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Detailed Assessment of Air Quality – High Street, Johnstone

Report for Renfrewshire Council

Customer:

Renfrewshire Council

Customer reference:

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Executive summary

Ricardo-AEA have been commissioned by Renfrewshire Council to undertake a Detailed Assessment of Air Quality and a source apportionment study for the area around High Street in Johnstone. The assessment has been undertaken to investigate the potential scale and extent of exceedances of the Scottish Air Quality Objectives for nitrogen dioxide (NO_2) and PM_{10} (particulate matter less than 10 microns in diameter) within the study area; and to determine the contribution of different source types to local NO_2 and PM_{10} concentrations.

This report describes a dispersion modelling study of road traffic emissions at High Street in Johnstone, Renfrewshire which has been conducted to allow a detailed assessment of NO_2 and PM_{10} concentrations at this location. The report also includes a source apportionment analysis of road traffic emissions which will help inform appropriate air quality action plan measures.

A combination of the available diffusion tube 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 $\mu g.m^{-3}$ annual mean objective were predicted at both ground level and 1st floor level at various locations along High Street during 2014.
- The results indicate that the NO_2 annual mean objective was predicted to be exceeded at up to 17 residential properties.
- Annual mean PM_{10} concentrations in excess of the 18 $\mu g.m^{-3}$ Scottish annual mean objective at both ground level and 1st floor level were predicted at various locations along High Street during 2014.
- The modelling results indicated that the PM_{10} annual mean objective was being exceeded at up to 25 residential properties during 2014.

Based on the available traffic data, the source apportionment study indicates that:

- Background NOx concentrations account for a relatively small proportion, up to 11.5% of total NOx concentrations within the study area; whereas background PM_{10} accounts for up to, a more significant, 67% of the total annual mean concentration at each receptor.
- At all receptor locations there is a high proportion of road NOx and PM_{10} attributable to bus movements. Action plan measures targeted at reducing emissions from buses will therefore likely help reduce NO_2 and PM_{10} concentrations.
- The proportion of NOx and PM_{10} emissions from HGV and LGV movements is relatively low when compared to other vehicle types at all receptor locations included in the source apportionment study.
- The locations where the highest pollutant concentrations are being measured and modelled are at locations where traffic is known to regularly be slow moving and within the high sided street canyon like topography. This indicates that any measures that can improve traffic flow at these locations where pollutant dispersion is poor will help to reduce vehicle emissions and concentrations. This could include for example, consideration of changes to traffic light phasing or traffic signal locations.

In light of this Detailed Assessment of air quality in Johnstone using the available monitoring data from 2014, **Renfrewshire Council is required to declare an Air Quality Management Area that includes all residential properties where exceedances of the annual mean NO_2 and PM_{10} objectives are predicted.**

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1 Introduction

Ricardo-AEA has been commissioned by Renfrewshire Council to undertake a Detailed Assessment of Air Quality at High Street, Johnstone. The assessment has been undertaken to investigate the scale and extent of potential exceedances of the Scottish Air Quality NO_2 and PM_{10} annual mean objectives within the study area. This report also includes a source apportionment analysis of road traffic emissions.

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) 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).

Error! Reference source not found. 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 & PM_{10} 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	200 $\mu g.m^{-3}$ not to be exceeded more than 18 times a year	1 hour mean
	40 $\mu g.m^{-3}$	Annual mean
Particles (PM_{10}) (gravimetric) Authorities in Scotland	50 $\mu g.m^{-3}$ not to be exceeded more than 7 times a year	24 hour mean
	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. **Error! Reference source not found.** 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 & PM_{10} 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
24-hr mean	PM_{10}	All locations where the annual mean objective would apply, together with hotels. Gardens of residential properties (should represent parts of the garden where relevant public exposure is likely, local judgement should be applied)	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 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 Johnstone.

In addition to this, the assessment also includes a source apportionment analysis, whereby the contribution of different sources of pollutants to overall concentrations are quantified so that action planning measures may be appropriately targeted.

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 NO_2 and PM_{10} concentrations at points of relevant exposure.
- Use dispersion modelling to produce contour plots showing the expected spatial variation in annual mean NO_2 concentrations.
- Recommend if Renfrewshire Council should declare an AQMA at any location within the study area in Johnstone and suggest its spatial extent.
- Apportion the main sources of NO_2 and PM_{10} at the locations where annual mean concentrations in excess of the objective are occurring.
- The modelling methodologies provided for Detailed Assessments outlined in the Scottish Government and Defra Technical Guidance LAQM.TG(09) were used throughout this study.

2 Detailed Assessment study area

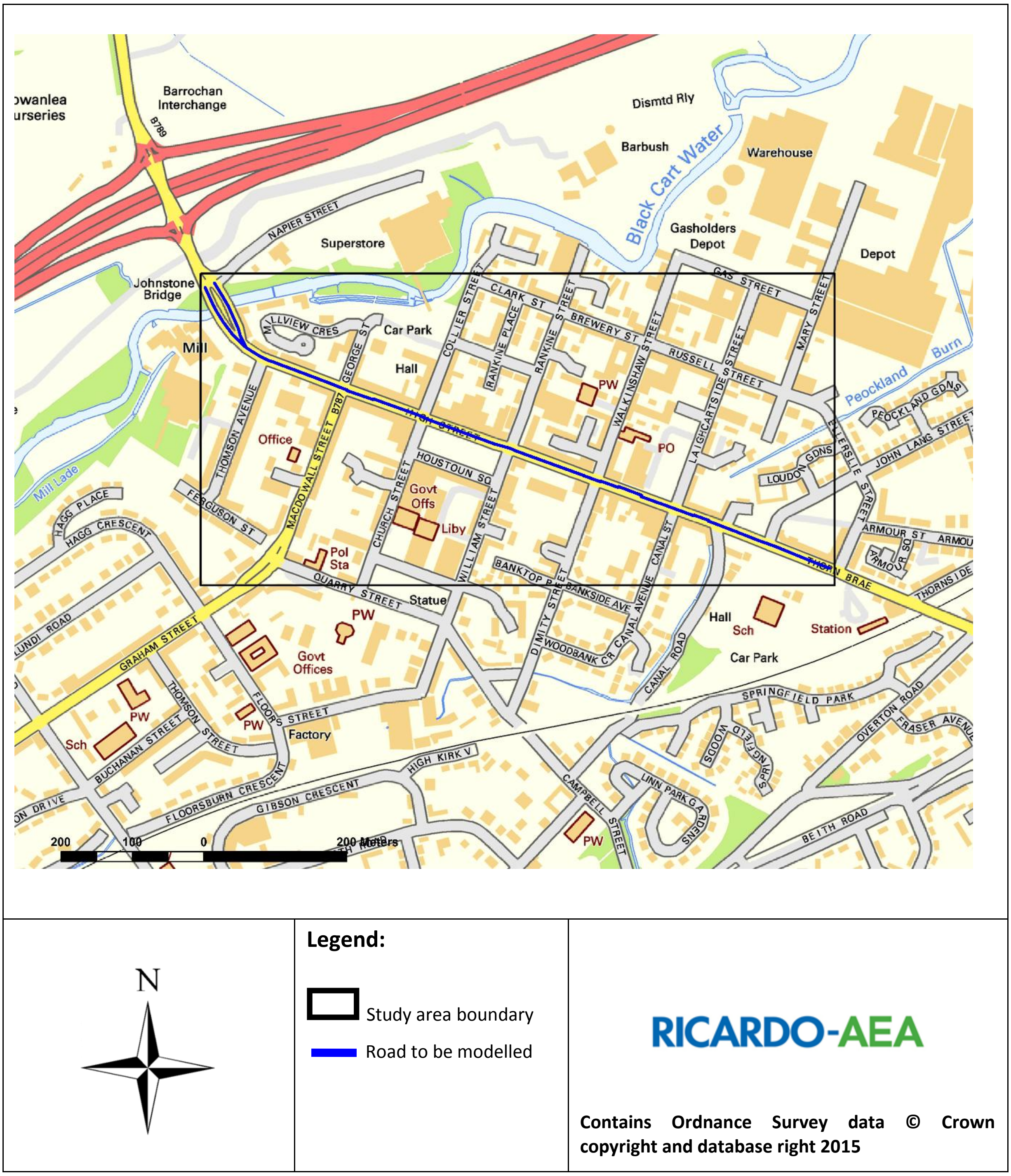
Johnstone is a town within Renfrewshire located in the west central Lowlands of Scotland. The town is approximately three miles west of neighbouring Paisley and twelve miles west of Glasgow.

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.

2.1.1 Model Domain

The study area comprises of residential, commercial and public properties with residential flats mainly at first floor height above commercial properties at locations along the High Street. 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 900 m by 450 m.

__Figure 1: Detailed Assessment Study Area__



2.1.2 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 facade of buildings in the model domain where relevant exposure exists. The receptors have been modelled at both 1.5 m and 4 m heights to represent human exposure at both ground floor level and 1st floor height. The locations of the selected receptors are presented in Figure 2 and Figure 3 and Table 3.

Figure 2: Model receptor locations – West section of High Street

Legend:

ADMS Receptor

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Figure 3: Model receptor locations – East section of High Street

Legend:

ADMS Receptor

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Table 3: Specified receptor locations

Specified Receptor	Address	Easting	Northing
Johnstone 7*	32 High Street	242914	663198
Johnstone 20*	62 High Street	242674	663286
Johnstone 59*	65 High Street	242656	663281
High St 1	14 Millview Crescent	242527	663341
High St 2	79 High Street	242567	663313
High St 3	70 High Street	242620	663307
High St 4	67 High Street	242650	663283
High St 5	1 Collier Street	242703	663277
High St 6	2 Collier Street	242732	663268
High St 7	2 Collier Street	242831	663231
High St 8	38 High Street	242861	663225
High St 9	36 High Street	242869	663219
High St 10	30 High Street	242890	663211
High St 11	5 High Street	243083	663123
High St 12	6 High Street	243095	663135

*These locations refer to diffusion tube locations

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 and fleet split

Traffic count data collected by a third party contractor[1] on behalf of Renfrewshire 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.

[1] Sky High Count On Us –SC2095 Renfrewshire ATC Report; January 2015

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 Average vehicle speed data

A GPS logger was used to measure average speeds during both the morning and evening peak periods and the daytime off peak periods. Measurements conducted during a one day survey were used to derive road link specific average speed data that can be used to calculate link specific pollutant emission rates in the Emissions Factors Toolkit. The GPS speed measurements were taken using a smartphone whilst driving through the study area multiple times at a sample rate of 1 per second. The data gathered has x,y coordinates as well as a record of average speed; the data is plotted spatially in a GIS whereby ADMS link specific average speeds can be calculated.

3.2.3 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. Peak periods in traffic flow were therefore accounted for in the model by applying the typical diurnal traffic flow profile to the average hourly emission rate assuming an average daily vehicle speed as measured during the GPS speed survey.

3.2.4 Vehicle emission factors

The latest version of the Emissions Factors Toolkit[2] (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] 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 Renfrewshire Council measured NO_2 concentrations at three diffusion tube sites within the study area in Johnstone. 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 Glasgow Bishopton site was used for the modelling assessment. The meteorological measurement site is located approximately 8 km north 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.

3.5 Background concentrations

Background pollutant concentrations for a dispersion modelling study can be accessed from either local monitoring data conducted at a background site or from the Scottish Government background maps[3]. The Scottish Government 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.

In this case there are no urban background monitoring sites in Johnstone therefore the Scottish Government mapped background NOx and PM_{10} concentrations for the relevant 1 km x 1km grid square were used. The mapped annual mean background NOx concentration for 2014 was 18.6 $\mu g.m^{-3}$ and for PM_{10} was 14.8 $\mu g.m^{-3}$.

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

4 Monitoring data 2014

Renfrewshire Council currently measure NO_2 concentrations within the study area in Johnstone at three diffusion tube sites. A map showing the location of each diffusion tube is presented in Figure 4.

Details of the NO_2 diffusion tube monitoring sites and the annual mean NO_2 concentrations measured during 2014 are presented in Table 4.

Annual mean NO_2 concentrations in excess of the 40 µg.m^{-3} objective were measured during 2014 at the Johnstone 20 and Johnstone 59 sites. Full details of bias adjustment factors applied to the diffusion tube results and QA/QC procedures are presented in the Renfrewshire Council 2015 LAQM Updating and Screening Assessment[4].

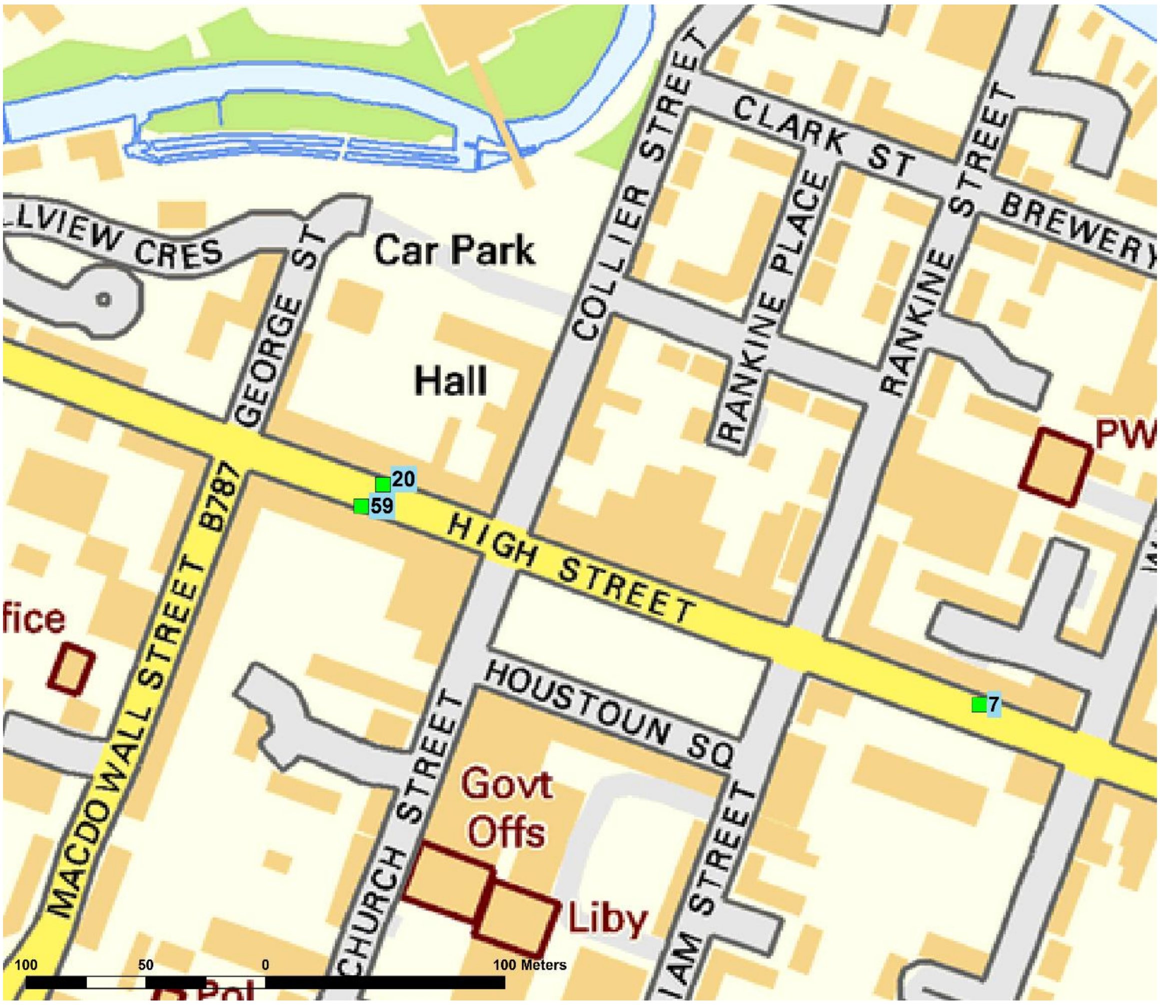
Table 4: NO_2 diffusion tube measurements 2014

Site	Type	Easting	Northing	Data Capture 2014 (%)	Bias corrected (1.06) annual mean 2014 (µg.m^{-3})
Johnstone 7	K	242914	663198	92 %	36.7
Johnstone 20	K	242674	663286	92 %	**45.2**
Johnstone 59	R	242656	663281	92 %	**57.0**

Exceedances of the annual mean objective in bold
R – Roadside monitoring location, 1-5m from the kerb of a busy road
UB – Urban Background, more than 50m from a busy road – residential
K – Kerbside monitoring location, within 1m of the kerbside of a busy road

[4] Ricardo-AEA (2015) Renfrewshire Council LAQM Updating and Screening assessment 2015.

Figure 4: Johnstone diffusion tube locations



Legend:

Diffusion tube location

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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 with local monitoring results. The available roadside diffusion tube 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 diffusion tube measurements. Further information on model verification is provided in Section 6.1 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 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 being used to represent concentrations further away from the road, the resolution of 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 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.

Queuing traffic was considered using the methodology described in Section 3.2 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 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 Renfrewshire 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.

5.1.1 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 (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

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.

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 concentration these are combined with.

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

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

Following various checking and refinements to the model input; the modelled Road NOx contribution required adjustment by an average factor of 2.7325 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 no further adjustments were made to the data. Model for the NO_2 monitoring data after adjustment is presented in

Table 5 and Figure 5. 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 1.95 µg.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.

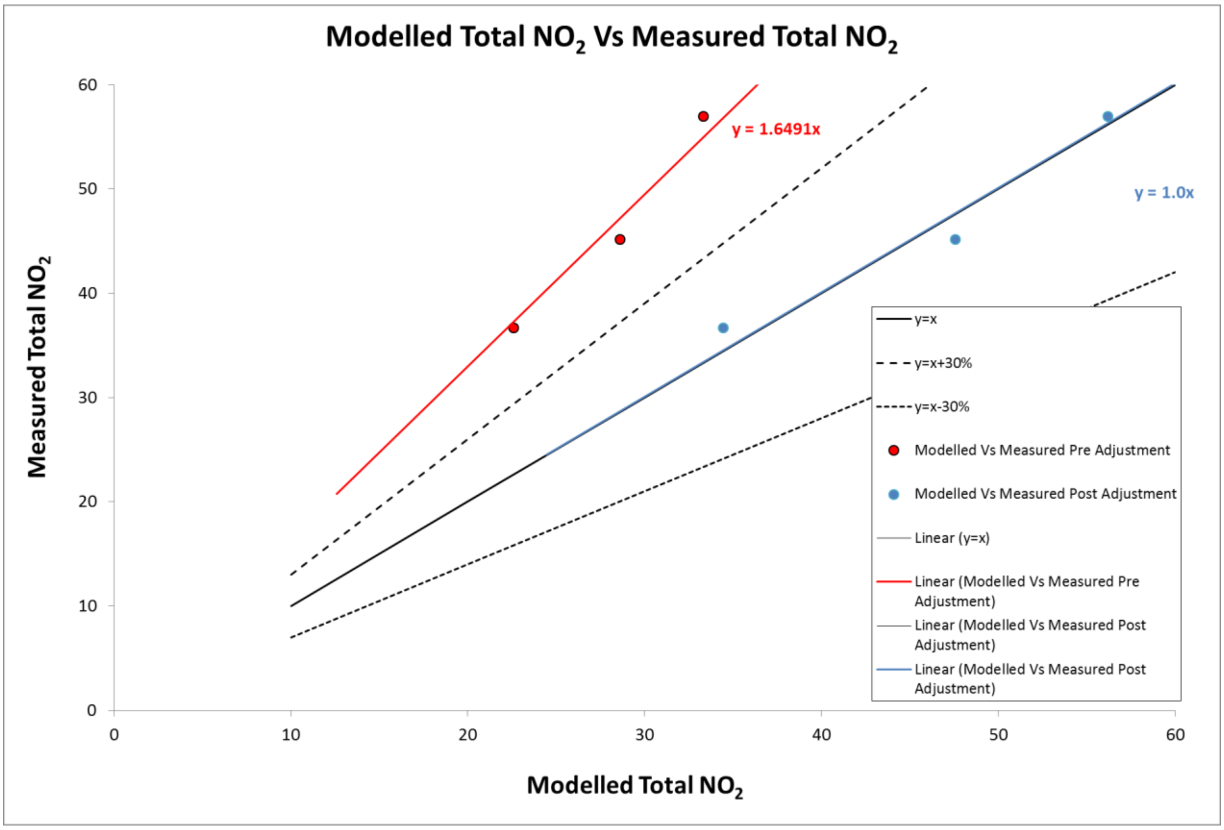
In the absence of any PM_{10} monitoring data with which to verify the models performance when predicting PM_{10} concentrations, the NOx primary adjustment factor of 2.7325 was also applied to all modelled road PM_{10} concentrations before adding the background concentration. This method is recommended by LAQM.TG(09) in instances where no PM_{10} measurements are available to support model verification.

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). Further information on the verification process including the linear regression analysis is provided in Appendix 3.

Table 5: Modelled vs. measured annual mean NO_2 concentrations 2014

Site	Measured (µg.m^{-3})	Modelled (µg.m^{-3})
Johnstone 7	36.7	34.4
Johnstone 20	45.2	47.6
Johnstone 59	57	56.2
	RMSE	**1.95**

Figure 5: Linear regression plot of modelled vs. monitored NO_2 annual mean 2014



6.2 Adjusted Modelling results

The adjusted predicted annual mean NO_2 and PM_{10} concentrations at each of the specified receptors are presented in Table 6 and 7 respectively, with exceedances of the respective air quality objectives highlighted in rose 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 both 1.5m and 1st floor height at the following specified locations:

- 70 High Street
- 67 High Street
- 1 Collier Street
- 5 High Street
- 6 High Street

At 14 Millview Crescent ground level receptor, the model predicted annual mean NO_2 concentration of 38.8 µg.m^{-3} which is less than the annual mean objective. However, this result should be considered in context with the estimated model uncertainty (RMSE as described in Section 6.1) which was 1.95 µg.m^{-3}. There is therefore a risk that the annual mean objective may also be exceeded at ground level residential properties at this location.

Table 6: Predicted annual mean NO_2 concentrations at specified receptors 2014

Receptor	Address	NO_2 annual mean (µg.m^{-3}) at 1.5m	NO_2 annual mean (µg.m^{-3}) at 4m
High St 1	14 Millview Crescent	38.8	30.5
High St 2	79 High Street	31.3	25.8
High St 3	70 High Street	52.5	50.0
High St 4	67 High Street	56.7	53.9
High St 5	1 Collier Street	58.2	53.3
High St 6	2 Collier Street	35.1	28.7
High St 7	1 Rankine Street	37.4	29.7
High St 8	38 High Street	30.6	25.8
High St 9	36 High Street	33.8	27.6
High St 10	30 High Street	30.2	25.3
High St 11	5 High Street	49.5	47.3
High St 12	6 High Street	51.6	47.6

6.2.2 Predicted NO_2 concentrations in comparison with the 1-hour short-term objective

LAQM. TG (09) states that if measured annual mean NO_2 concentrations are in excess of 60 µg.m^{-3} an exceedance of the 1-hr mean objective may be occurring.

The highest predicted concentration at a specified receptor occurred at High Street 5, 58.2 µg.m^{-3} and with the model uncertainty there is potential for the annual mean to be in excess of 60 µg.m^{-3} indicating the potential for the 1 hour mean to be exceeded. However at ground level at this location there are commercial properties only and it is not an outdoor location where the public would be expected to be present for an hour or more. It is therefore not considered a location of relevant exposure in terms of the 1-hr mean objective.

6.2.3 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 specified locations:

- 14 Millview Cresent
- 70 High Street
- 67 High Street
- 1 Collier Street
- 1 Rankine Street
- 5 High Street
- 6 High Street

Table 7 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	14 Millview Crescent	18	17
High St 2	79 High Street	17	16
High St 3	70 High Street	19	19
High St 4	67 High Street	20	20
High St 5	1 Collier Street	20	19
High St 6	2 Collier Street	17	17
High St 7	1 Rankine Street	18	17
High St 8	38 High Street	17	16
High St 9	36 High Street	17	17
High St 10	30 High Street	17	17
High St 11	5 High Street	19	19
High St 12	6 High Street	20	19

6.3 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 concentrations across the study area. Each grid has been modelled at both 1.5m and 4m heights to represent human exposure at ground and first floor level.

6.3.1 NO_2

Contour plots showing the spatial variation of the predicted 2014 annual mean NO_2 concentrations across the study area are presented in Figure 6 and Figure 7 . The NO_2 annual mean contour plots indicate that the 40 $\mu g.m^{-3}$ annual mean objective is being exceeded at ground level locations along the High Street. The location where the highest concentrations are predicted is at the section of High Street between MacDowall Street and Church Street but there are no residential receptors present here. Ground floor residential properties are present at both the eastern and western end of High Street. The contour plots indicates there is a risk that the objective is being exceeded at these properties during 2014.

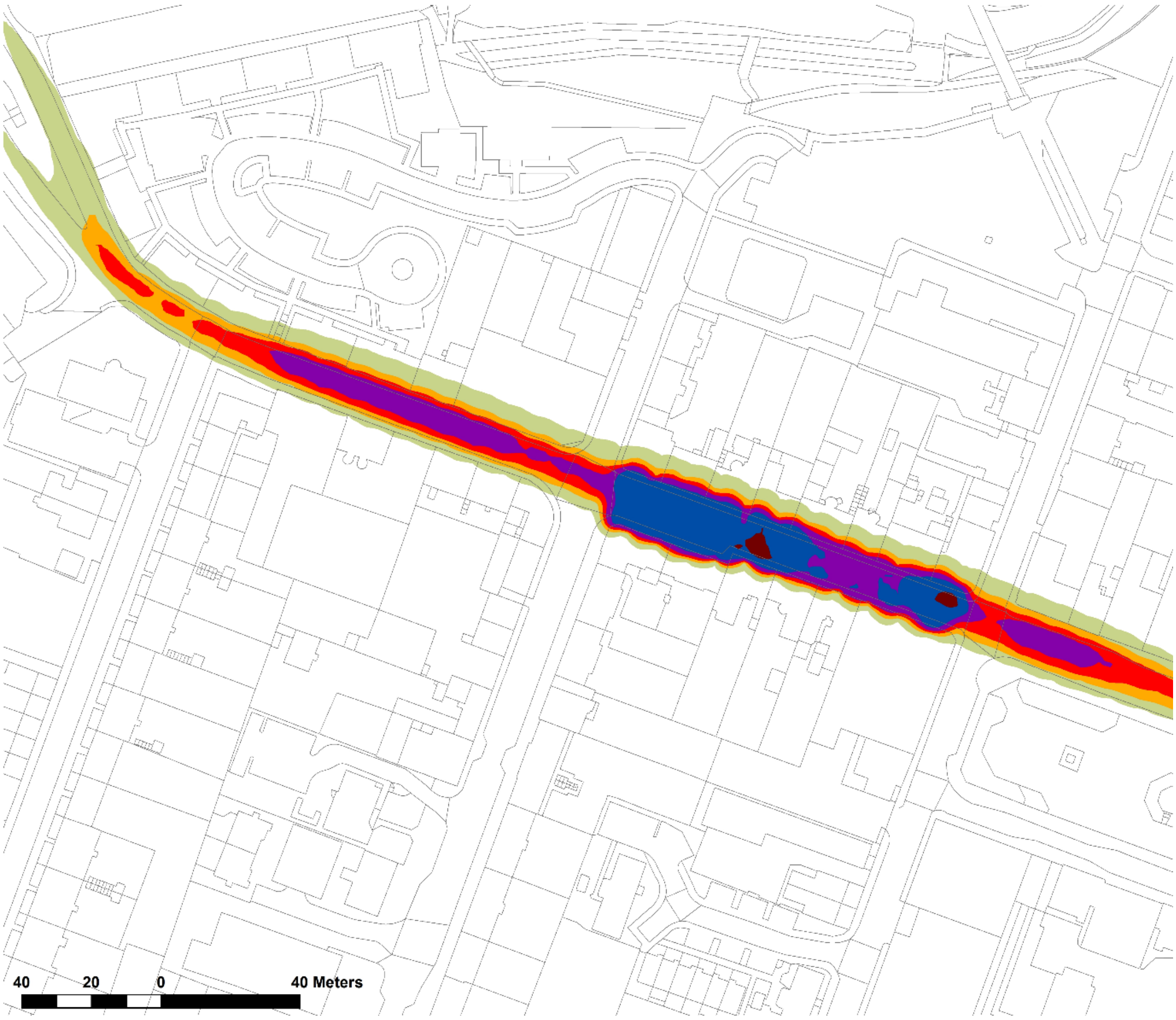
Other than at the eastern and western end of High Street, the majority of residential properties are mainly present at 1^{st} floor height along High Street with commercial properties present at ground level; a contour plot showing the predicted NO_2 annual mean at 4m height is presented in *Figure 10*. This plot indicates that the 40 $\mu g.m^{-3}$ objective was exceeded at 1^{st} floor properties at the section of High Street between MacDowall Street and Church Street and at the initial section of High Street east of the junction with Canal Street. Both of these locations have relatively high sided buildings on each side of the street i.e. canyon type topography, which limits pollutant dispersion and can cause recirculation of air during certain meteorological conditions.

6.3.2 PM_{10}

Contour plots showing the spatial variation of the predicted 2014 annual mean PM_{10} concentrations across the study area are presented in Figure 8 and Figure 9. The contours indicate that exceedances of the 18 $\mu g.m^{-3}$ Scottish PM_{10} annual mean objective occurred at ground level locations at the western end of High Street where residential properties are located.

A contour plot showing the predicted PM_{10} annual mean at 4m height is presented in *Figure 11*. The contours indicate that the PM_{10}annual mean objective was also exceeded at 1^{st} floor height at the same locations where concentrations in excess of the NO_2 annual mean objective were occurring at 1^{st} floor height.

Figure 6: Modelled NO_2 annual mean concentrations 2014 at 1.5m height – Western section of High Street, Johnstone



Legend:

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

- < 30
- 30 - 36
- 36 - 40
- 40 - 44
- 44 - 50
- 50 - 60
- 60 - 62.3

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Figure 7: Modelled NO_2 annual mean concentrations 2014 at 1.5m height – Eastern section of High Street, Johnstone

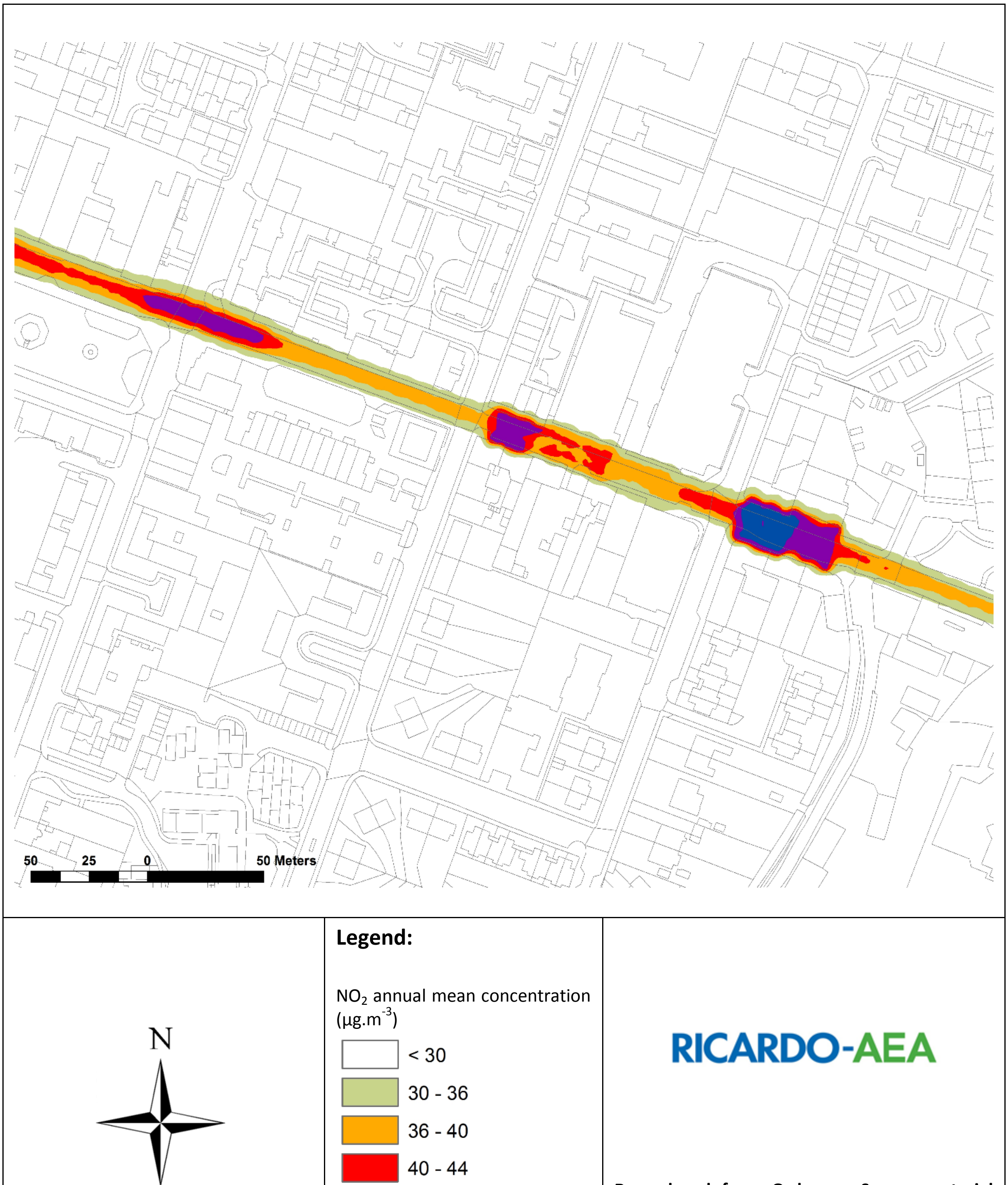
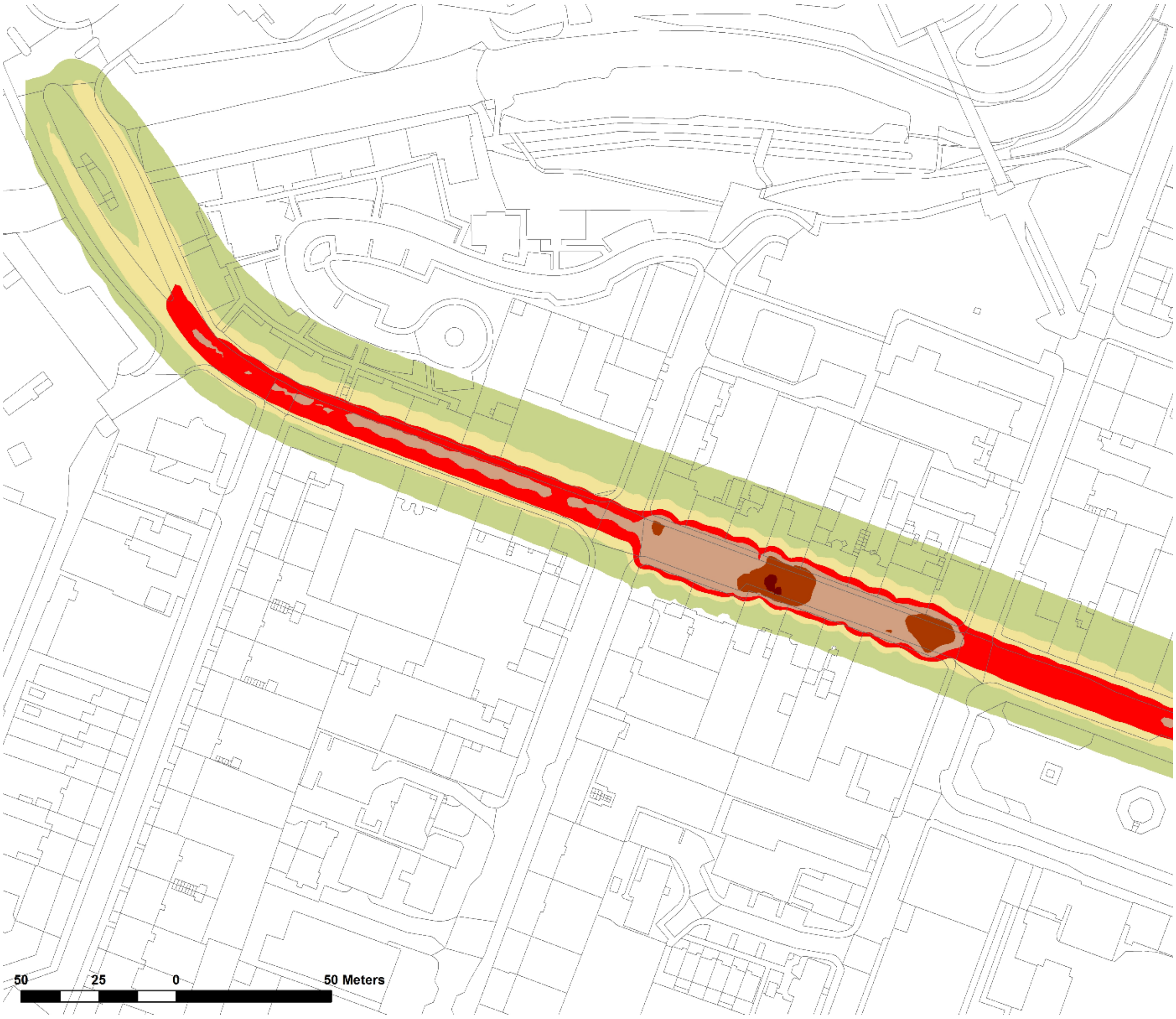


Figure 8: Modelled PM_{10} annual mean concentrations 2014 at 1.5m height – Western section of High Street, Johnstone

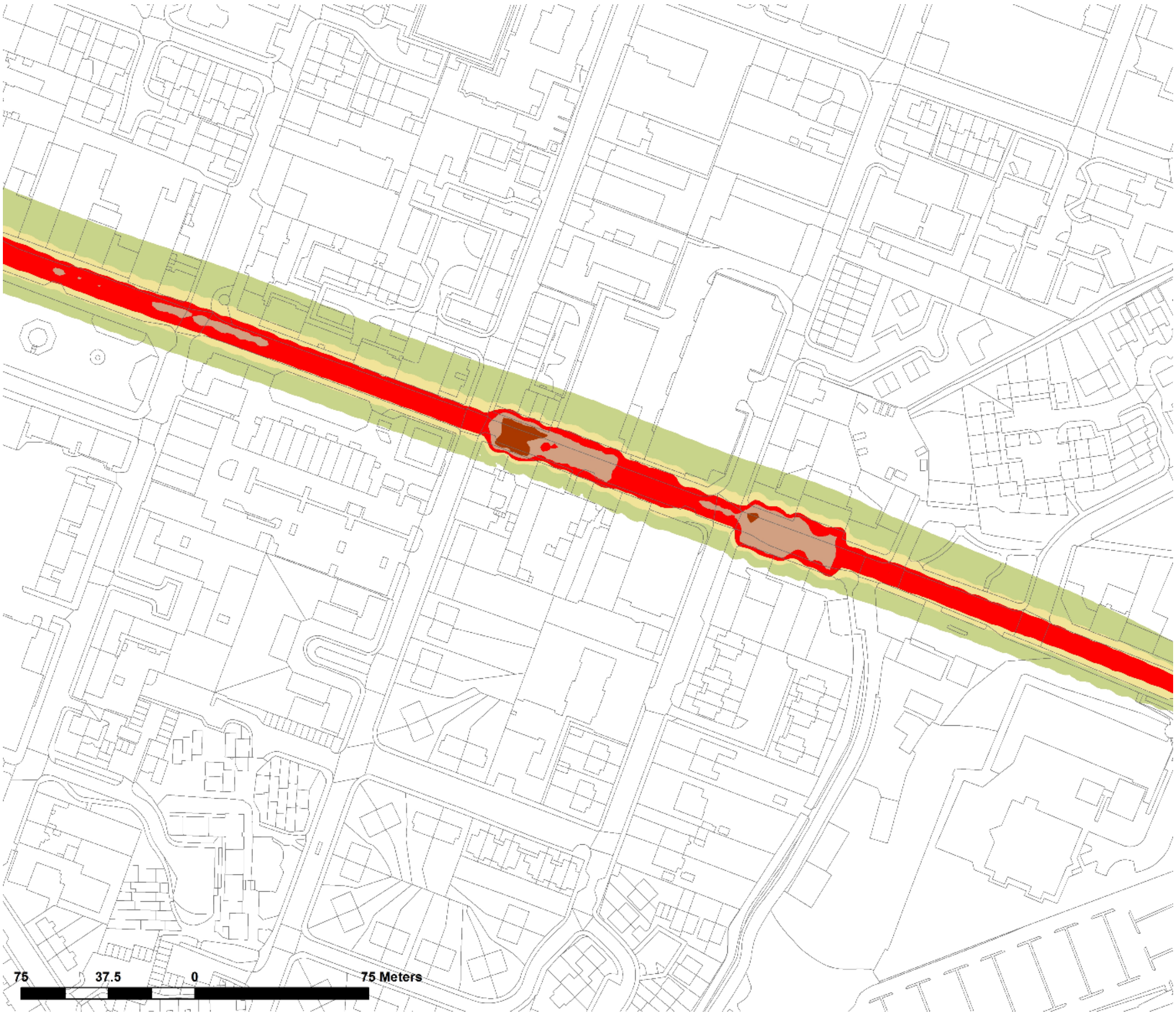


Legend:

PM_{10} annual mean concentration ($\mu g.m^{-3}$)

- < 16
- 16 - 17
- 17 - 18
- 18 - 19
- 19 - 20
- 20 - 21
- 21 - 21.2

Figure 9: Modelled PM_{10} annual mean concentrations 2014 at 1.5m height – Eastern section of High Street, Johnstone



Legend:

PM_{10} annual mean concentration ($\mu g.m^{-3}$)

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	< 16 16 - 17 17 - 18 18 - 19 19 - 20 20 - 21 21 - 21.2	**License number LA100023417**

Figure 10: Modelled NO_2 annual mean concentrations 2014 at 4m height –High Street, Johnstone

Legend:

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

- < 30
- 30 - 36
- 36 - 40
- 40 - 44
- 44 - 50
- 50 - 58.8

Figure 11: Modelled PM_{10} annual mean concentrations 2014 at 4m height –High Street, Johnstone

Legend:

PM_{10} annual mean concentration ($\mu g.m^{-3}$)

- < 16
- 16 - 17
- 17 - 18
- 18 - 19
- 19 - 20
- 20 - 20.6

7 Population Exposure

The contour plots indicate that the NO_2 annual mean objective was exceeded at up to 17 residential properties during 2014.

The contour plots indicate that the PM_{10} annual mean objective was exceeded at up to 25 residential properties during 2014.

Full details of the properties in the exceedance areas are presented in Figures B1 to B4 in Appendix B.

8 Source apportionment Study

Source apportionment is the process whereby the contribution of different pollutant sources to ambient concentrations are quantified. This aims to allow the Local Authority's action plan to target specific sources when attempting to reduce pollutant concentrations in the AQMA.

The source apportionment for the assessment should:

- Confirm that exceedances of the NO_2 and PM_{10} annual mean objective are due to road traffic.
- Determine the extent to which different vehicle types are responsible for the emission contributions to NOx/NO_2 and PM_{10} concentrations.
- Quantify what proportion of each pollutant is due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedance, or, whether national measures may be more effective in achieving the air quality objectives at this location.

To calculate the proportion of total pollutant concentrations attributable to various types of vehicles, the EfT was used; whereby emission sources were effectively switched on or off; e.g. for calculating the contribution from HGVs all other sources were set to zero. This allowed derivation of new emission rates for the road segments which were then modelled in ADMS-Roads to obtain the contribution of each source to ambient NO_2 concentrations at the worst-case specified receptor locations i.e. the locations where the highest concentrations were predicted.

The contributions from each of the following sources have been quantified:

- Background
- Cars
- Light Goods Vehicles
- Heavy Goods Vehicles
- Buses

The respective contributions from the above sources have been modelled at a selection of the receptor locations across the study area; this includes the locations where the highest NO_2 and PM_{10} annual mean concentrations were predicted. Table 8 and Table 9 summarise the relevant NOx contributions from the above sources at the worst-case receptor locations. The PM_{10} results are presented in Table 10 and Table 11. The source apportionment results are presented visually using segmented bar charts in Figure 12 to 15.

Examination of the source apportionment results indicates that:

- Background NOx concentrations account for a relatively small proportion, up to 11.5% of total NOx concentrations within the study area; whereas background PM_{10} accounts for up to a more significant 67% of the total concentration at each receptor.
- At all receptor locations there is a high proportion of road NOx and PM_{10} attributable to bus movements. Action plan measures targeted at reducing emissions from buses will therefore likely help reduce NO_2 and PM_{10} concentrations.
- The proportion of NOx and PM_{10} emissions from HGV and LGV movements is relatively low when compared to other vehicle types at all receptor locations included in the source apportionment study.
- The locations where the highest pollutant concentrations are being measured and modelled are at locations where traffic is known to be regularly slow moving and within high sided street canyon like topography. This indicates that any measures that can improve traffic flow at these locations where pollutant dispersion is poor will help to reduce annual mean concentrations. This could include for example, consideration of changes to traffic light phasing or traffic light locations.

Table 8: NOx source apportionment – Contribution by vehicle type (µg.m^{-3}) (excludes motorcycles)

Receptor location	Total NOx	Background	Road NOx	Cars	HGV	Buses	LGV
High St 3	174.6	18.6	156.0	46.0	16.1	89.2	4.7
High St 4	196.7	18.6	178.0	53.8	17.5	101.2	5.6
High St 5	192.0	18.6	173.3	51.0	17.8	99.4	5.2
High St 11	161.6	18.6	143.0	43.2	14.0	81.4	4.5
High St 12	163.4	18.6	144.8	43.8	14.2	82.4	4.5

Table 9: NOx source apportionment – Contribution by vehicle type (% of total NOx)

Receptor location	Total NOx	Background	Road NOx	Cars	HGV	Buses	LGV
High St 3	100%	10.7%	89.3%	26.3%	9.2%	51.1%	2.7%
High St 4	100%	9.5%	90.5%	27.3%	8.9%	51.5%	2.8%
High St 5	100%	9.7%	90.3%	26.6%	9.3%	51.8%	2.7%
High St 11	100%	11.5%	88.5%	26.7%	8.6%	50.4%	2.8%
High St 12	100%	11.4%	88.6%	26.8%	8.7%	50.4%	2.8%

Table 10: PM_{10} source apportionment – Contribution by vehicle type (µg.m^{-3}) (excludes motorcycles)

Receptor location	Total PM_{10}	Background	Road PM_{10}	Cars	HGV	Buses	LGV
High St 3	22.4	14.8	7.5	3.2	0.4	3.7	0.2
High St 4	23.9	14.8	9.1	3.8	0.5	4.5	0.3
High St 5	23.0	14.8	8.2	3.4	0.5	4.0	0.3
High St 11	22.2	14.8	7.4	3.1	0.4	3.6	0.2
High St 12	22.3	14.8	7.5	3.2	0.4	3.7	0.2

Table 11: PM_{10} source apportionment – Contribution by vehicle type (% of total PM_{10})

Receptor location	Total PM_{10}	Background	Road PM_{10}	Cars	HGV	Buses	LGV
High St 3	100%	66.3%	33.7%	14.1%	1.9%	16.6%	1.1%
High St 4	100%	62.0%	38.0%	16.0%	2.1%	18.7%	1.2%
High St 5	100%	64.5%	35.5%	14.8%	2.0%	17.5%	1.2%
High St 11	100%	66.8%	33.2%	14.0%	1.8%	16.4%	1.1%
High St 12	100%	66.5%	33.5%	14.1%	1.8%	16.5%	1.1%

Figure 12: High Street, Johnstone - NOx source apportionment (expressed in µg.m^{-3})

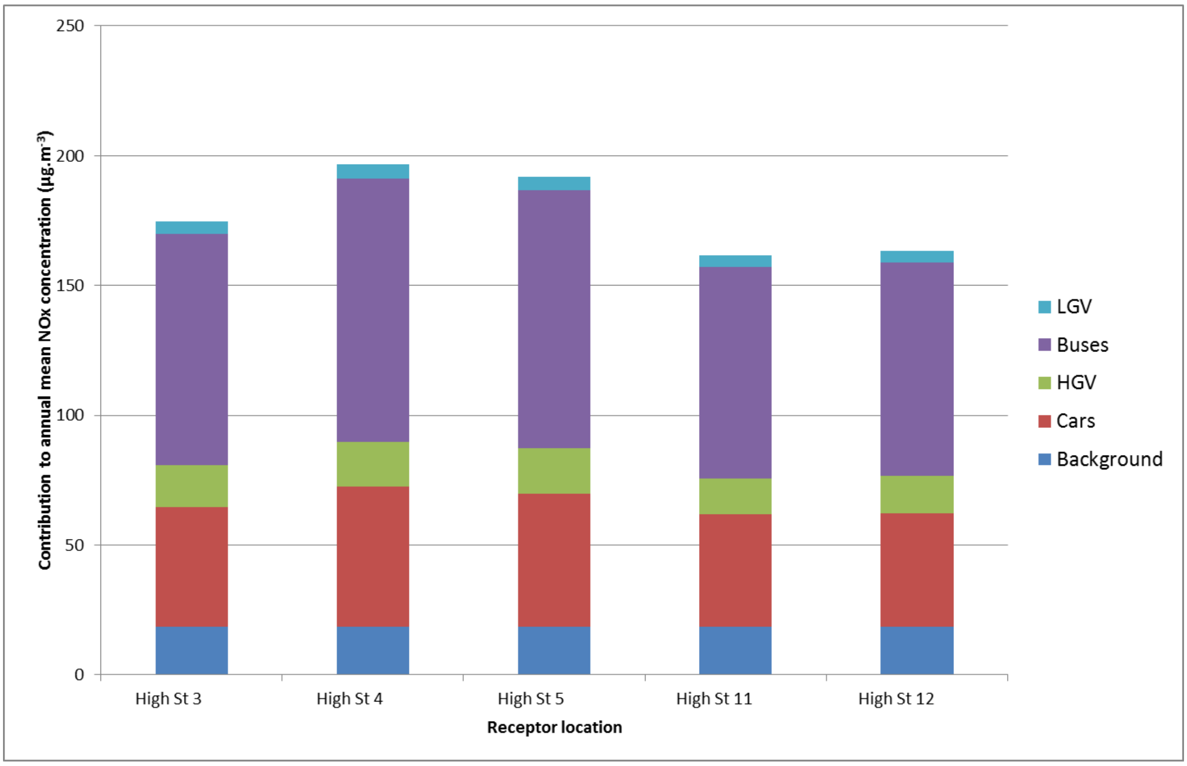


Figure 13: High Street, Johnstone - NOx source apportionment (expressed as a percentage)

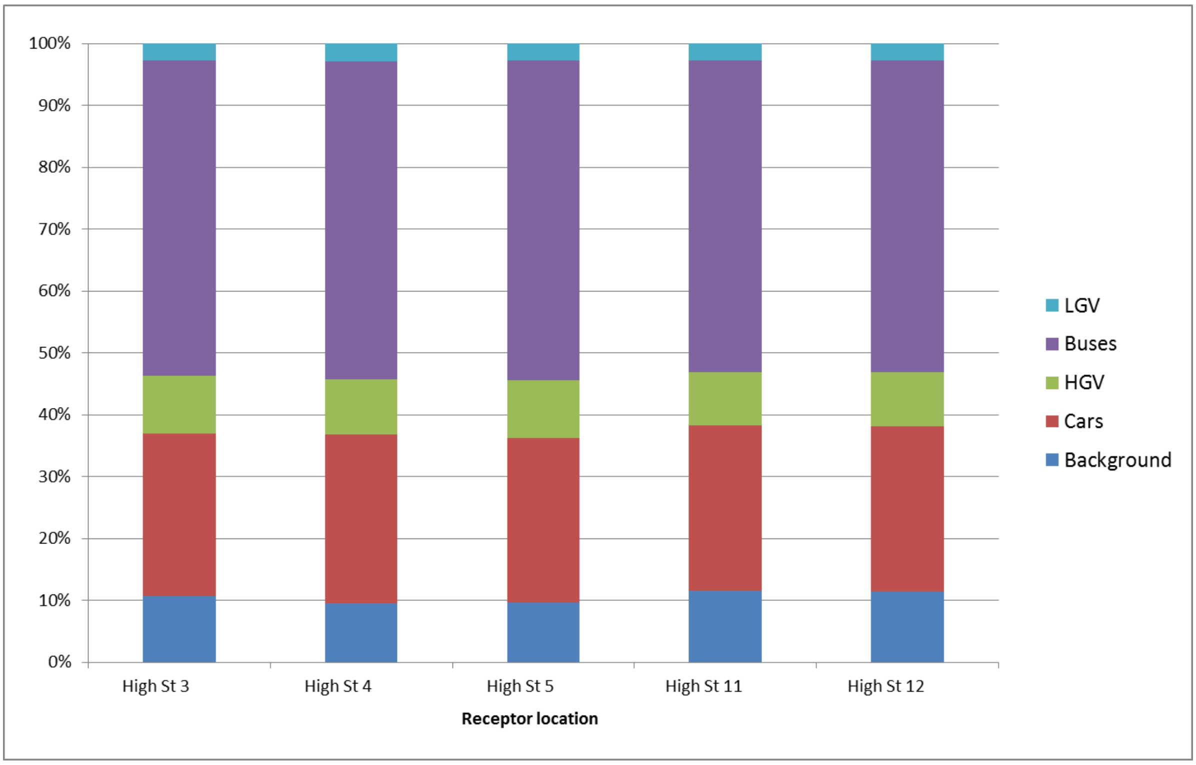


Figure 14: High Street, Johnstone – PM_{10} source apportionment (expressed in $\mu g.m^{-3}$)

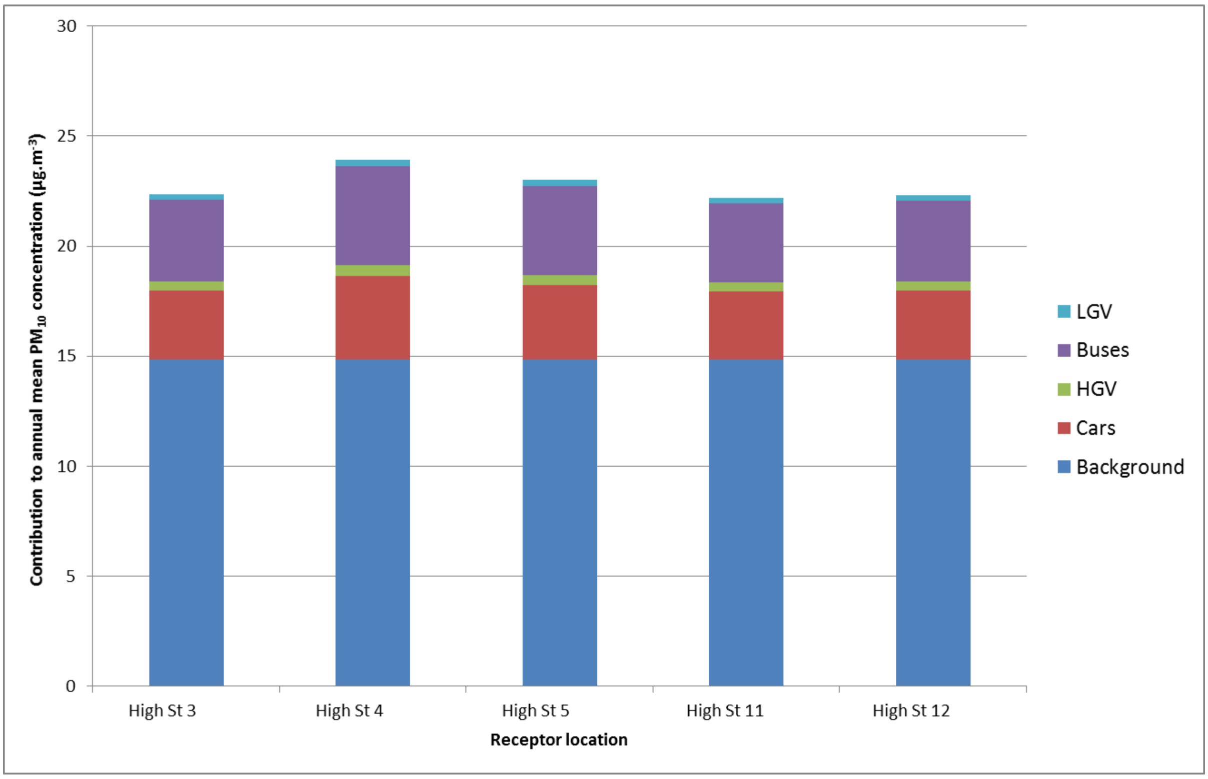
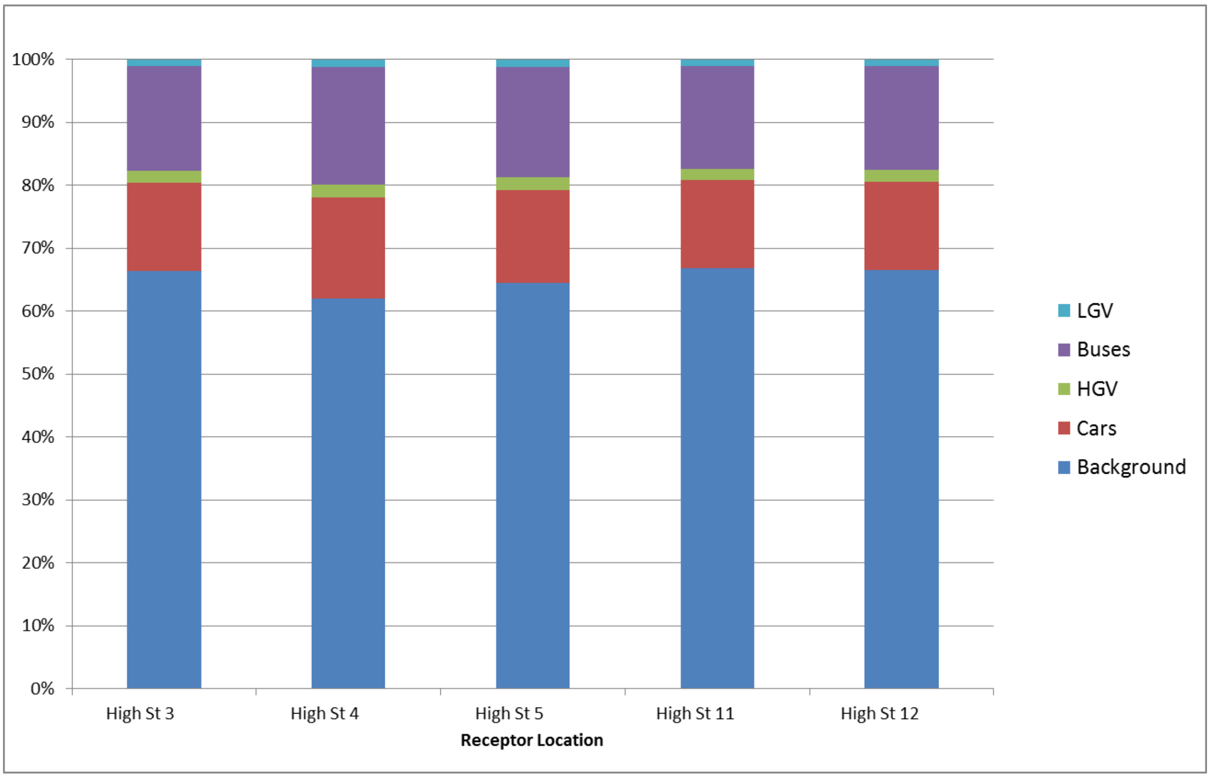


Figure 15: High Street, Johnstone – PM_{10} source apportionment (expressed as a percentage)



9 Summary and conclusions

This report describes a dispersion modelling study of road traffic emissions at High Street in Johnstone, Renfrewshire which has been conducted to allow a detailed assessment of NO_2 and PM_{10} concentrations at this location. This report also includes a source apportionment analysis of road traffic emissions which will help inform appropriate air quality action plan measures.

A combination of the available diffusion tube 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 were predicted at both ground level and 1st floor level at various locations along High Street during 2014.
- The results indicate that the NO_2 annual mean objective was predicted to be exceeded at up to 17 residential properties.
- Annual mean PM_{10} concentrations in excess of the 18 µg.m^{-3} Scottish annual mean objective at both ground level and 1st floor level were predicted at various locations along High Street during 2014.
- The modelling results indicated that the PM_{10} annual mean objective was being exceeded at up to 25 residential properties during 2014.

Based on the available traffic data, the source apportionment study indicates that:

- Background NOx concentrations account for a relatively small proportion, up to 11.5% of total NOx concentrations within the study area; whereas background PM_{10} accounts for up to, a more significant, 67% of the total annual mean concentration at each receptor.
- At all receptor locations there is a high proportion of road NOx and PM_{10} attributable to bus movements. Action plan measures targeted at reducing emissions from buses will therefore likely help reduce NO_2 and PM_{10} concentrations.
- The proportion of NOx and PM_{10} emissions from HGV and LGV movements is relatively low when compared to other vehicle types at all receptor locations included in the source apportionment study.
- The locations where the highest pollutant concentrations are being measured and modelled are at locations where traffic is known to regularly be slow moving and within the high sided street canyon like topography. This indicates that any measures that can improve traffic flow at these locations where pollutant dispersion is poor will help to reduce vehicle emissions and concentrations. This could include for example, consideration of changes to traffic light phasing or traffic signal locations.

In light of this Detailed Assessment of Air quality in Johnstone using the available monitoring data from 2014, **Renfrewshire Council is required to declare an Air Quality Management Area that includes all residential properties within the areas where exceedances of the annual mean NO_2 and PM_{10} objectives are predicted.**

10 Acknowledgements

Ricardo-AEA gratefully acknowledges the support received from Karen McIndoe, Amy Sharpe and Callum Keenan at Renfrewshire Council when completing this assessment.

Appendices

Appendix 1: Traffic Data

Appendix 2: Meteorological Dataset

Appendix 3: Model Verification

Appendix 1 – Traffic Data

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

Traffic data for the assessment was available from a local survey commissioned by Renfrewshire Council. The one week traffic surveys conducted in January/February 2015 provided information on daily average flow and fleet split. To quantify the average daily number of buses the data was supplemented with local bus timetable information.

Table A1.1: Johnstone 2014 - Annual Average Daily Flows

Street	%Cars	%LGV	%HGV	%Bus	AADF 2014
High Street combined directions	90.9 %	3.8 %	2.1 %	2.5 %	9532

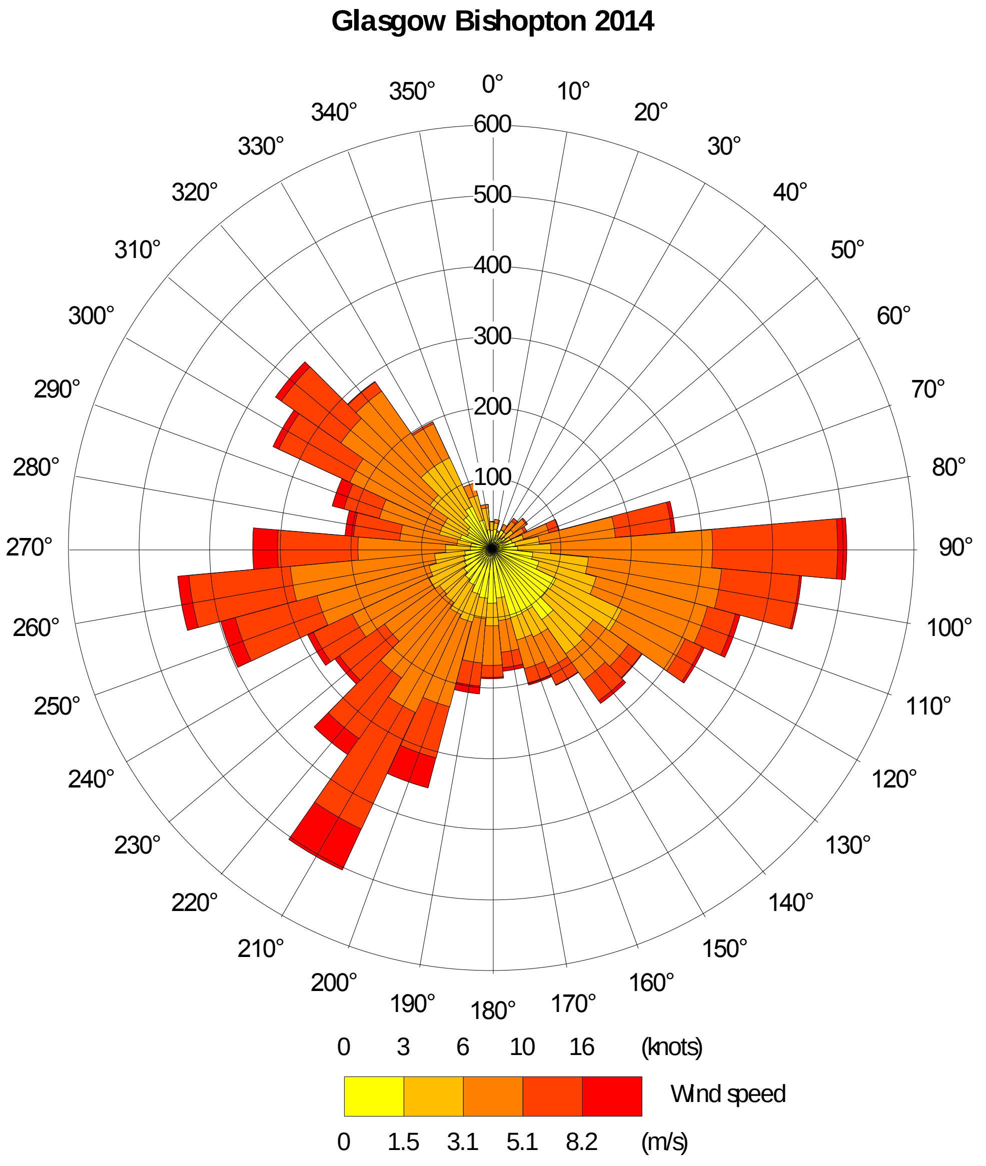
LGV – Light Goods Vehicles

HGV – Heavy Goods Vehicles (Articulated and Rigid)

Appendix 2 – Meteorological dataset

The wind rose for the Glasgow Bishopton 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 6.1 above, the model was verified using annual mean NO_2 measurements from the various NO_2 diffusion tube sites 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 the 2014 calendar year at the diffusion tube sites. The model output of Road NOx (the total NOx originating 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 diffusion tube 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 Road 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 2.7325 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.

Model uncertainty can be estimated by calculating the root mean square error (RMSE). In this case the calculated RMSE was 1.95 $\mu g.m^{-3}$ after adjustment which is within the suggested value (10% of the objective being assessed) in LAQM.TG(09). The model has therefore performed sufficiently well for use within this assessment.

In the absence of any PM_{10} monitoring data with which to verify the models performance when predicting PM_{10} concentrations, the NOx primary adjustment factor of 2.7325 was also applied to all modelled road PM_{10} concentrations before adding the background concentration. This method is recommended by LAQM.TG(09) in instances where no PM_{10} measurements are available to support model verification.

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

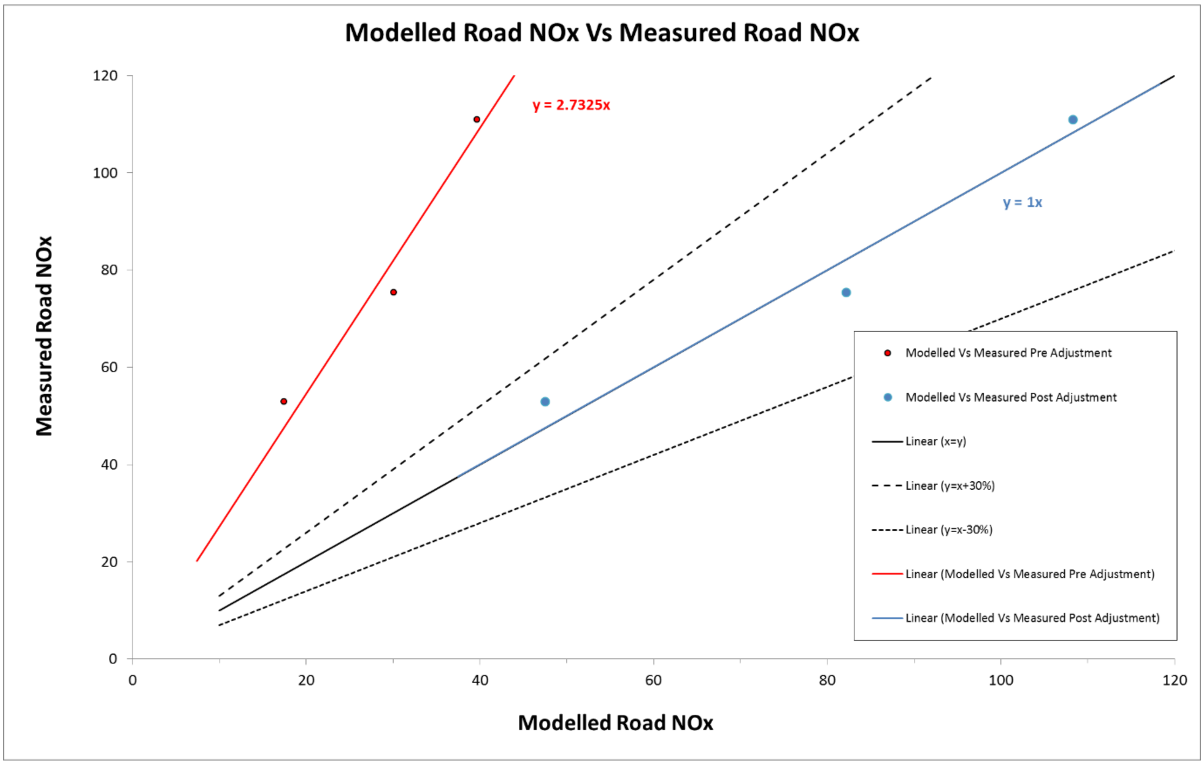
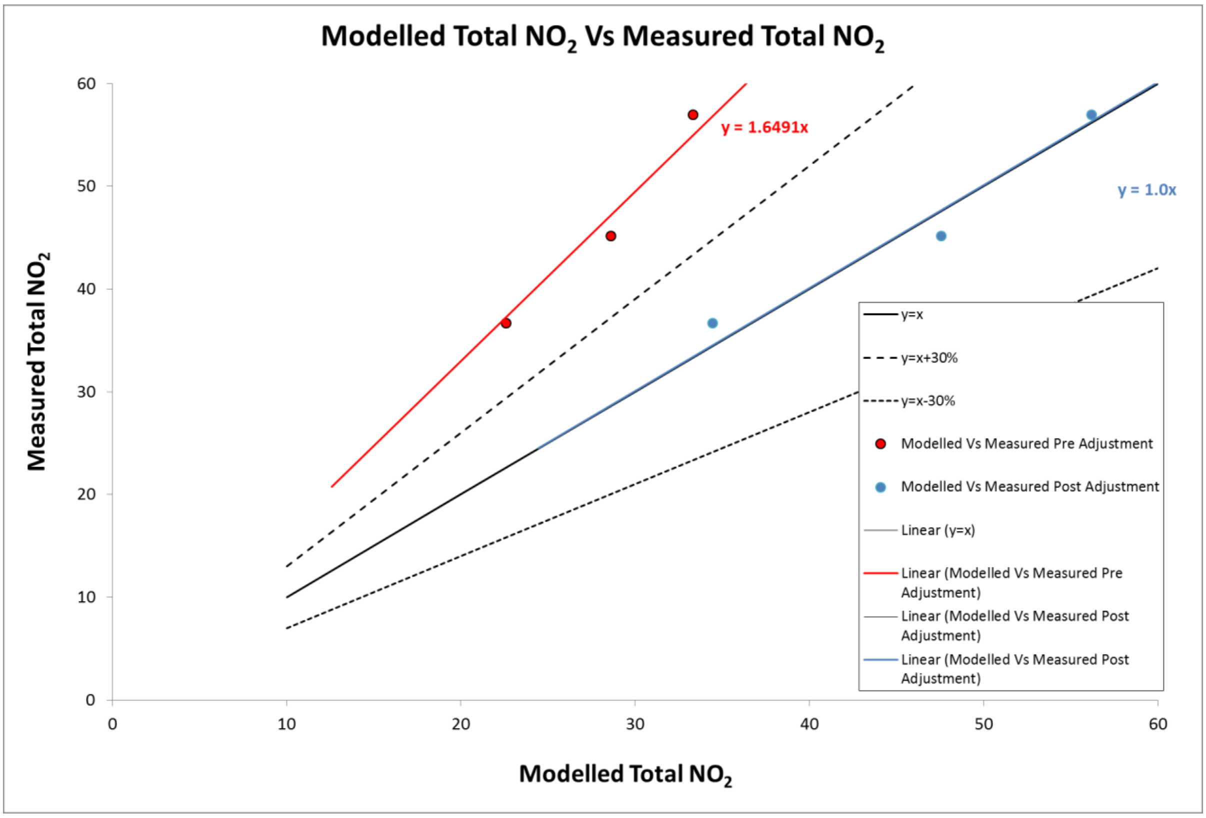
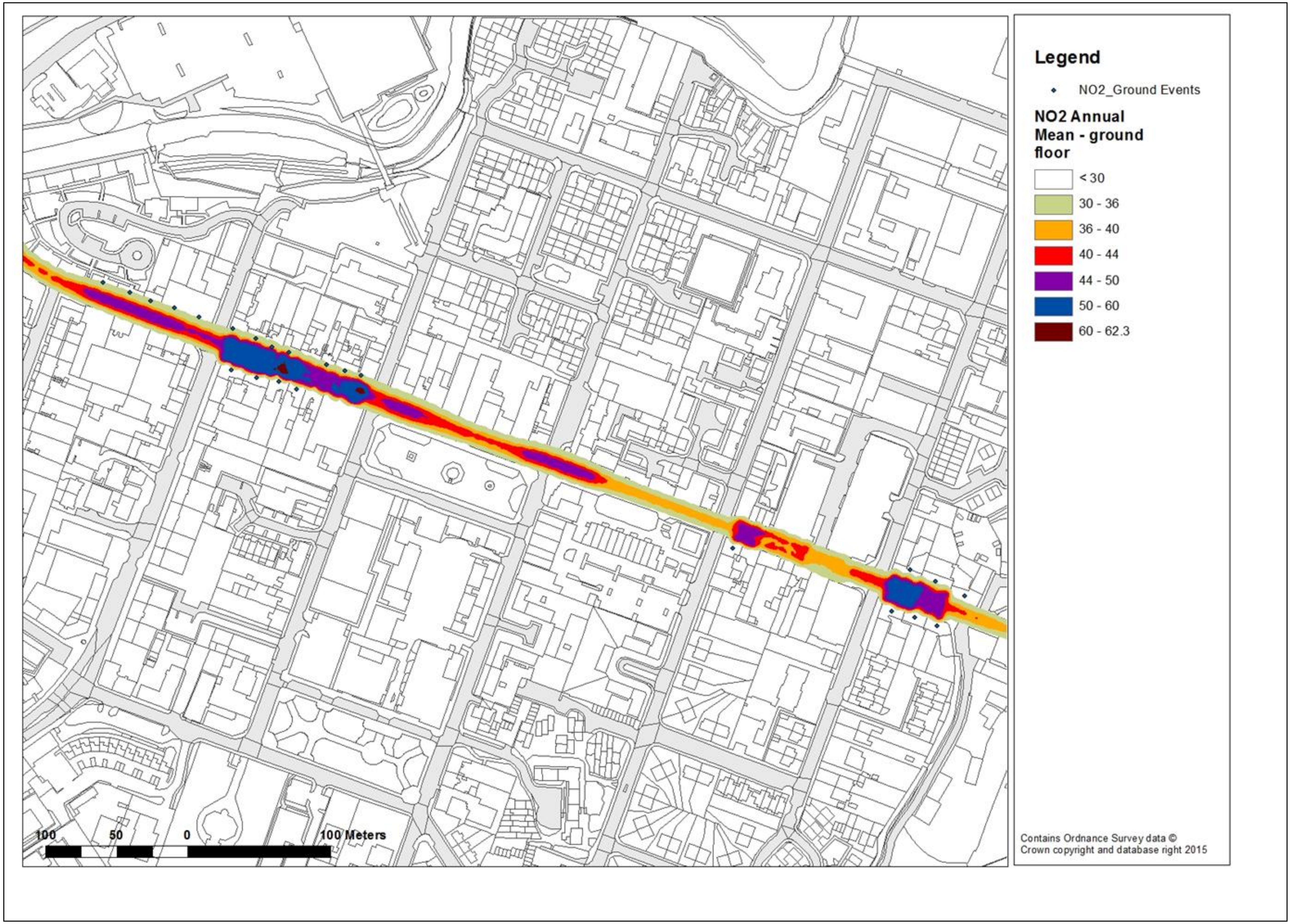
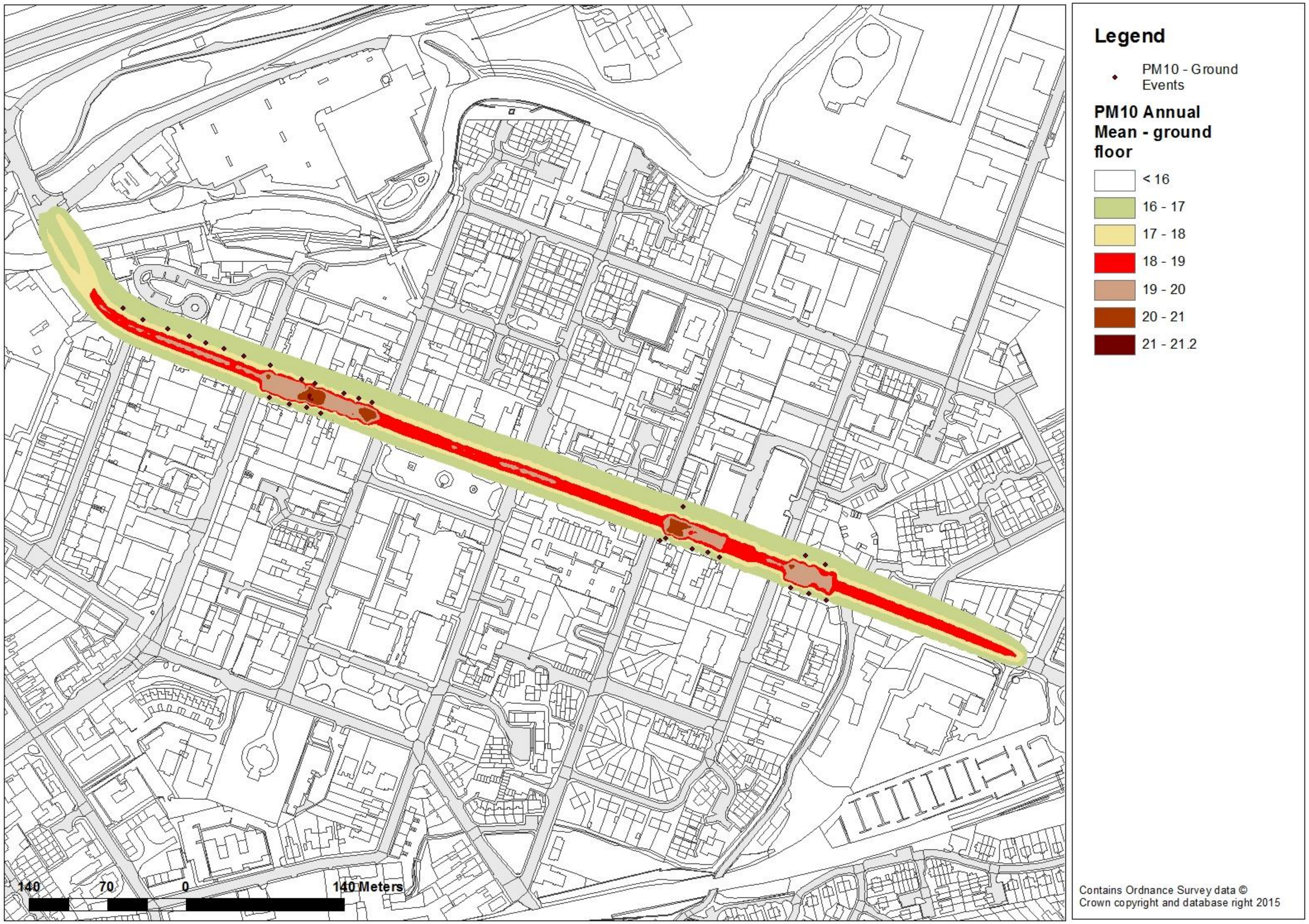


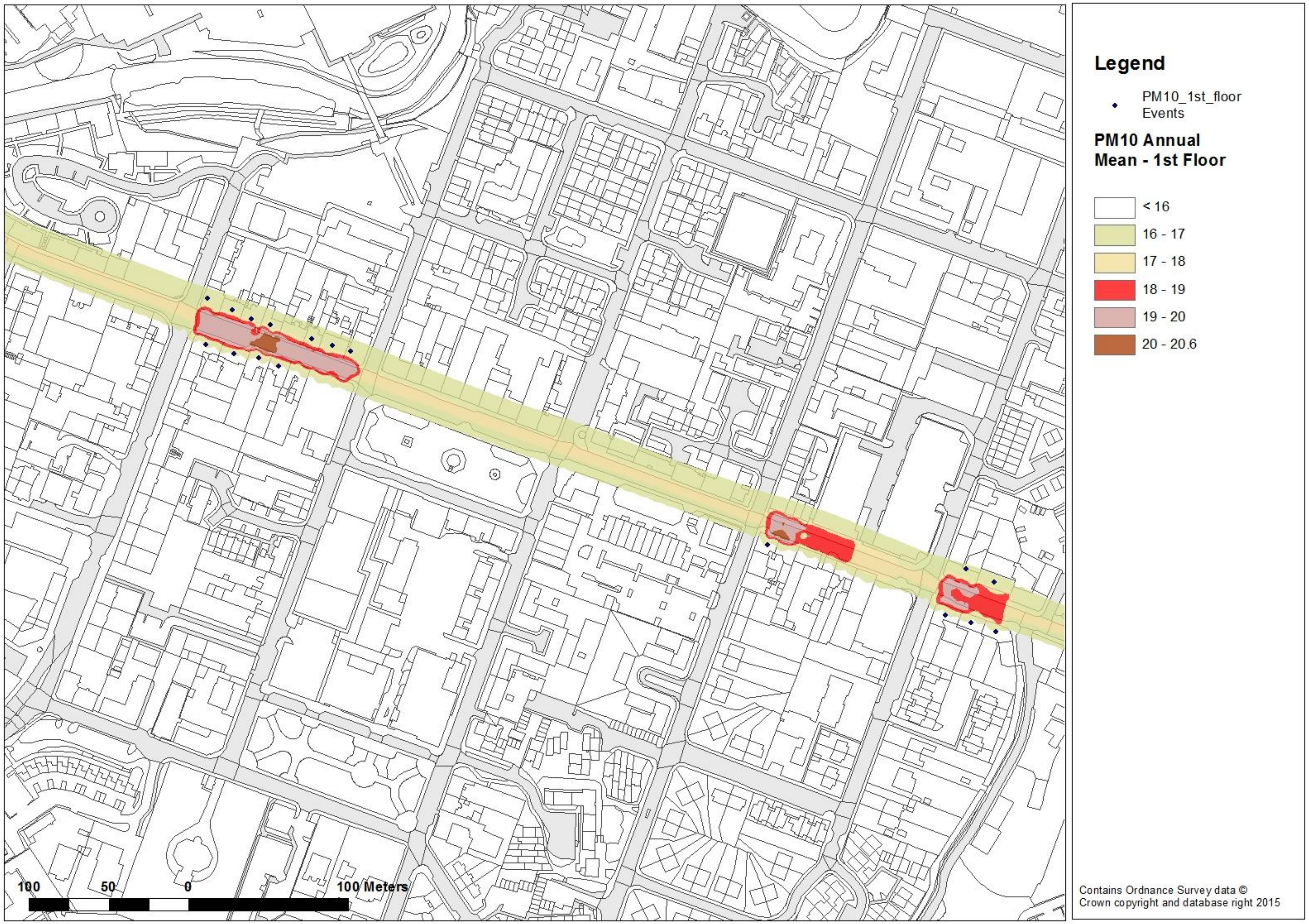
Figure A3.2 Comparison of modelled vs. monitored NO_2 annual mean 2014



Appendix B: A3 Contour Plots


Legend
NO2_Ground Events
NO2 Annual Mean - ground floor
< 30
30 - 36
36 - 40
40 - 44
44 - 50
50 - 60
60 - 62.3
100
50
0
100 Meters
Contains Ordnance Survey data © Crown copyright and database right 2015


Legend
PM10 - Ground Events
PM10 Annual Mean - ground floor
< 16
16 - 17
17 - 18
18 - 19
19 - 20
20 - 21
21 - 21.2
140
70
0
140 Meters
Contains Ordnance Survey data © Crown copyright and database right 2015


Legend
PM10_1st_floor Events
PM10 Annual Mean - 1st Floor
< 16
16 - 17
17 - 18
18 - 19
19 - 20
20 - 20.6
100
50
0
100 Meters
Contains Ordnance Survey data © Crown copyright and database right 2015

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