Durham County Council Local Air Quality Management: Detailed Assessment of the West End of Durham City

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Executive Summary

Durham County Council has declared an AQMA for NO_2 in parts of the City of Durham on the basis on the outcome from ongoing Local Air Quality Management Review and Assessment. However, recent monitoring data has identified potential breaches of the annual mean NO_2 objective at locations to the west of the AQMA.

Therefore, this Detailed Assessment has been undertake to determine whether it is appropriate to declare an AQMA in this area, and to identify any other nearby locations of concern that should also be included in the AQMA, or where further monitoring or modelling assessment work may be required. This assessment was undertaken to assess the following roads and locations outside the AQMA to the west of the City Centre:

- Alexandria Crescent / Sutton Street;
- Crossgate Lights junction;
- Crossgate Peth;
- Nevilles Cross junction.

The concentration of NO_2 predicted using a detailed dispersion model, which was verified using the monitoring data recorded in the City of Durham in 2011, and also discussed subjectively by comparison with the new continuous monitoring equipment installed in Crossgate Lights in 2012.

The assessment identified breaches of the annual mean air quality objective at locations outside the AQMA and recommended that the AMQA is extended to include the following roads:

- Nevilles Cross Bank as far as Broom Lane, which is at the bottom of the steep hill and marks the edge of this residential area.
- Nevilles Cross junction;
- Crossgate Peth;
- Crossgate junction;
- Alexandria Crescent;
- Sutton Street; and
- Castle Chare, where it should connect with the existing AQMA.

1 Introduction

AECOM was commissioned by Durham County Council unitary authority to undertake an assessment of air quality in the City of Durham. Recent monitoring data has identified potential breaches of the annual mean NO_2 objective at locations to the west of the AQMA, which are the subject of this Detailed Assessment.

The Council has declared an AQMA for NO_2 in parts of the City of Durham on the basis of previous detailed dispersion modelling and extensive air quality monitoring.

1.1 Detailed Assessment

With regard to a Detailed Assessment, LAQM.TG(09) (Defra, 2009) states that the objectives are:

> '*to determine, with reasonable certainty, whether or not there is a likelihood of the objectives not being achieved...to allow the authority to have confidence in the decision that it reaches to declare, not declare, or revoke/amend an AQMA. Where a likely exceedence of the objectives is identified, then the authority will also need to determine the magnitude and geographical extent of the exceedence.'*

1.2 Scope of this Report

This report considers areas to the west of the City Centre; Crossgate lights junction, Nevilles Cross junction, The Peth and Colpitts Terrace, where monitoring has recorded NO_2 concentrations in excess of 40 $\mu g/m^3$ indicating a risk of exceedences of the annual mean objective at residential properties outside the AQMA.

1.3 Report Structure

- Section 2 provides an overview of air quality guidance and legislation;
- Section 3 explains the methodology which was followed in this assessment;
- Section 4 presents the current air quality in the City of Durham based on recent monitoring data and previous LAQM reports;
- Section 5 presents the results of the Detailed Assessment;
- Section 6 concludes the assessment.

1.4 Further Assessment

This report has been completed in coordination with the Durham City Further Assessment 2012 (DC, 2012), which considers the area within the AQMA. Whilst the reports are effectively independent, they are mutually supporting and may be read in conjunction. To this end, the modelling methodologies, presentation structure and sensitive receptor numbering may be compared directly.

The Further Assessment determined that although the National Air Quality Objective was not likely to be exceeded at the section to the east of the junction of Sherburn Road the objective was shown to be exceeded at the location of sensitive receptors at the junction of Dragon Lane and therefore it is likely that this section of the AQMA will be retained. However a final decision in this regard will be made during 2013. The assessment is summarised further in Section 4.1.4.

2 Legislation and Policy

2.1 Overview of Relevant Air Quality Legislation and Policy

The provisions of Part IV of the Environment Act 1995 establish a national framework for air quality management, which requires all Local Authorities in England, Northern Ireland, Scotland and Wales to conduct local air quality reviews. Section 82(1) of the Act requires these reviews to include an assessment of the current air quality in the area and the predicted air quality in future years. Should the reviews indicate that the objectives prescribed in the UK Air Quality Strategy (Defra, 2007) and the Air Quality (England) Regulations (Defra, 2010) will not be achieved; the Local Authority is required to designate an Air Quality Management Area (AQMA). Action must then be taken at a local level to ensure that air quality in the AQMA improves.

2.1.1 UK Air Quality Strategy

The UK Air Quality Strategy (AQS) identifies nine ambient air pollutants that have the potential to cause harm to human health. These pollutants are associated with local air quality problems, with the exception of ozone, which is instead considered to be a regional problem. The Air Quality Regulations set objectives for the seven pollutants that are associated with local air quality. These objectives aim to reduce the health impacts of the pollutants to negligible levels.

2.1.2 Local Air Quality Management Review and Assessment

It is the responsibility of the Local Authority to undertake Review and Assessment work in accordance with the regime defined in the Defra technical Guidance LAQM.TG(09). The purpose of the regime is to update and publish information regarding local air quality monitoring and to identify possible areas of exceedence through screening and modelling.

Part of the regime is to undertake Detailed Assessments of possible areas of exceedence, which may be subsequently declared as an AQMA. The purpose of the Detailed Assessment is to identify with reasonable certainty whether or not a likely exceedence of the EU limit value and national objective (an annual mean concentration of 40 $\mu g/m^3$ for nitrogen dioxide) will occur at locations of potential exposure. To fulfil this requirement the Detailed Assessment is required to determine the magnitude and geographical extent of the exceedence.

2.1.3 European Air Quality Directives

The European Air Quality Framework Directive (96/62/EC) on ambient air quality assessment and management defines the policy framework for 12 air pollutants known to have a harmful effect on human health and the environment. The limit values for the specific pollutants are set through a series of Daughter Directives.

- Directive 1999/30/EC (the 1st Daughter Directive) sets limit values (values not to be exceeded) for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and oxides of nitrogen (NO_x), particulate matter and lead in ambient air.
- Directive 2000/69/EC (the 2nd Daughter Directive) establishes limit values for concentrations of benzene and carbon monoxide in ambient air.
- Directive 2002/3/EC (the 3rd Daughter Directive) establishes long-term objectives, target values, an alert threshold and an information threshold for concentrations of ozone in ambient air.
- Directive 2004/107/EC (the 4th Daughter Directive) establishes a target value for the concentration of arsenic, cadmium, nickel and benzo(a)pyrene in ambient air so as to avoid, prevent or reduce harmful effects of arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons on human health and the environment as a whole.

The Air Quality Standards Regulations 2010 replaced the previous Regulations that gave effect to the provisions of Air Quality Framework; First; Second; and Third Air Quality Directives; and give effect to the latest Fourth Air Quality Daughter Directive too. The new Regulations apply to England with the exception of Regulation 29 (relating to reporting requirements) which applies to the entire UK.

Council Directive 2008/50/EC came into force in 2008, and was transposed into national legislation in 2010.

Key points to note are that it:

- consolidates existing air quality legislation apart from the 4th Daughter Directive, which will be brought within the new Directive at a later date;
- provides a new regulatory framework for $PM_{2.5}$; and

- makes provision under Article 22 for Member States to postpone attainment deadlines and allow an exemption from the obligation to limit values for certain pollutants, subject to strict conditions and assessment by the European Commission (EC).

2.1.4 Air Quality Objectives and Limit Values

The air quality objectives and limit values currently applicable to the UK can therefore be split into two groups. Each has a different legal status and is therefore handled differently within the framework of UK air quality policy. These are:

- UK air quality objectives set down in regulations for the purposes of local air quality management; and
- European Union (EU) limit values transcribed into UK legislation for which compliance is mandatory.

2.2 Nitrogen Dioxide

The Government and the Devolved Administrations adopted two Air Quality Objectives for NO_2 to be achieved by the end of 2005. From 2010, mandatory EU air quality limit values for NO_2 were to apply in the UK until 2015, although breaches of the limit have continued to occur in several regions. The EU limit values for NO_2 are the same as the national objectives for 2005 but the limit values are mandatory (Defra, 2007):

- An annual mean concentration of 40 micrograms per cubic metre ($\mu g/m^3$); and
- An hourly mean concentration of 200 $\mu g/m^3$, to be exceeded no more than 18 times per year.

The number of exceedences of the hourly objective show considerable year-to-year variation, and is driven by meteorological conditions, which give rise to winter episodes of poor dispersion and summer oxidant episodes.

NO_2 and nitric oxide (NO) are both oxides of nitrogen, and are collectively referred to as NO_X. All combustion processes produce NO_X emissions, largely in the form of NO, which is then converted to NO_2, mainly as a result of its reaction with ozone in the atmosphere. Therefore the ratio of NO_2 to NO is primarily dependent on the concentration of ozone and the distance from the emission source.

In recent years a trend has been recognised whereby roadside NO_2 concentrations have not been falling, or have been increasing, at certain monitoring sites, despite emissions of NO_X falling. The 'direct NO_2' phenomenon is having an increasingly marked effect at many urban locations around the country and must be considered when undertaking modelling studies and in the context of future local air quality strategy. At the end of September 2010 Defra released a brief FAQ (Frequently Asked Question) note on the issue (Defra, 2010), acknowledging that NO_2 concentrations have not fallen as projected over the past 6-8 years, and also published a draft report in March 2011 entitled "Trends in NO_X and NO_2 emissions and ambient measurements in the UK" (Defra, 2011), which discusses the disparity between modelling and monitoring in detail. In September 2012, Defra published the Emission Factors Toolkit (EFT) (v5.1.3) to incorporate the updated NO_X emissions factors and vehicle fleet information based on current measurements and projections. Further details are provided in Section 3.3.

3 Assessment Methodology

3.1 Assessment Procedure

The Detailed Assessment was undertaken to assess the following roads outside the AQMA:

- Alexandria Crescent / Sutton Street;
- Crossgate Lights junction;
- Crossgate Peth;
- Nevilles Cross junction.

The modelling assessment was undertaken in accordance with the methodology defined in technical guidance LAQM.TG(09) (Defra, 2009b). The detailed modelling assessment considered all roads in the study area where monitoring data have recorded concentrations exceeding, or potentially exceeding (i.e. within ~10% of the objective), the annual mean NO_2 objective.

The model assessment year was 2011, as this was the most recent year for which high quality and verified monitoring data is available (see Section 4.2) for model verification purposes (see Section 3.8). Correlating meteorological data from 2011 was used in the model (see Section 3.5).

3.2 AAQuIRE

The AAQuIRE dispersion modelling software, developed by AECOM, was used to predict the local air quality for areas in the City outside AQMA. AAQuIRE uses the CALINE4 model for the dispersion of road-traffic emissions. The model is fully validated and has been extensively used worldwide. Further details are provided in Appendix A.

3.3 Emissions Factors

As discussed in Section 2.2, in recent years it has been recognised that NO_2 concentrations have typically not fallen as had been widely anticipated, particularly at roadside monitoring sites nationwide, despite emissions of NO_X falling. At the end of September 2010 Defra released a brief FAQ note on the issue (Defra, 2010), acknowledging that NO_2 concentrations have not fallen as projected over the past 6-8 years.

The modelling study uses the emission database published by Defra in September 2012 in the Emission Factors Toolkit EFT (v5.1.3) (http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft). The EFT specifically incorporates updated NO_X emissions factors and vehicle fleet information based on current measurements and projections, which are essential for the modelling study.

3.4 Conversion of NO_X to NO_2

The proportion of NO_2 in NO_X varies greatly with location and time according to a number of factors including the amount of oxidant available and the distance from the emission source. NO_X concentrations are expected to decline in future years due to falling emissions, therefore NO_2 concentrations will not be limited as much by ozone and consequently it is likely that the NO_2/NO_X ratio will increase in the future.

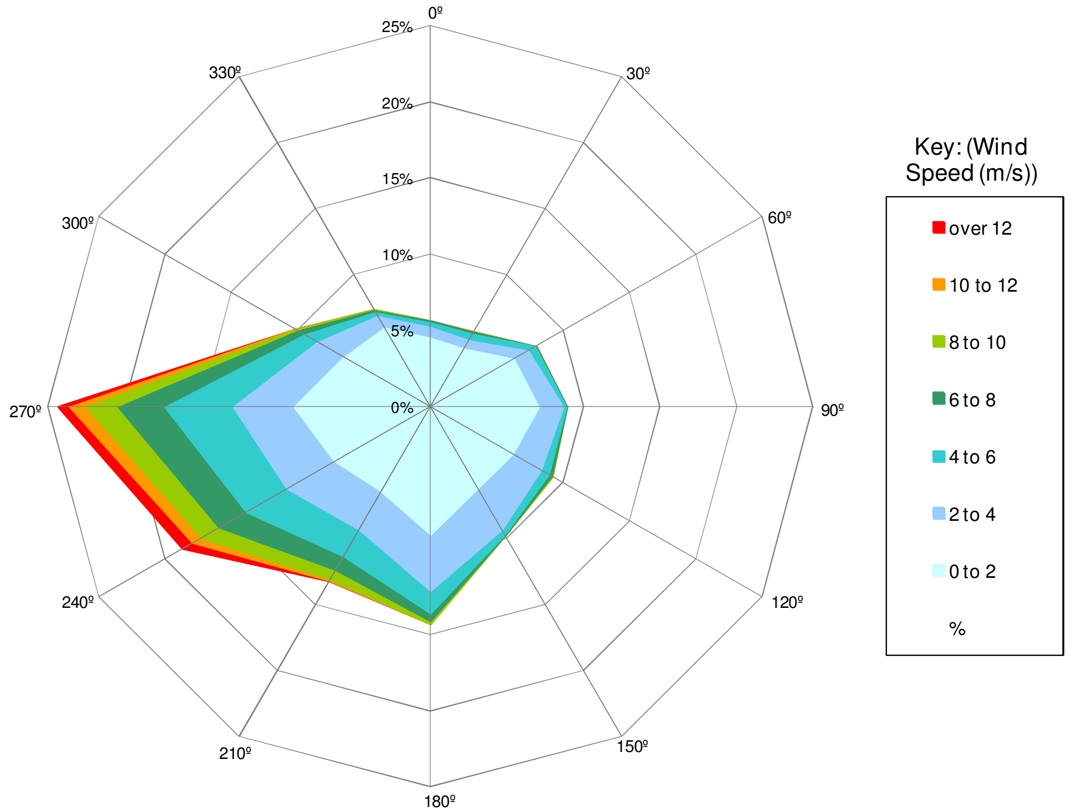
In this assessment modelled NO_X values were converted to NO_2 using the 'NO_X to NO_2' calculator version 3.2, published in September 2012, and available on the Defra local air quality management website (Defra, 2012). The year and region for which the modelling has been undertaken are specified and local factors, such as an appropriate factor of NO_X emitted as NO_2, are used in the calculation.

3.5 Meteorological Data

The meteorological dataset applied to the model was recorded at Newcastle Airport in 2011. The airport is located approximately 15 km to the north of the study site and is considered to be a good representation of the regional conditions at the study site.

The prevailing meteorological conditions are indicated by the wind rose in Figure 1, whereby the prevailing direction is from the west, with a strong south-westerly component, which is considered to be broadly typical for the study area and the UK as a whole. The prevailing wind direction will increase dispersions of atmospheric pollutants towards the east and north, resulting in slightly greater exposure at receptor locations to the north-east of the roads. However, in reality the situation is generally more complex due to the influence of topography, and more importantly in urban areas, the influence of buildings and the orientation of roads.

Figure 1: Newcastle Airport Windrose, 2011



3.6 Traffic Data

Traffic data for the entire city, in the form of annual average daily traffic (AADT) flows, heavy goods vehicle (HGV; vehicles greater than 3.5 t) percentages and average vehicle speeds for all road links within the model domain are required to predict pollutant concentrations arising from traffic (knowledge regarding factors such as typical traffic conditions, queuing, and road gradient help to improve the predictions). The traffic data used in the model are provided in Appendix B, and are calculated from automatic and manual counts recorded between 2010 and 2012 by DCC. For the purposes of the modelling study it was assumed that there has been no significant change in flow between 2010 and 2012 as many of the roads are all already at maximum capacity during peak hours.

The data were used to determine daily average speed and flow profiles (Figure 2 and 3), which were assigned to the modelled roads to improve the model predictions. These profiles account for congestion when peak traffic times results in greater numbers of vehicles and lower speeds:

- Figure 2 illustrates the daily flow profile, which was very similar for all of the roads for which hourly data were available. Flows increase substantially from 06:00 to a morning rush-hour peak at 08:00, then increase gradually through the day to an afternoon peak at 16:00 before tailing-off slowly during the evening.

- Figure 3 illustrates the speed profile of roads for which hourly speed data were available. Typically, the speed profile mirrors the flow profile, as would be expected.

Figure 2: Average Diurnal Vehicle Flow Profile for Modelled Roads

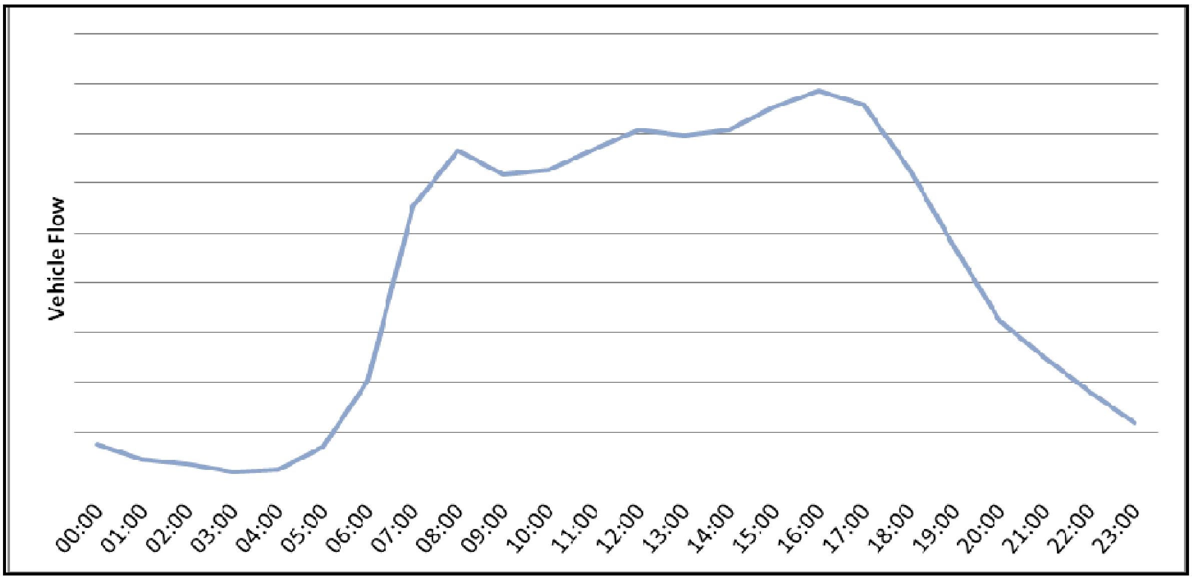
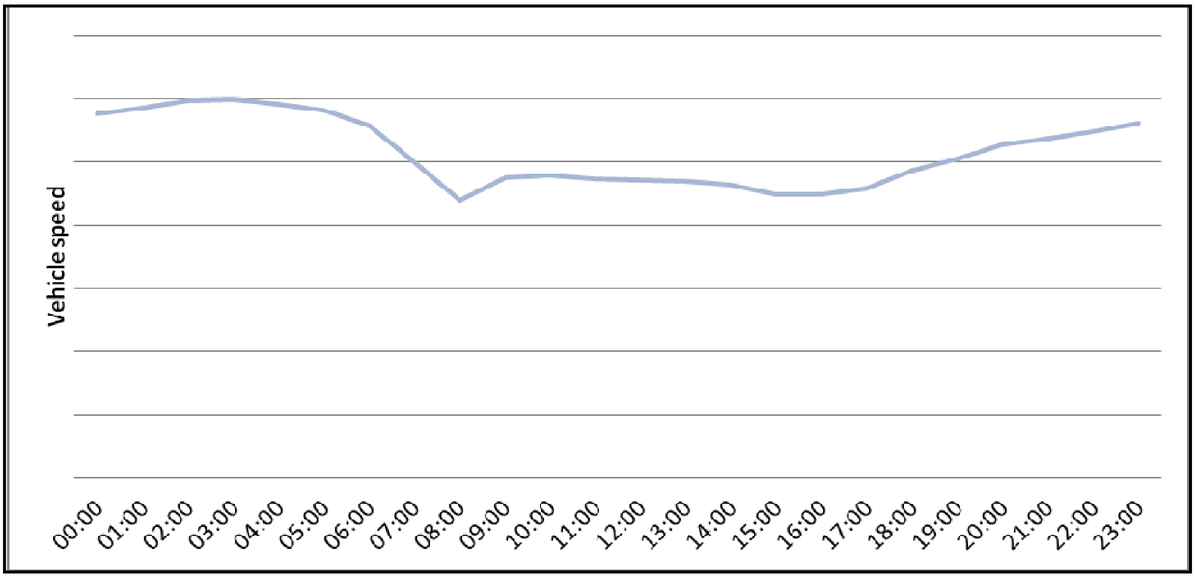


Figure 3: Average Diurnal Vehicle Speed Profile for Modelled Roads



3.6.1 Queuing Traffic

Queuing traffic is acknowledged as a potentially significant emission source in many urban areas. Several areas within the City of Durham are subject to significant congestion and queuing at busy times, particularly at the approaches to roundabouts. The effects of queuing on traffic flow at busy junctions and roundabouts have been included in the model.

3.7 Study Area and Modelled Receptors

3.7.1 Durham City

The City of Durham is a medieval settlement with many narrow, steep hills, although a significant road with dual-carriageway sections has been constructed through the centre, providing a major east-west link across the City. The different areas of the City have very different characteristics, with regard to the road attributes and the proximity of receptors.

The residential areas to the east of the city are predominantly terraced and semi-detached properties set back from the road. This area includes Gilesgate and Sunderland Road, which comprises part of the AQMA.

The centre of the City is predominantly commercial, although there are also residential properties and flats near the major roads. The Leazes Road and Millburngate Bridge are wide multi-lane roads that are typically at different levels to the surrounding properties and link two major roundabouts where peak-hour queues typically occur.

The New Elvet area is south of the City Centre and is comprised of relatively narrow lanes, terraced buildings and residential properties. This is not a major vehicle thoroughfare, but is an access route to the City Centre from the south and south-east.

The area to the west of the City Centre, which is the focus of this study, between Millburngate and Nevilles Cross comprises part of the main east-west road link. It is comprised of terraced residential properties facing directly onto narrow steep roads which are characteristic of street-canyons where air flow is constrained.

3.7.2 Receptors

A number of residential properties were specifically selected as sensitive receptors and are presented in Table 1, and Appendix F, Figures 9, 10 and 11. Receptors were selected as those anticipated to be exposed to the highest concentrations of road vehicle emissions, due to proximity to areas of congestion and high flows.

The Council undertakes air quality monitoring at locations throughout the City, which is discussed in the following Section 4. Many of the monitoring sites are considered to be representative of relevant exposure, and so they have also been used as sensitive receptor locations (Table 2).

In addition to the sensitive receptor locations, a plot of the predicted NO_2 concentrations was provided for the whole study area. In accordance with LAQM.TG(09) a fine 10 m grid was used to predict areas of potential high pollutant concentrations.

Table 1: Modelled Sensitive Receptor Locations

ID	Location	Height (m)	X	Y
1	Newcastle Road	1.5	426106	542118
2	Nevilles Cross Bank	1.5	426141	541947
3	Darlington Road	1.5	426178	541814
4	Crossgate Peth 1	1.5	426213	541959
5	Crossgate Peth 2	1.5	426312	542004
6	Crossgate Peth 3	1.5	426660	542149
7	Sutton Street	1.5	426803	542417
8	Atherton Street	1.5	426829	542535
9	Crossgate Lights	1.5	426831	542315

Table 2: Monitoring at Locations Representative of 'Relevant Exposure'

ID	Location	Height (m)	X	Y
D13	Hawthorn Terrace	1.5	426790	542442
D69	1 Alexandria Crescent	1.5	426832	542314
D75	Nevilledale Terrace	6	426704	542137
D76	The Peth	8 (property raised above road)	426697	542209
D78	Nevilles Cross Out	1.5	426226	541986
D79	Nevilles Cross in	1.5	426133	541930
D80	Stone bridge	1.5	426226	541986

3.8 Model Verification

When using modelling techniques to predict concentrations, it is desirable to make a comparison between the modelling results and monitoring data, to ensure that the model is reproducing actual observations and to ensure greater confidence can be placed in the predicted concentrations.

Modelling results are subject to systematic and random error; systematic error arises due to many factors, such as uncertainty in the traffic data and the composition of the vehicle fleet, and uncertainty in the meteorological dataset. This can usually be addressed and, if necessary, adjusted for by comparison with local monitoring data.

The model results were compared with the monitoring undertaken by the local authority at locations throughout the study area, which determined that it would be necessary to apply an adjustment factor to the raw model results.

Where possible, it is preferable to verify the model by comparison with a continuous monitoring instrument, as this is a reference method and considered to be more accurate than passive methods. However, the continuous monitor at Crossgate Lights was operational for only part of 2012, and was not operational at all during 2011. Therefore, a single verification factor of 2.99 was calculated using only the diffusion tube monitoring data, whilst a subjective discussion of the comparison with the continuous monitoring data is provided in Section 4.2.3.

Furthermore, sufficient diffusion tube monitoring data was available to calculate a Root Mean Square Error (RMSE), which is indicative of the range of confidence that may be applied to the model results. The range was used to identify all areas of potential exceedences.

Further details of the procedure are provided in Appendix D.

4 Baseline Conditions

4.1 Air Quality Management Area

Durham County Council (DCC) is a 'unitary' Council, established on 1st April 2009 when the seven former District and Borough Councils within the County merged with the previous Durham County Council. This authority is now responsible for Review and Assessment duties for the county administrative area, including the City of Durham.

With regard to the City of Durham, the declaration of an AQMA was recommended in 2008, although due in part to the Council reorganisation it was not declared until May 2011. The extent of the AQMA is provided in Appendix E, Figure 8 and is composed of a single area including Highgate, Milburngate, Framwellgate Peth, Milburngate Bridge, Leazes Road and Gilesgate as far as the area around Dragons Lane junction.

4.1.1 2011 Progress Report

The 2011 Progress Report reviewed monitoring data from the local NO_2 diffusion tube network, which was significantly extended in 2011. This report identified exceedences of the annual mean NO_2 objective at areas outside the AQMA and concluded that it would be necessary to undertake the following Detailed Assessments:

- Claypath, in the city centre (undertaken in August 2011)
- New Elvet, Church Street and Hallgarth, south of the city centre (undertaken in August 2011)
- Crossgate lights, Nevilles Cross, The Peth and Colpitts Terrace, to the west of the city centre (the subject of this report).

4.1.2 2012 Durham City Further Assessment

In accordance with LAQM.TG(09) Guidance, a Further Assessment was submitted in December 2012, for the Durham City AQMA (Appendix E, Figure 8), declared in May 2011, for the annual mean NO_2. The purpose of the Further Assessment was to confirm the extent of exceedences of the objectives, define what improvement in air quality and corresponding reduction in emissions is required to attain the objective and provide information on source contribution. The latter will provide useful information for the development of the Air Quality Action Plan.

The Further Assessment concluded that only six properties were predicted to experience exceedences of the annual mean objective, all of which were located on Gilesgate. However, the number of properties increased to 28 if the model error is taken into account, with 23 properties located on Gilesgate, three on Leazes Road, one near the Framwellgate Roundabout and one at Dragon Lane. In conclusion, it was determined that although the National Air Quality Objective was not likely to be exceeded at the section to the east of the junction of Sherburn Road, the objective was shown to be exceeded at the location of sensitive receptors at the junction of Dragon Lane and therefore it is likely that this section of the AQMA will be retained. A final decision in this regard will be made during 2013.

The source apportionment study indicated that the required reduction in NO_X necessary to achieve the annual mean objective is as high as 90% at a very small area in the vicinity of the Gilesgate Roundabout, elsewhere reductions of up to 20-25% should be sufficient to ensure that the air quality objectives will be met. The source apportionment study has determined that cars are the single most significant emission source, although buses and HGVs contribute a similar but disproportionally significant amount. Therefore, reducing emissions from buses and HGVs should be a specific target of the Air Quality Action Plan.

4.2 Monitoring

4.2.1 Passive Monitoring

The Council currently undertakes monitoring for NO_2 using passive diffusion tubes at 47 locations in Durham City. The monitoring data recorded in the study area is provided in Table 3, and the locations within the study area shown in Appendix F, Figures 9, 10 and 11.

Passive monitoring data was recorded during 2012, but has not been used in this report as only 11-months of data were available at the time of writing and the national bias-adjustment factors were not published at the time of writing this report. A local bias adjustment factor will in the future be calculated, but at the time of writing collocated data (with the continuous analyser on Crossgate (see Section 4.2.2)) were only available for October and November 2012.

2011 monitoring data has been used in this report. The 2011 data were bias adjusted using a collocation study at the (now discontinued) continuous monitoring station at Gilesgate. Further details of the adjustment are provided in the 2012 USA (DCC< 2012). Fourteen exceedences of the annual mean objective were recorded in 2011, and eleven of these locations were outside the extent of the current AQMA; of these, several were at locations of relevant exposure. Exceedences of the annual mean NO_2 objective were recorded at the following eight locations within the study area, three of which (D78, D79 and D80) are at locations of relevant exposure:

- D71, Opposite EBGB
- D72, Opposite Hawthorn Terrace lamppost
- D12, Colpitts Terrace
- D11, Crossgate Lights
- D77, Archery Rise
- D78, Nevilles Cross (relevant exposure)
- D79, Nevilles Cross (relevant exposure)
- D80, Stone Bridge (relevant exposure)

One monitoring location at an urban background site was installed at The Sands (D59) in 2011 and has been used to inform the background NO_2 concentrations (discussed below in Section 4.3). This monitoring location is located approximately 500 m to the north-east of the study area.

Table 3: Non-continuous Monitoring in the Study Area

ID	Location	Co-ordinates		Site Type	Within AQMA	Relevant Exposure	Distance to kerb, m	2011 Data Capture	Annual mean concentration µg/m³				
		X	Y						2007	2008	2009	2010	2011
D7	Highgate	427134	542688	Roadside	Yes	Y	3m	100%					
D14	The Gates	427166	542634	Roadside	Yes	N	2m	92%					
D10	North Road	427038	542564	Roadside	No	N (>10 m)	3 m	100%	37.2	35.5	39.31	38.4	33.2
D12	Colpitts Terrace	426768	542369	Kerbside	No	N (3 m)	0 m	100%	-	-	**56.01**	**47.2**	**45.5**
D11	Crossgate Lights	426839	542298	Kerbside	No	N (5 m)	0 m	100%	-	-	-	**41.5**	**40.0**
D13	Hawthorn Terrace	426790	542442	Roadside	No	Y	3 m	100%	-	-	-	33.3	28.7
D43	The Peth	426510	542045	Roadside	No	N (10 m)	2 m	100%	-	-	-	**57.0**	**50.7**
D69	1 Alexandria Crescent	426832	542314	Roadside	No	Y	2m	58%	-	-	-	-	38.3
D70	The Peth south	426659	542123	Roadside	No	N (11m)	2	58%	-	-	-	-	36.4
D71	Opposite EBGB	426785	542358	Kerbside	No	N (4m)	0 m	50%	-	-	-	-	**56.4**
D72	Opposite Hawthorn Terr lamppost 42	426805	542437	Kerbside	No	N (2 m)	0 m	58%	-	-	-	-	**43.3**
D73	6 Sutton St	426808	542495	Kerbside	No	N (2 m)	0 m	50%	-	-	-	-	36.2
D75	Nevilledale Terrace	426704	542137	Roadside	No	Y	17 m	42%	-	-	-	-	25.4
D76	The Peth	426697	542209	Suburban	No	Y	12 m	42%	-	-	-	-	19.7
D77	Archery Rise	426475	542036	Roadside	No	N (8m)	2 m	42%	-	-	-	-	**50.8**
D78	Nevilles Cross Out	426226	541986	Roadside	No	Y	0 m	42%	-	-	-	-	**41.4**
D79	Nevilles Cross In	426133	541930	Roadside	No	Y	1 m	42%	-	-	-	-	**55.8**
D80	Stone bridge	425933	541587	Kerbside	No	Y	1 m	25%	-	-	-	-	**40.9**

Note: Exceedences of the UK air quality standard objective highlighted in bold.
Where data capture is <80% it has been seasonally, adjusted. Details of this process are published in the 2012 USA (DCC, 2012).

4.2.2 Automatic Monitoring

Continuous monitoring was undertaken at Gilesgate, within the AQMA, from May 2011 until July 2012. This site was outside the study area, and so it was not used for model verification in this study. Further details about this site are published in the 2012 USA (DCC, 2012).

Continuous monitoring is undertaken at Crossgate, located adjacent to the A690 in the city centre, at the junction of St Margaret's and Crossgate Peth. The site was operational from the 29th September 2012 and therefore only 3 months of ratified data (October-December) was available at the time of undertaking the Detailed Assessment, and so the data was not used in the modelling process. Nevertheless, the 3 months of data were seasonally adjusted in accordance with the procedure and calculations presented in Appendix C by comparison with the four closest AURN monitoring sites. These AURN sites have been used previously for seasonal adjustment, and further discussion about site selection is provided in the 2012 USA (DCC, 2012). It should be noted that the AURN data had not been fully validated at the time of determining the adjustment, and so these data may be subject to change later in 2013.

According to Table 4, the annual mean concentrations recorded at Crossgate Lights are clearly in excess of the annual mean objective, although no breaches of the hourly standard were recorded during this period and the 99.8th percentile is well below the 200 µg/m^3 standard. These data should be treated with caution as they are based on only 3 months monitoring.

Table 4: Continuous Monitoring in the Study Area, 2012

ID	Location	Co-ordinates		Site Type	Within AQMA	Relevant Exposure	Distance to kerb, m	Data Capture		Annual Mean [A], µg/m^3	99.8th Percentile [B], µg/m^3
		X	Y					Period	Year		
CL	Crossgate Lights	426842	542295	Roadside	N	N (5m)	3m	99%	26%	49.6	147.0

Note: [A] Annual mean seasonally adjusted. [B] Due to low data capture the percentile is used to indicate potential breaches of the hourly objective.

4.2.3 Comparison of Passive and Continuous Data (2012)

Three diffusion tubes were collocated at the continuous monitor installed at Crossgate on 29 September 2012. As there is insufficient data to calculate an annual mean bias adjustment in this location, a subjective comparison was done using data from the nearby long-term diffusion tube monitoring site at D11, which is located closer to the kerbside approximately 4 m to the north-west of the continuous monitor.

A comparison of the unadjusted passive diffusion tube data recorded in October and November 2012 is shown in Table 5. This indicates that concentrations recorded nearer the road (D11) in 2012 were higher than those recorded at the analyser (D91/92/93), which would be as expected.

However, the monthly mean concentration recorded at the Crossgate Lights continuous monitor in 2012 was higher than the collocated diffusion tubes (D91/D92/D93) for the same period, which suggests that they were un-reading. Furthermore, the seasonally adjusted annual mean concentration recorded at the continuous monitor was substantially higher than the 2011 annual mean recorded at D11 (see Table 3, above), despite the continuous monitoring being further from the road.

In summary, based on the limited available data, this suggests that the annual mean roadside concentrations recorded in this area during 2012 may be substantially higher than those recorded in 2011.

Table 5: Comparison of Passive and Automatic Data Recorded Near Crossgate Lights in 2012

ID	Site	Location	Notes	2012 Monthly Mean Concentration, µg/m^3	
				October	November
D11	Diffusion Tube	Kerbside	Unadjusted	57.0	50.3
D91/92/93	Collocated Tubes	Roadside	Unadjusted average value from three tubes	48.5	43.7
CL	Continuous Monitor	Roadside	Adjusted using seasonal bias	50.7	50.6

4.3 Background Concentrations

A large number of sources of air pollutants exist which individually may not be significant, but collectively, over a large area, need to be considered. The concentrations calculated by the model due to vehicle emissions can then be added to background concentrations to give the total concentration.

The Council monitored urban background NO_2 concentrations at one site in 2011; The Sands (D59). The annual mean concentration recorded in this location was very low, and well below the annual mean objective (see Table 6). The data capture for this period was 75%, and so it was seasonally adjusted by comparison with regional monitoring data, as discussed in the 2012 USA (DCC, 2012).

Table 6: Background Monitoring Data

ID	Location	Co-ordinates		Site Type	Within AQMA	Relevant Exposure	Distance to kerb, m	Annual mean concentration µg/m^3				
		X	Y					2007	2008	2009	2010	2011
D59	The Sands	427652	542991	Background	No	N (10 m)	N/A	-	-	-	-	17.7

Modelled estimates of background air quality concentrations are also provided on the Defra Air Quality website (Defra, 2011b) for each 1 km Ordnance Survey (OS) square in the UK. The estimated background concentrations for the OS grid squares containing the study area are provided in Table 6. These data were downloaded in January 2013. Adjusted NO_2 concentrations, to account for contributions from roads that have been modelled, were calculated using version 3.1 of the NO_2 Background Selector Tool.

Table 7: Archive Background Pollutant Concentrations (µg/m^3)

Pollutant	2011	
	Total	Adjusted
NO_X	27.9	24.0
NO_2	18.6	16.3

For modelling purposes it is preferential to use actual monitored rather than modelled background concentrations. Therefore the NO_2 concentration recorded in 2011 at The Sands was used for the Detailed Assessment. In any event, the annual mean concentration recorded at The Sands was 17.7 µg/m^3, which is very similar to the estimated value presented in Table 7.

5 Results

The Detailed Assessment was undertaken to assess the following roads to the west of the AQMA where monitoring has identified potential breaches of the annual mean air quality objective for NO_2:

- Alexandria Crescent / Sutton Street;
- Crossgate Lights junction;
- Crossgate Peth;
- Nevilles Cross junction.

5.1 Sensitive Receptors

As discussed in Section 3.7.2, the 2011 annual mean concentration of NO_2 was predicted at sensitive receptors considered to represent locations of relevant exposure. In addition, many of the air quality monitoring sites in the study area are representative of relevant exposure, and so these were also included in the model.

As discussed in Section 3.8, the model was verified by comparison with the air quality monitoring data recorded by DCC in 2011.

The results presented in Table 8 indicate the annual mean objective for NO_2 was predicted to be breached at one sensitive receptor location, and four monitoring locations representative of relevant exposure (see Section 3.7.2), with a maximum predicted concentration of 45.6 $\mu g/m^3$ predicted to occur at D78 Nevilles Cross Out:

- 9 Crossgate Lights,
- D13 Hawthorn Terrace,
- D69 1 Alexandria crescent,
- D78 Nevilles Cross Out
- D79 Nevilles Cross In.

The model under-predicted at some monitoring locations (when compared to the 2011 monitoring data), including locations with measurements in breach of the annual mean objective. In particular, the model predicted relatively lower concentrations than those recorded at the following monitoring sites:

- D11 Crossgate Lights
- D12 Colpitts Terrace
- D43 The Peth
- D70 The Peth South
- D75 Nevilledale Terrace
- D77 Archery Rise
- D79 Nevilles Cross In
- D80 Stone Bridge

However, the addition of the RMSE (i.e. model error) calculated in Appendix D compensates for this under-prediction, and is considered to be a cautious approach to identify the areas of likely exceedence. Taking account of the RMSE four further sensitive receptors and one monitoring location representative of relevant exposure may be at risk of exceeding the annual mean objective:

- Receptor 2, Nevilles Cross Bank
- Receptor 4, Crossgate Peth
- Receptor 7, Sutton Street
- Receptor 8, Atherton Street
- D80 Stone Bridge

As discussed in Section 4.2.3, the new continuous monitoring instrument at Crossgate Lights recorded a very high seasonally adjusted annual mean concentration, which was greater than the concentration recorded at a nearby kerbside diffusion tube in

2011, despite it being set back further from the road. This may indicate that the annual mean roadside concentrations recorded in this area during 2012 are higher than those recorded in 2011, and so the inclusion of the RMSE value is considered to be a reasonable approach. However the 2012 monitoring data should be treated with caution as it is only based on 3 months of readings.

Table 8: Predicted Annual Mean NO_2 Concentrations, 2011, at Locations that are Representative of 'Relevant Exposure'

ID	Location	Type	Annual Mean NO_2, µg/m^3	
			Modelled	**Modelled Inc. RMSE**
1	Newcastle Road	SR	30.1	23.9 - 36.3
2	Nevilles Cross Bank	SR	37.4	31.1 - **43.6**
3	Darlington Road	SR	28.6	22.4 - 34.8
4	Crossgate Peth 1	SR	36.2	30.0 - **42.4**
5	Crossgate Peth 2	SR	29.7	23.5 - 35.9
6	Crossgate Peth 3	SR	26.7	20.5 - 32.9
7	Sutton Street	SR	38.0	31.8 - **44.2**
8	Atherton Street	SR	37.9	31.6 - **44.1**
9	Crossgate Lights	SR	**43.5**	37.3 - **49.7**
D13	Hawthorn Terrace	Monitor	**43.6**	37.4 - **49.8**
D6	14 Providence Row	Monitor	24.6	18.4 - 30.8
D69	1 Alexandria Crescent	Monitor	**44.2**	38.0 - **50.4**
D75	Nevilledale Terrace	Monitor	22.8	16.6 - 29.0
D76	The Peth	Monitor	24.7	18.5 - 30.9
D78	Nevilles Cross Out	Monitor	**45.3**	39.0 - **51.5**
D79	Nevilles Cross in	Monitor	**42.6**	36.4 - **48.8**
D80	Stone Bridge	Monitor	35.5	29.2 - **41.7**

Note: Bold values indicates breaches of the annual mean objective.

5.1.1 Predicted Future Concentrations

A further model run was completed to predict the potential local air quality effects in the future. The model year 2016 was selected as 5-years after the 2011 base year. The model applied 2016 emission rates from the 2012 EFT (see Section 3.3), 2016 NO_X/NO_2 conversion calculations (see Section 3.4), 2011 meteorological data and verification. It was assumed that traffic flows and background pollutant concentrations would not change from 2011.

The results of this modelling are presented in Table 9.

The study predicted that the annual mean concentration of NO_2 is likely to decrease in the future by approximately 15%. This should be sufficient to reduce the concentration of NO_2 to below the annual mean objective in most locations, although the RMSE of the model highlights potential continued risk of exceedences at five locations:

- Receptor 9, Crossgate Lights
- D13, Hawthorn Terrace
- D69, 1 Alexandria Crescent
- D78, Nevilles Cross Out
- D79, Nevilles Cross In

Table 9: Predicted Annual Mean NO_2 Concentrations, 2016, at Locations that are Representative of 'Relevant Exposure'

ID	Location	Type	Annual Mean NO_2, µg/m^3	
			Modelled	Modelled Inc. RMSE
1	Newcastle Road	SR	26.0	19.8 – 32.2
2	Nevilles Cross Bank	SR	31.7	25.4 – 37.9
3	Darlington Road	SR	25.2	18.9 – 31.4
4	Crossgate Peth 1	SR	31.0	24.8 – 37.2
5	Crossgate Peth 2	SR	25.7	19.5 – 31.9
6	Crossgate Peth 3	SR	24.0	17.8 – 30.2
7	Sutton Street	SR	31.6	25.4 – 37.8
8	Atherton Street	SR	31.6	25.4 – 37.8
9	Crossgate Lights	SR	35.8	29.6 – **42.0**
D13	Hawthorn Terrace	Monitor	35.9	29.7 – **42.1**
D6	14 Providence Row	Monitor	22.0	15.8 – 28.2
D69	1 Alexandria Crescent	Monitor	36.4	30.2 – **42.6**
D75	Nevilledale Terrace	Monitor	21.0	14.8 – 27.2
D76	The Peth	Monitor	22.2	16.0 – 28.4
D78	Nevilles Cross Out	Monitor	37.4	31.2 – **43.6**
D79	Nevilles Cross in	Monitor	35.9	29.7 – **42.1**
D80	Stone Bridge	Monitor	30.1	23.8 – 36.3

Note: Bold values indicates breaches of the annual mean objective.

5.2 Plotted Results

The model results were plotted at a resolution of 10 m in order to demonstrate the geographical extent of the predicted annual mean concentration of NO_2. These data are shown in Appendix F, Figure 9, 10 and 11.

Annual mean NO_2 concentrations in excess of the annual mean objective were predicted at Nevilles Cross Bank and around the Nevilles Cross junction, which is likely to be due to congestion and the steep hills around the junction. The residential properties on the steep section of Nevilles Cross Bank extend as far as Broom Lane. A few properties to the north-east of the Nevilles Cross junction were also predicted to fall within the RMSE of the model and may be exposed to high concentrations of NO_2. Further to west of Broom Lane, the model is considered less likely to under-predict, as the road is more open and less susceptible to street-canyon characteristics. Therefore, the addition of the RMSE is unlikely to apply to this area.

The road characteristics around Newcastle Road and Darlington Road are not conducive to street canyoning, and so it is not considered appropriate to apply the RMSE in these areas. However, even without the application of the RMSE, the model still indicates a potential breach of the annual mean NO_2 objective at one property on Newcastle Road to the north-east of the Nevilles Cross junction.

No significant exposure was predicted on Crossgate Peth, as the properties on this road are generally set back from the kerb and raised above the road, although potential exposure within the RMSE of the model was predicted at a few properties at the western end of the road near to the Nevilles Cross junction, including St Margarets Health Centre NHS building.

Very high concentrations clearly in excess of the objective were predicted on Alexandria Crescent and Sutton Street, where the road is relatively narrow and steep. The monitoring data has recorded breaches of the annual mean objective in this area, and also clearly indicated street-canyon characteristics by the significant variation of monitoring data on opposite sides of the road.

The model also predicted potential concentrations in excess of the annual mean objective on North Road, near the bus station. Whilst many of the buildings in this area are commercial, there are residential flats on the first floor. However, monitoring is undertaken in this area at location D10 (North Road) and the 2012 USA (DCC, 2012) determined that the annual mean objective is unlikely to be breached at a location of relevant exposure.

5.2.1 Population Exposure

The technical guidance LAQM.TG(09) (Defra, 2009) requires that the Detailed Assessment should include an estimate of the number of people exposed to pollutant concentrations above the objectives in order to help Defra and the Devolved Administrations quantify the health benefits of improving air quality.

The predicted number of properties on each road predicted to exceed the annual mean objective are shown in Table 10. The greatest number of properties are on Nevilles Cross Bank, due to the number of houses very close to the road, although there are also a significant number of properties on Alexandria Crescent and Sutton Street. Furthermore, if the RMSE is taken into account, the number of properties potential exposed is doubled.

Table 10: Estimated Population Exposure

Road	Estimated Number of Properties > Annual Mean Objective	
	40 µg/m^3	40 µg/m^3 Plus RMSE
Nevilles Cross Bank	56	99
Newcastle Road	1	0 [A]
Darlington Road	0	0 [A]
Crossgate Peth	1	22
Alexandria Crescent	13	18
Sutton Street	11	22

Note: [A] As these roads are not considered to display street canyoning characteristics, the application of the RMSE is not considered to be appropriate to determine potential exposure and so values of 0 have been applied.

5.3 Summary

The model predicted annual mean concentrations of NO_2 in excess of the objective at locations outside the AQMA.

The model predicted several areas where the annual mean NO_2 objective is likely to be breached, which generally follows the main east-west road route through the City.

6 Conclusions

A detailed air quality dispersion modelling assessment was undertaken to assess air quality in the City of Durham, to the west of the existing AQMA. The AQMA was declared for part of the City due to high concentrations of NO_2, although recent monitoring data and Review and Assessment reporting has indicated that further breaches are occurring outside the AQMA.

Therefore, this Detailed Assessment was undertaken to assess the following roads and locations outside the AQMA to the west of the City Centre:

- Alexandria Crescent / Sutton Street;
- Crossgate Lights junction;
- Crossgate Peth;
- Nevilles Cross junction.

6.1 Conclusions

The Detailed Assessment concluded that

- Monitoring data identified locations outside the AQMA to the west of the City Centre where the annual mean concentration of NO_2 was exceeding the objective. This is likely to be partly due to the narrow, steep roads and street-canyon characteristics in this area.
- The dispersion model predicted high concentrations excess of the annual mean NO_2 objective were predicted to occur on Alexandria Crescent and Sutton Street. 24 properties were predicted to breach the objective in this location, with a maximum concentration of 44 $\mu g/m^3$.
- Concentrations excess of the annual mean NO_2 objective were predicted on Crossgate Peth at a single property at the Nevilles Cross junction. Further exposure of residential properties on this road were not predicted as many properties are set back from the kerb and raised above the road.
- Exceedences of the annual mean objectives were predicted to occur to the west of the Nevilles Cross area, on Nevilles Cross Bank where 56 properties were predicted to breach the objective with a maximum concentration of 43 $\mu g/m^3$.
- The assessment also considered the effects of model error, whereby an RMSE was calculated by comparison with monitoring data. This approach determined that the annual mean NO_2 concentrations in the study area may be considerably higher, up to approx 50 $\mu g/m^3$, and resulting in significantly greater numbers of properties breaching the objective.

6.2 Recommendations

Breaches of the annual mean air quality objective are predicted to occur at locations outside the AQMA.

The extent of the AQMA should account on the error range of the model, and particularly where it under predicted around Nevilles Cross, Crossgate Peth, Crossgate Lights, Alexandria Crescent and Sutton Street due to street canyoning. The error range is shown as the yellow boundary in Appendix F, Figure 9, 10 and 11.

The areas around Darlington Road, Newcastle Road, and to the west of Broom Lane on Nevilles Cross Bank should not include for the RMSE error as these areas do not display street canyon characteristics, and therefore should not be included in the AQMA.

Therefore, it is recommended that the AMQA is extended to include the following roads:

- Nevilles Cross Bank as far as Broom Lane, which is at the bottom of the steep hill and marks the edge of this residential area.
- Nevilles Cross junction, including the row of properties to the North-east on Newcastle Road;
- Crossgate Peth;
- Crossgate junction;
- Alexandria Crescent;
- Sutton Street; and
- Castle Chare, where it joins with the existing AQMA.

7 References

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Appendices

Appendix A: AAQuIRE Software

Appendix B: Traffic Flow Data

Appendix C: Seasonal Adjustment

Appendix D: Model Verification

Appendix E: Extent of Existing AQMA

Appendix F: Plotted Model Outputs

Appendix A: AAQuIRE Software

The AAQuIRE 6.2 software is a system that predicts Ambient Air Quality in Regional Environments and comprises a regional air quality model and statistical package.

AAQuIRE was developed by Faber Maunsell Ltd (now AECOM) to meet three requirements in predictive air quality studies. The first requirement was an immediate need for a system that produced results that could be interpreted easily by non-air quality specialists to allow for proper informed inclusion of air quality issues in wider fora, the main example being to allow consideration of air quality issues in planning processes. This was achieved by allowing results to be generated over a sufficiently large study area, and at an appropriate resolution, for the issue being considered. The results are also presented in a relevant format, which is normally a statistic directly comparable with an air quality criterion or set of measured data being considered. AAQuIRE can also produce results directly comparable with all ambient air quality standards.

The second requirement was for a system to be based, initially, on existing and well-accepted and validated dispersion models. This has two advantages. The primary one is that it avoids the need to prove a new model against the accepted models and therefore enhances acceptability. The second advantage is that when appropriate new models are developed they can be included in AAQuIRE and be compared directly with the existing models, and sets of measured data, using the most appropriate statistics.

The final primary requirement for AAQuIRE was a consideration of quality assurance and control. An important aspect of modelling is proper record keeping ensuring repeatability of results. This is achieved within AAQuIRE by a set of log files, which record all aspects of a study and allow model runs to be easily repeated.

The ways in which AAQuIRE and the models currently available within it operate are discussed below.

The operation of AAQuIRE can be divided into five main stages. These are:

- the preparation of the input data;
- the generation of model input files;
- dispersion modelling;
- the statistical treatment of dispersion modelling results; and
- the presentation of results.

The first step in operating AAQuIRE is to prepare the input data. The following data are needed for the year and pollutant to be modelled:

- meteorological data expressed as occurrence frequencies for specified combinations of wind speed, direction, stability and boundary layer height;
- road system layout and associated traffic data within and immediately surrounding the study area;
- industrial stack locations and parameters; and
- a grid of model prediction locations (receptors).

The modelling is always carried out to give annual average results from which appropriate shorter period concentrations can be derived.

The second stage is the generation of the model input files required for the study. All the data collated in the first stage can be easily input into AAQuIRE, using the worksheets, drop down boxes and click boxes in the Data Manager section of the software. Data from spreadsheets can be easily pasted into worksheets, so that any complicated procedures required for data manipulation can be achieved before entry into AAQuIRE. Several diurnal and seasonal profiles can be defined for each separate source. The relevant meteorological data can also be specified at this stage.

The third stage is executing the models. The study area will usually be divided up into manageable grids and run separately using the Run Manager in AAQuIRE. The results from the separate files can be combined at a later stage. Pollutant concentrations are determined for each receptor point and each meteorological category and are subsequently combined.

The fourth stage is the statistical processing of the raw dispersion results to produce results in the relevant averaging period. Traffic sources and industrial sources can be combined at this stage provided the same receptor grid has been used for both. Background concentrations should also be incorporated at this stage.

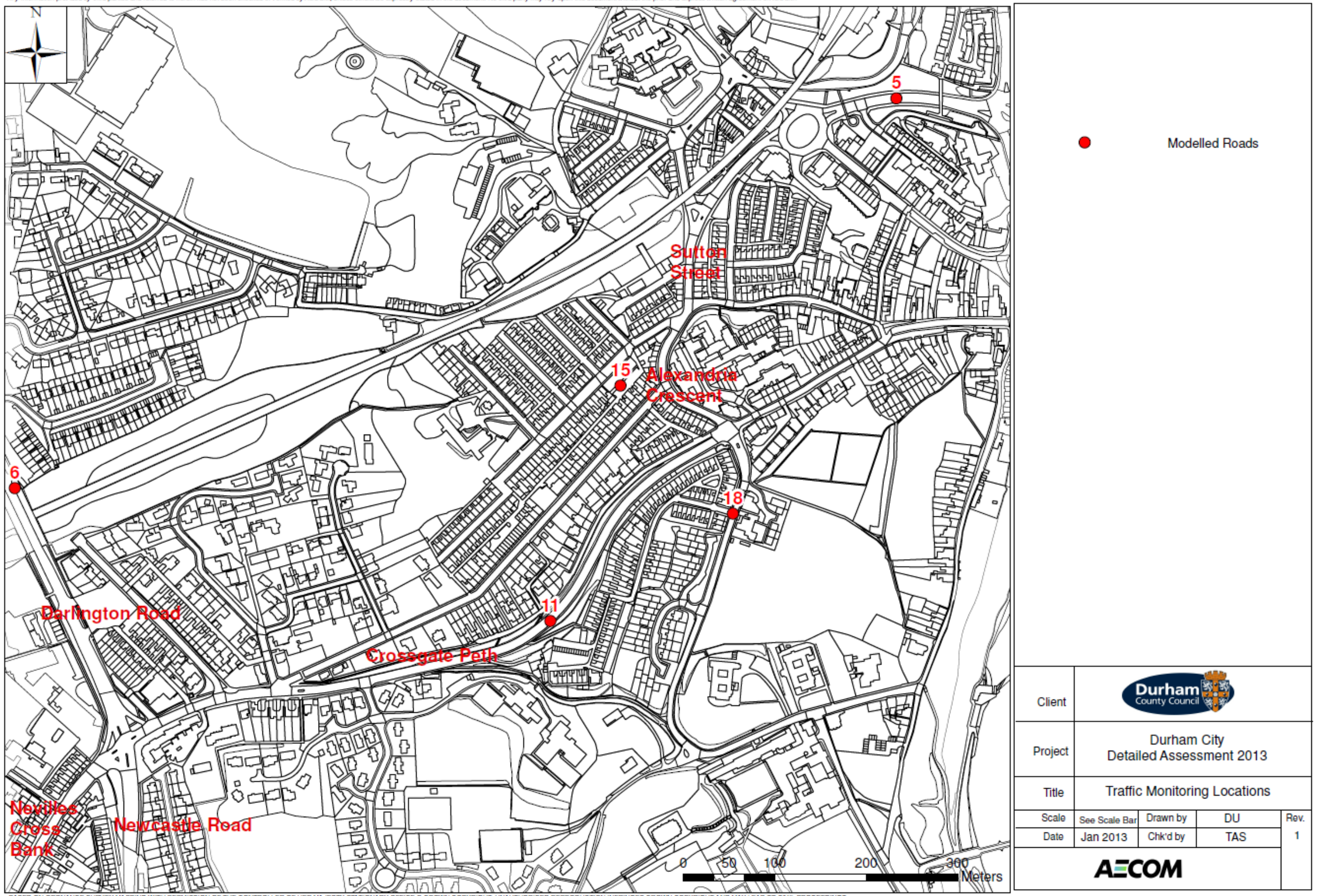
The final stage is presentation of results. Currently the result files from the statistical interpretation are formatted to be used directly by the Surfer package produced by Golden Software Inc. Alternative formats are available to permit interfacing with other software packages. On previous projects the results have been imported into a GIS (e.g. ArcView and Map Info).

Appendix B: Traffic Flow Data

Table 11: Traffic Flow Data Used in Model

ID	Model Road ID	Record Year	AADT	Speed km/hr
1	Millburngate Bridge EB	2010	24717	46
	Millburngate Bridge WB	2010	24831	43
4	Framwellgate Peth	2010	26532	55
	Framwellgate NB	2010	13266	55
	Framwellgate SB	2010	13266	55
5	Castle Chare	2010	16407	37
	Castle Chare WB	2010	8204	37
	Castle Chare EB	2010	8204	37
6	Newcastle Road	2012	21673	32
	Newcastle Road NB	2012	10805	31
	Newcastle Road SB	2012	10868	33
7	Nevilles Cross Bank	2012	19761	31
	Nevilles Cross Bank EB	2012	9780	29
	Nevilles Cross Bank WB	2012	9981	32
11	Crossgate Peth	2011	13949	47
	Crossgate Peth WB	2011	6541	44
	Crossgate Peth EB	2011	7408	50
15	Alexandria Crescent	2012	15076	36
	Alexandria Crescent NB	2012	8833	20
	Alexandria Crescent SB	2012	6242	16
16	Darlington Road	2012	13530	34
	Darlington Road NB	2012	7022	36
	Darlington Road SB	2012	6509	33
18	Margery Lane	2012	3714	31
	Margery Lane NB	2012	1707	33
	Margery Lane SB	2012	2007	29
19	North Road (one-way)	2012	1839	14

Figure 4: Traffic Flow Recording Locations Used in Model



Appendix C: Seasonal Adjustment

The Crossgate Lights automatic monitor was used as part of a co-location study. However, it was only operational from September 2012 and achieved data capture of only 26% (99% capture during the operational period). Therefore, the annual mean recorded at Crossgate Lights was determined by seasonal adjustment using the data recorded in 2012 at the four nearest AURN monitoring sites.

Table 12: Summary of Regional AURN Monitoring Data

Site	Site Type		Concentration of NO_2, µg/m^3		Ratio (Period/Annual)
			Annual Mean,	Oct – Dec Mean	
Sunderland Silksworth	Automatic Continuous Analyser	Urban Background	19.5	23.3	0.83
High Muffles		Rural	6.5	9.4	0.69
Billingham		Urban Industrial	20.9	25.3	0.83
Newcastle Centre		Urban Centre	29.8	39.2	0.76

Note: At the time of writing, the fourth quarter data for the AURN monitoring stations was provisional, and so these calculations are indicative.

Table 13: Seasonal Adjustment of Crossgate Lights Automatic Monitor, µg/m^3

Site	Data Capture	Missing Period	Period Mean Value	Ratio	Adjusted Mean, 2012
CL	26%	Jan-Sept 2012	62.8	0.79	49.6

Appendix D: Model Verification

The model under-estimated concentrations when compared to the monitoring undertaken in 2011. Due to this discrepancy, the modelled results were adjusted in accordance with the procedure detailed in technical guidance LAQM.TG(09)

The bias adjustment factors were calculated by comparisons to the model data with 2011 monitoring data. The standard deviation was calculated by comparing the model data to the 2011 monitoring data.

Three monitoring locations were excluded from the adjustment calculations as it is was not possible to account for these data in the adjustment. These were site D13, D14 and D73, where the street canyon characteristics resulted in adjacent sites recording significantly higher concentrations that the model could not replicate. Monitoring location was D76 also over-predicted by the model, but to a much lesser degree, and so it was included in the calculations. All of the monitoring locations were used to calculate the overall RMSE, as it was considered important to account for the potential discrepancy of the model.

An adjustment factor was calculated as follows:

$NO_{X\ [monitored,\ traffic\ contribution]} = NO_{X\ [monitored]} - NO_{X\ [background]}$
$NO_{X\ [modelled,\ traffic\ contribution]} = NO_{X\ [modelled]} - NO_{X\ [background]}$

$\text{Adjustment Factor} = NO_{X\ [monitored,\ traffic\ contribution]} / NO_{X\ [modelled,\ traffic\ contribution}$

The adjustment factors were subsequently applied to the modelled NO_X concentrations, and background NO_X added to give the adjusted NO_X concentrations ($NO_{X\ [model\ adjusted]}$):

$NO_{X\ [model\ adjusted,\ traffic\ contribution]} = NO_{X\ [modelled,\ traffic\ contribution]} \times \text{Adjustment Factor}$
$NO_{X\ [model\ adjusted]} = NO_{X\ [model\ adjusted,\ traffic\ contribution]} + NO_{X\ [background]}$

The adjusted NO_X concentrations were then converted to NO_2 using version 3.2 of the 'NO_2 to NO_X' calculator provided by the Air Quality Archive and in accordance with the technical guidance, LAQM.TG(09).

Table 14: Comparison of Modelled and Monitored NO_2 Concentrations

	Site Name	Monitored Total NO_2	Modelled Total NO_2	% Difference [(mod-mon)/mon]
D7	Highgate	35.5	25.2	-29%
D14	The gates	35.5	33.2	-7%
D10	North Road	33.2	26.6	-20%
D12	Colpitts Terrace	45.5	26.3	-42%
D11	Crossgate Lights	40.0	25.4	-36%
D13	Hawthorn Terrace	28.7	27.4	-4%
D43	The Peth	50.7	25.9	-49%
D69	1 Alexandria cres	38.3	27.7	-28%
D70	The peth south	36.4	24.3	-33%
D71	Opp EBGB Durha	56.4	34.0	-40%
D72	Opp Hawthorn terr lamppost 42	43.3	29.8	-31%
D73	6 Sutton St	36.2	32.1	-11%
D75	Nevilledale terr	25.4	19.4	-23%
D76	The peth	19.7	20.1	2%
D78	Nevilles Cross Out	41.4	28.1	-32%
D79	Nevilles Cross In	55.8	27.0	-52%
D80	Stone bridge	40.9	24.1	-41%

Figure 5: Total Modelled versus Monitored NO_2

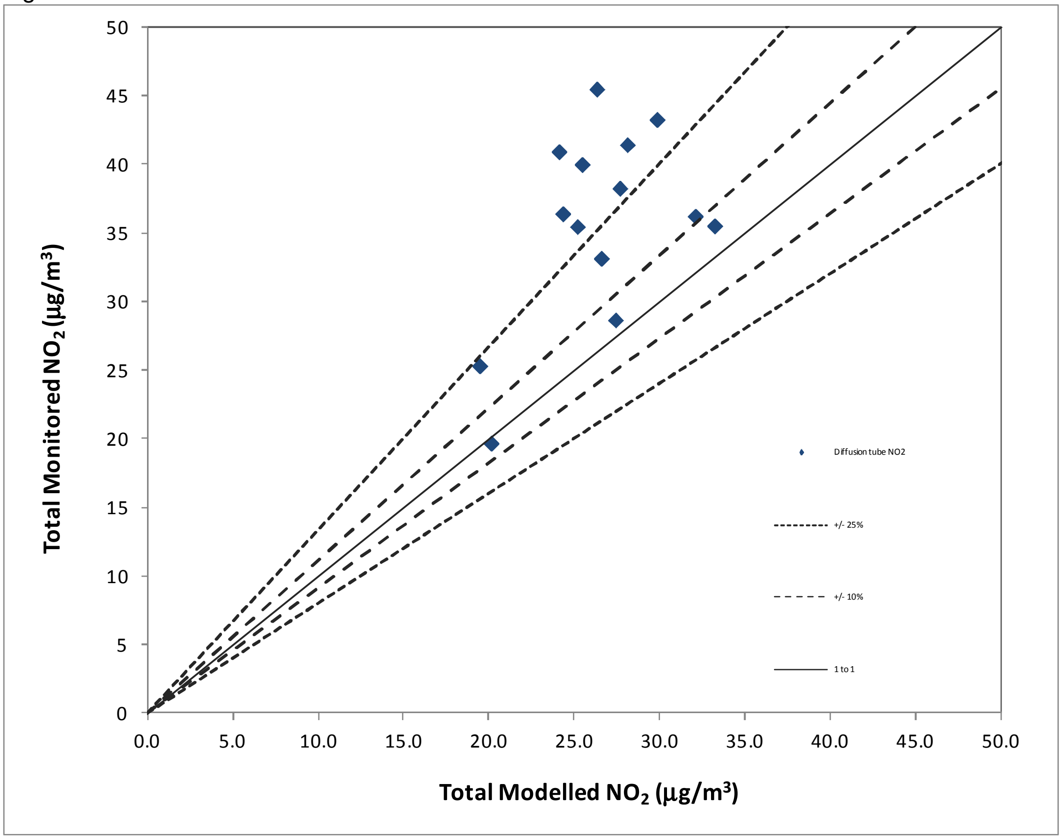


Table 15: Determination of Modelled and Monitored Rd NO_2 and Modelled Rd NO_X

Site Name	Monitored Total NO_2	Monitored Road NO_X	Adj Bknd NO_2	Monitored Road Contribution NO_2 (tot-bgd)	Monitored Road Contribution NO_X (tot-bgd)	Modelled Road Contribution NO_X (excl bgd)
D7	35.48	39.13	17.70	17.78	39.13	15.35
D10	33.18	33.55	17.70	15.49	33.55	18.41
D12	45.50	65.83	17.70	27.80	65.83	17.83
D11	40.01	50.72	17.70	22.32	50.72	15.96
D43	50.74	81.49	17.70	33.05	81.49	16.96
D69	38.28	46.19	17.70	20.58	46.19	20.81
D70	36.43	41.50	17.70	18.73	41.50	13.52
D71	56.43	99.85	17.70	38.73	99.85	35.44
D72	43.30	59.62	17.70	25.60	59.62	25.71
D75	25.35	15.79	17.70	7.66	15.79	3.48
D76	19.72	4.05	17.70	2.03	4.05	4.78
D78	41.44	54.54	17.70	23.75	54.54	21.76
D79	55.78	97.68	17.70	38.08	97.68	19.29
D80	40.94	53.20	17.70	23.25	53.20	13.05

Figure 6: Modelled Road-NO_X versus Monitored Road-NO_X All Areas

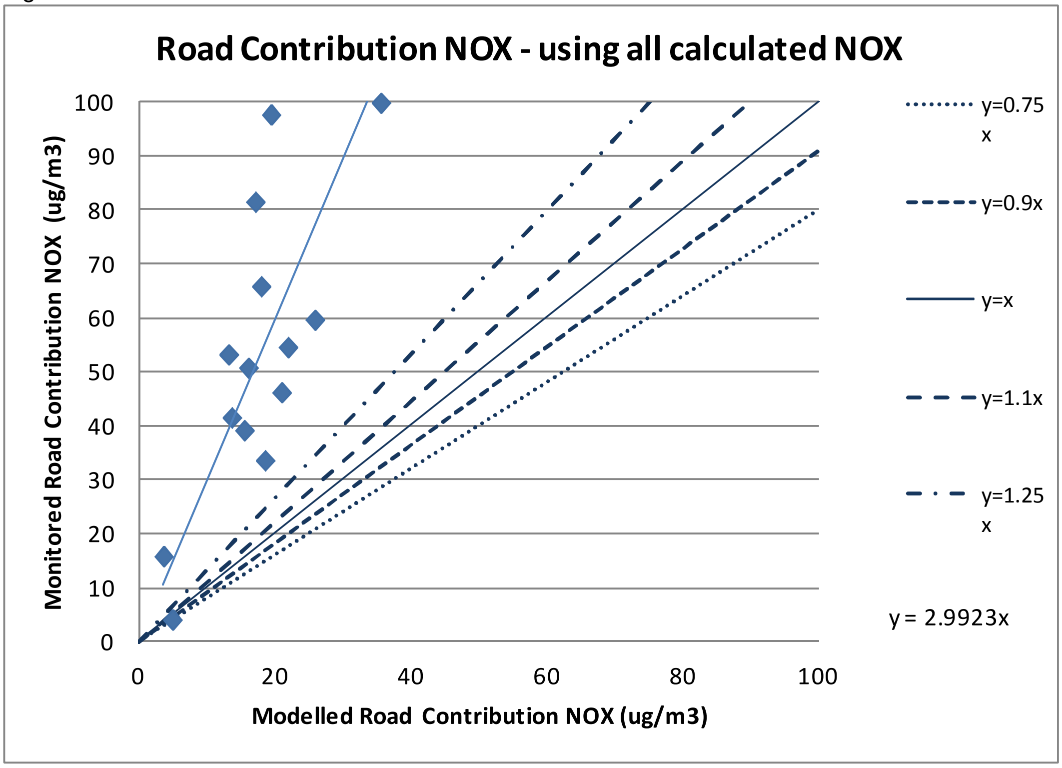
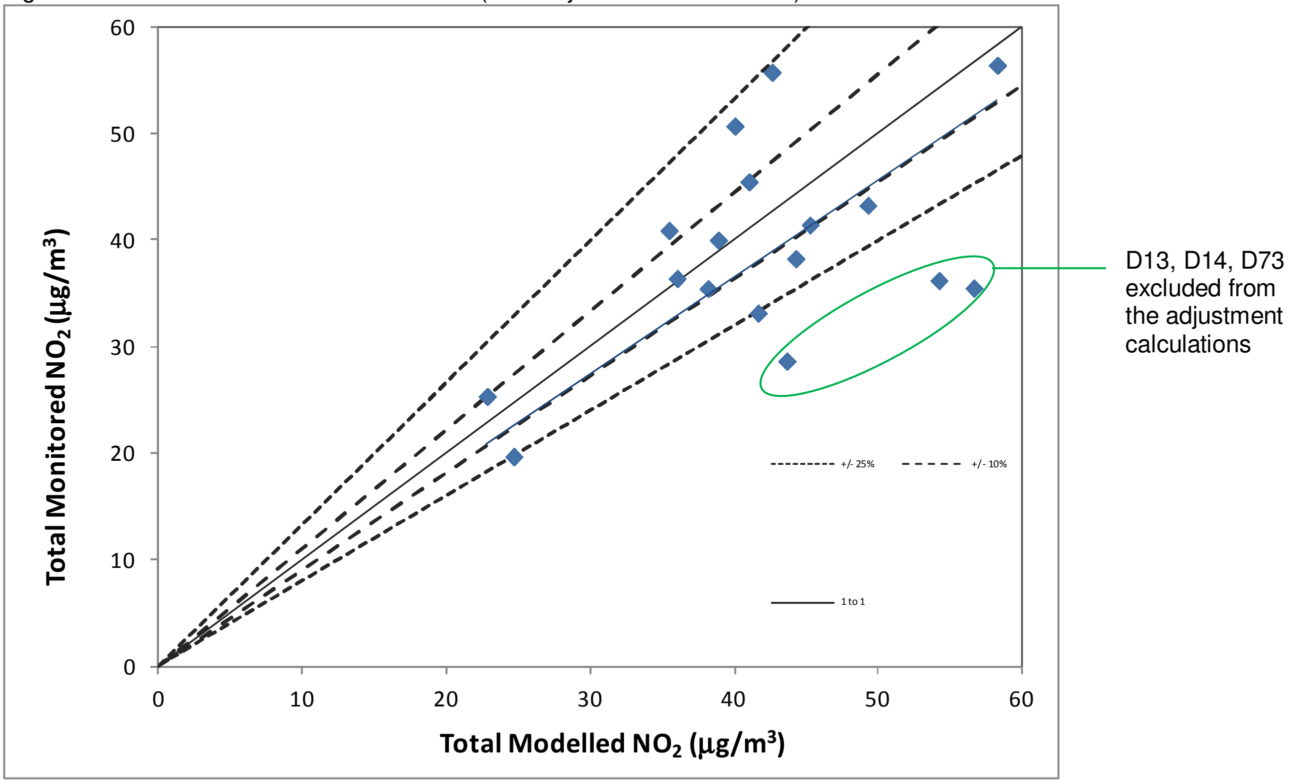


Table 16: Determination of the Adjustment Factor and Total Adjusted NO_2

Site ID	Adjusted Modelled Road Contribution NO_X	Adjusted Modelled Total NO_2	Monitored Total NO_2	% Difference [(mod-mon)/mon]
D7	45.9	38.2	35.5	8%
D14 [A]	100.5	56.6	35.5	59%
D10	55.1	41.7	33.2	26%
D12	53.3	41.0	45.5	-10%
D11	47.8	38.9	40.0	-3%
D13 [A]	60.6	43.6	28.7	52%
D43	50.7	40.0	50.7	-21%
D69	62.3	44.2	38.3	16%
D70	40.4	36.0	36.4	-1%
D71	106.0	58.3	56.4	3%
D72	76.9	49.3	43.3	14%
D73 [A]	92.5	54.2	36.2	50%
D75	10.4	22.8	25.4	-10%
D76	14.3	24.7	19.7	25%
D78	65.1	45.3	41.4	9%
D79	57.7	42.6	55.8	-24%
D80	39.1	35.5	40.9	-13%

Note: [A] Sites D13, D14 and D73 were excluded from the adjustment calculations as it is was not possible to account for these data in the adjustment, as shown by the very high positive % Difference.

Figure 7: Total Modelled and Monitored NO_2 (after adjustment of road NO_X)



Statistical Analysis

The data in Table 12 indicate the statistical confidence attributed to the model. The data show that the verification significantly improves the accuracy of the model, with a resultant RMSE of +/- 6.2 µg/m^3.

This range is shown in the plots (Appendix F) to define the extent of the areas of exceedence.

Table 17: Statistical Analysis of Model

	Ideal Value	Unverified	Verified
Correlation coefficient	1	0.78	0.79
RMSE	0	16.09	6.20
fractional bias	0	0.42	-0.01

Appendix E: Extent of Existing AQMA

Figure 8: Extent of Existing AQMA

Appendix F: Plotted Model Outputs

Figure 9: Predicted Annual Mean NO_2, western end of the declared AQMA in Durham city to Crossgate Lights

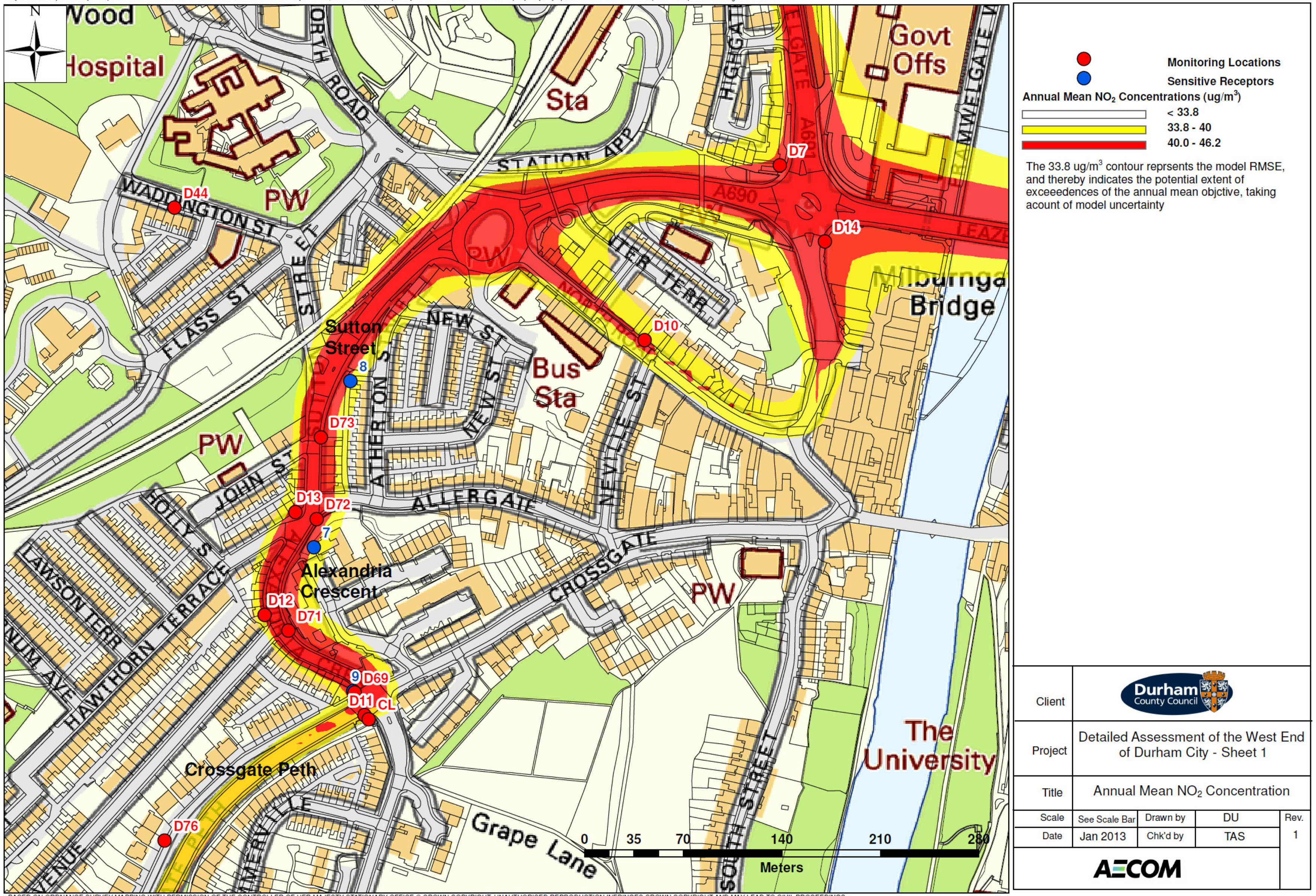


Figure 10: Predicted Annual Mean NO_2, east side of Nevilles Cross to Crossgate Lights

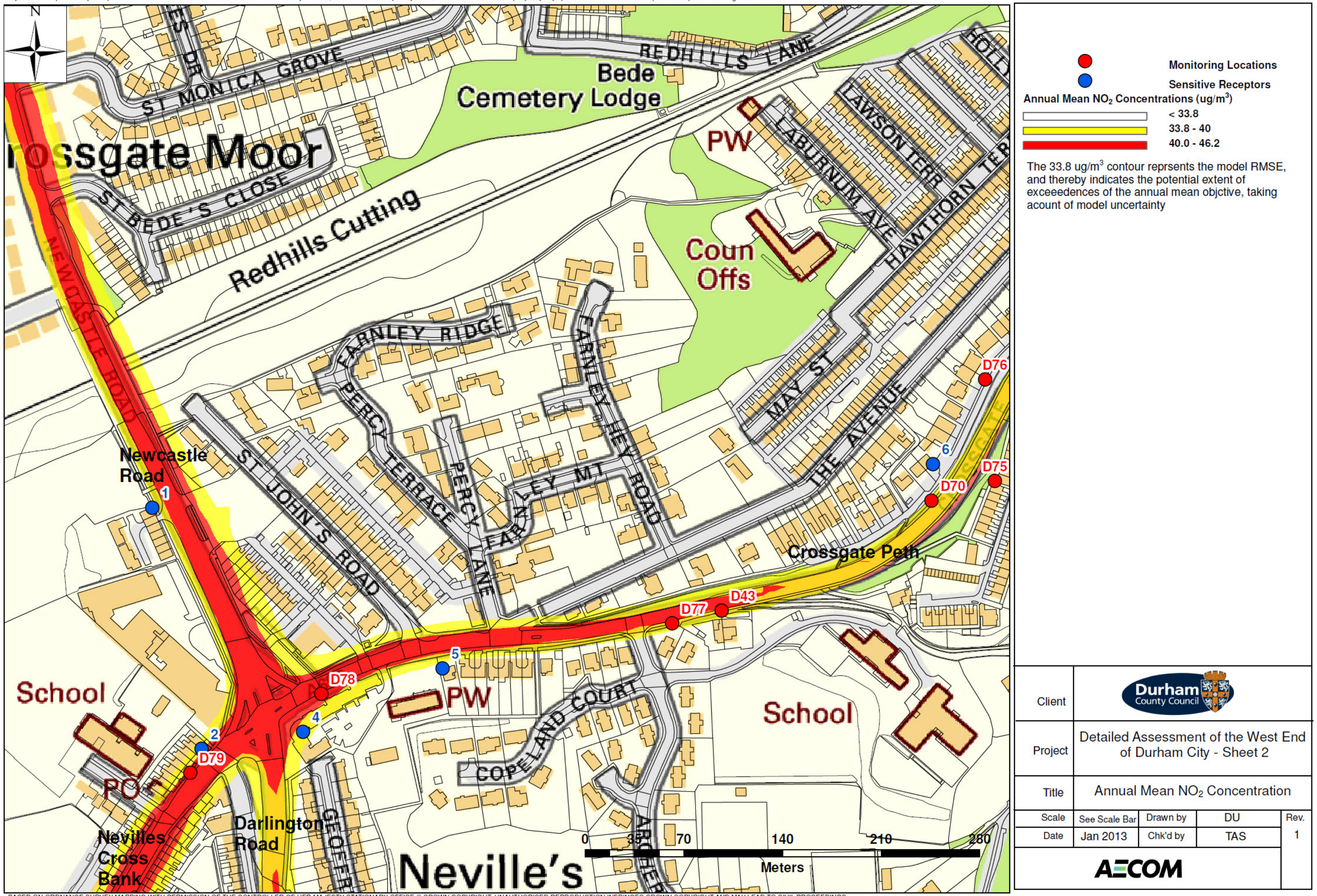


Figure 11: Predicted Annual Mean NO_2, Nevilles Cross (Including the junction of Darlington Road and Newcastle Road) to the western extent down Nevilles bank to Stonebridge Roundabout