Ricardo Energy & Environment

Updated Detailed Assessment of Air Quality – High Street, Linlithgow

Report for West Lothian Council

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Ricardo in Confidence

Customer:

West Lothian Council

Customer reference:

Contact:

Jennifer Simpson
Ricardo Energy & Environment
2nd Floor, Blythswood Square, Glasgow,
G2 4BG, United Kingdom

t: +44 (0) 1235 75 33346

e: Jennifer.simpson@ricardo.com

Ricardo-AEA Ltd is certificated to ISO9001 and ISO14001

Author:

Bouvet, Celine

Approved By:

Simpson, Jennifer

Date:

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Executive summary

Ricardo Energy & Environment were commissioned by West Lothian Council to undertake a Detailed Assessment of Air Quality for the area around High Street in Linlithgow. The assessment has been undertaken to investigate the potential scale and extent of exceedances of the Scottish Air Quality Objectives in the study area.

This report describes a dispersion modelling study of road traffic emission at High Street in Linlithgow, West Lothian which has been conducted to allow a detailed assessment of NO_2 and PM_{10} concentrations at this location.

A combination of the available diffusion tube and automatic monitoring data and atmospheric dispersion modelling using ADMS-Roads has been used to conduct the study. The study utilises the latest available traffic and meteorological data for 2014.

The modelling study has indicated the following:

- NO_2 concentrations in excess of the 40 µg.m^{-3} annual mean objective occurred at 342 High Street where the predicted NO_2 annual mean concentration is 40.6 µg.m^{-3}.
- At specified receptors, High St 16, 17 and 18, the predicted NO_2 annual mean is below the annual mean objective. However these results should be considered in context with the estimated model uncertainty (RMSE as described in Section 5.1.3) which was 3.91 µg.m^{-3}. There is a risk that the annual mean objective may also be exceeded at ground level residential properties at these locations
- There were no exceedances of the NO_2 annual mean objective at first floor height where there are residential properties
- Annual mean PM_{10} concentrations in excess of the 18 µg.m^{-3} Scottish objective occurred at several locations along High Street at 10 residential properties.

In light of this update of the Detailed Assessment of Air Quality in Linlithgow using the available monitoring data from 2014, West Lothian Council is required to declare an Air Quality Management Area for the exceedances of both the annual mean NO_2 objective and the Scottish PM_{10} annual mean objective.

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Appendices

1 Introduction

Ricardo Energy & Environment were commissioned by West Lothian Council to undertake a Detailed Assessment of Air Quality at High Street, Linlithgow. The assessment has been undertaken to investigate the scale and extant of potential exceedances of the NO_2 and PM_{10} annual mean Scottish Air Quality Objectives within the study area.

1.1 Policy Background

The Environment Act 1995 placed a responsibility on the 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's Technical Guidance - LAQM.TG(09).

Table 1 lists the objectives relevant to this assessment that are included in the Air Quality Regulations 2000 and (Amendment) Regulations 2002 for the purposes of Local Air Quality Management (LAQM).

Table 1 NO_2 Objectives included in the Air Quality Regulations and subsequent Amendments for the purpose of Local Air Quality Management

Pollutant	Air Quality Objective Concentration	Measured as
Nitrogen dioxide	40 $\mu g.m^{-3}$	Annual mean
Particles (PM_{10}) (gravimetric) Authorities in Scotland	18 $\mu g.m^{-3}$	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 NO_2 and PM_{10} should and should not apply.

Table 2 Examples of where the NO_2 Air Quality Objectives should and should not apply

Averaging Period	Pollutant	Objectives should apply at….	Objectives should not generally apply at…
Annual mean	NO_2, PM_{10}	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

1.3 Purpose of the Detailed Assessment

This study is a Detailed Assessment, which aims to assess the magnitude and spatial extent of any exceedances of the NO_2 and PM_{10} annual mean objectives at locations where relevant human exposure may occur within the study area in Linlithgow.

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 before use in the dispersion model;
- Use dispersion modelling to produce numerical predictions of NO_2 and PM_{10} concentrations at points of relevant exposure;
- Use dispersion modelling to produce contour plots of NO_2 and PM_{10} concentrations;
- Recommend if West Lothian Council should declare an AQMA at any location within the study area in Linlithgow and suggest its spatial extent.

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

1.5 Previous Review and Assessment

The regulations require the local authority to undertake a Progress Report every year, except every 3rd year when an Updating and Screening Assessment (USA) is required.

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

The 2011 Detailed Assessment of fine particulate matter concentrations in High Street, Linlithgow indicated that the annual mean PM_{10} objective was being exceeded along the length of the High Street. The report concluded that the Council should proceed with declaring an AQMA in High Street, Linlithgow.

The 2012 USA concluded that the PM_{10} annual mean concentration measured in 2011 was below the 18 $\mu g.m^{-3}$ objective. The site location was however identified as not being representative of worst-case exposure in Linlithgow; SEPA and the Scottish Government recommended moving the automatic monitoring site to a more representative location within Linlithgow. The automatic monitoring station was moved to a worst case location in October 2013.

The 2014 Progress Report indicated that measured annual mean NO_2 and PM_{10} concentrations were in excess of the objectives in Linlithgow High Street. The distance corrected NO_2 concentrations were however below the objective and were only based on two months' worth of data. The report concluded that a Detailed Assessment for Linlithgow High Street was necessary.

2 Detailed Assessment study area

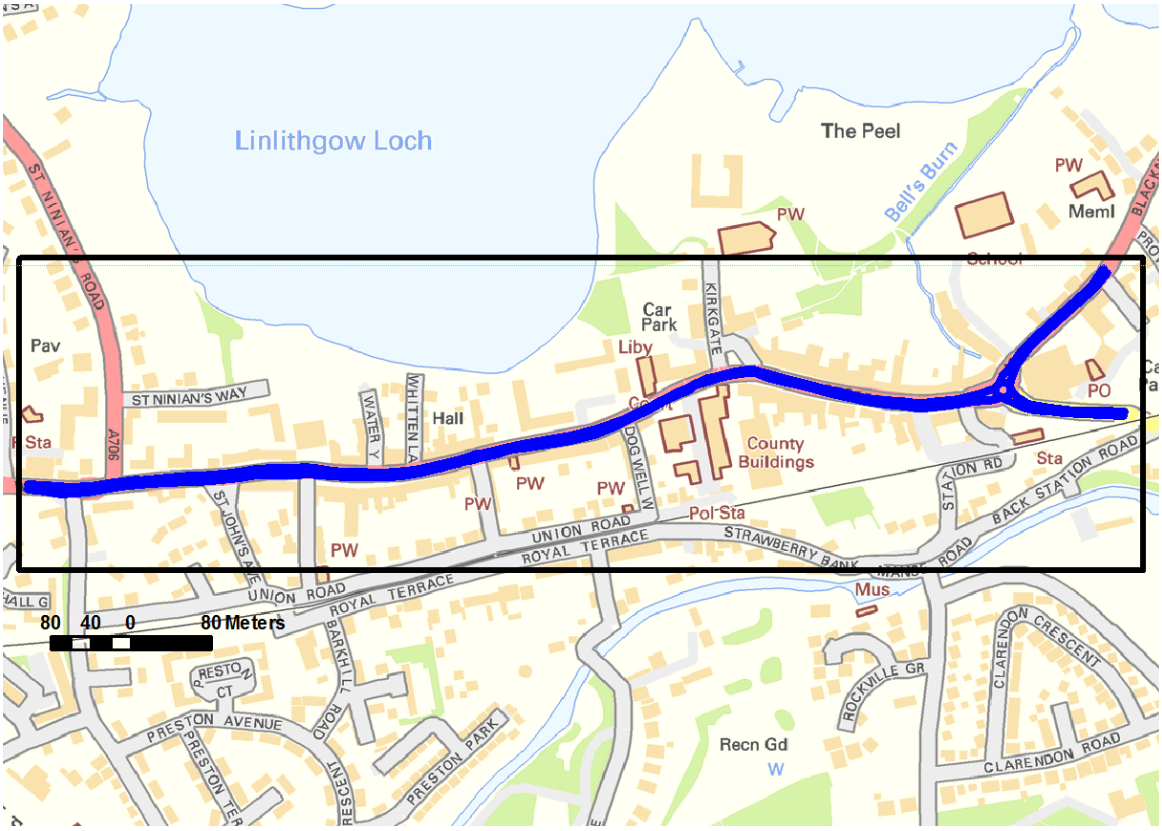
Linlithgow is a town located in the north-west of West Lothian, close to the border with Falkirk. It lies 30 km west of Edinburgh along the main railway route to Glasgow.

This Detailed Assessment is concerned with road traffic emissions from the High Street which passes through the town centre. The assessment considers road traffic emissions where relevant exposure is present close to the road.

2.1 Model domain

The study area comprises of both residential, commercial and public properties with residential flats at first floor height above commercial properties at many locations along the High Street. The study area, including the roads modelled and the extent of the detailed assessment is presented in Figure 1. The size of the study area is approximately 1,120 m by 310 m, with a grid resolution of 1.12 m x 3 m.

Figure 1 Detailed Assessment Study Area



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Legend:

Study area boundary

Road to be modelled

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2.2 Receptor Locations

The model has been used to predict NO_2 and PM_{10} annual mean concentrations at a selection of discrete receptors within the study area in addition to the diffusion tube sites. The receptors are located at the façade of buildings in the model domain where relevant exposure exists within the pollution hotspots identified from the modelled contour plots. The receptors have been modelled at both 1.5 m and 4 m to represent human exposure at ground floor level and 1st floor height where present. The locations of the selected receptors are presented in Table 3 and shown in Figure A.4 in Appendix 4.

Table 3 Receptor Locations

Receptor	Address	Easting	Northing
High St 1	315 to 325 High St	299594	677025
High St 2	303 to 313 High St	299614	677027
High St 3	293 High St	299672	677041
High St 4	257 to 259 High St	299771	677047
High St 5	201 to 203 High St	299898	677045
High St 6	131 to 135 High St	300056	677081
High St 7	123 to 125 High St	300081	677086
High St 8	63 High St	300277	677131
High St 9	374 to 396 High St	299632	677062
High St 10	350 to 372 High St	299669	677063
High St 11	36 High St	300403	677133
High St 12	2 to 4 High St	300484	677157
High St 13	318 to 340 High St	299720	677065
High St 14	290 to 315 High St	299761	677070
High St 15	342 High St	299708	677060
High St 16	103 to 105 High St	300138	677115
High St 17	DT 14/2	300420	677119
High St 18	DT 15	299929	677070
High St 19	DT 16	299911	677052
High St 20	DT 17	300479	677148
High St 21	DT 18	300485	677125
High St 22	DT 19	300398	677132
High St 23	DT 20	300399	677116

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.

3.2 Road traffic data

3.2.1 Average flow and fleet split

Traffic count data collected by a third party contractor[2] on behalf of West Lothian Council were used for the assessment, this included weekly automatic count and vehicle classification split data. Appendix 1 summarises all of the traffic flow data used for the road links modelled.

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 into the modelling.

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 were available for the assessment. 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 locally specific average weekday, Saturday and Sunday diurnal profiles of traffic flow across the study area were calculated using the local automatic traffic count data, but no hourly speed measurement data were available.

3.2.3 Vehicle emission factors

The latest version of the Emissions Factors Toolkit[3] (EFT V6.0.2 November 2014 release) was used in this assessment to calculate pollutant emission factors for each road link modelled. The calculated emission factors were then imported into 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 pollutant/kilometre/second is generated for input into the dispersion model. In the latest version of the EFT, NOx emissions factors previously based on DFT/TRL functions have been replaced by factors from COPERT 4 v10. These emissions factors are widely used for the purpose of calculating emissions from road traffic in Europe. Defra recognise these as the current official emission factors for road traffic sources when conducting local, regional and national scale dispersion modelling assessments.

[2] Sky High Count On Us – SCO 1464 West Lothian ATC Report – March 2015
[3] http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft

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. Much of the supporting data in the EFT is provided by the Department for Transport (DfT), Highways Agency and Transport Scotland.

Vehicle emission projections are based largely on the assumption that emissions from the fleet will fall as newer vehicles are introduced at a renewal rate forecast by the DfT. Any inaccuracy in the projections or the COPERT IV emissions factors contained in the EFT will be unavoidably carried forward into this modelling assessment.

3.3 Ambient monitoring

During 2014 West Lothian Council measured NO_2 concentration at seven diffusion tube sites within the study area in Linlithgow. In addition, NO_2 and PM_{10} concentrations are monitored by an automatic monitoring site located at the east end of Linlithgow High Street within area being modelled in this assessment.

Further details of these monitoring locations and recent measured concentrations are provided in Section 4.

3.4 Meteorological data

Hourly sequential meteorological data (wind speed, direction etc.) for 2014 measured at the Edinburgh Airport site was used for the modelling assessment. The meteorological measurement site is located approximately 14 km east 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. A wind rose of the meteorological site is presented in Appendix 2.

3.5 Background concentrations

Background NOx and PM_{10} concentrations for a dispersion modelling study can be assessed from either local monitoring data conducted at a background site or from the Defra background maps[4]. The Defra background maps are the outputs of a national scale dispersion model provided at a 1 km x 1 km resolution and are therefore subject to a degree of uncertainty.

In this case there are no urban background monitoring sites in Linlithgow, therefore the mapped background NOx and PM_{10} concentrations for the relevant 1 km x 1 km grid squares were used. The mapped annual mean background NOx and PM_{10} concentrations used in this assessment are presented in Table 4. The contribution of A-roads within each grid square has been removed from the background concentrations to avoid double counting.

Table 4 Linlithgow Study Area background NOx and PM_{10} values 2014 (µg.m^{-3})

X	Y	Total background	A Roads contribution	Total minus A Roads
		NOx		
299500	677500	23.2	1.6	21.6
300500	677500	22.5	1.9	20.6
		PM_{10}		
299500	677500	13.7	0.0	13.7
300500	677500	13.2	0.0	13.2

[4] Defra (2012) http://laqm1.defra.gov.uk/review/tools/background.php (accessed September 2012)

4 Monitoring data 2014

4.1 NO_2

West Lothian Council currently monitors NO_2 within the study area in Linlithgow at seven diffusion tubes sites and one automatic site. A map showing the location of each monitoring site is presented in Figure 2.

Full details of bias adjustment factors applied to the diffusion tube results and QA/QC procedures are presented in the West Lothian Council 2015 LAQM Updating and Screening Assessment.

NO_2 monitoring data for the past 3 years are presented in Tables 5.

There were no exceedances of the NO_2 annual mean objective at any of the monitoring sites along High Street in 2014. However, measured NO_2 concentrations were in excess of the annual mean objective at several locations in 2012 and 2013, resulting in the need to proceed to a Detailed Assessment at High Street, Linlithgow.

However during 2014 measured annual mean NO_2 concentrations at all monitoring locations are below the annual mean objective. This may be as a result of the low bias adjustment factor applied in 2014. Historically an adjustment factor of around 1 has been used, in 2014 the factor used was 0.81. Therefore the downward trend in annual mean NO_2 concentrations may be a result of the much lower bias adjustment factor.

Table 5 NO_2 Monitoring Data 2012 to 2014

Site	Type	2012 (Bias Adjustment Factor = 1.09)	2013 (Bias Adjustment Factor = 1.02)	2014 (Bias Adjustment Factor = 0.81)
Diffusion Tubes				
DT14/2 Linlithgow High St 2	R	N/A	**44**	33.3
DT15 Linlithgow H St NW	R	**43**	**40**	30.0
DT16 Linlithgow H St SW	R	**42**	**45**	35.2
DT17 Linlithgow H St NE	R	35	33	24.7
DT18 Linlithgow H St SE	R	31	**41**	31.5
DT19 Linlithgow H St N	R	**41**	**40**	28.1
DT20 Linlithgow H St S	R	**45**	**42**	32.9
Automatic Site				
CM 1(2)	R	N/A	**44.5**	32.4*

R – Roadside monitoring location, 1-5m from the kerb of a busy road

*This concentration has been annualised following the TG(09) method. A factor of 0.832 has been used.

4.2 PM_{10}

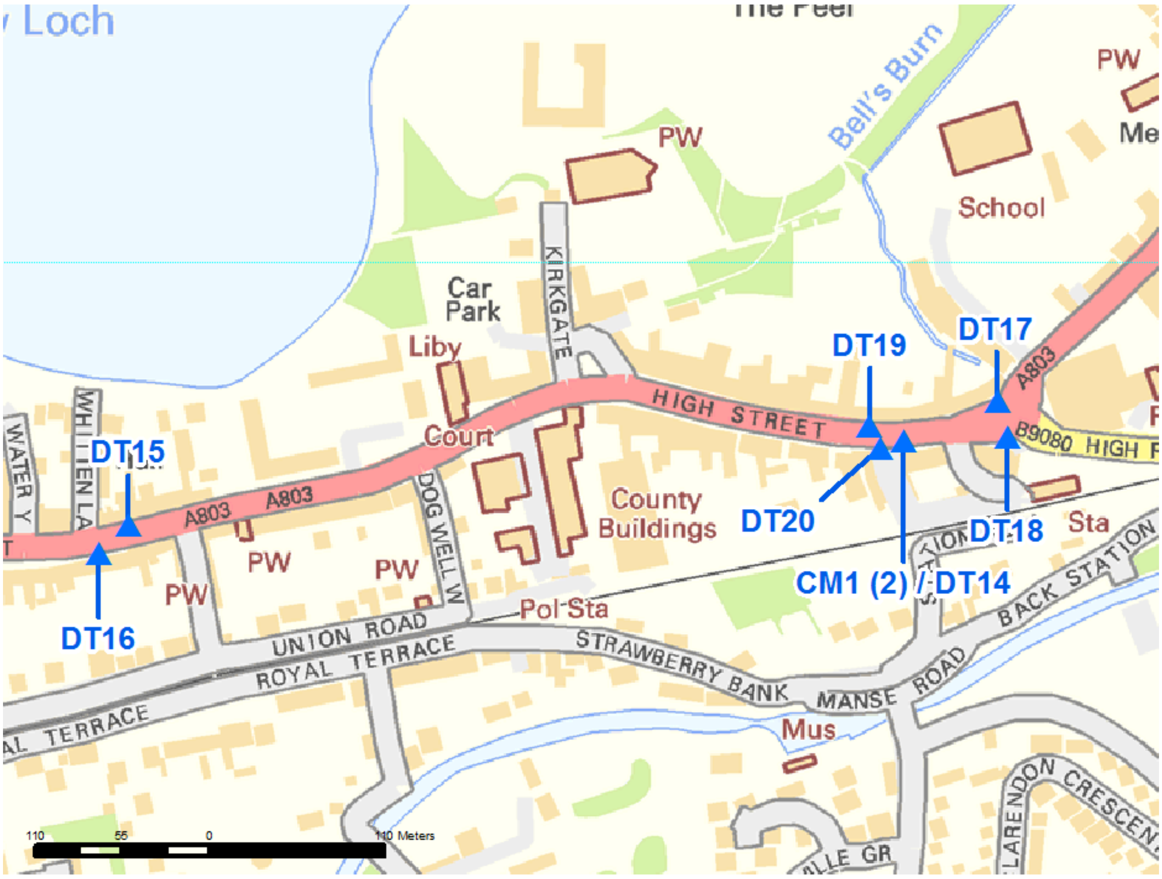
Measured PM_{10} annual mean concentrations have been exceeding the 18µg.m^{-3} Scottish annual mean objective at the automatic monitoring site in 2013 and 2014.

Monitoring data for the past 3 years are presented in Table 6.

Table 6 PM_{10} Monitoring Data 2012 to 2014

Site	Type	2012 (Bias Adjustment Factor = 1.09)	2013 (Bias Adjustment Factor = 1.02)	2014 (Bias Adjustment Factor = 0.81)
CM 1(2)	R	N/A	**18**	**18.1**

Figure 2 Linlithgow Monitoring Sites Locations



Legend:

▲ Monitoring sites locations

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5 Modelling methodology

Annual mean concentrations of NO_2 and PM_{10} during 2014 have been modelled within the study area using the atmospheric dispersion model ADMS Roads (version 3.4).

The model has been verified by comparison of the modelled predictions of road NOx and road PM_{10} with local monitoring results. The available roadside monitoring sites measurements within the study area (described in Section 4 above) were used to verify the annual mean road NOx 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 sites measurements. Further information on model verification is provided in Section 5.1.3 and Appendix 3.

A surface roughness of 0.5 m was used in the modelling to represent the sub-urban conditions in the model domain. A limit for the Monin-Obukhov 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 being used to represent concentrations further away from the road, the resolution which is dependent upon the total size of the domain being modelled. The predicted concentrations were interpolated to derive values between the grid points using the Spatial Analyst tool in 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.

Queuing traffic was considered using the methodology described in Section 3.2.2 above; whereby a time varying emissions file was used in the model to account for daily variations in traffic.

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.

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[5] 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 accounts for the proportion of NOx released as primary NO_2. For the West Lothian Council area in 2014 with the “All other UK urban Traffic” option in the model, the NOx/NO_2 model estimates that 22.8% of NOx is released as primary NO_2.

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.

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] Defra (2014) NOx NO_2 Calculator v4.1 released June 2014; Available at http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc

6 Model Results

6.1 Verification of the Model

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. LAQM.TG(09) recommends making the adjustment to the road contribution of the pollutant only and not the background concentrations these are combined with.

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

6.1.1 NO_2

The modelled NOx concentrations in this study were verified using the available 2014 roadside diffusion tube and automatic measurements.

Following various checking and refinements to the model input; the modelled Road NOx contribution required adjustment by an average factor of 1.5218 to bring the predicted NO_2 concentrations within close agreement of those results obtained from the monitoring data. This factor was applied to all Road NOx concentrations predicted by the model; the adjusted total NO_2 concentrations were then calculated using the Defra NOx/NO_2 calculator.

After the NOx/NO_2 model was run, the total NO_2 concentration required adjustment by an average factor of 0.98 to bring the predicted NO_2 concentrations within close agreement of those results from the monitoring data. Model agreement for the NO_2 monitoring data after adjustment is presented in Table 8 and Figure 4. Full model verification data is provided in Appendix 3.

Model uncertainty can be estimated by calculating the root mean square error (RMSE). In this case the calculated RMSE was 3.91 $\mu g.m^{-3}$ after adjustment which is within the suggested value (10% of the objective being assessed) in LAQM.TG(09). The model has therefore been assessed to perform sufficiently well for use within this assessment.

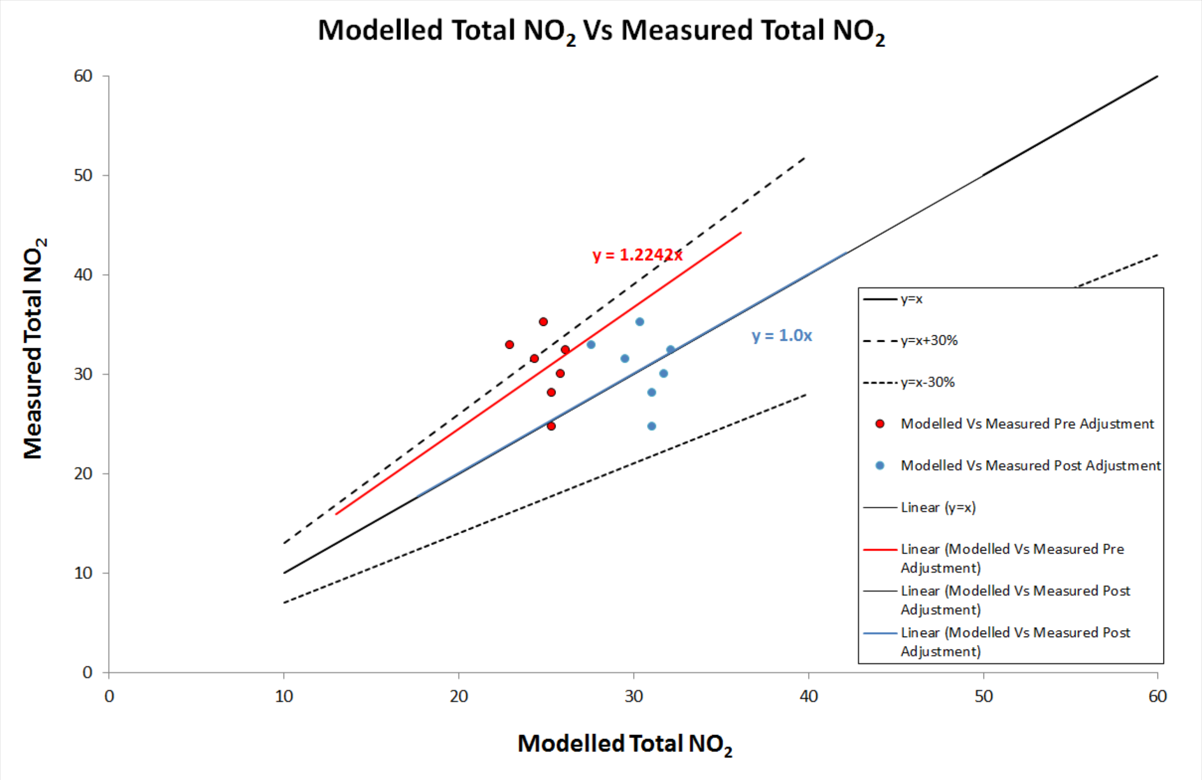
Verifying modelling data with diffusion tube data will always be subject to uncertainty due to the inherent limitations in such monitoring data (even data from continuous analysers has notable uncertainty). The model results should be considered in this context. Further information on the verification process including the linear regression analysis is provided in Appendix 3.

Table 8 Modelled vs. measured annual mean NO_2 concentrations 2014

Site	Measured ($\mu g.m^{-3}$)	Modelled ($\mu g.m^{-3}$)
CM1 (2)	32.4	32.1
DT15	30.0	31.8
DT16	35.2	30.4
DT17	24.7	31.1
DT18	31.5	29.6
DT19	28.1	31.1
DT20	32.9	27.6
	RMSE	**3.91**

As diffusion tube 14 is co-located with the automatic monitoring site, this diffusion tube has been removed from the verification.

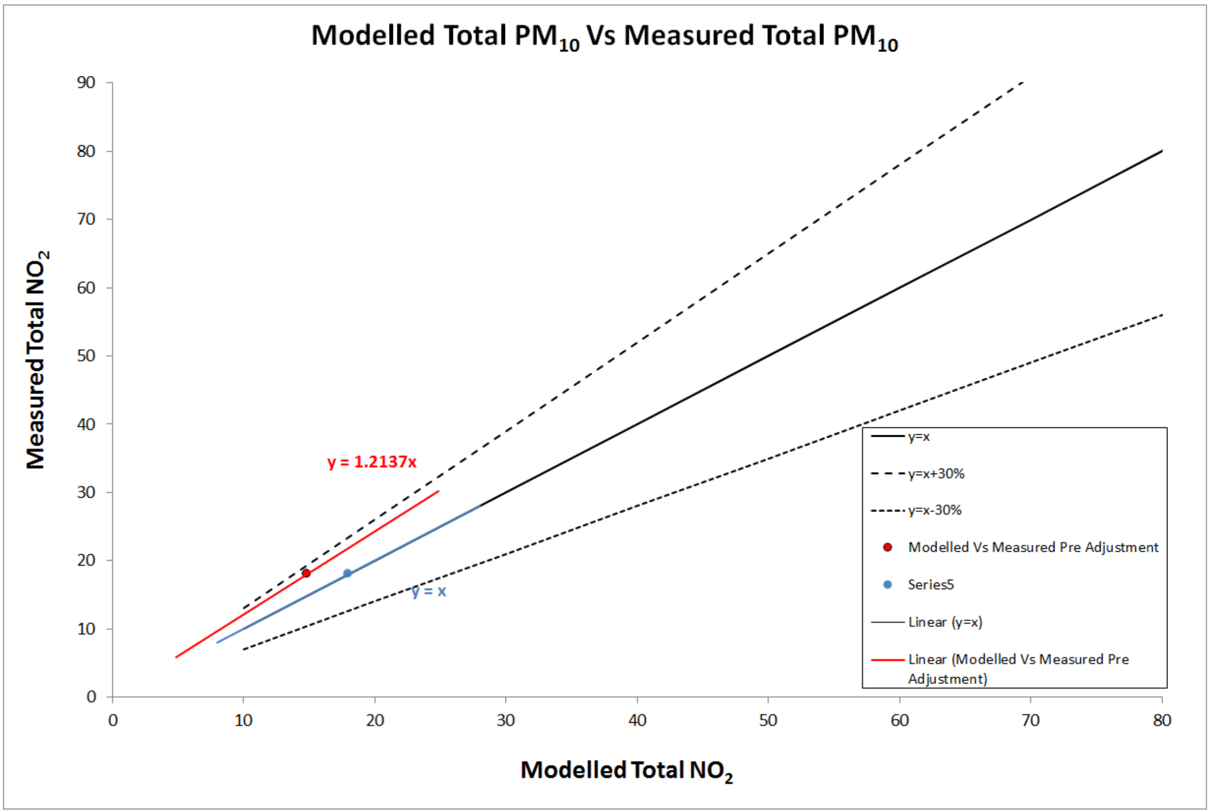
Figure 3 Linear regression plot of modelled vs. monitored NO_2 annual mean 2014



6.1.2 PM_{10}

The modelled PM_{10} concentrations in this study were verified against 2014 automatic site measurements. An adjustment factor of 2.956 was applied to all modelled PM_{10} concentrations before adding the background concentration.

Figure 4 Linear regression plot of modelled vs. monitored PM_{10} annual mean 2014



6.2 Adjusted Modelling Results

The adjusted predicted annual mean NO_2 and PM_{10} concentrations at each specified receptors are presented in Table 9 and 10 respectively, with exceedances of the respective objectives highlighted in pink cells.

6.2.1 NO_2

Annual mean NO_2 concentrations in excess of the 40 µg.m^{-3} annual mean objective were predicted at ground floor level at one location - 342 High Street.

At specified receptors, High St 16, 17 and 18, the predicted NO_2 annual mean is below the annual mean objective. However these results should be considered in context with the estimated model uncertainty (RMSE as described in Section 5.1.3) which was 3.91 µg.m^{-3}. There is a risk that the annual mean objective may also be exceeded at ground level residential properties at these locations.

Table 9 Predicted annual mean NO_2 concentrations at specified receptors 2014

Receptor	Address	NO_2 annual mean ($\mu g.m^{-3}$) at 1.5m	NO_2 annual mean ($\mu g.m^{-3}$) at 4m
High St 1	315 to 325 High St	26.3	21.0
High St 2	303 to 313 High St	25.9	21.0
High St 3	293 High St	32.8	23.0
High St 4	257 to 259 High St	28.4	21.5
High St 5	201 to 203 High St	28.6	21.8
High St 6	131 to 135 High St	29.9	22.1
High St 7	123 to 125 High St	28.5	21.9
High St 8	63 High St	23.7	19.7
High St 9	374 to 396 High St	30.3	23.1
High St 10	350 to 372 High St	30.4	23.1
High St 11	36 High St	33.7	22.9
High St 12	2 to 4 High St	29.9	22.7
High St 13	318 to 340 High St	33.8	24.1
High St 14	290 to 315 High St	29.3	22.4
High St 15	342 High St	**40.6**	24.8
High St 16	103 to 105 High St	38.0	24.5
High St 17	CM1(2)	37.7	22.4
High St 18	DT 15	36.6	24.4
High St 19	DT 16	35.3	23.3
High St 20	DT 17	34.7	24.0
High St 21	DT 18	33.6	22.3
High St 22	DT 19	35.7	22.9
High St 23	DT 20	31.2	21.2

6.2.2 PM_{10}

Annual mean PM_{10} concentrations in excess of the 18 µg.m^{-3} annual mean objective were predicted at 1.5m height at the following receptor locations:

- 293 High Street
- 318 to 340 High Street
- 342 High Street
- 103 to 105 High Street

Table 10 Predicted annual mean PM_{10} concentrations at specified receptors 2014

Receptor	Address	PM_{10} annual mean (µg.m^{-3}) at 1.5m	PM_{10} annual mean (µg.m^{-3}) at 4m
High St 1	315 to 325 High St	16.4	15.2
High St 2	303 to 313 High St	16.4	15.3
High St 3	293 High St	**18.1**	15.8
High St 4	257 to 259 High St	17.7	15.7
High St 5	201 to 203 High St	17.5	15.7
High St 6	131 to 135 High St	17.9	15.6
High St 7	123 to 125 High St	17.4	15.5
High St 8	63 High St	15.8	14.8
High St 9	374 to 396 High St	17.3	15.7
High St 10	350 to 372 High St	17.6	15.8
High St 11	36 High St	17.8	15.3
High St 12	2 to 4 High St	17.2	15.4
High St 13	318 to 340 High St	**18.2**	16.0
High St 14	290 to 315 High St	17.8	15.9
High St 15	342 High St	**19.9**	16.1
High St 16	103 to 105 High St	**19.6**	16.0
High St 17	CM1(2)	**19.6**	15.3
High St 18	DT 15	**19.7**	16.3
High St 19	DT 16	**19.2**	16.1
High St 20	DT 17	**18.4**	15.7
High St 21	DT 18	**18.2**	15.3
High St 22	DT 19	**18.2**	15.3
High St 23	DT 20	17.4	15.0

6.2.3 Modelling Results - Contour Plots

Annual mean NO_2 and PM_{10} concentrations have been predicted across a grid of points covering the entire study area. The gridded point values have been interpolated to produce contour plots showing the spatial variation of predicted concentration across the study area. Each grid has been modelled at heights of 1.5m and 4m to represent human exposure at ground and first floor levels.

6.2.3.1 NO_2

Contour plots showing the spatial variation of the predicted 2014 annual mean NO_2 concentrations across the study area at ground and first floor levels are presented in Figures 4 and 5 and in Appendix 4. The NO_2 annual mean contour plots indicate that the 40 $\mu g.m^{-3}$ objective is being exceeded at ground level locations along the High Street, however this is mainly limited to roadside locations.

Predicted annual mean concentrations at specified receptor 15, located at 342 High Street are predicted to be in excess of the NO_2 annual mean concentration, 40.6 $\mu g.m^{-3}$.

Residential properties are however mainly present at 1st floor height along High Street where commercial properties are present at ground floor level; a contour plot showing the predicted NO_2 annual mean at 4m height is presented in Figure 6. This plot indicates that the 40 $\mu g.m^{-3}$ objective was not exceeded at any 1st floor properties along High Street.

6.2.3.2 PM_{10}

Contour plots showing the spatial variation of the predicted 2014 annual mean PM_{10} concentrations across the study area at ground floor level are presented in Figures 7 and 8. The contours indicate that exceedances of the Scottish annual mean objective occurred at ground level along High Street.

A contour plot showing the predicted PM_{10} annual mean at 4 m height is presented in Figure 9. The contours indicate that the Scottish annual mean objective was not exceeded at any residential location on High Street at 1st floor height.

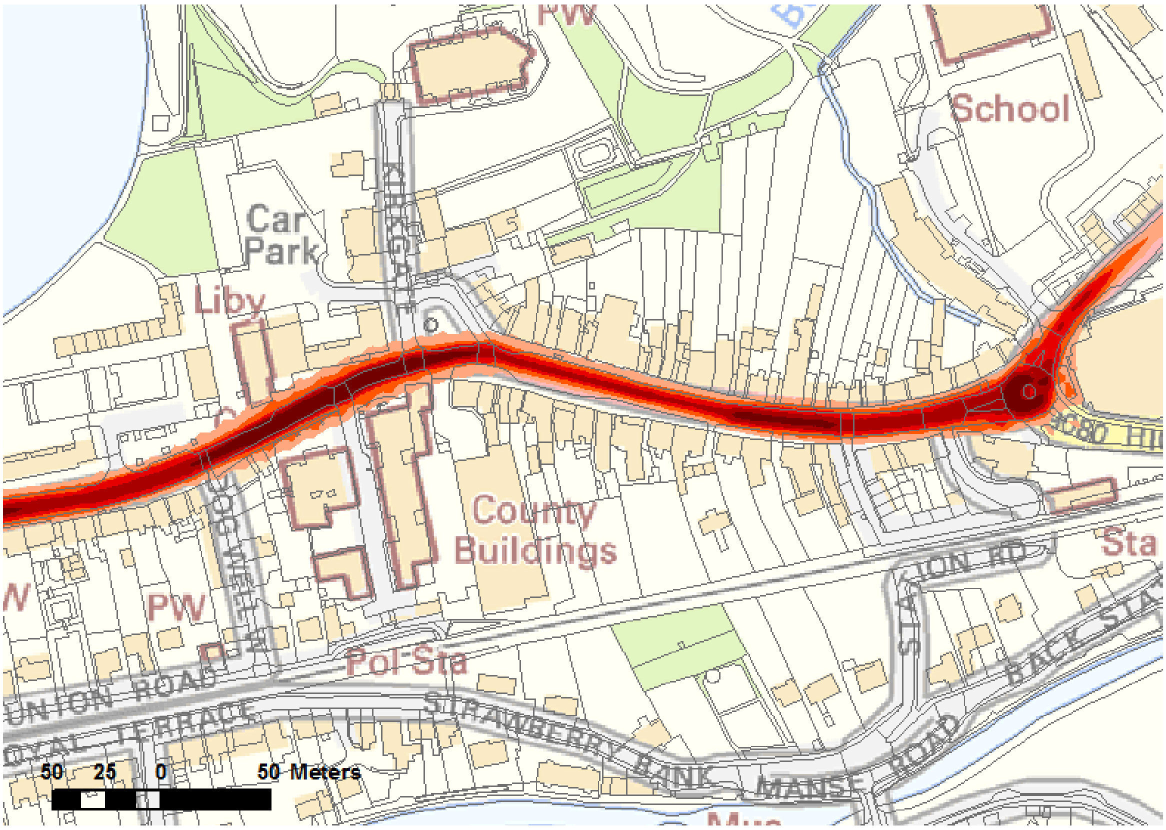
Figure 2 Modelled NO_2 annual mean concentrations 2014 at 1.5m height – Western section of High Street, Linlithgow

Legend:

NO_2 annual mean concentration ($\mu g.m^{-3}$)

- <32
- 32 - 36
- 36 - 40
- 40 - 44
- 44 - 48
- 48 - 63.8

Figure 3 Modelled NO_2 annual mean concentrations 2014 at 1.5m height – Eastern section of High Street, Linlithgow

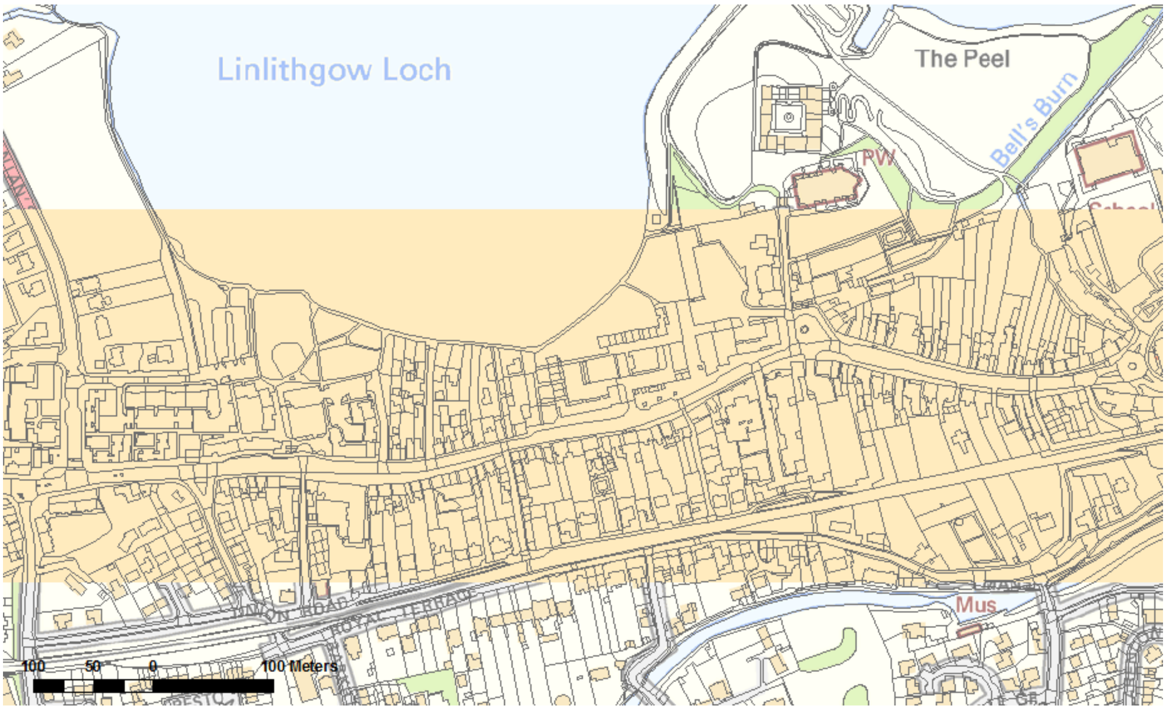


Legend:

NO_2 annual mean concentration ($\mu g.m^{-3}$)

- <32
- 32 - 36
- 36 - 40
- 40 - 44
- 44 - 48
- 48 - 63.8

Figure 4 Modelled NO_2 annual mean concentrations 2014 at 4m height – High Street, Linlithgow

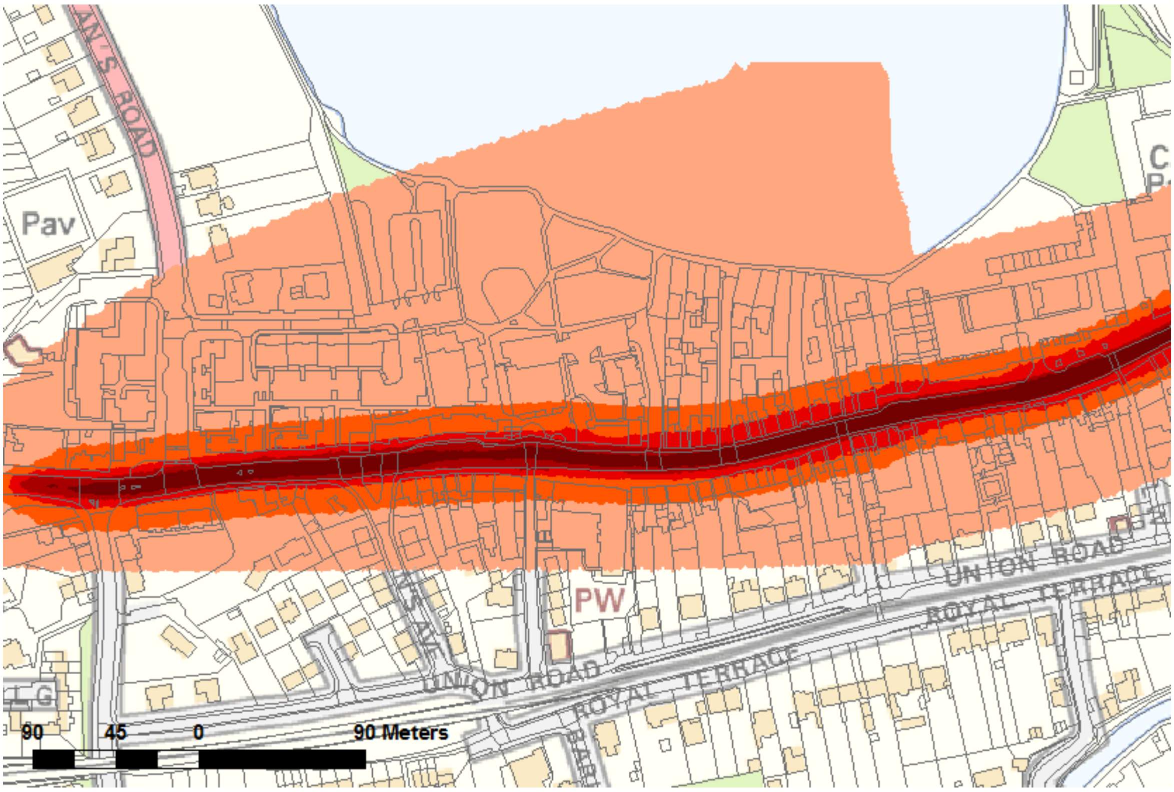


Legend:

PM_{10} annual mean concentration (µg.m^{-3})

- <32
- 32 - 36
- 36 - 40
- 40 - 44
- 44 - 48
- 48 - 63.8

Figure 5 Modelled PM_{10} annual mean concentrations 2014 at 1.5m height – Western section of High Street, Linlithgow

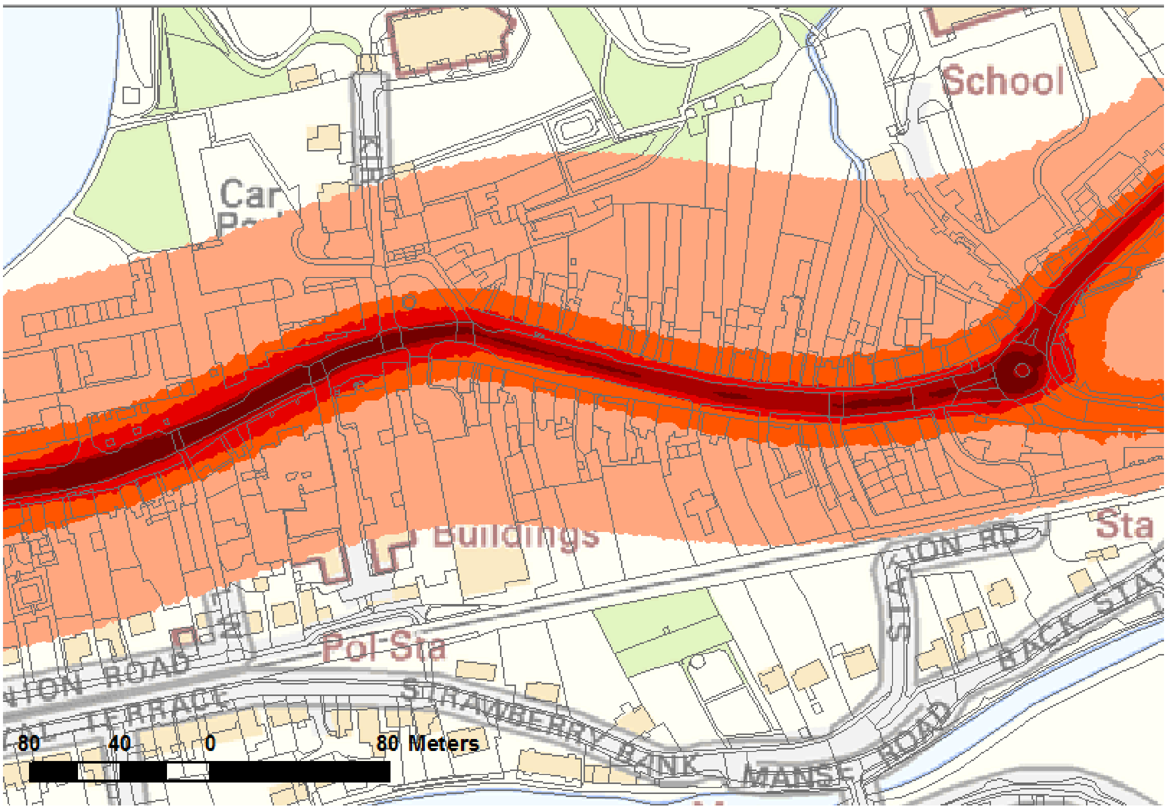


Legend:

PM_{10} annual mean concentration (µg.m^{-3})

- <14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 27.2

Figure 6 Modelled PM_{10} annual mean concentrations 2014 at 1.5m height – Eastern section of High Street, Linlithgow

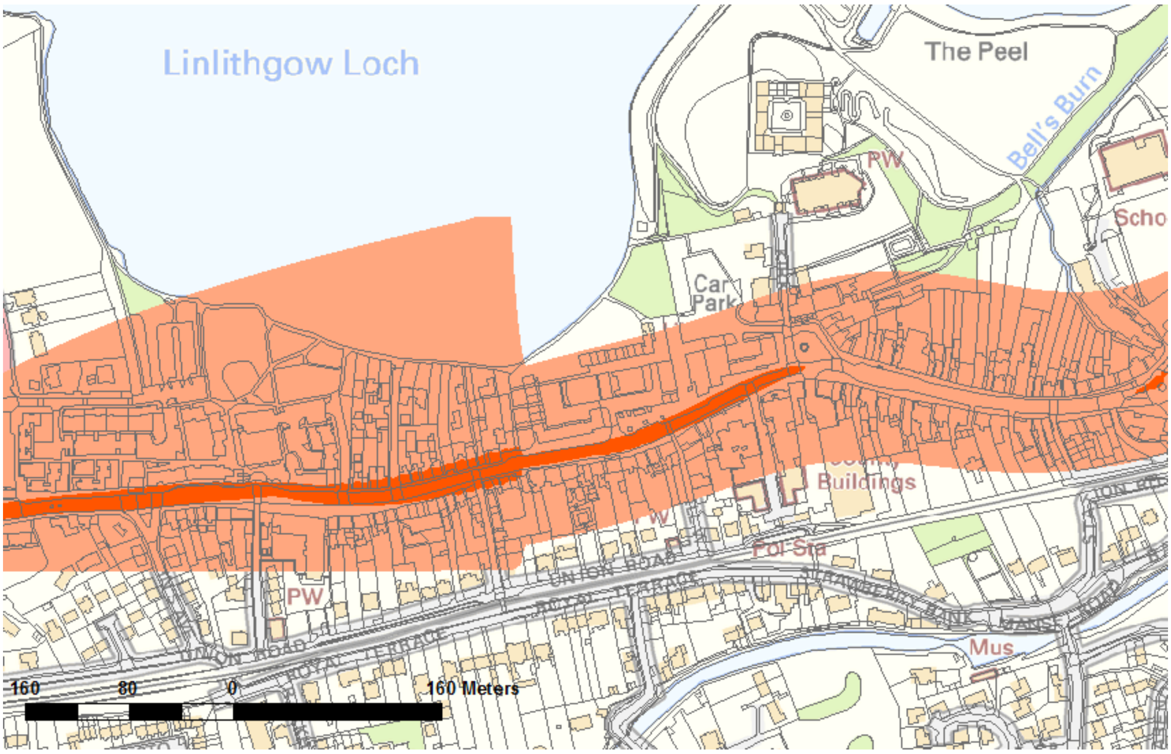


Legend:

PM_{10} annual mean concentration (µg.m^{-3})

- <14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 27.2

Figure 7 Modelled PM_{10} annual mean concentrations 2014 at 1.5m height – Eastern section of High Street, Linlithgow



Legend:

PM_{10} annual mean concentration (µg.m^{-3})

- <14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 27.2

7 Summary and Conclusions

This report describes a dispersion modelling study of road traffic emission at High Street in Linlithgow, West Lothian which has been conducted to allow a detailed assessment of NO_2 and PM_{10} concentrations at this location.

A combination of the available diffusion tube and automatic monitoring data and atmospheric dispersion modelling using ADMS-Roads has been used to conduct the study. The study utilises the latest available traffic and meteorological data for 2014.

The modelling study has indicated the following:

- NO_2 concentrations in excess of the 40 µg.m^{-3} annual mean objective occurred at 342 High Street where the predicted NO_2 annual mean concentration is 40.6 µg.m^{-3}
- At specified receptors, High St 16, 17 and 18, the predicted NO_2 annual mean is below the annual mean objective. However these results should be considered in context with the estimated model uncertainty (RMSE as described in Section 5.1.3) which was 3.91 µg.m^{-3}. There is a risk that the annual mean objective may also be exceeded at ground level residential properties at these locations.
- There are no exceedances of the NO_2 annual mean objective at first floor height where there are residential properties.
- Annual mean PM_{10} concentrations in excess of the 18 µg.m^{-3} Scottish objective occurred at several locations along High Street at 10 residential properties.

In light of this update of the Detailed Assessment of Air Quality in Linlithgow using the available monitoring data from 2014, West Lothian Council is required to declare an Air Quality Management Area for exceedances of both the annual mean NO_2 objective and the PM_{10} annual mean Scottish objective.

Appendices

Appendix 1 – Traffic Data

Table A1.1 summarises the Annual Average Daily Flows (AADF) of traffic on fleet compositions used within the model for each road link.

Traffic data for High Street was available from a local survey commissioned by West Lothian Council. The one week traffic surveys conducted in March 2015 provided information on daily average flow and fleet split. Traffic data for Blackness Road and High Port have been taken from the previous Detailed Assessment for Linlithgow. This is considered to be a conservative approach considering the traffic growth.

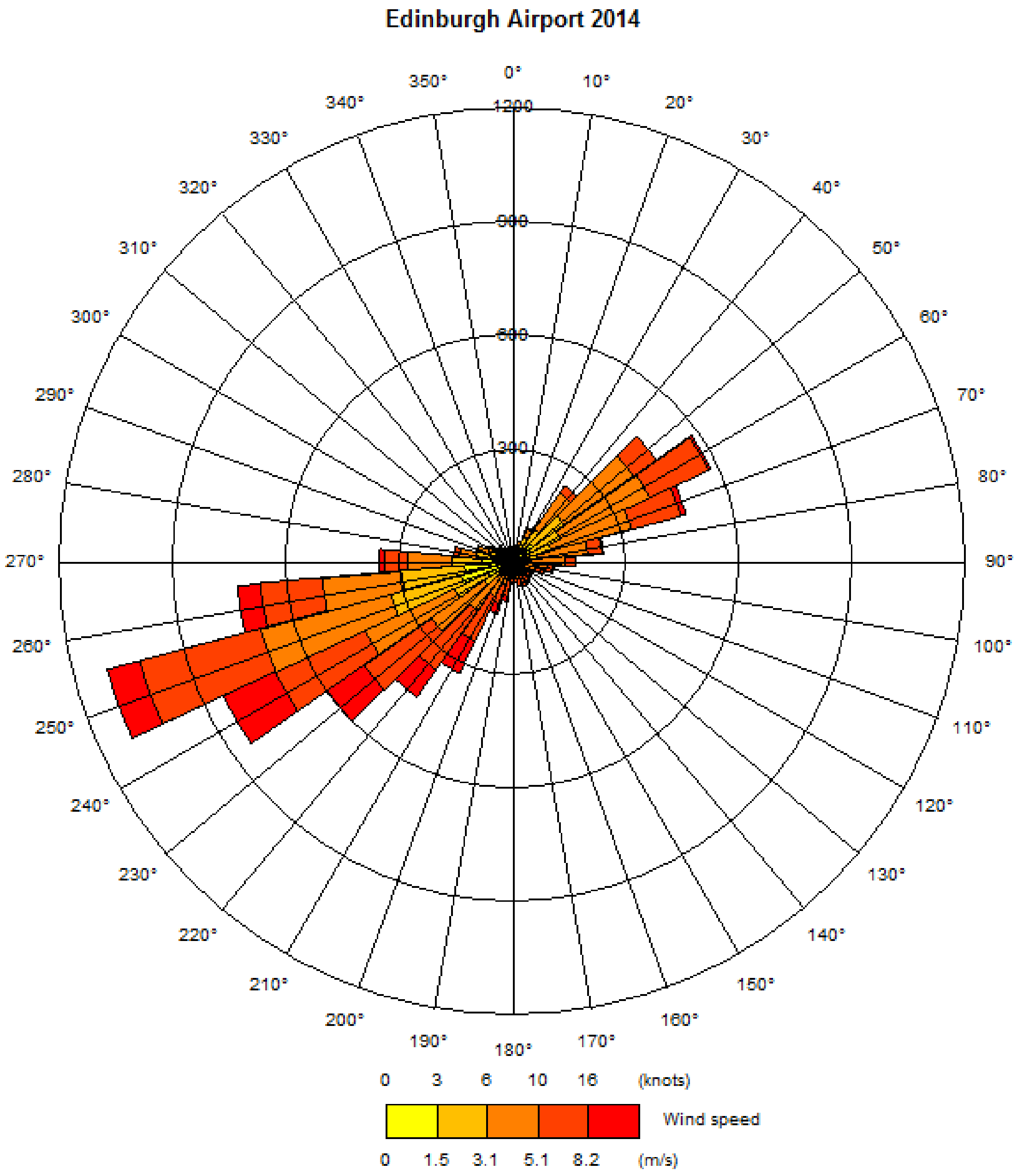
Table A1.1 Linlithgow 2014 – Annual Average Daily Flows – both directions combined

Street	%Cars	%LGV	%Rigid HGV	%Artic HGV	%Bus	%Motorcycle	AADF 2014
High Street west of New Well Wynd	90.7	6.2	1.3	0.3	0.9	0.6	14,551
High Street west of Roundabout	92.6	3.6	2.0	0.9	0.4	0.6	15,788
Blackness Road	92.3	4.8	1.4	0.7	0.4	0.5	11,236
High Port	93.0	4.5	1.2	0.2	0.4	0.6	6,462

Appendix 2 – Meteorological dataset

The wind rose for the Edinburgh Airport meteorological measurement site is presented in Figure A2.1.

Figure A2.1: Meteorological dataset wind rose



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.

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

As stated in Section 5.1.3 above, the model was verified using annual mean NO_2 measurements from the various NO_2 diffusion tube sites and one automatic monitoring site within the study area. 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 Road NOx concentrations during 2014 calendar year at the monitoring sites. The model output of Road NOx (the total NOx originated from road traffic) has been compared with the measured Road NOx, where the measured Road NOx contribution is calculated as the difference between the total NOx and the background NOx value. Total measured NOx for each monitoring site was calculated from the measured NO_2 concentration using the latest version of the Defra NOx/NO_2 calculator.

The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution. Subsequently, some refinements were made to the model input to improve the overall model performance.

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

A primary adjustment factor (PAdj) of 1.5218 based on model verification using 2014 monitoring results was applied to all modelled Road NOx data prior to calculating an NO_2 annual mean. A plot comparing modelled and monitored NO_2 concentrations before and after adjustment is presented in Figure A3.2.

After the NOx/NO_2 model was run, the total NO_2 concentration required adjustment by an average factor of 0.98 to bring the predicted NO_2 concentrations within close agreement of those results from the monitoring data. Model agreement for the NO_2 monitoring data after adjustment is presented in Table 8 and Figure 4. Full model verification data is provided in Appendix 3.

Model uncertainty can be estimated by calculating the root mean square error (RMSE). In this case the calculated RMSE was 3.91 $\mu g.m^{-3}$ after adjustment which is within the suggested value (10% of the objective being assessed) in LAQM.TG(09). The model has therefore been assessed to perform sufficiently well for use within this assessment.

The comparison of the modelled vs measured PM_{10} identified that the model was under-predicting the road PM_{10} contribution by a factor of 2.956. This factor was applied to all model road PM_{10} concentrations before adding the background concentration.

Figure A3.1: Comparison of modelled Road NOx vs. Measured Road NOx

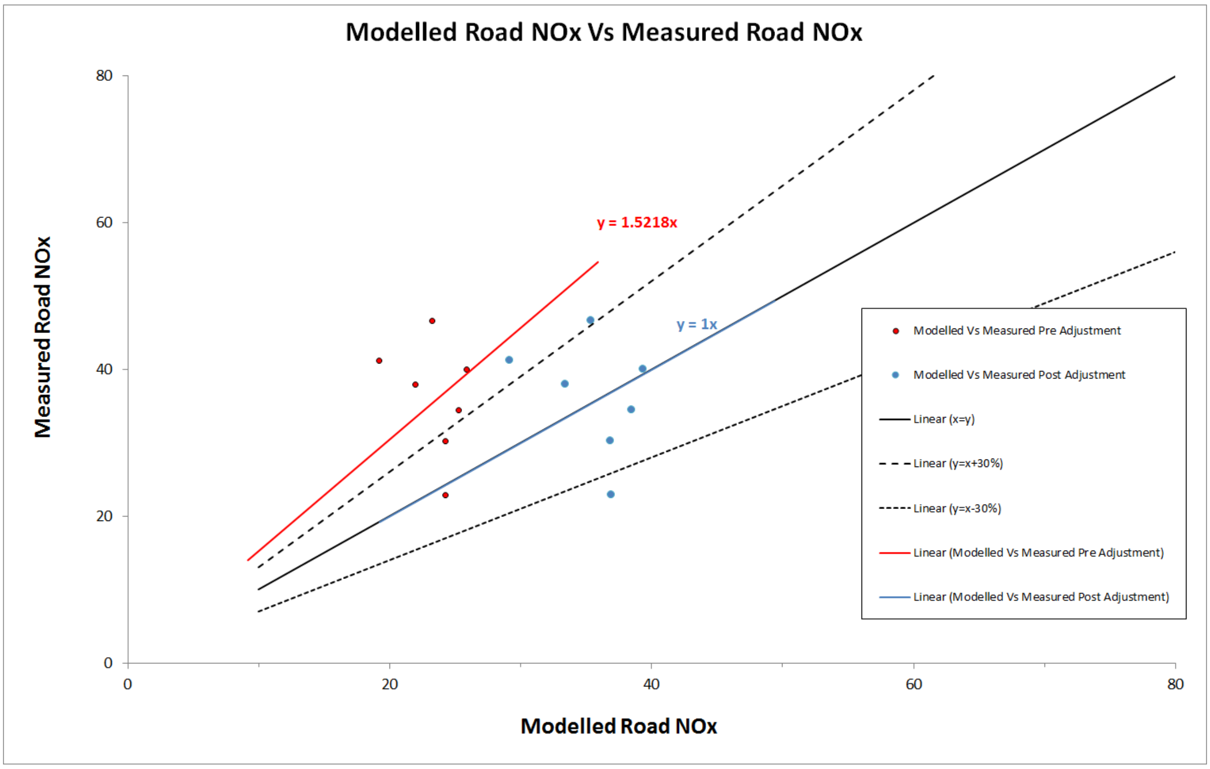
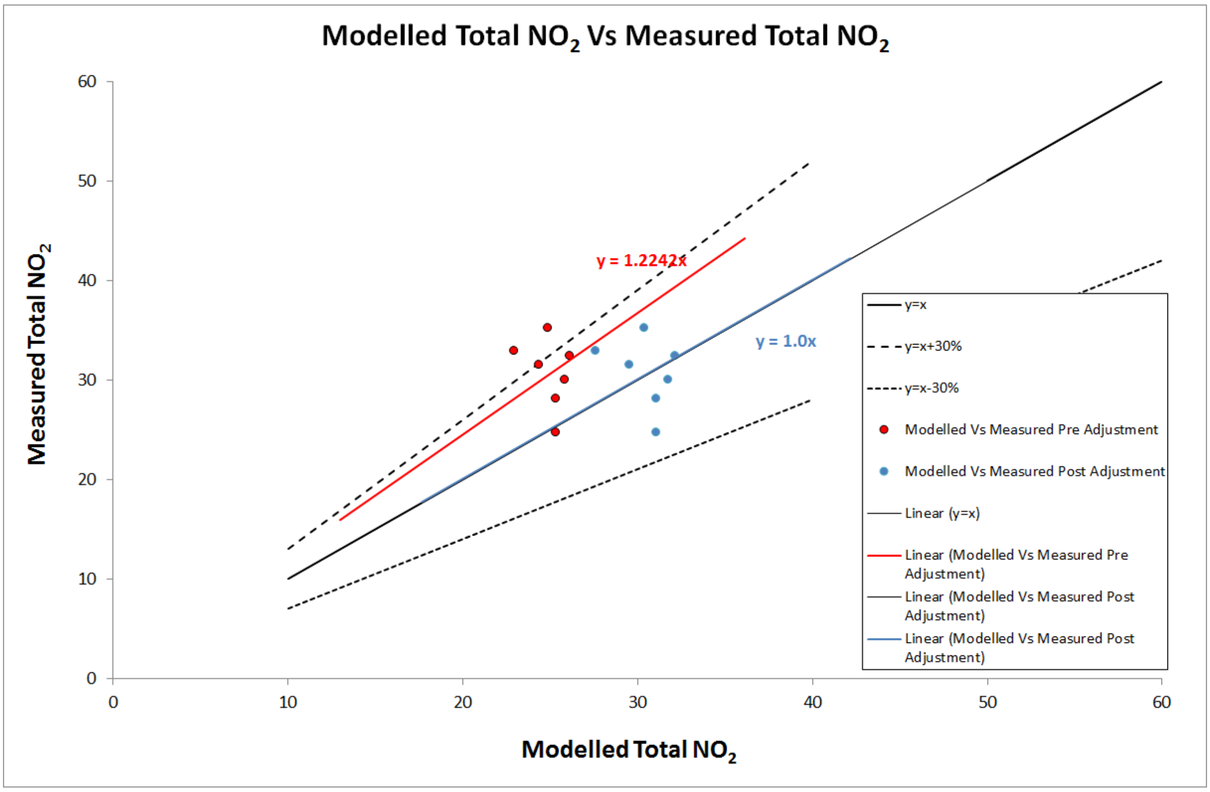
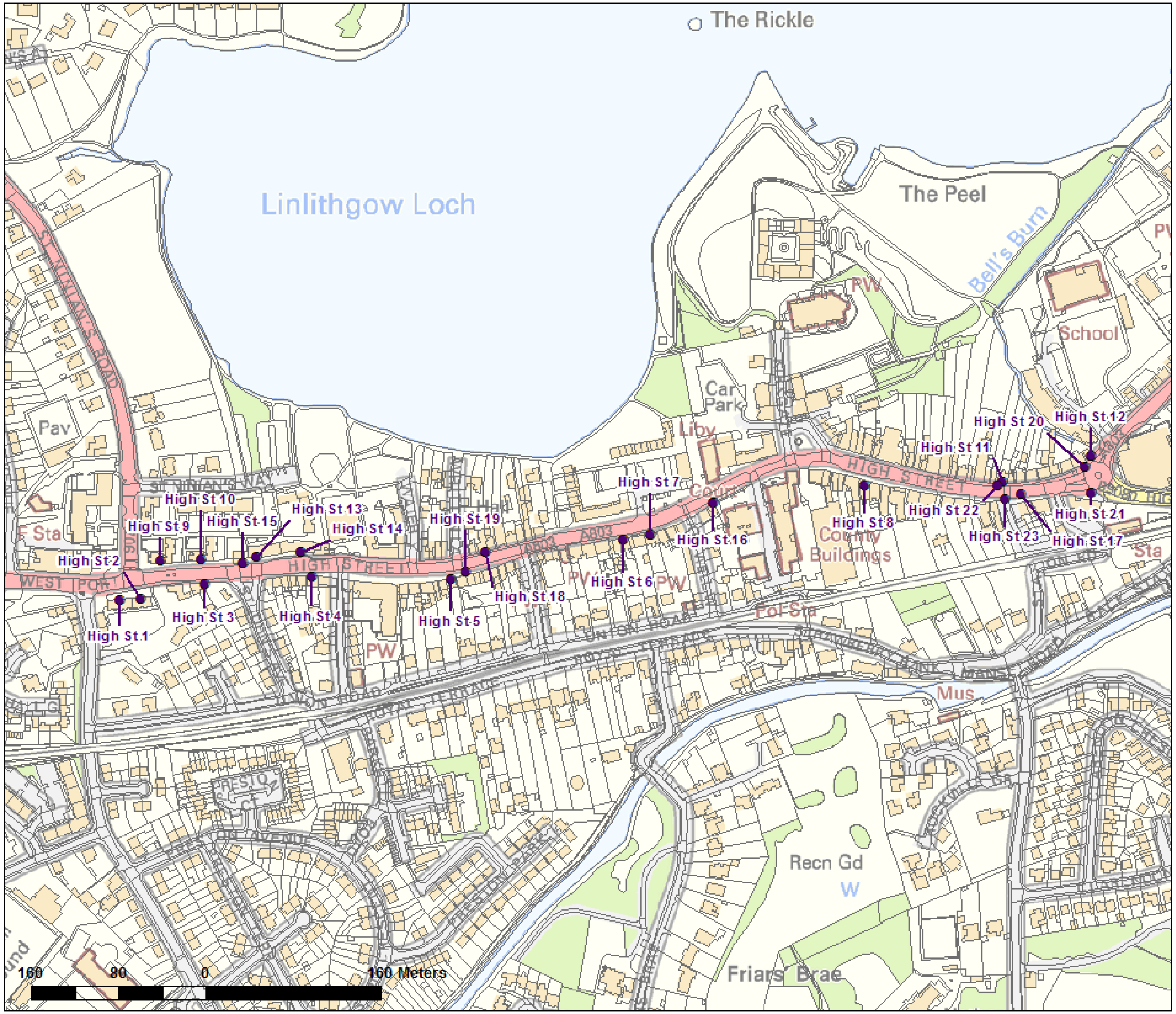


Figure A3.2: Comparison of modelled vs. monitored NO_2 annual mean 2014



Appendix 4 – Figures



Legend

Specified Receptors

Figure A4.1 Specified Receptor Locations

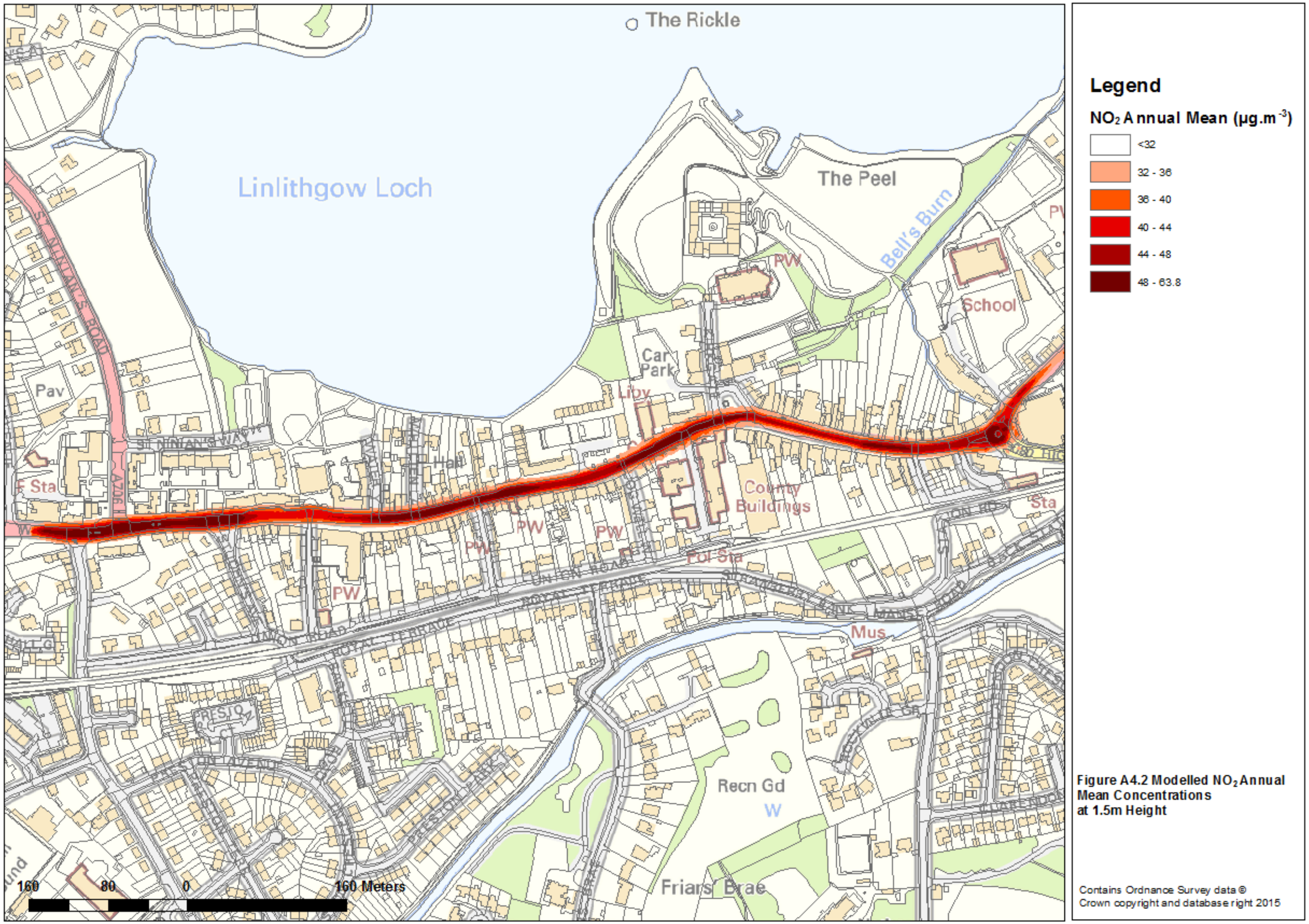


Figure A4.2 Modelled NO_2 Annual Mean Concentrations at 1.5m Height

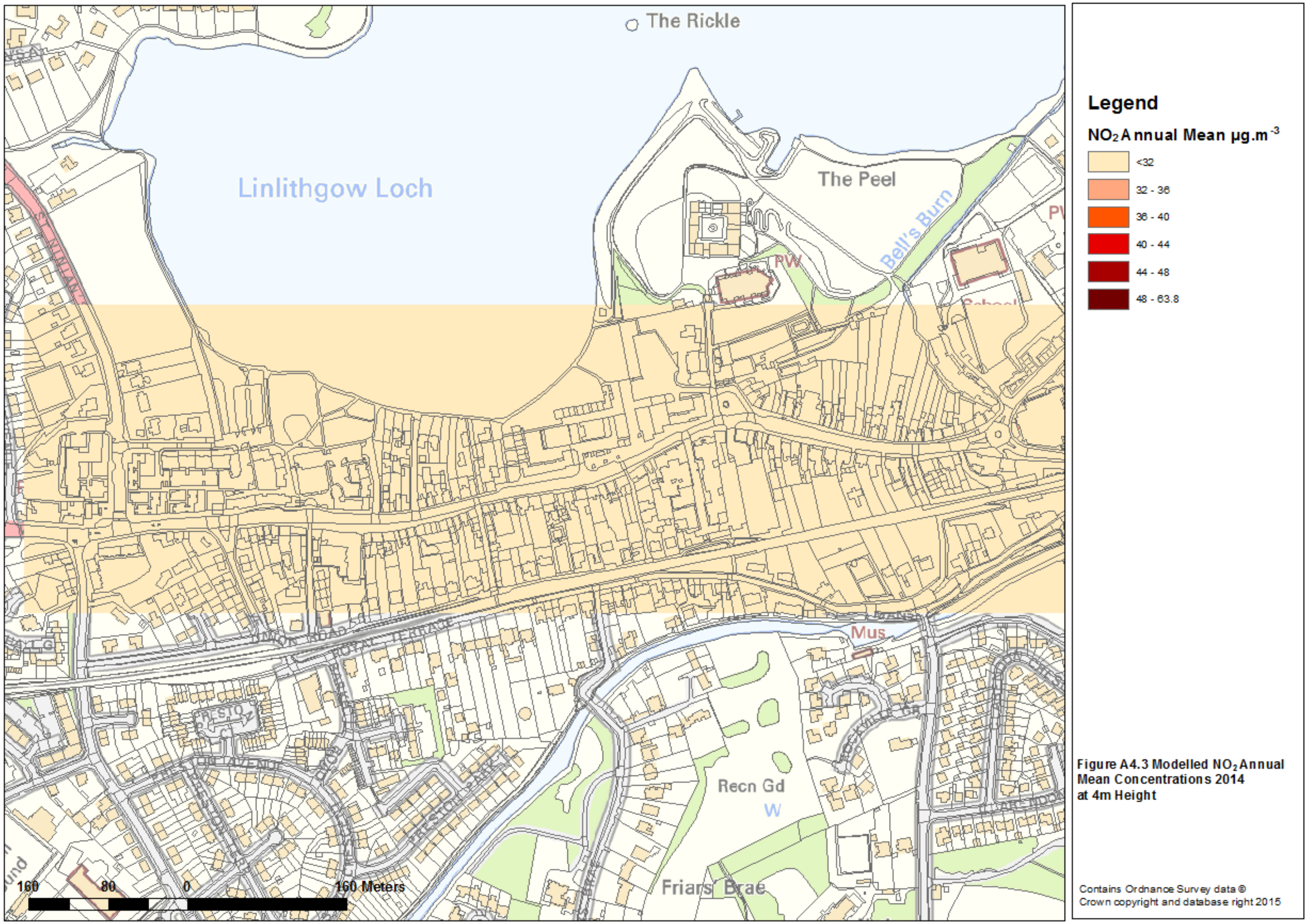


Figure A4.3 Modelled NO_2 Annual Mean Concentrations 2014 at 4m Height

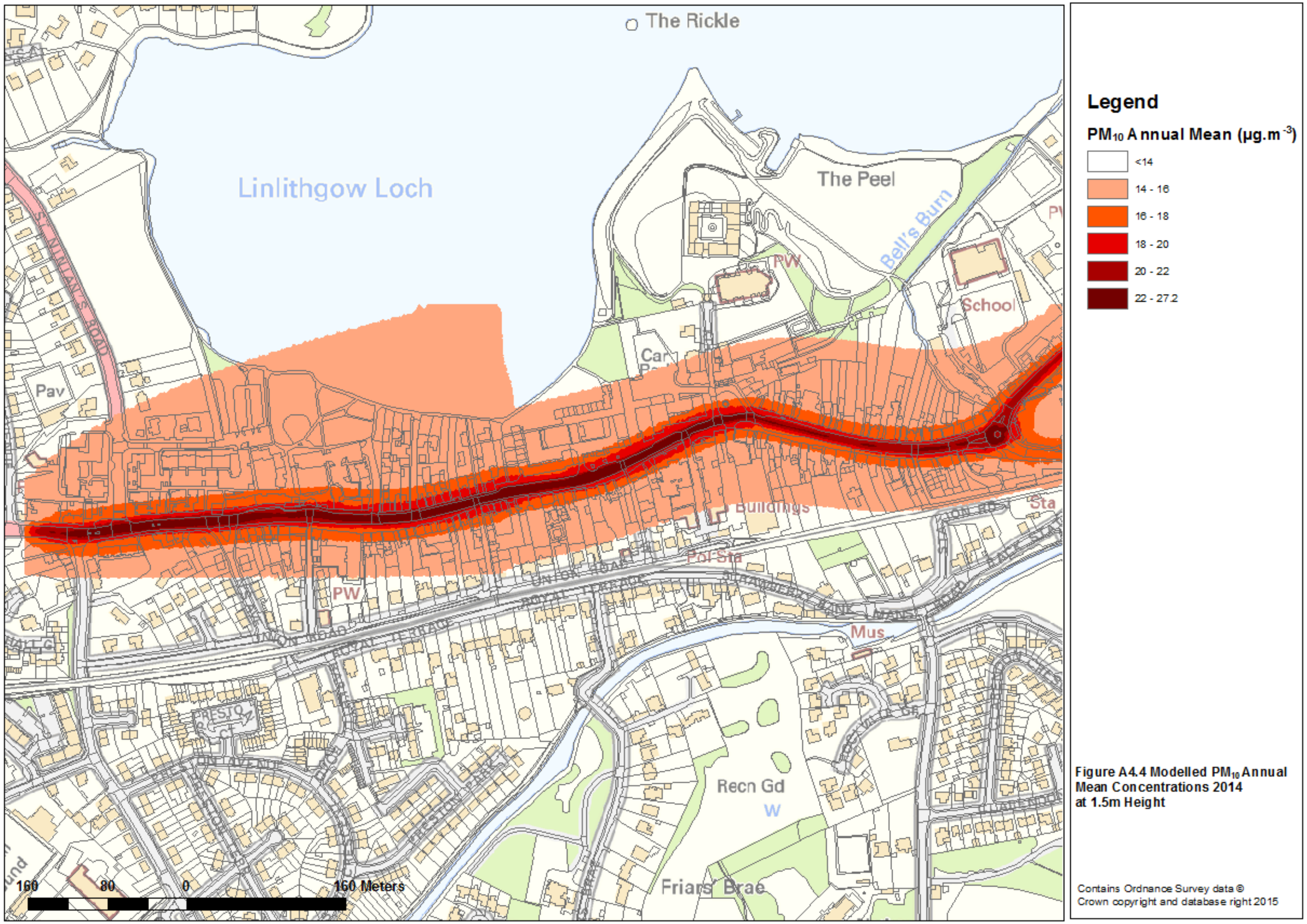


Figure A4.4 Modelled PM_{10} Annual Mean Concentrations 2014 at 1.5m Height

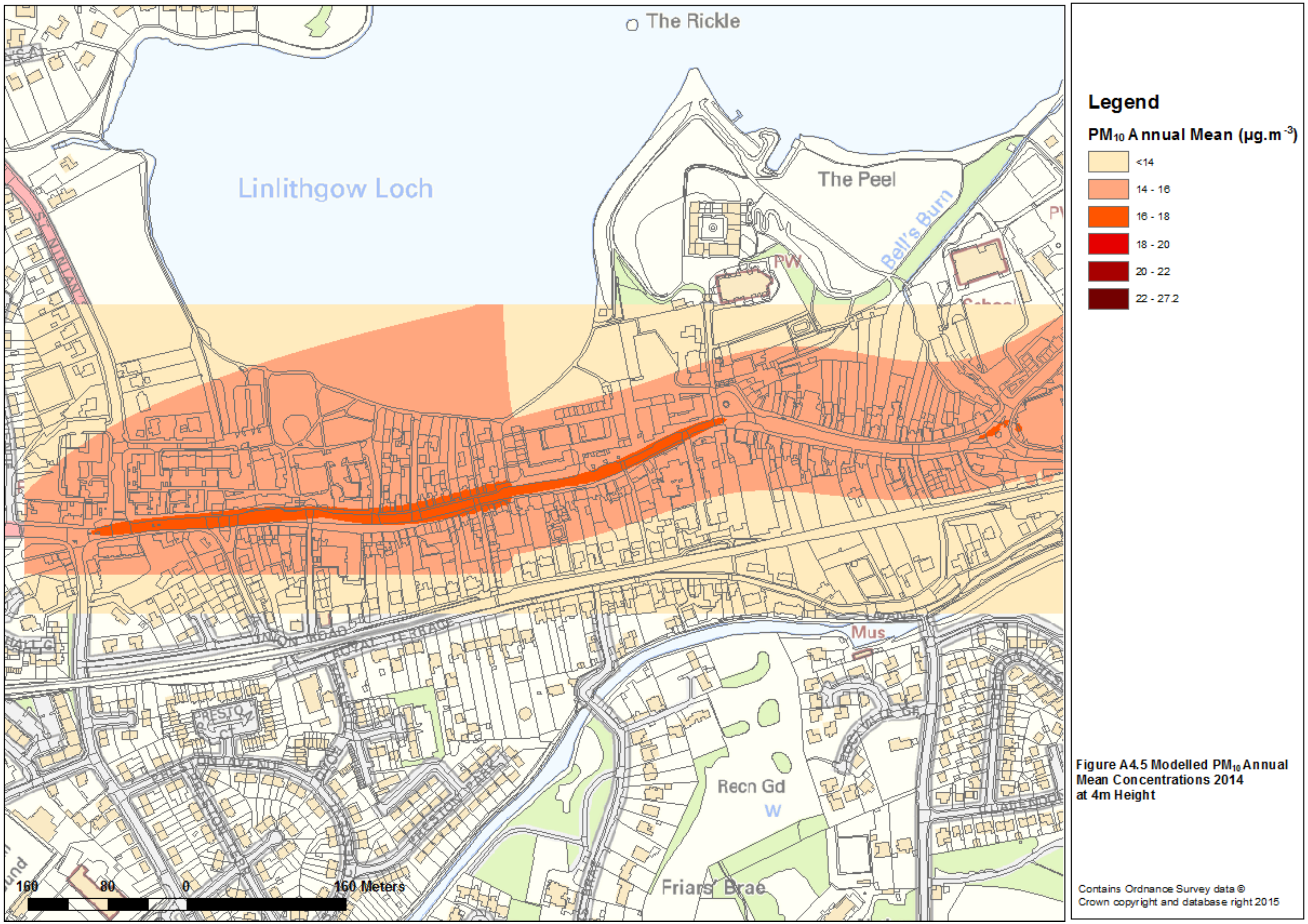


Figure A4.5 Modelled PM_{10} Annual Mean Concentrations 2014 at 4m Height

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR
United Kingdom

t: +44 (0)1235 753000
e: enquiry@ricardo.com

ee.ricardo.com