Ricardo Energy & Environment

Detailed Assessment of Air Quality – Renfrew Town Centre

Report for Renfrewshire Council

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Executive summary

Ricardo has been commissioned by Renfrewshire Council to undertake an updated Detailed Assessment of air quality and source apportionment study for Renfrew town centre. The assessment has been undertaken due to potential exceedances of the annual mean nitrogen dioxide (NO_2) objective level identified within the 2014 Progress Report, and investigates the potential scale and extent of exceedances of the Scottish Air Quality Objectives for NO_2 and PM_{10} (particulate matter less than 10 microns in diameter) at residential properties within the study area.

A previous Detailed Assessment for Renfrew town centre was undertaken in 2012 based on 2011 data. The dispersion modelling predicted no exceedances of NO_2 levels at first floor residential flats but potential exceedances at ground floor residential receptors. However, due to uncertainties with the model verification, it was recommended that additional monitoring in the town centre area be undertaken at ground floor receptors to confirm the model predictions. Additional diffusion tube monitoring was therefore carried out in the area. A review of the 2013 measurement data within the 2014 Progress Report indicated potential exceedances of the NO_2 annual mean objective.

This 2015 Detailed Assessment includes an updated dispersion modelling study of road traffic emissions in Renfrew town centre, and source apportionment analysis to determine the contribution of different road traffic source types to local NO_2 and PM_{10} concentrations 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 during 2014 at ground level and 1st floor height at:
    - Ground level and 1st floor level at number 15 Inchinnan Road.
    - 1st floor height at numbers at 1, 3, 5, 7, 9, 11, 13, 17 and 19 Inchinnan Road – there is no relevant exposure at ground level at these properties.
    - 1st floor height at numbers 2 and 4 Paisley Road.
- No PM_{10} concentrations in excess of the 18 $\mu g.m^{-3}$ Scottish annual mean objective were predicted at any locations of relevant exposure.
- An annual mean NO_2 concentration in excess of 60 $\mu g.m^{-3}$ was measured in 2014 at the Renfrew 8 diffusion tube site which is located at 15 Inchinnan Road. There is a risk that the short term NO_2 objective is being exceeded at this location where a residential property is present at ground floor.

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

- Road NOx concentrations account for a significant proportion, up to 86.5% of total NOx concentrations within the study area; whereas background PM_{10} accounts for up to 83.3% of the total concentration at each receptor.
- Depending on the receptor, the highest contribution of road NOx is either from cars (41.7% at R4-15 Inchinnan Rd) or buses (34.3% at R2-14d Paisley Rd), followed by HGVs (27.9% at R4-15 Inchinnan Rd); whereas at all receptor locations the highest proportion of road PM_{10} was found to be attributable to car movements.
- The proportion of NOx from HGV movements was found to be higher in Inchinnan Road than in Hairst Street and Paisley Road where the Bus contribution to NOx concentrations were higher.
- The locations where the highest pollutant concentrations were measured and modelled are at the section of Inchinnan Road approaching the traffic lights where traffic will regularly be slow moving. The high concentrations here also indicated that recirculation of air, due to in this case a one sided street canyon topography, is limiting dispersion. This indicated that any measures that can improve traffic flow at these locations where pollutant dispersion is poor will help to reduce vehicle emissions. This could include for example, consideration of changes to traffic light phasing.

In light of this updated Detailed Assessment of air quality in Renfrew Town Centre using 2014 monitoring data, **Renfrewshire Council is required to declare an Air Quality Management Area encompassing all areas of exceedances of the annual mean NO_2 objective predicted in this study.**

Renfrewshire Council should also declare an AQMA for the NO_2 hourly mean objective at the location on Inchinnan Road where a risk of the hourly mean objective being exceeded was identified.

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1 Introduction

Ricardo Energy & Environment has been commissioned by Renfrewshire Council to undertake a Detailed Assessment of Air Quality in Renfrew Town Centre, Renfrewshire. The assessment has been undertaken to investigate the scale and extent of potential exceedances of the annual mean Scottish Air Quality 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 the 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 & PM_{10} Annual Mean 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 µg.m^{-3}	Annual mean
Particles (PM_{10}) (gravimetric) Authorities in Scotland	18 µg.m^{-3}	Annual mean

1.2 Locations where the objectives apply

When carrying out the review and assessment of air quality it is only necessary to focus on areas where the public are likely to be regularly present and are likely to be exposed over the averaging period of the objective. Table 2 summarises examples of where the annual mean air quality objectives for NO_2 and PM_{10} should and should not apply.

Table 2 Examples of where the NO_2 & PM_{10} Annual Mean 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 Renfrew Town Centre.

A previous Detailed Assessment for Renfrew town centre was undertaken in 2012 based on 2011 data. This report concluded that there were no exceedances of NO_2 levels at the residential flats at first floor level within the town centre but that there may be exceedances at ground floor residential receptors. However, due to uncertainties with the model verification, it was recommended that additional monitoring in the town centre area be undertaken at ground floor receptors to confirm the model predictions. Additional diffusion tube monitoring was therefore carried out in the area. A review of the 2013 measurement data within the 2014 Progress Report indicated potential exceedances of the NO_2 annual mean objective at a diffusion tube site on Inchinnan Road, Renfrew.

This 2015 Detailed Assessment includes an updated dispersion modelling study of road traffic emissions in Renfrew town centre and source apportionment analysis to determine the contribution of different road traffic source types to local NO_2 and PM_{10} concentrations which will help inform appropriate air quality action plan measures.

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 Renfrew 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

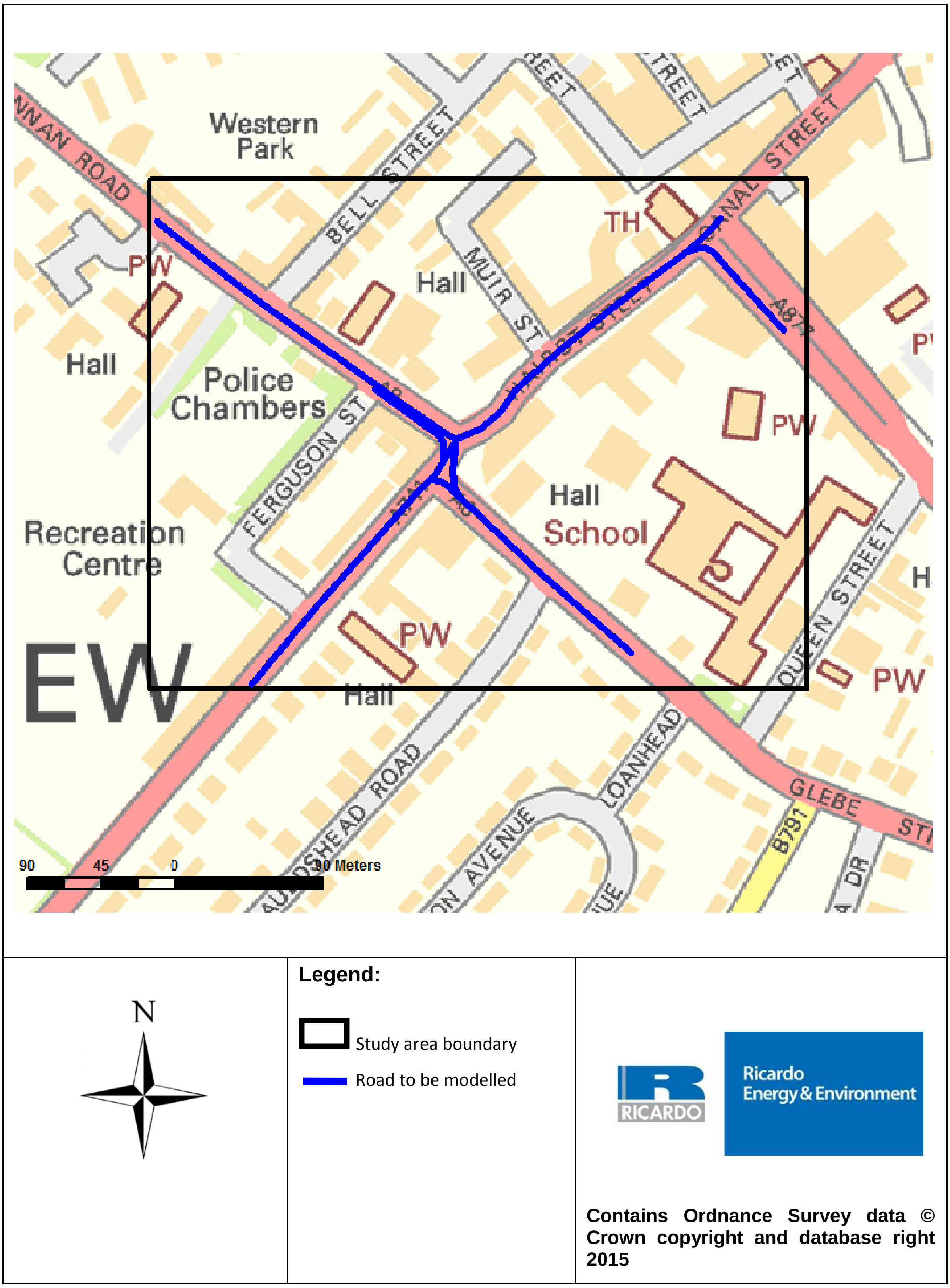
Renfrew is a town within Renfrewshire located in the west central lowlands of Scotland. The town is approximately three miles north east of neighbouring Paisley and 6 miles west of Glasgow.

This Detailed Assessment is concerned with road traffic emissions from roads within the town centre (Inchinnan Road, Hairst Street, Glebe Street and Paisley Road). The assessment considers road traffic emissions where relevant exposure i.e. residential properties are present close to the road.

2.1 Model domain

The study area comprises the main streets and junctions in Renfrew town centre - Inchinnan Road, Hairst Street, Glebe Street and Paisley Road. The town centre is a mix of commercial and residential properties. The majority of residential properties are flats and so receptors are located at ground floor and first floor level along these streets. 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 400m by 310m.

Figure 1 Detailed Assessment Study Area



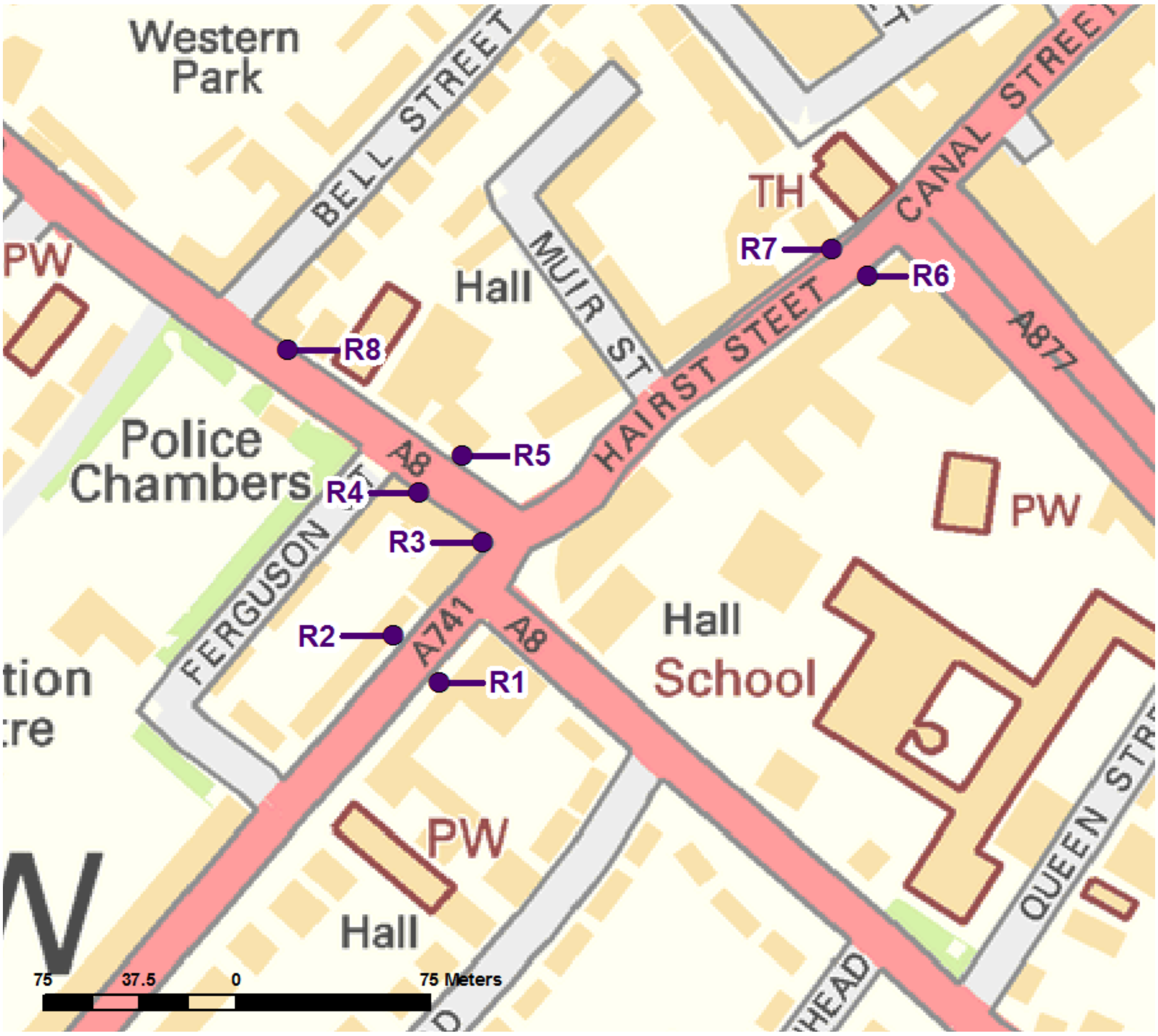
2.2 Receptor Locations

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. The receptors are located at the façade of buildings in the model domain where relevant exposure exists The receptors have been modelled at 1.5m and 4m to represent human exposure at ground and first floor level respectively. At some locations within the study area relevant exposure is only present at 1st floor height where commercial properties are present at ground floor level. The locations of the selected receptors are presented in Table 3 and Figure 2.

Table 3 Receptor Locations

Receptor	Address	Receptor height	Easting	Northing
R1	5 Paisley Road (Diffusion tube Renfrew 57)	1.5 m	250597	667473
R2	14d Paisley Road	1.5 m	250578	667491
R3	1 to 5 Inchinnan Road	4 m	250613	667527
R4	15 Inchinnan Road (Diffusion tube Renfrew 8)	1.5 m	250589	667547
R5	2 Inchinnan Road	4 m	250605	667561
R6	5 to 11 Hairst Street (Diffusion tube Renfrew 40)	4 m	250763	667631
R7	4 Hairst Street	4 m	250749	667641
R8	12 Inchinnan Road (Diffusion tube Renfrew 69)	1.5 m	250538	667602

Figure 2 Model Receptor Locations – Renfrew Town Centre



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● ADMS Receptor

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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[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.

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.

Average speeds were captured during the third party traffic count.

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. 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.

3.2.3 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

[1] Sky High Count On Us –SC2095 Renfrewshire ATC Report; January 2015
[2] http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft

emission factors for road traffic sources when conducting local, regional and national scale dispersion modelling assessments.

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 eight diffusion tube sites within the study area in Renfrew. Further details of these monitoring locations and 2014 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 10 km west 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 NOx 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. 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 Renfrew 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 and PM_{10} concentrations used in this assessment are presented in Table 4. The contribution of the M8 motorway and A-roads within each grid square have been removed from the background concentrations to avoid double counting.

Table 4 Renfrew Town Centre Study Area background NO_2 and PM_{10} values 2014 ($\mu g.m^{-3}$)

X	Y	Total background	A Roads contribution	Motorway contribution	Total minus both contributions
NOx					
249500	665500	28.4	1.28	7.5	19.6
PM_{10}					
249500	665500	14.6	0.03	0.2	14.3

4 Monitoring data 2014

Renfrewshire Council currently measures NO_2 concentrations within the study area in Renfrew at eight diffusion tube sites. A map showing the location of each monitoring location is presented in Figure 3.

Details of the monitoring sites and the annual mean NO_2 concentrations measured during 2014 are presented in Table 5.

Annual mean NO_2 concentrations in excess of the 40 $\mu g.m^{-3}$ objective were measured during 2014 at two sites. Distance corrected annual mean concentrations were also in excess of the 40 $\mu g.m^{-3}$ objective at the nearest residential properties.

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[3].

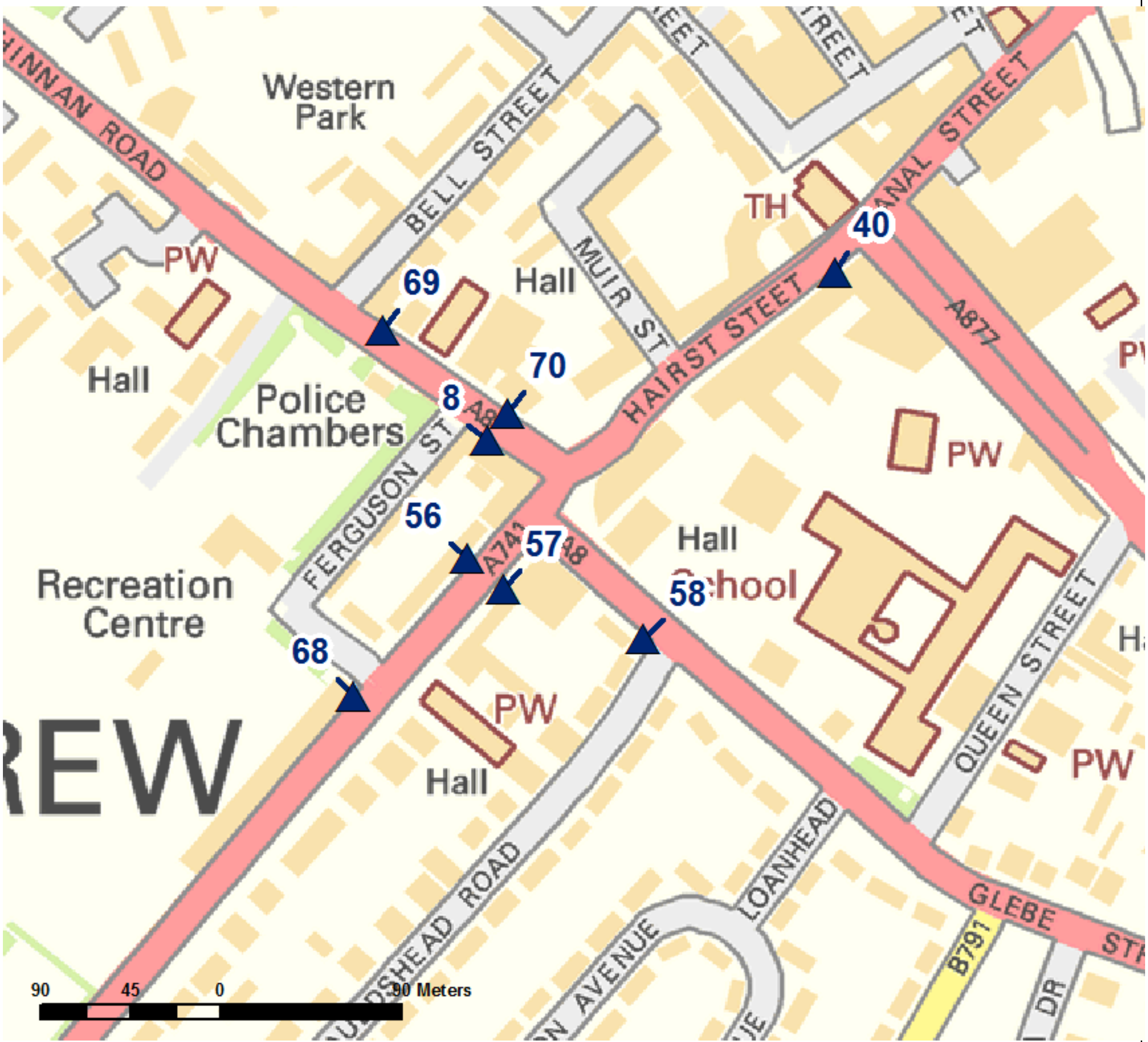
Table 5 NO_2 measurements 2014

Site	Type	Easting	Northing	Data Capture 2014 (%)	Bias corrected (1.06) annual mean 2014 ($\mu g.m^{-3}$)
Diffusion Tubes					
Renfrew 8 (15 Inchinnan Rd)	K	250589	667547	83	**62.0 (61.6)**
Renfrew 40 (Hairst St)	R	250763	667631	92	38.5
Renfrew 56 (16 Paisley Rd)	R	250579	667488	92	39.3
Renfrew 57 (5 Paisley Rd)	R	250597	667473	75	39.3
Renfrew 58 (10 Glebe St)	R	250667	667448	83	26.5
Renfrew 68 (28 Paisley Rd)	R	250522	667419	25	33.8
Renfrew 69 (12 Inchinnan Rd)	R	250537	667602	33	**44.3(44)**
Renfrew 70 (4 Inchinnan Rd)	R	250599	667561	25	32.0

Exceedances of the annual mean objective in boldC
Concentrations in brackets have been distance corrected to estimate NO_2 annual mean at nearest location where relevant exposure is present.
R – Roadside monitoring location, 1-5m from the kerb of a busy road
K – Kerbside monitoring location, within 1m from the kerb of a busy road

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

Figure 3 Renfrew Town Centre Monitoring Site Locations



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▲ **Monitoring site location**

Contains Ordnance Survey data © Crown copyright and database right 2015

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 and kerbside 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 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.

5.1.1 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[4] 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.

5.1.2 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.

[4] 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 concentration 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 all available 2014 diffusion tube measurements within the study area, with the exception of sites 68 and 70 as these measurements appeared to be outliers; the uncertainty was attributed to data capture being very low (25%) at each measurement site during 2014,

Following various checking and refinements to the model input; the modelled Road NOx contribution required adjustment by an average factor of 2.5874 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. A plot showing modelled NOx vs measured NOx concentrations is presented in Figure 4.

After the NOx/NO_2 model was run no further adjustments were made to the data. A comparison of measured vs modelled annual mean NO_2 concentrations at each diffusion tube site, following model adjustment, is presented in Figure 4 and Table 6**Error! Reference source not found.**

Figure 4 Linear regression plot of modelled vs. monitored NO_2 annual mean 2014

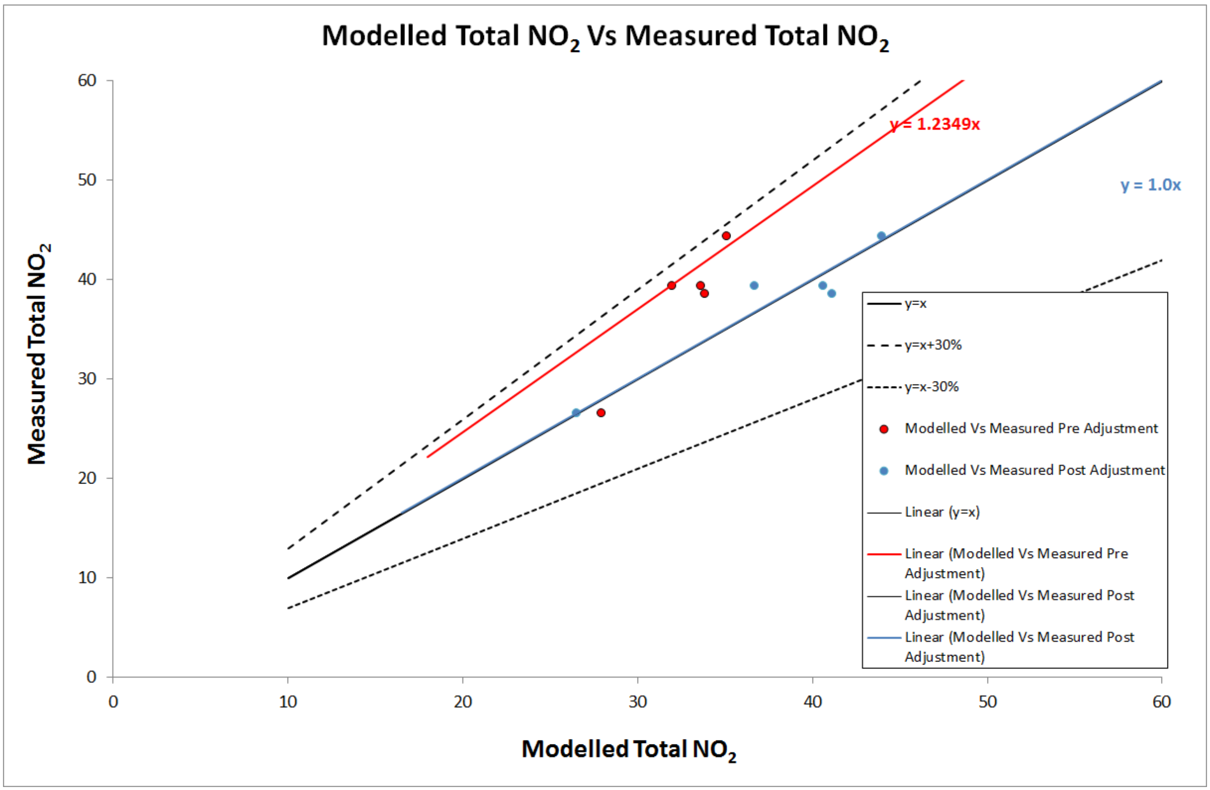


Table 6 Modelled vs. measured annual mean NO_2 concentrations at monitoring sites 2014

Diffusion Tube Sites	Tube height(m)	Measured ($\mu g.m^{-3}$)	Modelled ($\mu g.m^{-3}$)
Renfrew 8 (15 Inchinnan Rd)	2.4 m	62	60.8
Renfrew 40 (Hairst St)	2.5 m	38.5	41.2
Renfrew 56 (16 Paisley Rd)	2.4 m	39.3	40.6
Renfrew 57 (5 Paisley Rd)	2.4 m	39.3	36.7
Renfrew 58 (10 Glebe St)	2.3 m	26.5	26.5
Renfrew 69 (12 Inchinnan Rd)	2.0 m	44.3	44.0
		RMSE	**1.69**

Model uncertainty can be estimated by calculating the root mean square error (RMSE). In this case the calculated RMSE was 1.69 $\mu g.m^{-3}$ 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 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.

6.1.2 PM_{10}

In the absence of any PM_{10} monitoring data within Renfrew Town Centre with which to verify the models performance when predicting PM_{10} concentrations, the NOx primary adjustment factor of 2.5874 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 within the study area to support model verification.

6.2 Adjusted Modelling Results

The adjusted predicted annual mean NO_2 and PM_{10} concentrations at each specified receptors are presented in

Table 7 and

Table 8 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 $\mu g.m^{-3}$ annual mean objective were predicted at the following specified locations:

- 14d Paisley Road (R2)
- 1 to 5 Inchinnan Road (R3)
- 15 Inchinnan Road (R4)
- 2 Inchinnan Road (R5)
- 4 Hairst Street (R7)
- 12 Inchinnan Road (R8)

At R6 at 5 to 11 Hairst St where relevant exposure is at 1st floor height, the model predicted annual mean concentrations of 39.3 $\mu g.m^{-3}$ which is less than the annual mean objective.

It should be noted from the model verification section above, that at the diffusion tube which is at ground level at this location, the model is over predicting by 2.7 $\mu g.m^{-3}$; the annual mean concentration at 1st floor height is therefore likely to be less than 39.3 $\mu g.m^{-3}$ even when considering the estimated model uncertainty (RMSE as described in Section 6.1) which was 1.69 $\mu g.m^{-3}$.

Table 7 Predicted annual mean NO_2 concentrations at specified receptors 2014

Receptor	Location	Height (m)	NO_2 annual mean ($\mu g.m^{-3}$)
R1	5 Paisley Road (Renfrew 57)	1.5 m	37.4
R2	14d Paisley Road	1.5 m	**41.5**
R3	1 to 5 Inchinnan Road	4 m	**46.0**
R4	15 Inchinnan Road	1.5 m	**62.5**
R5	2 Inchinnan Road	4 m	**54.6**
R6	5 to 11 Hairst Street (Renfrew 40)	4 m	39.3
R7	4 Hairst Street	4 m	**40.3**
R8	12 Inchinnan Road	1.5 m	**44.5**

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

It is difficult to accurately predict if the NO_2 1-hour mean objective is being exceeded using dispersion modelling. LAQM.TG(09) states that if an annual mean NO_2 concentrations in excess of 60 $\mu g.m^{-3}$ is observed, an exceedance of the 1-hr mean objective may be occurring. Annual mean NO_2 concentration in excess of 60 $\mu g.m^{-3}$ was measured at the Renfrew 8 diffusion tube site which is located at 15 Inchinnan Road. There is a risk that the short term NO_2 objective is being exceeded at this location and it therefore recommended that AQMA for the 1-hr objective is declared for this location.

6.2.3 PM_{10}

There are no predicted exceedances of the 18$\mu g.m^{-3}$ annual mean objective at any of the receptor locations.

Table 8 Predicted annual mean PM_{10} concentrations at specified receptors 2014

Receptor	Location	Height (m)	PM_{10} annual mean ($\mu g.m^{-3}$)
R1	5 Paisley Road (Renfrew 57)	1.5 m	15.9
R2	14d Paisley Road	1.5 m	16.3
R3	1 to 5 Inchinnan Road	4 m	16.3
R4	15 Inchinnan Road	1.5 m	15.5
R5	2 Inchinnan Road	4 m	15.0
R6	5 to 11 Hairst Street (Renfrew 40)	4 m	16.3
R7	4 Hairst Street	4 m	16.3
R8	12 Inchinnan Road	1.5 m	16.4

6.2.4 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.

6.2.4.1 NO_2

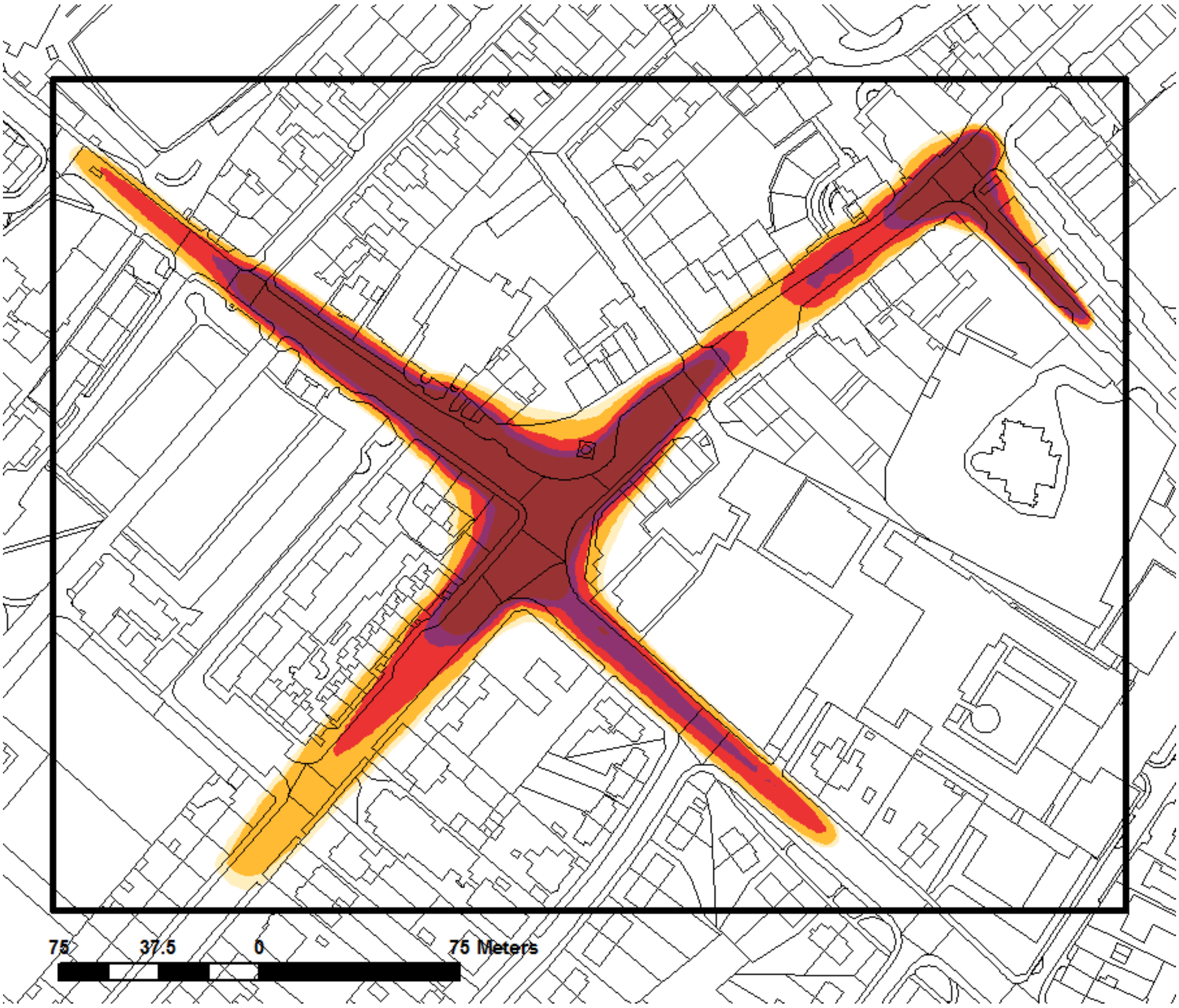
Contour plots showing the spatial variation of the predicted 2014 annual mean NO_2 concentrations across the study area at ground and 1st floor level are presented in Figure 5 and Figure 6. The NO_2 annual mean contour plots indicate that the 40 µg.m^{-3} objective is being exceeded at:

- Ground level and 1st floor level at number 15 Inchinnan Road.
- 1st floor height at numbers 1, 3, 5, 7, 9, 11, 13, 17 and 19 Inchinnan Road – there is no relevant exposure at ground level at these properties.
- 1st floor height at numbers 2 and 4 Paisley Road.
- Ground level at the two properties at 14a and 14d Paisley Road – examination of the model verification at diffusion tube site 56 indicates that the model is slightly over predicting at this location.

6.2.4.2 PM_{10}

Contour plots showing the spatial variation of the predicted 2014 annual mean PM_{10} concentrations across the study area at ground and 1st floor level are presented in Figure 7 and Figure 8. The PM_{10} annual mean contour plots indicate that the 18 µg.m^{-3} objective is not exceeded at any receptor locations.

Figure 5 Modelled NO_2 annual mean concentrations 2014 at 1.5m height – Renfrew Town Centre



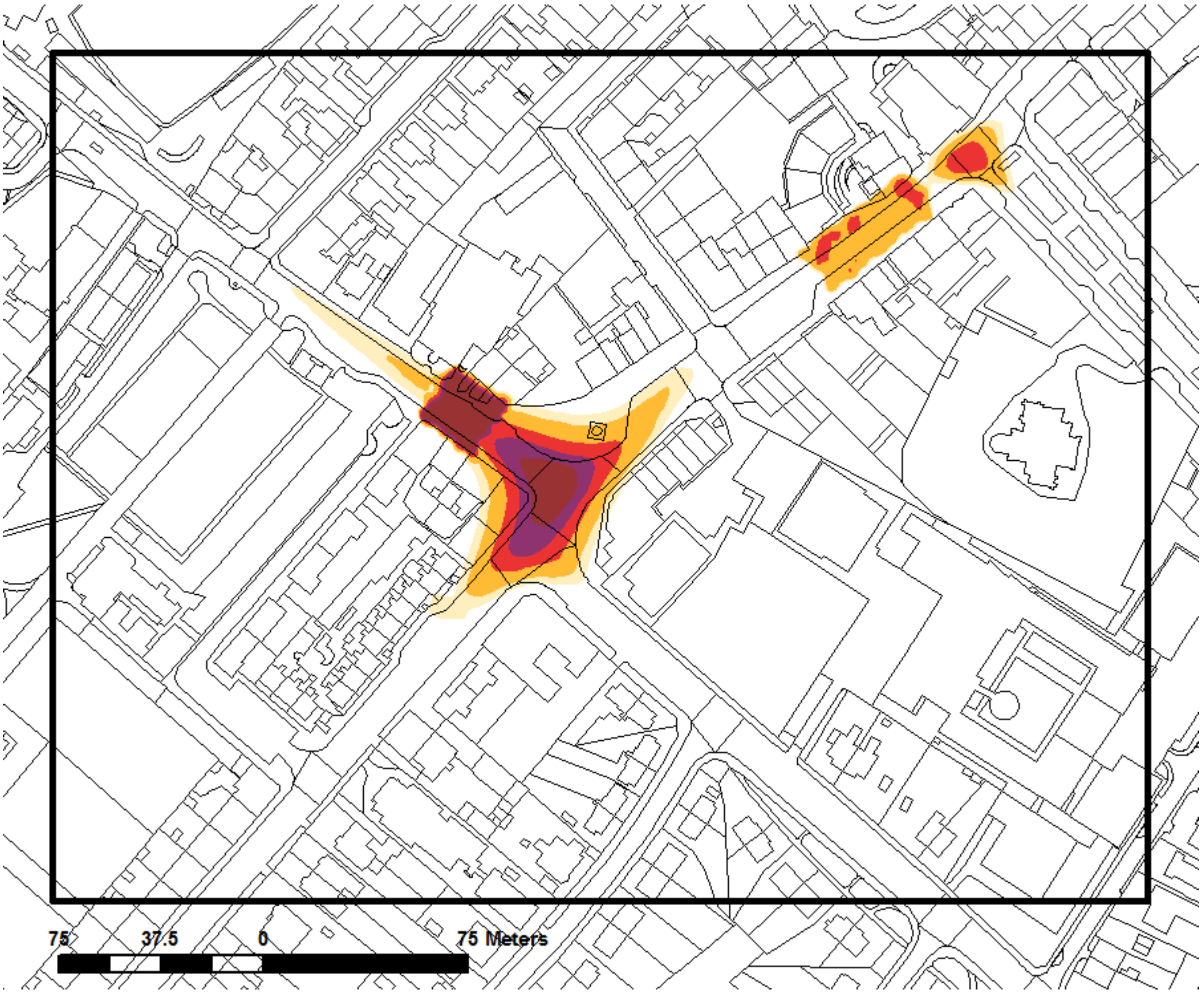
Legend:

Study area

NO_2 annual mean concentration (µg.m^{-3})

- <34
- 34 - 36
- 36 - 40
- 40 - 44
- 44 - 48
- 48 - 95.3

Figure 6 Modelled NO_2 annual mean concentrations 2014 at 4m height – Renfrew Town Centre



Legend:

Study area

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

- <34
- 34 - 36
- 36 - 40
- 40 - 44
- 44 - 48
- 48 - 95.3

Figure 7 Modelled PM_{10} annual mean concentrations 2014 at 1.5m height – Renfrew Town Centre

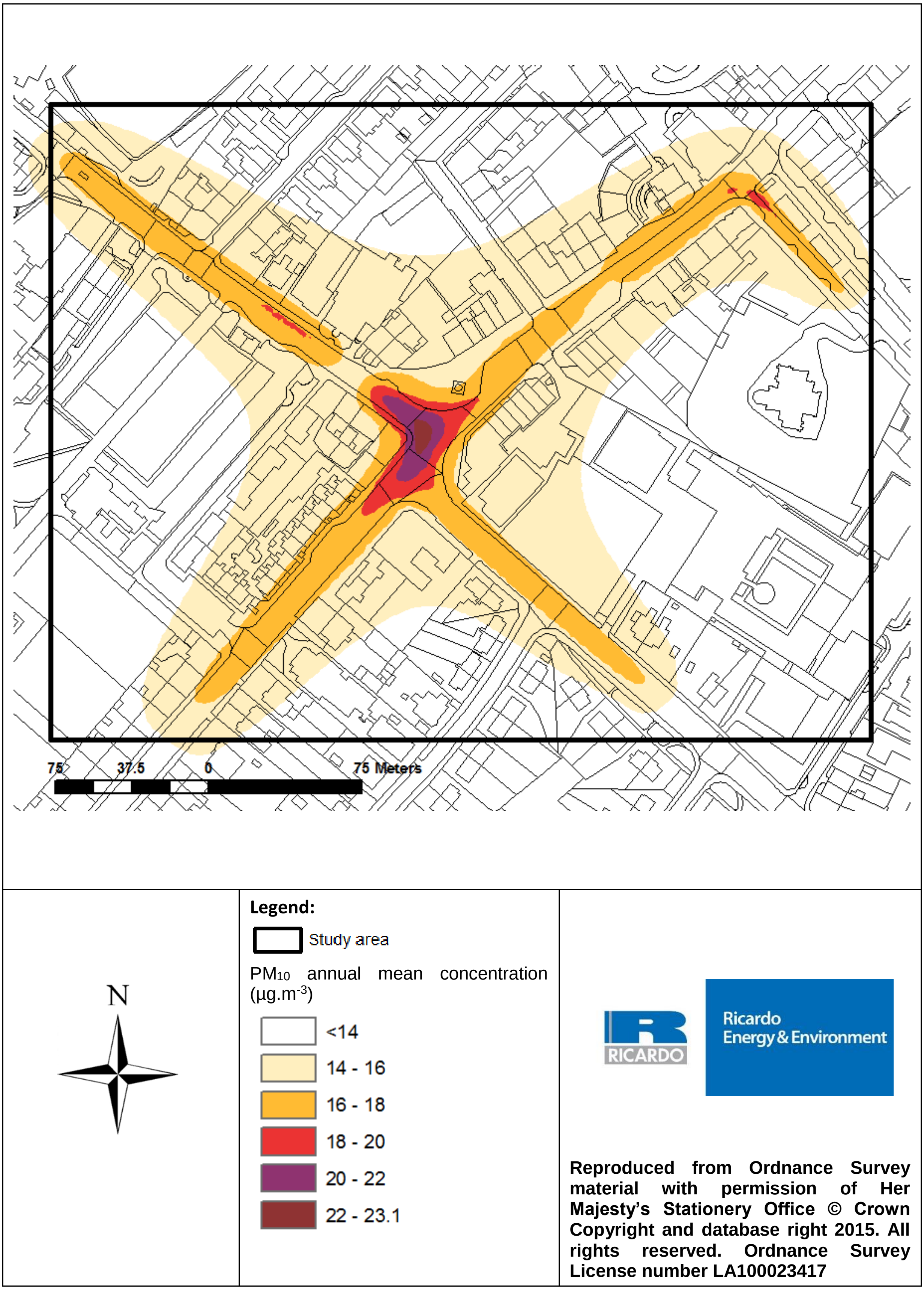
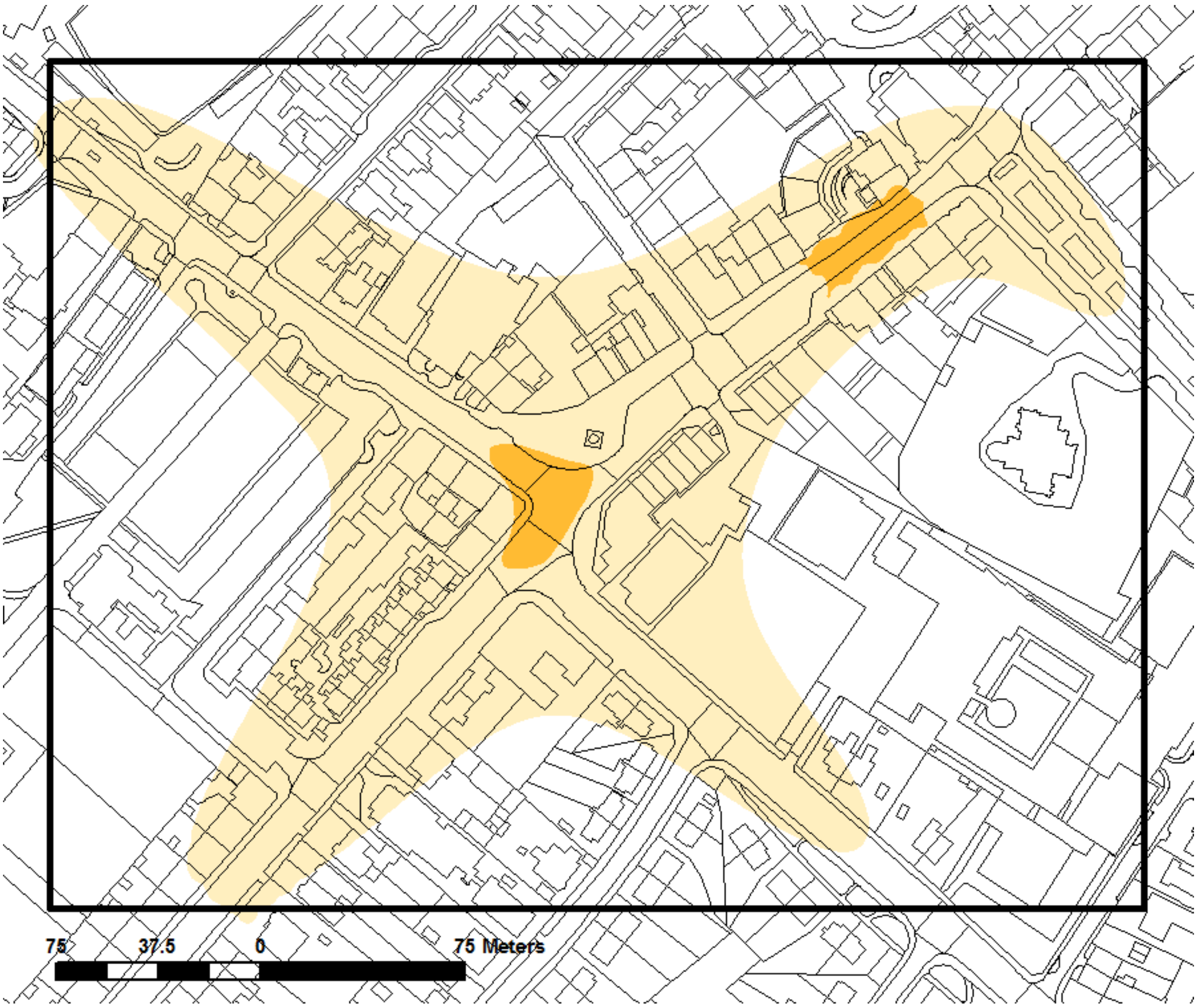


Figure 8 Modelled PM_{10} annual mean concentrations 2014 at 4m height – Renfrew Town Centre



Legend:

- Study area

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

- <14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 23.1

7 Source apportionment Study

Source apportionment is the process whereby the contributions of different pollutant sources to ambient concentrations are quantified. This aims to allow the Council'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 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 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 9 and Table 10 summarise the relevant NOx contributions from the above sources at the worst-case receptor locations. The PM_{10} results are presented in Table 11 and 12. The source apportionment results are presented visually using segmented bar charts in Figure 9 to 13.

Examination of the source apportionment results indicates that:

- Road NOx concentrations account for a significant proportion, up to 86.5% of total NOx concentrations within the study area; whereas background PM_{10} accounts for up to 83.3% of the total concentration at each receptor.
- Depending on the receptor, the highest contribution of road NOx is either from cars (41.7% at R4-15 Inchinnan Rd) or buses (34.3% at R2-14d Paisley Rd), followed by HGVs (27.9% at R4-15 Inchinnan Rd); whereas at all receptor locations the highest proportion of road PM_{10} is attributable to car movements.
- The proportion of NOx from HGV movements is higher in Inchinnan Road than in Hairst Street and Paisley Road where the Bus contribution to NOx concentrations is higher.
- The locations where the highest pollutant concentrations are being measured and modelled are at the section of Inchinnan Road approaching the traffic lights where traffic will regularly be slow moving. The high concentrations here also indicate that recirculation of air, due to in this case a one sided street canyon topography, is limiting dispersion. This indicates that any measures that can improve traffic flow at these locations where pollutant dispersion is poor will help to reduce vehicle emissions. This could include for example, consideration of changes to traffic light phasing.

Table 9 NOx source apportionment – Contribution by vehicle type (µg.m^{-3})

Receptor location	Total NOx	Background	Road NOx	Cars	HGV	Buses	LGV
R1 (5 Paisley Rd)	71.9	20.1	51.8	15.4	7.5	23.1	5.8
R2 (14d Paisley Rd)	86.1	20.1	66.1	19.3	9.8	29.5	7.4
R3 (1-5 Inchinnan Rd)	97.1	20.1	77.1	26.3	15.7	28.7	6.3
R4 (15 Inchinnan Rd)	148.6	20.1	128.5	61.9	41.5	16.9	8.2
R5 (2 Inchinnan Rd)	122.1	20.1	102.0	48.9	32.5	14.3	6.4
R6 (5-11 Hairst St)	73.9	20.1	53.9	19.3	5.8	24.4	4.4
R7 (4 Hairst St)	75.0	20.1	54.9	20.0	6.1	24.4	4.5
R8 (12 Inchinnan Rd)	75.3	20.1	55.2	29.5	16.7	5.3	3.7

Table 10 NOx source apportionment – Contribution by vehicle type (% of total NOx)

Receptor location	Total NOx	Background	Road NOx	Cars	HGV	Buses	LGV
R1 (5 Paisley Rd)	100%	27.9%	72.1%	21.4%	10.5%	32.1%	8.1%
R2 (14d Paisley Rd)	100%	23.3%	76.7%	22.4%	11.4%	34.3%	8.6%
R3 (1-5 Inchinnan Rd)	100%	20.7%	79.3%	27.1%	16.2%	29.6%	6.5%
R4 (15 Inchinnan Rd)	100%	13.5%	86.5%	41.7%	27.9%	11.4%	5.5%
R5 (2 Inchinnan Rd)	100%	16.4%	83.6%	40.0%	26.6%	11.7%	5.3%
R6 (5-11 Hairst St)	100%	27.1%	72.9%	26.1%	7.9%	33.0%	5.9%
R7 (4 Hairst St)	100%	26.8%	73.2%	26.6%	8.2%	32.5%	6.0%
R8 (12 Inchinnan Rd)	100%	26.7%	73.3%	39.1%	22.2%	7.1%	5.0%

Table 11 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
R1 (5 Paisley Rd)	15.9	13.4	2.5	1.2	0.3	0.7	0.3
R2 (14d Paisley Rd)	16.5	13.4	3.2	1.5	0.3	0.9	0.4
R3 (1-5 Inchinnan Rd)	16.4	13.4	3.0	1.6	0.4	0.6	0.3
R4 (15 Inchinnan Rd)	16.3	13.4	2.9	1.4	1.0	0.3	0.2
R5 (2 Inchinnan Rd)	15.6	13.4	2.2	1.0	0.8	0.2	0.1
R6 (5-11 Hairst St)	16.3	13.4	2.9	1.7	0.2	0.8	0.3
R7 (4 Hairst St)	16.4	13.4	3.0	1.7	0.2	0.8	0.3
R8 (12 Inchinnan Rd)	16.5	13.4	3.1	2.2	0.5	0.1	0.2

Table 12 PM_{10} source apportionment – Contribution by vehicle type (% of total NOx)

Receptor location	Total PM_{10}	Background	Road PM_{10}	Cars	HGV	Buses	LGV
R1 (5 Paisley Rd)	100%	84.1%	15.9%	7.7%	1.7%	4.5%	2.0%
R2 (14d Paisley Rd)	100%	80.9%	19.1%	9.2%	2.0%	5.4%	2.5%
R3 (1-5 Inchinnan Rd)	100%	81.6%	18.4%	10.1%	2.5%	3.9%	2.0%
R4 (15 Inchinnan Rd)	100%	82.1%	17.9%	8.6%	6.4%	1.7%	1.2%
R5 (2 Inchinnan Rd)	100%	85.7%	14.3%	6.6%	5.3%	1.5%	0.9%
R6 (5-11 Hairst St)	100%	81.9%	18.1%	10.2%	1.4%	5.0%	1.5%
R7 (4 Hairst St)	100%	81.6%	18.4%	10.4%	1.4%	5.1%	1.6%
R8 (12 Inchinnan Rd)	100%	81.2%	18.8%	13.5%	3.2%	0.8%	1.2%

Figure 9 Renfrew Town Centre - NOx source apportionment (expressed in $\mu g.m^{-3}$)

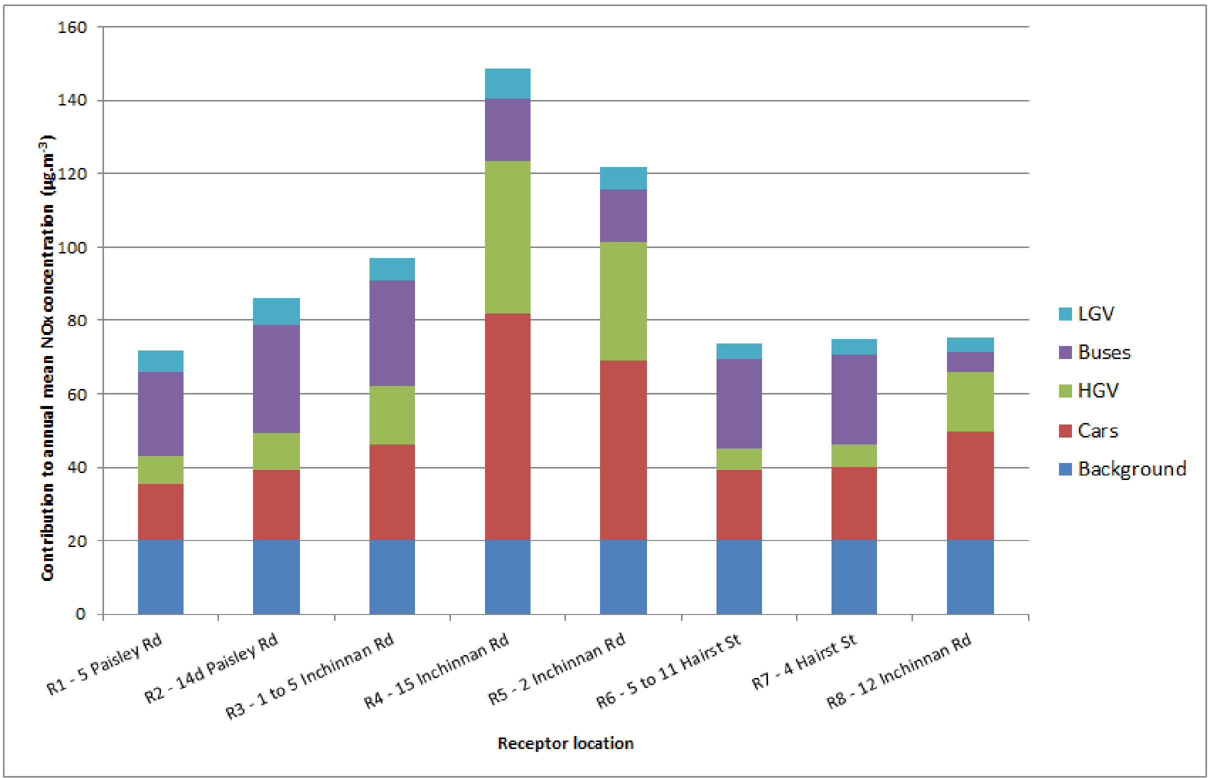


Figure 10 Renfrew Town Centre - NOx source apportionment (expressed as a percentage)

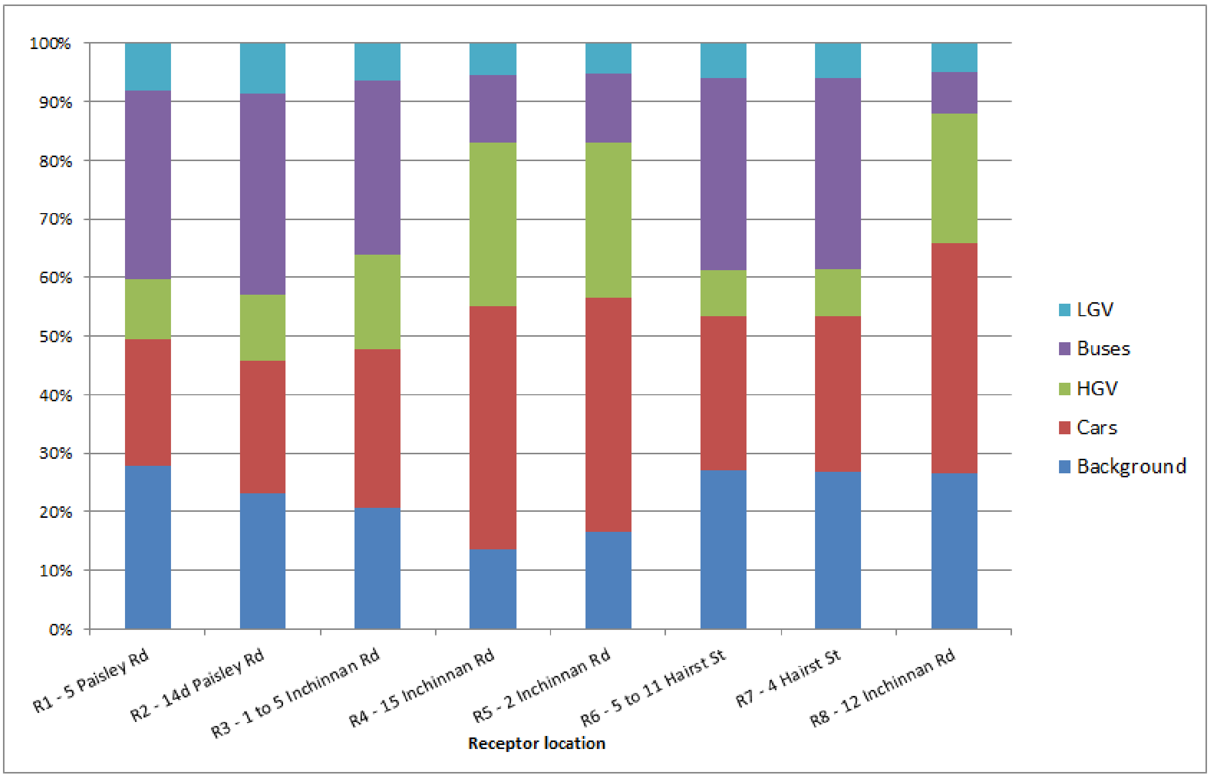


Figure 11 Renfrew Town Centre – PM_{10} source apportionment (expressed in $\mu g.m^{-3}$)

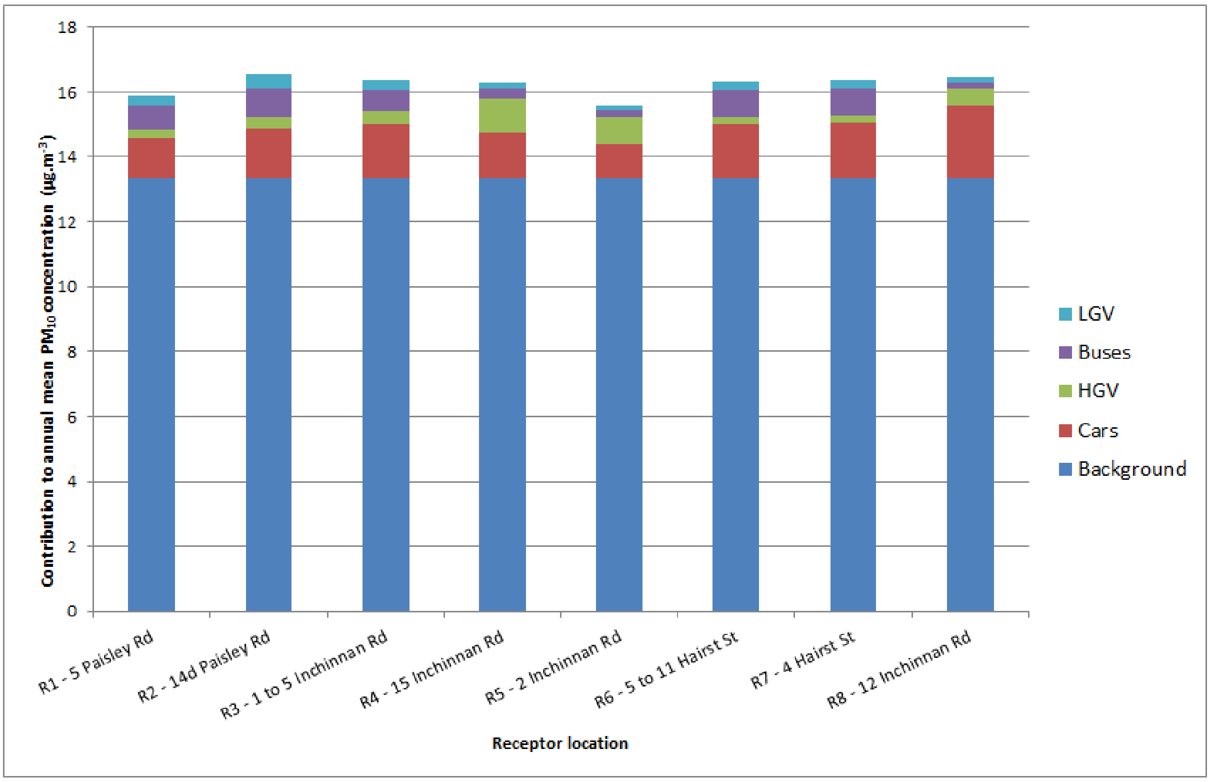
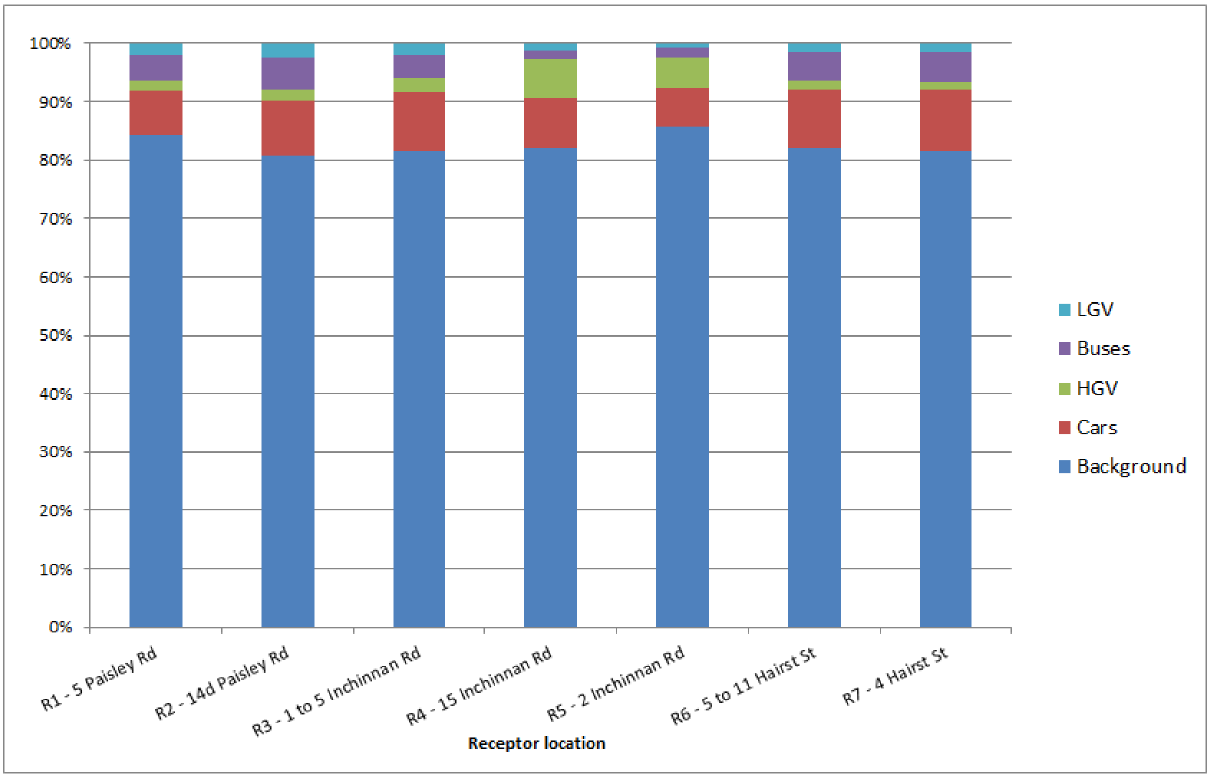


Figure 12 Renfrew Town Centre – PM_{10} source apportionment (expressed as a percentage)



8 Summary and conclusions

This report describes a dispersion modelling study of road traffic emissions in Renfrew town centre, 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 μg.m^{-3} annual mean objective were predicted during 2014 at ground level and 1st floor height at:
  - Ground level and 1st floor level at number 15 Inchinnan Road.
  - 1st floor height at numbers at 1, 3, 5, 7, 9, 11, 13, 17 and 19 Inchinnan Road – there is no relevant exposure at ground level at these properties.
  - 1st floor height at numbers 2 and 4 Paisley Road.
- No PM_{10} concentrations in excess of the 18 µg.m^{-3} Scottish annual mean objective were predicted at any locations of relevant exposure.
- An annual mean NO_2 concentration in excess of 60 µg.m^{-3} was measured in 2014 at the Renfrew 8 diffusion tube site which is located at 15 Inchinnan Road. There is a risk that the short term NO_2 objective is being exceeded at this location where a residential property is present at ground floor.

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

- Road NOx concentrations account for a significant proportion, up to 86.5% of total NOx concentrations within the study area; whereas background PM_{10} accounts for up to 83.3% of the total concentration at each receptor.
- Depending on the receptor, the highest contribution of road NOx is either from cars (41.7% at R4-15 Inchinnan Rd) or buses (34.3% at R2-14d Paisley Rd), followed by HGVs (27.9% at R4-15 Inchinnan Rd); whereas at all receptor locations the highest proportion of road PM_{10} is attributable to car movements.
- The proportion of NOx from HGV movements is higher in Inchinnan Road than in Hairst Street and Paisley Road where the Bus contribution to NOx concentrations is higher.
- The locations where the highest pollutant concentrations are being measured and modelled are at the section of Inchinnan Road approaching the traffic lights where traffic will regularly be slow moving. The high concentrations reported here also indicate that recirculation of air, due to in this case a one sided street canyon topography, is limiting dispersion. This indicates that any measures that can improve traffic flow at these locations where pollutant dispersion is poor will help to reduce vehicle emissions. This could include for example, consideration of changes to traffic light phasing.

In light of this updated Detailed Assessment of air quality in Renfrew Town Centre using 2014 monitoring data, **Renfrewshire Council is required to declare an Air Quality Management Area encompassing all areas of exceedances of the annual mean NO_2 objective predicted in this study.**

Renfrewshire Council should also declare an AQMA for the NO_2 hourly mean objective at the location on Inchinnan Road where a risk of the hourly mean objective being exceeded was identified.

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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 2015 provided information on daily average flow and fleet split for Inchinnan Road. In addition, traffic data from surveys carried out by the Department for Transport data have been used.

Table A1.1 Montgomery Drive, Renfrew 2014 - Annual Average Daily Flows

Street	%Cars	%LGV	%HGV	%Bus	%Motorcycles	AADF 2014
Canal Street Junction	95.5	0	4.5	0	0	1,633
Glebe Street	85.5	9.3	2.0	3.0	0.2	8,333
Hairst Street	83.2	7.5	2.3	6.9	0.1	8,099
High Street	76.4	9.6	1.6	11.9	0.5	6,777
Inchinnan Road	90.6	4.4	4.1	0.5	0.4	12,316
Paisley Road	74.7	13.0	3.4	8.4	0.5	10,786
Junction Paisley Road / Inchinnan Road	90.6	4.4	4.1	0.5	0.4	6,158
Junction Hairst street / Glebe Street	85.5	9.3	2.0	3.0	0.2	4,167

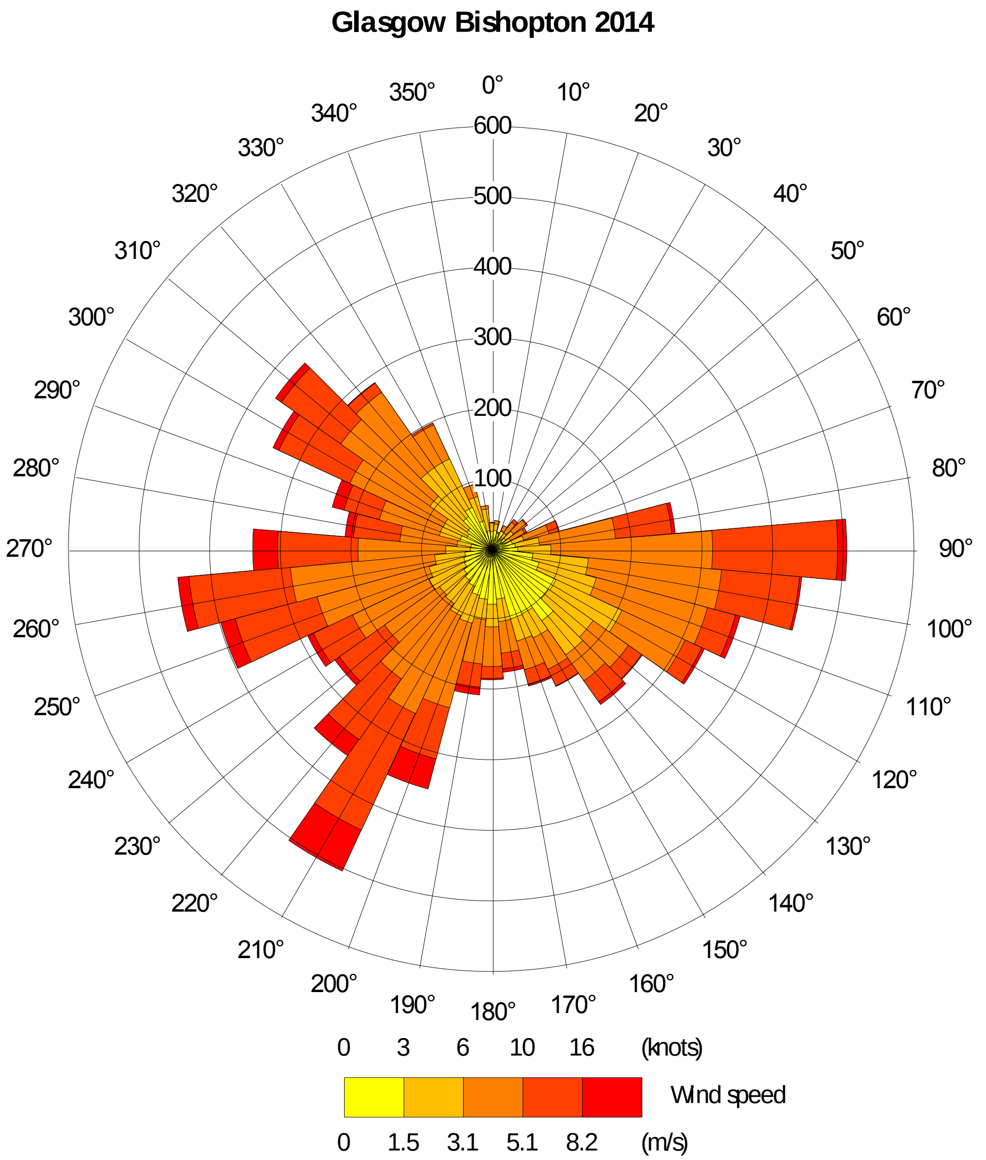
LGV – Light Goods Vehicles

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 above, the modelled NOx concentrations in this study were verified using all available 2014 diffusion tube measurements within the study area, with the exception of sites 68 and 70 as these measurements appeared to be outliers; the uncertainty was attributed to data capture being very low (25%) at each measurement site during 2014.

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 2.5874 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 1.69 $\mu g.m^{-3}$ 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 2.5874 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

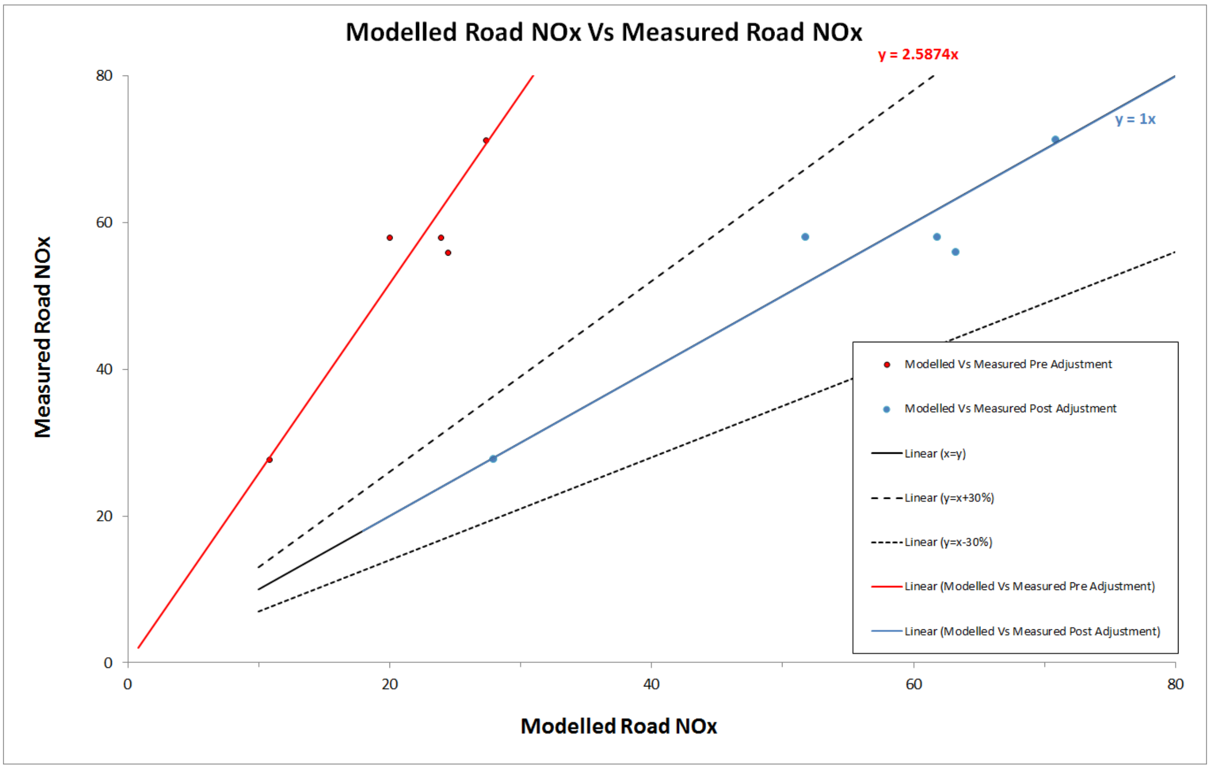
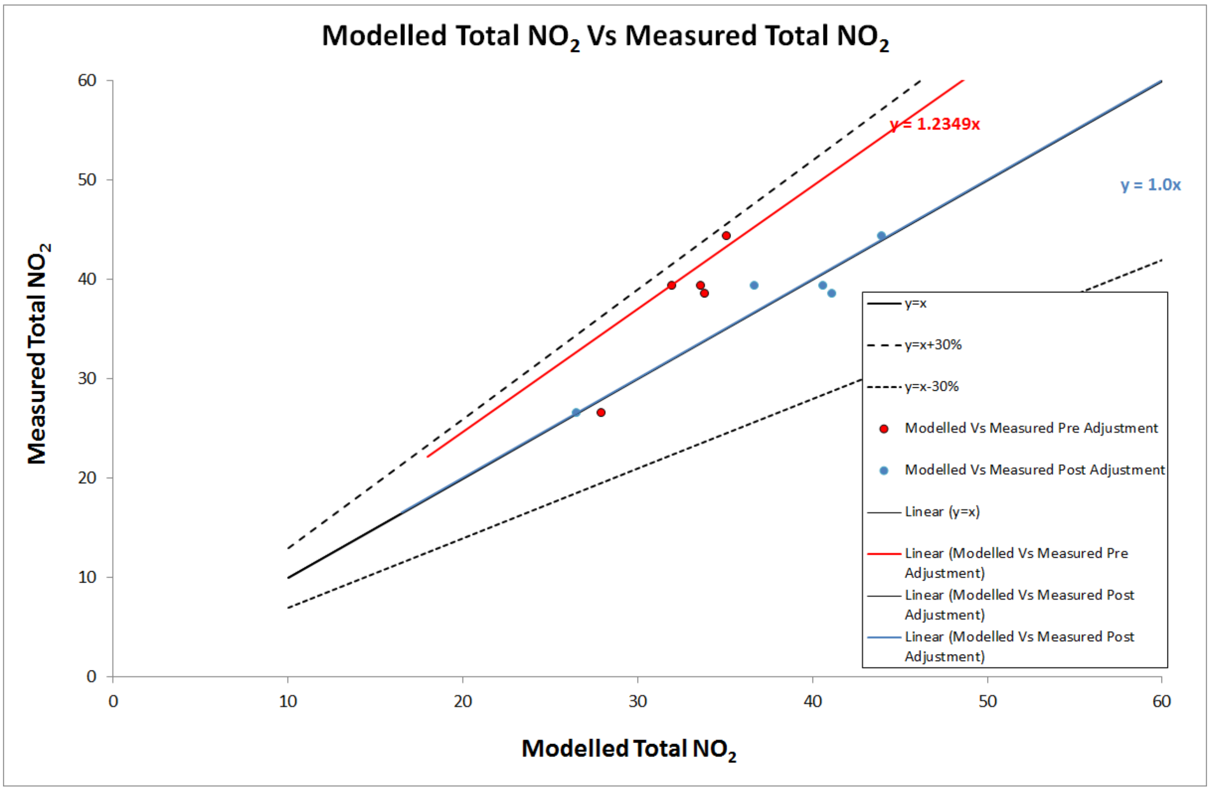


Figure A3.2 Comparison of modelled vs. monitored NO_2 annual mean 2014



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