
Detailed Assessment of Air Quality 2013

Main Street, Uddingston, South Lanarkshire

Report for South Lanarkshire Council

Ricardo-AEA/R/ED56927001-UddDA

Issue Number 1

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Customer:

South Lanarkshire Council

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Executive summary

Ricardo-AEA have been commissioned by South Lanarkshire Council to undertake a Detailed Assessment of Air Quality for the area around the Main Street/Bellshill Road junction in Uddingston. The assessment has been undertaken to investigate the potential scale and extent of exceedances of the Air Quality Objectives in the study area. This Detailed Assessment will allow South Lanarkshire Council to decide whether or not an Air Quality Management Area is required at the study location. The assessment is being carried out based on the conclusions of the 2009 Updating and Screening Assessment.

This atmospheric dispersion modelling study, which has used the most recent traffic, monitoring and meteorological data for the area, indicates that there are no exceedances of the NO₂ annual mean objective occurring at locations with relevant exposure.

In light of this Detailed Assessment of Air Quality, South Lanarkshire Council are not required to declare an Air Quality Management Area at this time.

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1 Introduction

Ricardo-AEA has been commissioned by South Lanarkshire Council to undertake a Detailed Assessment of Air Quality at Main Street in Uddingston, South Lanarkshire. The assessment has been undertaken to investigate the scale and extent of potential exceedances of the Air Quality Objectives within the study area. The Detailed Assessment will allow South Lanarkshire Council to decide whether or not an Air Quality Management Area is required at this location.

1.1 Policy background

The Environment Act 1995 placed a responsibility on UK Government to prepare an Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland. The most recent version of the strategy (2007) sets out the current UK framework for air quality management and includes a number of air quality objectives for specific pollutants.

The 1995 Act also requires that Local Authorities “Review and Assess” air quality in their areas following a prescribed timetable. The Review and Assessment process is intended to locate and spatially define areas where the AQS objectives are not being met. In such instances the Local Authority is required to declare an Air Quality Management Area (AQMA), carry out a Further Assessment of Air Quality, and develop an Air Quality Action Plan (AQAP) which should include measures to improve air quality so that the objectives may be achieved in the future. The timetables and methodologies for carrying out Review and Assessment studies are prescribed in Defra and the devolved administrations’ Technical Guidance- LAQM.TG(09).

Table 1 lists the objectives relevant to this assessment that are included in the Air Quality (Scotland) Regulations 2000 (Scottish SI 2000 No 97) and the Air Quality (Scotland) (Amendment) Regulations 2002 (Scottish SI 2002 No 297) for the purposes of Local Air Quality Management (LAQM).

Table 1: NO₂ Objectives for the purpose of Local Air Quality Management

Pollutant	Air Quality Objective	
	Concentration	Measured as
Nitrogen dioxide (NO ₂)	200 µg.m ⁻³ not to be exceeded more than 18 times a year	1 hour mean
	40 µg.m ⁻³	Annual mean

1.2 Locations where the 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 to be exposed over the averaging period of the objective. Table 2 summarises examples of where the air quality objectives for NO₂ should and should not apply.

Table 2: Examples of where the NO₂ Air Quality Objectives should and should not apply

Averaging Period	Pollutants	Objectives <i>should</i> apply at ...	Objectives <i>should not</i> 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
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.

1.3 Purpose of this Detailed Assessment

This study is a Detailed Assessment, which aims to assess the magnitude and spatial extent of any exceedances of the NO₂ objectives at locations where relevant human exposure may occur within selected locations in the study area in Uddingston.

1.4 Overview of the Detailed Assessment

The general approach taken to this Detailed Assessment was:

- Collect and interpret data from previous Review and Assessment reports.
- Collect and analyse recent traffic, monitoring, meteorological and background concentration data for use in a dispersion modelling study.
- Use dispersion modelling to produce numerical predictions of NO₂ concentrations at points of relevant exposure.
- Use dispersion modelling to produce contour plots of NO₂ concentrations;
- Recommend if South Lanarkshire Council should declare an AQMA at any location within the study area and suggest its spatial extent.

The modelling methodologies provided for Detailed Assessments outlined in Defra Technical Guidance LAQM.TG(09)¹ were used throughout this study.

1.5 Previous Air Quality Review and Assessment work

Updating and Screening Assessment (2009)

A review of roads traffic sources within the South Lanarkshire Council area identified that traffic flow counts of 13,900 AADT were recorded at the section of Main Street, Uddingston between the junctions with Church St/Spindlerow Road and the junction with Bellshill Road. This was in excess of the screening criteria of 5,000 AADT specified in TG(09) for narrow congested streets, over which a detailed assessment is required for NO₂. The report recommended that the council proceed to a Detailed Assessment at this location.

Delays with completion of Detailed Assessment

The requirement to conduct a Detailed Assessment of NO₂ in Uddingston was originally identified in the 2009 Updating and Screening assessment. Automatic monitoring commenced in Uddingston during 2011. Due to problems with site calibrations during the initial period of operation, it was not possible to ratify the data captured during 2011. Unfortunately another unforeseen problem with the automatic-calibration system on the analyser during 2012 meant that again it was not possible to ratify the 2012 monitoring data.

Manual calibrations commenced at the automatic monitor in March 2013 allowing sufficient ratified monitoring data for the 2013 calendar year. Additional NO₂ diffusion tubes were also deployed in during September 2012 to supplement the monitoring data available for the study. The monitoring data used for this Detailed Assessment is therefore considered much better than was previously available.

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

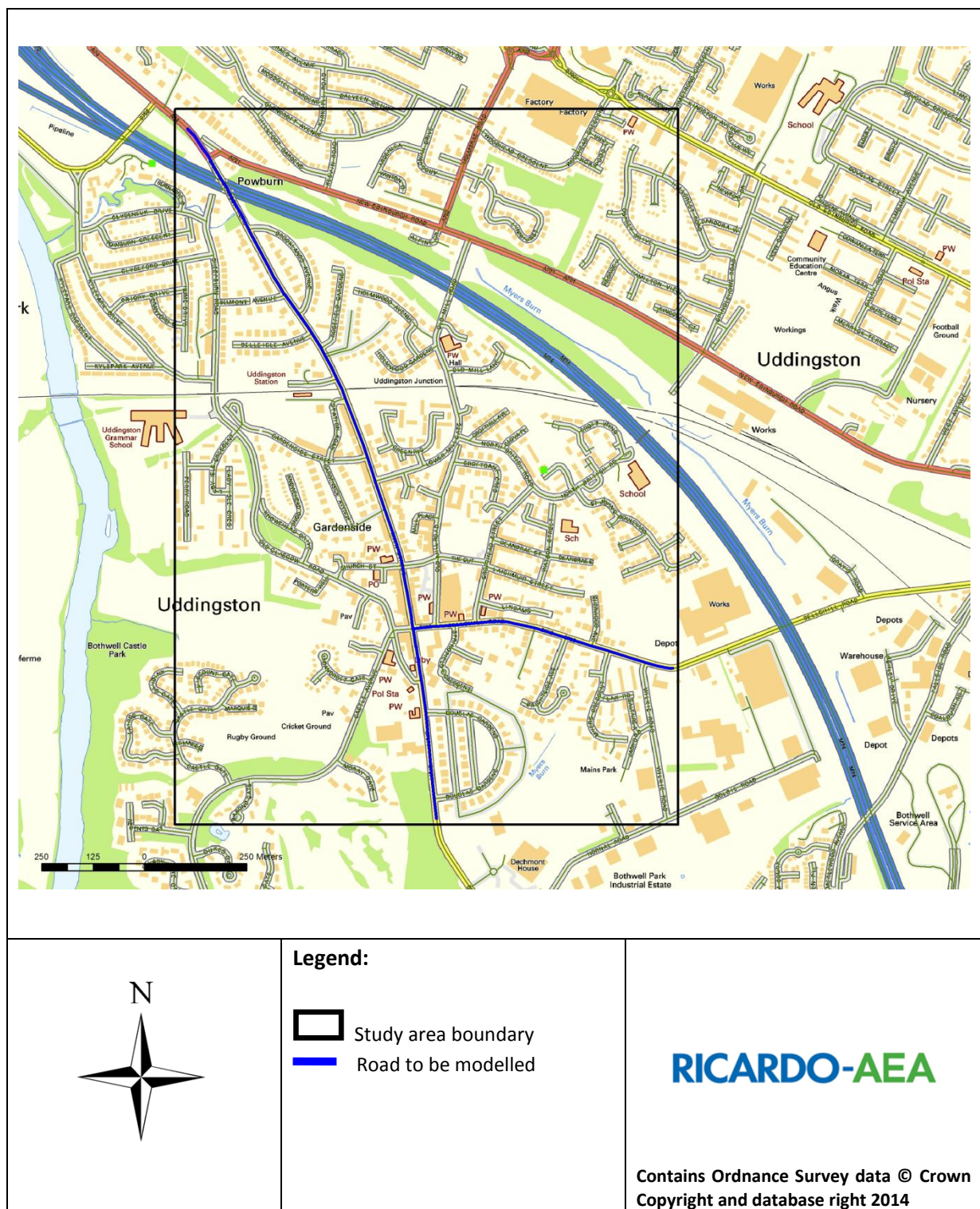
2 Detailed Assessment study area

Uddingston is a small town located to the north of the South Lanarkshire area approximately 12 km southeast of central Glasgow.

The Detailed Assessment is concerned with Main St, Uddingston; and the roads close to the junction of Main St with Bellshill Road and Bothwell Road. The study area has also been extended north of Main Street to include Glasgow Road up to the boundary with the North Lanarkshire Council area boundary where Glasgow Road crosses the M74 motorway.

The assessment will consider road traffic emissions from the main roads in the study area and includes the effects of high-sided streets, which are modelled as street canyons where they are present.

The study area, including the roads modelled and the extent of the detailed assessment is presented in Figure 1 below. The size of the study area is approximately 1.2 km by 1.75 km.

Figure 1: Detailed Assessment study area

3 Information used to support this assessment

3.1 Maps

Ordnance Survey based GIS data of the model domain and a road centreline GIS dataset were used in the assessment. This enabled accurate road widths and the distance of the housing to the kerb to be determined in ArcMap.

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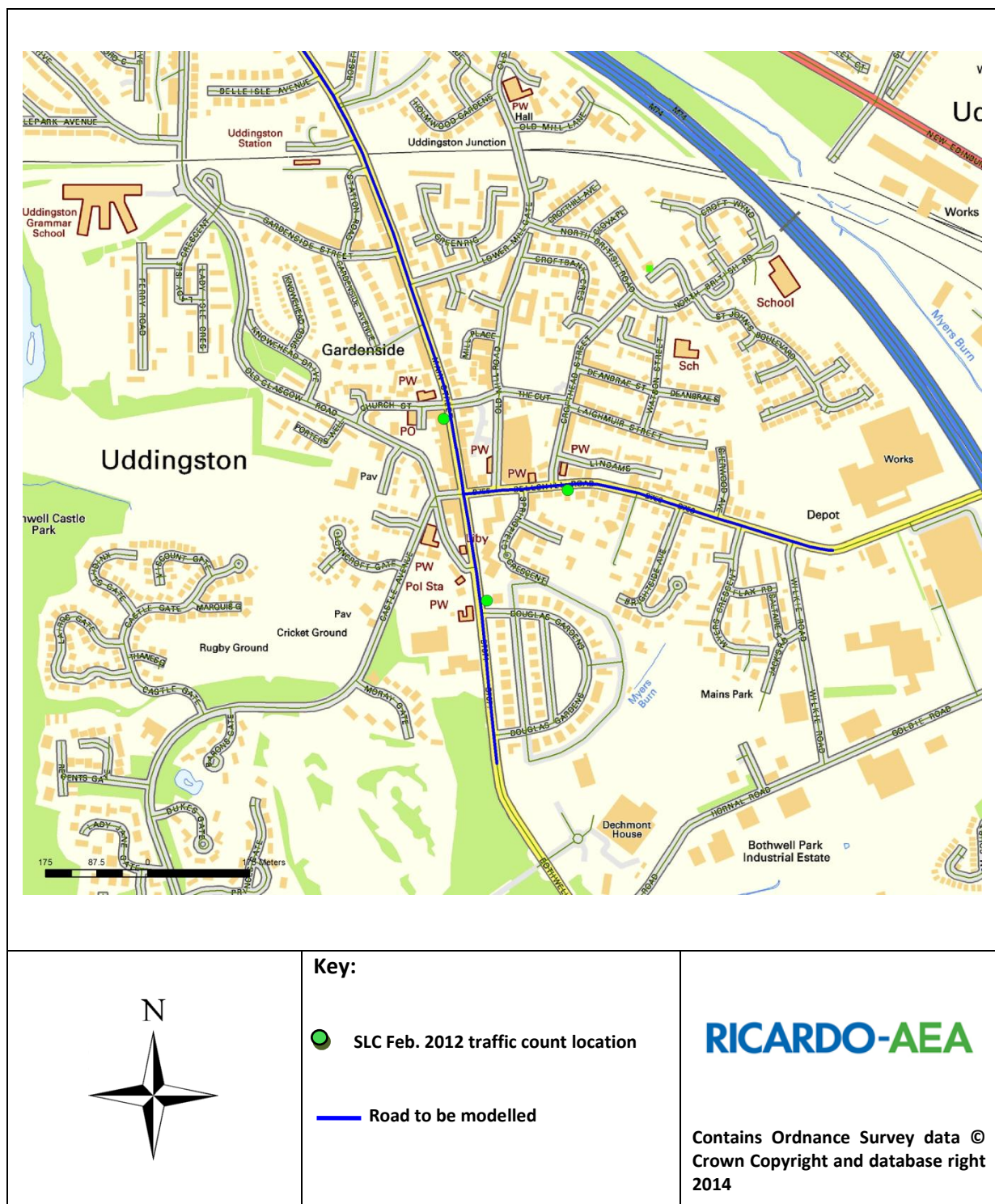
3.2 Road traffic data

3.2.1 Average flow, speed and fleet split

South Lanarkshire Council provided annual average daily traffic (AADT) flow data containing percentage splits for various vehicle classes from a video traffic count study conducted in February 2012 at three locations on Bellshill Road, Main Street and Bothwell Road. All AADT flows were factored forward to the 2013 study year using the NRTF Central growth forecast. A map showing the traffic count locations is presented in Figure 2. No measured speed data were available for the roads being modelled, vehicle speeds for road links were assumed based on local knowledge and professional judgement.

It should be noted that traffic patterns in urban locations are complex and it is not possible to fully represent these in atmospheric dispersion models. By attempting to describe these complex traffic patterns using quite simple metrics (AADT, average speed and vehicle split composition) a degree of uncertainty is introduced to the modelling.

Figure 2: Traffic count locations



3.2.2 Congestion

During congested periods average vehicle speeds reduce when compared to the daily average; the combination of slower average vehicle speeds and more vehicles lead to higher pollutant emissions during peak hours; it's therefore important to account for this when modelling vehicle emissions to estimate pollutant concentrations.

No queue observation data from traffic surveys was available for the assessment. As an alternative indicative method of observing local traffic patterns, real time traffic flows were observed a number of times using the traffic layer on Google maps. These online maps are derived from real time GPS measurements so can be considered quite robust. The observations indicated that traffic becomes congested (i.e. very slow moving) occasionally when heading south along Main Street towards the junction with Bellshill Roads.

The TG(09) guidance states that the preferred approach to representing the resulting increase in vehicle emissions during these peak periods is to calculate the emission rate for the affected roads for each hour of the day or week, on the basis of the average speeds and traffic flows for each hour of the day. The hourly specific emission rates can then be used to calculate a 24-hr diurnal emission profile which can be applied to that section of road. In this case an annual average diurnal profile of traffic flow across the study area was available from the local traffic count data but no speed measurement data was available. Peak periods in traffic flow were therefore accounted for in the model by applying the diurnal traffic flow profile to the average hourly emission rate. To account for speed reductions during peak traffic periods, assumed average speeds were reduced at road sections where slow moving traffic was observed.

3.2.3 Emission factors

The latest version of the Emissions Factors Toolkit² (EFT V5.2c Jan 2013) release) was used in this assessment to calculate pollutant emissions factors for each road link modelled. The calculated emission factors were then imported in to the ADMS-Roads model.

Parameters such as traffic volume, speed and fleet composition are entered into the Eft, and an emissions factor in grams of NO_x/kilometre/second is generated for input into the dispersion model. In the latest version of the Eft, NO_x emissions factors previously based on DFT/TRL functions have been replaced by factors from COPERT 4 v8.1. These emissions factors were published in May 2011 through the European Environment Agency and are widely used for the purpose of calculating emissions from road traffic in Europe.

The latest version of the EFT also includes addition of road abrasion emission factors for particulate matter; and changes to composition of the vehicle fleet in terms of the proportion of vehicle km travelled by each Euro standard, technology mix, vehicle size and vehicle category.

Vehicle emission projections are based largely on the assumption that emissions from the fleet will reduce as newer vehicles are introduced. Any inaccuracy in the emissions factors contained in the EFT will be unavoidably carried forward into this modelling assessment.

² <http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft>

3.3 Meteorological data

Hourly sequential meteorological data (wind speed, direction etc.) for 2013 from the Glasgow Airport meteorological measurement site were used for the modelling assessment. The meteorological measurement site is located approximately 23 km WNW of the study area and has good data quality for the period of interest.

Meteorological measurements are subject to their own uncertainty which will unavoidably carry forward into this assessment.

3.4 Background concentrations

Background NO_x concentrations for a dispersion modelling study can be derived from either local monitoring data conducted at a background site or from the Scottish LAQM background maps³.

A CSV file containing concentrations across the South Lanarkshire Council area was accessed from the Air Quality in Scotland website and the background NO_x concentration for the appropriate grid square extracted. The source contributions of background pollutant concentrations attributable to road traffic on the primary A roads within the study area were also subtracted from the total background to avoid double counting emissions from the roads. The mapped annual mean NO_x background concentration for the relevant grid square during 2013 was 34 µg.m⁻³. It should be noted that the background maps are the outputs of a national scale dispersion model provided at a 1km x 1km resolution and are therefore subject to a degree of uncertainty.

The closest urban background NO₂ diffusion tube monitoring site is located at North British Road which is approximately 650m north east of the Main Street/Bothwell Street junction. The NO₂ annual mean measured at North British Road during 2013 was 27.5 µg.m⁻³ which when back calculated using the NO_x to NO₂ calculator equates to a background total NO_x concentration of 55 µg.m⁻³ which is much higher than the mapped background concentration of 34 µg.m⁻³ at the study area. Comparison of the measured background concentration with the mapped concentration at the location of the background monitoring site (which is in a different 1km grid square than the study area) confirmed that background concentrations are predicted to be much higher at the background monitoring location as it is located much closer to the M74 motorway.

The mapped background annual mean total NO_x concentration of 34 µg.m⁻³ was therefore considered most appropriate for use in the modelling assessment.

³ Air Quality in Scotland website(2014) <http://www.scottishairquality.co.uk/maps>

4 Ambient monitoring

South Lanarkshire Council currently measures NO₂ concentrations at one continuous analyser and two diffusion tube site within the study area in Uddingston. A map showing the location of the monitoring sites is presented in Figure 3.

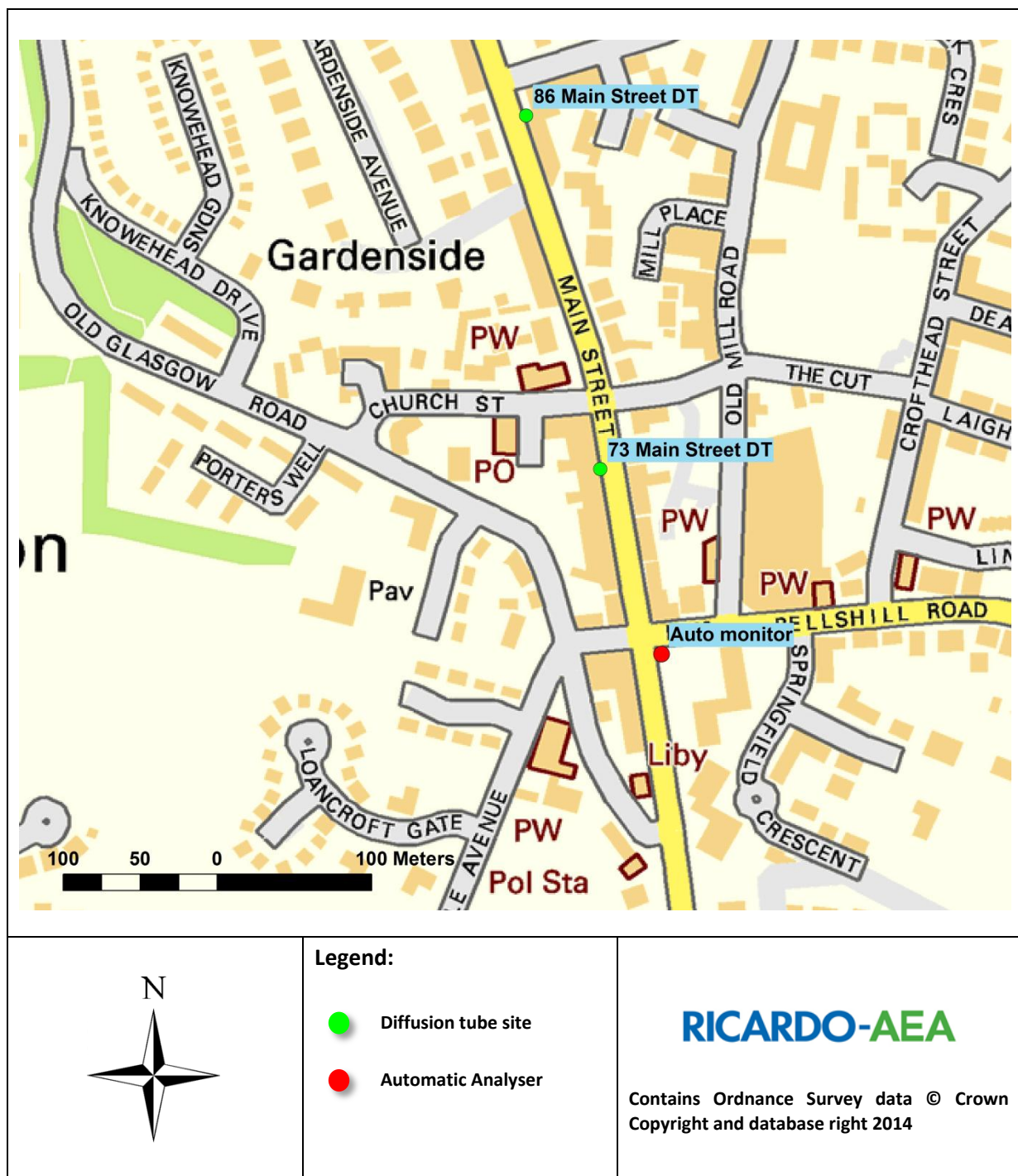
Details of the monitoring sites and the annual mean concentrations measured during 2013 are presented in Table 3. All diffusion tube results have been bias adjusted using a factor of 0.79 accessed from the latest National database of co-location factors⁴. Full details of bias adjustment factors applied to the diffusion tube results and QA/QC procedures are presented in South Lanarkshire Council's 2014 LAQM Progress Report.

No annual mean NO₂ concentrations in excess of the 40 µg.m⁻³ objective were measured in Uddingston during 2013.

Table 3: NO₂ measurements - comparison with annual mean objective

Site	Type	OS Grid Ref.		Relevant exposure Y/N with distance (m)	Data Capture 2013 (%)	NO ₂ Annual mean 2013 (µg.m ⁻³)
		Easting	Northing			
Uddingston automatic analyser	R	269663	660304	Y (2m)	97%	27
73 Main Street	R	269620	660425	Y (0m)	100%	33.3
86 Main Street	R	269571	660654	Y (0m)	100%	25.9
Exceedances of the annual mean objective are highlighted in bold R – Roadside monitoring location, 1-5m from the kerb of a busy road						

⁴ NPL(2013) Database_Diffusion_Tube_Bias_Factors-v03_14-Final-v2.xls (available to download at <http://laqm.defra.gov.uk/> (accessed April 2014))

Figure 3: Uddingston NO₂ monitoring locations

5 Modelling

5.1 Modelling methodology

Annual mean concentrations of NO₂ have been modelled within the study area using the atmospheric dispersion model ADMS Roads (version 3.2).

The model was verified by comparing the modelled predictions of road NO_x with local monitoring results. The available measurements (described in Section 4 above) were used to verify the annual mean road NO_x model predictions. Following initial comparison of the modelled concentrations with the available monitoring data, refinements were made to the model input to achieve the best possible agreement with the monitoring results. Further information on model verification is provided in Section 5.1.3 and Appendix 3

A surface roughness of 1 m was used in the modelling to represent the urban area in the model domain. A limit for the Monin-Obukhov length of 10 m was applied to represent a small town.

The source-oriented grid option was used in ADMS-Roads; this option provides finer resolution of predicted pollutant concentrations along the roadside, with a wider grid spaced at approximately 12m being used to represent concentrations further away from the road. The grid height was set at 1.5m to represent ground level exposure as there are a mix of residential properties at both ground floor and 1st floor height above commercial premises within the study area. The predicted concentrations were interpolated to derive values between the grid points using the Spatial Analyst tool in the GIS software ArcMap 10. This allows contours showing the predicted spatial variation of pollutant concentrations to be produced and added to the digital base mapping.

It should be noted that any dispersion modelling study has a degree of uncertainty associated with it; all reasonable steps have been taken to reduce this where possible.

Slow moving traffic was treated in the model using the methodology described in Section 3.2.2 above. A time varying emissions file was used in the model to account for the daily variation in traffic flow.

5.1.1 Treatment of modelled NO_x road contribution

It is necessary to convert the modelled NO_x concentrations to NO₂ for comparison with the relevant objectives. The Defra NO_x/NO₂ model⁵ was used to calculate NO₂ concentrations from the NO_x concentrations predicted by ADMS-Roads. The model requires input of the background NO_x, the modelled road contribution and accounts for the proportion of NO_x released as primary NO₂. For the South Lanarkshire Council area in 2012 with the “All UK Traffic” option specified in the model, the NO_x/NO₂ model estimates that 22.9% of NO_x is released as primary NO₂.

5.1.2 Validation of ADMS Roads

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; this is usually conducted by the model developer.

⁵ Defra & The Devolved Administrations (2012) NO_x to NO₂ conversion spreadsheet; Available at <http://www.scottishairquality.co.uk/lagm/tools>

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 baseline model

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. Dispersion models of this nature carry a degree of uncertainty for the reasons explained in previous sections so it is important to check their performance against measurements and adjust their outputs accordingly. A full description of the model verification procedure for the baseline models is presented in Appendix 2.

A primary NO_x adjustment factor (PAdj) of 1.005 based on model verification using monitoring results covering the study period was applied to all modelled Road NO_x data prior to calculating an NO₂ annual mean. After the NO_x/NO₂ model was run no further adjustments were made to the data. Model agreement for the NO₂ monitoring data after adjustment is presented in Table 4 and Figure 4.

To evaluate the model performance and uncertainty, 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. Details of the RMSE calculation are presented in Appendix 2.

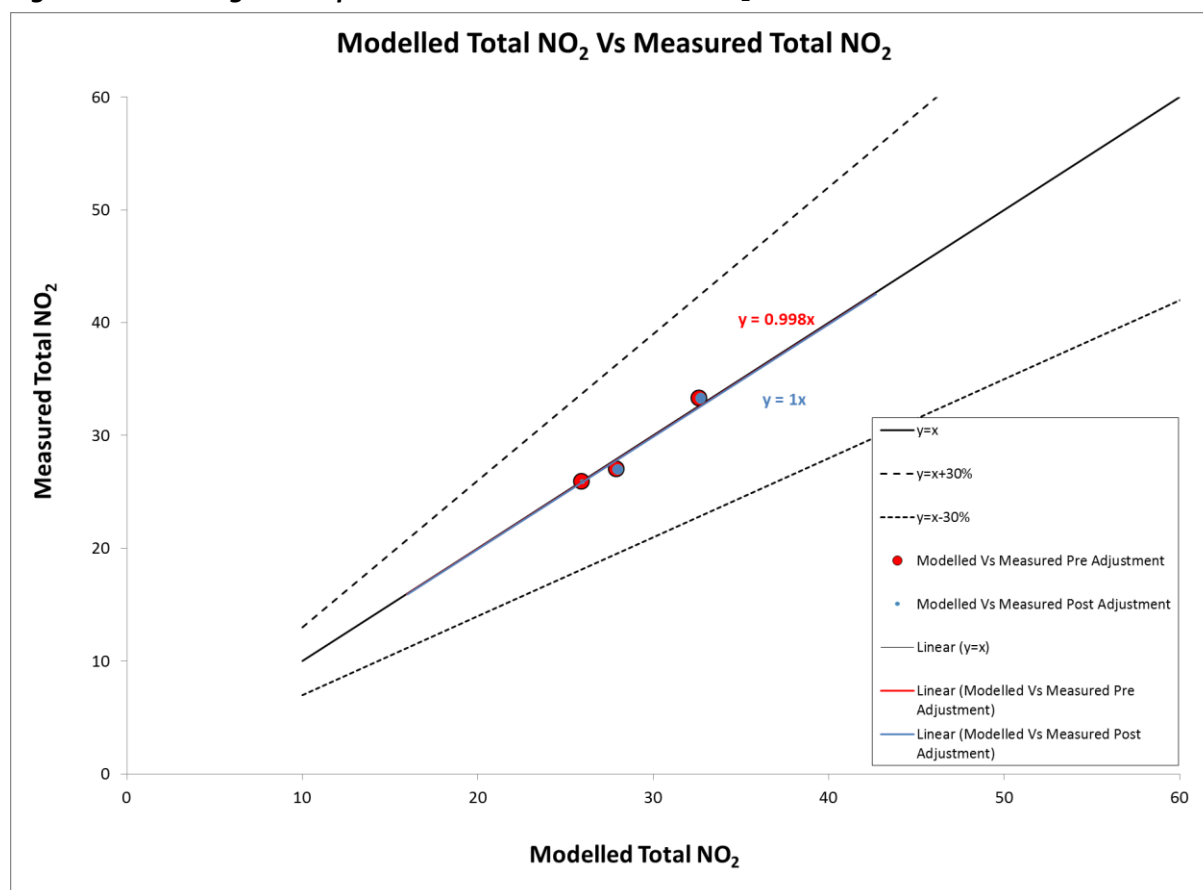
It is recommended that the RMSE is below 25% of the objective that the model is being compared against, but ideally under 10% of the objective i.e. 4 µg.m⁻³ (NO₂ annual mean objective of 40 µg.m⁻³). In this case the RMSE for the NO₂ annual mean was calculated at 0.66 µg.m⁻³; the model uncertainty is therefore well within the recommended value and the model has performed well for use within this assessment.

Verifying modelling data with diffusion tube monitoring data 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 results should be considered in this context.

Further information on the verification process, including linear regression plots, is provided in Appendix 3.

Table 4: Modelled vs. measured annual mean NO₂ concentrations 2013

Site	NO ₂ annual mean concentration (µg.m ⁻³)	
	Measured	Modelled
Auto monitor	27.0	28.0
73 Main Street DT	33.3	32.7
86 Main Street DT	25.9	26.0
RMSE =		0.66

Figure 4: Linear regression plot - modelled vs. monitored NO₂ annual mean

5.2 Modelling results

Annual mean NO₂ concentrations have been predicted at a selection of receptor locations within the study area where relevant exposure is present at both ground level and first floor height residential properties. The receptors are located at the facade of buildings in the model domain where relevant exposure is present next to the roads sources being modelled. Receptors modelled at 4m height are representative of 1st floor level exposure at residential properties above commercial premises.

Pollutant concentrations have also been predicted across a grid of points at ground level (1.5m) to create a contour plot showing the spatial variation in annual mean NO₂ concentrations.

5.2.1 NO₂ Annual mean concentrations

The predicted annual mean NO₂ concentrations at each of the specified receptors during 2013 are presented in Table 5. Maps representing the predicted annual mean NO₂ concentrations at the specified receptors using graduated colours are presented in Figure 5 to Figure 7. No annual mean NO₂ concentrations in excess of the 40 µg.m⁻³ objective were predicted at any of the specified receptor locations during 2013.

A contour plot showing the predicted spatial variation in annual mean NO₂ concentrations is presented in Figure 8. The contour plot does not indicate that there are any locations of relevant exposure within the study area where annual mean NO₂ concentrations are in excess of the 40 µg.m⁻³ objective.

Table 5: Predicted annual mean NO₂ concentrations at specified receptors 2013

Receptor location	Height (m)	OS Grid reference		Annual mean NO ₂ concentration (µg.m ⁻³)
		X	Y	
Auto monitor	1.8m	269660.1	660305.1	28.0
73 Main Street DT	2.3m	269620.0	660425.0	32.7
86 Main Street DT	2.5m	269571.8	660654.3	26.0
Main St 1	4m	269635.1	660330.4	23.4
Main St 2	4m	269647.8	660366.3	31.5
Main St 3	4m	269627.5	660377.9	22.9
Main St 4	4m	269639.4	660417.6	23.7
Main St 5	4m	269613.3	660459.8	23.0
Main St 6	1.5m	269632.1	660487.7	26.2
Main St 7	2m	269592.5	660506.9	23.4
Main St 8	4m	269613.0	660543.3	23.4
Main St 9	4m	269611.3	660556.6	23.2
Main St 10	4m	269576.3	660583.8	22.6
Main St 11	1.5m	269561.6	660614.8	24.1
Main St 12	1.5m	269545.8	660662.6	24.1
Main St 13	1.5m	269554.4	660710.6	26.4
Main St 14	1.5m	269529.5	660721.4	24.7
Bellshill Rd 1	4m	269662.5	660324.9	25.0
Bothwell Rd 1	4m	269639.4	660301.7	23.5
Bothwell Rd 2	4m	269645.7	660260.3	22.7

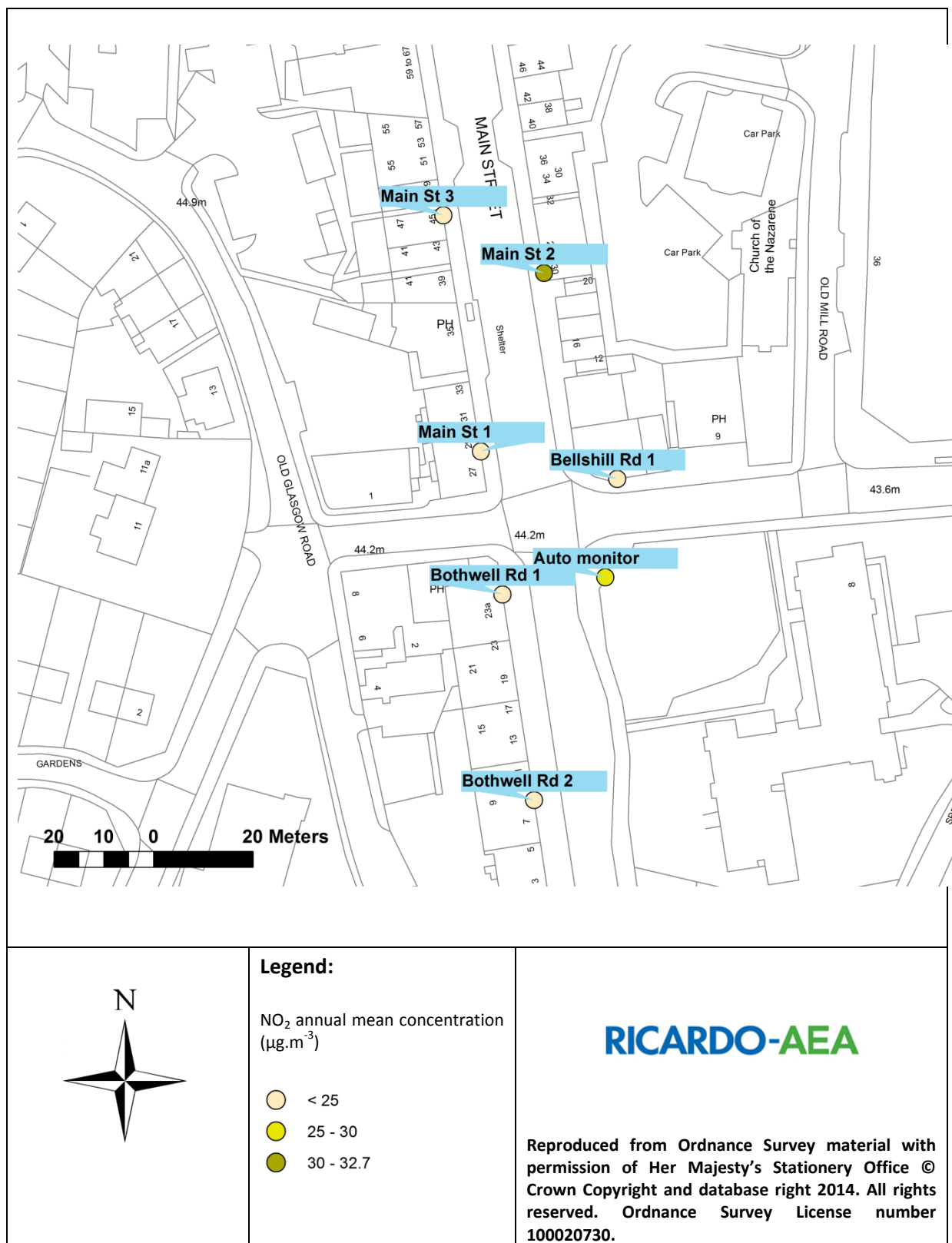
Figure 5: Predicted NO₂ annual mean at specified receptor locations – Main St/Bellshill Rd junction

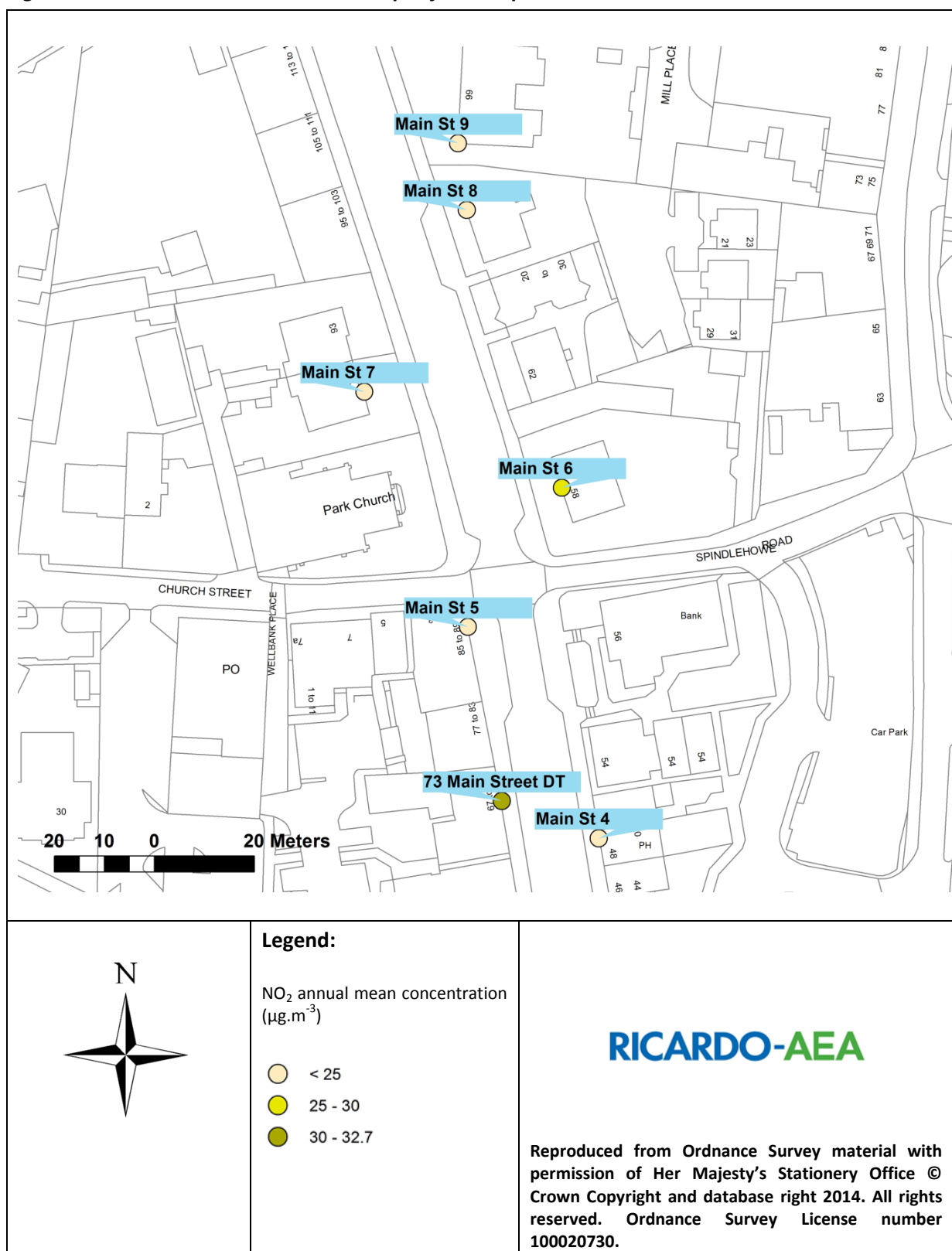
Figure 6: Predicted NO₂ annual mean at specified receptor locations – Main Street 4 - 9

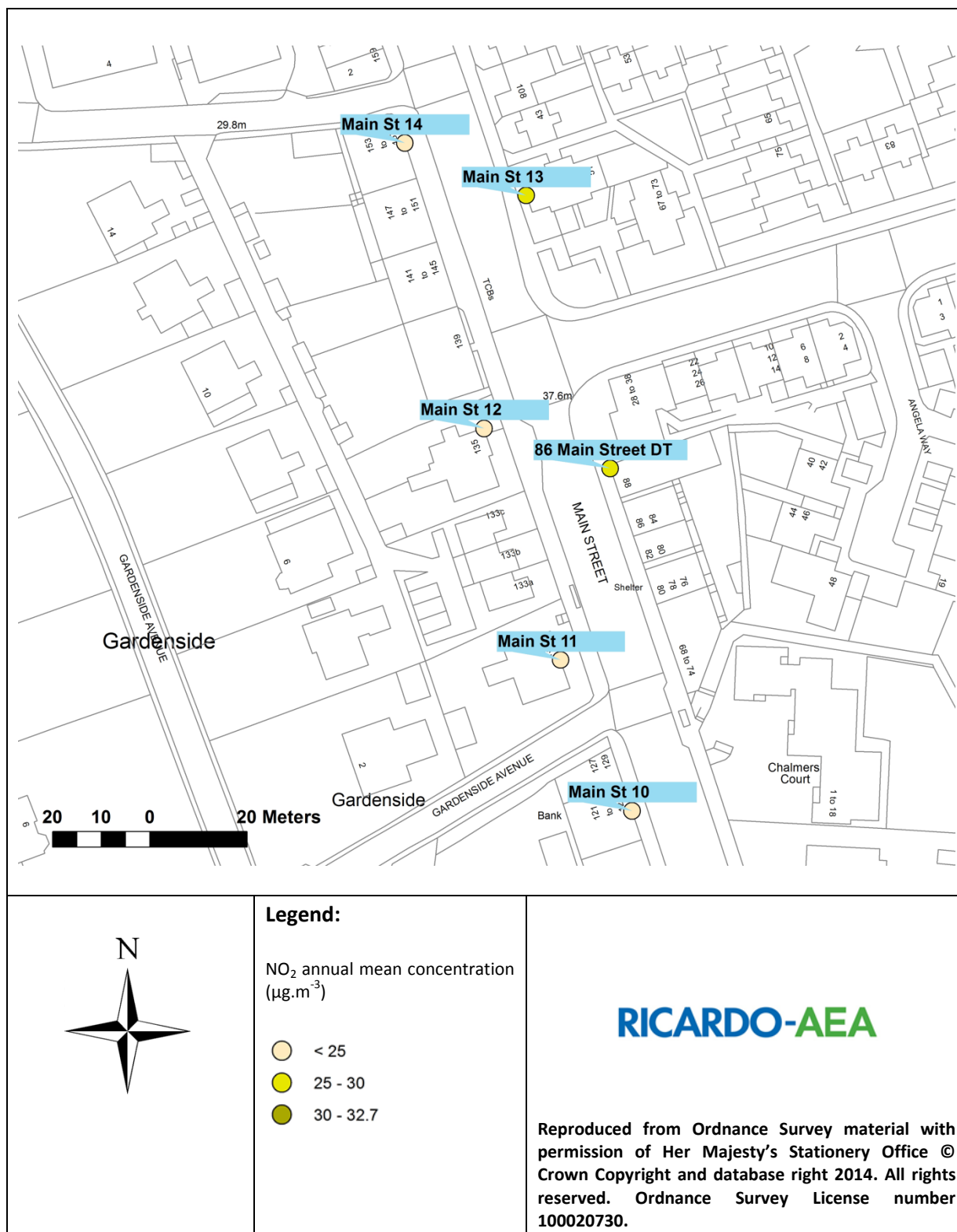
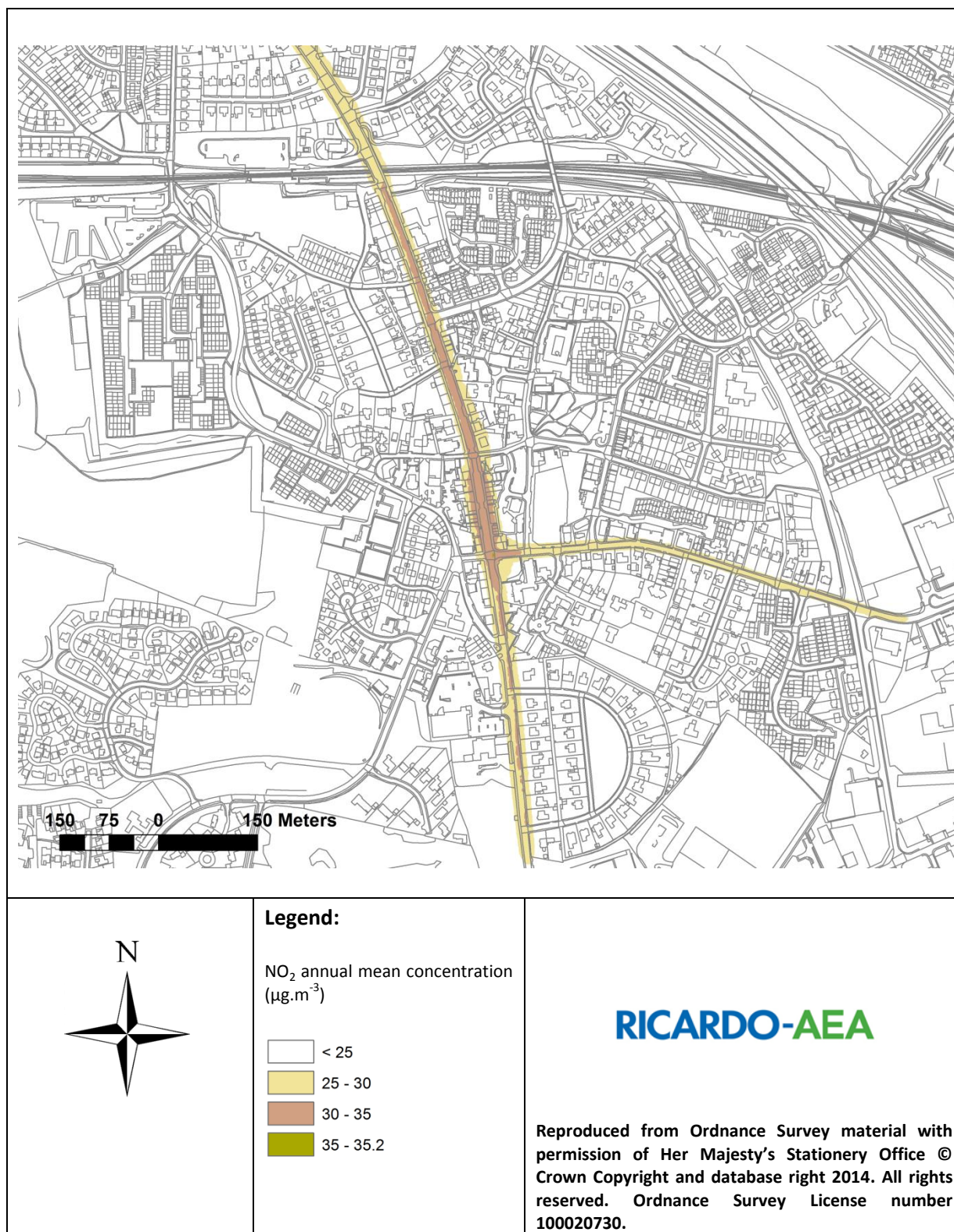
Figure 7: Predicted NO₂ annual mean at specified receptor locations – Main Street 10 - 14

Figure 8: Predicted NO₂ annual mean concentration contour

6 Conclusion

A dispersion modelling study of road traffic emissions in the area around the Main Street/Bellshill Road junction in Uddingston, South Lanarkshire has been conducted to allow a detailed assessment of NO₂ concentrations at this location.

The modelling study, which has used the most recent traffic, monitoring and meteorological data for the study area indicates that there are no exceedances of the NO₂ annual mean objective occurring at locations where there is relevant exposure.

In light of this Detailed Assessment of Air Quality, South Lanarkshire Council are not required to declare an Air Quality Management Area at this time.

7 Acknowledgements

Ricardo-AEA gratefully acknowledges the support received from Bronah Byrne, Anne Crossar and Andrew Smith of South Lanarkshire Council when completing this assessment.

Appendices

Appendix 1: Traffic data

Appendix 2: Meteorological data – Windrose

Appendix 3: Model Verification

Appendix 1: Traffic data

Table A2.1 summarises the Annual Average Daily Traffic (AADT) counts and fleet compositions used within the model. Traffic data were growth adjusted forward to 2013 using the NRTF Central growth forecast for 2011 to 2016

Table A2.1: Annual Average Daily Flows - 2013

Street	%Cars	%LGV	%HGV	%Bus	%2WM	AADF 2013
Main St (North of junction with Bellshill Rd)	85.8	8.9	3.6	1.6	0.1	12398
Main St (South of junction with Bellshill Rd)	88.8	7.1	2.3	1.6	0.1	12043
Bellshill Road	85.8	9.0	4.9	0.2	0.1	7030

LGV – Light Goods Vehicles

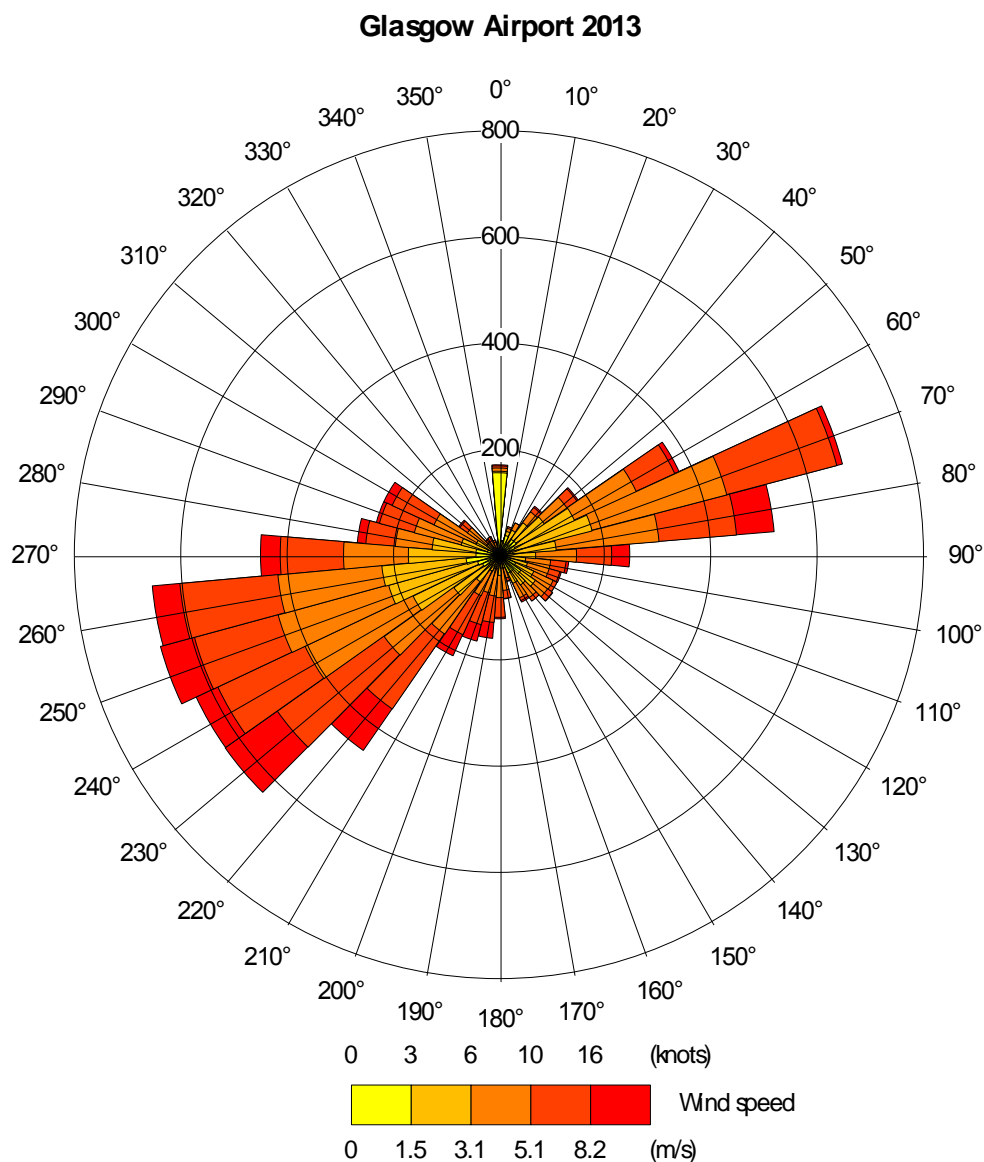
HGV – Heavy Goods Vehicles (Articulate and Rigid)

2WM - Motorcycles

Appendix 2: Meteorological data – Windrose

The Wind Rose for the 2013 Glasgow Airport meteorological dataset is presented in Figure A2.1

Figure A2.1 Meteorological dataset windrose



Appendix 3: Model Verification

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. This helps to identify how the model is performing at the various monitoring locations. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. LAQM.TG(09) recommends making the adjustment to the road contribution only and not the background concentration these are combined with.

NO₂

The approach outlined in Example 2 of LAQM.TG(09) has been used in this case.

It is appropriate to verify the performance of the ADMS Roads model in terms of primary pollutant emissions of nitrogen oxides (NO_x = NO + NO₂). To verify the model the predicted annual mean Road NO_x concentrations were compared with concentrations measured at the monitoring sites during the study period.

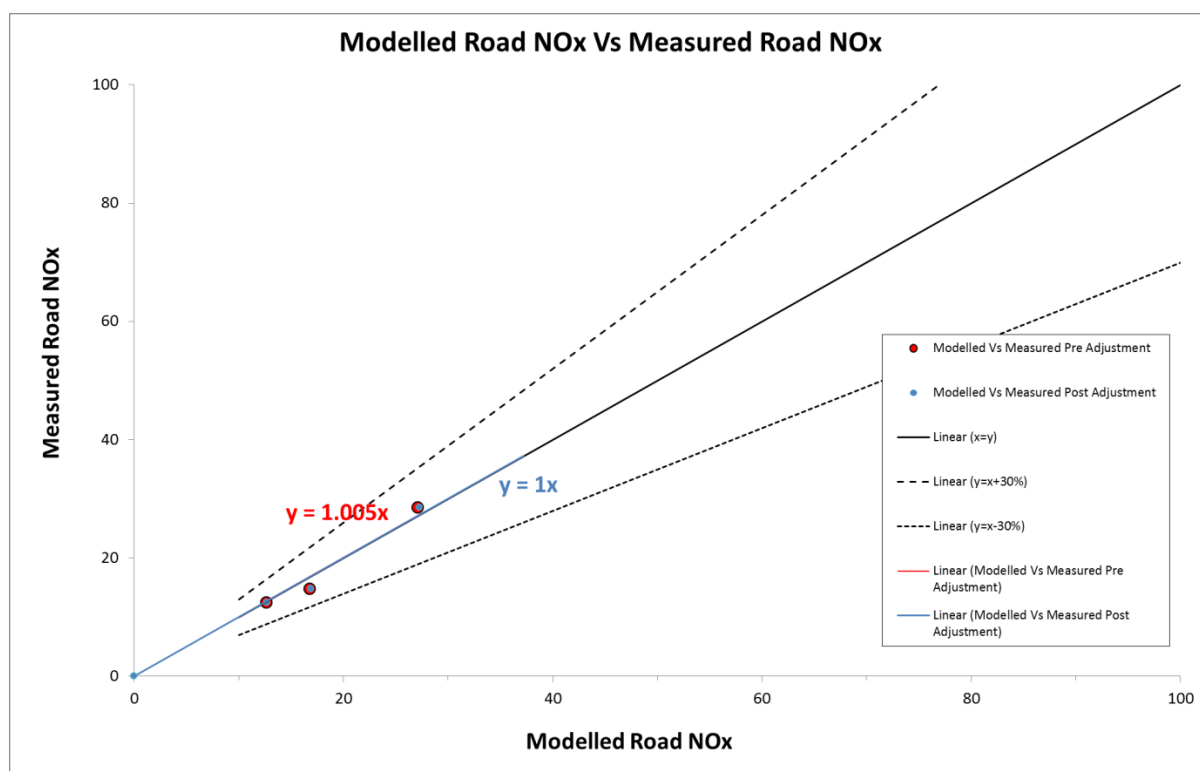
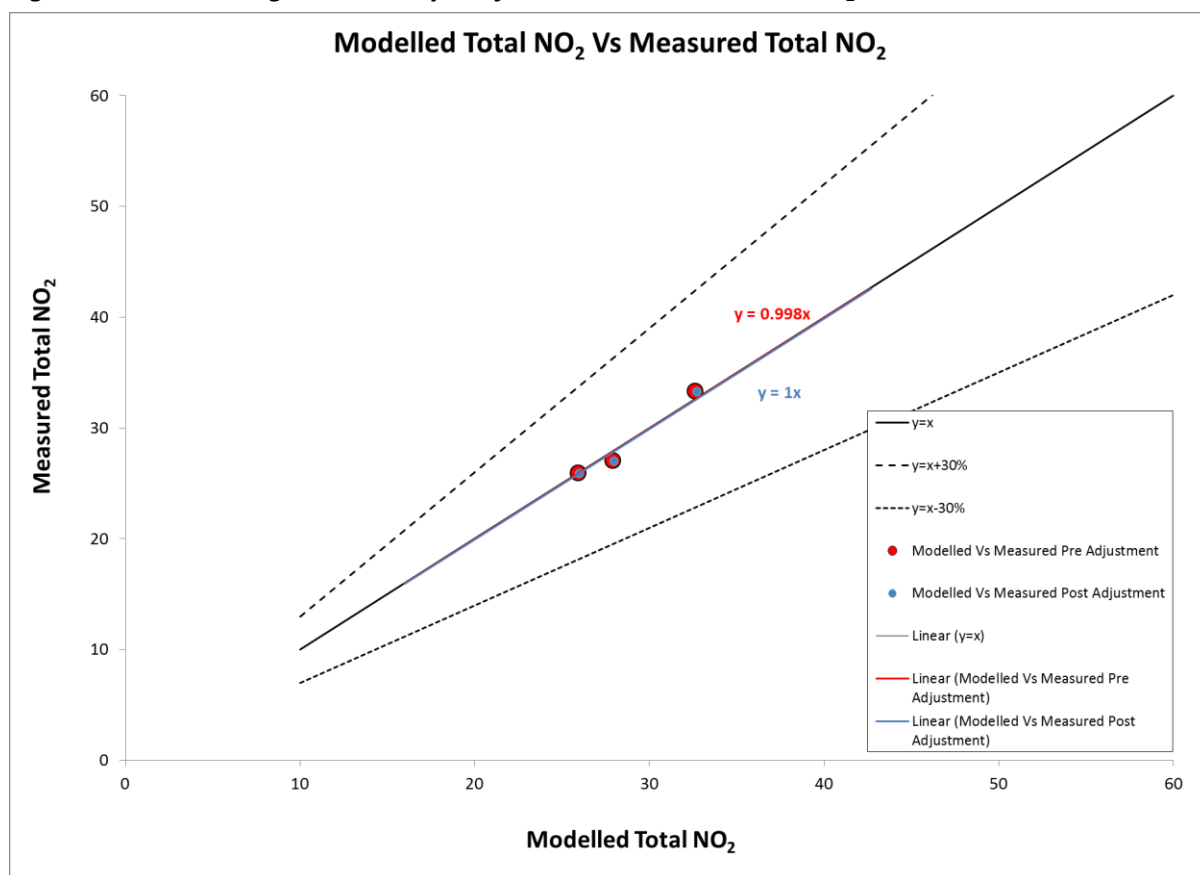
The model output of Road NO_x (the total NO_x originating from road traffic) has been compared with the measured Road NO_x, where the measured Road NO_x contribution is calculated as the difference between the total NO_x and the background NO_x value. Total measured NO_x for each diffusion tube was calculated from the measured NO₂ concentration using the latest version of the Defra NO_x/NO₂ calculator.

The initial comparison of the modelled vs measured Road NO_x identified that the model was under-predicting the Road NO_x contribution and the relationship between the various measurement was not linear. Refinements were subsequently made to the model input to improve the overall model performance.

The gradient of the best fit line for the modelled Road NO_x contribution vs. measured Road NO_x contribution was then determined using linear regression and used as the adjustment factor. This factor was then applied to the modelled Road NO_x concentration for each modelled point to provide adjusted modelled Road NO_x concentrations. A linear regression plot comparing modelled and monitored Road NO_x concentrations before and after adjustment is presented in Figure A3.1.

The background NO_x concentration was then added to determine the adjusted total modelled NO_x concentrations. The total annual mean NO₂ concentrations were then determined using the NO_x/NO₂ calculator.

A primary NO_x adjustment factor (PAdj) of **1.005** based on model verification using the 2013 monitoring results was applied to all modelled Road NO_x data prior to calculating an NO₂ annual mean. A plot comparing modelled and monitored NO₂ concentrations before and after adjustment during 2013 is presented in Figure A3.2.

Figure A3.1 Comparison of modelled Road NO_x Vs Measured Road NO_x before and after adjustmentFigure A3.2: Linear regression analysis of modelled vs. monitored NO₂ annual mean 2013

To evaluate the model performance and uncertainty, 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. The calculated RMSE is presented in Table A3.1.

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 i.e. 4 µg.m⁻³ (NO₂ annual mean objective of 40 µg.m⁻³). In this case the RMSE is calculated at 0.66 µg.m⁻³; the model uncertainty is therefore considered good and the model has performed sufficiently well for use within this assessment.

Table A3.1: Root mean square error

Site	NO ₂ annual mean concentration (µg.m ⁻³)	
	Measured	Modelled
Auto monitor	27.0	28.0
73 Main Street DT	33.3	32.7
86 Main Street DT	25.9	26.0
RMSE =		0.66



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