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Air Quality Study Report:

The Kibworths

Date: 21st June 2019

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Reference:	J1000A_1_F2	**Date:**	21st June 2019
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Executive Summary

Air quality within The Kibworths has been modelled with a detailed atmospheric dispersion model, using detailed modelled traffic data and vehicle emission factors which include the influence of acceleration and deceleration of vehicles.

Annual mean concentrations of NO_2, PM_{10} and $PM_{2.5}$ have been predicted at sensitive properties within the AQMA, as well as an array of receptors across The Kibworths, for a Base scenario and two traffic management option scenarios (Options B and D). The models have been verified against local measurements and a number of sensitivity tests carried out.

The results demonstrate that annual mean PM_{10} and $PM_{2.5}$ concentrations within The Kibworths are acceptable (below the annual mean objectives) and the traffic management options will not change this. In terms of NO_2, Options B and D will both lead to large improvements in the AQMA, with Option D giving the largest improvements. It is thus recommended that Option D is implemented as part of the Air Quality Action Plan measures.

With the traffic management option implemented, air quality conditions might remain unacceptable at a single property (62 Leicester Road) in the near-term; with NO_2 concentrations marginally above the objective. Air quality conditions are likely to improve in the future as the uptake of newer vehicles continues, which have cleaner emissions. It is therefore recommended that NO_2 monitoring continues close to this property and consideration is given to other measures of the Air Quality Action Plan.

1 Introduction

1.1 Air Pollution Services Ltd (APS) is has been commissioned by Harborough District Council to undertake an air quality feasibility study to determine whether traffic management options lead to improvements in air quality within The Kibworths (adjoining villages of Kibworth Beauchamp and Kibworth Harcourt).

Relevance of Air Quality

1.2 Air pollution has negative impacts on the health of people, especially vulnerable members of the population, such as the elderly, children and people already suffering from pre-existing health conditions (including respiratory and cardiovascular conditions (WHO, 2013)). Evidence suggests that it can cause permanent lung damage in babies and young children (Royal College of Paediatrics and Child Health, 2016) and exacerbates lung and heart disease in older people (Simoni, et al., 2015). It is therefore pertinent to ensure exposure to poor air quality is minimised.

EU and UK Air Quality Management Legislation

1.3 In 1996 the European Commission published the Air Quality Framework Directive (96/62/EC) on ambient air quality assessment and management. This directive defined the policy framework for 12 air pollutants known to have harmful effects on human health and the environment. Limit Values (pollutant concentrations not to be exceeded by a certain date) for each specified pollutant were set through a series of Daughter Directives.

1.4 Directive 1999/30/EC (the 1st Daughter Directive) sets Limit Values for pollutants in ambient air, including nitrogen dioxide (NO_2) and particulate matter with an average aerodynamic diameter not exceeding 10 micrometres (PM_{10}). In May 2008, the Directive 2008/50/EC on ambient air quality and cleaner air for Europe came into force. This Directive consolidates the above. This was transposed into national legislation in the Air Quality Standards Regulations 2010, where the Limit Values are defined as Standards. The national government has the duty of ensuring the air quality Standards are complied with.

1.5 In addition to Standards there are Objectives. Objectives are derived from the Standards and are a compromise between what is desirable purely on health grounds and what is practical in terms of feasibility and costs. Each Objective has a date by when it must be achieved. For NO_2 these must be achieved by 31st December 2005 and continue to apply thereafter. For PM_{10} these must be achieved by 31st December 2004 and continue to apply thereafter.

1.6 Under Part IV of The Environment Act 1995 (HMSO, 2002), a local authority has a duty to regularly review, assess and control air pollution. The implementation of these duties is set out in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Defra, 2007). This includes a framework for Local Air Quality Management (LAQM) and sets out the air quality Standards and Objectives to which local authorities are required to work towards. The Standards and Objectives for NO_2 and PM_{10} are detailed in Table 1.

Table 1: Relevant Air Quality Standards and Objectives

Pollutant	Time Period	Standards and Objectives Thresholds	Objective Dates to be achieved
Nitrogen Dioxide (NO_2)	1-hour Mean	200 µg/m^3 not to be exceeded more than 18 times a year	2005
	Annual Mean	40 µg/m^3	2005
Fine Particles (PM_{10})	24-hour Mean	50 µg/m^3 not to be exceeded more than 7 times a year	2004
	Annual Mean	40 µg/m^3	2004
Fine Particles ($PM_{2.5}$)	Annual Mean	25 µg/m^3	2020

1.7 The annual mean objectives apply at locations where members of the public might be regularly exposed, such as building façades of residential properties, schools, hospitals and care homes. The PM_{10} 24-hour mean objective also applies at these locations as well as at hotels and residential gardens. The NO_2 1-hour mean objective applies at both the annual mean and 24-hour mean locations of exposure and at any outdoor location where members of the public might reasonably be expected to spend one hour or longer, such as busy pavements, outdoor bus stations and locations with outdoor seating.

Background to The Kibworths Air Quality

1.8 The LAQM process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where an exceedance of an objective is considered likely the local authority must declare an Air Quality Management Area (AQMA) and prepare an Air Quality Action Plan (AQAP) setting out the measures it intends to put in place in pursuit of the objectives.

1.9 Harborough District Council have undertaken NO_2 monitoring within The Kibworths for many years as part of their LAQM duties. Measured concentrations for the past six years are given in Table 2 and the locations of the monitoring sites are presented in Figure 2. An exceedance was measured in 2015 at monitoring site 34n, located along the A6 in The Kibworths, and an AQMA was subsequently declared.

1.10 In 2019, the Council prepared an AQAP setting out measures to improve air quality within The Kibworths. This included traffic management options and a measure to assess the air quality impact of these options.

Table 2: Measured Annual Mean NO_2 Concentrations (µg/m^3) [a]

Site ID	Site Name	2013	2014	2015	2016	2017	2018
12n	A6 Kibworth	30.4	28.2	29.7	21.7	23.8	28.4
31n	69 Leicester Road, Kibworth	-	-	33.1	30.5	33.6	31.0
34n	Sign Outside 64 Leicester Road, Kibworth	-	-	**55.0**	**52.9**	**56.9**	**49.3**
35n	Lamppost Outside 78 Leicester Road, Kibworth	-	-	-	33.4	32.5	32.0
36n	Signpost Just North of 11 Leicester Road, Kibworth	-	-	-	**42.7**	**44.3**	34.4
38n	Coach and Horse, Kibworth	-	-	-	-	22.5	19.4
39n	Lamppost 29 Church Road, Kibworth	-	-	-	-	-	18.1
40n	106 Main Street, Kibworth	-	-	-	-	24.4	21.0

[a] Exceedances of the objective are presented in bold.

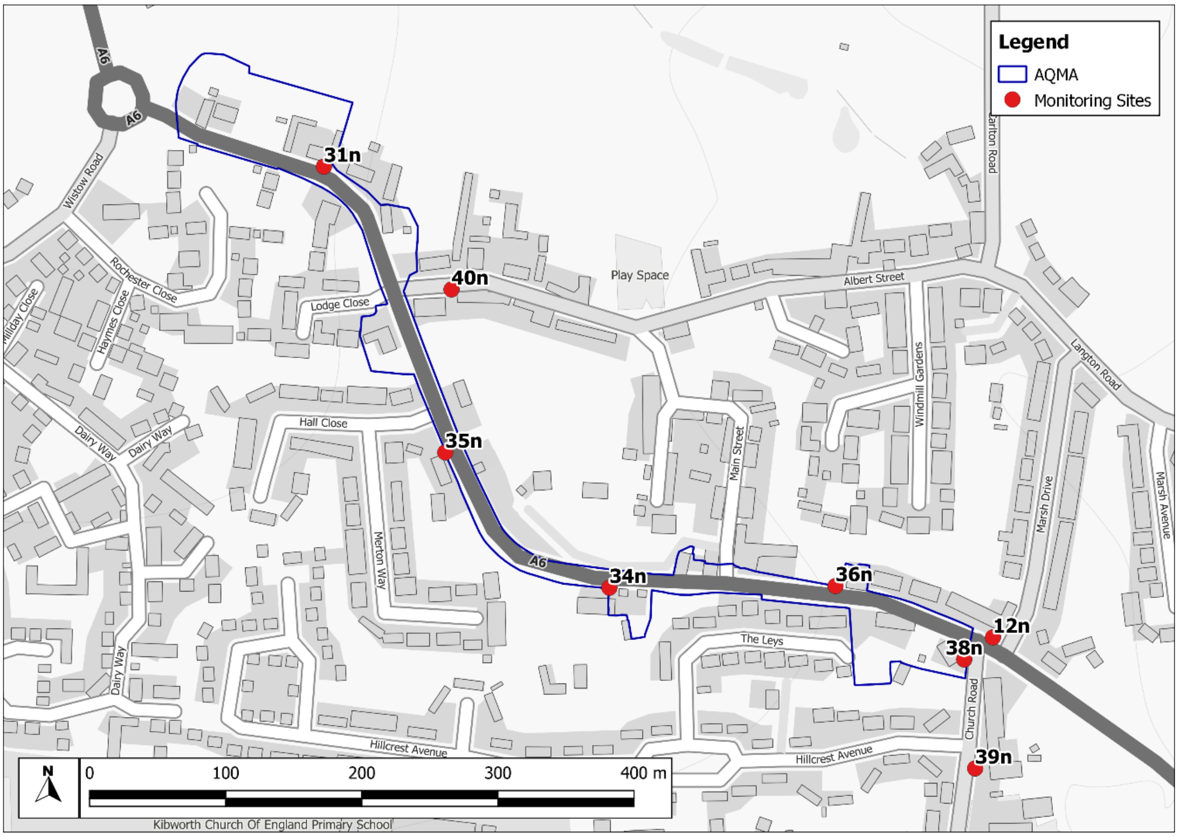

Figure 1: AQMA and Monitoring Sites

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AQAP Options

1.11 Following the publication of the AQAP, Leicestershire County Council was commissioned by Harborough District Council to produce a peak hour microsimulation traffic model for The Kibworths to test different traffic management options. The PTV VISSIM microsimulation model was used to simulate movements of individual vehicles through The Kibworths during the AM (08:00-09:00) and PM (17:00-18:00) peak hours for a base year of 2018. This model utilised information from the Leicester and Leicestershire Integrated Transport Model (LLITM) and was validated using Automatic Traffic Count (ATC), Manual Classified Count (MCC) and journey time surveys.

1.12 Microsimulation traffic models give the benefit of providing traffic information over short distances of roads, which in turn can be used to provide detailed information for changes in vehicle emissions during acceleration and deceleration, which is commonly not accounted for in air quality assessments. This microsimulation model provided traffic details for every second within the peak hours modelled.

1.13 In addition to the Base scenario, four traffic management options were tested within this microsimulation model; these included:

- Option A – Junction alterations at the A6/Wistow Road and A6/Church Road/Marsh Drive junctions. The junction alteration at the A6/Church Road/Marsh Drive junction introduces traffic signals and involves the removal of right turns in and out of Marsh Drive. The alteration at the A6/Wistow Road junction involves slightly widening of some of the roundabout lanes;

- Option B – Junction alterations at the A6/Wistow Road, A6/Church Road/Marsh Drive and A6/New Road junctions. The alteration at the A6/New Road junction replaces the existing priority junction with a roundabout;

- Option C – Southward extension of the 30 mph speed limit along the A6; and

- Option D – Junction alterations at the A6/Wistow Road, A6/Church Road/Marsh Drive and A6/New Road junctions, as well as a new housing estate at Wistow Road in Kibworth Harcourt.

1.14 Full details of these options are provided in the Kibworth Microsimulation Model Applications Report (Leicestershire County Council, 2019). The locations of the junction alterations, 30 mph extension and new housing estate are presented in Figure 2 below.

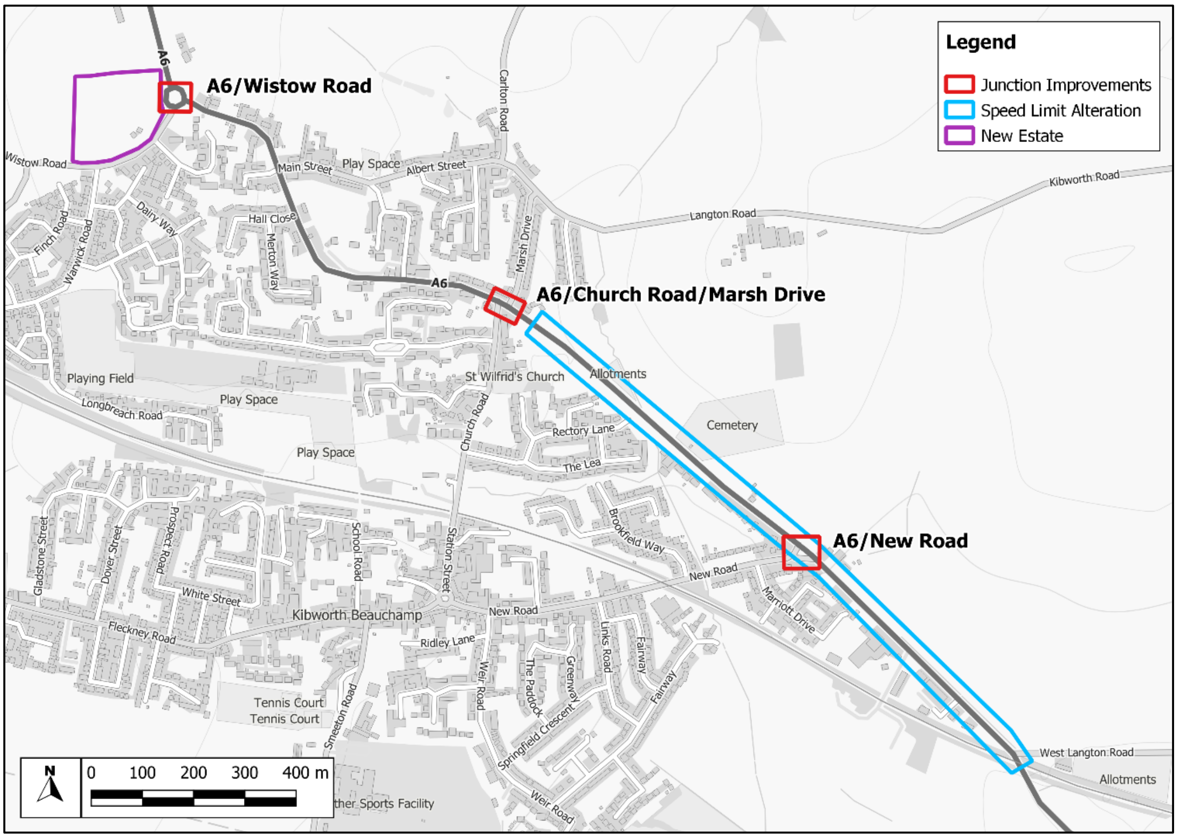

Figure 2: Locations of Traffic Management Alterations, Proposed Speed Limit Change and New Estate

Scope of Assessment

1.15 Based on the conclusions of the Kibworth Microsimulation Model Applications Report (Leicestershire County Council, 2019), Harborough District Council requested air quality to be assessed for Options B and D, as well as the Base scenario.

2 Methodology

2.1 The following section sets out the approach taken to the modelling of pollutant concentrations, the derivation of the emissions and modelling assumptions.

Modelling approach overview

2.2 Concentrations of NO_2, PM_{10} and $PM_{2.5}$ have been predicted at locations of sensitive exposure within The Kibworths for the Base scenario and Options B and D for the year of 2018, using the ADMS-Roads atmospheric dispersion model (v4.1.1) with the latest vehicle emission factors available from TNO. In addition, a sensitivity test has been carried out where the latest vehicle emission factors available from Defra's Emission Factor Toolkit (EFT) (v9.0) have been used.

Modelled Roads

2.3 The road links included in the dispersion model have been extracted from the microsimulation model. The road links and widths have been aligned with data from 2019 MasterMap tiles covering The Kibworths (provided by Harborough District Council). The modelled road links for the Base scenario are shown in Figure 3, and the changes in road links in Option B and D are illustrated in Figure 4.

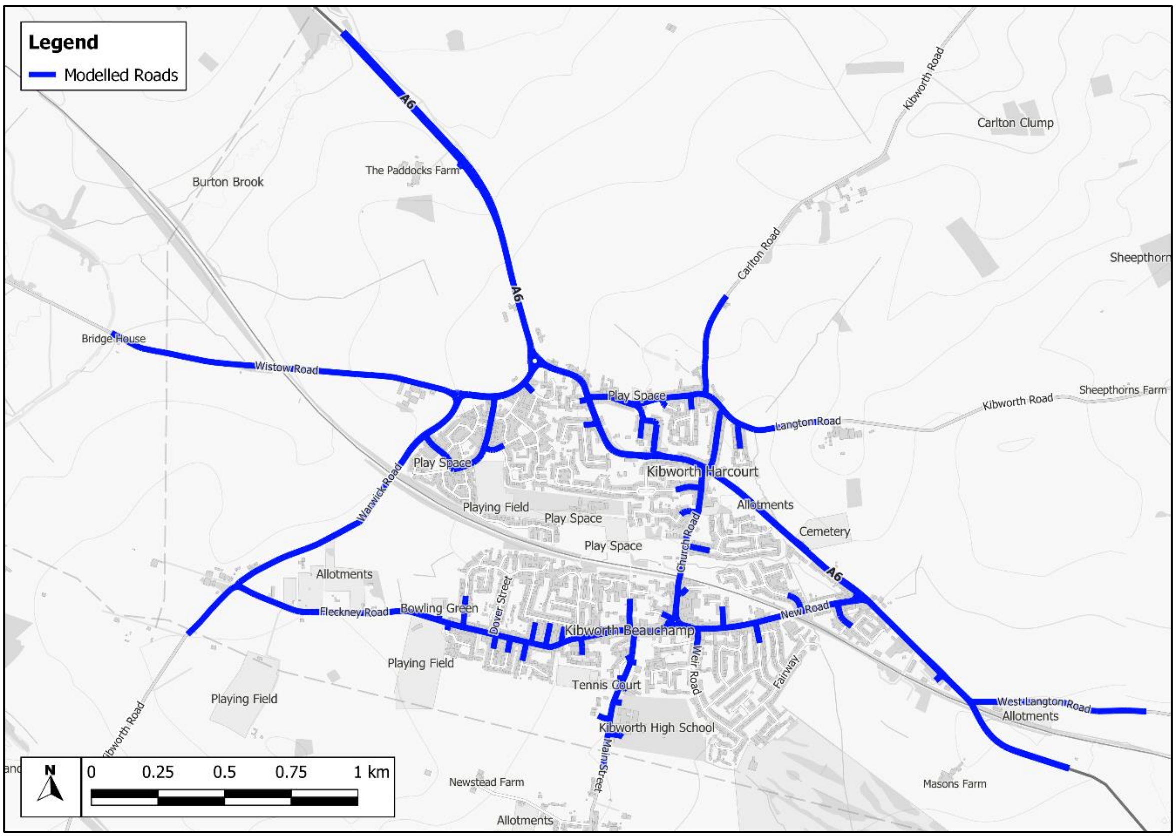

Figure 3: Modelled road links in the Base scenario

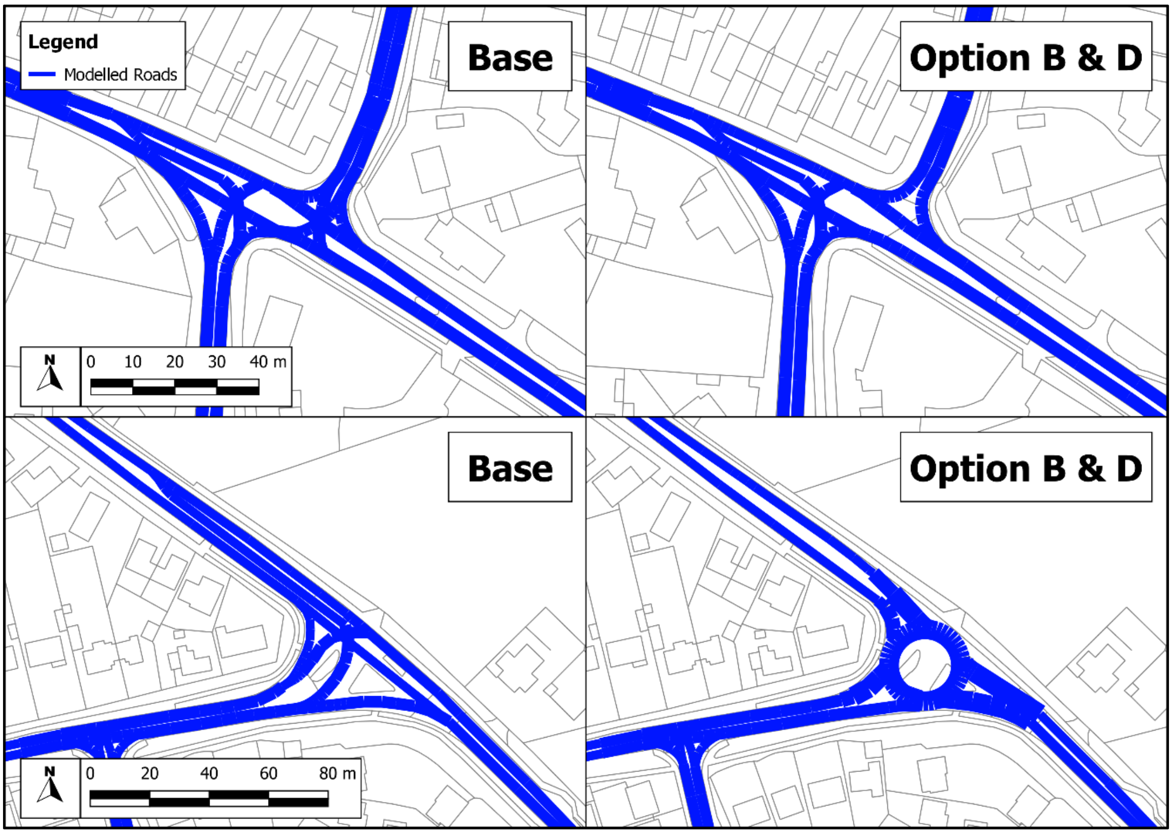

Figure 4: Changes to road links in the Option scenarios; Right-hand turns removed from Marsh Drive at the A6/Church Road/Marsh Drive junction (top) and creation of a roundabout at the A6/New Road junction (bottom)

Street Canyons

2.4 Most roads in The Kibworths are fairly open, however there are several links that are considered to be street canyons. These roads have buildings or vegetation along one or both sides of the road, leading to restricted dispersion of pollution away from the road and higher pollutant concentrations within the street canyon. These roads have therefore been modelled as street canyons using the Advanced Street Canyon Module, with Network Mode applied, within the ADMS-Roads model.

2.5 These are:

- the A6 between Wistow Road and Lodge Close
- sections of Main Street;
- the A6 just west of Main Street;
- Smeeton Road;
- Fleckney Road/High Street between Imperial Road and Station Street; and

- Station Street.

2.6 These street canyons are shown in Figure 5 below.

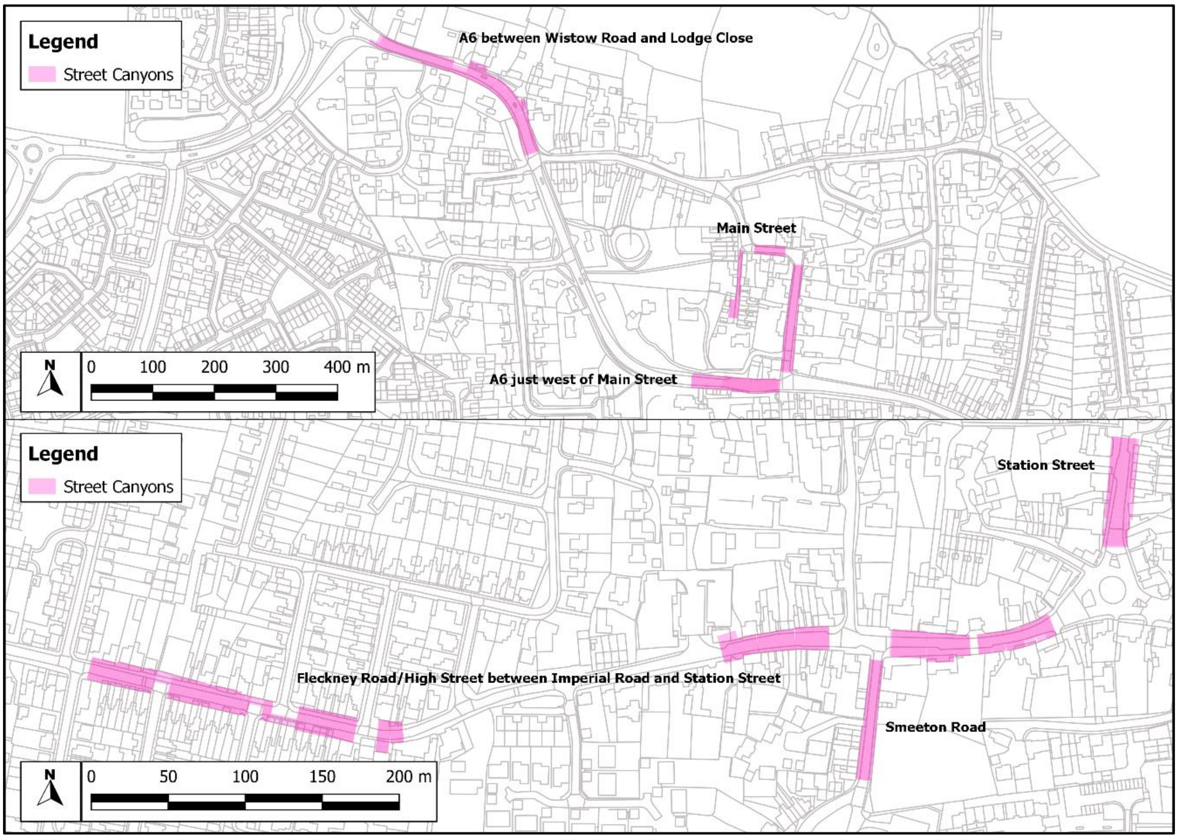

Figure 5: Modelled street canyons

Traffic Data

2.7 Traffic data have been taken from the PTV VISSIM microsimulation model, which was used to simulate movements of individual vehicles through The Kibworths during Tuesday AM (08:00-09:00) and PM (17:00-18:00) peak hours for the Base and Option scenarios for the year of 2018. The peak hour traffic flows, vehicle speeds and the percentage of cars, Light Goods Vehicles (LGVs), Heavy Goods Vehicles (HGVs) and buses have been extracted from the PTV VISSIM model output files for each model road link.

Vehicle Emissions

2.8 There exists a variety of vehicle emission models, ranging from macro scale to micro scale. In macro scale models, such as COPERT (Computer Programme to calculate Emissions from Road Transport), emissions factors are estimated as a function of average speed, or are determined by traffic situations, such as HBEFA (Handbook Emission Factors for Road Transport). These emission factors, although useful, do have a number of limitations. The emission factors are typically given for an average-speed over an entire road link and therefore have limited spatial resolution; over the length of a link, different vehicles will operate differently and produce different emission levels along the link. Modern vehicles equipped with sophisticated after-treatment devices can also emit very short, high spikes, often occurring during gear changes and high acceleration, which is not taken account of within average-speed emission factors. Average-speed functions are normally based on a certain drive cycle, which can vary significantly in reality. A degree more detailed than this are traffic-variable emission models, such as TEE (ENEA traffic emissions and energetics model), but these still have similar limitations.

2.9 Micro scale models, such as VERSIT+ (Exhaust emissions model from TNO) and PHEM (Passenger car and Heavy duty Emission Model), are significantly more detailed and can estimate instantaneous emission factors, either as a function of specific driving patterns or engine operation.

2.10 VERSIT+ is a statistical emission model developed by TNO and can calculate instantaneous real-world emissions of road vehicles. The model has been tested against over 20,000 measurements of cold and warm engines on over 3,200 different vehicles. It takes account of driving cycles, driving behavior, traffic situations, speed, acceleration, gradients, gears, cold-starts, idling, engine aging cold-start aging, and incorporates emission tests from portable emissions measurement systems (PEMS), engine loads, test beds and bag samples. Overall, it is a very detailed emissions model that can overcome many of the limitations of macro models.

2.11 The PTV VISSIM microsimulation model includes an optional add-on module (EnViVer Enterprise) that can calculate VERSIT+ emission factors directly from the microsimulation model traffic data. VERSIT+ emission factors have therefore been used in the air quality modelling to provide detailed time-resolved pollutant emission data from vehicles travelling in The Kibworths.

2.12 Air pollution assessments in the UK are commonly carried out using Defra's Emission Factor Toolkit (EFT), which is provided by Defra to allow Local Authorities to simply calculate pollutant emissions from road traffic. The EFT is based on COPERT 5, an average-speed macro scale model. As a sensitivity test, concentrations have also been predicted using vehicle emission factors from the EFT.

2.13 The EFT can provide emission factors for NOx, PM_{10} and $PM_{2.5}$, whilst VERSIT+ can only provide emission factors for NOx and PM_{10}. The predicted PM_{10} concentrations have therefore been adjusted by the EFT's ratio of $PM_{2.5}$ to PM_{10} to obtain $PM_{2.5}$ concentrations.

Peak-Hour to Daily Adjustment

2.14 In order to utilise vehicle emission factors available from Defra, Annual Average Daily Traffic (AADT) flows were needed for each model road link for inclusion within the EFT. A Tuesday peak-hour to AADT scaling factor was therefore derived from ATC surveys undertaken by Leicestershire County Council. Hourly traffic flows were obtained from two ATC surveys; one located on the A6 between Main Street and Church Road and one located on Church Road. These surveys were carried out for a period of 18 days (15th September – 2nd October 2018) and the average hourly flows from these surveys were calculated. Initially, the ratio of hourly traffic flows for the sum of Tuesday AM and PM peak hours to the sum of all hours for a whole week was derived in order to obtain a peak-hour to Weekly Average Daily Traffic (WADT) flow factor (4.984). National statistics on monthly traffic flows available from the Department for Transport (DfT) (2019) were used to derive a September to annual scaling factor (0.954). This was then applied to the peak-hour to WADT flow factor, to get a Tuesday peak-hour to AADT scaling factor of 4.754. This factor was then applied to the sum of peak-hour flows to obtain AADT flows for each of the model road links. The AADT flows, along with the speeds and fleet composition, were used in the EFT, which was used to calculate average emissions per second per kilometer.

2.15 Similarly, an adjustment was required for the VERSIT+ emissions. Peak-hour emissions were obtained from EnViVer, but these did not represent the average-hourly emission throughout a day. For each road link, the peak-hour emissions were divided by the peak-hour traffic flow and multiplied by the calculated AADT flow to derive the total daily emissions. These were then divided by the number of seconds in a day to obtain average emissions per second. Ratioing the emissions like this implies the same traffic flow characteristic throughout the day (e.g., speed, acceleration, deceleration etc.). In the absence of interpeak and off-peak hour traffic models this assumption was used. Concentrations and impacts may be overstated in certain locations because of this assumption.

Fleet Composition

2.16 Two additional ATC surveys along with Automatic Number Plate Recognition (ANPR) surveys were undertaken on the 18th September 2018 along the A6 towards the north and south of The Kibworths. Hourly traffic flows were obtained from these surveys for each vehicle type and Euro Emission Class. The Euro Class proportions in EnViVer and the EFT have been adjusted to match the proportions measured by the surveys. A summary of this fleet composition is presented in Table 3 and Euro emission classes in Table 4.

2.17 Most cars in The Kibworths are petrol or diesel fueled, but there is a small percentage of electric vehicles operating. Virtually all Light Goods Vehicles (LGVs), Heavy Goods Vehicles (HGVs) and Buses are diesel fueled. While there is a high proportion of new vehicles (Euro 6/VI), there are quite a lot of fairly old cars and some very old buses in operation that will emit fairly high pollutant emissions.

Table 3: Summary of the fleet composition for The Kibworths (%)

Vehicle Type	Petrol	Diesel	LPG	CNG	Electric
Car	45.1	51.9	0.0	0.0	3.0
LGV	0.0	99.9	0.1	0.0	0.0
HGV	0.0	100.0	0.0	0.0	0.0
Bus	0.0	100.0	0.0	0.0	0.0

Table 4: Summary of the Euro Class proportions for The Kibworths (%)

Vehicle Type	Euro 1/I	Euro 2/II	Euro 3/III	Euro 4/IV	Euro 5/V	Euro 6/VI
Car	0.0	0.1	1.1	20.7	39.9	38.2
LGV	0.0	0.0	0.9	18.8	55.4	24.9
HGV	0.0	0.0	2.4	13.7	46.3	37.5
Bus	2.8	3.2	22.2	6.9	37.9	27.0

Time-Based Profiles

2.18 The 18-day ATC surveys carried out on the A6 and Church Road were also used to derive diurnal traffic flow profiles for each day of the week. A seasonal (monthly) traffic flow profile was taken from DfT national statistics (DfT, 2019). Both the diurnal and seasonal profiles have been used in the model to adjust the emissions for each hour of the year modelled.

2.19 During the ATC surveys some erroneous zero values were obtained during a recording fault; resulting in lower factors for Wednesday afternoons and Thursday mornings than other weekdays, and slightly higher factors on other days (as shown in Figure 6). Annual mean concentrations are the focus of this study; thus these errors in the diurnal profiles will be insignificant on the annual mean concentrations. Furthermore, the same profile has been applied to all scenarios, meaning the scenarios themselves are directly comparable.

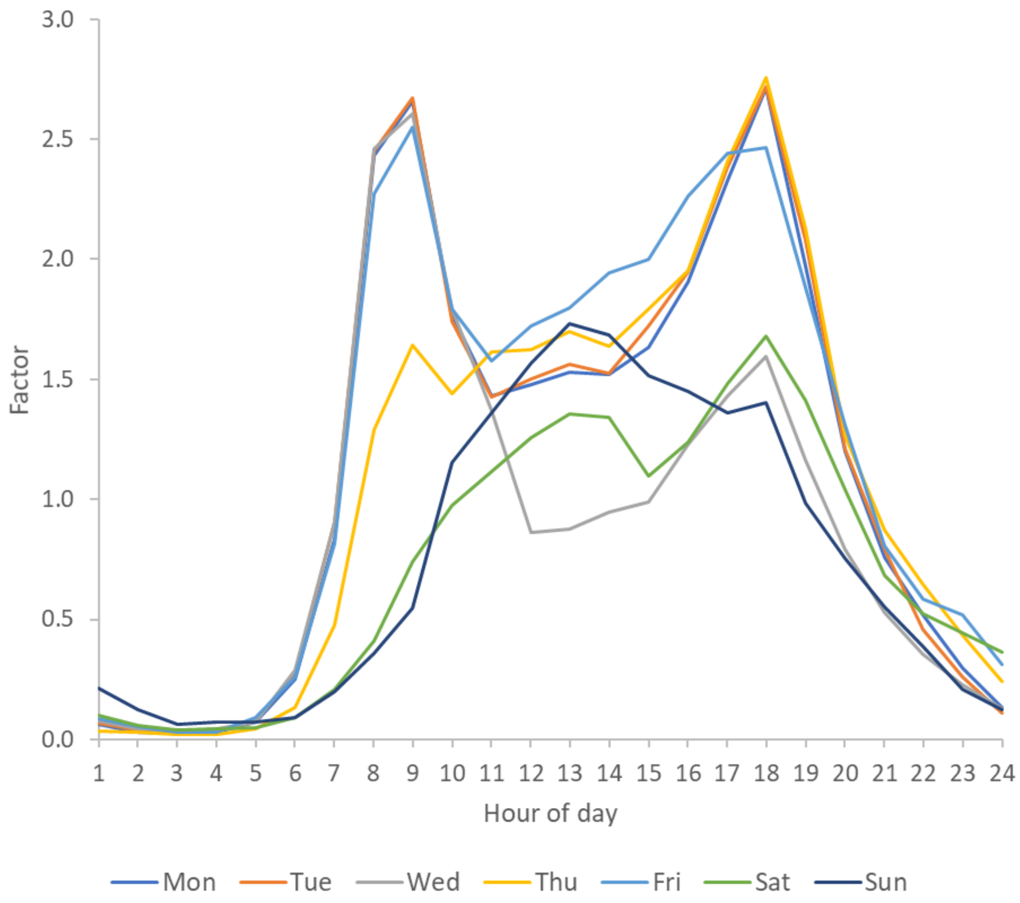

Figure 6: Diurnal profile for each day of the week used in the model, where the factor is the value that the average daily emissions are multiplied by in the model

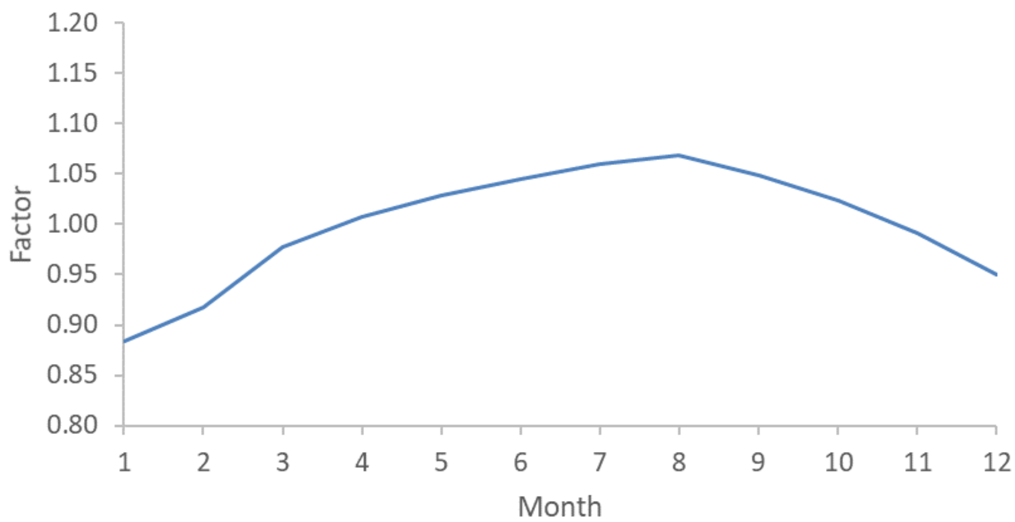

Figure 7: Seasonal profile for each month of the year used in the model

Wake effects

2.20 As vehicles travel along a road a wake is left behind the vehicles as air in the path of travel is forced around the vehicle. The wake can be considered the turbulence induced by the movement of the vehicle, which affects the dispersion of pollution away from roads. The AADT traffic flows have been entered into the ADMS-roads dispersion modeling in order to account for vehicle wake effects which will vary on each link depending on the proportion of large vehicles to small vehicles.

Receptor Locations

2.21 Concentrations of NO_2, PM_{10} and $PM_{2.5}$ have been modelled at 19 specific receptors that represent exposure at each of the residential properties within the AQMA, as these are the locations of most concern. Within each of these properties, receptors have been located where exposure is likely to be worst (i.e. nearest the road and road junctions). The locations of these receptors are described in Table 5 and presented in Figure 8. Concentrations have been modelled at 1.5 m and 4.5 m above ground to represent typical breathing height of people at the ground- and first-floor levels.

Table 5: Details of specific receptor locations

Receptor ID	Receptor Location	Modelled Height (m)	In Modelled Street Canyon
1	Residential property at Westfield Lodge, 81 Leicester Road	1.5	Yes
2	Residential property at The Paddocks Farm, 71 Leicester Road	1.5	Yes
3	Residential property at 53 Leicester Road	1.5	No
4	Residential property at 51 Leicester Road	1.5	Yes
5	Residential property at 1 Lodge Close	1.5	No
6	Residential property at 64 Leicester Road	1.5	No
7	Residential property at the first-floor of 64 Leicester Road	4.5	Yes
8	Residential property at 62 Leicester Road	1.5	Yes
9	Residential property at 60 Leicester Road	1.5	Yes
10	Residential property at 58 Leicester Road	1.5	Yes
11	Residential property at 56 Leicester Road	1.5	Yes
12	Residential property at 25 Leicester Road	1.5	Yes
13	Residential property at 2 Main Street, fronting onto Leicester Road at the first-floor	4.5	Yes
14	Residential property at 2 Main Street, at corner of junction with Leicester Road	1.5	No
15	Residential property at 2 Main Street	1.5	Yes
16	Residential property at 11 Leicester Road	1.5	No
17	Residential property at 14 Leicester Road	1.5	No
18	Residential property at the first-floor of The Coach & Horses Inn	4.5	No
19	Residential property at Westfield Lodge, 81 Leicester Road	4.5	No

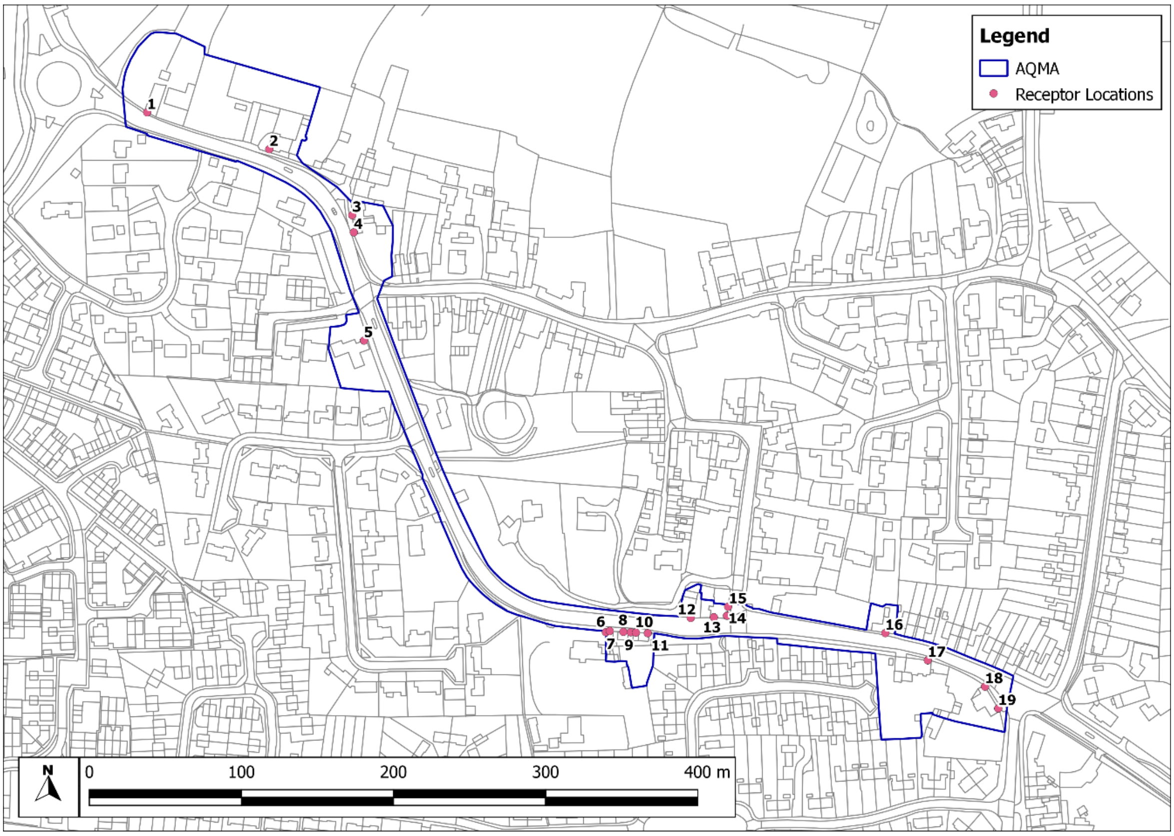

Figure 8: Specific receptor locations and AQMA

2.22 Concentrations of NO_2, PM_{10} and $PM_{2.5}$ have also been modelled for an array of receptors covering the urban area of The Kibworths, with varying resolution, to illustrate how each traffic management option changes air quality throughout The Kibworths. These receptors are shown in Figure 9 and have been modelled at a height of 1.5 m.

2.23 In addition, concentrations have also been modelled at all the monitoring sites within The Kibworths, at the heights of the monitors (1.8 m), in order to verify the models.

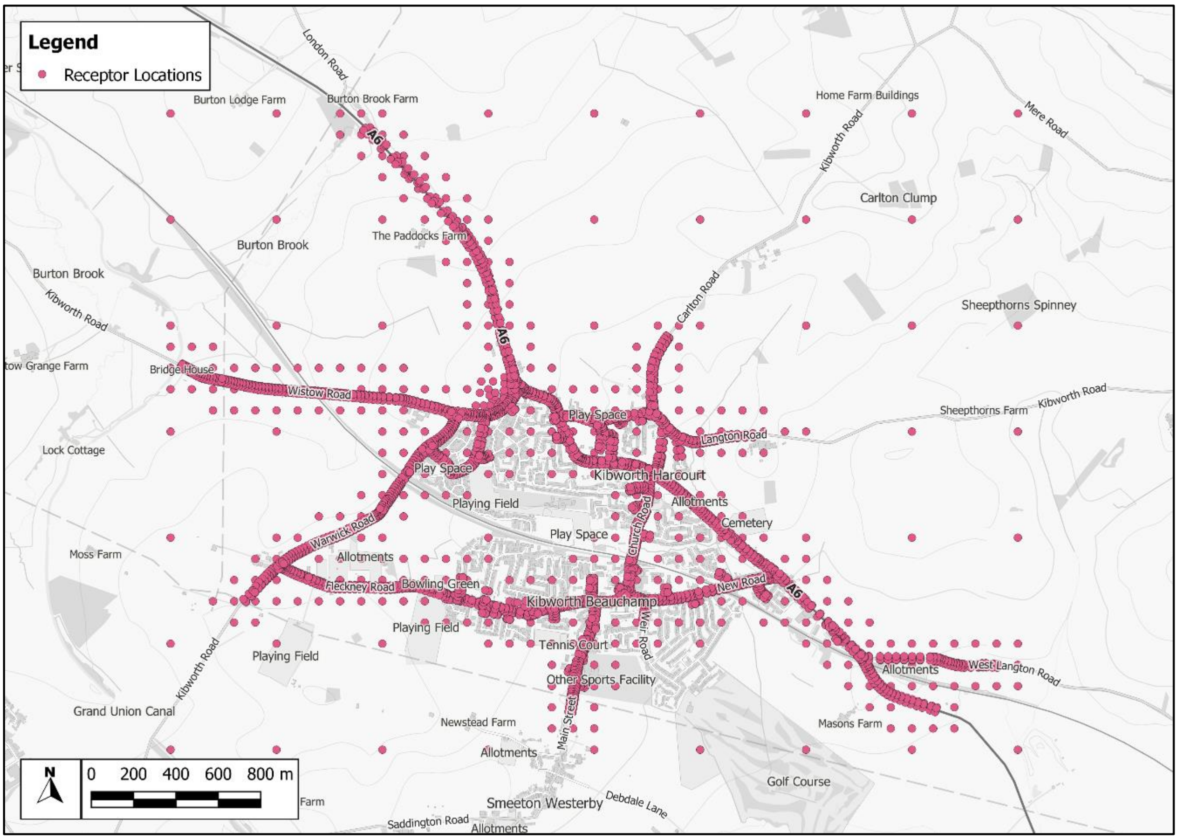

Figure 9: Nested grid of receptor locations

Meteorology

2.24 Meteorological data has been taken from the Church Lawford Meteorological Station for the year of 2018. This station is located in Rugby, approximately 30 km southwest of The Kibworths, and is considered to be representative of meteorological conditions in The Kibworths; both the station and The Kibworths are located in flat rural areas in the Midlands and will experience very similar meteorological conditions. In addition to the meteorological data, the model requires values to be set for a number of parameters, for both the meteorological station and the dispersion site (The Kibworths). Details of the parameter values used in the modelling are provided in Table 6 below. It is considered that only the surface roughness will be different between the meteorological and dispersion site; the value for the dispersion site has been set higher to take account of the urban topography.

Table 6: Meteorological parameters values used in the model

Parameter	Meteorological Site Value	Dispersion Site Value
Latitude (°)	52.54	52.54
Surface roughness (m)	0.3	0.5
Surface albedo	0.23	0.23
Minimum Monin-Obukhov length (m)	10	10
Priestley-Taylor parameter	1	1

2.25 Figure 10 shows the frequency of wind speeds and directions measured at the Church Lawford meteorological station in 2018 (left), which has been inputted into the model, as well as the frequency of wind speeds and directions processed by the ADMS-roads model for the dispersion site (right). These illustrate that wind predominantly comes from the southwest and that the model has marginally lower wind speed at the dispersion site.

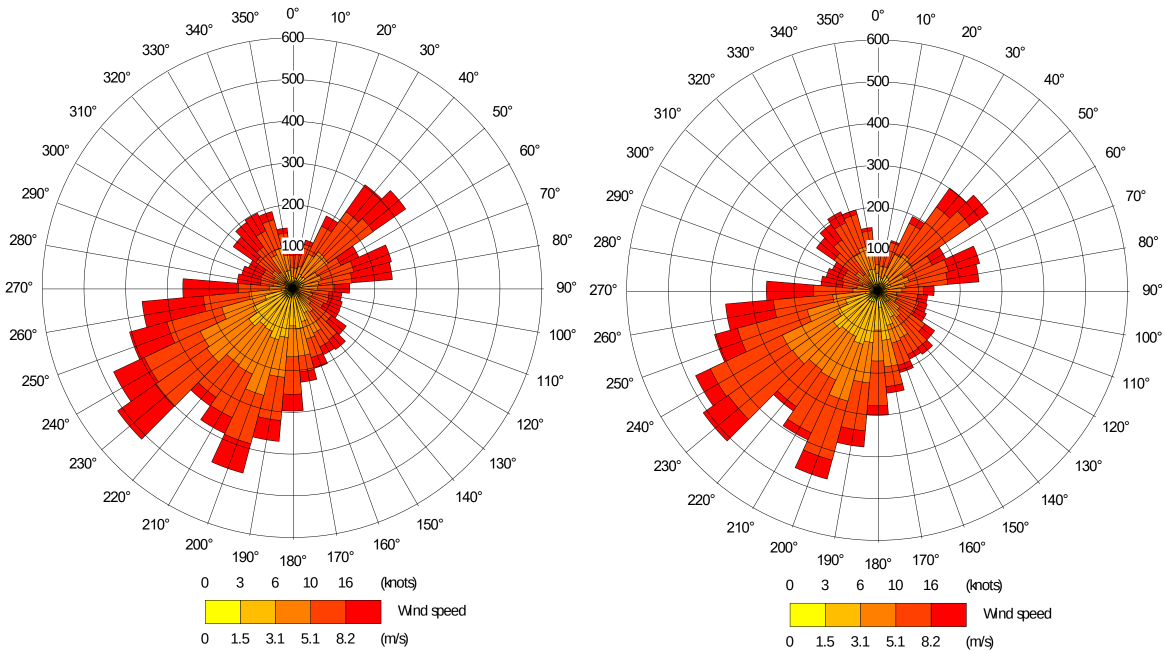

Figure 10: Wind Rose showing the frequency of wind speed and wind direction for the meteorological station at Church Lawford (Left) and the modelled dispersion site (Right) for the year of 2018

Background Concentrations

2.26 Ambient background concentrations of NO_2, PM_{10} and $PM_{2.5}$ have been taken from the latest national maps provided by Defra (2019). These give background concentrations for every 1x1 km grid cell across the UK for each year from 2017 until 2030. Concentrations for 2018 have been extracted for the grid cells that cover The Kibworths area. For NO_2, these varied between 9.1 – 11.9 µg/m^3, for PM_{10} these vary between 13.2 – 14.9 µg/m^3, and for $PM_{2.5}$ these vary between 8.7 – 9.2 µg/m^3. These concentrations have been bilinearly interpolated to give specific background concentrations at each receptor location.

Model Verification

2.27 The modelling will inherently have some uncertainties and may not reflect real conditions in The Kibworths. A model verification exercise has therefore been undertaken to derive a factor with which to adjust the predicted concentrations from the model so that they match local conditions as closely as possible. The methodology of this follows the guidance set out by Defra in Box 7.14 and Box 7.15 of LAQM.TG(16) (Defra, 2018).

2.28 Concentrations of road-NOx (i.e. the contribution associated with road traffic) and primary NO_2 have been predicted using the ADMS-roads dispersion model at all the nitrogen dioxide monitoring sites within The Kibworths.

2.29 Initially, the measured NO_2 concentrations at the monitoring sites have been inputted into Defra's NOx to NO_2 Calculator, along with the background NO_2 concentrations and f-NO_2 values, in order to obtain 'measured' road-NOx concentrations at the monitoring sites. The primary NO_2 emission factor (f-NO_2) at each monitoring site was calculated by taking the ratio of predicted primary NO_2 concentration to predicted road-NOx concentration.

2.30 The predicted road-NOx concentration has then been compared to the 'measured' road-NOx concentration, see Figure 11. An adjustment factor of 1.862 has been derived from the equation of the linear trend line that has been fitted through zero. This factor indicates that the model is slightly underpredicting concentrations at the monitoring sites. Further statistics of the fit are given in Figure 11. This adjustment factor has been applied to all predicted road-NOx concentrations to uplift the values to match the real measured 2018 conditions in the local area. It should be acknowledged, however, that this adjustment will force the modelling to match average conditions; concentrations at some locations will remain slightly underpredicted and others overpredicted. This is illustrated in Figure 12, which shows a comparison of the measured NO_2 concentrations and the total (i.e. road plus background) predicted NO_2 concentrations. Further statistics of this comparison are given in Figure 11, which demonstrate that the predicted NO_2 concentrations have an insignificant fractional bias (~0) and an acceptable root mean square error (RMSE <10).

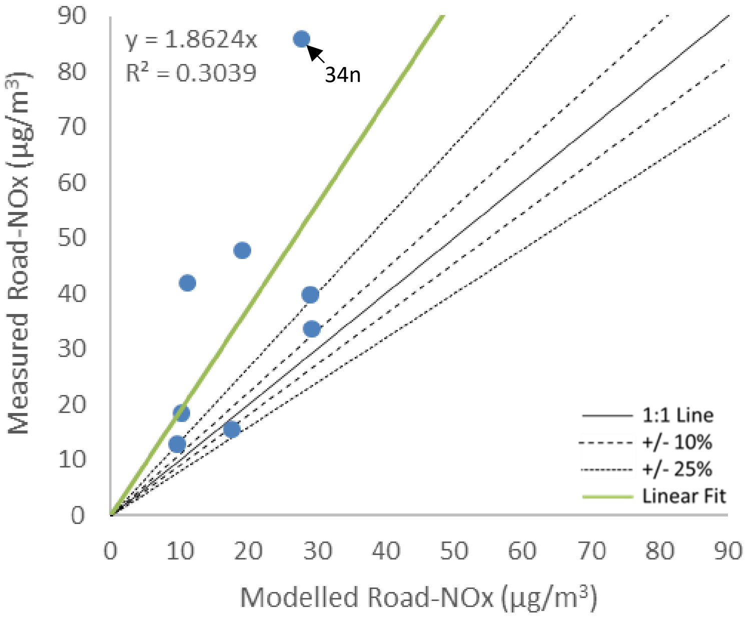

Figure 11: Comparison of predicted road-NOx to 'measured' road-NOx

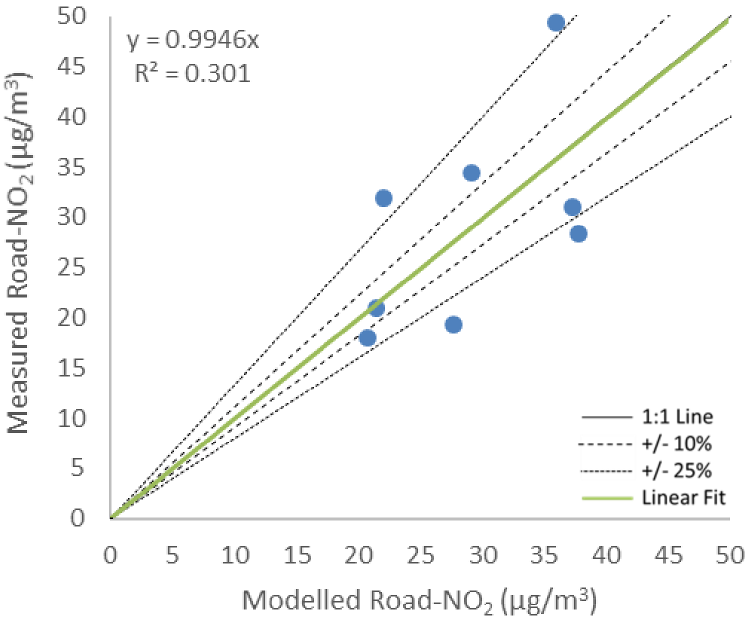

Figure 12: Comparison of predicted NO_2 to measured NO_2

Table 7: Model Verification Statistics

Statistic	Road-NOx	NO_2
Correlation Coefficient (r) [a]	0.564	0.567
Real Mean Squared Error (RSME) [b]	25.86	7.99
Fractional Bias (FB) [c]	0.628	0.005

a This is used to measure the linear relationship between predicted and measured concentrations. A value of zero means no relationship and a value of 1 means absolute relationship (ideal value).

b RMSE is used to define the average error or uncertainty in the model. The ideal value is zero, if greater than 25% of the objective (i.e. 10 µg/m^3) then it is recommended that the model be revisited.

c This is used to identify if the model shows a systematic tendency to over or under predict. FB values range between -2 and +2 and has an ideal value of zero. Negative values indicate a model over-prediction and positive values indicate a model under-prediction.

2.31 There are no PM_{10} or $PM_{2.5}$ monitoring sites within The Kibworths with which to verify the model against. Following the guidance set out in LAQM.TG(16) (Defra, 2018), the road-NOx adjustment factor has therefore been applied to all road-PM_{10} and road-$PM_{2.5}$ concentrations.

Post Processing

2.32 Concentrations of road-NOx and primary NO_2 have been predicted at each receptor using the ADMS-Roads model. The primary NO_2 emission factor (f-NO_2) at each receptor has been calculated by taking the ratio of predicted primary NO_2 concentration to road-NOx concentration. The f-NO_2 values along with the adjusted modelled road-NOx concentrations and background NO_2 concentrations have been inputted into Defra's NOx to NO_2 calculator (v7.1) in order to obtain predicted road-NO_2 concentrations at each receptor. This tool has been run assuming the traffic is described as 'All non-urban UK traffic', which is considered appropriate for the traffic associated with the rural villages within The Kibworths. The road-NO_2 concentrations have then been added to the background NO_2 concentrations to obtain total NO_2 concentrations at the receptors. Similarly, the adjusted road-PM_{10} and road-$PM_{2.5}$ concentrations have been added to the background PM_{10} and $PM_{2.5}$ concentrations to obtain total PM_{10} and $PM_{2.5}$ concentrations at the receptors.

Impact Descriptors and Significance

2.33 The is no formal guidance on how to assess the impacts or significance of air quality. In the absence of this, Environmental Protection UK (EPUK) and the Institute of Air Quality Management (IAQM) jointly produced guidance for the consideration of air quality with the land-use planning and development control processes (EPUK/IAQM, 2017). This suggests a framework for describing the impacts based on the annual mean concentration and the change in concentration as a percentage relative to the air quality objective. Table 8 summarises this for the annual mean objective for NO_2 and PM_{10}. It also sets out a methodology to judge whether the impacts will have a 'significant' or 'not significant' effect on human-health. The assessment framework for describing impacts can be used as a starting point to make a judgement, but there are other influences that might need to be accounted for, such as the existing and future air quality conditions without any scheme implemented, the extent of population exposure to the impacts, the influence and validity of any assumptions adopted when predicting impacts, whether the air quality objectives are met by the local authority, and whether any mitigation measures might affect the significance; the overall judgement of significance is therefore based on professional judgement (details of APS's professional experience is set out in Appendix A3).

Table 8: Annual mean NO_2 and PM_{10} impact descriptors for individual receptors

Annual Mean Concentration with Option (µg/m³)	Change in Concentration (µg/m³)							
	<-4.2	-4.2 – -2.2	-2.2 – -0.6	-0.6 – 0	0 – 0.6	0.6 – 2.2	2.2 – 4.2	>4.2
<30.2	Moderate Beneficial	Slight Beneficial	Negligible	Negligible	Negligible	Negligible	Slight Adverse	Moderate Adverse
30.2 – 37.8	Moderate Beneficial	Moderate Beneficial	Slight Beneficial	Negligible	Negligible	Slight Adverse	Moderate Adverse	Moderate Adverse
37.8 – 41.0	Substantial Beneficial	Moderate Beneficial	Moderate Beneficial	Slight Beneficial	Slight Adverse	Moderate Adverse	Moderate Adverse	Substantial Adverse
41.0 – 43.8	Substantial Beneficial	Substantial Beneficial	Moderate Beneficial	Moderate Beneficial	Moderate Adverse	Moderate Adverse	Substantial Adverse	Substantial Adverse
>43.8	Substantial Beneficial	Substantial Beneficial	Substantial Beneficial	Moderate Beneficial	Moderate Adverse	Substantial Adverse	Substantial Adverse	Substantial Adverse

Uncertainty

2.34 The assessment involves a range of uncertainties, including the model inputs, assumptions, the model, model verification and post-processing of model results. A brief overview of the key uncertainties is discussed below.

2.35 There are inherent uncertainties associated with the microsimulation traffic model; this simulated individual vehicles travelling on the roads in The Kibworths for two peak hours. This was produced to estimate vehicle trips in a realistic way, but the routing, timing, driving conditions and driving behavior of vehicles will vary over a longer timescale. The model was also run for only two peak hours and assumptions were made to obtain daily flows, although it should be recognised that the uncertainty of this has been minimised by using data from traffic surveys undertaken in The Kibworths.

2.36 The emission factors also involve a considerable amount of uncertainty. Due to the nature of the VERSIT+ emission factor model, as explained in paragraphs 2.8 to 2.15, the emissions are reliant on the computer simulated location of the modelled vehicles. In comparison, emissions from the EFT are link averages and do not explicitly take account of acceleration or deceleration. While the focus of this study uses the VERSIT+ emission, to take account of the uncertainty in vehicle emissions, a sensitivity test has been included whereby emission factors from the EFT have been used.

2.37 The model itself is based on assumptions of a range of parameters, including street canyons, road widths and meteorological related parameters. There is uncertainty in all these parameters, but the modelling has been setup in a robust way based on professional experience to best represent the conditions. One of the main uncertainties in the model is meteorological data; this has been based on measurements made at a representative meteorological station, and although meteorological conditions will remain similar, it entirely likely that meteorological conditions will vary in subsequent years and lead to marginally different concentrations.

2.38 The ambient background concentrations are also uncertain. While these are provided by Defra, the 1 km^2 resolution is coarse and the maps do not include all sources of pollution. Given the rural location of The Kibworths and no obvious significant sources of pollution in the local area, it is considered likely that the background maps at this area are reasonable. To minimise the uncertainty in the spatial resolution of the maps, the background concentrations have been interpolated to each receptor; essentially smoothing out the coarseness of the maps.

2.39 Emerging evidence (Grange, S, et al., 2017) suggests that the f-NO_2 has been decreasing in recent years, which is not taken into account within Defra's EFT or NOx to NO_2 Calculator. If lower f-NO_2 values were assumed, then the predicted concentrations would likely be slightly lower throughout The Kibworths. Until more detailed scientific analysis is undertaken to understand the full extent of why f-NO_2 is decreasing and how it will behave in the future, it remains an uncertainty.

2.40 A model verification exercise has been undertaken to adjust the predicted concentrations from the model so that they match local conditions as best as possible. This has adjusted concentrations to match average conditions; some locations will remain underpredicted and some overpredicted. In particular, it is acknowledged that concentrations predicted at monitoring site 34n are underpredicted. This monitoring site measured the highest concentrations and is the reason for the AQMA being declared. It is thus important to ensure the results are accurate at this location. A sensitivity test has therefore been carried out to adjust the model to match conditions at this location.

2.41 Although there is a wide range of uncertainty associated with air quality modelling, the predictions made by this assessment have been carried out in a robust manner in order to minimise uncertainties where possible.

3 Assessment

3.1 Based on modelling using VERSIT+ vehicle emissions, the predicted concentrations of NO_2, PM_{10} and $PM_{2.5}$, as well as the impact descriptions, for the Base, Option B and Option D scenarios, are presented in Table 9, Table 10 and Table 11, respectively, for the specific receptor locations.

Predicted NO_2 Concentrations

3.2 In the Base scenario only Receptor 1 exceeds the annual mean objective. In Options B and D Receptor 1 is below the objective, but Receptor 2 exceeds the objective. It should be acknowledged that these receptors are located near monitoring site 31n which has consistently measured concentrations between 30.5 – 33.6 µg/m^3; the model is therefore considered to be overpredicting concentrations at these locations.

3.3 Option B leads to nine beneficial impacts, eight negligible impacts and two adverse impacts (Receptor 2 and 5). Receptor 2 is located close to monitoring site 31n and Receptor 5 is located between 31n and 35n; concentrations are well below the objective at both of these monitoring sites and it is thus considered that the model is overstating the concentrations and impacts at these Receptors.

3.4 Option D leads to eleven beneficial impacts, seven negligible impacts and one adverse impact (Receptor 2).

3.5 Contours of each scenario are presented in Figure 13, Figure 14 and Figure 15. Figure 13 demonstrates that there are several hotspots of exceedances of the annual mean NO_2 objective primarily located around the junctions along the A6. Changes in concentrations with Options B and D implements are presented in Figure 16 and Figure 17, which show that there is a reduction of concentrations across much of the AQMA for both Option B and Option D, with the greatest reductions in Option D. There are also increases in concentrations outside of the AQMA, including at the A6/New Road junction where the traffic management measures include the creation of a roundabout; it does not significantly worsen air quality at sensitive locations near this junction though as concentrations remain well below the objectives.

Predicted PM Concentrations

3.6 Predicted annual mean PM_{10} and $PM_{2.5}$ concentrations are below the objectives at all receptors in all scenarios. The impacts are described as negligible in for both Option B and D.

Table 9: Predicted NO_2 Concentrations (µg/m^3) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
1	**43.0**	36.2	37.4	Substantial Beneficial	Substantial Beneficial
2	36.4	**46.3**	**40.4**	Moderate Adverse	Moderate Adverse
3	22.5	21.5	21.2	Negligible	Negligible
4	37.5	33.8	32.6	Moderate Beneficial	Moderate Beneficial
5	24.4	27.7	22.9	Slight Adverse	Negligible

6	18.9	19.0	17.9	Negligible	Negligible
7	29.7	25.4	26.1	Moderate Beneficial	Slight Beneficial
8	35.1	33.0	30.3	Slight Beneficial	Moderate Beneficial
9	17.3	17.0	16.2	Negligible	Negligible
10	25.3	24.7	22.0	Negligible	Slight Beneficial
11	25.6	24.8	22.1	Negligible	Slight Beneficial
12	31.2	27.6	25.8	Moderate Beneficial	Moderate Beneficial
13	20.1	17.9	17.9	Slight Beneficial	Slight Beneficial
14	22.3	18.8	18.9	Slight Beneficial	Slight Beneficial
15	20.7	18.3	18.2	Slight Beneficial	Slight Beneficial
16	30.4	28.7	26.8	Slight Beneficial	Moderate Beneficial
17	25.2	26.2	23.9	Negligible	Negligible
18	17.6	18.0	17.9	Negligible	Negligible
19	18.1	18.4	18.3	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

Table 10: Predicted PM_{10} Concentrations (µg/m³) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
1	18.3	17.3	17.4	Negligible	Negligible
2	17.0	17.3	16.8	Negligible	Negligible
3	15.4	15.3	15.3	Negligible	Negligible
4	17.8	17.6	17.4	Negligible	Negligible
5	15.3	15.6	15.2	Negligible	Negligible
6	14.6	14.7	14.5	Negligible	Negligible
7	15.9	15.5	15.6	Negligible	Negligible
8	16.6	16.5	16.2	Negligible	Negligible
9	14.5	14.5	14.4	Negligible	Negligible
10	15.4	15.4	15.1	Negligible	Negligible
11	15.4	15.5	15.1	Negligible	Negligible
12	16.2	16.0	15.8	Negligible	Negligible
13	14.8	14.7	14.7	Negligible	Negligible
14	14.9	14.7	14.7	Negligible	Negligible
15	14.8	14.6	14.6	Negligible	Negligible
16	15.7	15.5	15.4	Negligible	Negligible
17	15.0	15.1	14.9	Negligible	Negligible
18	14.1	14.1	14.1	Negligible	Negligible
19	14.2	14.1	14.1	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

Table 11: Predicted $PM_{2.5}$ Concentrations (µg/m³) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
1	11.5	10.9	11.0	Negligible	Negligible
2	10.8	11.0	10.6	Negligible	Negligible
3	9.8	9.7	9.7	Negligible	Negligible

4	11.3	11.2	11.1	Negligible	Negligible
5	9.7	9.9	9.7	Negligible	Negligible
6	9.4	9.4	9.4	Negligible	Negligible
7	10.2	10.0	10.1	Negligible	Negligible
8	10.7	10.7	10.4	Negligible	Negligible
9	9.3	9.3	9.3	Negligible	Negligible
10	9.9	10.0	9.7	Negligible	Negligible
11	9.9	10.0	9.8	Negligible	Negligible
12	10.4	10.3	10.2	Negligible	Negligible
13	9.6	9.5	9.5	Negligible	Negligible
14	9.7	9.5	9.5	Negligible	Negligible
15	9.5	9.4	9.4	Negligible	Negligible
16	10.2	10.1	10.0	Negligible	Negligible
17	9.7	9.8	9.7	Negligible	Negligible
18	9.2	9.2	9.2	Negligible	Negligible
19	9.2	9.2	9.2	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

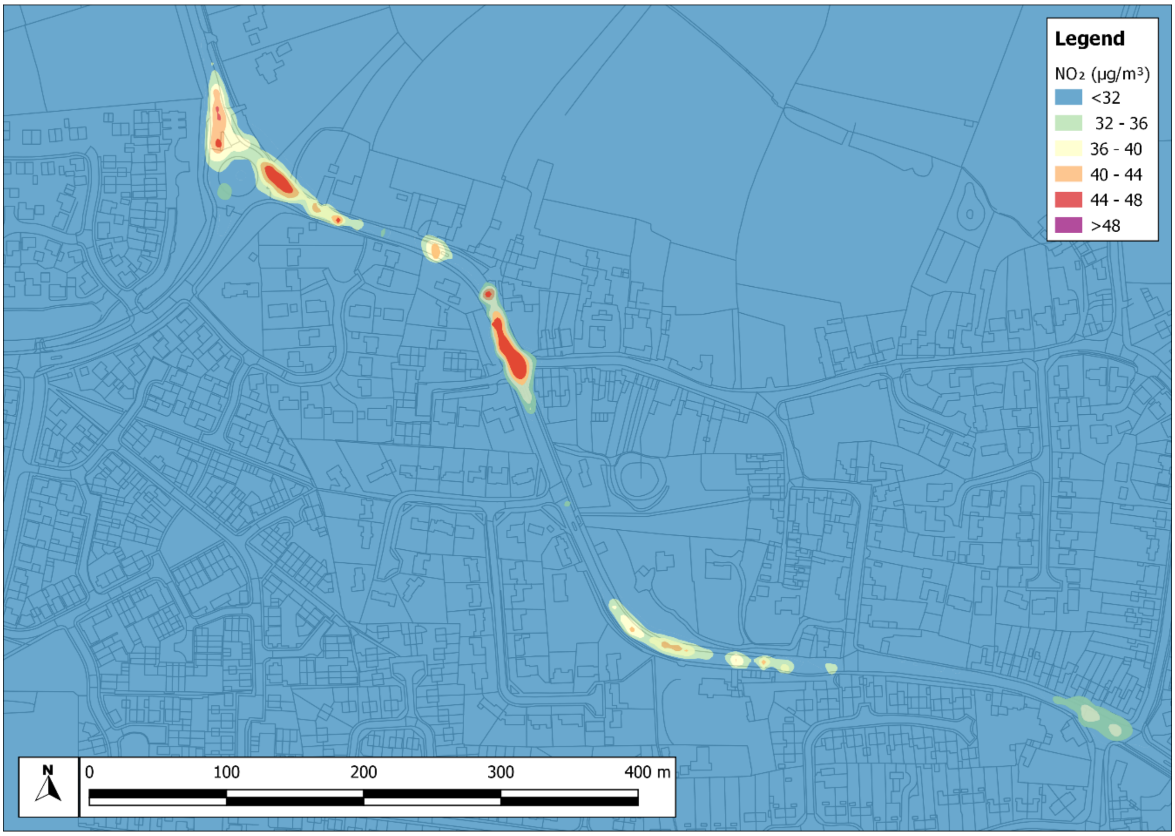

Figure 13: Predicted NO_2 concentrations in the Base Scenario

Figure 14: Predicted NO_2 concentrations in the Option B Scenario

Figure 15: Predicted NO_2 concentrations in the Option D Scenario

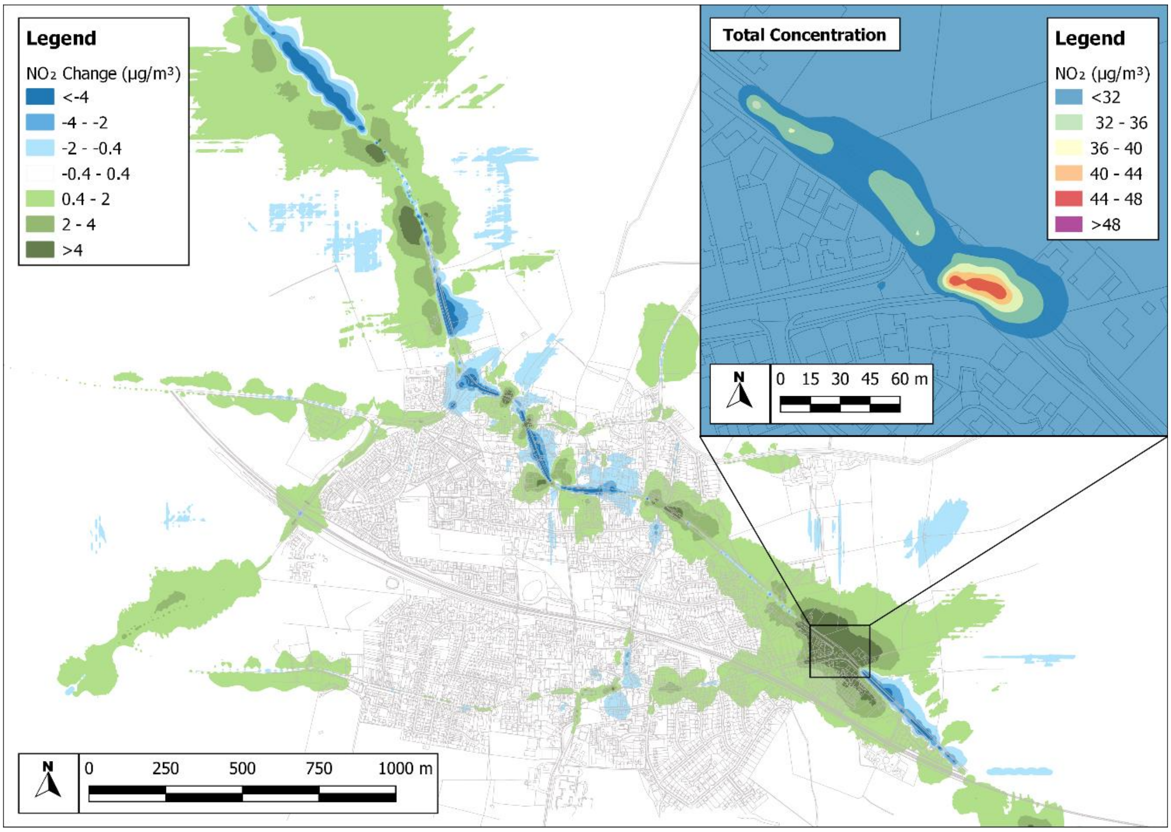

Figure 16: Difference in predicted NO_2 concentrations between Option B and the Base Scenario (Option B minus Base) and Option B concentrations at the A6/New Road junction

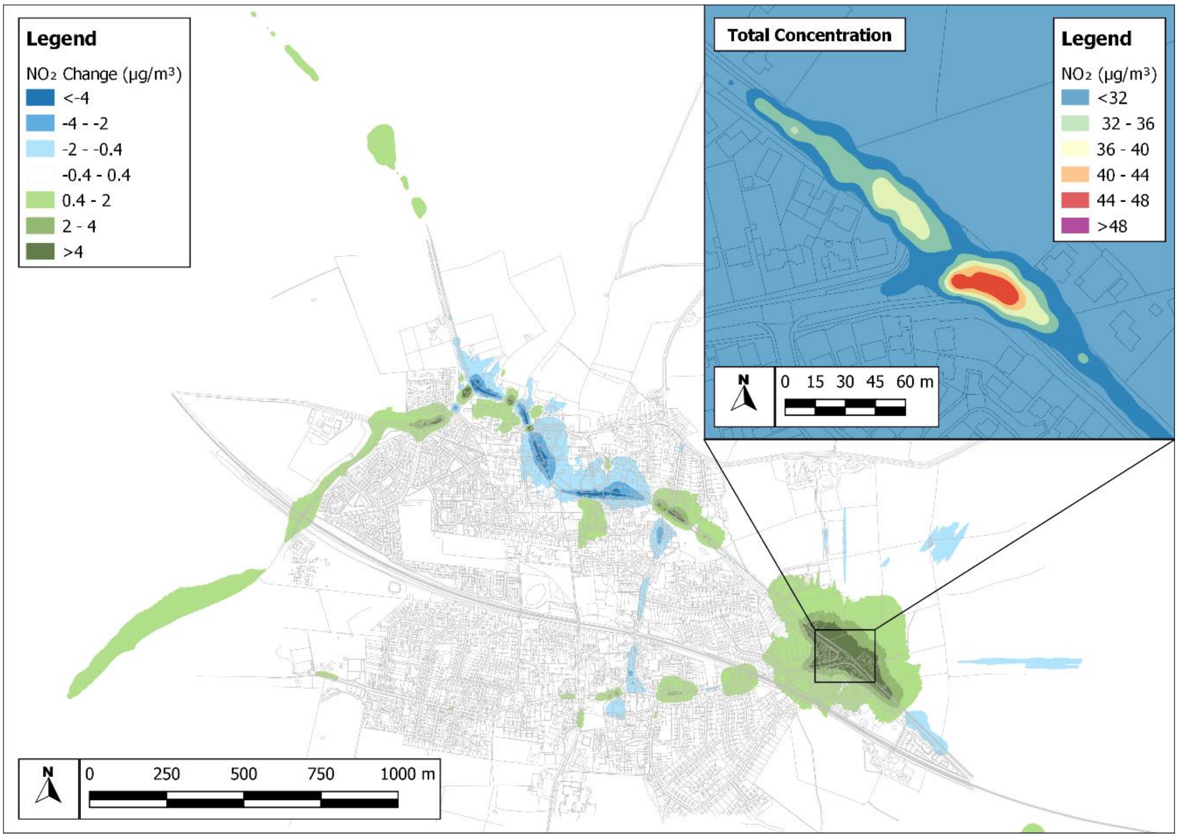

Figure 17: Difference in predicted NO_2 concentrations between Option D and the Base Scenario (Option D minus Base) and Option B concentrations at the A6/New Road junction

Verification Sensitivity Test

3.7 As explained in paragraph 2.40, a sensitivity test has been carried out assuming the model adjustment factor for road-NOx is that calculated based purely on the comparison of measured to modelled road-NOx at the 34n monitoring site, the site with the highest measured NO_2 concentration; this has been undertaken to demonstrate what conditions would be like if the model matched the measured concentrations at this monitor.

3.8 The results and details of this sensitivity test are provided in Appendix A1 and show NO_2 concentrations are predicted to exceed the annual mean objective at Receptors 7, 8, 12 and 16. The highest concentration of 48.1 µg/m^3 is predicted at Receptor 8. This receptor is located close to monitoring site 34n, which measured 49.3 µg/m^3 in 2018; this sensitivity test is thus considered to robustly represent conditions at these worst-case locations.

3.9 In Option B and D, NO_2 concentrations are predicted to exceed the objective only at Receptor 8, with concentrations reducing to 45.1 µg/m^3 and 41.1 µg/m^3, respectively. These are significant reductions.

3.10 For Option B, the impacts are described as beneficial at eleven receptors, negligible at five receptors and adverse at three receptors (Receptor 2, 5 and 17). Receptor 17 is located about half-way between these monitoring sites and other monitoring sites that have not measured exceedances. It is likely that concentrations and the impact are slightly overpredicted at this receptor. As explained in paragraph 3.3 the concentrations and impacts at Receptor 2 and 5 are also considered to be overstated.

3.11 For Option D, the impacts are described as beneficial at ten receptors, negligible at two receptors and adverse at one receptor (Receptor 2).

3.12 Predicted PM_{10} and $PM_{2.5}$ concentrations are below the annual mean objective at all receptors in all scenarios. The impacts are described as negligible in for both Option B and D.

EFT Sensitivity Test

3.13 Although the microsimulation traffic model has been setup in a robust manner, the fine spatial resolution of VERSIT+, which varies emissions over short distances along a link, could potentially lead to spikes in emissions occurring at different parts of a link than in reality. To account for this uncertainty, a further sensitivity test has been carried out using vehicle emission factors obtained from Defra's EFT, instead of VERSIT+, which provides link-average emission factors and do not take account of factors such as acceleration and deceleration.

3.14 The results of this sensitivity test are provided in Appendix A2 and predict exceedances of the annual mean NO_2 objective at five receptors (1, 2, 4, 8 and 12) in the Base scenario, and predicted exceedances at four receptors (1, 4, 8 and 12) in the Option B and D scenarios. As previously discussed, the exceedances at Receptors 1, 2 and 4 demonstrate the model is overpredicting concentrations at these locations, since measured concentrations close to these receptors are below the objective.

3.15 The impacts for Option B are described as beneficial at three receptors, negligible at ten receptors and adverse at six receptors. For Option D, the impacts are predicted to be beneficial at nine receptors and negligible at ten receptors.

3.16 Looking at Receptors 8 and 12, which are predicted to exceed the objective, Option B leads to a substantial adverse impact at Receptor 8 and a moderate adverse impact at Receptor 12. Option D, however, leads to substantial beneficial impacts at both receptors.

3.17 Predicted annual mean PM_{10} and $PM_{2.5}$ concentrations are below the objectives at all receptors in all scenarios. The impacts are described as negligible in for both Option B and D.

Summary of Impact Descriptors

3.18 Table 12 shows the summary of the predicted impact descriptors for the main assessment and the sensitivity tests. In the assessment and the sensitivity tests both Option B and D result in more beneficial impacts than adverse, apart from Option B in the EFT sensitivity test. Overall, Option D leads to more improvements than Option B.

Table 12: Summary of Impact Descriptors

Impact Descriptor		Option B	Option D
Assessment			
Adverse	Substantial	-	-
	Moderate	1	1
	Slight	1	-
Negligible		8	7
Beneficial	Slight	5	6
	Moderate	3	4
	Substantial	1	1
Verification Sensitivity Test			
Adverse	Substantial	1	1
	Moderate	1	-
	Slight	1	-
Negligible		5	5
Beneficial	Slight	4	3
	Moderate	1	4
	Substantial	6	6
EFT Sensitivity Test			
Adverse	Substantial	1	-
	Moderate	4	-
	Slight	1	-
Negligible		10	10
Beneficial	Slight	-	2
	Moderate	1	3
	Substantial	2	4

EPUK/IAQM Significance of Effects

3.19 While not strictly relevant to this assessment, the EPUK and the IAQM guidance (2017) on air quality with regards to planning and development control provides advice on assessing significance.

3.20 Following the guidance, both Option B and Option D are judged to not have a 'significant' adverse effect on air quality. These judgements take account of the sensitivity tests carried out and are based upon:

- Annual mean concentrations of PM_{10} and $PM_{2.5}$ all being below the objectives and all PM impacts being negligible;
- exceedances of the annual mean NO_2 objective predicted to likely occur at Receptors 8 and 12 with Options B and D;
- Option D having a great number of beneficial impacts than Option B;
- Option D reducing concentrations at Receptors 8 and 12 significantly more than what Option B does; and

- Option B potentially leading to adverse impacts at Receptors 8 and 12, while Option D will lead to large improvements.

3.21 In summary, it can be concluded that both Option B and D demonstrate a benefit to the air quality within the AQMA. Furthermore, Option D demonstrates the greatest level of improvement in the AQMA.

3.22 The traffic modelling carried out by the PTV VISSIM microsimulation model is a behavioral traffic model which accounts for traffic routing which is dependent on congested roads etc. Although Option D introduces additional traffic onto the road network from the new development, the traffic model expects most of this traffic will travel to and from Leicester on the A6. The traffic model predicts that the presence of the development, which is part of Option D, will cause existing traffic to change their routing patterns due to additional congestion near the development; this results in changes to air quality conditions within the AQMA, with larger improvements at the worst-case locations.

4 Summary and Conclusions

4.1 Air quality within The Kibworths has been modelled with a detailed atmospheric dispersion model, using microsimulation traffic model data and instantaneous emission factors from TNO. Concentrations of NO_2 and PM_{10} have been predicted at 19 specific receptor locations representing worst-case exposure at the façades of sensitive properties within the AQMA, as well as an array of receptors across The Kibworths, for a Base scenario and two traffic management option scenarios (Options B and D).

4.2 The results demonstrate that annual mean PM_{10} and $PM_{2.5}$ concentrations within The Kibworths are acceptable and the traffic management options will not change this. In terms of NO_2, the model predicts mostly beneficial impacts. These results are based on a model verification which provides the best fit of the model to measured NO_2 concentrations at all monitoring sites in The Kibworths. However, it leads to NO_2 concentrations being underpredicted at monitor 34n, where the highest NO_2 concentrations are measured. To take account of this, a sensitivity test has been carried out where the model verification only uses this monitor, to ensure the model matches measured concentration at this location. This leads to NO_2 concentrations predicted to exceed the annual mean objective at Receptor 8, which is located close to monitoring site 34n, for the Base scenario and predicts mostly beneficial impacts, with concentrations reducing largely at Receptor 8 in Option B and even more in Option D.

4.3 In addition, to take account of the uncertainty in vehicle emission and spatial uncertainty in vehicle emissions, link-average emissions from Defra's EFT have also been used. The results of which also demonstrate Receptor 8 to exceed the objective. In addition, the results also predict Receptor 12 to exceed the objective too; this receptor is also located close to measured exceedances. Option B is predicted to lead to moderate to substantial adverse impacts at these receptors, while Option D will lead to substantial beneficial. Use of the EFT data would result in similar conclusion to the VERSIT+ emission database across the study area, however, the very greater detail of the VERSIT+ emissions provides better understanding at a very local level.

4.4 Taking into account all of the above, overall it is judged that although Option B will lead to large improvements in NO_2 concentrations, it has the potential to lead to adverse impacts at some of the worst-case locations within the AQMA. Option D is predicted to lead to large improvements, including at the worst-case locations, and is therefore considered to improve air quality conditions to the greatest degree within The Kibworths.

5 Glossary and References

Glossary

AADT	*Annual Average Daily Traffic*
Air Quality Standards	*Concentrations recorded over a given time period, which are considered to be acceptable in terms of what is scientifically known about the effects of each pollutant on health and on the environment.*
An exceedance	*A period of time (defined for each standard) where the concentration is higher than that set out in the Standard.*
An objective	*The target date on which exceedances of a Standard must not exceed a specified number.*
APS	*Air Pollution Services Ltd*
AQAP	*Air Quality Action Plan*
AQMA	*Air Quality Management Area*
ATC	*Automatic Traffic Count*
COPERT	*Computer Programme to calculate Emissions from Road Transport*
DfT	*Department for Transport*
EFT	*Emission Factor Toolkit*
EPA	*Environmental Protection Act*
EPUK	*Environmental Protection UK*
EU Limit Values	*Legally binding EU parameters that must not be exceeded. Limit values are set for individual pollutants and are made up of a concentration value, an averaging time over which it is to be measured, the number of exceedances allowed per year, if any, and a date by which it must be achieved. Some pollutants have more than one limit value covering different endpoints or averaging times.*
HBEFA	*Handbook Emission Factors for Road Transport*
HGV	*Heavy Goods Vehicle*
IAQM	*Institute of Air Quality Management*
LAQM	*Local Air Quality Management*
LGV	*Light Goods Vehicle*

LLITM	*Leicestershire Integrated Transport Model*
MCC	*Manual Classified Count*
NO_2	*Nitrogen Dioxide*
NOx	*Nitrogen Oxides*
$\mu g/m^3$	*Microgrammes per cubic metre*
PEMS	*Portable Emissions Measurement Systems*
PHEM	*Passenger car and Heavy duty Emission Model*
PM_{10}	*Small airborne particles, more specifically particulate matter less than 10 micrometres in aerodynamic diameter*
RMSE	*Root Mean Square Error*
Target values	*Used in some EU Directives and are set out in the same way as limit values. They are to be attained where possible by taking all necessary measures not entailing disproportionate costs.*
TEE	*ENEA traffic emissions and energetics model*
VERSIT+	*Exhaust emissions model from TNO*
VISSIM	*Microsimulation traffic model from PTV Group*
WADT	*Week Average Daily Traffic*
WHO	*World Health Organization*

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Appendix A1 Verification Sensitivity Test Results

A1.1 It is acknowledged that concentrations will inevitably be underpredicted or overpredicted at different locations. The model verification described in paragraphs 2.27 to 2.31 leads to NO_2 concentrations being underpredicted at monitoring site 34n, where the highest concentrations have been measured. To take account of this, the results are also presented here assuming the model matches measured concentrations perfectly at this monitoring site. The derived road-NOx adjustment factor for 34n is 3.093; all predicted road-NOx and road-PM_{10} concentrations have been multiplied by this adjustment factor.

A1.2 The predicted NO_2, PM_{10} and $PM_{2.5}$ concentrations are given in Table A1, Table A2 and Table A3, respectively, for the specific receptor locations close to monitoring sites 34n and 36n, where measured exceedances have occurred. Concentrations are not presented for the other receptors or nested grid, as concentrations at these locations would be largely overpredicted.

Table A1: Predicted NO_2 Concentrations (µg/m^3) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
6	23.7	23.8	22.1	Negligible	Negligible
7	**40.1**	33.7	34.9	Substantial Beneficial	Substantial Beneficial
8	**48.1**	**45.1**	**41.1**	Substantial Beneficial	Substantial Beneficial
9	21.1	20.5	19.3	Negligible	Negligible
10	33.6	32.7	28.5	Slight Beneficial	Moderate Beneficial
11	34.0	32.8	28.6	Slight Beneficial	Moderate Beneficial
12	**42.1**	36.9	34.2	Substantial Beneficial	Substantial Beneficial
13	25.5	21.9	21.9	Slight Beneficial	Slight Beneficial
14	29.0	23.5	23.6	Moderate Beneficial	Moderate Beneficial
15	26.5	22.7	22.5	Slight Beneficial	Slight Beneficial
16	**41.2**	38.8	35.9	Substantial Beneficial	Substantial Beneficial
17	33.5	35.0	31.5	Slight Adverse	Slight Beneficial

[a] Exceedances of the objective are shown in bold.

Table A2: Predicted PM_{10} Concentrations ($\mu g/m^3$) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
6	15.0	15.2	14.9	Negligible	Negligible
7	17.2	16.6	16.8	Negligible	Negligible
8	18.4	18.3	17.8	Negligible	Negligible
9	14.8	14.9	14.7	Negligible	Negligible
10	16.3	16.5	15.9	Negligible	Negligible
11	16.4	16.5	16.0	Negligible	Negligible
12	17.7	17.5	17.0	Negligible	Negligible
13	15.5	15.2	15.2	Negligible	Negligible
14	15.7	15.3	15.3	Negligible	Negligible
15	15.4	15.1	15.1	Negligible	Negligible
16	16.9	16.8	16.5	Negligible	Negligible
17	15.9	16.1	15.7	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

Table A3: Predicted $PM_{2.5}$ Concentrations ($\mu g/m^3$) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
6	9.7	9.8	9.6	Negligible	Negligible
7	11.1	10.7	10.8	Negligible	Negligible
8	11.9	11.8	11.4	Negligible	Negligible
9	9.6	9.6	9.5	Negligible	Negligible
10	10.5	10.6	10.3	Negligible	Negligible
11	10.6	10.6	10.3	Negligible	Negligible
12	11.4	11.3	11.0	Negligible	Negligible
13	10.0	9.8	9.8	Negligible	Negligible
14	10.1	9.9	9.9	Negligible	Negligible
15	9.9	9.8	9.8	Negligible	Negligible
16	11.0	10.9	10.7	Negligible	Negligible
17	10.3	10.4	10.2	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

Appendix A2 EFT Sensitivity Test Results

A2.1 In order to take account of the uncertainty in emissions, the modelling has been carried out using vehicle emissions from Defra's EFT. The model verification exercise has been undertaken for this modelling, to ensure these emissions reflect air quality conditions in The Kibworths are as close as possible to the measured data. The verification process follows the same approach described in paragraphs 2.27 to 2.31.

A2.2 The predicted road-NOx concentration has been compared to the 'measured' road-NOx concentration (see Figure A1) and an adjustment factor of 3.867 has been derived from the equation of the linear trend line that has been fitted through zero. This factor indicates that the model is generally underpredicting concentrations at the monitoring sites and is underpredicting by a greater degree than that found when using VERSIT+ emissions. Further statistics of the fit are given in Table A4. This adjustment factor has been applied to all predicted road-NOx concentrations to uplift the values to match the real conditions in the local area. It should be acknowledged, however, that this adjustment will force the modelling to match average conditions; at some locations concentrations will remain slightly underpredicted and others overpredicted. This is illustrated in Figure A2, which shows a comparison of the measured NO_2 concentrations and the total (i.e. road plus background) predicted NO_2 concentrations. Further statistics of this comparison are given in Table A4, which demonstrate that the predicted NO_2 concentrations have an insignificant fractional bias and an acceptable RMSE.

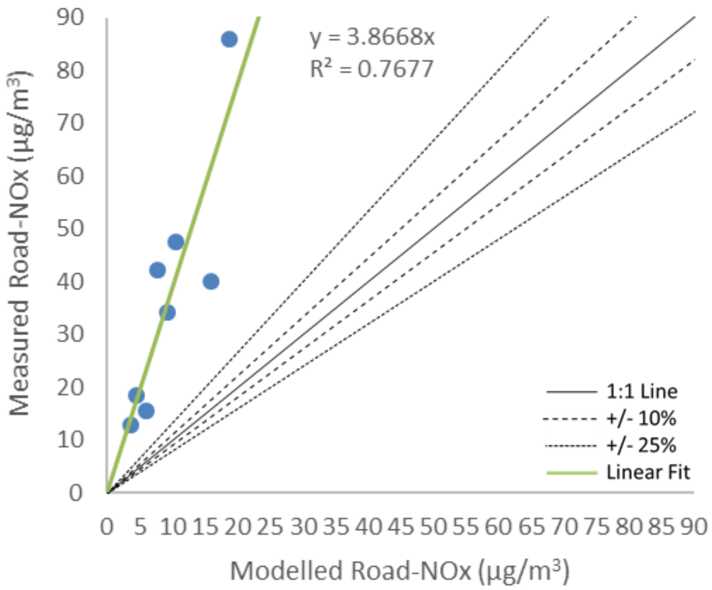

Figure A1:Comparison of predicted road-NOx to 'measured' road-NOx

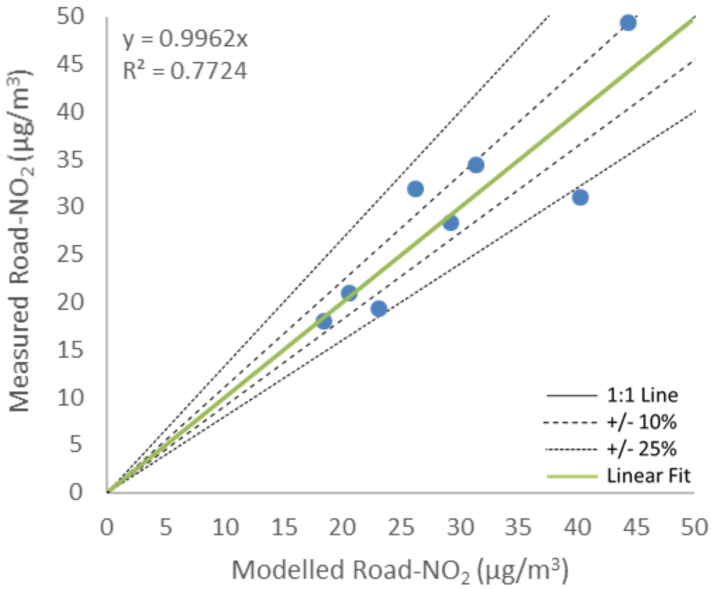

Figure A2:Comparison of predicted NO_2 to measured NO_2

Table A4: Model Verification Statistics

Statistic	Road-NOx	NO_2
Correlation Coefficient (r)	0.876	0.879
Real Mean Squared Error (RSME)	32.83	4.561
Fractional Bias (FB)	1.180	-0.002

[a] This is used to measure the linear relationship between predicted and measured concentrations. A value of zero means no relationship and a value of 1 means absolute relationship (ideal value).

[b] RMSE is used to define the average error or uncertainty in the model. The ideal value is zero, if greater than 25% of the objective (i.e. 10 µg/m³) then it is recommended that the model be revisited.

[c] This is used to identify if the model shows a systematic tendency to over or under predict. FB values range between -2 and +2 and has an ideal value of zero. Negative values indicate a model over-prediction and positive values indicate a model under-prediction.

A2.3 The predicted NO_2, PM_{10} and $PM_{2.5}$ concentrations at the specific receptor locations are given in Table A5, Table A6. Contours of the Base, Option B and D scenarios are presented in Figure A3, Figure A4 and Figure A5, and contours of the differences between Option B and D to the Base scenario are presented in Figure A6 and Figure A7, respectively.

Table A5: Predicted NO_2 Concentrations (µg/m³) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
1	**50.9**	**47.6**	**47.9**	Substantial Beneficial	Substantial Beneficial
2	**40.5**	43.1	38.6	Moderate Adverse	Moderate Beneficial
3	24.3	23.4	23.5	Negligible	Negligible
4	**49.7**	**48.9**	**47.5**	Substantial Beneficial	Substantial Beneficial
5	25.2	29.0	24.3	Slight Adverse	Negligible
6	19.7	20.9	19.0	Negligible	Negligible
7	36.6	32.8	33.8	Moderate Beneficial	Moderate Beneficial
8	**44.0**	**44.7**	**40.2**	Substantial Adverse	Substantial Beneficial
9	18.4	19.3	17.6	Negligible	Negligible

10	30.8	33.7	28.7	Moderate Adverse	Slight Beneficial
11	31.4	34.0	29.1	Moderate Adverse	Moderate Beneficial
12	**43.6**	**44.8**	**40.2**	Moderate Adverse	Substantial Beneficial
13	22.4	21.4	21.3	Negligible	Negligible
14	24.7	23.7	23.4	Negligible	Negligible
15	22.6	22.2	21.6	Negligible	Negligible
16	34.1	33.5	32.0	Negligible	Slight Beneficial
17	26.2	27.7	25.1	Negligible	Negligible
18	16.7	16.7	16.5	Negligible	Negligible
19	16.8	16.6	16.5	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

Table A6: Predicted PM_{10} Concentrations (μg/m^3) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
1	19.3	19.2	19.2	Negligible	Negligible
2	17.5	18.1	17.5	Negligible	Negligible
3	15.6	15.6	15.5	Negligible	Negligible
4	18.7	18.8	18.6	Negligible	Negligible
5	15.6	16.1	15.6	Negligible	Negligible
6	14.8	14.9	14.7	Negligible	Negligible
7	16.7	16.4	16.6	Negligible	Negligible
8	17.6	18.0	17.4	Negligible	Negligible
9	14.6	14.7	14.6	Negligible	Negligible
10	16.1	16.6	16.0	Negligible	Negligible
11	16.1	16.7	16.0	Negligible	Negligible
12	17.6	17.9	17.4	Negligible	Negligible
13	15.0	14.9	14.9	Negligible	Negligible
14	15.3	15.2	15.3	Negligible	Negligible
15	15.0	15.1	15.0	Negligible	Negligible
16	16.3	16.4	16.2	Negligible	Negligible
17	15.3	15.5	15.3	Negligible	Negligible
18	14.2	14.2	14.2	Negligible	Negligible
19	14.2	14.2	14.2	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

Table A7: Predicted $PM_{2.5}$ Concentrations (μg/m^3) and Impact Descriptors [a]

Receptor	Base	Option B	Option D	Option B Impact	Option D Impact
1	12.2	12.1	12.1	Negligible	Negligible
2	11.1	11.5	11.0	Negligible	Negligible
3	9.9	9.9	9.9	Negligible	Negligible
4	11.9	12.0	11.8	Negligible	Negligible
5	9.9	10.2	9.9	Negligible	Negligible
6	9.5	9.6	9.5	Negligible	Negligible
7	10.8	10.5	10.6	Negligible	Negligible

8	11.4	11.6	11.2	Negligible	Negligible
9	9.4	9.5	9.4	Negligible	Negligible
10	10.4	10.7	10.3	Negligible	Negligible
11	10.4	10.7	10.3	Negligible	Negligible
12	11.3	11.6	11.2	Negligible	Negligible
13	9.7	9.6	9.6	Negligible	Negligible
14	9.9	9.8	9.8	Negligible	Negligible
15	9.7	9.7	9.7	Negligible	Negligible
16	10.6	10.6	10.5	Negligible	Negligible
17	10.0	10.1	9.9	Negligible	Negligible
18	9.3	9.3	9.2	Negligible	Negligible
19	9.3	9.2	9.2	Negligible	Negligible

[a] Exceedances of the objective are shown in bold.

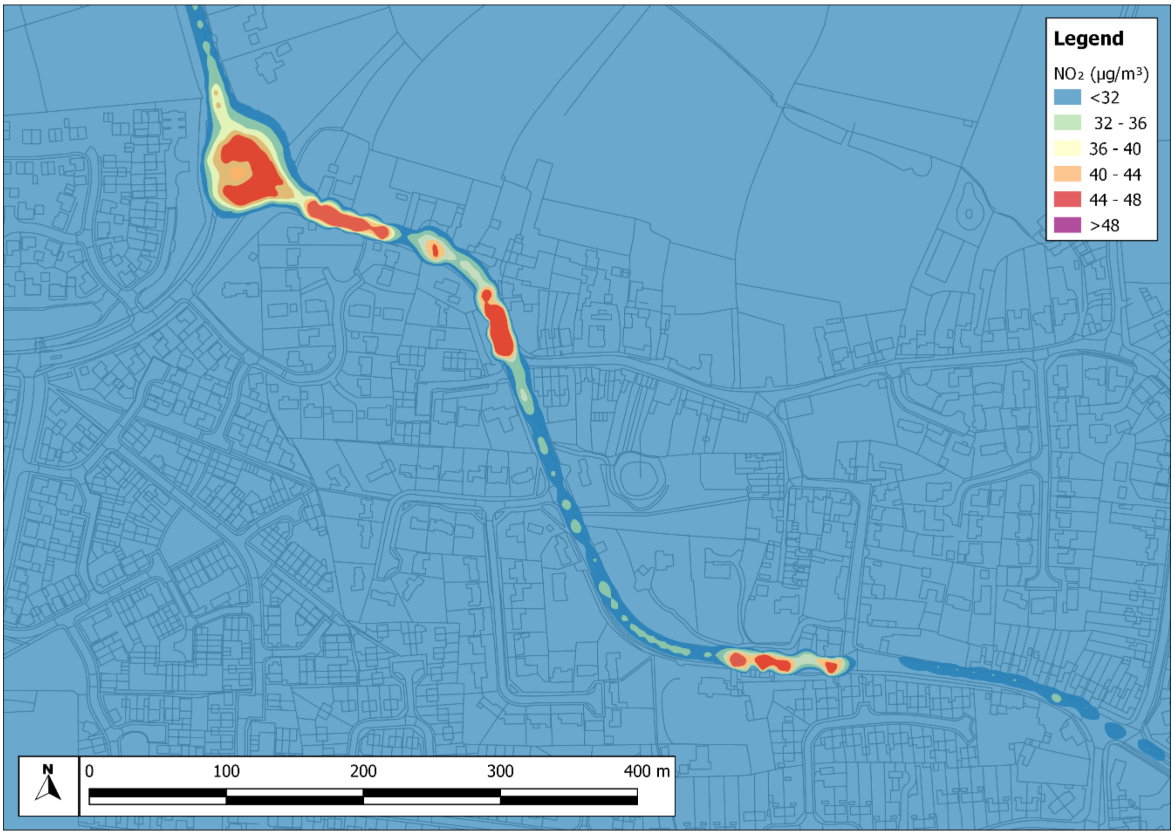

Figure A3: Predicted NO_2 concentrations in the Base Scenario

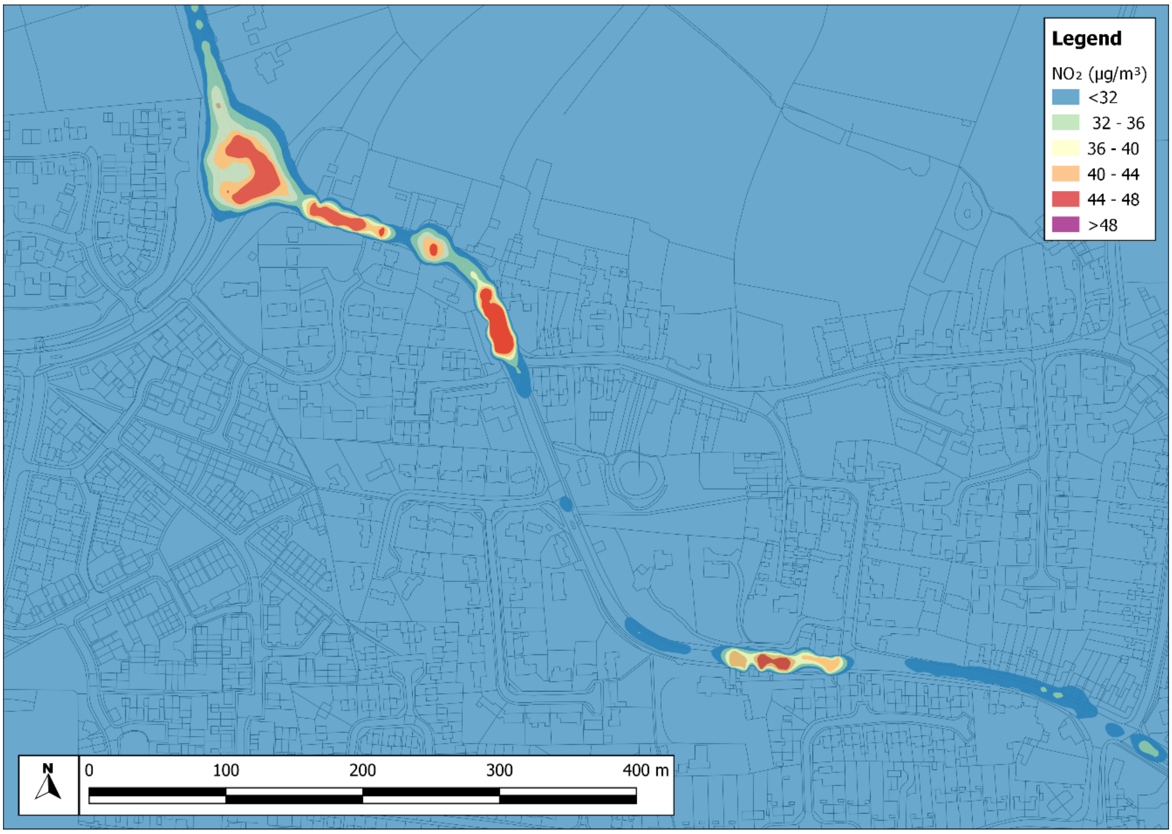

Figure A4: Predicted NO_2 concentrations in the Option B Scenario

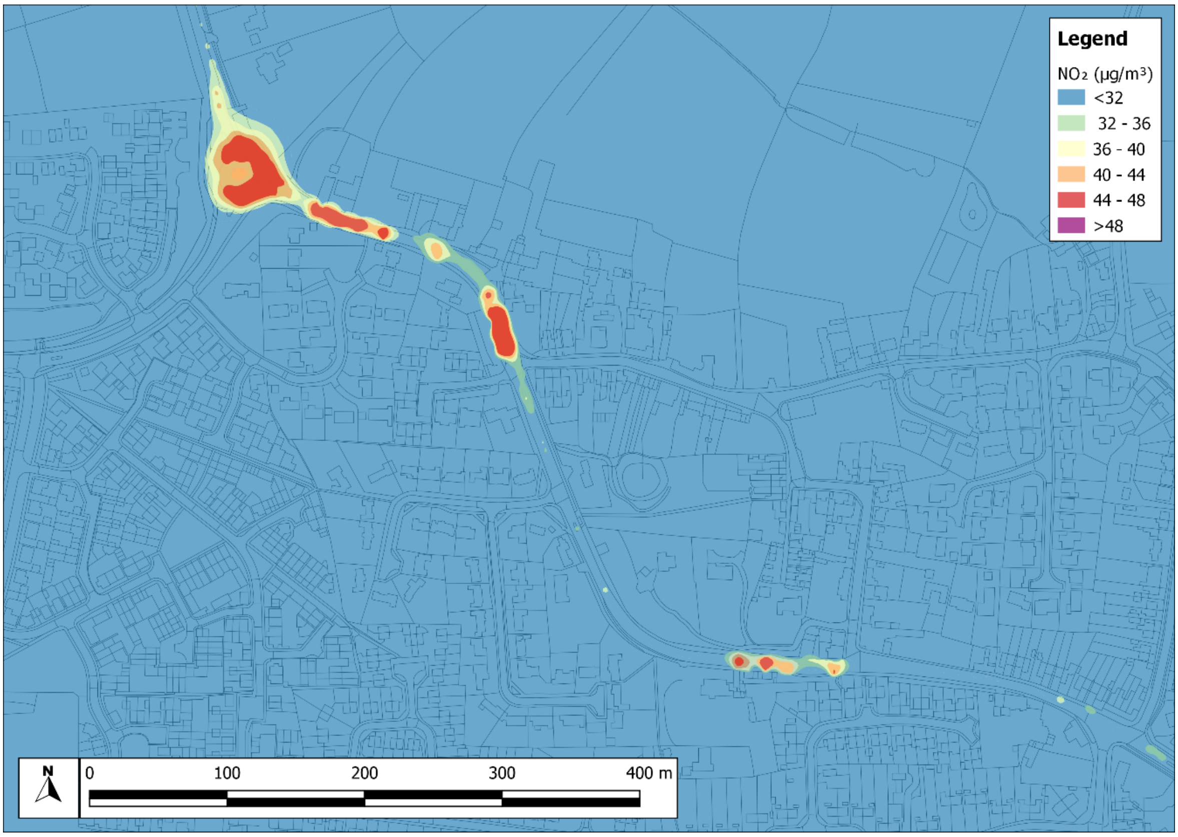

Figure A5: Predicted NO_2 concentrations in the Option D Scenario

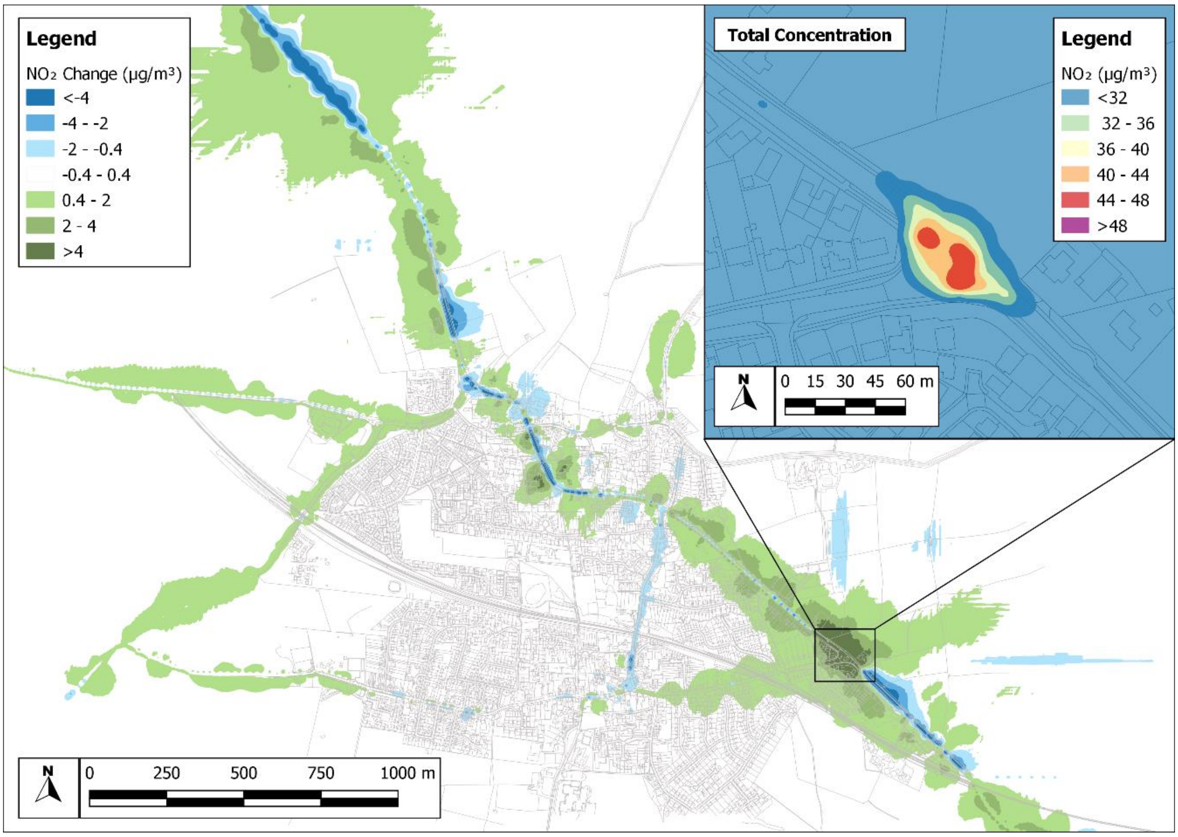

Figure A6: Difference in predicted NO_2 concentrations between Option B and the Base Scenario (Option B minus Base) and Option B concentrations at the A6/New Road junction

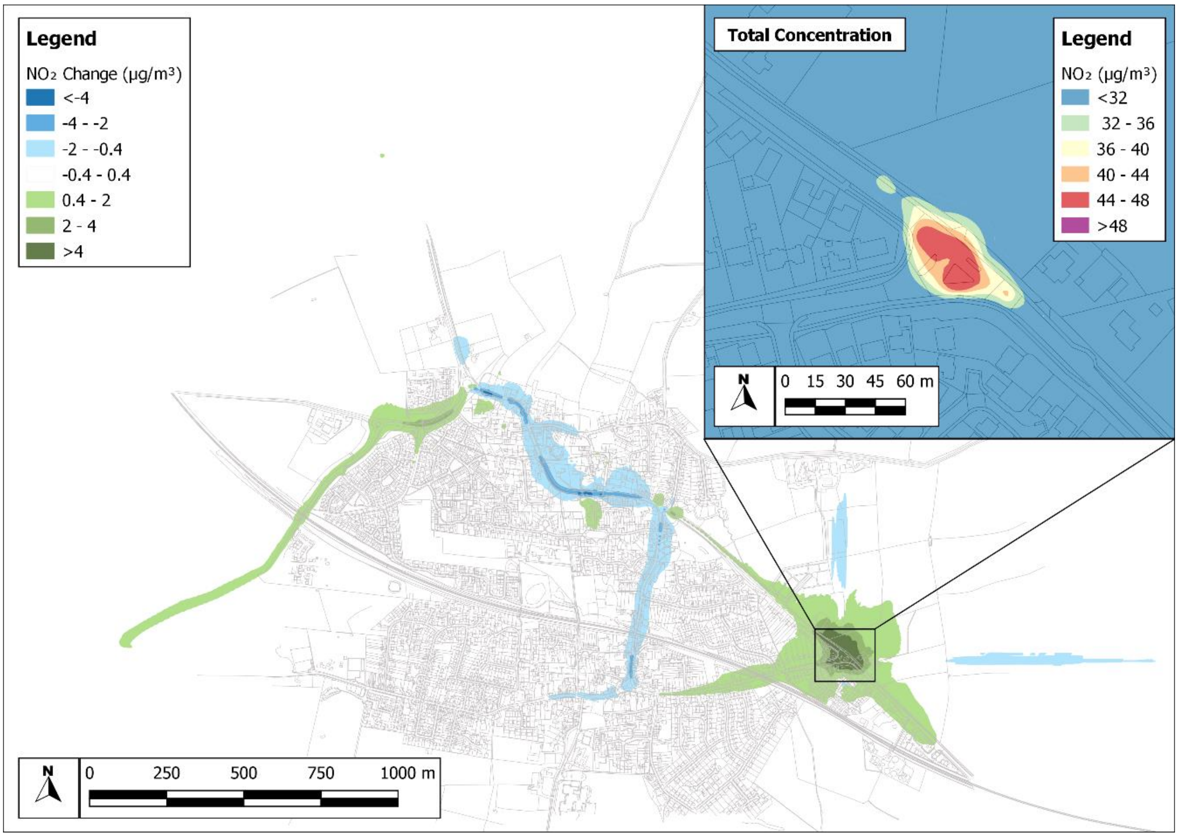

Figure A7: Difference in predicted NO_2 concentrations between Option D and the Base Scenario (Option D minus Base) and Option D concentrations at the A6/New Road junction

Appendix A3 Professional Experience

A3.1 The air quality study has been undertaken by Dr Austin Cogan and Kieran Laxen and reviewed by Dr Claire Holman. All members of the team have extensive experience in carrying out air quality studies on behalf of local authorities across the UK. Details of their experience is provided below.

	**Dr Austin Cogan, MPhys (Hons) PhD MIEnvSc MIAQM** Dr Cogan is a Director of APS and has over ten years' experience in environmental sciences. Austin has extensive experience of air quality, dust and odour assessments for a range of industries as well as services for local authorities, including Clean Air Zone and micro-simulation modelling. He is also an international expert in the field of climate change, having monitored greenhouses gases globally, published numerous scientific papers and presented at conferences internationally.
	**Kieran Laxen, MEng (Hons) MIEnvSc MIAQM** Mr Laxen is a Director of APS and has over eleven years' experience in the field of air quality. Kieran is an active member of the IAQM committee. He has extensive experience of air quality monitoring and is a leading UK expert in the assessment of power generating facilities for both permitting and planning applications. He has been a stakeholder in Defra's and the Environment Agency's consultations into implementing the MCPD and Specified Generator Controls.
	**Dr Claire Holman, BSc (Hons), PhD, CSci, CEnv, FIEnvSc, FIAQM** Dr Holman is an associate of APS, has nearly 40 years of experience and has advised national governments in Europe, Asia and Africa, as well as the European Commission on a range of strategic air quality and climate change issues. Claire has contributed to the development of IAQM and EPUK professional guidance, is currently the chair of the institute, has been a member of a Government air quality review group, and advised the Department for Transport on their cleaner vehicles and fuels research programme. She is an experienced expert witness for planning and CPO inquiries and litigation