Air Quality
CONSULTANTS

Detailed Assessment of Air Quality in Inverness for The Highland Council

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Experts in air quality
management & assessment

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Client	Highland Council	Principal Contact	Nick Thornton

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Report Prepared By:	Suzanne Hodgson

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Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
12 Airedale Road, London SW12 8SF Tel: 0208 673 4313
aqc@aqconsultants.co.uk

Registered Office: 12 St Oswalds Road, Bristol, BS6 7HT
Companies House Registration No: 2814570

Contents

The Highland Council confirms that it accepts the recommendations made in this report.

1 Introduction

1.1 Air Quality Consultants Ltd. has been commissioned by The Highland Council to undertake a Detailed Assessment of air quality in Inverness. In 2013, The Highland Council completed a Progress Report for air quality, which concluded that a Detailed Assessment was required as a result of measured exceedences of the nitrogen dioxide annual mean objective along Queensgate and Union Street, in Inverness city centre.

1.2 The aim of this Detailed Assessment is to determine whether the annual mean nitrogen dioxide objective is exceeded at relevant locations and, if so, the extent of exceedences and thus the boundary of the Air Quality Management Area (AQMA) required.

Background

1.3 The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Defra, 2007) sets out a framework for air quality management, which includes a number of air quality objectives. National and international measures are expected to achieve these objectives in most locations, but where areas of poor air quality remain, air quality management at a local scale has a particularly important role to play. Part IV of the Environment Act 1995 requires local authorities to periodically review and assess air quality in their areas. The role of this process is to identify areas where it is unlikely that the air quality objectives will be achieved. These locations must be designated as AQMAs and a subsequent Air Quality Action Plan (AQAP) developed in order to reduce pollutant emissions in pursuit of the objectives.

1.4 Review and Assessment is a long-term, ongoing process, structured as a series of ‘rounds’. Local Authorities in England, Scotland and Wales have now completed the first, second, third and fourth rounds of Review and Assessment, with the fifth round well underway.

1.5 Technical Guidance for Local Air Quality Management (LAQM.TG(09)) (Defra, 2009) sets out a phased approach to the Review and Assessment process. This prescribes an initial Updating and Screening Assessment (USA), which all local authorities must undertake. It is based on a checklist to identify any matters that have changed since the previous round. If the USA, or subsequent Progress Reports, identify any areas where there is a risk that the objectives may be exceeded, which were not identified in the previous round, then the Local Authority should progress to a Detailed Assessment.

1.6 The purpose of the Detailed Assessment is to determine whether an exceedence of an air quality objective is likely and the geographical extent of that exceedence. If the outcome of the Detailed Assessment is that one or more of the air quality objectives are likely to be exceeded, then an Air Quality Management Area (AQMA) must be declared.

1.7 This report represents a Detailed Assessment in the fifth round of Review and Assessment, It follows the findings of monitoring in 2012, which concluded that there were measured concentrations in exceedence of the annual mean nitrogen dioxide objective value of 40 $\mu g/m^3$, along Queensgate and Union Street, in Inverness city centre (Highland Council, 2013). Additional diffusion tube monitoring sites were set up in January 2013 along Queensgate, at first- and second-floor levels, to inform work towards this Detailed Assessment, which aims to identify the extent of annual mean concentrations in excess of the annual mean objective, and where there are predicted exceedences, whether these occur at locations with relevant exposure.

The Air Quality Objectives

1.8 The Government's Air Quality Strategy (Defra, 2007) provides air quality standards and objectives for key air pollutants, which are designed to protect human health and the environment. The 'standards' are set as concentrations below which health effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of a particular pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of the costs, benefits, feasibility and practicality of achieving the standards. It also sets out how the different sectors: industry, transport and local government, can contribute to achieving the air quality objectives. The objectives are prescribed within The Air Quality (England) Regulations 2000 (Stationery Office, 2000) and The Air Quality (England) (Amendment) Regulations 2002 (Stationery Office, 2002).

1.9 Table 1 summarises the objectives which are relevant to this report. Appendix 1 provides a brief summary of the health effects of nitrogen dioxide.

Table 1: Air Quality Objectives for Nitrogen Dioxide

Pollutant	Time Period	Objective
Nitrogen Dioxide	1-hour mean	200 $\mu g/m^3$ not to be exceeded more than 18 times a year
	Annual mean	40 $\mu g/m^3$

1.10 The air quality objectives only apply where members of the public are likely to be regularly present for the averaging time of the objective (i.e. where people will be exposed to pollutants). For annual mean objectives, relevant exposure is limited to residential properties, schools and hospitals. The 1-hour objective applies at these locations as well as at any outdoor location where a member of the public might reasonably be expected to stay for 1 hour or more, such as shopping streets, parks and sports grounds, as well as bus stations and railway stations that are not fully enclosed.

1.11 Measurements across the UK have shown that the 1-hour nitrogen dioxide objective is unlikely to be exceeded unless the annual mean nitrogen dioxide concentration is greater than 60 $\mu g/m^3$

(Defra, 2009). Thus exceedences of 60 µg/m^3 as an annual mean nitrogen dioxide concentration are used as an indicator of potential exceedences of the 1-hour nitrogen dioxide objective.

2 Assessment Methodology

Monitoring

2.1 Monitoring for nitrogen dioxide in the study area was carried out by The Highland Council using 16 passive diffusion tubes sites in 2013. The monitoring sites are shown in Figure 1.

2.2 Diffusion tubes were prepared and analysed by Gradko International Ltd. using the 20% TEA in water method. It is necessary to adjust diffusion tube data to account for laboratory bias. A bias adjustment factor for 2013 of 0.9 has been calculated by The Highland Council from a local co-location study. The national bias adjustment factor, for 2013, from the database of national factors provided on the Review and Assessment Helpdesk website (spreadsheet version 03/14) was 0.95. This was based on 24 studies, one of which was The Highland Council's study. A comparison of the national and locally-derived bias-adjustment factors, between 2009 and 2013, is provided in Appendix A2.

2.3 In its Review and Assessment reports, The Highland Council adjusted its diffusion tube results using national bias-adjustment factors in 2009 and 2010 and local-bias adjustment factors derived from a triplicate of diffusion tubes located with the Telford Street automatic analyser in 2011 and 2012. Prior to 2010 and in 2013, the local bias-adjustment factors have been steady (around 0.9); in 2011 and 2012 these increased to 1.09 and 1.26 respectively. With the exception of 2011 and 2012, the application of the relevant national bias-adjustment factor is a conservative approach, and provides a consistency in the monitoring results, since the national bias-adjustment factors for the relevant laboratory have remained relatively consistent over time. The variability in the locally-derived bias-adjustment factors over time and the high factors in recent years adds uncertainty to the co-location study, therefore the use of the national bias-adjustment factor for all years (2009 to 2013) is considered more appropriate for use in this Detailed Assessment. For information, the locally derived bias-adjusted results are presented in Appendix A3.

Modelling

2.4 Annual mean nitrogen dioxide concentrations have been predicted using detailed dispersion modelling (ADMS-Roads v3.2). The model outputs have been verified against the monitoring data described above and shown in Table 2, in Section 3. Further details of the modelling methodology and model verification are provided in Appendix A4.

2.5 Concentrations have been predicted for a grid of receptors, with a resolution of 3 m, across the study area to allow concentration isopleths to be plotted.

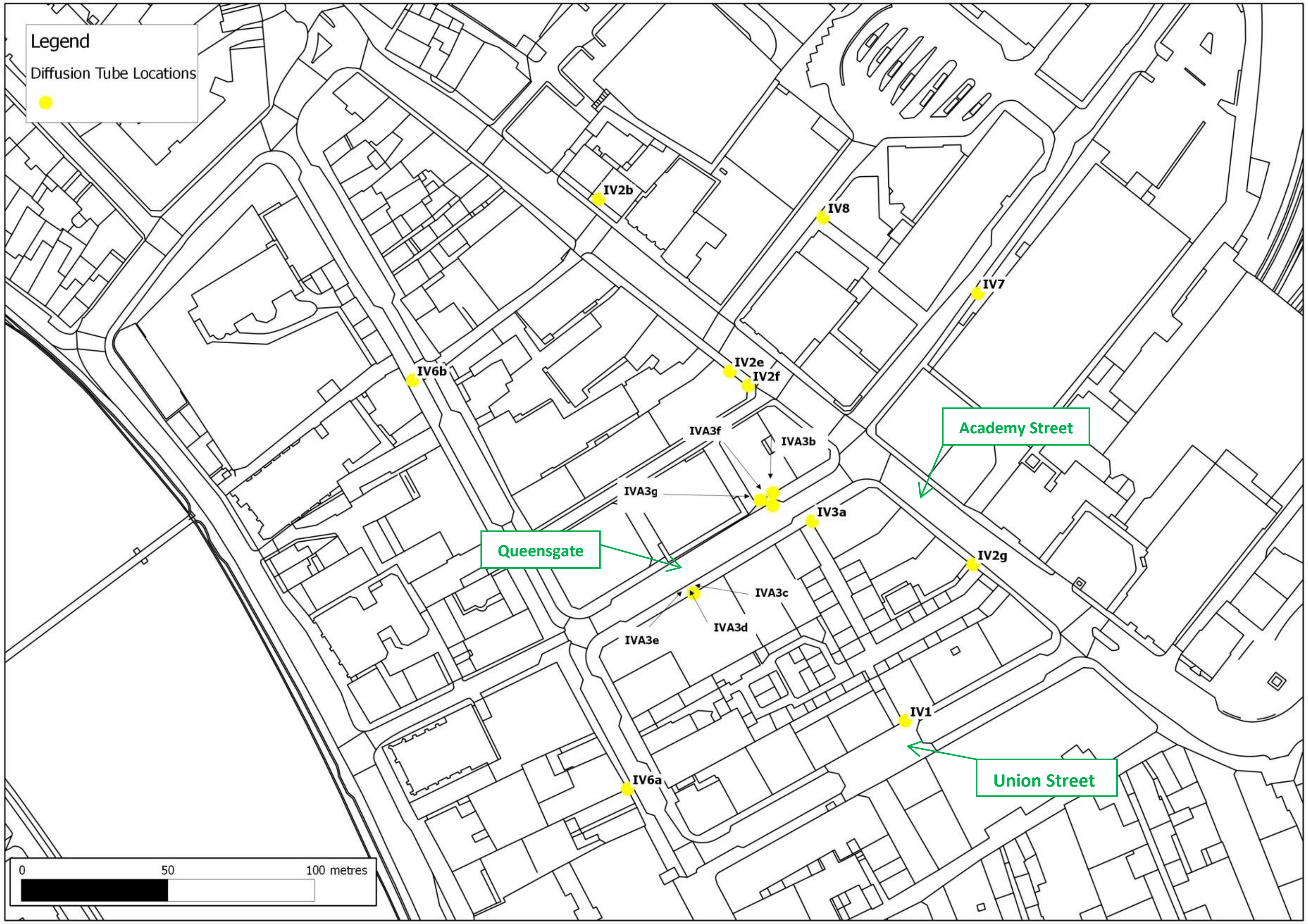

Figure 1 Detailed Assessment Monitoring Locations

3 Results

Monitoring

3.1 Monitoring data for the diffusion tube monitoring sites located in the study area (Figure 1), using national bias-adjustment factors, are summarised in Table 2. The results of monitoring using local-bias adjustment factors derived by The Highland Council are provided, for information, in Appendix A2.

Table 2: Annual Mean Nitrogen Dioxide Concentrations, Inverness City Centre, 2009 - 2013 (µg/m^3)

Site	Site Type	Site Description	Height	2009	2010	2011	2012	2013
IV1	Roadside	Union Street	3.0	26.3	26.8	23.4	31.8	27.4
IV2b	Roadside	Academy Street B	2.0	30.3	29.3	25.7	27.1	27.6
IV2e	Roadside	Academy Street E	2.5	-	-	-	-	**42.1**
IV2f	Roadside	Academy Street F	2.0	-	-	-	-	39.9
IV2g	Roadside	Academy Street G	3.0	-	-	-	-	**40.8**
IV3a	Roadside	Queensgate A	3.0	**46.4**	**41.9**	39.7	35.8	35.5
IV3b	Kerbside	Queensgate B	2.5	36.1	36.3	28.1	**43.2**	**46.3**
IV3c	Roadside	Queensgate C	3.0	-	-	-	35.5	31.7
IV3d	Roadside	Queensgate D	6.8	-	-	-	-	33.6
IV3e	Roadside	Queensgate E	9.6	-	-	-	-	34.7
IV3f	Roadside	Queensgate F	5.4	-	-	-	-	34.4
IV3g	Roadside	Queensgate G	9.6	-	-	-	-	29.4
IV6a	Roadside	Church Street A	2.5	-	-	-	-	29.5
IV6b	Roadside	Church Street B	2.5	-	-	-	-	19.2
IV7	Roadside	Strothers Lane	2.5	-	-	-	-	33.9
IV8	Roadside	Margaret Street	2.5	-	-	-	-	25.2
Objective				**40**				

3.2 Between 2009 and 2013, using national bias-adjustment factors, measured concentrations were above the annual mean objective value (40 µg/m^3) along Queensgate in 2009, 2010, 2012 and 2013 and on Academy Street in 2013. Elsewhere, measured concentrations were below the objective.

3.3 The measured exceedences of the annual mean objective value along Queensgate occurred at ground-level, where there is no relevant exposure. At the other diffusion tube monitoring sites (which were set-up in 2013) along Queensgate, from ground- to second-floor levels, measured concentrations were below the objective. The annual mean objective was exceeded at two monitoring locations on Academy Street, in 2013, with the concentration just below the objective at one site. These diffusion tubes are located at ground-level, where there is no relevant exposure.

3.4 There are no measured concentrations exceeding 60 µg/m^3, and thus exceedences of the 1-hour objective are unlikely.

Modelling

3.5 Isopleth maps of the modelled annual mean nitrogen dioxide concentrations at first- to third-floor levels across the study area are presented in Figures 3 to 5; the figures also show where there is relevant exposure at the various floor levels. No ground-floor contour has been produced as there is no relevant exposure at ground-floor level anywhere within the study area.

3.6 Figures 3 and 4 show that predicted concentrations exceed the annual mean objective value of 40 µg/m^3 along Academy Street. There is relevant exposure at the first- and second-floor levels, where there is predicted to be an exceedence of the annual mean objective, at the corner of Queensgate and Academy Street (2 Queensgate).

3.7 Figure 5 shows that predicted concentrations are all below the annual mean objective value of 40 µg/m^3 at the third-floor level, within the study area.

3.8 The isopleths show the 40 µg/m^3 contour in red, as well as the 36 µg/m^3 contour in orange. There is some uncertainty surrounding both the measured and modelled concentrations. It is therefore recommended that an AQMA is declared to include, as a minimum, those residential properties which lie within the 36 µg/m^3 contour, in order to be precautionary. Objective exceedences are predicted at approximately six apartments along Academy Street (which have a total maximum occupation of 18 people).

3.9 No exceedences of 60 µg/m^3 as an annual mean nitrogen dioxide concentration have been identified at locations of relevant exposure, and thus exceedences of the 1-hour objective are unlikely.

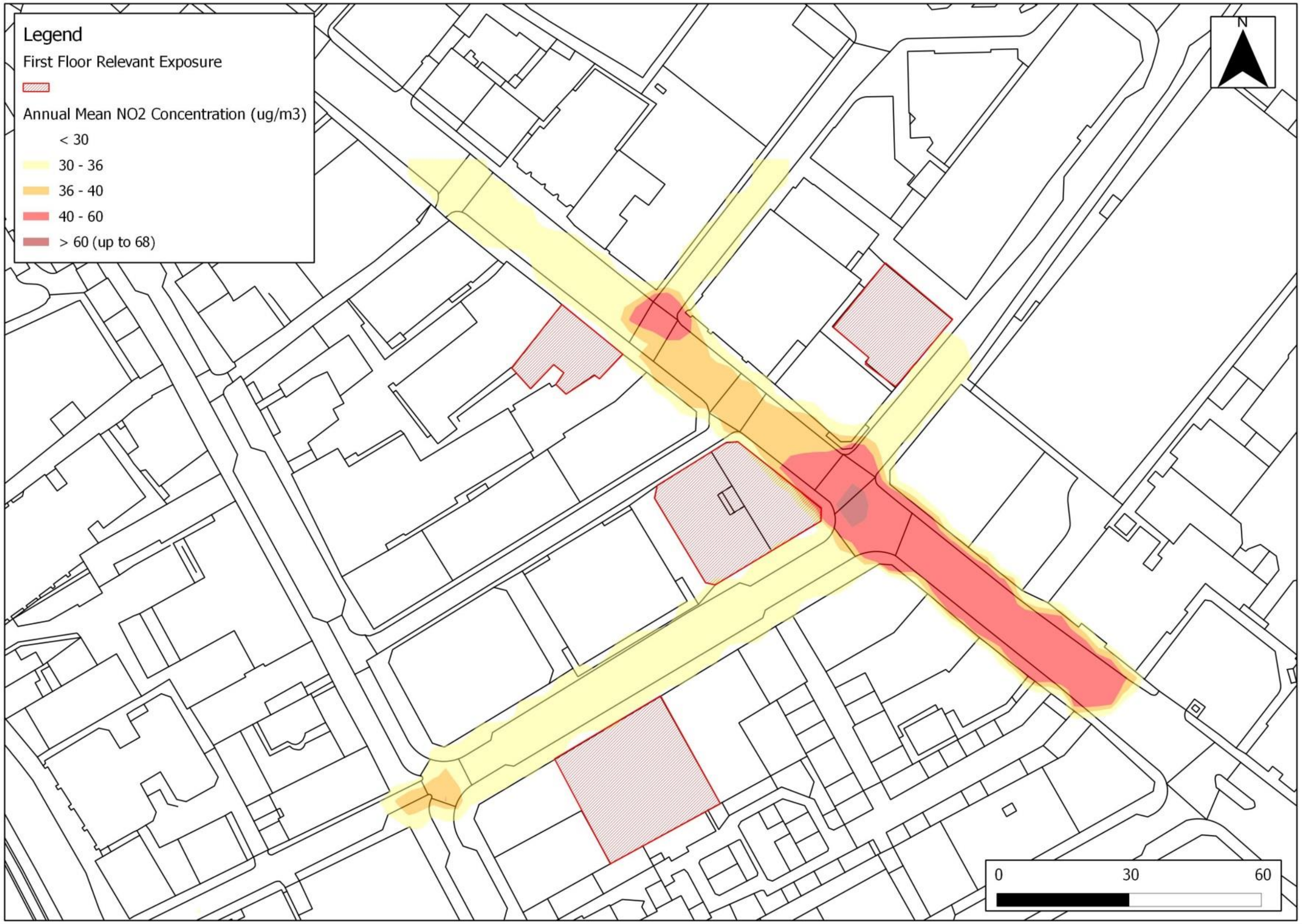

Figure 3: Predicted Annual Mean Nitrogen Dioxide Concentrations, in 2013 (First Floor)

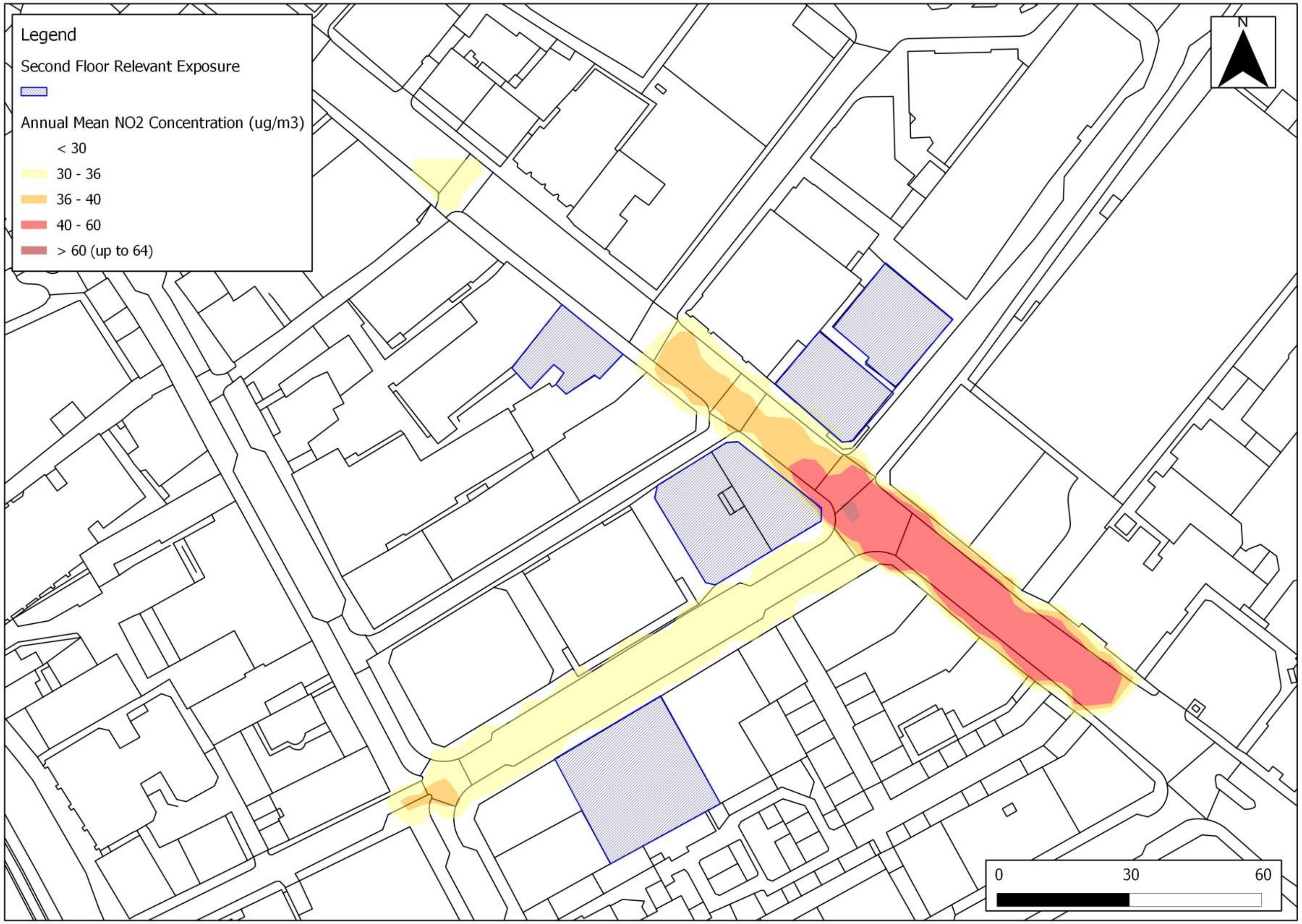

Figure 4: Predicted Annual Mean Nitrogen Dioxide Concentrations, in 2013 (Second Floor)

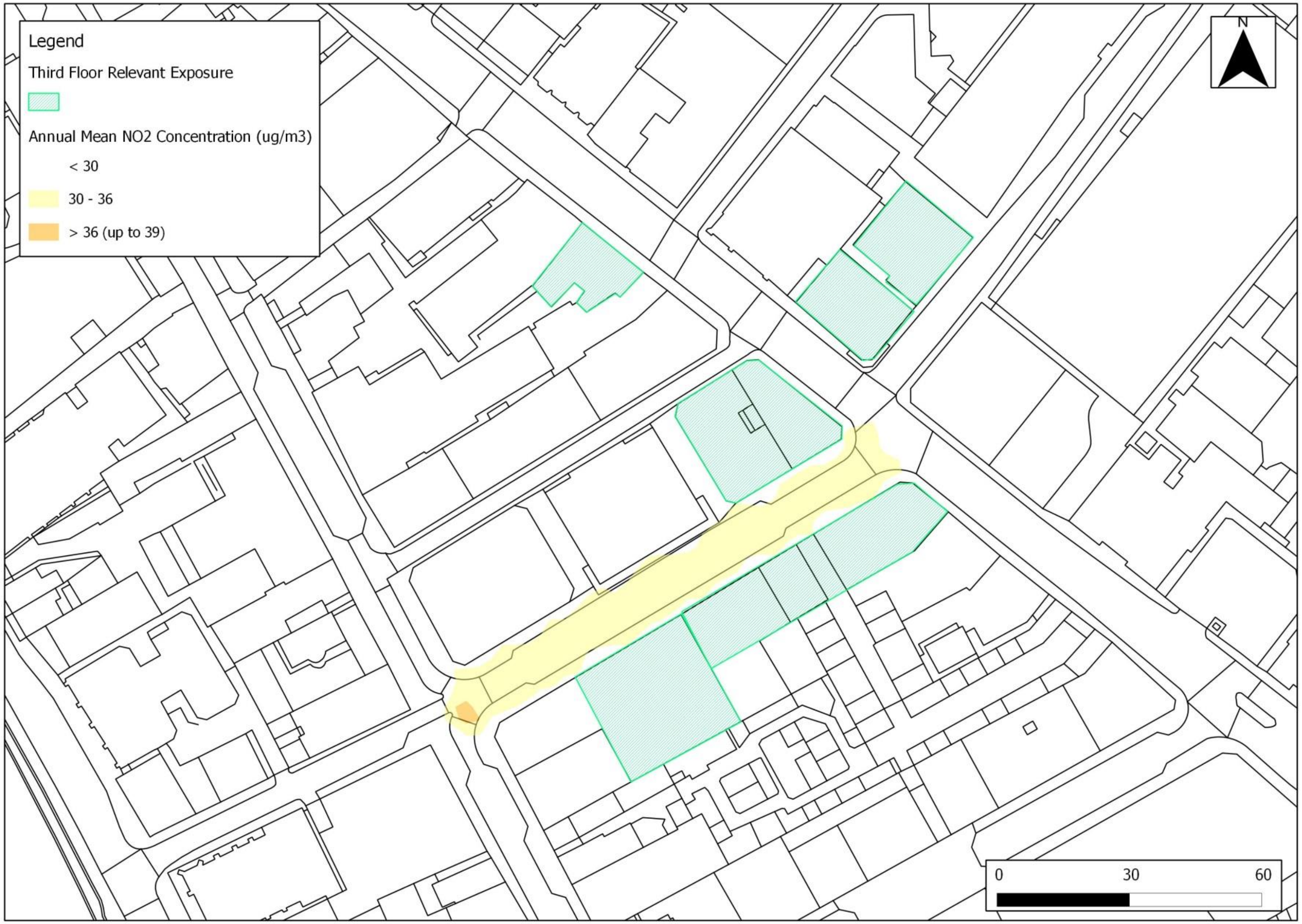

Figure 5: Predicted Annual Mean Nitrogen Dioxide Concentrations, in 2013 (Third Floor)

4 Conclusions and Recommendations

4.1 A Detailed Assessment has been carried out for nitrogen dioxide within Inverness city centre. This area was identified as being at risk of exceeding the annual mean air quality objective for nitrogen dioxide, based on monitoring in 2012, as set out in The Highland Council's 2013 Progress Report.

4.2 The Detailed Assessment has been carried out using a combination of monitoring data for 2013 and modelled concentrations. Concentrations of nitrogen dioxide have been modelled for 2013 using the ADMS-Roads dispersion model. The model has been verified against measurements made at the 16 nitrogen dioxide diffusion tube monitoring locations which lie adjacent to the road network included in the model.

4.3 The assessment has identified that the annual mean nitrogen dioxide objective is being exceeded at first- and second- floor levels at the corner of Academy Street with Queensgate (2 Queensgate), where there is relevant exposure. No exceedences of 60 $\mu g/m^3$ as an annual mean nitrogen dioxide concentration have been identified at locations of relevant exposure, and thus exceedences of the 1-hour objective are unlikely.

4.4 There is some uncertainty surrounding both the measured and modelled concentrations. It is therefore recommended that an AQMA is declared to include, as a minimum, those residential properties that lie within the 36 $\mu g/m^3$ contour to be precautionary.

4.5 It is also recommended that The Highland Council continues monitoring nitrogen dioxide at the existing monitoring locations, and expands the network to include 2 Queensgate, at varying levels, if possible.

5 References

Defra, 2007. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, July 2007.

Defra, 2009. Review & Assessment: Technical Guidance LAQM.TG(09).

Defra, 2014. LAQM Support website. Available at: www.defra.gov.uk/environment/quality/air/airquality/local/support/index.htm

The Highland Council, 2013. 2013 Progress Report. Available at: http://www.highland.gov.uk/NR/rdonlyres/7F255B05-59A7-459E-86D7-CC6961C36D4D/0/2013AirQualityProgressReport.pdf

Stationery Office, 2000. Air Quality Regulations, 2000, Statutory Instrument 928.

Stationery Office, 2002. Air Quality (England) (Amendment) Regulations, 2002, Statutory Instrument 3043.

6 Glossary

Standards	A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal.
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date, taking into account costs, benefits, feasibility and practicality. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides.
Exceedence	A period of time where the concentration of a pollutant is greater than the appropriate air quality objective.
AQMA	Air Quality Management Area
ADMS-Roads	Atmospheric Dispersion Modelling System for Roads.
NO_X	Nitrogen oxides (taken as NO + NO_2)
NO	Nitric Oxide
NO_2	Nitrogen dioxide.
$\mu g/m^3$	Microgrammes per cubic metre.
Roadside	A site sampling between 1 m of the kerbside of a busy road and the back of the pavement. Typically this will be within 5 m of the road, but could be up to 15 m (Defra, 2009).
HDV	Heavy Duty Vehicle
LDV	Light Duty Vehicle
MCL	Motorcycles
AADT	Annual Average Daily Traffic flows

A1 Summary of Health Effects of Nitrogen Dioxide

Table A1.1: Summary of Health Effects of Nitrogen Dioxide

Pollutant	Main Health Effects
Nitrogen Dioxide	Short-term exposure to high concentrations may cause inflammation of respiratory airways. Long term exposure may affect lung function and enhance responses to allergens in sensitised individuals. Asthmatics will be particularly at risk (Defra, 2007).

A2 Comparison of National and Local Bias-Adjustment Factors

A2.1 Table A2.1 shows the national bias-adjustment factors for the 20% TEA in Water method, analysed by Gradko International and local bias-adjustment factors from the co-location study on Telford Street in Inverness.

Table A.2.1: National and Local Bias-Adjustment Factors

Year	National Factor [a]	Local Factor
2009	0.90	0.76 [b]
2010	0.92	0.95
2011	0.90	1.09
2012	0.96	1.26 [c]
2013	0.95	0.9

[a] Based on number of studies, 2009 = 34, 2010, 42, 2011 = 41, 2012 = 35, 2013 = 24

[b] Accuracy was determined based on eight periods, as three periods out of 11 had poor precision. Data capture was poor in December, which is why accuracy was determined over 11 months.

[c] Average monitoring data at co-located diffusion tubes in May and June much lower than during other months (e.g. in region of 10 µg/m^3 compared with 30 µg/m^3). If removed, this local bias-adjustment factor reduces to 1.06.

A3 Locally Bias-Adjusted Diffusion Tube Results

Table A.3.1: Annual Mean Nitrogen Dioxide Concentrations, Inverness City Centre, 2009 - 2013 (µg/m^3)

Site	Site Type	Site Description	Height	2009	2010	2011	2012	2013
IV1	Roadside	Union Street	3.0	22.2	27.6	28.3	**41.7**	25.3
IV2b	Roadside	Academy Street B	2.0	25.6	30.2	31.2	35.5	25.6
IV2e	Roadside	Academy Street E	2.5	-	-	-	-	39.0
IV2f	Roadside	Academy Street F	2.0	-	-	-	-	37.0
IV2g	Roadside	Academy Street G	3.0	-	-	-	-	37.8
IV3a	Roadside	Queensgate A	3.0	39.2	**43.3**	**48.1**	**47.0**	32.9
IV3b	Kerbside	Queensgate B	2.5	30.4	37.5	34.0	**56.7**	**42.9**
IV3c	Roadside	Queensgate C	3.0	-	-	-	**46.5**	29.4
IV3d	Roadside	Queensgate D	6.8	-	-	-	-	31.1
IV3e	Roadside	Queensgate E	9.6	-	-	-	-	32.1
IV3f	Roadside	Queensgate F	5.4	-	-	-	-	31.9
IV3g	Roadside	Queensgate G	9.6	-	-	-	-	27.2
IV6a	Roadside	Church Street A	2.5	-	-	-	-	27.3
IV6b	Roadside	Church Street B	2.5	-	-	-	-	17.8
IV7	Roadside	Strothers Lane	2.5	-	-	-	-	31.4
IV8	Roadside	Margaret Street	2.5	-	-	-	-	23.3
Objective				**40**				

A4 Dispersion Modelling Methodology

Meteorological Data

A4.1 The model has been run using the full year of meteorological data that corresponds to the most recent set of nitrogen dioxide monitoring data (2013). The meteorological data has been taken from the monitoring station located at Inverness/Dalcross Airport, which is considered suitable for this area.

Background Concentrations

A4.2 The background concentrations across the study area have been defined using the national pollution maps published by Defra (2014a). These cover the whole country on a 1x1 km grid and are published for each year from 2010 until 2025. The maps include the influence of emissions from a range of different sources; one of which is road traffic. There are some concerns that Defra may have over-predicted the rate at which road traffic emissions of nitrogen oxides will fall in the future. The maps currently in use were verified against measurements made during 2010 at a large number of automatic monitoring stations and so there can be reasonable confidence that the maps are representative of conditions during 2010. Similarly, there is reasonable confidence that the reductions which Defra predicts from other sectors (e.g. rail) will be achieved.

A4.3 In order to calculate background nitrogen dioxide and nitrogen oxides concentrations in 2013, it is assumed that there was no reduction in the road traffic component of backgrounds between 2010[1] and 2013. This has been done using the source-specific background nitrogen oxides maps provided by Defra (2014a). For each grid square, the road traffic component has been held constant at 2010 levels, while 2013 values have been taken for the other components. Nitrogen dioxide concentrations have then been calculated using the background nitrogen dioxide calculator which Defra (2014a) publishes to accompany the maps. The result is a set of 'adjusted 2013 background' concentrations.

A4.4 As an additional step, the 'adjusted 2012 background' mapped values have been calibrated against national background measurements made as part of the AURN during 2012 (see Figure A4.1). Based on the 62 sites with more than 75% data capture for 2012, the maps over-predict the background concentrations by 1.9%, on average. This has been allowed for in production of the calibrated 'adjusted' 2012 background concentrations.

[1] This approach assumes that has been no reduction in emissions per vehicle but also that traffic volumes have remained constant. This is not the same as the assumption made for dispersion modelling, in which emissions per vehicle are held constant while traffic volumes are assumed to change year on year. Overall, this discrepancy is unlikely to influence the overall conclusions of the assessment.

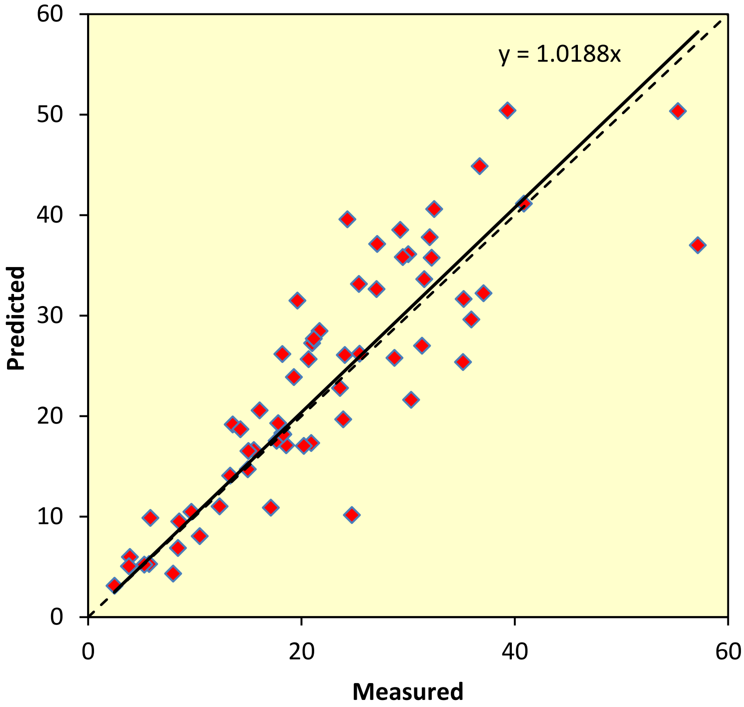

Figure A4.1: Predicted Mapped versus Measured Concentrations at AURN Background Sites in 2012

A4.5 Background concentrations of nitrogen dioxide have been taken from the national maps of background concentrations published by Defra (Defra, 2011). The background concentrations used in the modelling are presented in Table A4.1.

Table A4.1: Background Concentrations (µg/m³)

	NOx	NO_2
2013	16.2	12.2

Traffic Data

A4.6 Predictions have been carried out using the ADMS-Roads dispersion model (v3.2). The model requires the user to provide various input data, including emissions from each section of road, and the road characteristics (including road width and street canyon height, where applicable). Vehicle emissions have been calculated based on vehicle flow, composition and speed data using the Emission Factor Toolkit (Version 5.2c) published by Defra (2014a).

A4.7 Table A4.2 provides a list of the roads within the study area that have been modelled as street canyons. These roads have canyon-like features, which reduce dispersion of traffic emissions, and can therefore lead to concentrations of pollutants being higher here than they would be in areas with greater dispersion.

Table A4.2: Modelled Street Canyons

	Width (m)	Height (m)
Academy Street	Between 12 – 21 m	Between 9 - 11
Bridge Street	21 m	6 m
Church Street	Between 14 – 16 m	Between 11 – 14 m
Fraser Street	9 m	11 m
Queensgate	16 m	14 m
Margaret Street	9 m	9 m
Strother's Lane	Between 12 – 16 m	9 m
Union Street	15 m	14 m

A4.8 Twelve hour traffic (7am to 7pm) flows, diurnal flow profiles, speeds, and vehicle fleet composition data have been provided by The Highland Council. The 12-hour data were converted to a 24-hour Annual Average Daily Traffic (AADT) flow using permanent 24-hour automatic traffic count (ATC) located on Telford Street in 2013, using a factor of 1.24. The 12-hour traffic count was undertaken in August 2011, and so the flows have been growthed to 2013 values using a growth factor provided by The Highland Council (1.015) and adjusted from an August monthly flow to an annual flow using monthly profile data from the DfT (0.95) (DfT, 2014). The traffic data used in the modelling is presented in Table A4.3.

Table A4.3: Summary of Traffic Data used in the Assessment (AADT)

Road Link	AADT	Vehicle Fleet Composition (%)				
		Car	LGV	HGV	Bus	M/C[a]
Queensgate	3,314	66.4	14.6	3.7	14.6	0.7
Fraser Street	709	52.8	7.7	1.7	37.6	0.2
Church Street (North West of Queensgate)	769	77.4	15.8	3.3	2.3	1.2
Church Street (South East of Queensgate)	1,833	68.2	16.4	3.6	11.1	0.6
Bank Street (North West of Fraser Street)	11,440	78.0	14.3	3.4	3.4	0.9
Bank Street (South East of Fraser Street	11,935	77.4	13.9	3.3	4.5	0.8
Union Street	1,789	69.8	15.4	3.3	11.0	0.5
Academy St (btn Q'gate and Union St)	12,480	80.8	10.4	2.6	5.6	0.6
Academy St (South East of Union Street	11,885	81.8	8.8	2.2	6.6	0.6
Strothers Lane	2,601	72.3	10.5	1.9	14.1	1.1
Academy St (btn Q'gate and Margaret St)	11,836	80.7	10.9	2.8	5.0	0.6
Academy St (North West of Margaret St)	11,384	81.5	11.3	2.9	3.7	0.6
Academy St (South East of Chapel St)	11,374	81.6	11.2	2.8	3.7	0.7

Road Link	AADT	Vehicle Fleet Composition (%)				
		Car	LGV	HGV	Bus	M/C[a]
Margaret Street	1,352	63.9	5.6	2.3	28.2	0.1
Friar Lane	11,040	77.2	15.0	3.5	3.5	0.8
Chapel Street	13,809	78.0	15.3	3.7	2.3	0.7
Young Street	18,067	84.6	10.3	1.8	2.5	0.8
Bridge Street	15,989	82.7	12.2	2.4	2.0	0.7
Castle Street	5,752	82.4	13.3	2.2	1.3	0.8
Church St WJ2	769	77.4	15.8	3.3	2.3	1.2

a M/C = Motorcycle

A4.9 Figure A4.2 shows the road network included within the model and defines the study area.

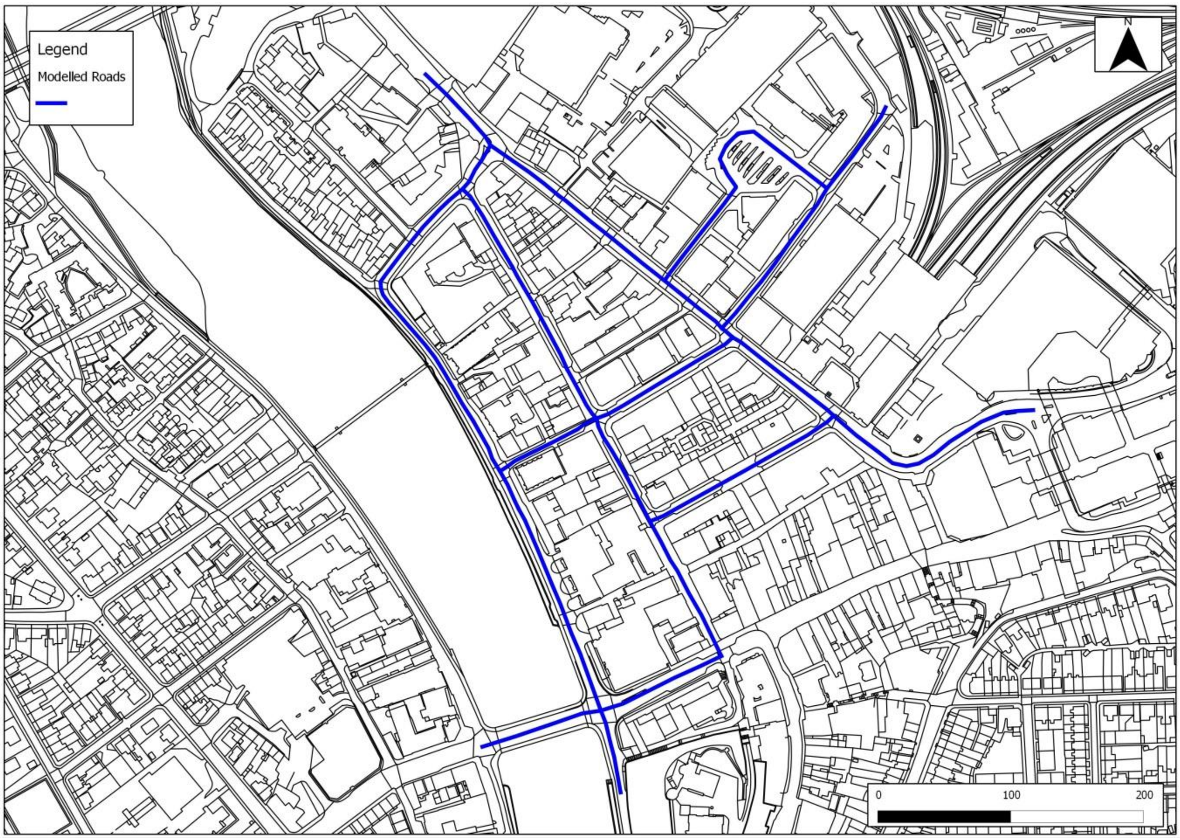

Figure A4.2: Modelled Road Network

Model Verification

A4.10 In order to ensure that ADMS-Roads accurately predicts local concentrations, it is necessary to verify the model against local measurements. The verification methodology is described below.

A4.11 Most nitrogen dioxide (NO_2) is produced in the atmosphere by reaction of nitric oxide (NO) with ozone. It is therefore most appropriate to verify the model in terms of primary pollutant emissions of nitrogen oxides (NOx = NO + NO_2). The model has been run to predict the annual mean NOx concentrations during 2013 at the diffusion tube monitoring sites in Inverness city centre. Concentrations have been modelled at the height of the monitors shown in Table 2 in the main report.

A4.12 The model output of road-NOx (i.e. the component of total NOx coming from road traffic) has been compared with the 'measured' road-NOx. Measured road-NOx has been calculated from the measured NO_2 concentrations and the predicted background NO_2 concentration using the NOx from NO_2 calculator available on the Defra LAQM Support website (Defra, 2014a).

A4.13 A primary adjustment factor has been determined as the slope of the best-fit line between the 'measured' road contribution and the model derived road contribution, forced through zero (Figure A4.3). This factor has then been applied to the modelled road-NOx concentration for each receptor to provide adjusted modelled road-NOx concentrations. The total nitrogen dioxide concentrations have then been determined by combining the adjusted modelled road-NOx concentrations with the predicted background NO_2 concentration within the NOx from NO_2 calculator. A secondary adjustment factor has finally been calculated as the slope of the best-fit line applied to the adjusted data and forced through zero (Figure A4.4).

A4.14 The following primary and secondary adjustment factors have been applied to all modelled nitrogen dioxide data:

- Primary adjustment factor : 1.809
- Secondary adjustment factor: 1.009

A4.15 The results imply that the model has under predicted the road-NOx contribution. This is a common experience with this and most other models. The final NO_2 adjustment is minor.

A4.16 Figure A4.5 compares final adjusted modelled total NO_2 at each of the monitoring sites, to measured total NO_2, and shows a 1:1 relationship.

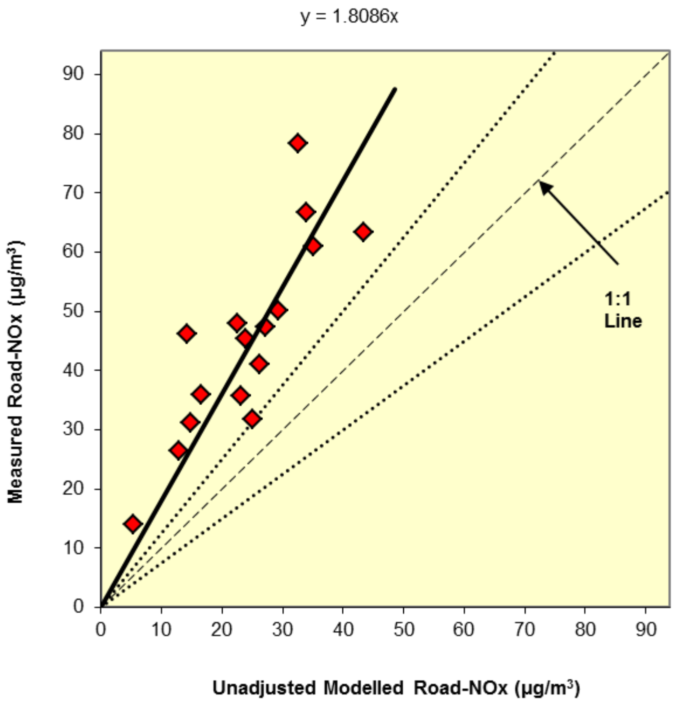

Figure A4.3: Comparison of Measured Road NOx to Unadjusted Modelled Road NOx Concentrations. The dashed lines show ± 25%.

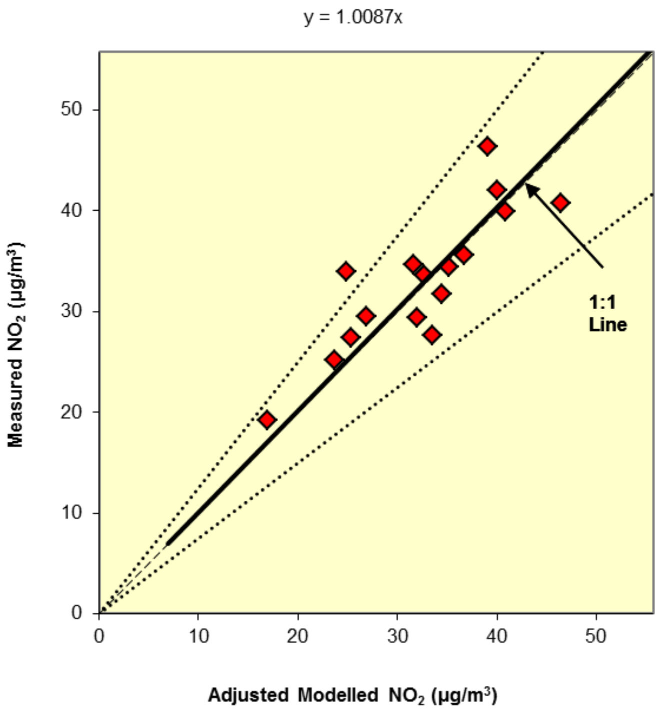

Figure A4.4: Comparison of Measured Total NO_2 to Primary Adjusted Modelled Total NO_2 Concentrations. The dashed lines show ± 25%.

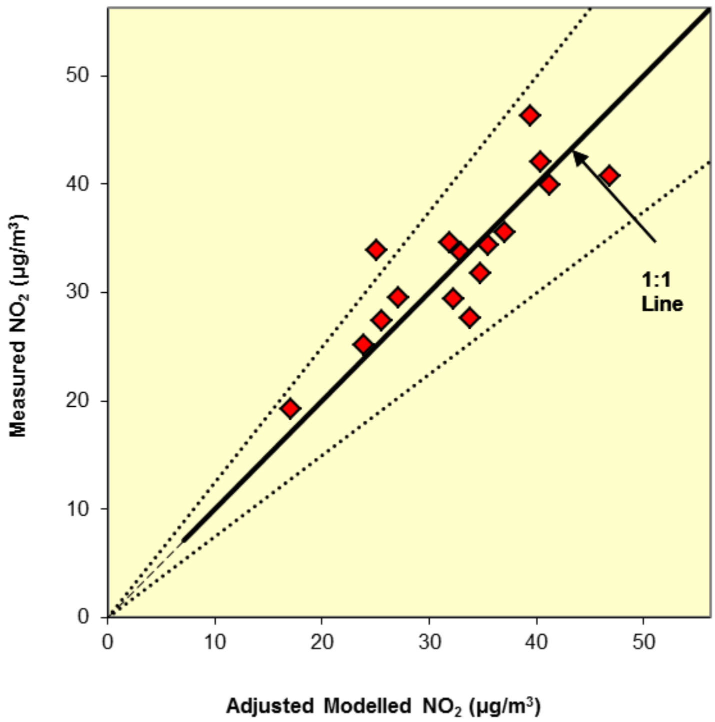

Figure A4.5: Comparison of Measured Total NO_2 to Final Adjusted Modelled Total NO_2 Concentrations. The dashed lines show ± 25%.

Model Post-processing

A4.17 The model predicts road-NOx concentrations at each grid point. These concentrations have then been adjusted using the primary adjustment factor, which, along with the background NO_2, is processed through the NOx from NO_2 calculator available on the Defra LAQM Support website (Defra, 2014c). The traffic mix within the calculator has been set to "All other-urban UK traffic", which is considered suitable for the study area. The calculator predicts the component of NO_2 based on the adjusted road-NOx and the background NO_2. This is then adjusted by the secondary adjustment factor to provide the final predicted concentrations.

Uncertainty

6.1 Uncertainty is inherent in all measured and modelled data. All values presented in this report are the best possible estimates, but uncertainties in the results might cause over- or under-predictions. All of the measured concentrations presented have an intrinsic margin of error. Defra (2011) suggests that this is of the order of plus or minus 20% for diffusion tube data and plus or minus 10% for automatic measurements.

6.2 The model results rely on traffic data provided by The Highland Council, and any uncertainties inherent in these data will carry into this assessment. There will be additional uncertainties introduced because the modelling has simplified real-world processes into a series of algorithms. For example: it has been assumed that wind conditions measured at Inverness Airport during 2013 will have occurred throughout the study area during 2013; and it has been assumed that the dispersion of emitted pollutants will conform to a Gaussian distribution over flat terrain. In addition, assumptions that a number of the streets form street canyons, adds a level of uncertainty, since the model assumes full street canyons, whereas in reality a number of street have broken sections which is likely to allow for greater dispersion within the streets than will be assumed by the model.

6.3 An important step in the assessment is verifying the dispersion model against the measured data. By comparing the model results with measurements, and correcting for the apparent under-prediction of the model, the uncertainties can be reduced. The limitations to the assessment should be borne in mind when considering the results set out in the following sections. While the model should give an overall accurate picture, i.e. one without bias, there will be uncertainties for individual receptors. The results are 'best estimates' and have been treated as such in the discussion.