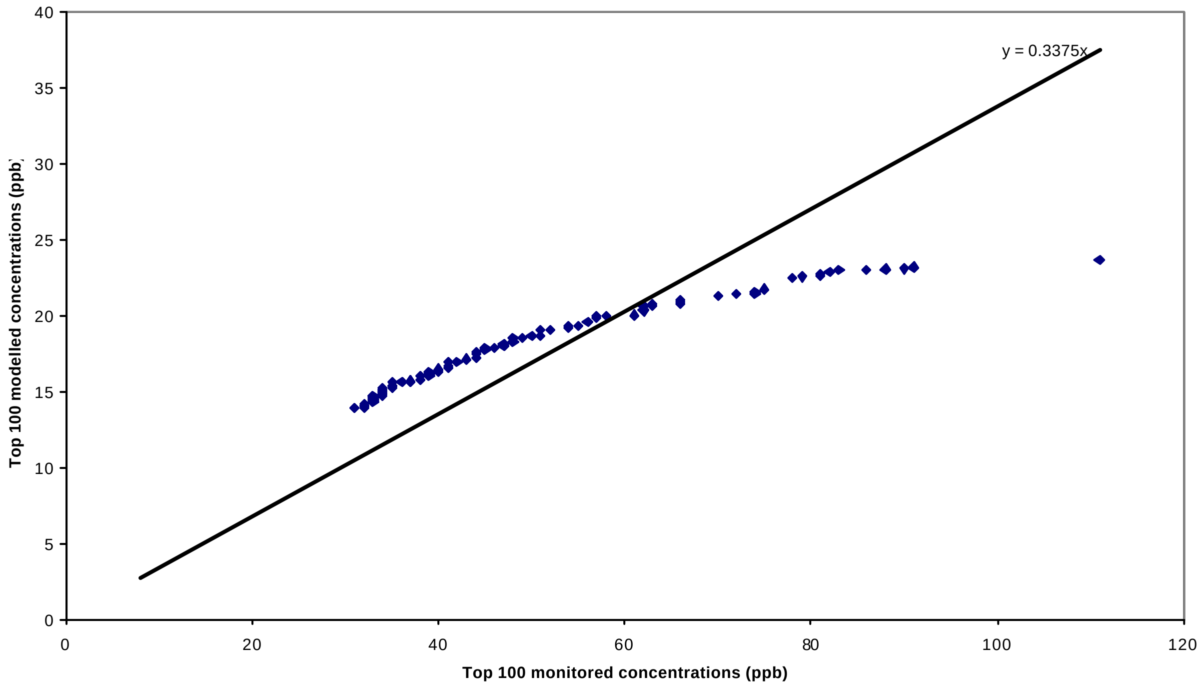


Figure 2: Top 100 Modelled v Top 100 Monitored 15- Minute Sulphur Dioxide Concentrations – City Centre (1/03/99 to 29/02/00)



It can be seen from Figures 1 and 2 that generally the model under predicted the highest sulphur dioxide concentrations by a factor of about 3. To try and correct for this bias, a factor of 3 was applied to all the modelling results for the Bootham Hospital and City Centre sites and the modelled 99.9th percentiles recalculated. After correcting for bias, the model was found to over estimate the 99.9th percentiles of 15 minute at the City Centre and Bootham sites by approximately 60%. Table 1 summarises the differences between the monitored and modelled 99.9th percentiles of 15 minute means for the City Centre and Bootham Hospital monitoring sites.

Table 1: Comparison of the Difference Between Measured and Modelled 99.9th Percentiles of 15 Minute Sulphur Dioxide Concentrations

Monitoring Site	Measured 99.9th Percentile of 15 Minute Means	Modelled 99.9th Percentile of 15 Minute Means	Bias Corrected Modelled 99.9th Percentile of 15 Minute Means
Bootham Hospital	57 ppb	31 ppb	90 ppb
City Centre	55 ppb	30 ppb	89 ppb

The maximum 99.9th percentile of 15 minute means predicted by the uncorrected model for any point in York was 32ppb (85µg/m^3). If it is assumed that as a worse case the model under predicted this value by a factor of 3 then the maximum bias corrected value would be 96ppb. This is below the objective value and it is therefore reasonable to assume that no exceedances of the 100ppb 15 minute mean objective are likely to occur at any point in the City.

As the 15-minute mean is the most stringent of the current sulphur dioxide objectives, it is reasonable to assume that if this objective is being met the hourly and 24 hourly objectives will also be met. It was therefore not necessary to undertake modelling of hourly and 24 hourly sulphur dioxide concentrations.

3.0 Model Validation – PM_{10}

CERC Ltd were commissioned by the City of York Council to carry out modelling of the 90th percentile of fixed 24 hour average PM_{10} concentrations in the City of York.

The 90th percentile is the value which is approximately equivalent to the 35th highest fixed 24 hour average PM_{10} concentration predicted in any one year. If this is less than the 50ug/m^3 objective (not to be exceeded more than 35 times in any one year) then the fixed 24 hour average PM_{10} objective should be met.

The model predicted that in 1999 the maximum 90th percentile of fixed 24 hour average PM_{10} concentrations at any point in the City of York would be 37.8µg/m^3 (GRAV), falling to 35µg/m^3 (GRAV) by the 2004 compliance date.

To validate the model the following steps were undertaken

1. The PM_{10} model was run using meteorological data for the period March 1999 to February 2000.

2. The results from this model run were compared with real time monitoring data collected from the real time monitoring sites at Bootham Hospital, Clifton Moor and Fishergate during the period March 1999 to February 2000.

Comparing the results directly showed that the model under predicted the 90th percentile of fixed 24 hour average PM_{10} concentrations by an average of 11% at the Clifton Moor and Fishergate roadside monitoring sites. At the Bootham Hospital urban background site, the model over predicted the 90th percentile of fixed 24 hour average PM_{10} concentrations by 13%.

To estimate the bias in the model for the roadside sites, all the measured daily average PM_{10} concentrations for the Clifton Moor and Fishergate sites were plotted against the predicted daily average concentrations for the same sites – Figure 3. A ***y=mx*** line of best fit was then drawn through the scatterplot and the value of **m** determined. This process was repeated on a separate plot for the Bootham Hospital Urban Background site – Figure 4. All plots and regression lines were drawn automatically using Microsoft Excel 5 software.

Figure 3: Measured V Modelled Daily Average PM_{10} Concentrations – Roadside Sites

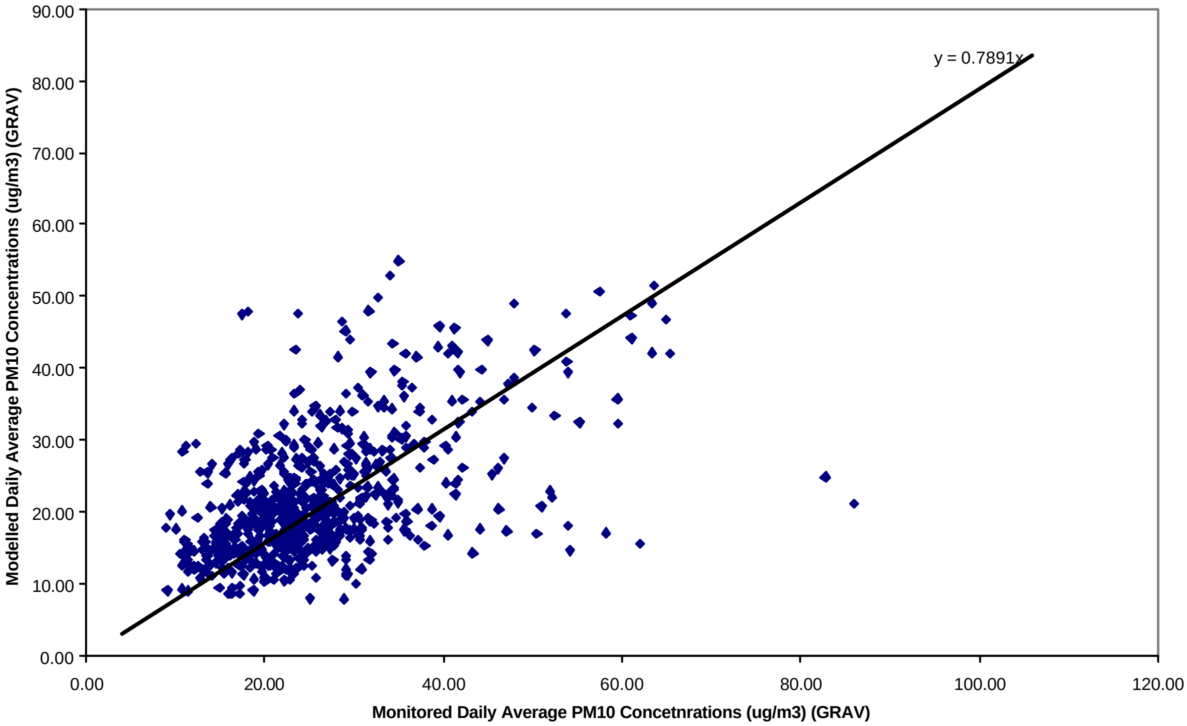
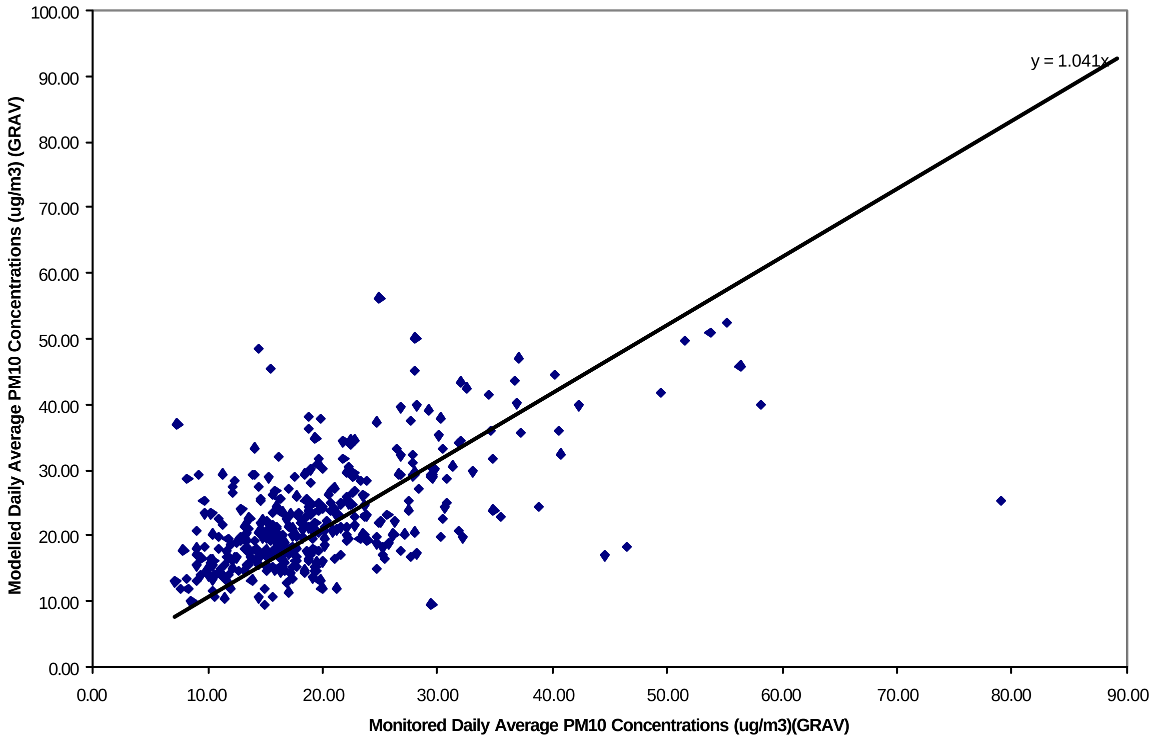


Figure 4: Measured V Modelled Daily Average PM_{10} Concentrations – Urban Background Site



As can be seen from Figure 3, the model generally under predicted the fixed 24 hour average PM_{10} concentrations at the roadside sites by a factor of 0.79 (21%). At the Bootham Hospital urban background site the model generally over predicted the fixed 24 hour averages by a factor of 1.04 (4%).

To correct the roadside predictions for bias, all the daily average model outputs for the Clifton Moor and Fishergate sites were increased by 21% and the 90th percentiles of the daily averages for each site recalculated. After correcting for bias the model was found to over predict the 90th percentile of fixed 24 hour average PM_{10} concentrations at the roadside sites by an average of 13%.

To correct the background predictions for bias, all the daily average model outputs for the Bootham site were reduced by 4% and the 90th percentile of the daily averages recalculated. After correcting for bias the model was found to over predict the 90th percentile of fixed 24 hour average PM_{10} concentrations at the Bootham Hospital background site by an average of 9%.

A summary of the monitored and modelled 90th percentiles of daily average PM_{10} concentrations is given in Table 2.

Table 2: Comparison of Difference Between Measured and Modelled 90th Percentiles of Daily Average PM_{10} Concentrations.

Monitoring Site	Measured 90th Percentile of Daily Averages	Modelled 90th Percentile of Daily Averages	Bias Corrected Modelled 90.4th Percentile of Daily Averages
Bootham Hospital	30.4 μg/m^3 (GRAV)	34.5 μg/m^3 (GRAV)	33.1μg/m^3 (GRAV)
Fishergate	37.6 μg/m^3 (GRAV)	33.9 μg/m^3 (GRAV)	42.9 μg/m^3 (GRAV)
Clifton Moor	37.3 μg/m^3 (GRAV)	32.8 μg/m^3 (GRAV)	41.6 μg/m^3 (GRAV)

The maximum 90th percentile predicted by the model for 2004 was 35.0μg/m^3 (GRAV). For this prediction to represent a breach of the 50.0μg/m^3 (GRAV) objective the model would have to be under estimating by at least 42%. The validation work has shown that the model does under predict at roadside sites, but not to this extent. It is therefore considered that no breaches of the current fixed 24 hour average PM_{10} objective are likely based on the findings of this modelling study.

No modelling of the annual average PM_{10} objective has been undertaken. However, as this objective is less stringent than the current 24 hour objective it is considered unlikely that any breaches of the annual average objective will occur.

4.0 Model Validation – Nitrogen Dioxide

Modelling of nitrogen dioxide in York was undertaken by CERC Ltd to allow comparison with both the hourly and annual mean nitrogen dioxide air quality objectives. Different approaches to model validation have been taken for each of the objectives.

4.1 Validation of Hourly Objective Modelling Results

To assess air quality against the hourly nitrogen dioxide objective, CERC Ltd were commissioned by the City of York Council to carry out modelling of the 99.8th percentile of hourly nitrogen dioxide concentrations in York.

The 99.8th percentile is the value which is equivalent to the 18th highest hourly nitrogen dioxide concentration predicted in any one year. If this is less than the 105ppb (200µg/m^3) objective (not to be exceeded more than 18 times in any one year) then the hourly nitrogen dioxide objective should be met.

The model predicted that in 1999 the highest 99.8th percentile of hourly nitrogen dioxide concentrations in the City of York would be 71.4ppb (134µg/m^3), falling to 61.5ppb (117µg/m^3) by the 2005 compliance date.

To validate the model the following steps were undertaken

1. The nitrogen dioxide model was run using meteorological data for the period March 1999 to February 2000.

2. The results from this model run were compared with real time monitoring data collected from the real time monitoring sites at Bootham Hospital, Clifton Moor and Fishergate during the period March 1999 to February 2000.

Comparing the modelled and monitored results directly showed that at the Bootham Hospital urban background site the model over predicted the 99.8th percentile by 42%. At the Fishergate and Clifton Moor roadside monitoring sites the model behaved better, over predicting the 99.8th percentiles by an average of 26%.

When modelling the 99.8th percentile of hourly nitrogen dioxide concentrations the model predictions of greatest interest are the top 18 readings as these are the ones which determine whether of not a breach of the hourly nitrogen dioxide objective is predicted. The ability of the model to accurately predict the highest concentrations was therefore investigated further.

The top 100 modelled hourly averages and the top 100 monitored hourly averages for the Fishergate and Clifton Moor sites were plotted on a scattergraph – Figure 5. A ***y=mx*** line of best fit was then drawn through the scatter and the value of **m** determined. The process was then repeated for the Bootham Hospital urban background site – Figure 6. All plots and regression lines were drawn automatically using Microsoft Excel 5 software.

Figure 5: Top 100 Modelled v Top 100 Monitored Hourly Nitrogen Dioxide Concentrations – Fishergate and Clifton Moor Roadside Sites (1/03/99 to 29/02/00)

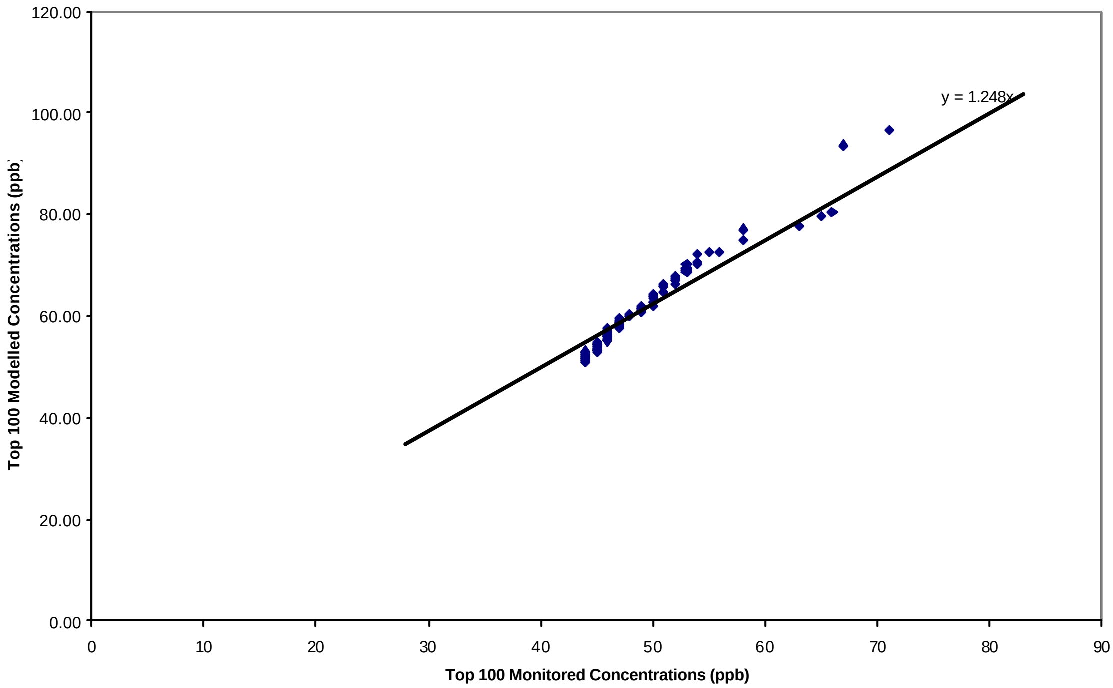
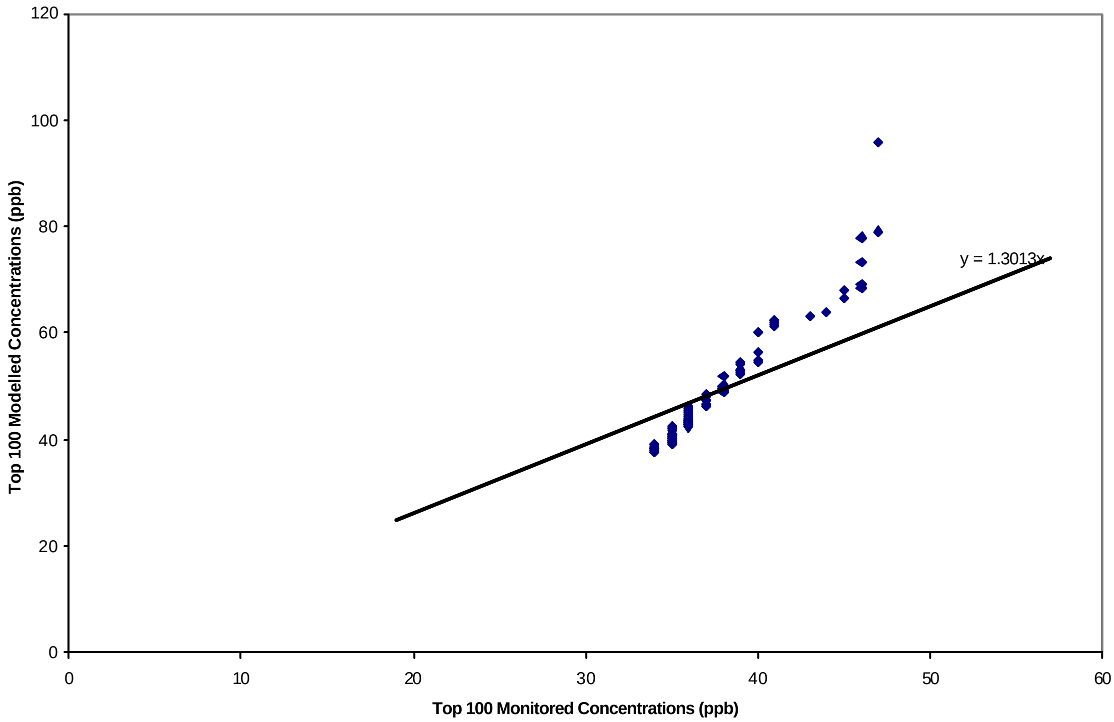


Figure 6: Top 100 Modelled v Top 100 Monitored Hourly Nitrogen Dioxide Concentrations - Bootham Hospital Urban Background Site (1/03/99 to 29/02/00)



It can be seen from Figure 5 that generally the model over predicted the highest hourly nitrogen dioxide concentrations at the roadside sites. The slope of the line, ***m***, was found to be 1.25 indicating that the model generally over predicts the highest hourly nitrogen dioxide concentrations by around 25%. To try and correct for this bias, all the model outputs for the roadside sites were reduced by 25% and the modelled 99.8th percentiles recalculated. Having done this the model was found to overestimate the 99.8th percentiles of hourly means at the roadside sites by an average of 6%.

It can be seen from Figure 6 that generally the model also over predicted the highest hourly nitrogen dioxide concentrations at the Bootham Hospital urban background site. The slope of the line, m, was found to be 1.30 indicating that the model generally over predicts the highest nitrogen dioxide concentrations at background sites by around 30%. To try and correct for this bias, all the model outputs for the Bootham Hospital were reduced by 30% and the modelled 99.8th percentiles recalculated. Having done this the model was found to over estimate the 99.8th percentile of hourly means at the urban background site by 9%. A summary of the predicted and measured 99.8th percentiles of hourly nitrogen dioxide concentrations is given in Table 3.

Table 3: Comparison of the Difference Between Measured and Modelled 99.8th Percentiles of Hourly Nitrogen Dioxide Concentrations

Monitoring Site	Measured 99.8th Percentile of Hourly Averages	Modelled 99.8th Percentile of Hourly Averages	Bias Corrected Modelled 99.8th Percentile of Hourly Averages
Bootham Hospital (Urban Background)	40.0 ppb	56.9 ppb	43.7 ppb
Clifton Moor (Roadside)	48.0 ppb	59.2 ppb	51.1 ppb
Fishergate (Roadside)	50.0 ppb	64.2 ppb	52.7 ppb

4.2 Validation of Annual Average Objective Modelling Results

The ideal method of validating the annual average nitrogen dioxide predictions would have been to compare the model outputs for numerous locations against real time monitoring data.

In the City of York, annual average nitrogen dioxide concentrations were only available from five automatic monitoring sites for a one year period. Two of these sites are roadside locations and three background locations. As roadside sites and background sites must be treated separately, the maximum number of points available to put on a scattergraph would therefore have been three – insufficient to provide a realistic bias factor. An alternative approach using diffusion tube data has therefore been used to validate the model.

The ADMS-Urban Model was run using meteorological data for the period 29th June 1999 to 4th August 2000. This period covered the exposure times for the diffusion tubes in the following surveys:

- City Wide Survey 2 - (29/06/99 – 04/07/00)
- Survey A - (30/06/99 – (05/07/99)
- Survey B - (01/07/99 – 06/07/00)
- Survey C - (02/07/99 – 07/07/00)

Full details of these surveys can be found in Technical Annex 2 – Air Quality Monitoring in York.

For each hour during the period 29th June 1999 to 4th August 2000 an hourly concentration of nitrogen dioxide was predicted for 50 of the kerbside and roadside diffusion tube monitoring sites.

For each of the 50 diffusion tube monitoring sites an annual average nitrogen dioxide concentration was then calculated. This was done by taking the average of the hourly nitrogen dioxide concentrations over the periods which coincided with the exposure of the diffusion tubes at each particular site.

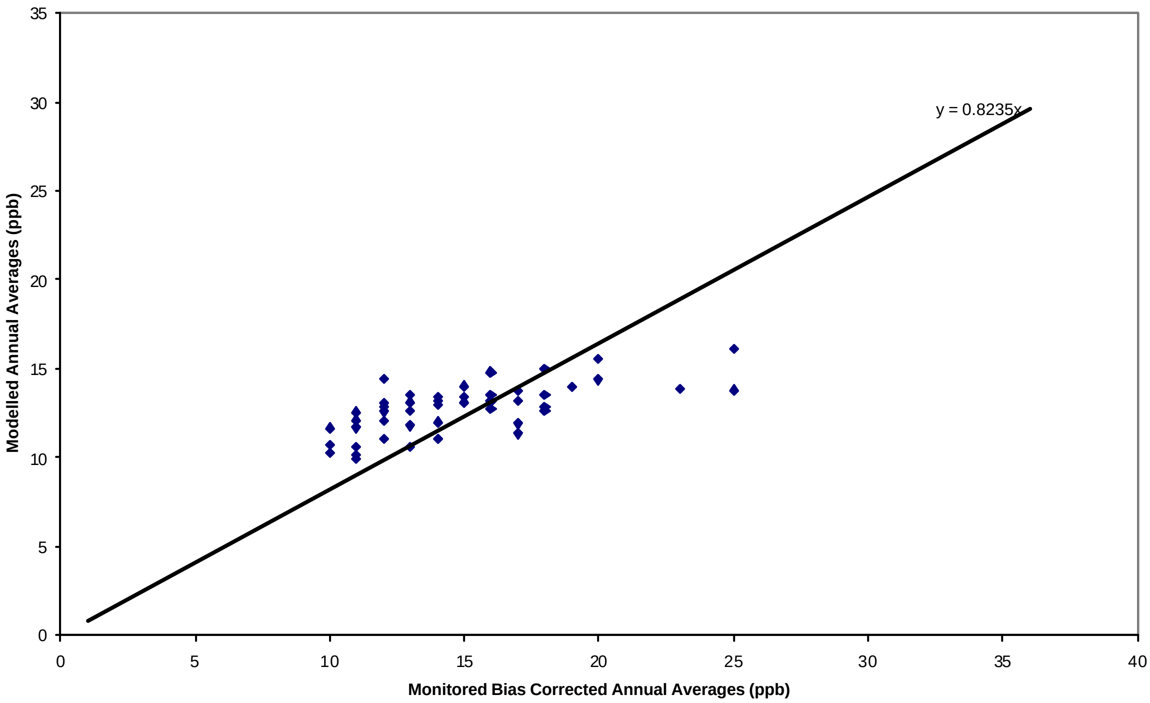
Table 4 shows the predicted and measured annual average nitrogen dioxide concentrations at each of the diffusion tube sites. The nitrogen dioxide diffusion tube measurements shown have been corrected for bias when compared to a real time chemiluminescence analyser. Details of the diffusion tube monitoring sites and the calculation of the bias factors can be found in Technical Annex 2: Air Quality Monitoring in York.

Table 4: Measured and Predicted Nitrogen Dioxide Concentrations at Kerbside and Roadside Sites in York

Site	Bias Corrected Measured Annual Average Nitrogen Dioxide Concentration (ppb)	Predicted Annual Average Nitrogen Dioxide Concentration (ppb)	Site	Bias Corrected Measured Annual Average Nitrogen Dioxide Concentration (ppb)	Predicted Annual Average Nitrogen Dioxide Concentration (ppb)
1	17	11	A50	18	13
2	17	14	A53	15	14
7	25	16	A54	16	15
15	20	15	A61	10	12
16	20	14	A63	14	12
25	16	14	A72	11	11
29	11	10	A78	10	10
30	18	13	A82	11	12
35	13	11	A83	12	11
36	25	14	B2	15	13
37	19	14	B17	11	10
40	17	12	B19	10	11
41	18	15	B27	12	14
43	14	13	B49	15	13
45	12	12	B56	13	13
49	18	14	B63	11	12
A1	23	14	C11	14	11
A5	16	13	C18	14	11
A7	17	13	C23	19	14
A18	14	13	C29	13	12
A19	16	13	C35	13	13
A20	14	13	C38	15	13
A25	12	13	C41	12	13
A27	11	13	C48	12	13
A43	11	12	C53	13	14

To calculate the bias in the model, the measured annual average nitrogen dioxide concentrations were plotted against the modelled concentrations and a ***y=mx*** line of best fit applied, as shown in Figure 7.

Figure 7: Measured v Modelled Annual Average Nitrogen Dioxide Concentrations



As can be seen from Figure 7, the model generally under predicted the annual average nitrogen dioxide concentrations at the kerbside and roadside sites giving a bias factor, ***m***, of 0.82. This is equivalent to an under prediction of 22%.

To correct for the bias in the model, the annual average concentrations predicted by the model were increased by 22% and the contour plots for the whole of the city re-plotted. The bias corrected annual average nitrogen dioxide contour plots for 1999 and 2005 can be found in the Second and Third Stage Review and Assessment of Air Quality in York (section 10.6.4).

Having corrected for model for bias, the degree of uncertainty in the model was then assessed using the method outlines in the guidance note LAQM.TG3(00) – Selection and Use of Dispersion Models.

Using this method, the uncertainty in the model is measured by calculating the '*root mean square difference in concentrations (RMS)'* between the bias corrected modelled data and the bias corrected measured data, in accordance with Equation 1.

Equation 1 -

$$RMS = \sqrt{\frac{SUM\,(Measured_i - Predicted_i)^2}{(n-1)}}$$

where n= number of sites for which modelled and monitored data have been compared.

Using this method the RMS was found to be 2.9 ppb. The uncertainty in the bias corrected model was therefore found to be +/- 2.9ppb.

To determine if an Air Quality Management Area should be declared in the City of York based on the annual average nitrogen dioxide modelling results, the approach outlined in the NSCA document 'Turning Reviews into Action'[2] was followed.

A "U" value was first calculated by dividing the RMS value by the mean of the observed data. This gave a "U" value of 0.19. The model standard deviation (SDM) was then calculated by multiplying the 21ppb annual average objective by the "U" value as follows:

$$\begin{aligned} SDM &= 0.19 * 21 \\ &= 4.0 \end{aligned}$$

Contours were then drawn where the model predicted the following values:

- 21ppb+ 2*SDM = 29.0ppb
- 21ppb+ SDM = 25ppb
- 21ppb = 21ppb
- 21ppb – SDM = 17ppb
- 21ppb – 2*SDM = 13.0ppb

The resultant contour plots can be found in the Second and Third Stage Review and Assessment of Air Quality (Figures 107 and 108).

Using this method means that:

- Areas with a predicted concentration greater than 29ppb in 2005 are almost certain to breach the annual average objective.

- Areas with a predicted concentration less than 13ppb in 2005 are almost certain to meet the objective.

- Areas between 17.0ppb and 25ppb are the areas of greatest uncertainty with respect to meeting the annual average objective.

To take account of the uncertainty in the model it is suggested in the NSCA Toolkit 'Turning Reviews into Action' that an Air Quality Management Area should be declared wherever the predicted annual average nitrogen dioxide concentration in 2005 is greater than 21ppb-SDM. In the case of the City of York this means that any areas with a predicted annual average nitrogen dioxide concentration of greater than 17.0ppb in 2005 should be declared as Air Quality Management Areas. On examination of the contour plots it is found that no areas in the City of York meet this criteria. However, if a contour is drawn at

[2] NATIONAL SOCIETY FOR CLEAN AIR, Local Authority Toolkit – Turning Reviews into Action, 2000.

only 1ppb lower i.e 16ppb, then a greater proportion of the Inner Ring road is highlighted.

It is shown in the Second and Third Stage Review and Assessment of Air Quality in York that the areas highlighted by the 16ppb contour, on the bias corrected model, match well with those areas where nitrogen dioxide diffusion tube monitoring has also indicated potential for breaches of the annual average objective. The majority of these areas are congested street canyons. In these types of location the model appears to be underestimating the actual concentrations by a factor greater than the average bias factor of 22% calculated from the consideration of 50 kerbside and roadside diffusion tube sites.

5.0 Conclusions

The model validation work has shown as expected that the greatest errors are associated with the predictions for the short-term objectives. In these situations rapid variations in meteorological conditions and emissions make accurate predictions difficult.

The model predictions for the 99.9th percentile of 15 minute sulphur dioxide concentrations show the greatest deviation from monitored data. Without correcting for bias, the model was found to under predict the measured 99.9th percentile at the Bootham Hospital and City Centre sites by 54%. Correcting for bias did not improve the accuracy demonstrating that as expected, there is a high level of random error associated with predicting the 99.9th percentile. The highest 99.9th percentile of 15 minute sulphur dioxide concentrations predicted by the model for 1999 was 32ppb (50$\mu g/m^3$). Assuming that as a worst case the model has underestimated this figure by a factor of 3, the highest expected value would be 96ppb which is still below the air quality objective of 100ppb. Although modelling has not been undertaken for the hourly and 24 hourly sulphur dioxide objectives, it can be assumed that if the more stringent 15-minute objective is being met, then these other less stringent objectives will also be met.

For PM_{10}, the uncorrected model was found to over estimate the 90th percentile of fixed 24 hour averages by 13% at the Bootham Hospital urban background site. At the two roadside monitoring sites the model was found to under predict by an average of 11%. Correcting for bias improved the behaviour of the model at the background site such that it only over predicted by 9%, but it did not improve the predictions for the roadside sites.

The maximum 90th percentile predicted by the model for 2004 was 35.0$\mu g/m^3$ (GRAV). For this prediction to represent a breach of the 50.0$\mu g/m^3$ (GRAV) objective the model would have to be under estimating by at least 42%. The validation work has shown that the model does under predict at roadside sites, but not to this extent. It is therefore considered that no breaches of the current fixed 24 hour average PM_{10} objective are likely based on the findings of this modelling study. Although no modelling of annual average PM_{10} concentrations has been undertaken, it can be assumed that if the more stringent fixed 24 hour objective is being met then the less stringent annual average objective will also be met.

For nitrogen dioxide the greatest errors were again associated with the predictions for the short term hourly objective. Without correcting for bias the model was found to over predict the 99.8th percentile of hourly averages by 42% at the Bootham Hospital urban background site and an average of 26% at the roadside sites. After correcting for bias the model behaved better, over predicting at the background site by 9% and at the roadside sites by an average of only 6%. The highest 99.8th percentile of hourly averages predicted by the model for 1999 was 71.4ppb. Assuming that the uncorrected model over predicts by 26% at roadside sites then the highest expected 99.8th percentile of hourly averages is more likely to be around 53ppb, well below the 105ppb hourly average objective.

For the annual average nitrogen dioxide objective the model was found to generally under predict roadside concentrations by 22% and have a random error of ± 3 ppb.

In general the model has been found to behave well. With the exception of the short term 15-minute sulphur dioxide objective it has consistently given predictions within the ± 50% tolerance limits suggested in LAQM.TG3(00).