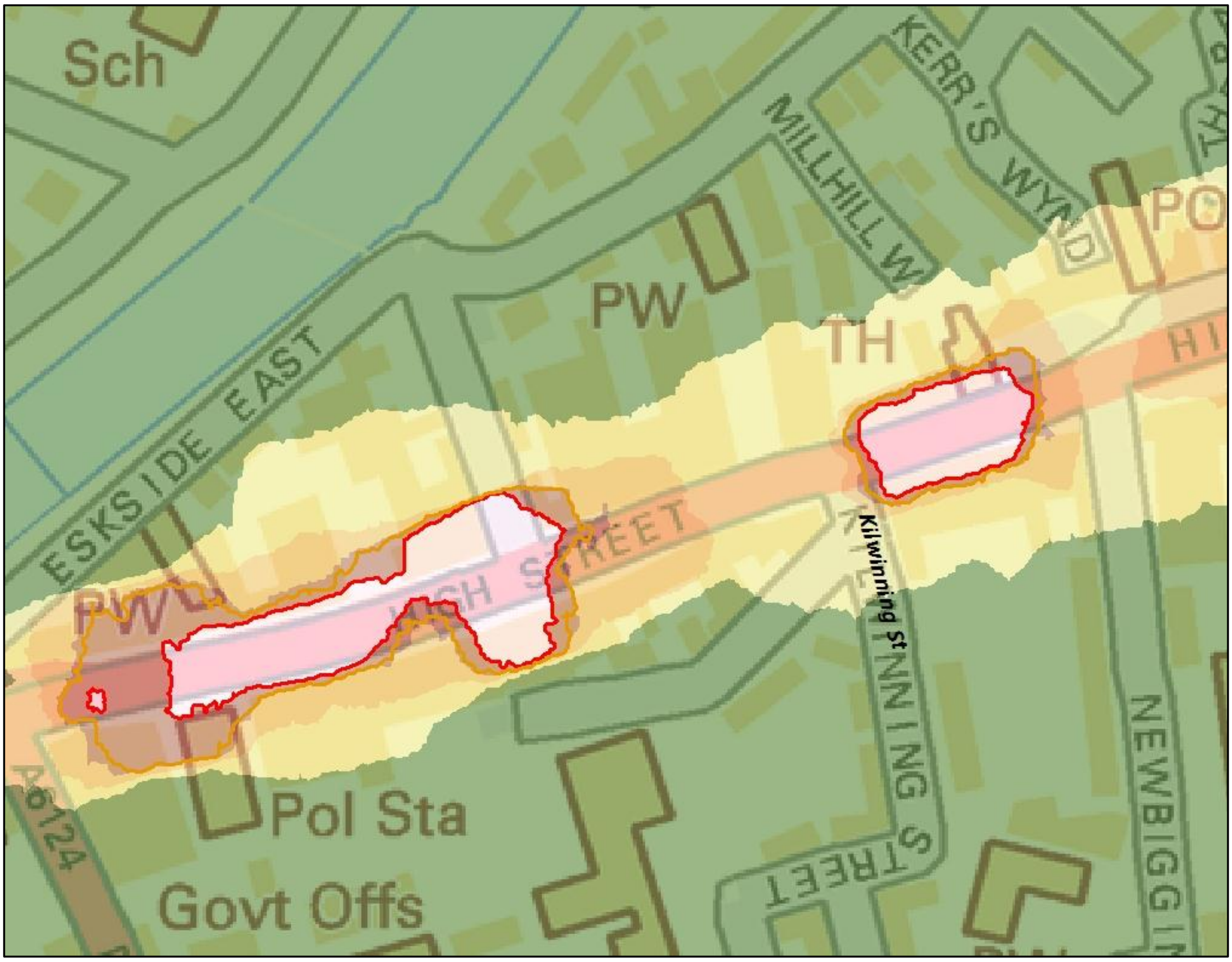
Air Quality Further Assessment for Musselburgh



Report for East Lothian Council

Ricardo-AEA/R/3424
Issue 1
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Contact:

Stephen Stratton

2nd Floor, 18 Blythswood Square, Glasgow, G2 4BG
t: 01235 75 3072
e: @ricardo-aea.com
Ricardo-AEA is certificated to ISO9001 and ISO14001

Author:

Stephen Stratton

Approved By:

Dr Scott Hamilton

Date:

19/06/2014

Ricardo-AEA reference:

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Executive summary

Over recent years it has been identified that the annual mean NO_2 objective is being exceeded in the area of High Street, Musselburgh and as a result, an AQMA has been declared. The AQMA encompasses the High St between Bridge St in the West and Newbigging St in the East. The 2012 Detailed Assessment also highlighted that the measured concentrations of NO_2 were also above the annual mean objective of 40 µg m^{-3} during the study period.

This study is a Further Assessment, which aims to revisit the findings of the previous Detailed Assessment, and carry out source apportionment and mitigation scenario modelling to satisfy Further Assessment requirements.

This Further Assessment considers the High Street in Musselburgh.

In this Further Assessment concentrations of NO_2 have been assessed in East Lothian Council's Musselburgh AQMA for 2012. A combination of available monitoring data and a dispersion modelling techniques using ADMS-Roads were used throughout the study. The study took account of traffic conditions in each area and meteorological data available for the specified study period.

The study has confirmed the findings of the previous Detailed Assessment, namely that there are exceedences of the annual mean NO_2 objective where relevant exposure exists. The contour plots prepared for this study indicate that the current AQMA boundary includes all relevant sources and does not require revocation or amendment at this time.

In the High St AQMA approximately 24 buildings consisting of approximately 31 residential properties were estimated to lie within the 40 µg m^{-3} contour, equating to an exposed population of around 69.

It is estimated that ambient NOx reductions in the AQMA of between 0% and 27% are required in order to achieve compliance with the annual mean NO_2 objective.

The source apportionment exercise indicates that emissions from buses form the largest contribution at all locations along the High St AQMA. The largest proportion that can be attributed to emissions from buses is seen at 147 High St with 38% of the NOx emissions estimated to be as a result of moving and queuing buses, and buses at bus stops. On average throughout the AQMA, 29% of NOx emissions can be attributed to bus activity.

In the case of moving versus queuing traffic, queuing traffic contributes the largest proportion at all locations except 87 High St. The largest proportion that can be attributed to queuing traffic is seen at 69 High St with 57% of the total NOx emissions estimated to be as a result of queuing traffic. On average throughout the AQMA, 34% of the total NOx emissions can be attributed to queuing traffic.

Modelling of the mitigation scenarios agreed with the Council indicates that an integrated package of interventions would provide the best NOx reductions. Measures that reduce overall traffic, reduce queuing and reduce bus numbers, where appropriate, will reduce road NOx significantly. These measures are however very challenging (both financially and technically) to implement.

The monitoring and dispersion modelling carried out to support this Further Assessment indicate that the NO_2 annual mean objective is still being exceeded within the High Street, Musselburgh AQMA. That said, the boundary of the AQMA is appropriate and does not require revocation or amendment at this time.

This report has been prepared for East Lothian Council by a third party. East Lothian Council accept and take ownership of its findings.

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1 Introduction

1.1 National Air Quality Strategy

All local authorities (LAs) are obliged to review and assess air quality under the Environment Act 1995. A requirement of the Act was that the UK Government prepares an Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland. The AQS was published in January 2000 with a revised version published in July 2007.

Within the AQS, national air quality objectives are set out and LAs are required to review and assess air quality against these objectives. Table 1.1 lists the objectives for NO_2 that are included in Regulations for the purposes of Local Air Quality Management (LAQM) with dates they should be achieved.

Table 1.1 Objectives Included in the Air Quality Regulations and Subsequent Amendments for the Purpose of Local Air Quality Management.

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Nitrogen dioxide	200 µg m^{-3} not to be exceeded more than 18 times a year	1 hour mean	31.12.2005
	40 µg m^{-3}	annual mean	31.12.2005

1.2 Purpose of the Detailed Assessment

This study aims to assess the magnitude and spatial extent of any exceedences of the air quality objectives for NO_2 in the vicinity of High Street, Bridge Street and North High Street, Musselburgh, East Lothian.

1.3 Locations where the Air Quality Objectives Apply

When carrying out the review and assessment of air quality it is only necessary to focus on areas where the public are likely to be regularly present and are likely be exposed over the averaging period of the objective.

Table 1.2 summarises examples of where air quality objectives for NO_2 should and should not apply.

Table 1.2 Examples of Where the NO_2 Air Quality Objectives Should and Should Not Apply

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
Annual mean	NO_2	All locations where members of the public might be regularly exposed. Building façades of residential properties, schools, hospitals, care homes etc.	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties. Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
1 hour mean	NO_2	All locations where the annual mean and 24 and 8-hour mean objectives apply. Kerbside sites (e.g. pavements of busy shopping streets). Those parts of car parks and railway stations etc. which are not fully enclosed. Any outdoor locations to which the public might reasonably be expected to have access.	Kerbside sites where the public would not be expected to have regular access.

1.4 Overview of the Approach Taken

The general approach taken to this further assessment was to:

- Collect and interpret data from previous review and assessment reports;
- Collect and analyse all available traffic data, air quality monitoring data and background concentration data for use in the models;
- Identify potential hotspots where it is likely that the AQS objectives would not be met;
- Model NO_2 concentrations throughout the study area;
- Produced contour plots of the modelled pollutant concentrations;
- Recommend whether East Lothian Council should retain, revoke or amend the AQMAs previously declared;
- Perform a source apportionment analysis; and
- Test proposed mitigation scenarios to inform air quality improvement interventions.

The methodologies outlined in Technical Guidance LAQM.TG(09)[1] were used throughout this Further Assessment.

This Further Assessment includes the modelling of agreed scenarios, source apportionment and required reduction in NO_2 calculations. The report will focus on the NO_2 annual mean objective.

Previous research carried out on behalf of Defra and the Devolved Administrations identified a relationship between the annual mean and the 1-hour mean objective, such that exceedances of the latter were considered unlikely where the annual mean was below 60 µg m^{-3}. The report identified the need to re-evaluate the monitoring data from time to time in order to confirm that this relationship remained appropriate.

There are no areas in the AQMAs where concentrations of this magnitude are expected at locations with relevant exposure hence we focus on the annual mean objective.

1.5 Conclusions of Previous Reports for NO_2

Four Air Quality Review and Assessment rounds have now been completed by east Lothian Council. Table 1.3 summarises the conclusions for NO_2 from assessments carried out in rounds 2 to 4 between 2004 and 2011.

[1] Local Air Quality Management Technical Guidance LAQM.TG(09), Defra, 2009

Table 1.3 Conclusions from previous Air Quality Review and Assessment Reports

Review and Assessment Round	Reports	Conclusions
2	Updating and Screening Assessment 2004[2] Detailed Assessment 2005[3] Progress Report 2005[4]	It was identified the exceedences of the NO_2 objectives could occur in the Musselburgh area, which was mainly due to road traffic sources. The subsequent Detailed Assessment concluded that it was unlikely that NO_2 concentrations would exceed the strategy objectives.
3	Updating and Screening Assessment 2006[5] Progress Report 2007[6] Progress Report 2009[7]	It was concluded that it was unlikely that the NO_2 objectives had been exceeded during this round.
4	Updating and Screening Assessment 2009[8] Progress Report 2010[9] Detailed Assessment 2010[10] Progress Report 2011[11]	It was concluded in 2009 that a Detailed Assessment for both NO_2 and PM_{10} was required to assess the possible air quality impacts of a biomass boiler installed at Queen Margaret University. The Detailed Assessment concluded that it was unlikely that the objectives for both PM_{10} and NO_2 would be exceeded as a result of emissions from the biomass boiler. The conclusion of the 2011 Progress Report, however, concluded that it was likely that the annual mean objective for NO_2 had been exceeded at two locations; 147 and 183 High St, Musselburgh. As a result it was recommended that a Detailed Assessment of NO_2 concentrations should be carried out in the area of the High Street, Musselburgh.
5	Detailed Assessment 2012[12] Updating and Screening Assessment 2012[13] Progress Report 2013[14]	The Detailed Assessment indicated that the annual mean objective for NO_2 was likely to have been exceeded at 4 receptors on High St and 3 receptors on Bridge St. It was noted that the highest annual average NO_2 concentrations were predicted receptors located close to bus stops and that the majority of the predicted annual mean exceedences are marginal. An element of uncertainty has been introduced to the model as a result of estimating emissions from both queuing traffic and stationary buses. Therefore it would be appropriate to carry out monitoring of NO_2 at a representative sample of exceeding receptors to confirm the results of this modelling assessment. This would greatly enhance the reliability of the forthcoming Further Assessment and allow better delineation of any required Air Quality Management Area (AQMA) boundary. Passive monitoring of NO_2 in Musselburgh and the results of a Detailed Assessment of NO_2 due to road traffic sources in Musselburgh that was completed in June 2012 continue to indicate concentrations at various locations that are close to the Annual Mean

[2] Local Air Quality Management: Updating and Screening Assessment, Enviros Consulting Ltd, March 2004 Available from http://www.eastlothian.gov.uk/download/meetings/id/3669/04_environment_act_1005-local_air_quality_management_road_traffic_vehicle_emissionsfixed_penaltyscotland_regulations_2003 [Accessed on 02/04/2012]
[3] Local Air Quality Management: Detailed Assessment, East Lothian Council, April 2005
[4] Local Air Quality Management: Progress Report East Lothian Council, August 2005 [Online] Available from http://www.eastlothian.gov.uk/downloads/file/526/air_quality_leaflet [Accessed on 02/04/2012]
[5] Local Air Quality Management: Updating and Screening Assessment, East Lothian Council, August 2006
[6] Local Air Quality Management: Progress Report East Lothian Council, July 2007
[7] Local Air Quality Management: Progress Report East Lothian Council, February 2009
[8] Local Air Quality Management: Updating and Screening Assessment, East Lothian Council, August 2006
[9] Local Air Quality Management: Progress Report East Lothian Council, October 2010
[10] Air Quality Assessment: Queen Margaret University Biomass Boiler, AEA, October 2010
[11] Local Air Quality Management: Progress Report East Lothian Council, June 2011
[12] Air Quality Detailed Assessment for Musselburgh, AEA, AEAT/ENV/R3281, June 2012
[13] Local Air Quality Management: Updating and Screening Assessment, East Lothian Council, November
[14] Air Quality Progress Report for East Lothian Council, East Lothian Council, August 2013

		Objective. It was considered appropriate by East Lothian Council to carry out passive monitoring of NO_2 at a representative sample of these exceeding receptor locations to confirm the results of the modelling assessment. East Lothian Council started monitoring NO2 concentrations at 5 new locations on Musselburgh Bridge Street and High Street on 3rd May 2012 using passive diffusion tubes. These new monitoring sites are located at receptors 167 High Street (Tube No 29), 137 High Street (Tube No 30), 69 High Street (Tube No 31), 86 High Street (Tube No 32) and 15 Bridge Street Tube No 28). East Lothian Council should consider the declaration of an AQMA for the NO2 annual mean objective after submission of the next LAQM Report, the 2013 Progress Report, due for submission by the end of April 2013 if monitoring results obtained from new locations, in addition to existing monitoring locations, confirms the modelling results that the NO2 annual mean objective has been exceeded. The 2013 Progress Report concluded that with the additional monitoring carried out no exceedednces of the annual mean NO2 objective were measured on Bridge St. However further exceedences were measured at 167 and 69 High St. As a result of these exceedences and the Deatailed Assessment an AQMA will be declared in Musselburgh.

2 Study Location

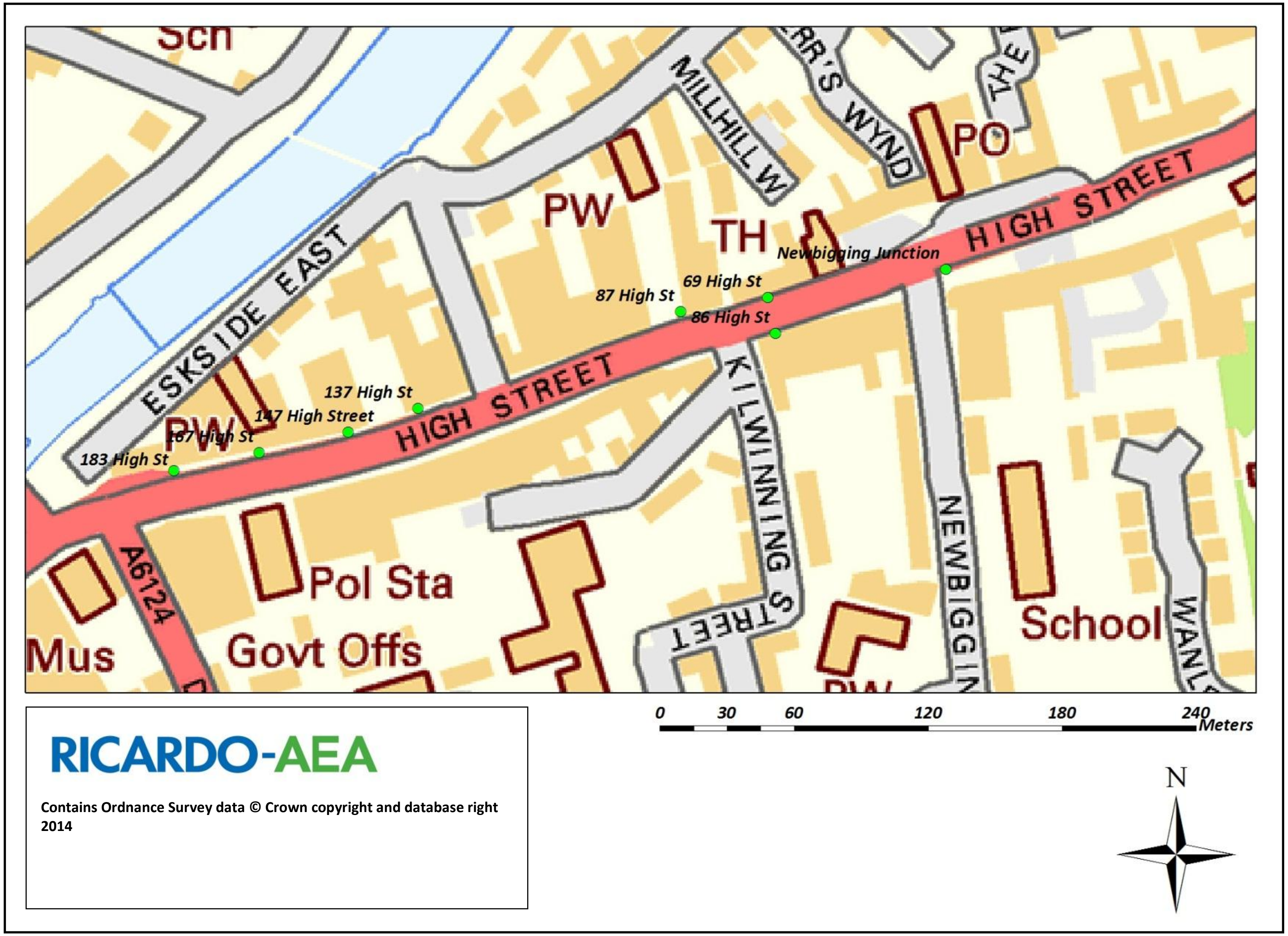
Musselburgh is located 6 miles east of Edinburgh on the south shore of the Firth of Forth in Scotland at the mouth of the River Esk. The town has a population of approximately 22,000 and, administratively, it is within the council region of East Lothian, which covers an area of approximately 679 km^2 with a total population of approximately 90,000.

This Detailed Assessment has been carried out as a result of the conclusions outlined in the 2011 Progress Report. Although previous reports indicated possible exceedences of the annual average NO_2 objective at only two locations on High Street (147 and 183), the view was taken to model NO_2 concentrations on three roads; High Street, Bridge Street and North High Street in order that the automatic monitoring site and additional diffusion tube sites could be used to verify the model. Figure 2.1 shows the study area and includes locations of the NO_2 monitoring sites with the automatic monitoring being located at 133 North High Street.

The assessment estimates NO_2 concentrations in the area of the A199; High Street. The A199 is a busy trunk road that runs 30 miles from Leith in the north of Edinburgh to the A1 in the East (approximately 2 miles west of Dunbar). The study area comprises of a mixture of commercial and residential, two to four storey properties. The majority of commercial properties are located at ground level with residential properties being located at first floor level and above.

A consequence of the multi-storey buildings is the existence of street canyons within the model area.

Figure 2.1 Study Area for the Detailed Assessment

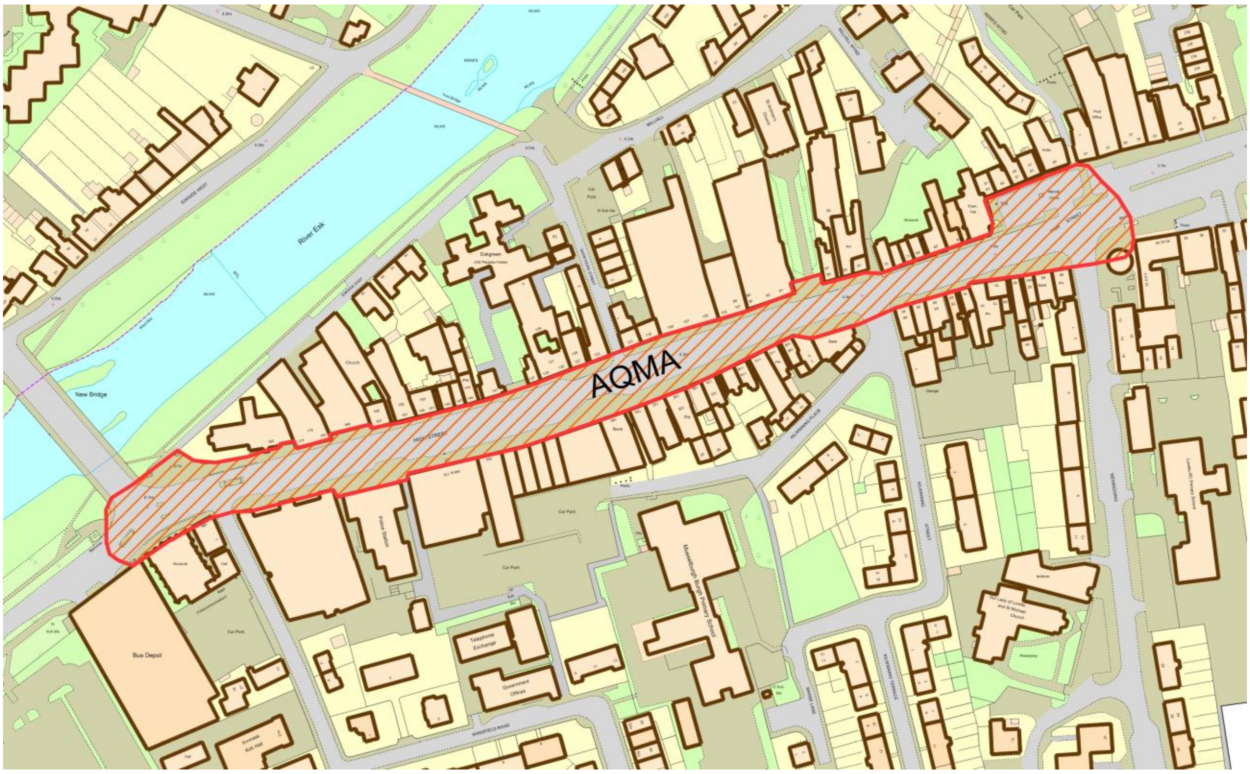


2.1 AQMA Location

East Lothian Council declared an AQMA encompassing High Street, Musselburgh in November 2013. The AQMA boundary is shown in Figure 2.2 below.

This assessment allows the findings of the recent Detailed Assessment to be checked in light of new monitoring and traffic data, and also to assess the appropriateness of the AQMA boundary shown below.

Figure 2.2 AQMA - High Street, Musselburgh (Newbigging to The Mall)



3 Information Used to Support this Assessment

3.1 Maps

East Lothian Council provided OS Landline data of the model domain. This enabled accurate road widths and the distance of the housing to the kerb to be determined in the GIS system.

3.2 Road Traffic Data

3.2.1 Average Flow, peed and Fleet Split

The base year of 2012 was used for this assessment. Automatic traffic counts were carried out at two locations on High St for a period of one week during October 2013. Both vehicle type and speed were recorded. Queue data were not available for the study area and as a result, professional judgement has been used to estimate traffic patterns with estimates of traffic queues.

Table 3.1 summarises annual average daily traffic flows (AADF) used for this study. A more detailed breakdown of the traffic data, including speeds and queuing, is detailed in Appendix 1.

Table 3.2 Annual Average Daily Flow (AADF) - Musselburgh

Street	Road Type	AADF
High Street	Principal Urban	14,989

3.2.2 Emissions Factors

The most recent version of the Emissions Factors Toolkit[15] (EfT V5.2c) was used in this assessment and the factors derived were used in the ADMS-Roads. Parameters such as traffic volume, speed and fleet composition are entered into the EfT tool and an emissions factor in grams of NOx/kilometre/second (g km^{-1} s^{-1}) is generated for input into the dispersion model. The version of the EfT used incorporates the latest emission factors published in 2009 by Department for Transport.

3.3 Ambient Monitoring

3.3.1 Nitrogen Dioxide

Concentrations of NO_2 are monitored at sites throughout East Lothian using diffusion tubes. Eight of these sites lie within the area modelled in this assessment, as shown in Figure 2.1. Details of the type, locations, and concentrations measured by the diffusion tubes are given in Chapter 4. A triplicate diffusion tube site is co-located with an automatic monitoring site at 133 North High Street.

[15]Department of Transport, Emission Factor Toolkit (Version 5.2c), January 2013 [Online]
Available at http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft [Accessed on 11/11/2012]

4 Monitoring - NO_2

4.1 New Monitoring Data

East Lothian Council monitors NO_2 using diffusion tubes at 8 locations within the area of interest. Automatic monitoring of NO_2 is also carried out at one location within the study area; at 133 North High Street.

A summary of relevant monitoring data for 2012 are presented in Table 4.1. A data capture rate of 100% or greater was achieved at four diffusion tube sites. The remaining diffusion tube sites located at numbers 167, 137, 69 and 86 High St were commissioned in May 2012 and therefore only achieved a data capture rate of 67%. For these sites the data were annualised using the approach as detailed in Technical Guidance LAQM.TG(09). Three automatic monitoring sites were used to determine an adjustment factor; Bush, East Lothian Musselburgh N High St and Edinburgh St Leonards. In this case an adjustment factor of **1.03** was calculated and used to annualise the diffusion tube data (Table 4.2).

All diffusion tube data have been adjusted using a locally derived bias adjustment factor. The annual average NO_2 concentration measured by the co-located tubes was 31 $\mu g\ m^{-3}$ with the automatic analyser measuring 24 $\mu g\ m^{-3}$. These data from the co-located triplicate diffusion tube monitoring site and automatic monitoring site were used with to calculate a local bias adjustment factor of **0.8**.

All monitoring sites can be described as relevant exposure sites. The measurements results indicate that exceedences of the annual mean objective of greater than 40 $\mu g\ m^{-3}$ were measured at 147, 167 and 69 High St with measured annual mean NO_2 concentrations of 43, 42 and 47 $\mu g\ m^{-3}$. Concentrations approaching the annual mean objective were measured at 183 High St, with a measured annual average NO_2 concentration of 39 $\mu g\ m^{-3}$.

As detailed in Technical Guidance LAQM.TG(09), Page 2-8, the NO_2 hourly mean objective is unlikely to have been exceeded if the measured annual mean concentration is less than 60 $\mu g\ m^{-3}$. It is therefore concluded that it is unlikely that the NO_2 hourly mean objective has been exceeded at any monitoring location during 2012.

Table 4.1 Monitoring Data Collected in Musselburgh 2012

Site	Type	Relevant Exposure	OS Coordinates		Data Capture 2012 (%)	Bias Adjusted Annual mean, F = 0.8 ($\mu g\ m^{-3}$)	Annualised Annual Mean, F = 1.03 ($\mu g\ m^{-3}$)
			x	y			
Newbigging Junction	R	Y	334659	672720	100	30	-
87 High St	R	Y	334526	672700	100	25	-
147 High Street	R	Y	334392	672652	100	43	-
183 High St	R	Y	334301	672632	100	39	-
167 High St	R	Y	334354	672643	67	42	43
137 High St	R	Y	334427	672664	67	34	35
69 High St	R	Y	334580	672713	67	47	48
86 High St	R	Y	334578	672695	67	32	33

Table 4.2 Adjustment Factor Calculation for Annualising 2012 Data

Site	Annual Mean NO_2 Concentration (A_m) 2012 (µg m^{-3})	Period Mean NO_2 Concentration (Pm), 01/05/12 – 31/12/12 (µg m^{-3})	Adjustment Factor, A_m/P_m
Bush	6	6	1.00
East Lothian Musselburgh N High St	24	23	1.04
Edinburgh St Leonards	24	23	1.04
		Average Adjustment Factor:	1.03

5 Modelling- NO_2

5.1 Modelling Methodology

Annual mean concentrations of NO_2 for 2012 have been modelled within the study area using ADMS Roads (version 3.1).

The model was verified and the outputs were adjusted by comparing the modelled predictions for road NO_x with local monitoring results. In this case, the modelled results were compared to the results gathered by the seven diffusion tube sites; the Mall Avenue site was excluded due to insufficient traffic count data for that Road.

The street canyon module within ADMS was used to model NO_2 concentrations within identified street canyons. This module models building downwash and resultant recirculation of pollutants within a street canyon.

Queuing traffic was modelled using the methodology detailed in CERC note[16] 60, which assumes queuing traffic is moving at 5 km h^{-1}, the average vehicle length is 4 m and a representative annual average daily flow for the queue is 30,000 vehicles. A time varying emissions profile was then set up to model the diurnal profile of the queues. In addition, CERC note[17] 51 was used for estimating emissions from stationary buses at bus stops. Buses were treated as volume sources combined with an estimate of hourly counts within ADMS. It was estimated from bus timetables that the majority of the bus services were operating for 16 hrs per day, Monday to Saturday, with half the bus numbers running on Sundays for 14 hrs per day. Both the methods for estimating emissions from queuing traffic and stationary buses will introduce an element of uncertainty to the model.

Concentrations of NO_2 were modelled at a height of 1.5 m, to better reflect concentrations at a height at which they are inhaled, and at 4 m to predict concentrations at relevant receptors located at first floor level.

Hourly sequential meteorological data for 2012 from the Edinburgh Gogarbank meteorological site was used, located approximately 15 km west of the study area. A wind rose of average wind speed and direction during 2012 is shown in Appendix 3.

A surface roughness of 1.0 m was used in the modelling and a limit for the Monin-Obukhov length of 30 m was applied to represent the large town.

The intelligent gridding option was used in ADMS-Roads, which provides spatially resolved concentrations along the roadside, with a wider grid spaced at approximately 30 m being used to represent concentrations further away from the road. These predictions were added to ArcGIS 10 and values between grid points are derived using interpolation in the Spatial Analyst tool. This allows contour concentrations to be produced and added to the base map provided by East Lothian Council. ***It should be noted that the contour plots presented in this document are only an indication of the spatial distribution of NO_2. This is due the inherent uncertainty introduced by any interpolation technique.***

Background concentrations of oxides of nitrogen (NOx) were derived from the Scottish Government background maps[18]. A csv file containing concentrations across East Lothian Council was obtained and the appropriate grid square was selected with the appropriate concentration for the assessment. In this case, a mapped NOx background concentration of 33.7 µg m^{-3} was used in this assessment

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[16] Cambridge Environmental Research Consultants Ltd, Modelling Queuing Traffic – note 60, 20th August 2004
[17] Cambridge Environmental Research Consultants Ltd, Modelling Bus Stops – note 51, 29th January 2004
[18] Scottish Backround Maps,Scottish Government [Online]
Available at http://www.scottishairquality.co.uk/maps.php?n_action=data [Accessed on 02/04/2012]

from grid square (334500, 672500). All A-road contributions from within the grid square were removed in order to prevent double counting of emissions within the model.

5.1.1 Treatment of Modelled NOx Road Contribution

It is necessary to convert the modelled NOx concentrations to NO_2 for comparison with the relevant objectives. The Defra NOx/NO_2 model[19] was used to calculate NO_2 concentrations from the NOx concentrations predicted by ADMS-Roads. The model requires input of the background NOx, the modelled road contribution and the proportion of NOx released as primary NO_2. For the purposes of this assessment we have assumed that 22.9% of NOx is released as primary NO_2 - the value associated with the "UK Traffic" option in the model. Additionally, the NO_x/NO_2 model has also been used to convert the monitored NO_2 back to NOx to allow comparison of modelled and monitored NOx.

5.1.2 Validation of ADMS-Roads

In simple terms, validation of the model is the process by which the model outputs are tested against monitoring results at a range of locations and the model is judged to be suitable for use in specific applications.

CERC have carried out extensive validation of ADMS applications by comparing modelled results with standard field, laboratory and numerical data sets, participating in EU workshops on short range dispersion models, comparing data between UK M4 and M25 motorway field monitoring data, carrying out inter-comparison studies alongside other modelling solutions such as DMRB and CALINE4, and carrying out comparison studies with monitoring data collected in cities throughout the UK using the extensive number of studies carried out on behalf of local authorities and DEFRA.

5.1.3 Verification of the Model

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. LAQM.TG(09) recommends making the adjustment to the road contribution only and not the background concentration these are superimposed onto. The approach outlined in Examples 2 and 3 beginning on Page A3-48 of LAQM.TG(09) has been used, and correction factors were calculated and applied to all modelled data.

The model generated in this study was verified using 8 monitoring sites within the study area. The comparison of monitored against modelled NOx revealed that the model required adjustment when compared with the local measurements. This primary adjustment factor was calculated to be **1.3014**.

Adjusting modelling data to diffusion tubes will always be subject to uncertainty due to the inherent limitations in such monitoring data (even data from continuous analysers has notable uncertainty). The model agrees well with available local monitoring without a primary adjustment and has therefore been assessed to perform sufficiently well for use within this assessment.

A secondary adjustment factor has been determined in order to take account of the error introduced by converting NOx to NO_2 using the DEFRA NOx/NO_2 tool. The secondary adjustment factor was calculated to be **1.0198**. Further information on the verification process is available in Appendix 3.

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[19] NO_x to NO_2 calculator, Defra [Online]
Available at http://laqm.defra.gov.uk/tools-monitoring-data/no-calculator.html [Accessed on 02/04/2012]

5.2 Modelling Results – NO_2

5.2.1 Numerical

Table 5.1 below shows the predicted modelled concentrations at each of the monitoring points in the model domain. As can be seen all model predictions are 10% or less from the measured NO_2 concentrations except for 86 High St. The model is deemed to have performed well if the root mean square error (RMSE) between the measured and modelled NO_2 concentrations is below 4 μg m^{-3} or 10% of the annual mean objective. As a result, this model has performed sufficiently well for the purposes of this Further Assessment with a calculated RMSE of 2.6 μg m^{-3}.

Table 5.1 Modelled/Measured NO_2 Concentrations in Model Domain After Adjustment

Site	Adjusted Modelled NO_2 Primary ADJ – 1.3014 Secondary ADJ – 1.0198	Measured	Difference (%)
Newbigging_Jnct	29	30	3.4
87_High_St	26	25	-3.8
147_High_St	45	43	-4.4
183_High_St	41	39	-4.9
167 High St	43	43	0.0
137 High St	38	35	-7.9
69 High St	46	48	4.3
86 High St	27	33	22.2
		NO_2 Root Mean Square Error (μg m^{-3})	**2.6**

In addition to predicting NO_2 annual mean concentrations at monitoring locations for verifying the model, further investigation is required to assess predicted concentrations at relevant receptors (discussed in Section 1.3). For the purposes of this assessment relevant receptors have been selected from ***High Street (A199).***

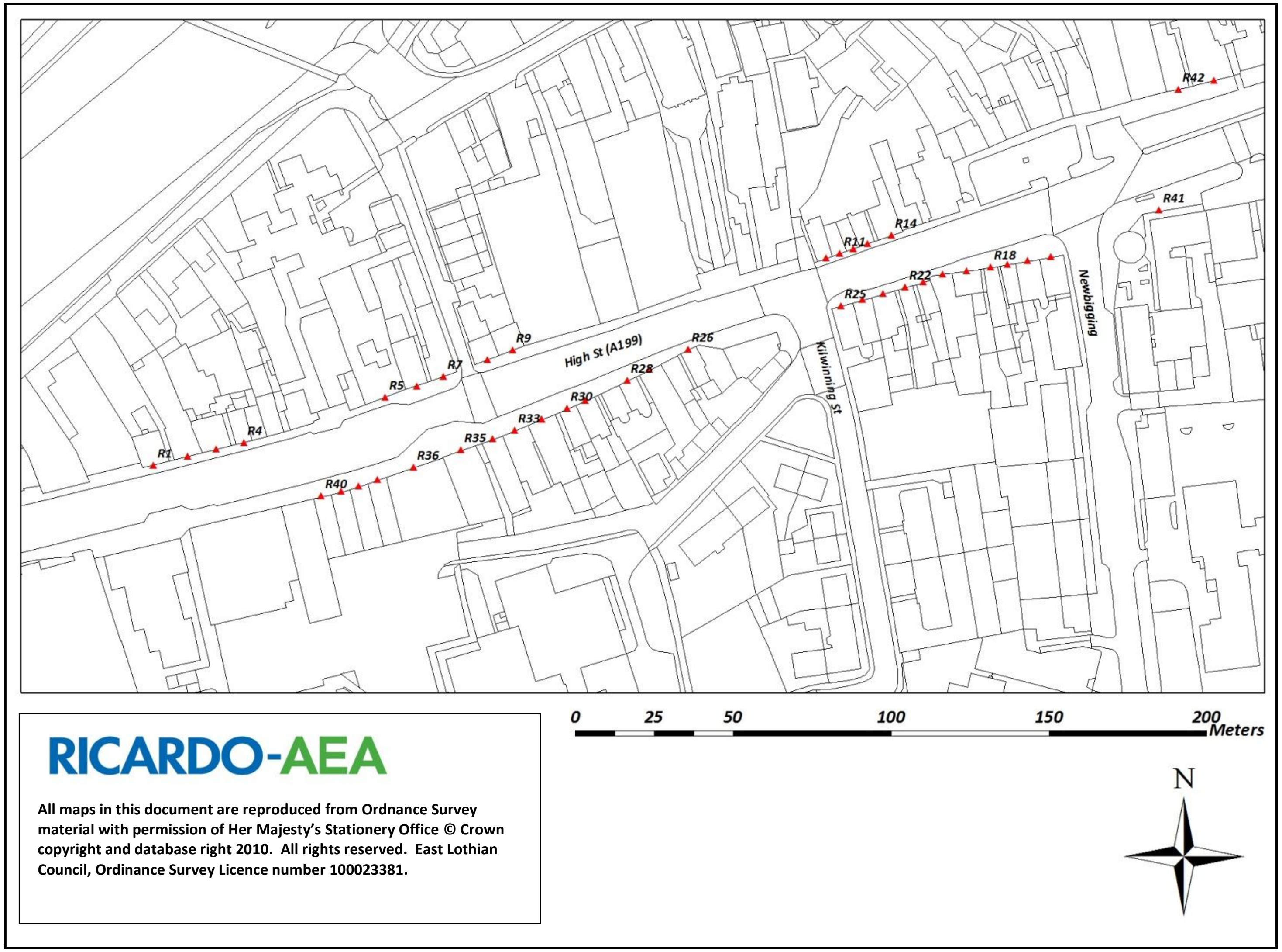
Table 5.2 details the modelled annual mean NO_2 concentrations at all receptor locations on High St, Musselburgh. Figure 5.1 shows the receptor locations within the context of the model domain. Not all relevant receptors existing close to the roads listed above have been detailed, but a spread of receptors has been used in order to assess the spatial distribution of any proposed Air Quality Management Area (AQMA).

As can be seen in the above table, likely exceedences of the annual mean NO_2 objective have been predicted at 11 receptors during 2012 (R1, R3, R4, R6, R7, R10 – R14 and R25. The highest predicted annual mean concentration modelled on High Street was 53 μg m^{-3} at receptor R7. Annual average NO_2 concentrations approaching the AQS objective have also been predicted at R2, R8, R9 and R16 with predicted annual mean concentrations of 37 - 40 μg m^{-3}.

Table 5.2 Modelled NO_2 Concentrations at Specified Receptors, High St, Musselburgh

Receptor Name	OS Coordinates			Adjusted Modelled Annual Average NO_2 Concentration ($\mu g\ m^{-3}$)
	x	y	z	
R1	334353.7	672642.6	4	**43**
R2	334364.6	672645.3	4	**40**
R3	334373.6	672647.6	4	**42**
R4	334382.3	672649.7	4	**43**
R5	334427.1	672664	4	35
R6	334437.1	672667.6	4	**47**
R7	334445.6	672670.6	4	**53**
R8	334459.5	672675.9	4	**38**
R9	334467.3	672678.9	4	**37**
R10	334566.7	672708	4	**46**
R11	334571.1	672709.6	4	**46**
R12	334575.3	672711	4	**46**
R13	334579.9	672712.7	4	**46**
R14	334587.3	672715.3	4	**43**
R15	334637.9	672708.5	4	30
R16	334630.6	672707.3	4	**37**
R17	334624.2	672706.1	4	35
R18	334618.8	672705.2	4	34
R19	334611.3	672704.1	4	30
R20	334603.5	672703	4	32
R21	334597.4	672700.5	4	32
R22	334591.8	672698.9	4	32
R23	334584.7	672696.8	4	31
R24	334578.1	672694.9	4	30
R25	334571.4	672693	4	**46**
R26	334522.9	672679.2	4	27
R27	334510.6	672672.9	4	35
R28	334503.7	672669.3	4	27
R29	334490.4	672663	4	27
R30	334484.6	672660.4	4	27
R31	334476.6	672657.1	4	27
R32	334476.5	672657.1	4	27
R33	334468	672653.6	4	28
R34	334461.1	672650.9	4	28
R35	334450.9	672647.4	4	28
R36	334436	672641.8	4	29
R37	334424.5	672638	4	31
R38	334418.6	672636	4	31
R39	334413.1	672634.3	4	32
R40	334406.8	672632.8	4	32
R41	334672.1	672723.2	4	33
R42	334678.3	672761.4	4	31
R43	334689.6	672764.2	4	32

Figure 5.1 Modelled Receptor Locations, Musselburgh 2012



5.2.2 Contour Plots

As discussed in previous sections, annual mean NO_2 concentrations were modelled at two heights, 1.5 m and 4 m. Figures 5.2 and 5.3 show the contour plots with predicted annual mean NO_2 concentrations on High Street at the two specified heights during 2012.

It has been confirmed by the monitoring and subsequent modelling that the 40 $\mu g\ m^{-3}$ annual average objective is likely to have been exceeded during 2012 at locations with relevant exposure. The contour plots have been prepared using the Kriging function in the Spatial Analyst extension of ArcGIS 10. Both 40 $\mu g\ m^{-3}$ and 36 $\mu g\ m^{-3}$ contours have been highlighted in the contour plots in order to give an indication of the possible extent of the exceedence area. These plots also confirm that the current AQMA boundary (Figure 2.2) is sufficient to cover all current sources that may result in an exceedence of the NO_2 annual mean objective in the area of High Street, Musselburgh.

Figure 5.2 Modelled Annual Average NO_2 Concentrations ($\mu g\ m^{-3}$) on High St at 1.5 m

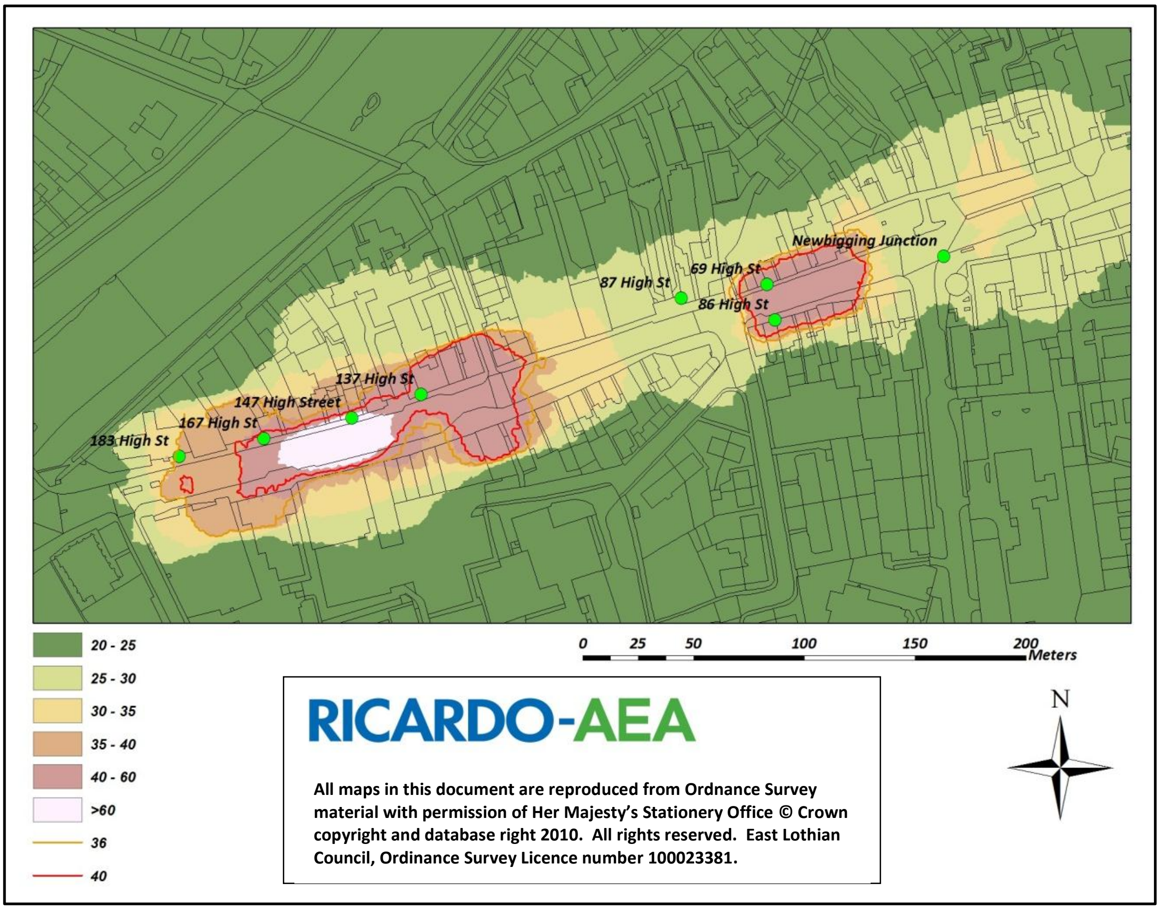
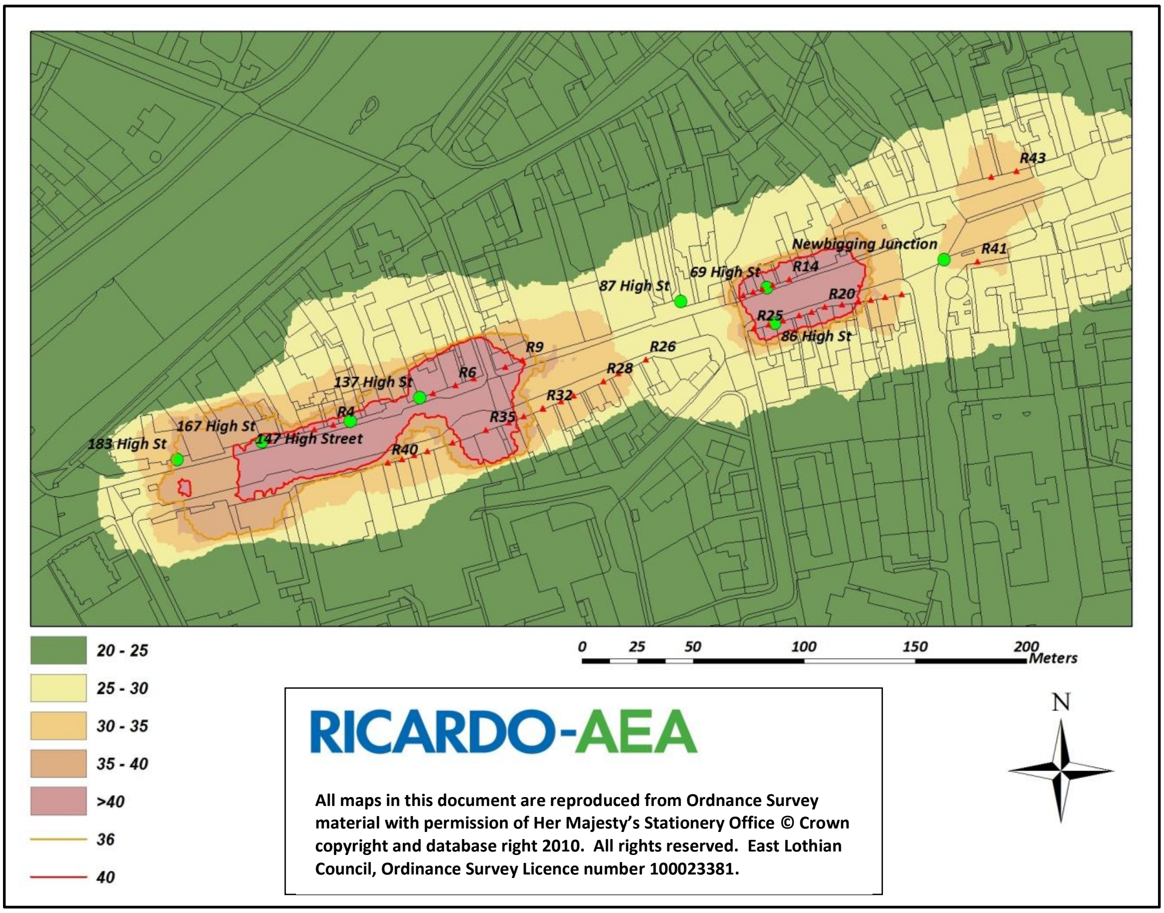


Figure 5.3 Modelled Annual Average NO_2 Concentrations ($\mu g\ m^{-3}$) on High St at 4 m



5.3 Population Exposure to Exceedences of the Annual Mean NO_2 Objective

A GIS analysis was carried out to estimate the number of properties within each of the AQMAs that were exposed to exceedences of the annual mean NO_2 objective during 2012.

In the High St AQMA approximately 24 buildings consisting of approximately 31 residential properties were estimated to lie within the 40 µg m^{-3} contour, equating to an exposed population of around 69 (based on census data which suggests an average occupancy per household of 2.23 in Scotland[20]).

[20] http://www.scotlandscensus.gov.uk/documents/censusresults/release1c/rel1c2tableA4.pdf

6 Source Apportionment

Source apportionment is the process whereby the sources of pollutants can be assessed so that the Local Authority can proceed with an action plan to attempt to address the air quality problems in the area of interest.

The source apportionment should:

- Confirm that exceedences of NO_2 are due to road traffic;
- Determine the extent to which different vehicle types are responsible for the emission contributions to NO_x and hence NO_2; and
- Quantify what proportion of total NO_x is due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedence or whether national measures would be a suitable approach to achieving the air quality objectives.

6.1 Locations and Sources Considered

The source apportionment exercise was carried out for all the Council's monitoring locations within the High St AQMA, Musselburgh.

The following sources have been considered:

- Background concentrations;
- Moving vehicles;
- Queuing vehicles;
- Light duty vehicles (LDV- comprising cars, vans, motorcycles);
- Heavy duty vehicles (HDV - articulated and rigid HGVs);
- Buses; and
- Buses at Bus Stops.

6.1.1 High Street AQMA

Table 6.1 and 6.2 summarise the relevant NOx contributions from the above sources at each of the monitoring locations in the Musselburgh High St AQMA. Figures 6.1 and 6.2 show the percentage contributions split by traffic source type and moving/queuing traffic, respectively.

The largest proportion that can be attributed to emissions from buses is seen at 147 High St with 38% of the NOx emissions estimated to be as a result of moving and queuing buses, and buses at bus stops. On average throughout the AQMA, 29% of NOx emissions can be attributed to bus activity.

In the case of moving versus queuing traffic, queuing traffic contributes the largest proportion at all locations except 87 High St. The largest proportion that can be attributed to queuing traffic is seen at 69 High St with 57% of the total NOx emissions estimated to be as a result of queuing traffic. On average throughout the AQMA, 34% of the total NOx emissions can be attributed to queuing traffic.

*Table 6.1 High St AQMA NOx Source Apportionment ($\mu g\ m^{-3}$)**

Location	Total NOx (a)	Road NOx (b)	Background (c)	Moving (d)	Queuing (e)	LDV (f)	HDV (g)	Bus (h)	Bus Stops (i)
Newbigging_Jnct	53.4	19.7	33.7	8.5	11.2	5.5	2.5	8.6	3.2
87_High_St	47.1	13.4	33.7	7.3	6.1	5.0	1.3	6.9	0.3
147_High_St	90.2	56.5	33.7	6.5	50.0	18.1	4.6	29.7	4.1
183_High_St	80.6	46.9	33.7	14.3	32.6	16.7	4.0	25.5	0.8
167 High St	84.9	51.2	33.7	17.5	33.7	17.7	4.2	26.7	2.6
137 High St	73.2	39.5	33.7	18.0	21.5	12.1	2.9	17.2	7.3
69 High St	94.5	60.8	33.7	7.0	53.8	20.7	5.4	34.5	0.3
86 High St	48.9	15.2	33.7	6.6	8.6	5.4	1.6	8.0	0.3

*Note that:

- a = b + c;
- b = d + e; **and**
- b = f + g + h + i

*Table 6.2 High St AQMA NOx Source Apportionment - Sources as % of Total NOx**

Location	Background (BG) % (a)	Moving % (b)	Queuing % (c)	LDV % (d)	HDV % (e)	Bus % (f)	Bus Stops % (g)
Newbigging_Jnct	63.1	15.9	21.0	10.3	4.6	16.0	5.9
87_High_St	71.5	15.5	12.9	10.5	2.7	14.6	0.7
147_High_St	37.4	7.2	55.4	20.0	5.1	33.0	4.5
183_High_St	41.8	17.8	40.4	20.7	5.0	31.6	0.9
167 High St	39.7	20.6	39.7	20.9	5.0	31.4	3.0
137 High St	46.0	24.5	29.4	16.5	3.9	23.6	9.9
69 High St	35.7	7.4	56.9	21.9	5.7	36.5	0.3
86 High St	68.9	13.4	17.6	11.0	3.2	16.3	0.6

*Note that:

- a + b + c = 100%;
- a + d + e + f + g = 100%

Figure 6.1 High St AQMA NOx Source Apportionment - Sources as % of Total NOx

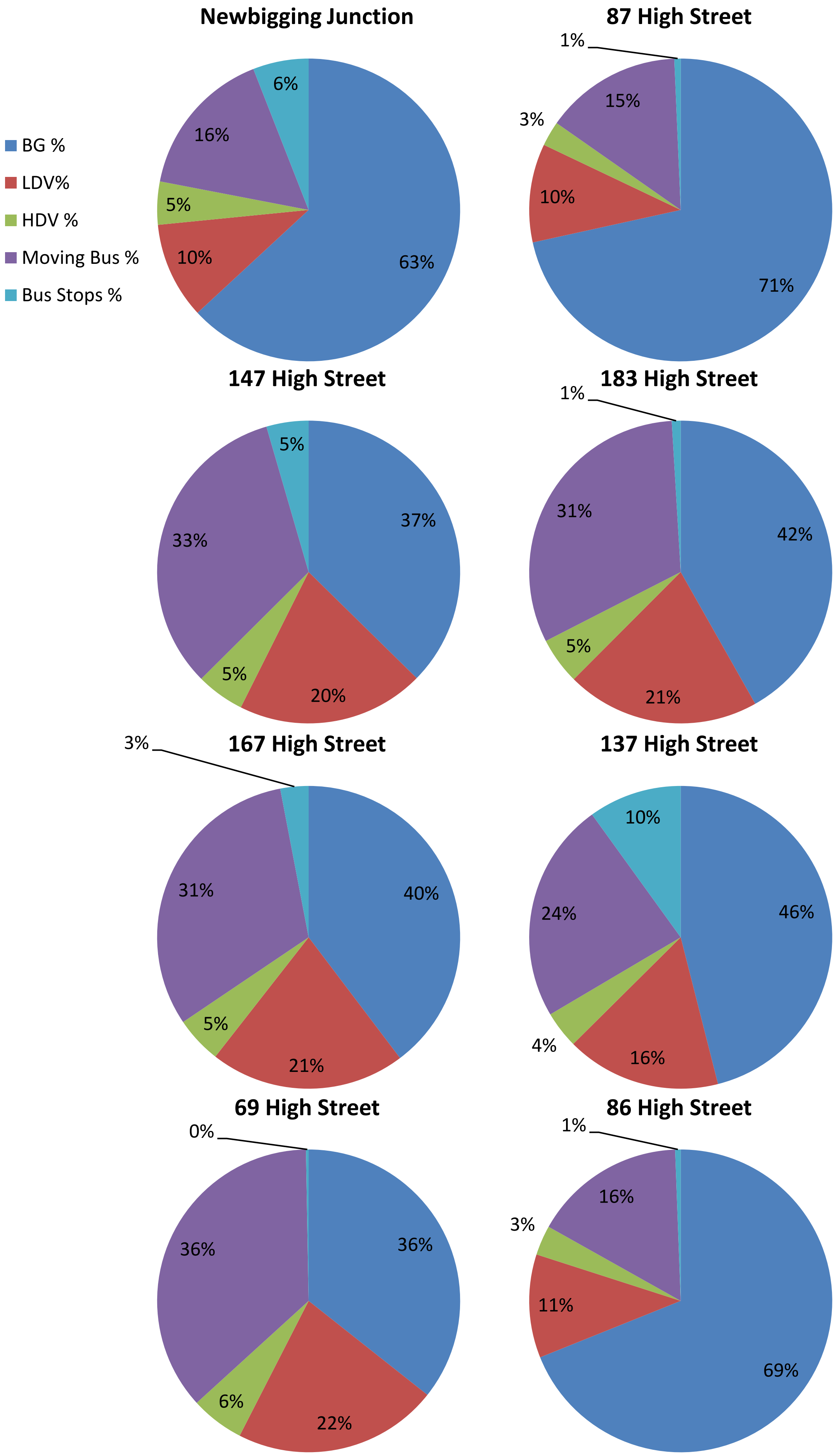
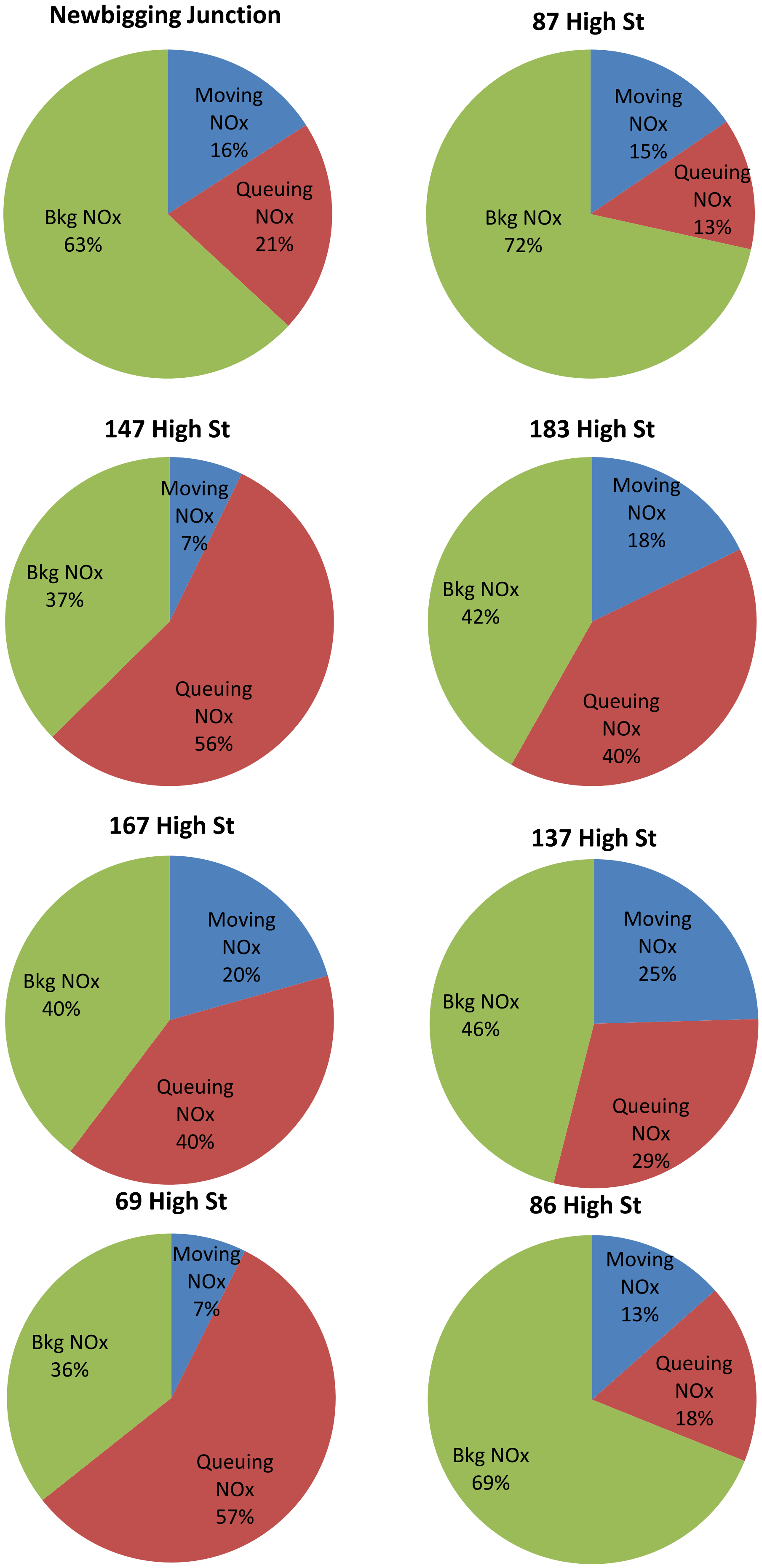


Figure 6.2 High St AQMA NOx Source Apportionment – Moving and Queuing Traffic Sources as % of Total NOx



7 Required Reduction in Ambient NOx Concentrations

The required reduction in Road-NOx concentrations to attain the objectives allows the Local Authority to judge the scale of the effort required to comply with the NO_2 objective. For NO_2, the required reduction in road contribution to ambient concentrations should be expressed in terms of NO_x as this is the primary emission and a non-linear relationship exists between NOx and NO_2 concentrations. The ambient concentrations of NOx required to achieve the annual mean objective for NO_2 at the locations of worst case relevant exposure have been derived using the NOx/NO_2 model described previously.

It should be noted that these data pertain to the ambient concentration reductions required to achieve the NO_2 annual mean objective. In reality the mass emissions reductions required to realise the ambient reductions could be much less- for example street canyons amplify the ambient effect of a unit of NOx emission. Also, the background concentration in the AQMA is reasonably high which means that the local road contribution has to be quite low in order to meet the objective.

7.1 Musselburgh High St AQMA

The largest reduction is required at 69 High Street with a required Road-NOx concentration reduction of 26.5% in order to meet the NO_2 annual mean objective. However, Road-NOx emissions need to be reduced by 4.7% – 26.5% at all receptors between 69 High St and 147 High St. Calculation of the required Road-NOx reduction at the relevant monitoring locations is shown 7.1 below.

Table 7.1 Reductions Required in Total-NOx Concentrations to Achieve the NO_2 Annual Mean Objective

Receptor	Current Total NOx (µg m^{-3})	Current Road-NOx (µg m^{-3})	Required Road NOx (µg m^{-3})	Road-NOx Reduction Required (%)
Newbigging_Jnct	53.4	19.7	44.7	0.0
87_High_St	47.1	13.4	44.7	0.0
147_High_St	90.2	56.5	44.7	-20.9
183_High_St	80.6	46.9	44.7	-4.7
167 High St	84.9	51.2	44.7	-12.7
137 High St	73.2	39.5	44.7	0.0
69 High St	94.5	60.8	44.7	-26.5
86 High St	48.9	15.2	44.7	0.0

8 Mitigation Scenarios

The findings of this Further Assessment will provide additional justification for the development of mitigation measures.

A number of hypothetical scenarios have been agreed with East Lothian Council in order to assess the level of intervention that would be required to meet the objectives. These have been modelled in ADMS-Roads using the same methodology but with updated traffic data to reflect the potential effect of the proposed intervention. The effect on ambient concentrations of NO_2 of six scenarios has been modelled at all of the monitoring locations used throughout the Further Assessment.

8.1 Scenarios

8.1.1 Scenario 1: Addition of second eastbound bus stop

This scenario involves the addition of a second eastbound bus stop at 91 High Street, Musselburgh. The location of the proposed bus stop is shown in Figure 8.1. It is proposed that the eastbound bus services are split between the resulting two bus stops as follows:

	Bus Stop 3 (Existing)	Bus Stop 11 (Proposed)
•	Lothian – 26 & 30	Lothian – 40, 44 & 44A
•	First – 124	First – 108
•	Eve – 128	Eve – 129
•	Horsburgh – T1	Horsburgh – T2

Figure 8.1 Bus stop locations – High Street, Musselburgh

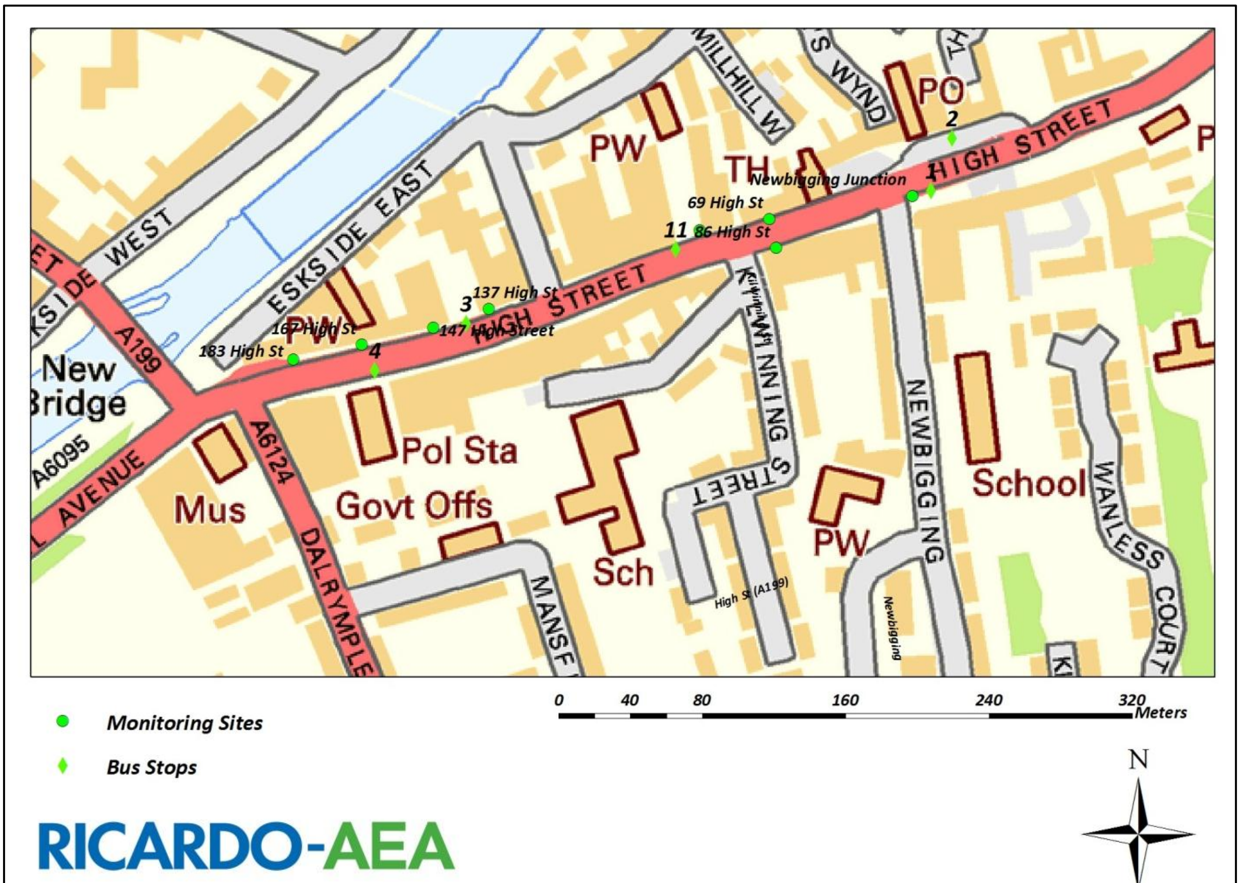


Table 8.1 details the predicted change in annual mean NO_2 concentrations at 8 receptors throughout High Street, Musselburgh. As can be seen, little or no change in NO_2 concentrations are predicted with concentrations predicted to rise by 1 $\mu g\ m^{-3}$ at 69 and 183 High Street and predicted to fall by 1 $\mu g\ m^{-3}$ at 137 High St. No information is available to support assumptions on how queuing would be affected so only the change in bus numbers at bus stops 3 and 11 have been modelled.

Table 8.1 NO_2 concentrations at receptors for the do-nothing and Scenario 1

Receptor	NO_2 2012 do-nothing ($\mu g\ m^{-3}$)	NO_2 2012 Scenario 1 ($\mu g\ m^{-3}$)
Newbigging_Jnct	29	29
87_High_St	26	26
147_High_St	45	45
183_High_St	41	42
167 High St	43	43
137 High St	38	37
69 High St	46	47
86 High St	27	27

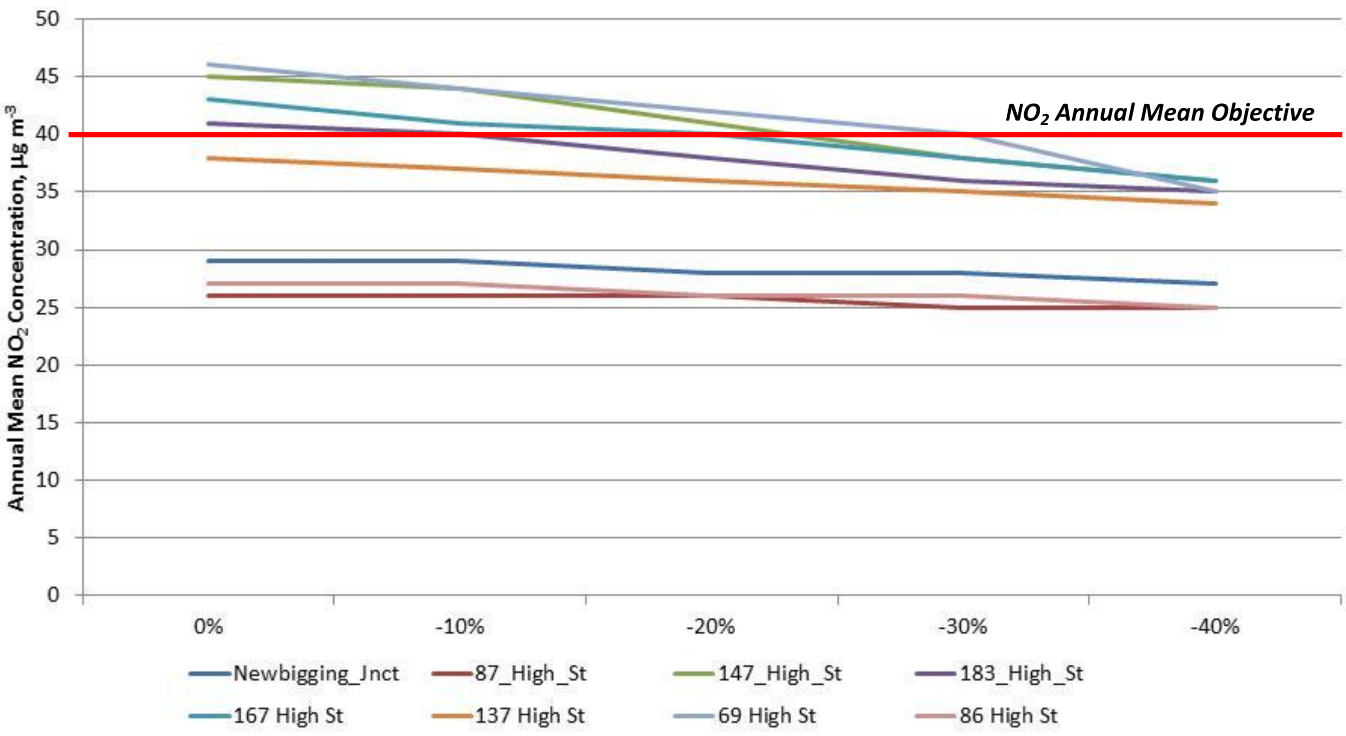
8.1.2 Scenario 2, 3, 4, 5: 10%, 20%, 30% and 40% reduction in queuing traffic

This scenario involves reducing the number of total number of vehicles queuing throughout the study area by a total of 10, 20, 30 and 40%. In this case both the queue lengths and the time that traffic are queuing was reduced by the same percentage (e.g. 10, 20, 30 and 40%). Table 8.2 and Figure 8.2 shows the estimated reduction in annual mean NO_2 concentrations at the 8 receptors throughout High St, Musselburgh. As can be seen, a reduction in queuing traffic of 30% or greater is predicted to reduce annual mean NO_2 concentrations to below or equal to 40 $\mu g\ m^{-3}$ at all receptors. The greatest reduction in NO_2 annual mean concentrations is predicted at 69 High St, with a reduction of 11 $\mu g\ m^{-3}$ to 35 $\mu g\ m^{-3}$, if queuing is reduced by 40%.

Table 8.2 NO_2 concentrations at receptors for the do-nothing and Scenarios 2 - 5

Receptor	NO_2 2012 do-nothing ($\mu g\ m^{-3}$)	NO_2 2012 Scenario 2 ($\mu g\ m^{-3}$)	NO_2 2012 Scenario 3 ($\mu g\ m^{-3}$)	NO_2 2012 Scenario 4 ($\mu g\ m^{-3}$)	NO_2 2012 Scenario 5 ($\mu g\ m^{-3}$)
Newbigging_Jnct	29	29	28	28	27
87_High_St	26	26	26	25	25
147_High_St	45	44	41	38	36
183_High_St	41	40	38	36	35
167 High St	43	41	40	38	36
137 High St	38	37	36	35	34
69 High St	46	44	42	40	35
86 High St	27	27	26	26	25

Figure 8.2 NO_2 concentrations at receptors for the do-nothing and Scenarios 2 - 5



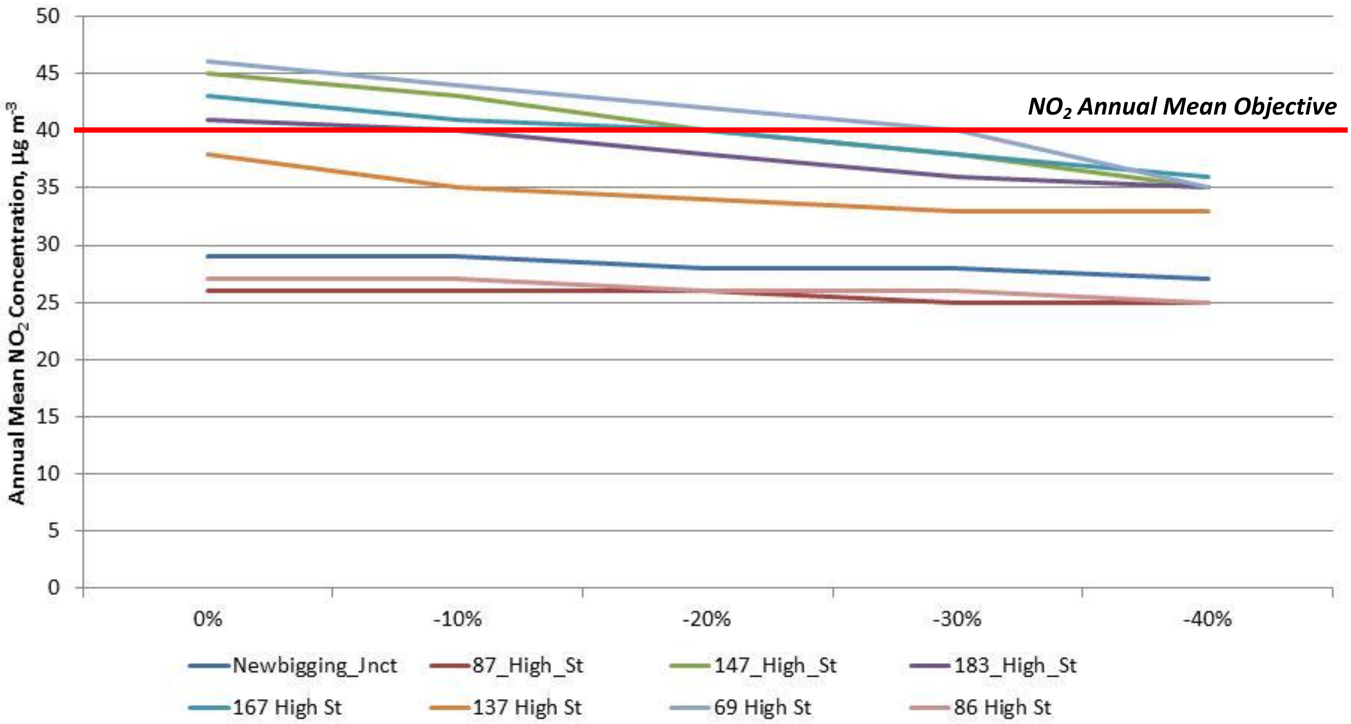
8.1.3 Scenario 6, 7, 8, 9: 10%, 20%, 30% and 40% reduction in queuing traffic in addition to second eastbound bus stop

This scenario involves reducing the number of total number of vehicles queuing throughout the study area by a total of 10, 20, 30 and 40% **combined** with Scenario 1. As can be seen, a reduction in queuing traffic of 30% or greater combine with the addition of a further bus stop is predicted to reduce annual mean NO_2 concentrations to below or equal to 40 µg m^{-3} at all receptors. The greatest reduction in NO_2 annual mean concentrations is predicted at 69 High St, with a reduction of 11 µg m^{-3} to 35 µg m^{-3}, if queuing is reduced by 40%.

Table 8.3 NO_2 concentrations at receptors for the do-nothing and Scenarios 6 - 9

Receptor	NO_2 2012 do-nothing (µg m^{-3})	NO_2 2012 Scenario 6 (µg m^{-3})	NO_2 2012 Scenario 7 (µg m^{-3})	NO_2 2012 Scenario 8 (µg m^{-3})	NO_2 2012 Scenario 9 (µg m^{-3})
Newbigging_Jnct	29	29	28	28	27
87_High_St	26	26	26	25	25
147_High_St	45	43	40	38	35
183_High_St	41	40	38	36	35
167 High St	43	41	40	38	36
137 High St	38	35	34	33	33
69 High St	46	44	42	40	35
86 High St	27	27	26	26	25

Figure 8.3 NO_2 concentrations at receptors for the do-nothing and Scenarios 6 - 9



8.1.4 Scenario 10, 11, 12: 5%, 10% and 20% reduction in moving traffic AADT

This scenario involves reducing the number of total number of vehicles travelling throughout the study areas by a total of 5, 10 and 20%. In this case, it was assumed that there would be no reduction in bus numbers and therefore the relative percentage of buses in the traffic composition was increased. It should also be noted that the NO_2 reductions would likely be realised due to an obvious reduction in queuing that would occur with reduction in AADT. No information is available to support assumptions on how queuing would be affected so moving traffic reductions only have been modelled. Table 8.4 shows the predicted changes in NO_2 annual mean concentrations were these reductions in moving traffic to be realised. As can be seen, reducing the total number of moving traffic only within High St, Musselburgh by up to 20% will have no impact on predicted annual mean NO_2 concentrations. This confirms that the dominating emission source within the High Street AQMA is queuing traffic and buses.

Table 8.2 NO_2 concentrations at receptors for the do-nothing and Scenarios 10 - 12

Receptor	NO_2 2012 do-nothing (µg m^{-3})	NO_2 2012 Scenario 10 (µg m^{-3})	NO_2 2012 Scenario 11 (µg m^{-3})	NO_2 2012 Scenario 12 (µg m^{-3})
Newbigging_Jnct	29	29	29	29
87_High_St	26	26	26	26
147_High_St	45	45	45	45
183_High_St	41	41	41	41
167 High St	43	43	43	43
137 High St	38	38	38	38
69 High St	46	46	46	46
86 High St	27	27	27	27

Therefore, modelling of the mitigation scenarios indicates that an integrated package of interventions would provide the best NOx reductions. Measures that reduce overall traffic, reduce queuing and reduce bus numbers, where appropriate, will reduce road NOx significantly. These measures are however very challenging (both financially and technically) to implement.

9 Conclusions

Over recent years it has been identified that the annual mean NO_2 objective is being exceeded in the area of High Street, Musselburgh and as a result, an AQMA has been declared. The AQMA encompasses the High St between Bridge St in the West and Newbigging St in the East. The 2012 Detailed Assessment also highlighted that the measured concentrations of NO_2 were also above the annual mean objective of 40 µg m^{-3} during the study period.

This study is a Further Assessment, which aims to revisit the findings of the previous Detailed Assessment, and carry out source apportionment and mitigation scenario modelling to satisfy Further Assessment requirements.

This Further Assessment considers the High Street in Musselburgh.

In this Further Assessment concentrations of NO_2 have been assessed in East Lothian Council's Musselburgh AQMA for 2012. A combination of available monitoring data and a dispersion modelling techniques using ADMS-Roads were used throughout the study. The study took account of traffic conditions in each area and meteorological data available for the specified study period.

The study has confirmed the findings of the previous Detailed Assessment, namely that there are exceedences of the annual mean NO_2 objective where relevant exposure exists. The contour plots prepared for this study indicate that the current AQMA boundary includes all relevant sources and does not require revocation or amendment at this time.

In the High St AQMA approximately 24 buildings consisting of approximately 31 residential properties were estimated to lie within the 40 µg m^{-3} contour, equating to an exposed population of around 69.

It is estimated that ambient NOx reductions in the AQMA of between 0% and 27% are required in order to achieve compliance with the annual mean NO_2 objective.

The source apportionment exercise indicates that emissions from buses form the largest contribution at all locations along the High St AQMA. The largest proportion that can be attributed to emissions from buses is seen at 147 High St with 38% of the NOx emissions estimated to be as a result of moving and queuing buses, and buses at bus stops. On average throughout the AQMA, 29% of NOx emissions can be attributed to bus activity.

In the case of moving versus queuing traffic, queuing traffic contributes the largest proportion at all locations except 87 High St. The largest proportion that can be attributed to queuing traffic is seen at 69 High St with 57% of the total NOx emissions estimated to be as a result of queuing traffic. On average throughout the AQMA, 34% of the total NOx emissions can be attributed to queuing traffic.

Modelling of the mitigation scenarios agreed with the Council indicates that an integrated package of interventions would provide the best NOx reductions. Measures that reduce overall traffic, reduce queuing and reduce bus numbers, where appropriate, will reduce road NOx significantly. These measures are however very challenging (both financially and technically) to implement.

The monitoring and dispersion modelling carried out to support this Further Assessment indicate that the NO_2 annual mean objective is still being exceeded within the High Street, Musselburgh AQMA. That said, the boundary of the AQMA is appropriate and does not require revocation or amendment at this time.

This report has been prepared for East Lothian Council by a third party. East Lothian Council accept and take ownership of its findings.

Appendices

Appendix 1 – Traffic Data 2012

Traffic Flows and Compositions

Table A1.1 summarises the Annual Average Daily Flows (AADF) of traffic and fleet compositions used within the model. Traffic flows were measured by two automatic traffic count (ATC) sites for a period of 1 week in October 2013. The locations of the two traffic counters are shown in Figure A1.1.

Table A1.1 Annual Average Daily Flows – Road Traffic 2012

Street	%Cars	%LGV	Rigid %HGV	Artic %HGV	%Buses	%2WM	AADF
High Street	89.8	2.4	0.7	0.4	5.7	1.0	14989

LGV – Light Goods Vehicles
HGV – Heavy Goods Vehicles (Articulate and Rigid)
2WM - Motorcycles

Queuing Traffic

CERC note 60 was used for estimating emissions from queuing traffic, which defines a representative AADF for queuing traffic to be 30,000 at 5 km h^{-1}, assuming an average vehicle length of 4m. The emissions from this AADF figure with the traffic composition of the corresponding road were then input into the Emission Factor Toolkit to calculate and emission rate. The emission rates were then used within the dispersion model as a separate line emissions of pre-defined length representing each queue.

Traffic Speeds

As stated in Technical Guidance LAQM.TG(09), the speed of traffic on a road will change approximately 50 m from a junction. For this study the two ATC sites were located close to two junctions at High St/Dalrymple Loan to the west and High St/Newbigging to the West. The counts provided diurnal variations in traffic speed and showed that speeds varied between 18.1 and 49.2 km hr^{-1} throughout an average day.

Bus Stops

A total of 4 bus stops are located throughout the study area. CERC note 51 was used for estimating emissions from stationary buses at the bus stops. Buses were treated as volume sources combined with an estimate of hourly counts within ADMS. Table A1.2 summarises the bus counts at each bus stop with the corresponding location shown in Figure A1.1. It was estimated from bus timetables that the majority of the bus services were operating for 16 hrs per day, Monday to Saturday, with half the bus numbers running on Sundays for 14 hrs per day.

Table A1.2 Average Daily Average Bus Counts - 2012

Bus Stop	Street	Bus Count
1	High Street	44
2	High Street	44
3	High Street	499
4	High Street	495

Pedestrian Crossings

A total of 2 pedestrian crossings and 2 traffic light junctions are located throughout the study area. Again CERC note 60 in combination with hourly estimates of queue lengths was used for estimating emissions from queuing traffic. The locations of the pedestrian crossings and traffic lights are shown in Figure A1.2.

Figure A1.2 Locations of Bus Stops, High St, Musselburgh

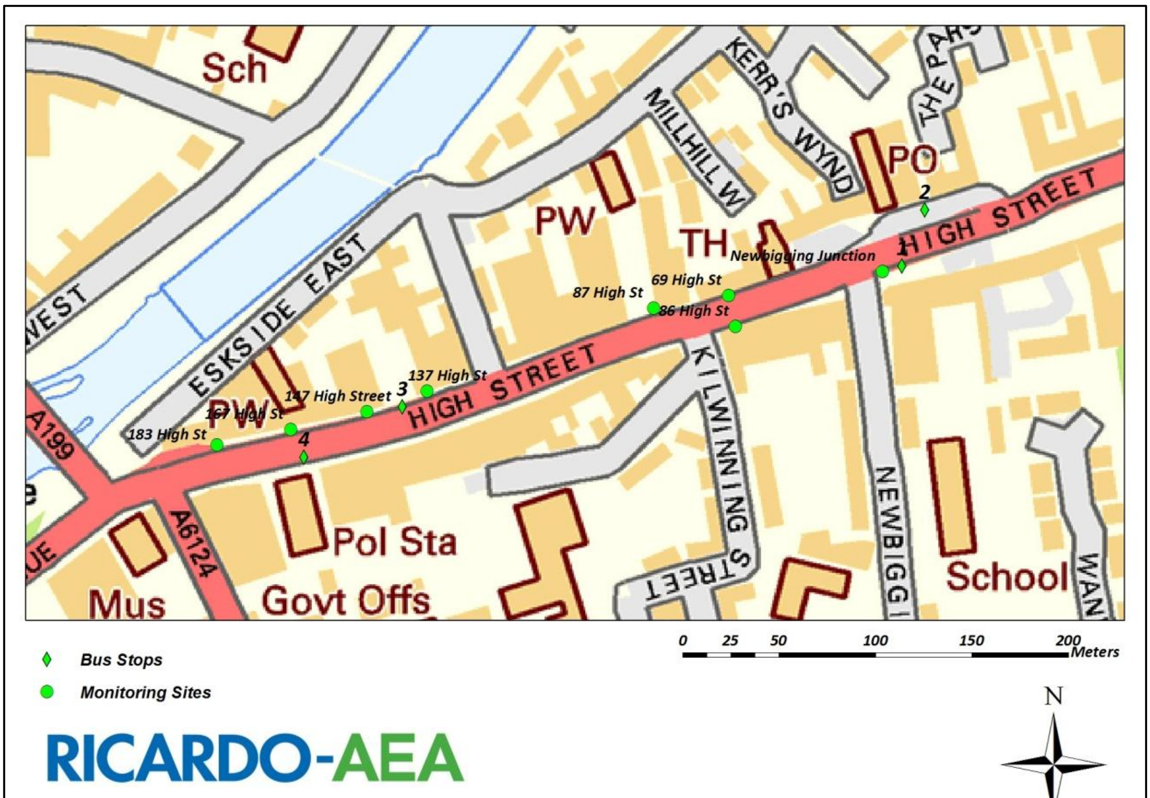
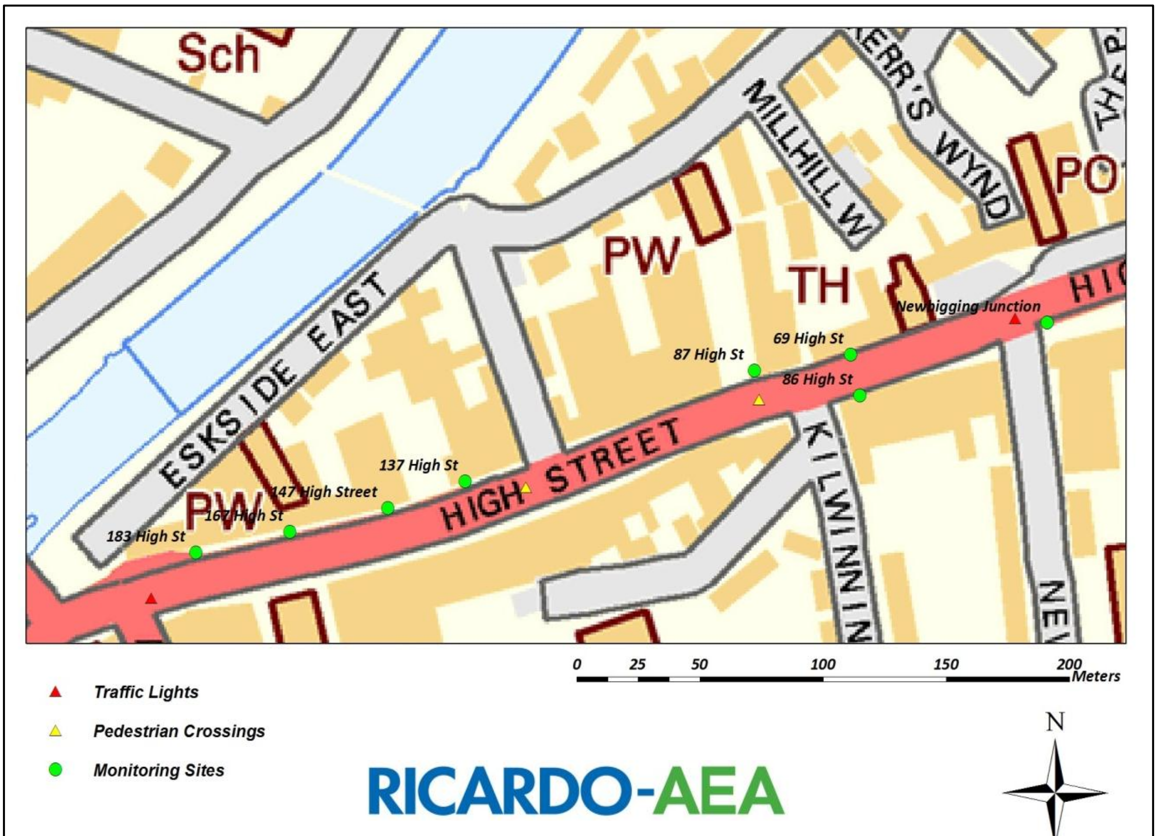


Figure A1.2 Locations of Traffic Lights and Pedestrian Crossings



Appendix 2 - Model Verification

It is appropriate to verify the ADMS Roads model in terms of primary pollutant emissions of nitrogen oxides (NOx = NO + NO_2). The model has been run to predict annual mean RoadNOx concentrations during 2012 at the diffusion tube sites in the area of the High Street, Musselburgh. The modelled NO_2 has then been calculated by using the output of RoadNOx (the total NOx originating from road traffic), the background NOx from the Scottish background maps, and the 2010 version of the Defra NOx/NO_2 calculator To calculate this adjustment factor the slope of the best fit line between the model-derived NOx and the measured NOx, forced through the origin, was calculated as shown in Figure A3.1. This factor was then applied to the modelled NOx concentration for each modelled point to provide adjusted modelled NOx concentrations. The model verification was carried out using 8 monitoring sites, which gave a primary adjustment factor of **1.3014**.

In order to take account of the error introduced by converting NOx to NO_2 using the DEFRA NOx/NO_2 tool, a secondary adjustment factor was determined. To calculate this adjustment factor the slope of the best fit line between the model-derived NO_2 and the measured NO_2, forced through the origin, was calculated as shown in Figure A3.2. This factor was then applied to the modelled NO_2 concentration for each modelled point to provide adjusted modelled NO_2 concentrations. The model verification was carried out using 8 monitoring sites, which gave a secondary adjustment factor of **1.0198**.

Figure A3.1 Comparison of modelled NOx Vs Measured NOx using all monitoring sites for verifying the model

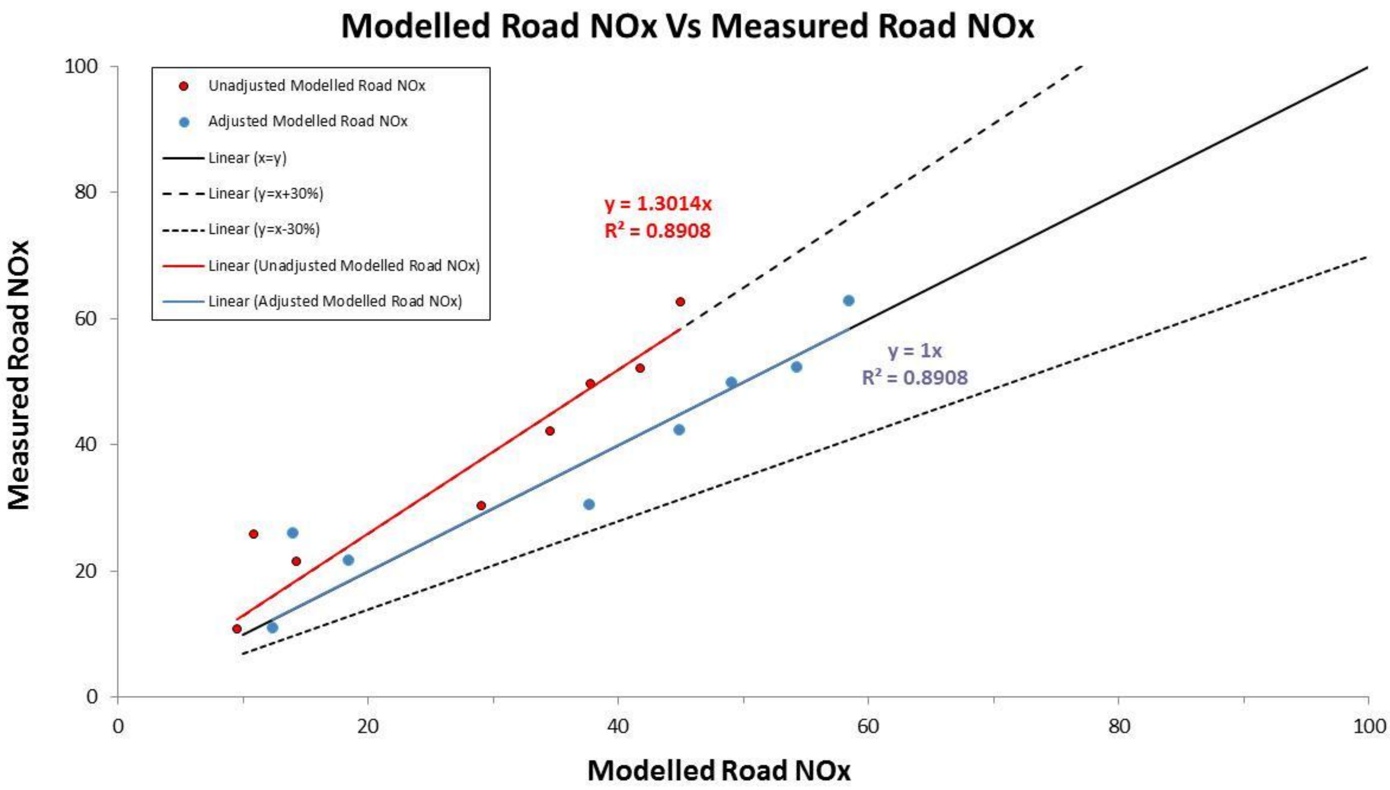
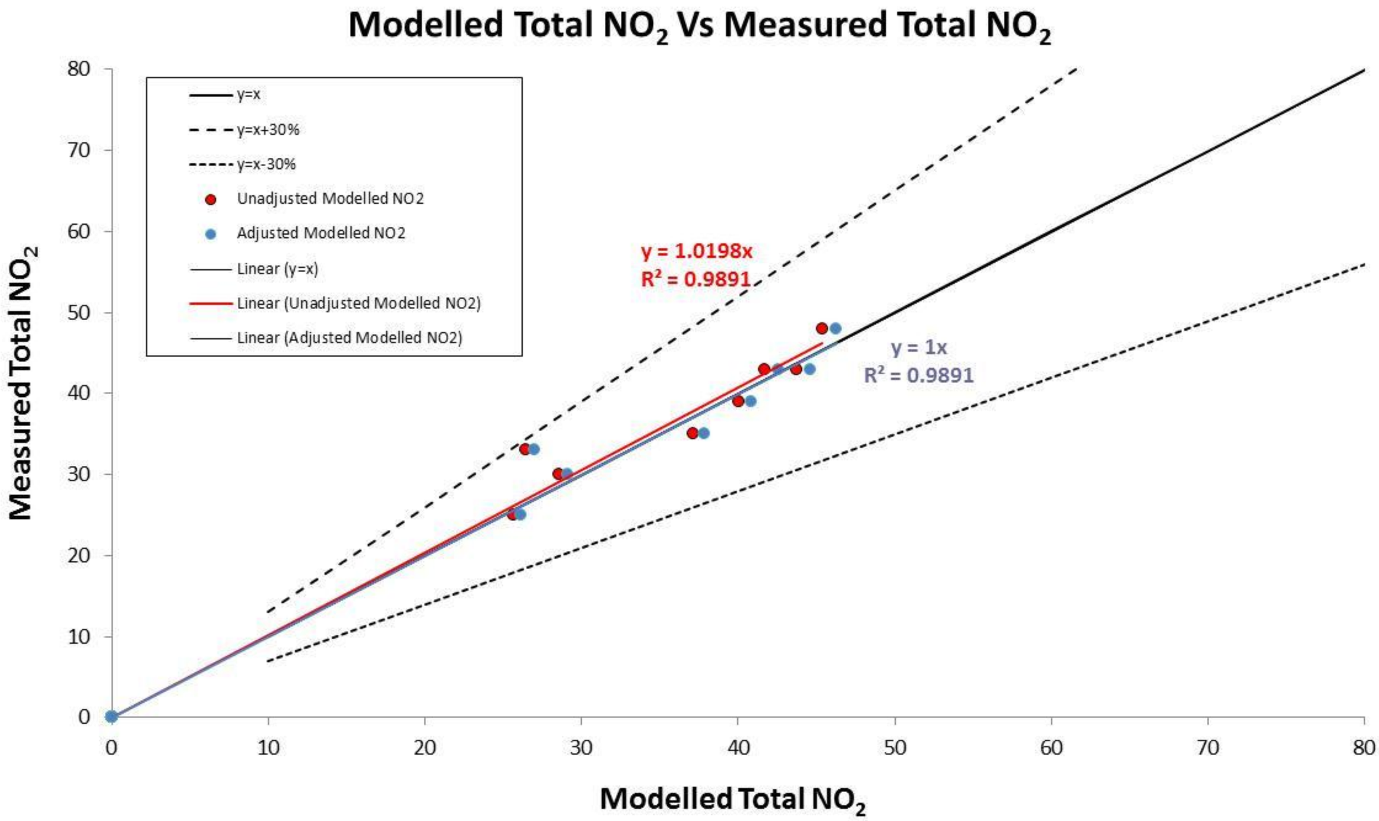


Figure A3.2 Comparison of modelled NO_2 Vs Measured NO_2 using all monitoring sites for verifying the model



In order to confirm the uncertainty in the adjustment factor derived above the Root Mean Square Error (RMSE) for the observed vs predicted NO2 annual mean concentrations was calculated, as detailed in Technical Guidance LAQM.TG(09), Box A3.7, Appendix 3. Table A3.1 summarises the results when using the secondary adjustment factor (F) of 1.043, as discussed above.

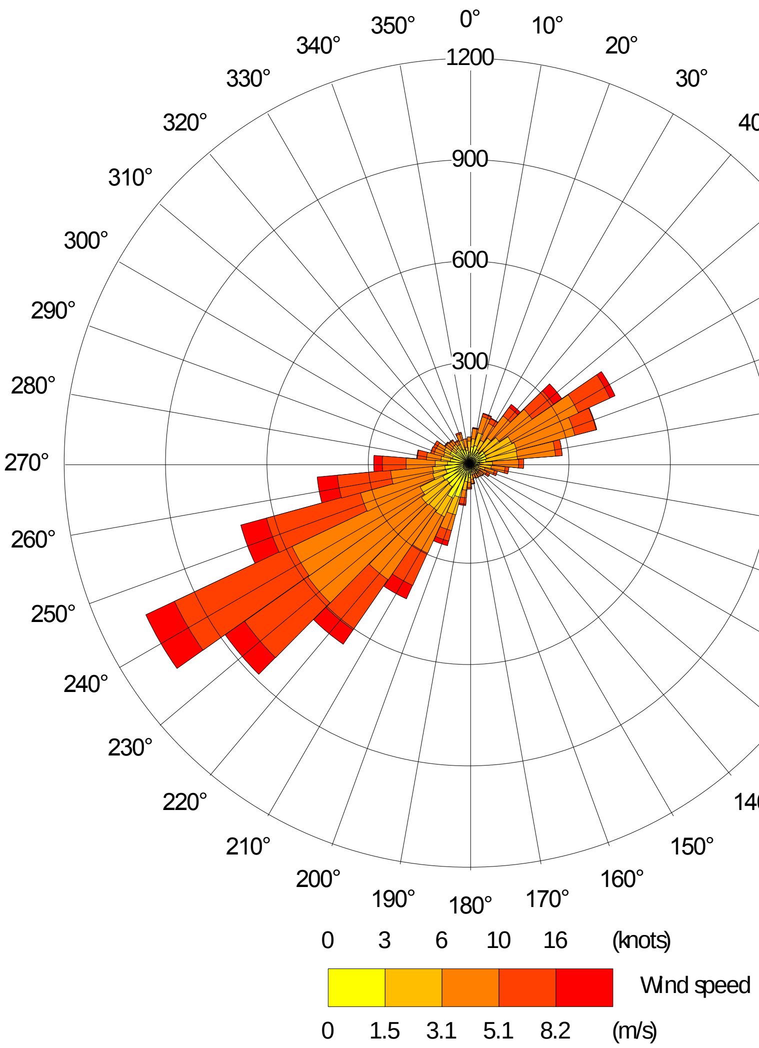
Table A1.1 Root Mean Square Error

Site Name	Grid Coordinates		Observed Annual Average NO_2 (µg m^{-3})	Modelled Results before Verification and Adjustment (µg m^{-3})	Modelled Results after Verification and Adjustment (µg m-3)
	x	y			
Newbigging_Jnct	334656	672723	30	27	29
87_High_St	334530	672699	25	24	26
147_High_St	334392	672652	43	39	45
183_High_St	334312	672633	39	36	41
167 High St	334354	672643	43	37	43
137 High St	334427	672664	35	33	38
69 High St	334580	672713	48	40	46
86 High St	334578	672695	33	25	27
			RMSE=	**5.1**	**2.6**

In this case the calculated pre adjustment RMSE is 5.1 μg m^{-3} and post adjustment RMSE is 2.6 μg m^{-3}. It is recommended that the RMSE is below 25% of the objective that the model is being compared against, but ideally under 10% of the objective (NO_2 annual mean objective of 40 μg m^{-3}). Therefore, the model has performed sufficiently well in this case with an RMSE of 6.5% of the objective.

Appendix 3 – Edinburgh Gogarbank Wind Rose - 2012

Figure A3.1 Edinburgh Gogarbank Wind Rose 2012



RICARDO-AEA

2nd Floor
18 Blythswood Square
Glasgow
G2 4BG
Tel: 01235 75 3566
Web: www.ricardo-aea.com