Air Quality CONSULTANTS

Combining Instantaneous Vehicle Emission Calculations with Dispersion Modelling to Identify Options to Improve Air Quality in Reigate and Banstead

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1 Executive Summary

1.1 This report explores the use of a micro-simulation traffic model, combined with instantaneous emission factors and detailed dispersion modelling, for predicting concentrations of nitrogen dioxide; particularly in the context of identifying options for traffic management within the Drift Bridge Air Quality Management Area.

1.2 A key difference between this study and others which have used micro-simulation traffic data is that emissions have been derived for every 2 m of the road network, with this network extended to cover each typical path of vehicle movements around the junction. This detail allows the spatial pattern of emissions, which is often lost in other studies which have combined micro-simulation traffic data and dispersion modelling, to be captured. Another important difference is that the traffic modelling has covered all 24 hours of a typical weekday as well as Saturdays and Sundays, whereas micro-simulation traffic models are often used to only simulate short periods of a day when traffic flows are greatest.

1.3 Application of this detailed approach can give appreciably different results from those predicted using more traditional methods. In particular, concentrations predicted using instantaneous emission factors vary across the study area to a much greater extent than those predicted using average-speed-based emission factors.

1.4 The two long-term roadside monitoring sites in the study area do not provide a robust basis for claiming that the instantaneous-based model performs more accurately than the average-speed-based model, but the instantaneous-based model certainly gives a more detailed picture and allows the effects of options to be tested which would not be possible using an average-speed-based model.

1.5 Of the options tested, the imposition of a 20 mph speed restriction is predicted to have the greatest benefits. This option is predicted to remove the need for the Air Quality Management Area. This finding is of interest, given that the average-speed-based emission factors predict a worsening of air quality associated with this measure.

2 Introduction

2.1 This report describes a detailed study into air quality around the Drift Bridge junction in Reigate and Banstead. The study has been carried out on behalf of Reigate and Banstead Borough Council (RBBC) by Air Quality Consultants Ltd., working in collaboration with SIAS Ltd.

2.2 A micro-simulation traffic model has been combined with an inventory of instantaneous vehicle emissions to predict traffic emissions from the local road network. A detailed dispersion model has then been used to predict concentrations around the junction. The study has been carried out for two key reasons:

- to develop a suitable method for translating the benefits of micro-simulation traffic models into air quality assessments; and
- to devise an appropriate strategy to improve air quality around the Drift Bridge junction.

2.3 The micro-simulation traffic model has determined the position of vehicles around the junction on a half-second time-step for (each half-second of) a typical week[1]. Vehicle emissions have then been calculated from these half-second data, and subsequently averaged over a 1-hour time-step. A key difference between this study and others which have used micro-simulation traffic data is that emissions have been extracted for every 2 m of the road network separately, with this network extended to cover each typical path of vehicle movements around the junction. This detail allows the spatial pattern of emissions, which is often lost in other studies which have combined micro-simulation traffic data and dispersion modelling, to be captured[2]. Another important difference is that the traffic modelling has covered all 24 hours of a typical weekday as well as Saturdays and Sundays, whereas micro-simulation traffic models are often used to only simulate short periods of a day when traffic flows are greatest.

2.4 This report describes the methodology, results, and conclusions of the assessment. It is accompanied by reports 74989 and 76356 by SIAS Ltd., which describes the traffic modelling.

[1] For 24 hours of a typical weekday, as well as for a Saturday and Sunday.

[2] The pairing of micro-simulation traffic models with instantaneous emissions models is frequently mentioned as being able to provide a very fine temporal resolution in emissions during peak hours, but is not typically used to provide a fine spatial resolution in concentrations.

3 Background

General Context

3.1 The main pollutant of concern associated with road traffic emissions is nitrogen dioxide, which is associated with adverse effects on human health. At high levels nitrogen dioxide causes inflammation of the airways. Long-term exposure may affect lung function and respiratory symptoms. Nitrogen dioxide also enhances the response to allergens in sensitive individuals (Defra, 2007). There is increasing evidence that exposure to nitrogen dioxide can lead to deaths (WHO, 2013).

3.2 The Government has established a set of air quality standards and objectives to protect human health. The 'standards' are set as concentrations below which effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of an individual pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of economic efficiency, practicability, technical feasibility and timescale. The objectives for use by local authorities are prescribed within the Air Quality Regulations, 2000, Statutory Instrument 928 (2000) and the Air Quality (England) (Amendment) Regulations 2002, Statutory Instrument 3043 (2002). The relevant objective is provided in Table 1.

Table 1: Relevant Air Quality Objective

Pollutant	Time Period	Objective
Nitrogen Dioxide	Annual mean	40 $\mu g/m^3$

3.3 The objectives for nitrogen dioxide were to be achieved by 2005, and continue to apply in all future years thereafter. The air quality objectives only apply where members of the public are likely to be regularly present for the averaging time of the objective (i.e. where people will be exposed to pollutants). For the annual mean objective, relevant exposure is mainly limited to residential properties, schools and hospitals.

3.4 Reigate and Banstead Borough Council (RBBC) has investigated air quality within its area as part of its responsibilities under the Local Air Quality Management regime. The Council operates a number of nitrogen dioxide monitoring sites using diffusion tubes prepared and analysed by Lambeth Scientific Services (using the 50% TEA in acetone method). These include two roadside diffusion tubes deployed close to the Driftway and Crossways properties, along Reigate Road (A240) and Fir Tree Road (A2022). There is also a diffusion tube located at an intermediate site along Grey Alders. Results for the years 2008 to 2012 are summarised in Table 2 and the sites are shown in Figure 1.

Table 2: Summary of Nitrogen Dioxide (NO_2) Diffusion Tube Monitoring (2008-2012) [a]

Site No.	Site Type	Location	Annual Mean (μg/m^3)				
			2008 [b]	2009 [b]	2010 [b]	2011 [c]	2012 [c]
RB21	Roadside	Opposite Drift Bridge Hotel, Reigate Road	**44.7**	**46.0**	**59.4**	38.6	**46.1**
RB22	Intermediate	Opposite 2 Grey Alders	22.5	24.6	24.7	19.8	25.6
RB106	Roadside	On one way sign, Crossways, Fir Tree Road	**41.6**	36.7	**41.0**	34.5	**40.8**
Objective			**40**				

[a] Exceedences of the objectives are shown in bold.

[b] Data taken from Progress Report 2011 (RBBC, 2011).

[c] Data provided by RBBC.

3.5 There are measured exceedences of the annual mean nitrogen dioxide objective at the roadside diffusion tubes, with higher concentrations measured along Reigate Road. There are no clear trends in monitoring results for the past five years. This contrasts with the expected decline due to the progressive introduction of new vehicles operating to more stringent standards.

3.6 In 2007, RBBC declared an Air Quality Management Area (AQMA) at the Driftways and Crossways properties for exceedences of the nitrogen dioxide annual mean objective. This AQMA is shown in Figure 1.

Background to Modelling Methods

3.7 Previous air quality modelling studies carried out on behalf of RBBC, which have covered the Drift Bridge junction, have been based on average-speed emission factors and used a combination of hour-by-hour and daily average measured traffic flows.

3.8 Nationally, there has been considerable recent interest in the use of micro-simulation traffic models and instantaneous emissions models within air quality assessments. Typically, such studies suffer from one or more of the following limitations:

- the traffic models used are only run for short periods of a single day, making it difficult to predict annual mean pollution concentrations;
- the calculated emissions are aggregated over long sections of road, making it difficult to predict roadside concentrations (which can vary appreciably over relatively short distances);

- the traffic models are configured in such a way that emissions which occur within a junction are assigned to the links either side of the junction rather than to specific turning movements; or
- detailed dispersion modelling is not carried out.

3.9 This current study has attempted to overcome these limitations using the methodology set out in the next section.

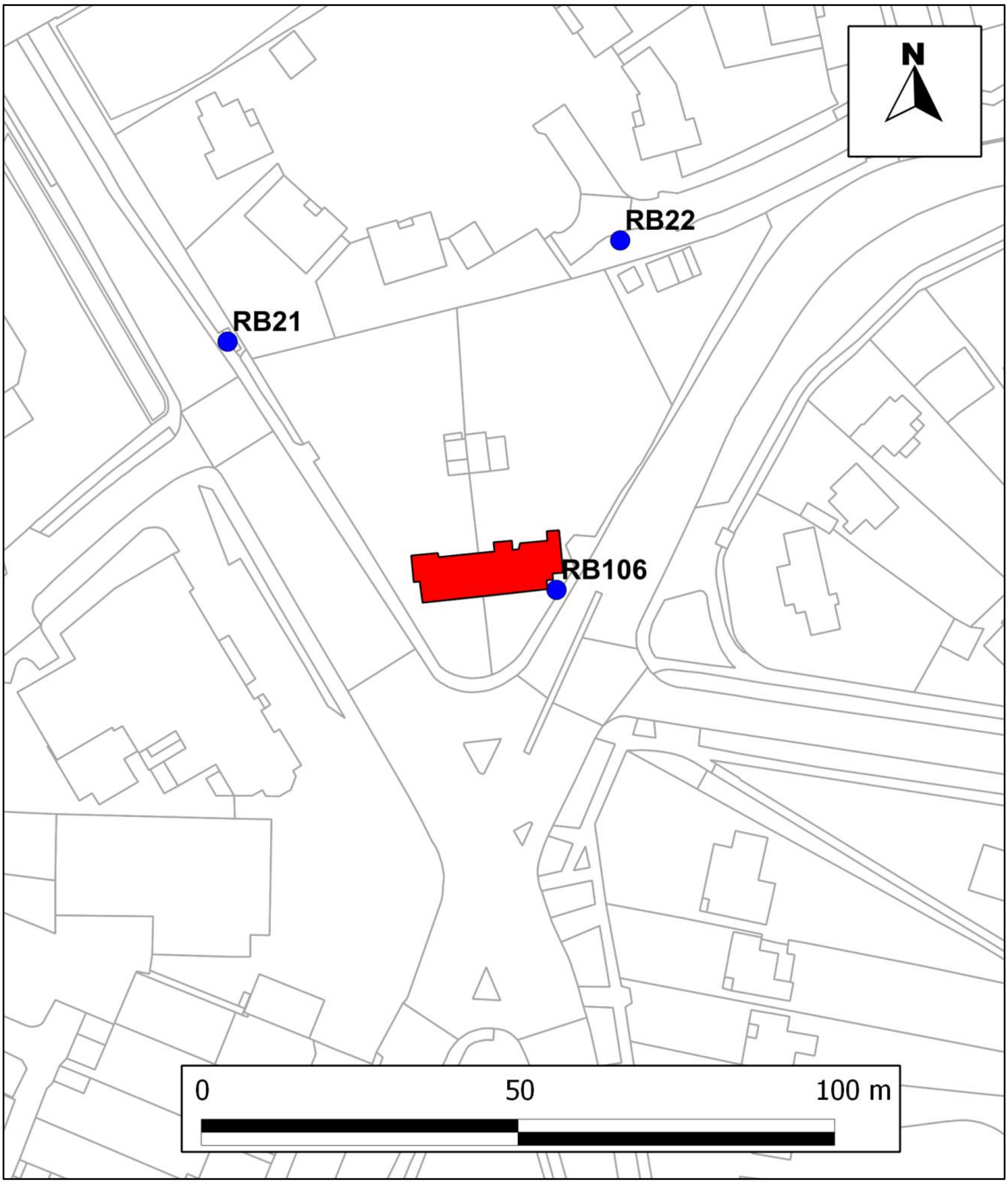

Figure 1: Drift Bridge AQMA (Red) and Diffusion Tube Monitoring Sites (Blue)

4 Methodology

Traffic and Emissions Calculations

4.1 SIAS Ltd. has modelled traffic travelling through the junction of Reigate Road and Fir Tree Road using the S-Paramics micro-simulation software, in conjunction with the ancillary PC-MOVA package to allow MOVA control to be accurately represented in the model. Transport Scotland's Analysis of Instantaneous Road Emissions (AIRE) micro-simulation emissions tool has then been used to provide nitrogen oxides emission rates from the modelled road traffic.

4.2 AIRE allows the effects of factors such as acceleration to be predicted directly, rather than indirectly, as is the case with 'average speed' emission factors (such as included in Defra's Emissions Factor Toolkit (EFT). It is, however, constrained in terms of vehicle fleets. New vehicles registered in the UK have to meet progressively tighter European type approval emissions categories, referred to as "Euro" standards. AIRE, in its current formulation, does not contain emission factors for new vehicles which conform to the latest Euro standards. However, it is widely recognised that the on-road performance of many modern vehicles is often no better than that of earlier models (Carslaw et al., 2011). Since the model has only been used to predict current-year emissions, and since the model results have been verified against local monitoring (see Sections 5.13 to 5.17), it is considered that AIRE is suitable for this assessment.

4.3 Rather than use the default vehicle fleet composition in AIRE, the vehicle fleet composition for urban non-London areas set in EFTv5.2 was adjusted based on the ratio of vehicle licensing statistics for Reigate and Banstead to those for Great Britain. This was then imported into AIRE.

4.4 SIAS Ltd. provided nitrogen oxides (NOx) emissions for every two metre section of each lane of Reigate Road, Fir Tree Road, College Road, Ruden Way and Warren Road, as well as the typical trajectories taken by vehicles moving through the junctions of these roads. These road sections are shown in Figure 2. The emissions data have been provided separately for every 5 minutes and for every hour of a typical weekday, a typical Saturday, and a typical Sunday. In addition, SIAS Ltd provided the hour-by-hour traffic flows and average speeds on each road section.

4.5 SIAS Ltd. carried out detailed junction surveys during 2012 and the calculated emissions are thus for 2012. SIAS report 74989 provides further details of the traffic modelling and emissions calculations.

Figure 2: Modelled Road Network

Dispersion Modelling

4.6 Predictions have been carried out using the ADMS-Roads dispersion model (v3.1). When the project began, 2011 was the most recent full year of diffusion tube and meteorology data and it was decided that the model would be run using 2011 meteorology. Whilst the traffic and AIRE modelling was carried out for 2012, the difference between these two years is likely to be negligible, particularly taking account of the ability of AIRE to account for more recent Euro classes.

4.7 The model has been run using hour-by-hour meteorological data collected during 2011 at Gatwick Airport. Figure 3 shows the wind direction and speed over six years, and shows that 2011 wind data are representative of those in most other years. The surface roughness has been set to 0.5 m to represent an open suburban setting.

4.8 All of the 2m link segments were input into the model as 2 m long straight lines. Each line was assigned a width of three meters. The emissions and traffic flows provided by SIAS were incorporated into the ADMS model using '.hfc' files, to simulate the temporal variation of emissions. It has been assumed that all bank holidays experienced the same emissions as Sundays.

Receptors

4.9 The model was run to predict the local road contribution to annual mean nitrogen oxides ('road-NOx') concentrations at the 109 receptors shown in Figure 4. In addition, concentrations have been predicted across a grid of 12,000 receptors. The results for these 12,000 receptors were used to generate concentration isopleths. The grid was made up of a 2 m x 2 m Cartesian grid within 20 m of the main roads, a 4 m x 4 m Cartesian grid within 50 m of the main roads, and 6 m x 6 m Cartesian grid over the rest of the study area.

Model Scenarios

4.10 The model was run for a number of different scenarios, initially to test the method and subsequently to investigate different traffic management options.

4.11 To test the method, the following scenarios have been modelled using the baseline traffic and emissions data:

- 1-hour AIRE emission profiles.

  For this test, the hour-by-hour emissions for each 2 m road section were taken directly from AIRE and input into ADMS by way of '.hfc' files.

- 1-hour Emission Factor Toolkit (EFT) emission profiles.

For this test, the hour-by-hour traffic flows and average speeds from the S-Paramics model for each 2 m road section were input into EFT version 5.2[3] (Defra, 2014b). The resultant average-speed-based hour-by-hour emissions were then input into ADMS by way of '.hfc' files.

[3] In July 2014, Defra issued a revised set of tools, comprising new vehicle emission factors, associated background concentration maps and NOx to NO_2 calculator. This assessment was carried out before the new tools were issued. The changes between the tools used here and those recently issued would not affect the conclusions of this assessment

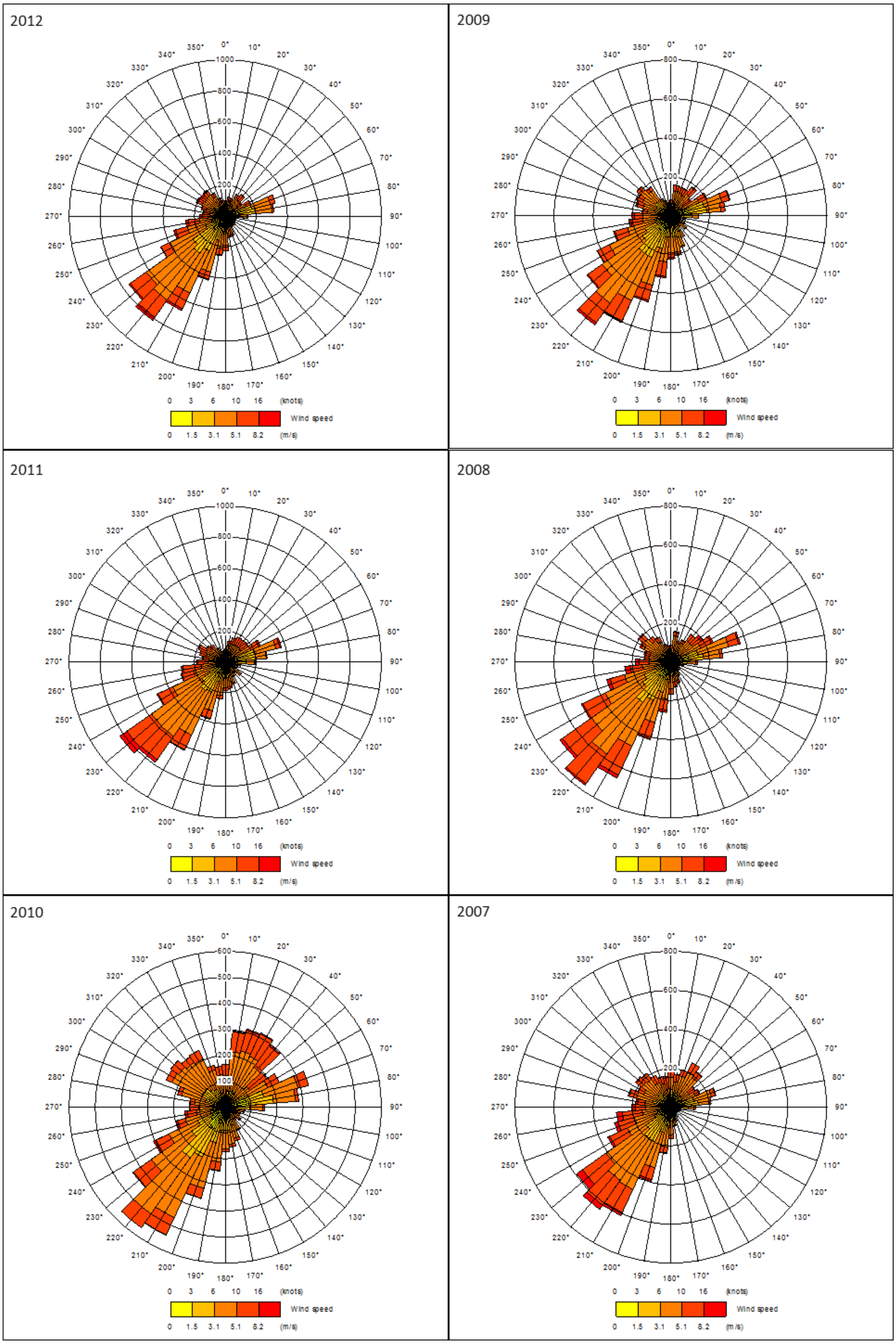

Figure 3: Wind Roses for Gatwick Airport over Six Years

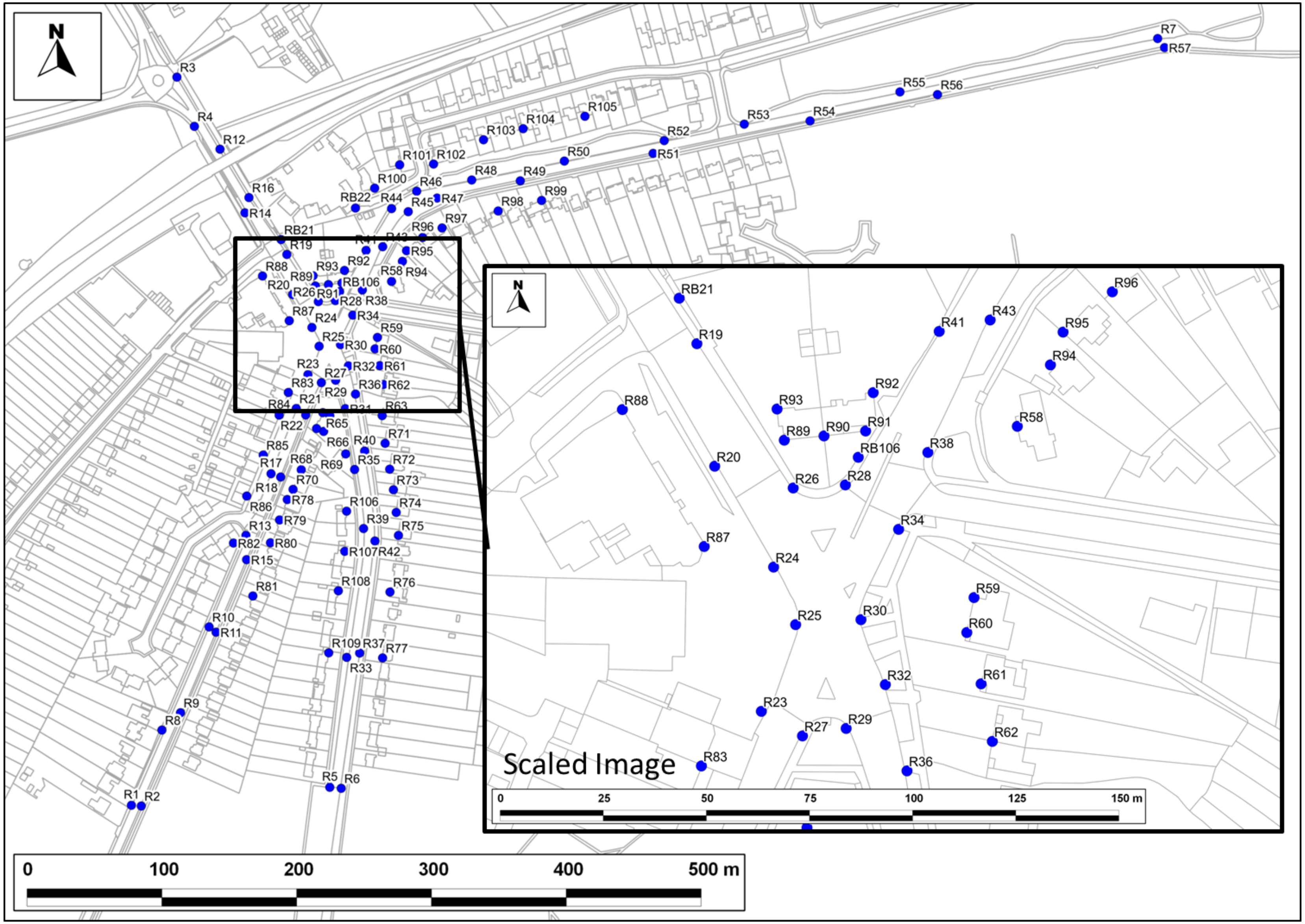

Figure 4: Receptor Locations

- 5-minute AIRE emission profiles.

  Because the meteorological data used were only collected on an hour-by-hour basis, it was necessary to assume hour-specific meteorology coinciding with the twelve 5-minute-specific emissions. This was achieved simply by running ADMS 12 times, so that the first model run used emissions for the first 5-minutes of each hour of the week, and the second run used the second 5-minute period etc. While it was not envisaged that this test would show significantly different results than the hour-by-hour tests, it was carried out for the sake of completeness and to ensure that averaging issues did not affect the results.

- 1-hour AIRE emission profiles with emissions averaged over whole road lengths.

  For this test, the hour-by-hour emissions were simply averaged across the entire length of each road link, rather than for each 2 metre section separately.

- 1-hour EFT emission profiles calculated with averaged speeds over whole road lengths.

  The hour-by-hour emissions for each 2 metre section were calculated using the AADT flow from the S-Paramics output for each 2 metre section and the average speed across the entire length of each road.

- Typical model setup using EFT emissions (Non-micro-simulation).

  The Annual Average Daily Traffic (AADT) flow was calculated from the S-Paramics outputs for a point at each arm of each junction. DfT data were then used to factor the calculated AADTs to represent hour-by-hour flows. Turning movements around the junction were estimated following the approach described in the Further Assessment for Drift Bridge (RBBC, 2007). AADT speeds were estimated based on current speed limits, with slower sections included within 25 m of the junction than further away.

4.12 To investigate different traffic management options, the modelling was based on the 1-hour AIRE emissions profiles using 2 m link lengths. The following scenarios were modelled, with the only differences from the 1-hour AIRE emissions test for the baseline scenario being the inputs to the micro-simulation traffic model:

- Option 1 – Introduce a 20 mph speed limit;
- Option 2 – Remove southbound left-hand lane of Reigate Road (north of the junction); and
- Option 3 – Extended green traffic light for Reigate Road.

Background Concentrations and Post-processing

4.13 Only emissions from the roads shown in Figure 2 have been modelled explicitly. The contribution from other sources has been included by way of the national background pollution maps published by Defra (2014a)[3]. These cover the whole country on a 1x1 km grid.

4.14 ADMS-Roads was used to predict road-NOx concentrations. These were combined with the background NO_2 concentration mentioned above within the NOx to NO_2 calculator available on the Defra LAQM Support website (Defra, 2014b)[3]. The traffic mix within the calculator has been set to "All other urban UK traffic", which is considered suitable for the study area.

5 Discussion and Testing of the Method

Effect of Splitting the Road Network into 2 m Sections

Potential Benefits of Fine Spatial Resolution in the Input Data

5.1 To understand the benefits of breaking the road network into short sections, it is necessary to understand the relative importance of vehicle emissions at different points along a road. In order to demonstrate this, a 500 m road was split into 10 m segments, with identical emissions assigned to each segment. A single receptor was positioned 3m from the edge of the road, half way along its length. The relative contribution of each 10 m segment is shown in Figure 5[4] and Figure 6. The 20 m of road within 10 m of the receptor contributes more than 50% to the total concentration arising from the 500 m long road. In the case of emissions predicted using AIRE, which can vary appreciably within a few metres along a section of road[5], the implication of Figure 5 is that the only way to accurately account for the effects of small-scale variations in emissions on nearby receptors is to break the road network down into short sections.

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4 The predicted concentrations are not evenly distributed in either road direction away from the receptor due to the meteorology used in the model.

5 For example, emissions are predicted to be higher in locations where vehicles tend to accelerate rapidly.

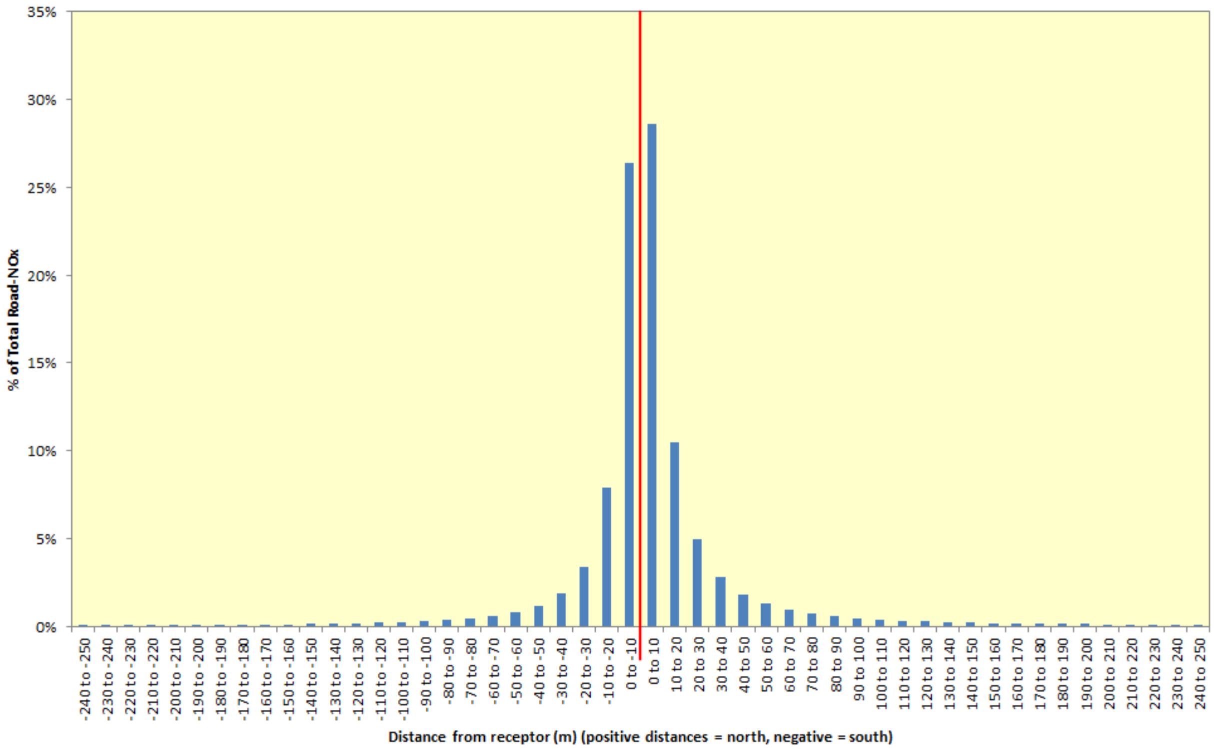

Figure 5: **Histogram of Relative Contribution of Road Emissions with Distance Along the Road**

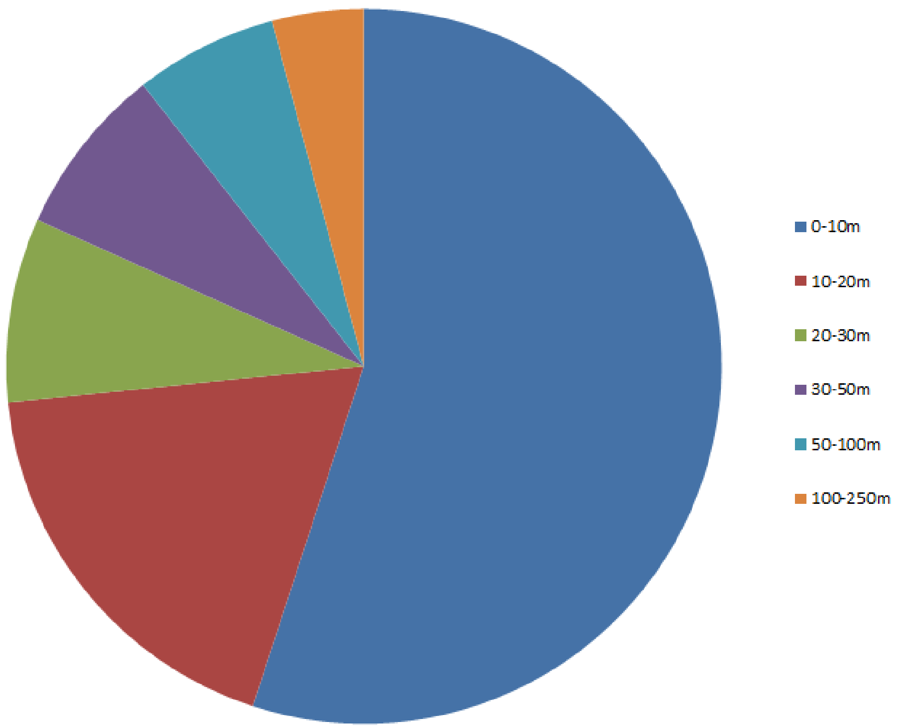

Figure 6: **Pie Chart of Relative Contribution of Road Emissions with Distance Along the Road**

Potential Disbenefits of Fine Spatial Resolution in the Input Data

5.2 The simple act of splitting a road into multiple sections can change the concentrations predicted using ADMS-Roads. This is demonstrated in Figure 7, which compares predicted annual mean road-NOx concentrations at receptors either side of a 900 m long road (a straight road running north-south with receptors 1.5 m and 10 m either side at 5 m intervals). The model was run first as a single road and again as 450 x 2m links. The differences shown in Figure 7 appear not to relate to rounding in the results files, and are more likely to reflect the way in which sources and concentrations are treated in the model itself. It is considered that the differences shown in Figure 7 are relatively small and do not prohibit the use of 2 m link sections in the model.

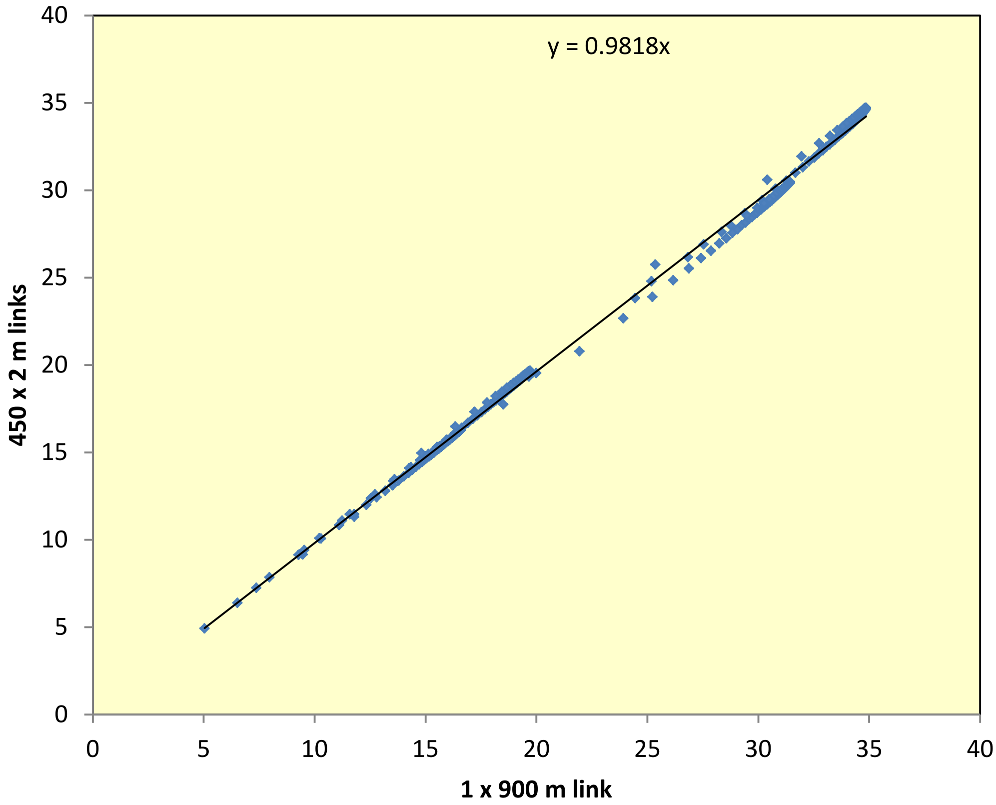

Figure 7: Influence of Link Length on Predicted Road-NOx (µg/m^3)

Comparison of 1-hour and 5-minute emission profiles

5.3 AIRE has been used to calculate emissions for every half-second during a weekday, Saturday and Sunday. These emissions have then been aggregated into: a) average hourly emissions (for each hour of the week), and b) average emissions during each 5-minute period in a week. The most appropriate meteorological data to use represent hourly averages. Concentrations have been predicted at the 109 receptors shown in Figure 4, first assigning the hourly emissions to the hourly meteorological data, and second running the model 12 times, each time assigning a different set of five-minute emissions to the whole hour of meteorology (for example, so that the first model run used emissions for the first 5-minutes of each hour of the week, and the second run used the second 5-minute period etc.). The results from the 12 model runs were then summed. In practice, it can be surmised, without running the model, that the only differences between these two tests will relate to rounding. Nevertheless, the tests were carried out and the results are set out in Figure 8. Subsequent modelling has been carried out using the 1-hour average data.

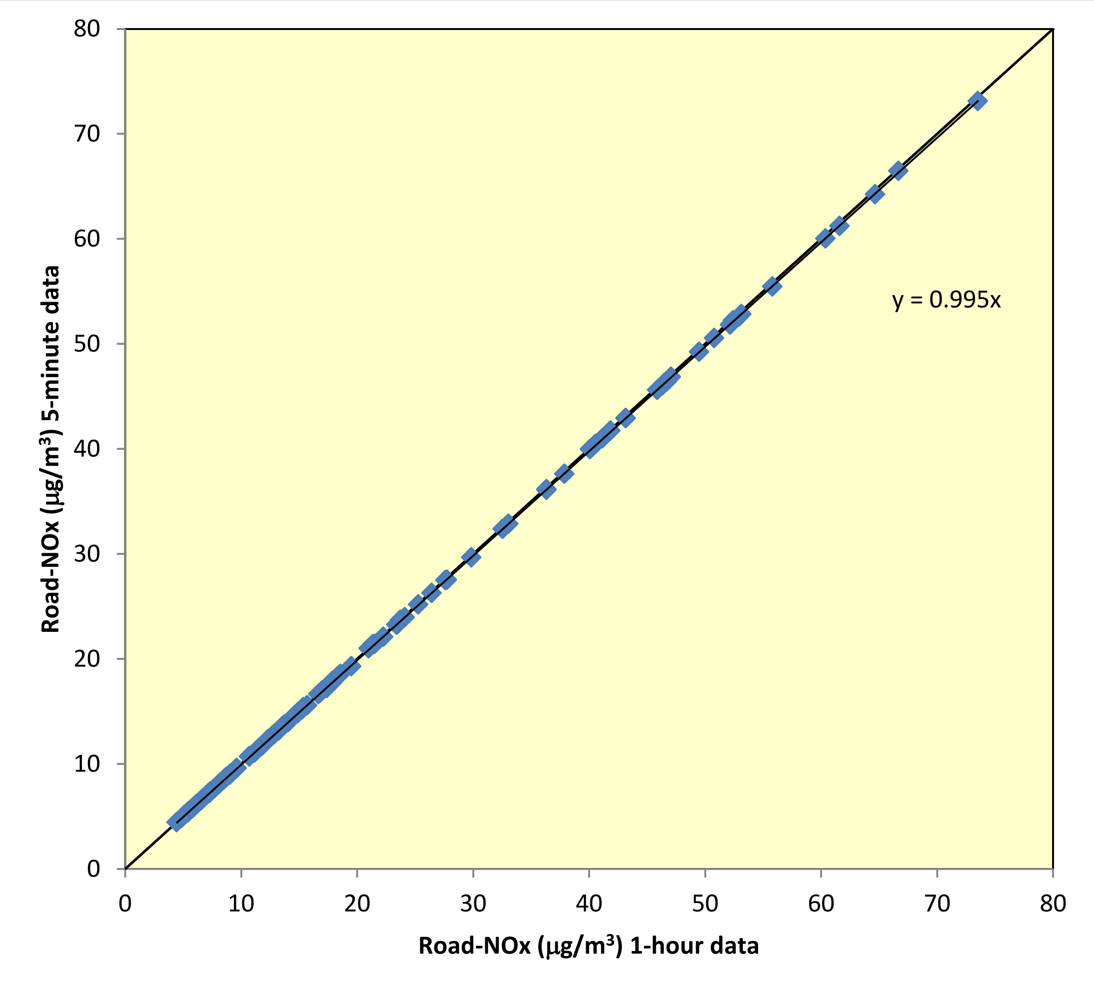

Figure 8: Predicted Annual Mean Road-NOx Based on 1-hour vs 5-minute Emissions

Emissions Calculations

5.4 This study has focused on using emissions calculated using the AIRE model. More typically, dispersion modelling studies of UK traffic emissions use the EFT published by Defra (2014a). This toolkit provides emissions for different vehicle types which vary based upon the average vehicle speed. In principal, these speeds relate to the average speed of a vehicle during an entire journey but the EFT is typically used with speeds averaged across multiple vehicles over a short stretch of road. An important point is that a given average speed can potentially be achieved by many different patterns of driving. For example, for an average speed of 20 kph, the EFT assumes a reasonable amount of stop-start driving. In practice, the same average speed could be achieved by driving at a constant 20 kph, by braking from a faster speed, or accelerating up to a faster speed.

5.5 While the EFT is constrained to give a constant emission rate from each vehicle type driving at a given speed, AIRE contains more flexibility and will give a different emission rate depending, for example, upon the amount of acceleration and idling which makes up the given average.

5.6 A very large number of urban dispersion modelling studies carried out in the UK using the EFT have underestimated the road component of NOx concentrations. Defra requires that model results are verified against local monitoring and, if required, adjusted to match the monitoring. The application of model 'adjustment factors' is thus widespread (and, many argue, necessary) in order to prevent models from under-predicting. Others argue that such an approach may cause model results to match measurements for the wrong reasons and that, away from monitoring sites, there can be little confidence in the results.

5.7 While the AIRE emission predictions have the potential to be more precise than those from the EFT, there is no apparent reason to expect them to be more accurate on average. Furthermore, while there is a large body of evidence supporting the use of the EFT for local air quality modelling, there is much less evidence as to the validity of AIRE.

5.8 It should also be noted that no account has been taken of variations in primary nitrogen dioxide emissions associated with different driving conditions. All nitrogen dioxide predictions in this study have been calculated using Defra's NOx to NO_2 calculator (Defra, 2014b) which uses the same primary nitrogen dioxide fractions for all roads in the study area. In practice, there is some evidence that primary nitrogen dioxide emissions are higher during heavy acceleration phases and as a result the differences between nitrogen dioxide predictions made using average-speed and instantaneous models could be even greater if the instantaneous model was also used to predict receptor-specific primary nitrogen dioxide proportions.

Comparison of EFT and AIRE

5.9 The hour-by-hour AIRE emissions data (for each 2 m road section) have been used with ADMS-Roads to predict annual mean road-NOx concentrations at the receptor locations shown in Figure 4.

5.10 The hour-by-hour traffic flows (for each 2 m link) and speeds have been taken from the S-Paramics model and entered into the EFT (Version 5.2c[3]). The EFT-based emissions have been run through ADMS-Roads in the same way as the AIRE data.

5.11 Figure 9 compares the annual average road-NOx at each receptor calculated using the 1-hour AIRE data and EFT data. There is a much greater range in the AIRE data, which is to be expected since the EFT averages out the effects of factors such as acceleration which AIRE treats explicitly.

The receptor where the EFT predicts the highest concentrations is only mid-range within the AIRE dataset. If the AIRE results are correct, then this indicates that the EFT-based modelling has missed those locations where concentrations are highest. In particular, the AIRE-based results predict much higher concentrations at R3, R28, and R30 than the EFT-based results. These are all very close to junctions (in the case of R3, the junction with College Road). The values in Figure 9 are tabulated in Appendix A1.

5.12 The 'flattened' shape of the scatter plot in Figure 9 is potentially significant, since many studies using average-speed emissions have found a similar shape when comparing predicted and measured concentrations (for example, see Appendix A2).

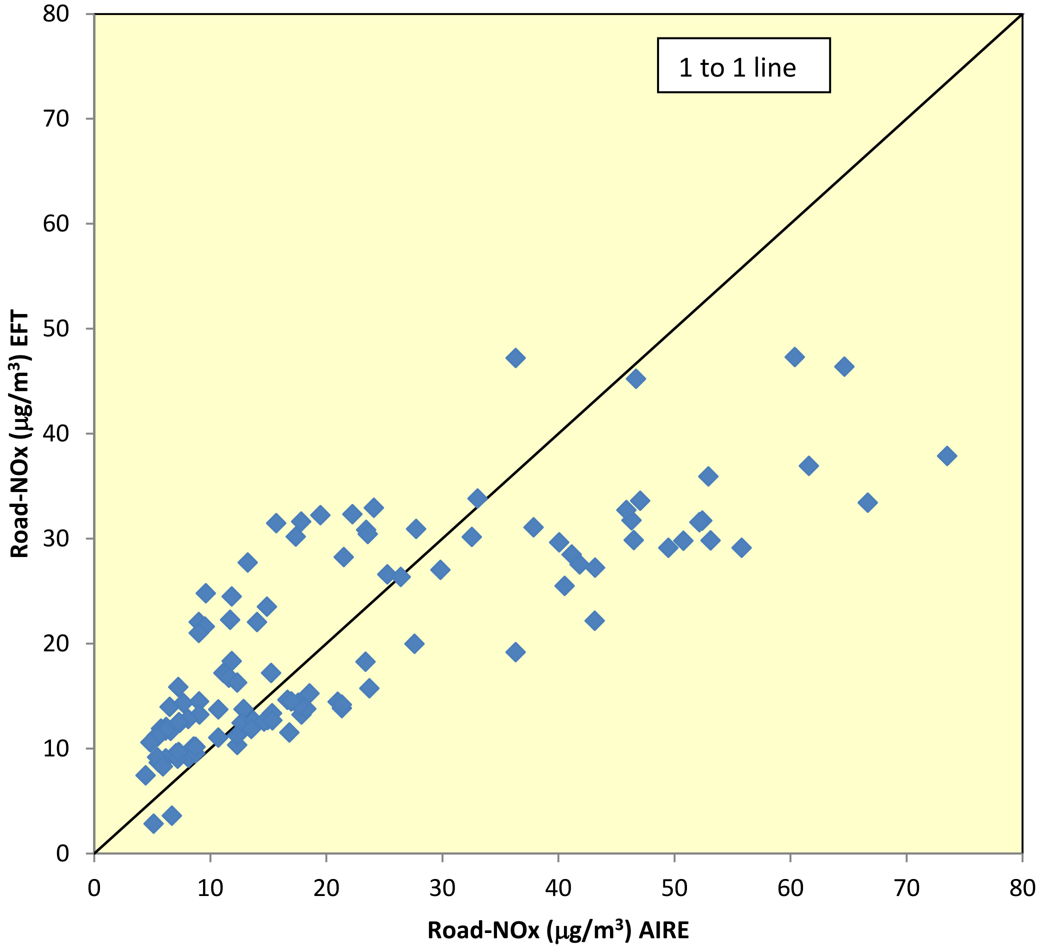

Figure 9: Predicted Annual Mean Road-NOx Based on AIRE vs EFT

Comparison of EFT and AIRE against Local Measurements

5.13 Road-NOx concentrations have also been modelled at the two roadside diffusion tube monitoring sites (RB21 and RB106). In order to compare predicted road-NOx with the equivalent measurements, 'measured' road-NOx has been calculated from the measured NO_2 concentrations and the predicted background NO_2 concentration using the NOx from NO_2 calculator available on the Defra LAQM Support website (Defra, 2014b)[3].

5.14 Figure 10 shows how the results predicted using EFT and AIRE compare with the roadside measurements. The further the data point from the 1:1 line, the more deviation there is between the model prediction and the measurement. As well as the 1:1 line, the plots include lines indicating 25% under-read and over-read. The 25% statistic has been used following the approach given by Defra (2009) for modelling carried out by local authorities. This requires that the majority of data points lie within +/- 25%. The CAFE Directive (2008) requires that models used for national-scale EU reporting of annual means can predict 90% of data within +/- 30% for NOx.

5.15 The EFT results display the characteristic bias that is often expected in this type of setting, with the modelled concentrations underestimating the measurements. The AIRE results do not display this; the modelled concentration underestimates at one diffusion tube site and overestimates at the other.

5.16 Defra describes a method of adjusting model results to calibrate them with local measurements (Defra, 2009). The EFT results have been adjusted by multiplying by 1.342 (which is the slope of the line in Figure 10 A), while the AIRE results have been provisionally adjusted by multiplying by 0.868 (which is the slope of the line in Figure 10 B). The total nitrogen dioxide concentrations have then been determined by combining the adjusted modelled road-NOx concentrations with the predicted background NO_2 concentration within the NOx from NO_2 calculator. Secondary adjustment factors (of 1.002 for the EFT data and 1.035 for the AIRE data) have then been determined by comparing the predicted against the measured NO_2 concentrations and applying the best-fit line (forced through zero) as the adjustment factor.

5.17 The adjusted NO_2 results are shown in Figure 11. Once the results are adjusted, the EFT results compare better with the measured values than the AIRE results. It is, however, noted that only limited conclusions can be drawn from a comparison against just two monitors. Because Figure 9 showed that AIRE predicts higher concentrations than the EFT in some locations but lower concentrations in others, it can be inferred that the precise positions of the monitors will have a strong bearing on how the two models compare in terms of reproducing the measurements. It should also be borne in mind that the diffusion tube results themselves will have an inherent degree of uncertainty. Overall, it is considered that the performance of both adjusted models is not unreasonable. It is also, however, noted that there is little basis for applying the adjustment factor of 0.868 (and subsequently 1.035) to the AIRE results. The AIRE data have therefore not been adjusted in any of the subsequent analyses. The performance of the unadjusted AIRE dataset in terms of total NO_2 is shown in Figure 12. It is largely the same as the adjusted dataset in this comparison.

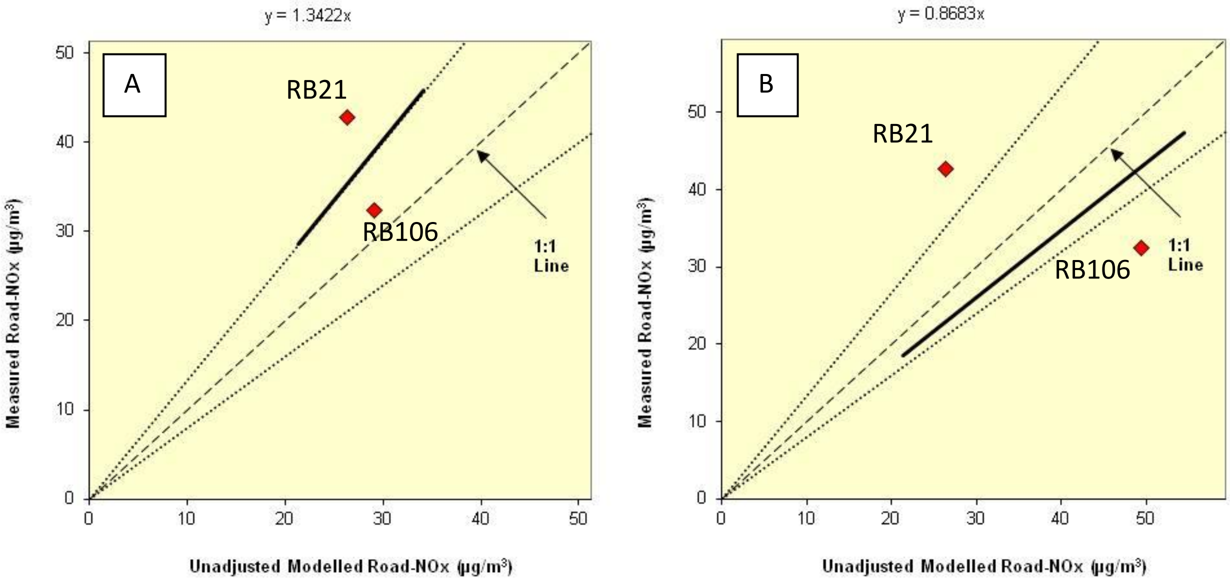

Figure 10: Measured vs Predicted Road-NOx (A) using EFT and (B) using AIRE

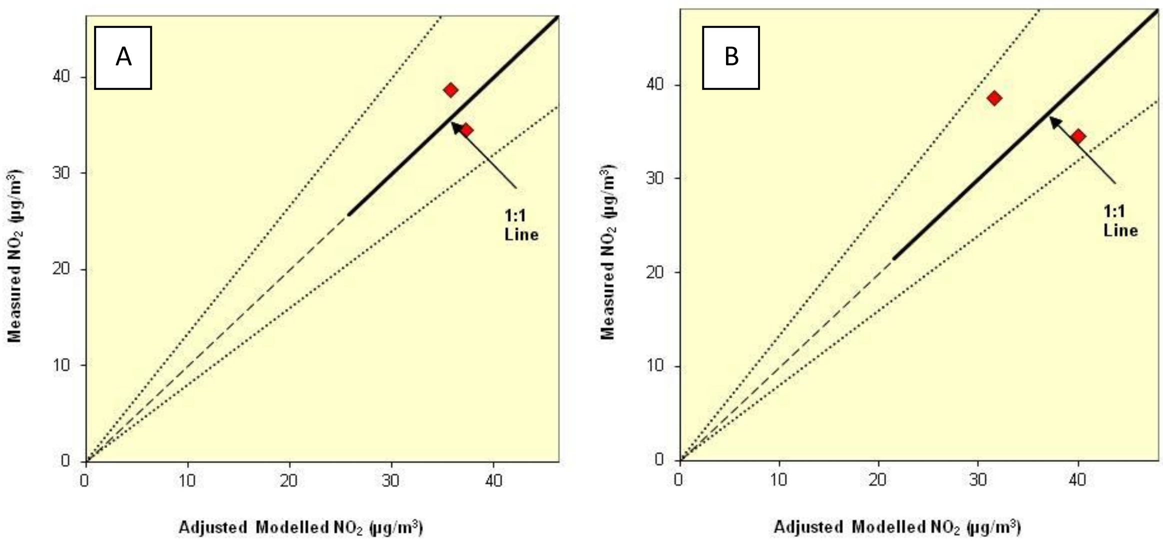

Figure 11: Measured vs Predicted Total NO_2 (A) using (measurement-adjusted) EFT and (B) using (measurement-adjusted) AIRE

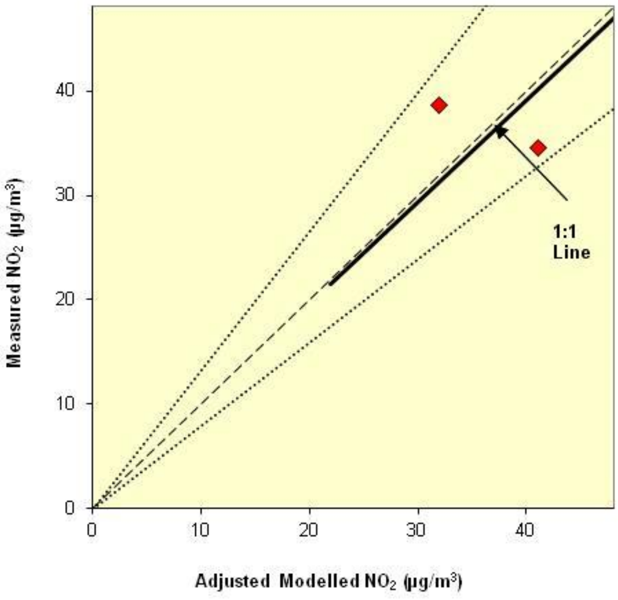

Figure 12: Measured vs Predicted Total NO_2 using Unadjusted AIRE Data

5.18 One implication of the results in this study is that, assuming that the along-road variation in road-NOx concentrations predicted by AIRE is correct, then the traditional approach of model verification and adjustment recommended by Defra (Defra, 2009) will inevitably be constrained when applied to average-speed-based models. The implication is that road-NOx concentrations will vary appreciably along a short section of road and so the precise position of the monitor along the road will define the adjustment that is subsequently applied across the entire road network.

Comparison of Adjusted EFT against Unadjusted AIRE

5.19 Figure 13 compares the unadjusted AIRE results for Road-NOx with the equivalent data for the adjusted EFT for all of the receptors. Figure 13 thus reproduces Figure 9, but uses adjusted EFT results instead of unadjusted data. After adjustment, the EFT predicts higher concentrations than AIRE at a large number of receptors, which are typically the receptors where both models predict lower concentrations. AIRE continues to predict higher concentrations than the EFT at some locations, which are typically those where both models predict higher concentrations. As noted in paragraph 5.11, this fits in with what might be expected, since the EFT is constrained to assign a single emission rate to many different locations at which AIRE will predict different emissions.

5.20 In order to demonstrate this, Figure 14, shows an approximate transect of receptors stretching northwest from the junction. It also labels a number of the road links nearest to these receptors (as Roads 24, 17, 18, 10, 22, and 45)[6]. Figure 15 shows how the modelled results using the

[6] The results (from running the 2 m road sections as individual sources) have been aggregated, rather than aggregating the model input data.

(adjusted) EFT compare with those from (unadjusted) AIRE. The EFT predicts consistently higher emissions than AIRE from Road 10. A possible explanation for this is that vehicles tend to spend more time idling and decelerating (phases associated with relatively low emissions) than is implied by their average speed in the EFT. Conversely, the AIRE results from Road 18 are higher than the EFT results at most receptors. This may suggest that emissions from vehicles in this lane are more affected by acceleration than is implied by their average speed in the EFT.

5.21 On the assumption that S-Paramics correctly predicts flow patterns, including acceleration rates, and that AIRE correctly apportions emissions across these flow patterns, it would be expected that the AIRE results would be more precise and more accurate than the EFT data. It is not within the scope of this report to the relative merits of different traffic models or how they treat acceleration profiles; although this is discussed further in Paragraph 7.16. Based on the evidence presented here, it can be concluded that S-Paramics, used with AIRE, has the potential to give a more precise spatial description of concentrations around the junction than would be possible using the EFT.

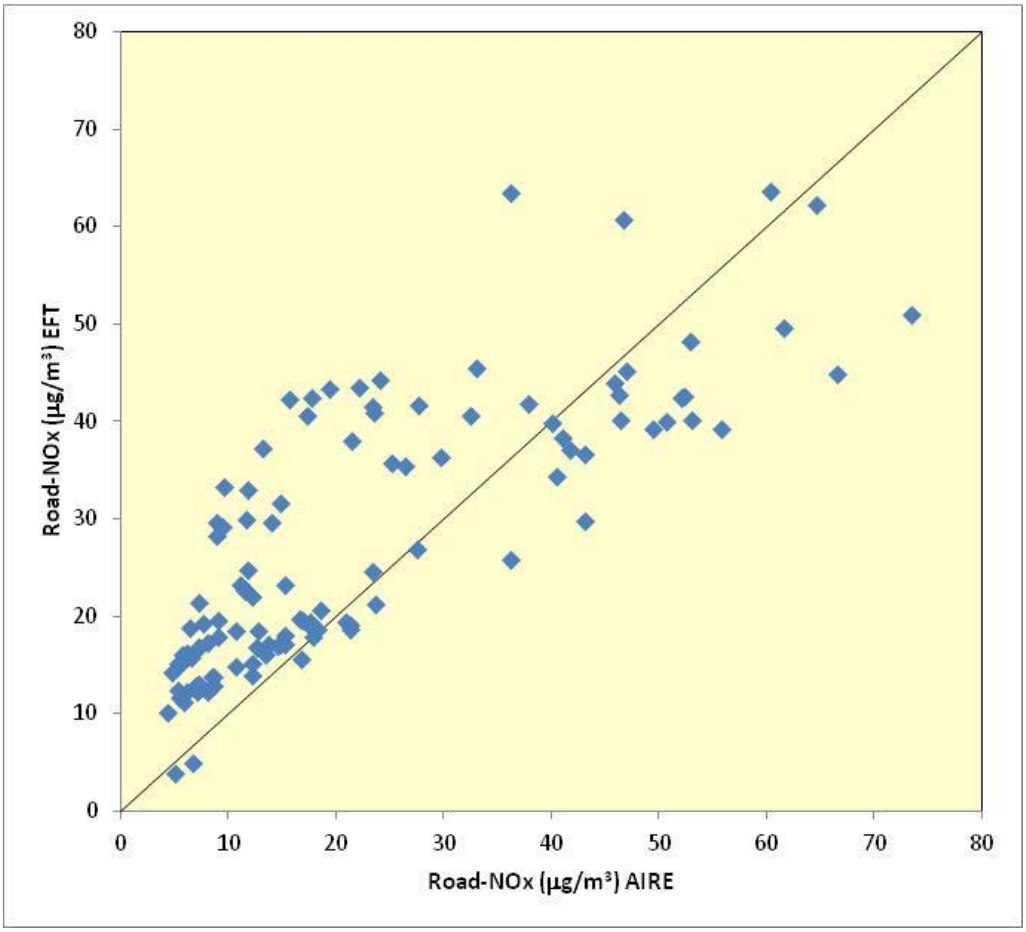

Figure 13: Predicted Annual Mean Road-NOx Based on Unadjusted AIRE vs Adjusted EFT

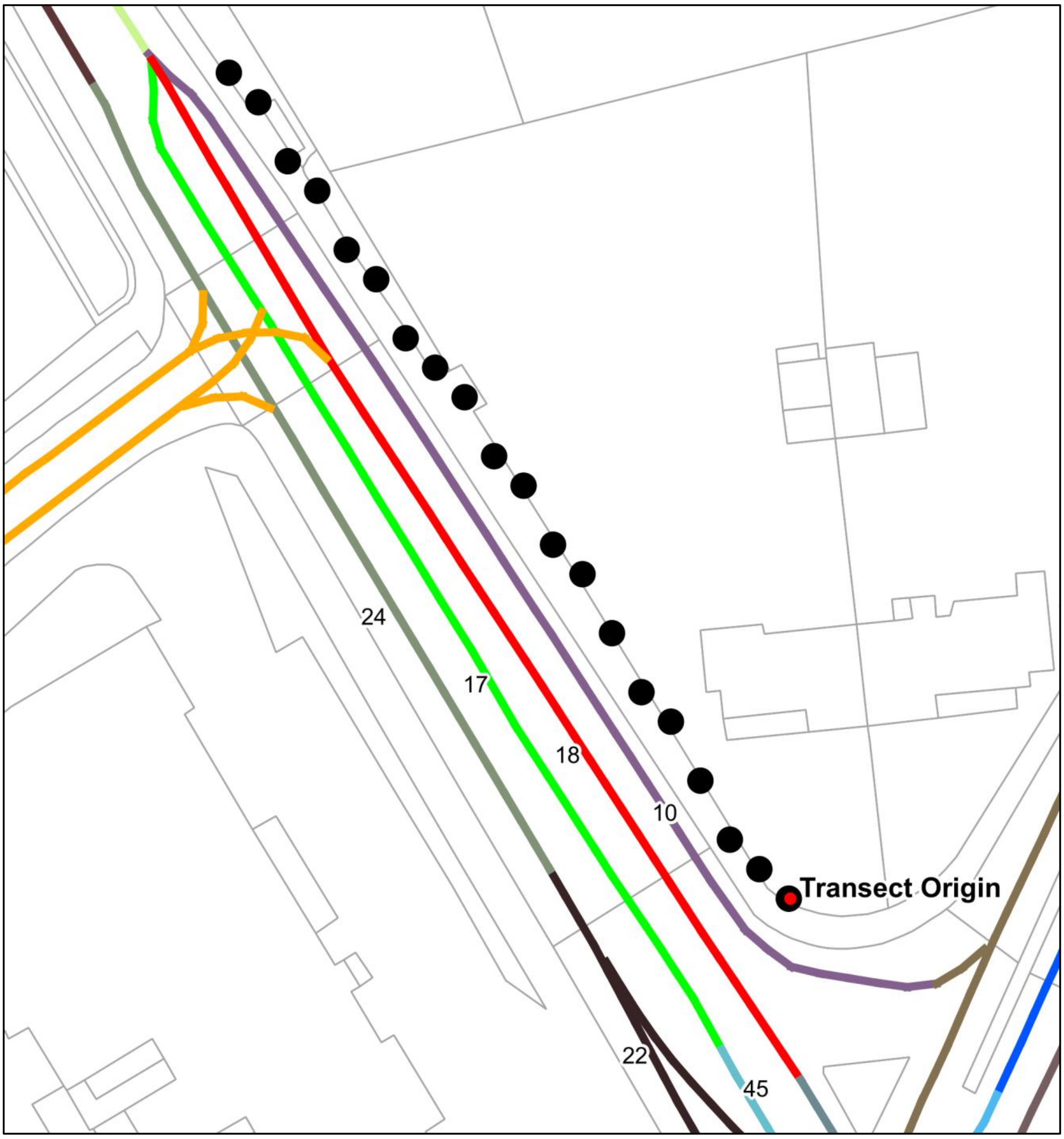

Figure 14: Transect of Receptors (Black Dots) Along Eastern Pavement of Reigate Road With Adjacent Road Sections

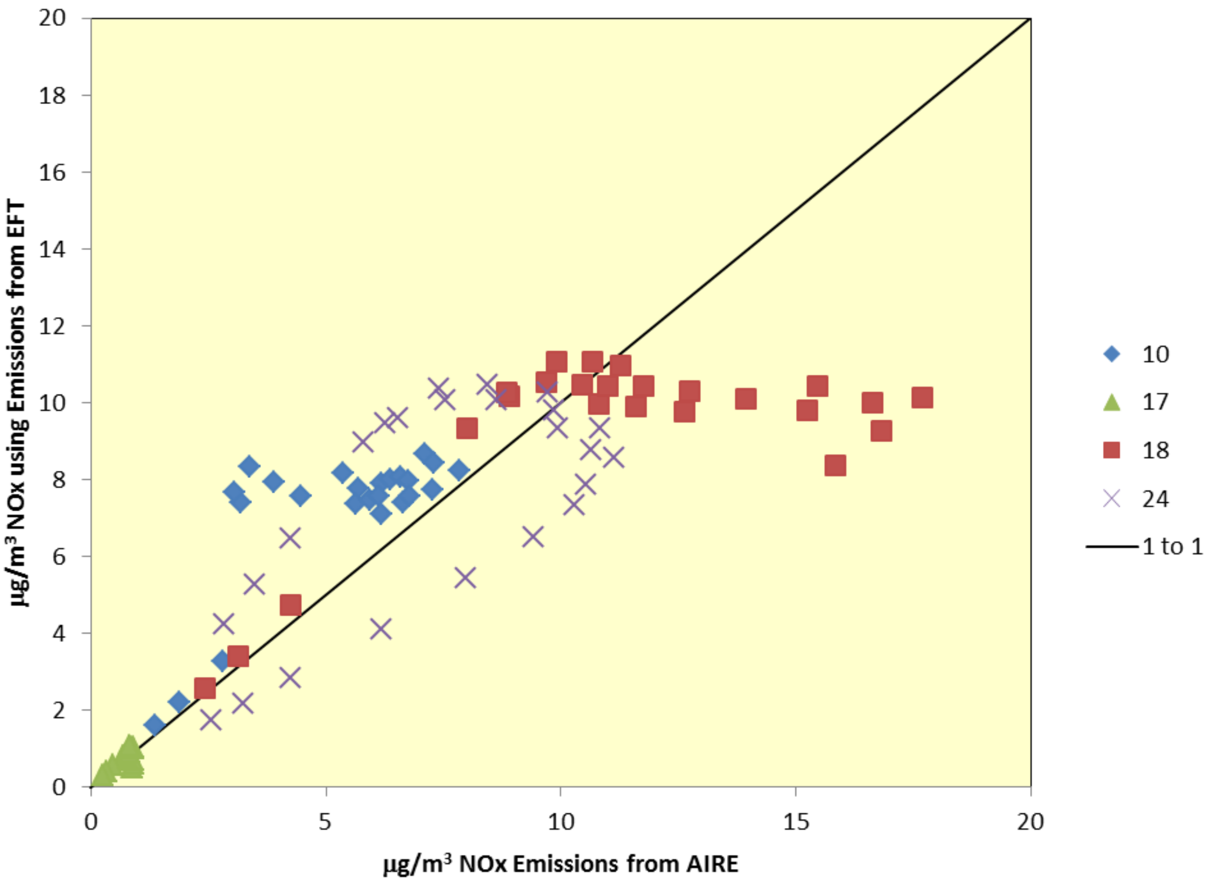

Figure 15: Predicted Annual Mean Road-NOx by Source, based on Unadjusted AIRE vs the adjusted EFT

Level of Detail in the Traffic Flows

5.22 The comparisons given above focus on how emissions are calculated, with the same traffic data used in all model configurations. In practice, the way in which S-Paramics was run for this study provides added detail over and above what would typically be available for a dispersion modelling study. For example, Table 3 compares the data available here with those available for the Further Assessment (FA) for the Drift Bridge AQMA submitted to Defra (RBBC, 2007).

Table 3: Differences in Availability of Traffic Data Comparing this Study with the FA (RBBC, 2007)

	Data available from S-Paramics	Data available to the FA
Spatial Detail	Direction-specific flows for each lane	Aggregated 2-way flows for each arm
	Detailed turning movement around the junction	Assumed turning movement based on the relative flows on each arm combined with local knowledge
	Separate flows / speeds for each 2 m section of road	Flows for entire arm, with estimated speeds slowed in the vicinity of the junction
Temporal Detail	Hour-by-hour traffic flows	AADT flows combined with local ATC data to generate a single weekly flow profile (i.e. the same flow profile assigned to all roads)

5.23 In order to demonstrate the combined effects of the differences in Table 3, concentrations of road-NOx have been predicted using a simple model setup (that would typically be achieved without any micro-simulation data). Traffic speeds have been estimated based on professional judgement, taking account of the road layout, speed limits and the proximity to a junction. The S-Paramics micro-simulation flow along each 2 m parallel segment of each lane for the start of each road have been combined and taken as the AADT flow for each road. The percentages of vehicle types have been calculated in the same way. Turning movements around the junction have been calculated based on the AADTs on the junction arms, apportioned by the relative flows in the FA.

5.24 Concentrations of road-NOx have then been predicted at all of the receptor locations, as well as for a grid of receptors covering the whole study area.

5.25 The simple scenario has been verified against the two local roadside diffusion tube monitors using the same approach set out in paragraph 5.16. A primary adjustment factor of 1.628 has been derived and applied to the predicted road-NOx concentrations. A secondary adjustment factor of 1.013 has been applied.

5.26 Table A1.1 in Appendix A1 tabulates the receptor results. Figure 16 shows the difference in predicted nitrogen dioxide concentrations between this basic model configuration and the equivalent modelling based on 1-hour AIRE micro-simulation emission profiles. There are some large differences (up to 19 µg/m^3) between the scenarios but very little change at the AQMA (<2 µg/m^3). The simple scenario predicts much lower concentrations along Reigate Road near to College Road, which is likely to be due to the model not taking account of the acceleration away from the roundabout, whereas the AIRE emission profiles do allow for acceleration. Similarly, the simple scenario also predicts slightly lower concentrations at the junction near the AQMA which is also likely to be due to acceleration. The simple scenario also predicts higher concentrations along Fir Tree Road and other sections of Reigate Road. Assuming the micro-simulation data to be correct, this would mean that typical modelling would under-predict emissions where acceleration occurs and may over-predict concentrations in other locations.

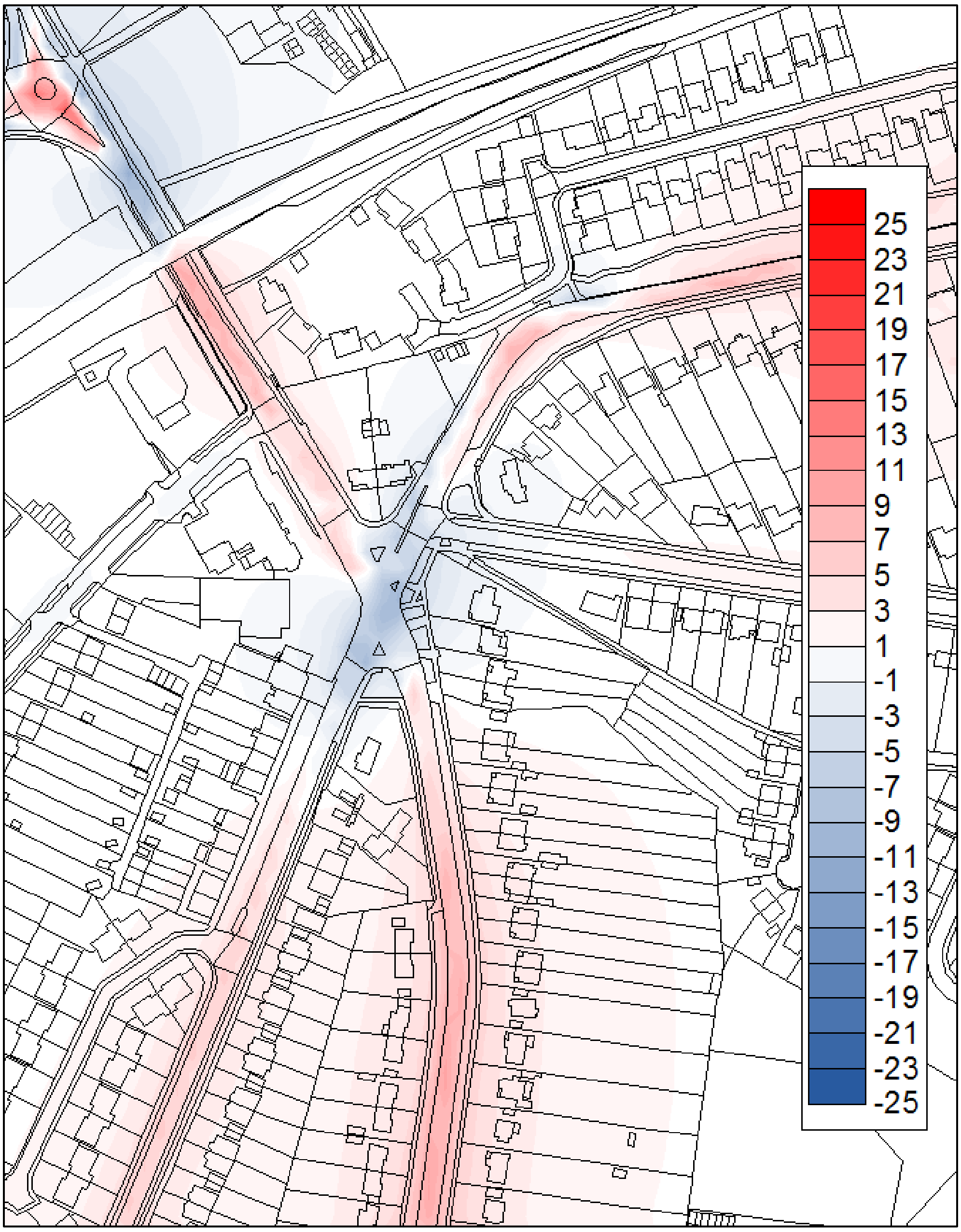

Figure 16: Difference in Predicted Annual Mean NO_2 (µg/m^3) between micro-simulation and non-micro-simulation scenarios (non-micro-simulation minus micro-simulation, so negative value represents lower non-micro-simulation concentration) – Whole Study Area

Benefits of Calculating Emissions for Each 2m Link Separately

5.27 In order to focus on some individual differences between the detailed data available for this study and that which is more usually used, the EFT has been used to calculate emissions for each 2 m link section (using the hourly-mean flows and speeds taken from S-Paramics). These emissions were then averaged along the links shown in Figure 14. ADMS was run, using both sets of emissions, to predict concentrations for the transect of receptors in Figure 14. Figure 17 summarises the results. There is little difference in hourly-mean speeds along these roads and there is very little difference between the two sets of results, which is to be expected given the constraints of the EFT.

5.28 Figure 18 compares the concentrations at receptors calculated using emissions from AIRE modelled for each 2m section with those calculated form the AIRE emissions averaged along the roads in Figure 14. As would be expected, there is significant variation between these two methods, with the 2 m data giving a range around the link average results.

5.29 Using detailed data also allows for the use of detailed speed information. To assess the difference between using detailed speed information and using an average speed (which is more commonly used), the EFT has been used to calculate emissions for each 2 m link section using the speed averaged along the links shown in Figure 14 for each hour and vehicle type. ADMS was run with these emissions to predict concentrations for the transect of receptors in Figure 14. The results are summarised in Figure 19, which shows a comparison of these predicted concentrations with concentrations predicted using emissions calculated with the EFT for each 2 m link section (using the hourly-mean flows and speeds taken from S-Paramics). This demonstrates that using detailed speed information can have a significant impact on predicted concentrations. Typically, most 2 m link sections have speeds close to the speed limit of the road, but some 2 m link sections have significantly lower speeds, for example, near to a junction. The resulting average speed is slightly lower than the speeds for most 2 m link sections. It is well established that NOx emissions are higher for low speeds (see Figure 39), thus using average speeds results in higher NOx emissions for most 2 m link sections. The overall effect is that using average speeds for roads will generally over-predict concentrations, particularly away from junctions.

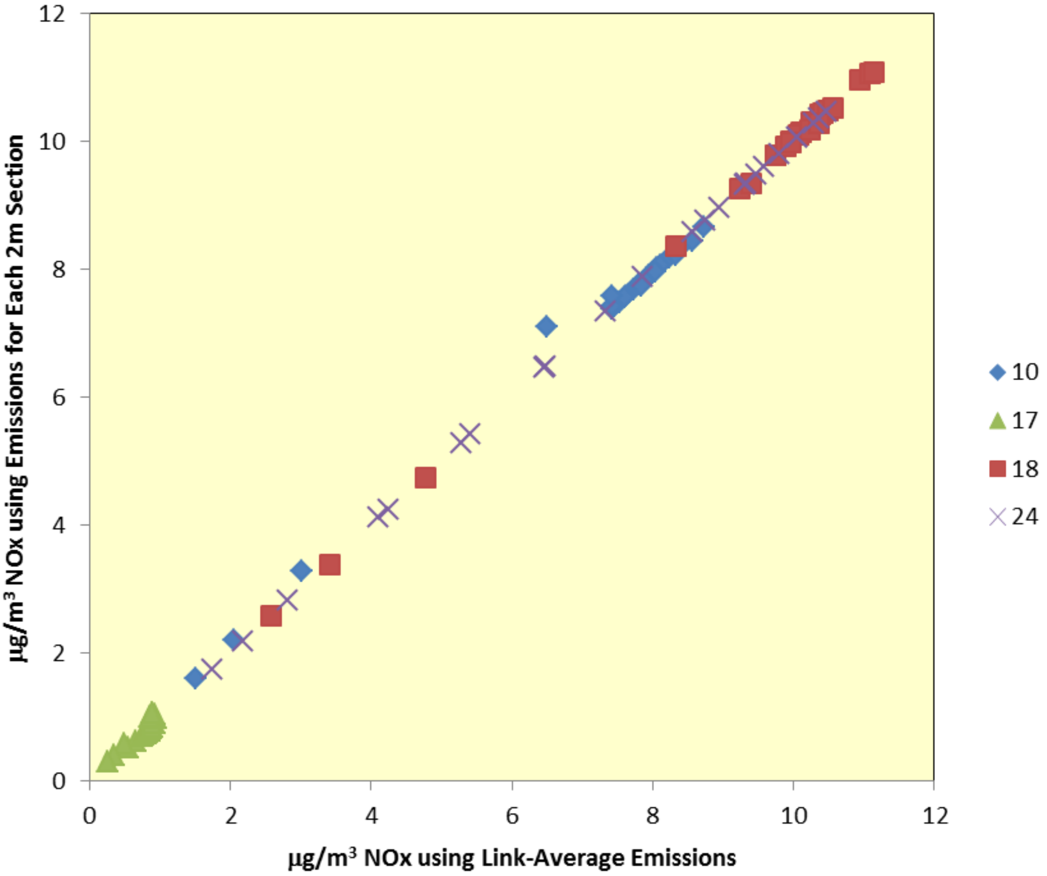

Figure 17: **Comparison of Concentrations Predicted using EFT Emissions for each 2 m section and using EFT emissions averaged over longer sections (i.e. emissions were averaged after running the EFT for each 2m section)**

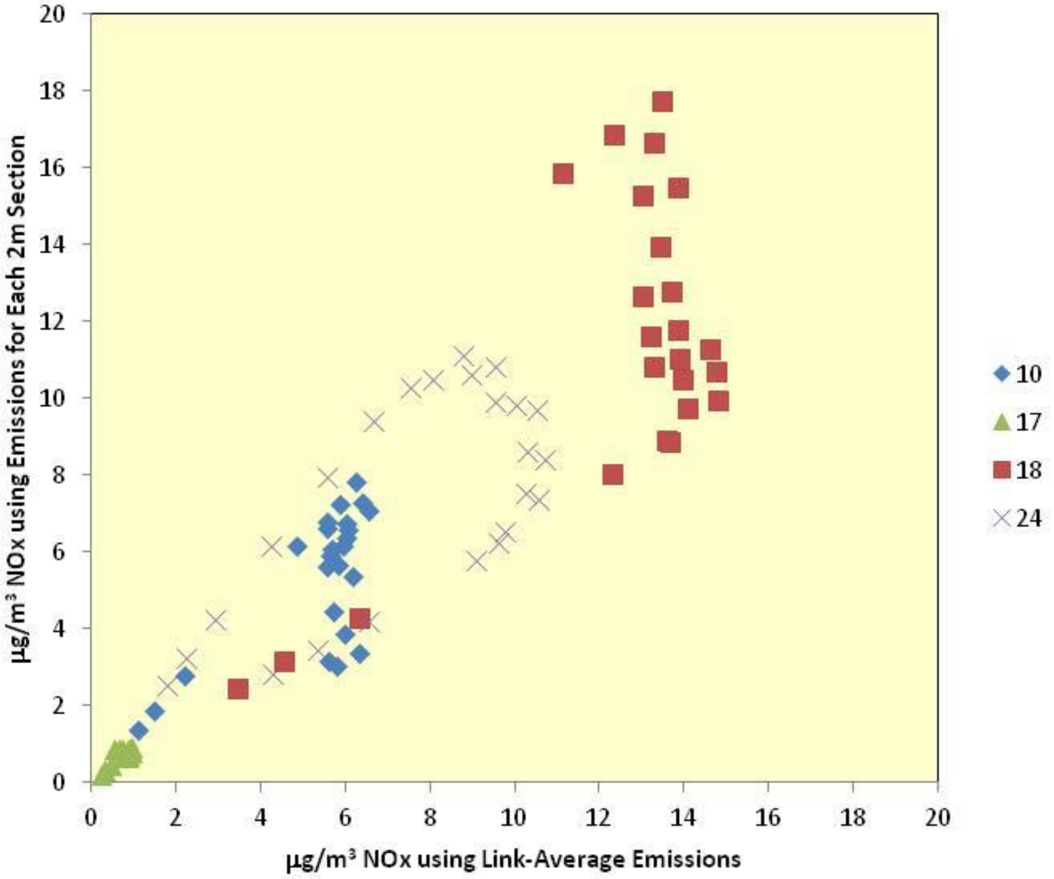

Figure 18: Comparison of Concentrations Predicted using AIRE Emissions for each 2 m section and using AIRE emissions averaged over longer sections (i.e. emissions were averaged after running the AIRE)

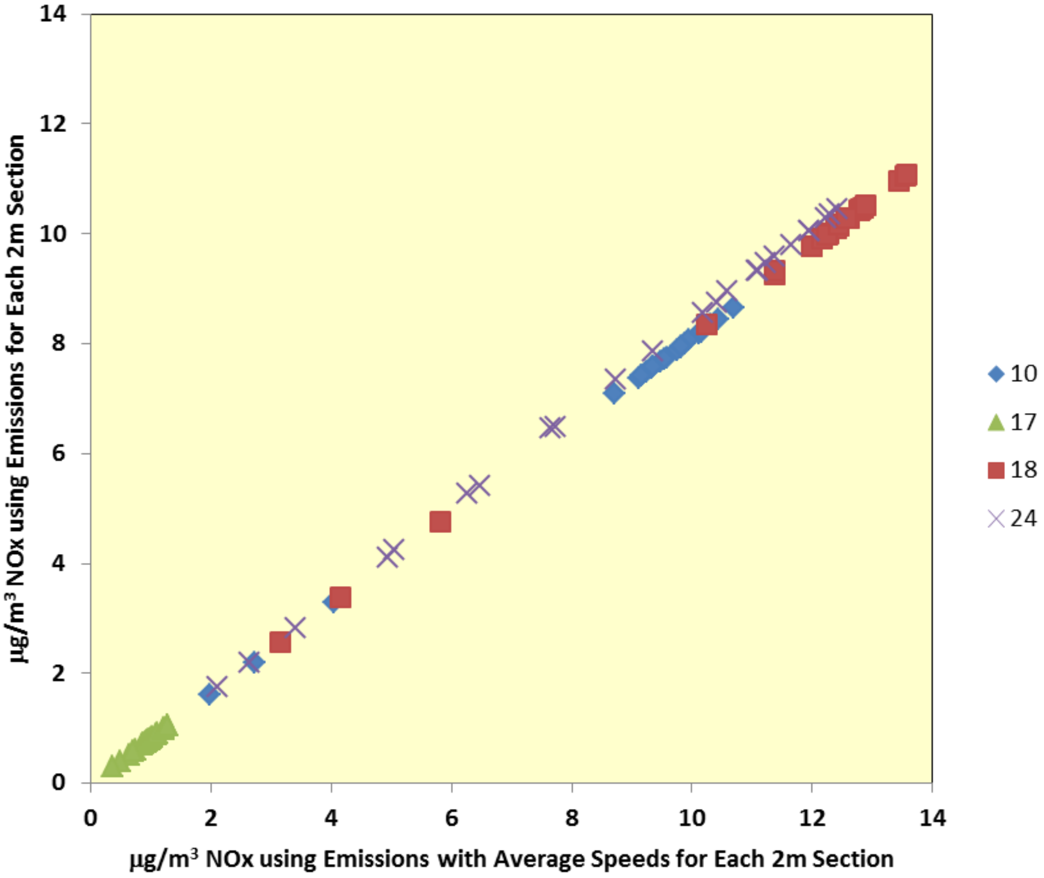

Figure 19: **Comparison of Concentrations Predicted using EFT emissions for each 2 m section with the speed averaged over longer sections (i.e. emissions were calculated using the average speed of all 2 m sections) and using EFT Emissions for each 2 m section (i.e. emissions were calculated using the 2 m section speeds individually)**

6 Discussion of Baseline Results

6.1 Figure 20 and Figure 21 show the predicted concentrations at the receptor locations, based on the 1-hour AIRE emissions and 2 m link sections. The nitrogen dioxide objective level is predicted to have been exceeded at 15 locations, with exceedences at two receptors (R89 and R91) that represent relevant exposure. These receptors are within the AQMA.

6.2 Concentration isopleths are shown in Figure 22 and Figure 23. These show the pollutant fall off with distance from the roads and also from the junction, and that objective exceedences are only predicted at the southeast and southwest corners of the AQMA. The contours also show a small area of high concentrations northeast of the junction (circled). These high concentrations correspond to an area where northbound traffic travelling along Fir Tree Road navigates the corner and then accelerates up the hill.

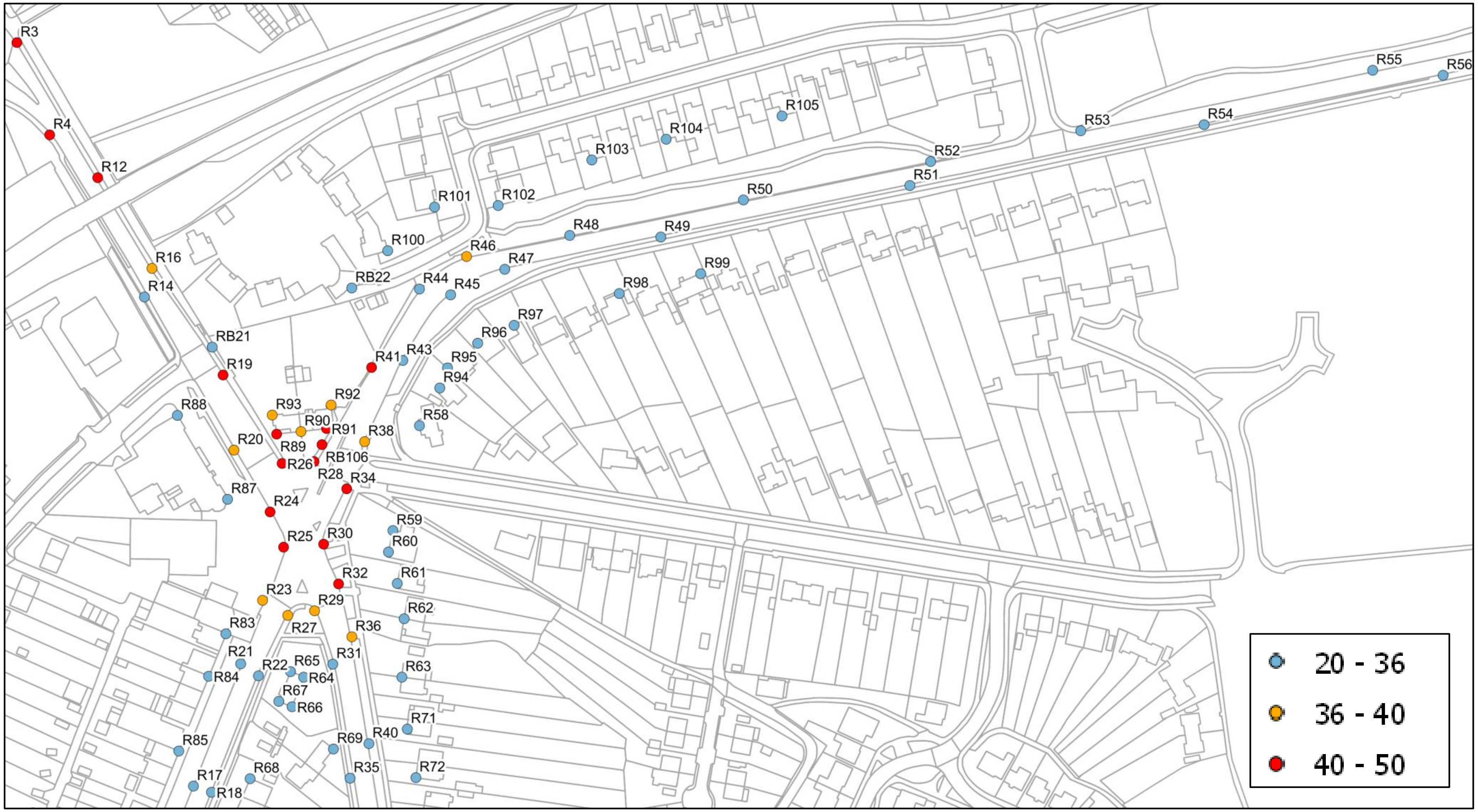

Figure 20: Northern Receptor Numbers and Predicted Annual Mean NO_2 in the Baseline Case ($\mu g/m^3$)

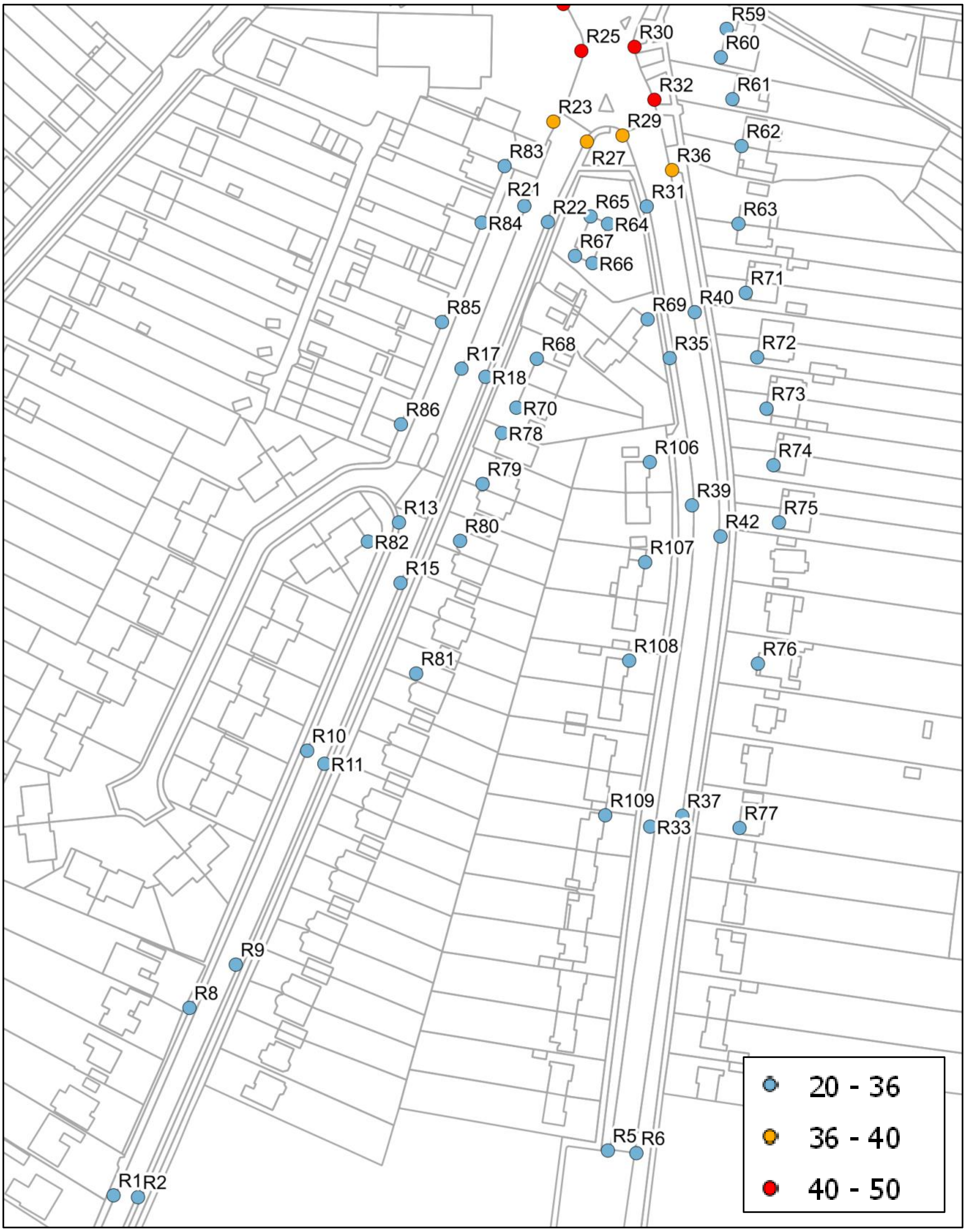

Figure 21: Southern Receptor Numbers and Predicted Annual Mean NO_2 in the Baseline Case (µg/m^3)

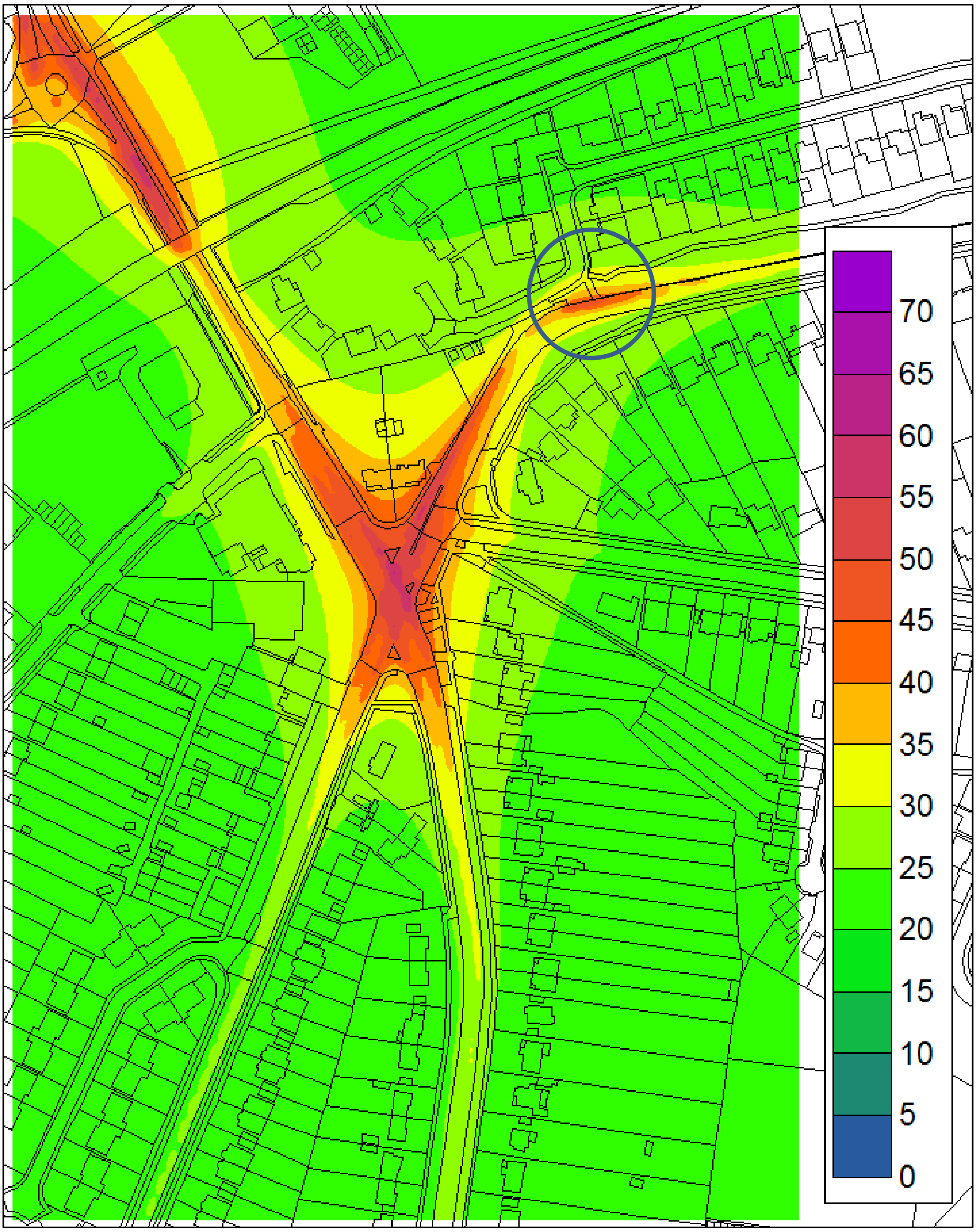

Figure 22: Predicted Annual Mean NO_2 (µg/m^3)

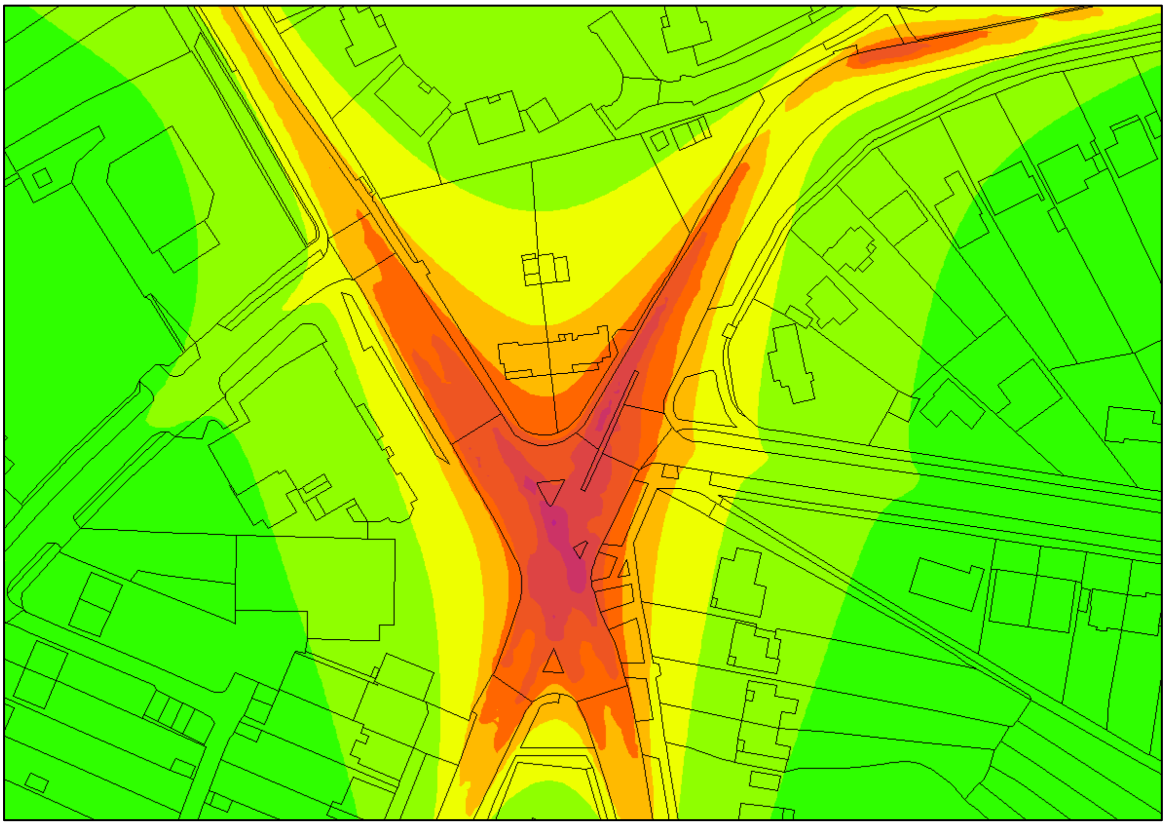

Figure 23: Predicted Annual Mean NO_2 ($\mu g/m^3$) – Just at Junction

Source Apportionment

6.3 As explained previously, each 2 m section of road has been entered into the model individually. The results have then been aggregated into 48 groups, which correspond with longer sections of the road network. Some of these sections are shown in Figure 24. Table 4 summarises the relative contribution of each road to total predicted road-NOx at five example receptors. Figure 20 shows the locations of these receptors. Receptors 12 and 18 are north of Reigate Road, to the north of Drift Bridge; Receptors 30 and 32 are southeast of the junction; Receptor 41 is north of Fir Tree Road; and Receptors 89 and 91 are both within the AQMA.

6.4 As an example of interpreting this table, at Receptor R89 (within the AQMA), 27% of road-NOx comes from vehicles travelling southbound on Reigate Road in the 'straight-ahead' lane (road section 18), 7% comes from vehicles travelling southbound on Reigate Road in the 'left turn' lane (road section 10), and 26% comes from vehicles travelling northbound on Reigate Road (road sections 22 and 24). The rest of the road-NOx (40%) comes from all of the other roads combined. Only 1% of road-NOx comes from vehicles travelling southbound on Reigate Road in the 'right turn' lane (road section 17). Thus, while reducing emissions from all roads would improve air quality within the AQMA, a more focused approach for the section of the AQMA adjacent to Reigate Road would be to target those road sections listed above.

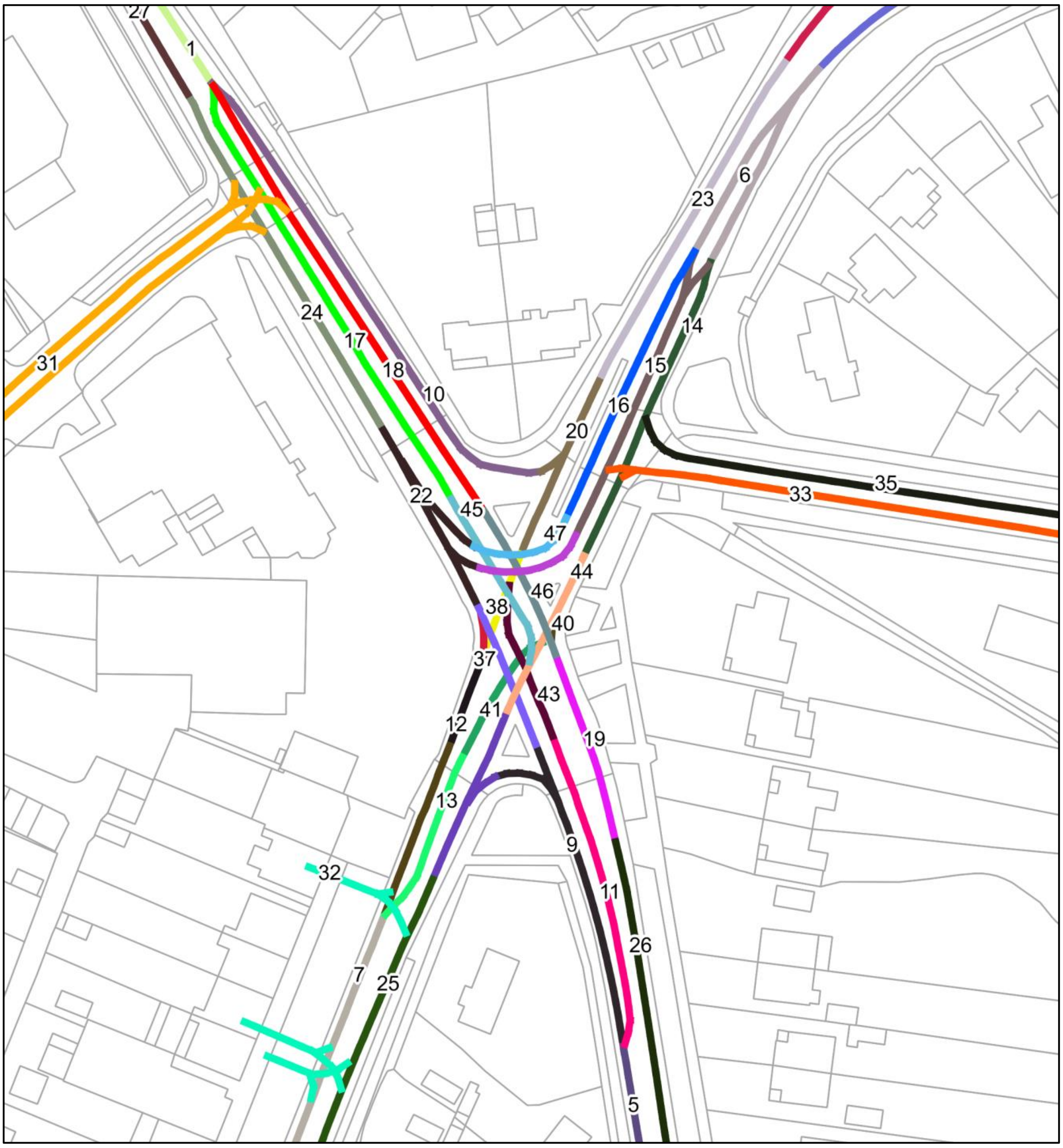

Figure 24: Road Sections Close to the Drift Bridge AQMA

Table 4: Road Source Contribution to Predicted Road-NOx for Seven Receptors

Receptor name	R12	R19	R30	R32	R41	R89	R91
Total NO_2 (µg/m^3)	45.1	40.1	49.5	42.1	42.4	40.2	41.6
Total Road-NOx (µg/m^3)	60.4	46.7	73.5	52.2	52.9	47.1	50.8
Source contribution to Road-NOx [a]							
1	**45%**	2%	0%	0%	1%	1%	1%
2	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	3%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%
8	3%	1%	0%	0%	1%	1%	1%
9	0%	0%	4%	**15%**	1%	1%	1%
10	0%	**21%**	0%	0%	1%	7%	2%
11	0%	0%	0%	1%	0%	0%	0%
12	0%	0%	2%	3%	0%	1%	1%
13	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	1%	0%	2%	1%	3%
15	0%	0%	0%	0%	1%	1%	2%
16	0%	1%	1%	0%	2%	2%	5%
17	0%	2%	0%	0%	0%	1%	0%
18	1%	**29%**	1%	1%	4%	**27%**	9%
19	0%	1%	**19%**	**44%**	1%	2%	2%
20	0%	1%	1%	1%	4%	6%	**23%**
21	0%	0%	4%	6%	1%	1%	1%
22	0%	3%	2%	1%	2%	**14%**	6%
23	0%	3%	1%	1%	**62%**	5%	**20%**
24	1%	**25%**	1%	1%	2%	**12%**	4%
25	0%	0%	1%	2%	0%	1%	1%
26	0%	0%	1%	4%	0%	1%	1%
27	**47%**	1%	0%	0%	1%	1%	0%
28	1%	2%	1%	1%	3%	1%	2%

29	0%	0%	0%	1%	0%	0%	0%
30	0%	0%	0%	1%	0%	0%	0%
31	0%	2%	0%	0%	0%	0%	0%
32	0%	0%	0%	0%	0%	0%	0%
33	0%	0%	0%	0%	0%	0%	0%
34	0%	0%	0%	0%	0%	0%	0%
35	0%	0%	0%	0%	0%	0%	0%
36	0%	0%	0%	0%	0%	0%	0%
37	0%	0%	3%	2%	0%	1%	1%
38	0%	0%	2%	1%	0%	1%	1%
39	0%	0%	0%	0%	0%	0%	0%
40	0%	0%	0%	0%	0%	0%	0%
41	0%	0%	0%	0%	0%	0%	0%
42	0%	1%	9%	5%	1%	2%	2%
43	0%	0%	1%	0%	0%	0%	0%
44	0%	0%	**14%**	3%	1%	1%	2%
45	0%	0%	2%	0%	0%	1%	1%
46	0%	1%	**22%**	3%	2%	4%	5%
47	0%	0%	1%	0%	0%	1%	1%
48	0%	0%	1%	0%	0%	0%	1%

[a] Percentages above 10% are shown in bold.

6.5 To provide additional information to help the development of traffic management options for emissions reduction, the model has been run to predict concentrations at a number of receptors running along the edge of the eastern pavement of Reigate Road. This is the same approximate transect as was shown in Figure 14. Figure 25 shows the source contribution of each road to the predicted Road-NOx along the edge of the pavement. The 'x' axis shows distance from the point marked "Transect Origin" in Figure 14. The 'y' axis shows the contribution of the more significant sources to total road-NOx. Receptor 89 (representing the worst-case location within the AQMA) is approximately level with the point 10 m along the transect.

6.6 The contribution from the southbound lane going straight ahead along Reigate Road (road Section 18) decreases with increasing distance from the junction; reflecting the predicted influence of the junction on driving patterns. The rapid reduction with distance from the junction in road Section 22 simply reflects the fact that this section does not extend all of the way up Reigate Road. Figure 25 also shows that the southbound left-turn lane approaching the junction from Reigate Road (road

Section 10) contributes less as it approaches the junction, which is probably because of the way the traffic queue is predicted to accelerate when clearing through the junction. This road section also contributes less than road Section 18, even though it is located closer to the transect receptors, due to the traffic flow being less. Similarly, the southbound right-turn lane approaching the junction from Reigate Road (road Section 17) contributes far less than both of these road sections due to the traffic flow being much smaller.

6.7 These observations were incorporated into the development of traffic management scenarios in the subsequent sections.

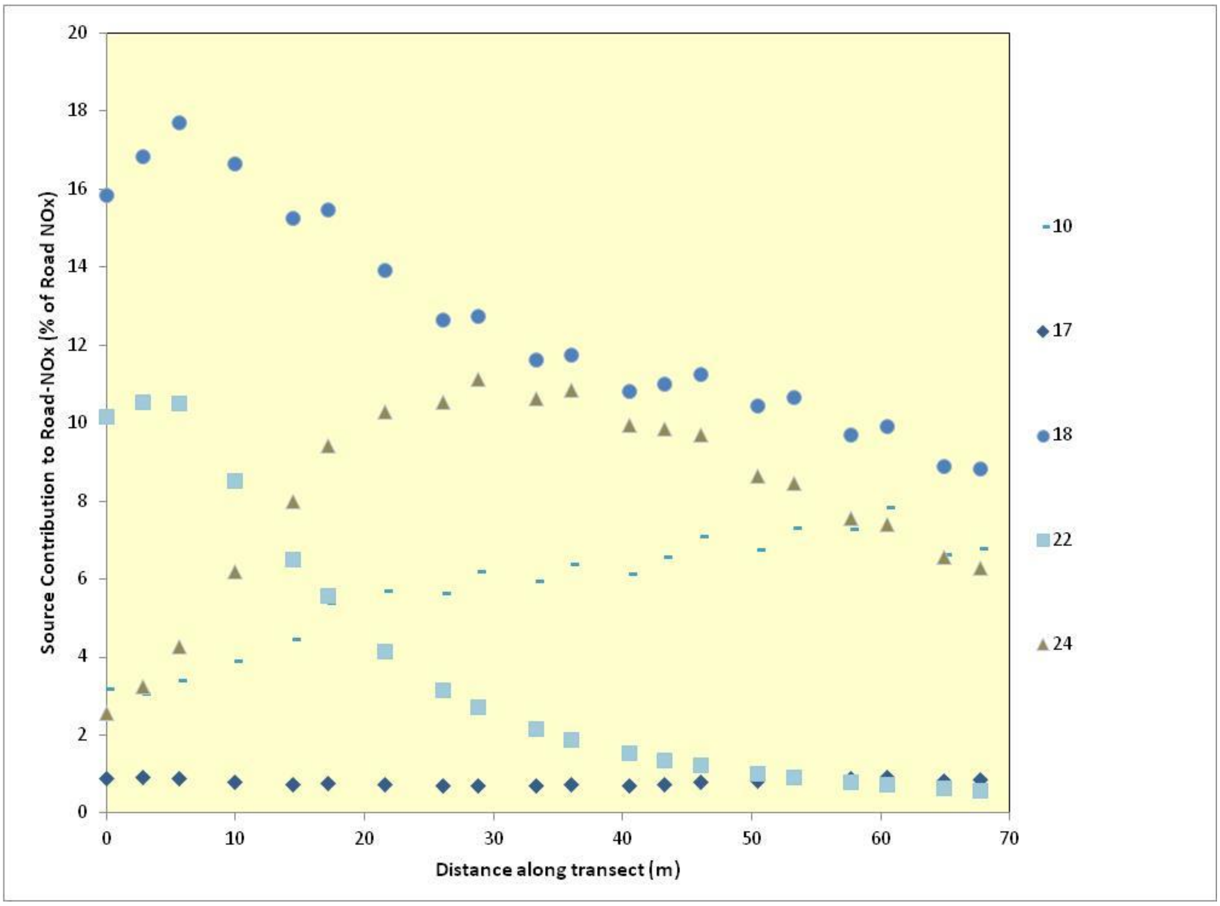

Figure 25: Road-NOx by Road Section vs Distance along Reigate Road

7 Traffic Management Scenarios

7.1 The potential reductions in pollutant concentrations that could be delivered by the following three traffic management options have been predicted:

- Option 1 – introduce a 20 mph speed limit;
- Option 2 – remove southbound left-hand lane of Reigate Road (north of the junction); and
- Option 3 – extended green traffic light.

7.2 All modelling is based on the same 2 m link, AIRE emissions, and 1 hr emission profile methodology as the baseline conditions modelling in Section 6. SIAS Ltd. has re-run S-Paramics for each option and calculated emissions using AIRE.

Option 1- Introduction of a 20 mph Speed Limit

7.3 The proposed 20 mph speed limit would extend from Reigate Road, immediately south of the College Road roundabout, to approximately 160 m south of the junction along Reigate Road and from Fir Tree Road, just south of Fir Tree Close, to around the High Beeches junction along Fir Tree Road.

7.4 Figure 26 shows the total predicted NO_2 concentration around the junction in both the base case and with Option 1. The concentrations are also tabulated in Appendix A1. At the Drift Bridge AQMA, the objective exceedences are predicted to be removed. At many of the other receptors around the junction, the predicted concentrations reduce from being near the objective (>36 µg/m^3) to more comfortably below the objective (< 36 µg/m^3). Option 1 causes the objective level to be exceeded at the junction of High Beeches to the east (see inset at the foot of Figure 26), but there is no relevant exposure in this area.

7.5 Figure 27 shows the predicted change in total concentrations at all modelled receptors. The predicted reduction in total annual mean nitrogen dioxide at two receptors south of the College Road roundabout (in northwest corner of Figure 27) is more than 10 µg/m^3, while the increase at High Beeches (near the northeast corner of Figure 27) is more than 10 µg/m^3. In the context of air quality action planning, these predicted changes are very large.

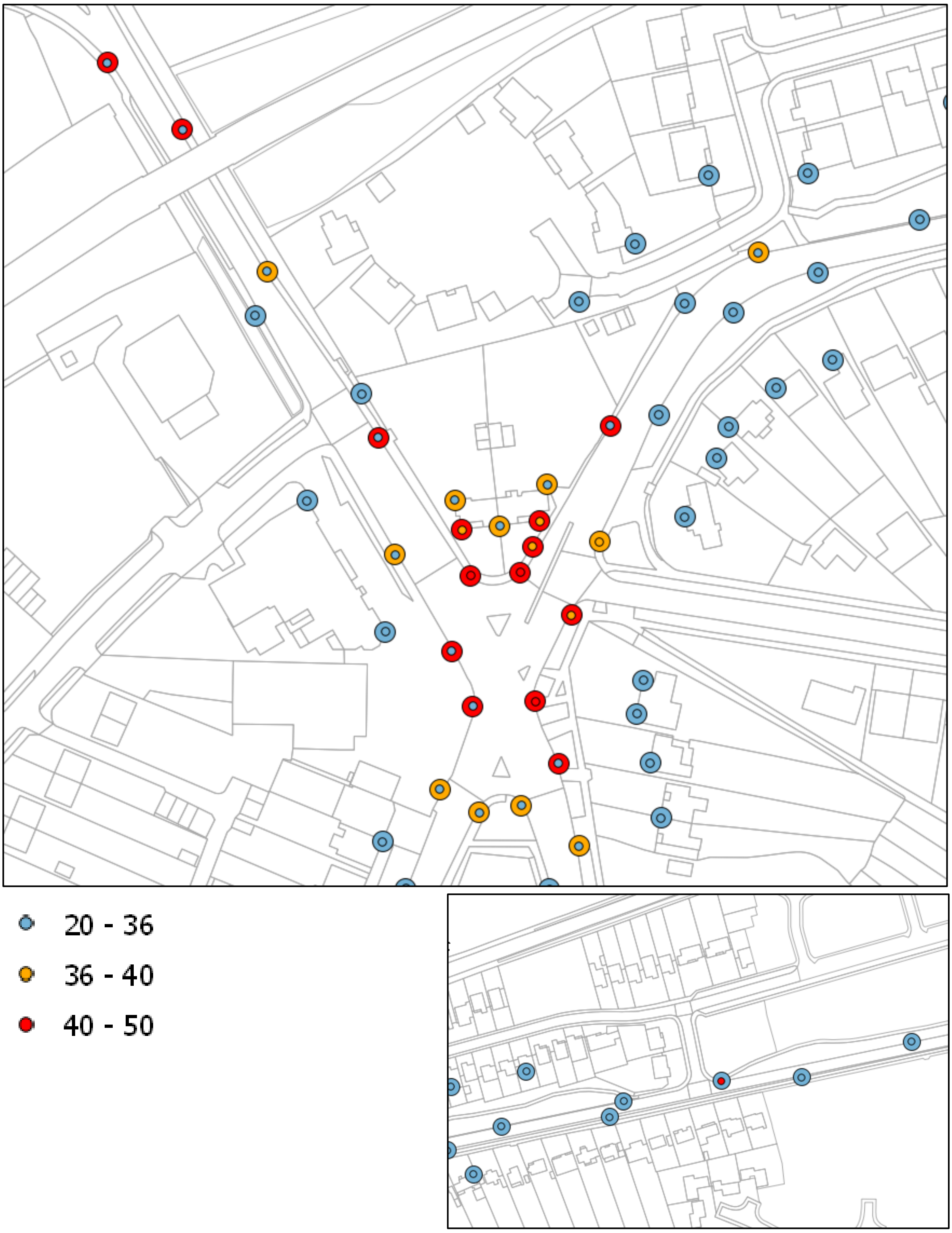

Figure 26: Predicted Annual Mean NO_2 in the Base Case (Big Circles) and under Option 1 (Small Circles) (µg/m^3)

7.6 The biggest reduction is at R12 (see Figure 28). Road-NOx at this receptor is predicted to reduce by more than 60%; from 60 µg/m3 to 22 µg/m^3. Of this 38 µg/m^3 change, 14 µg/m^3 relates to changes in emissions from the southbound carriageway of Reigate Road (road Section 1), while

24 µg/m^3 relates to emissions from the northbound carriageway (road Section 27). In order to investigate the predicted reduction here in more detail, the hourly emission profiles for a typical weekday on the 2 m link sections adjacent to Receptor 12 are set out in Table 5. Road segments 405 and 406 represent southbound traffic, while Segments 615 and 616 represent northbound traffic. There is an appreciable predicted reduction in emissions during every hour, with predicted emissions from northbound traffic reducing by more than 90%. While these changes appear extreme, through discussion with SIAS Ltd., it has been suggested that such large reductions in emissions are not unreasonable given the traffic smoothing that is predicted in the vicinity of College Road roundabout. Similarly, SIAS Ltd has suggested that the predicted reductions elsewhere, while large, can all be explained in terms of traffic smoothing. This is discussed further in Paragraph 7.16. The predicted increase at High Beaches (as well as along Fir Tree Road and Reigate Road at the southern edge of Figure 27) relate to traffic accelerating upon leaving the 20 mph zone.

7.7 Concentrations have also been predicted across the grid of 12,000 receptors described in Paragraph 4.9 in order to plot concentration isopleths. These are shown in Figure 29 and Figure 30. Under Option 1, there are no predicted objective exceedences in locations where the objectives apply. The changes between the base case and Option 1 are shown by way of isopleths in Figure 31. Concentrations are predicted to reduce appreciably across most of the study area, with increased concentrations at those points where the 20 mph zone ends and traffic is predicted to accelerate.

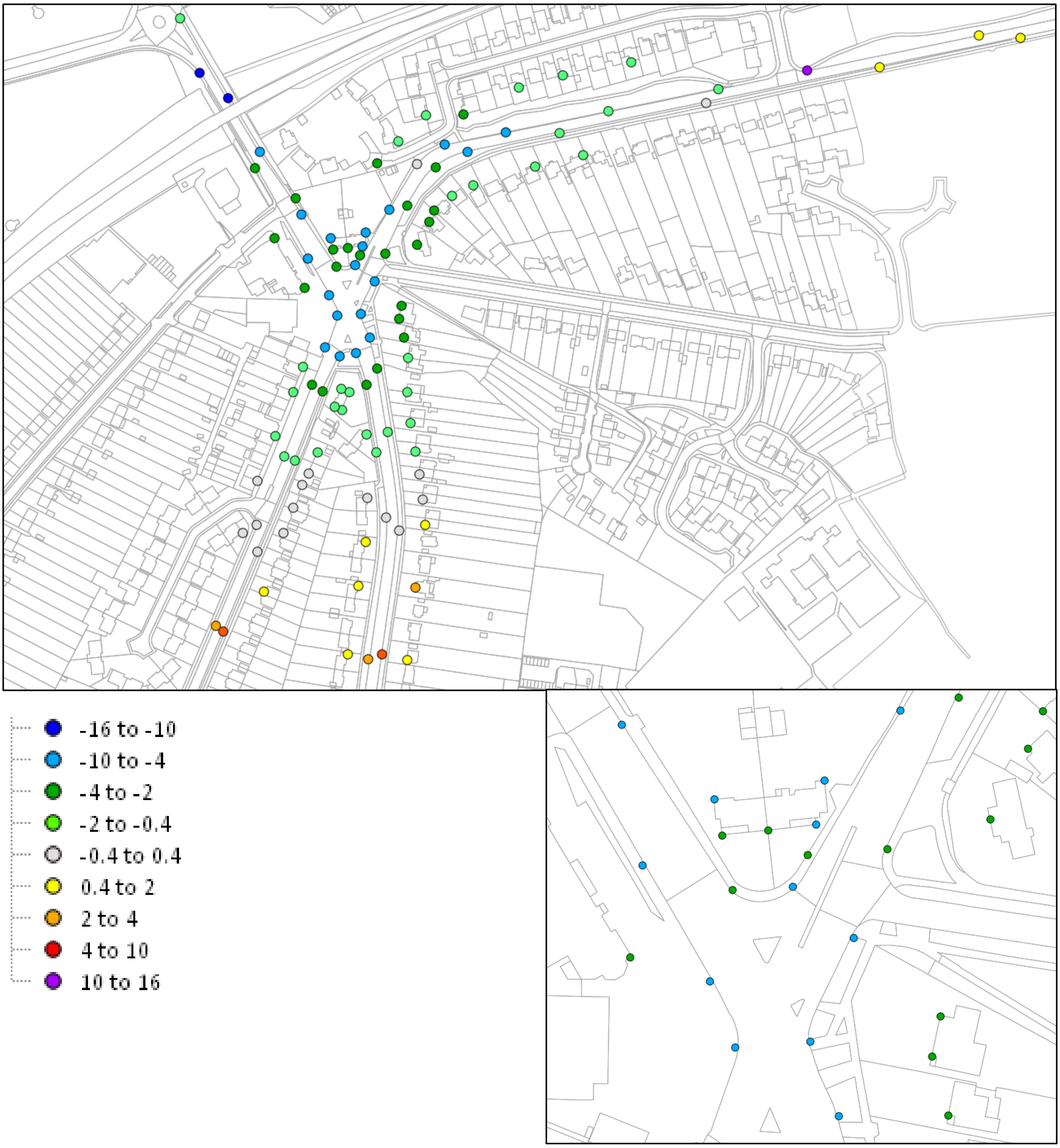

Figure 27: Change in Predicted Annual Mean NO_2 (µg/m^3)

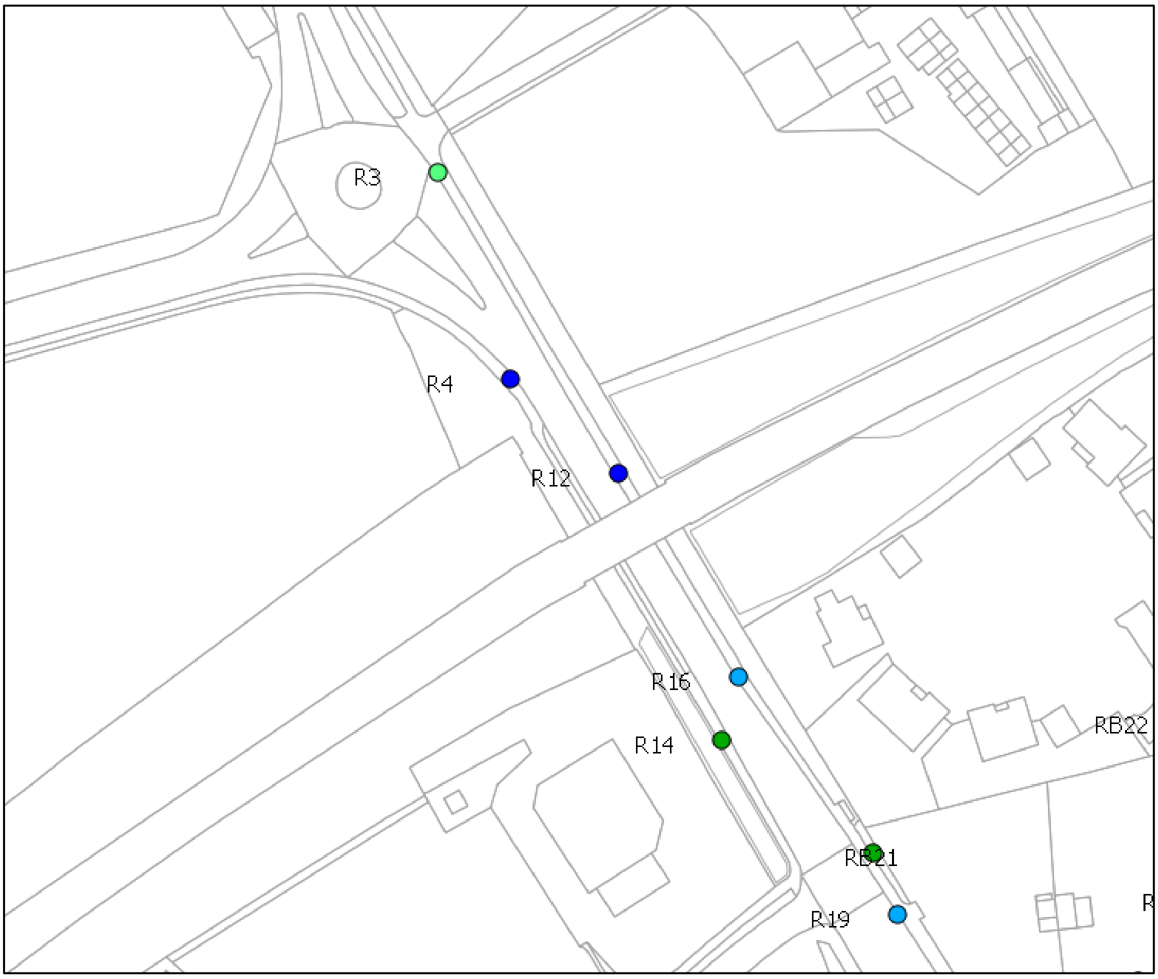

Figure 28: Change in Predicted Annual Mean NO_2 (µg/m^3) Showing the Location of Receptor Number 12.

Table 5: Change in Predicted NOx Emissions Near to Receptor 12

	Link	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16	hr17	hr18	hr19	hr20	hr21	hr22	hr23	hr24	Mean
		NOx Emissions (g/km/s)																								
Baseline	405	0.007	0.006	0.011	0.010	0.013	0.013	0.062	0.192	0.245	0.187	0.179	0.179	0.238	0.182	0.252	0.341	0.380	0.352	0.250	0.098	0.062	0.040	0.017	0.005	0.138
Baseline	406	0.007	0.006	0.009	0.011	0.013	0.013	0.063	0.191	0.227	0.184	0.181	0.181	0.238	0.188	0.248	0.328	0.363	0.344	0.246	0.097	0.065	0.042	0.017	0.007	0.136
Baseline	615	0.023	0.010	0.015	0.011	0.029	0.091	0.329	0.451	0.450	0.418	0.383	0.378	0.305	0.352	0.350	0.354	0.352	0.359	0.353	0.266	0.173	0.129	0.076	0.054	0.238
Baseline	616	0.024	0.011	0.016	0.012	0.033	0.091	0.336	0.457	0.451	0.429	0.387	0.384	0.307	0.351	0.359	0.359	0.349	0.359	0.348	0.263	0.171	0.127	0.074	0.052	0.240
Option 1	405	0.005	0.003	0.004	0.005	0.006	0.007	0.028	0.075	0.115	0.084	0.074	0.071	0.095	0.075	0.104	0.114	0.134	0.112	0.091	0.044	0.033	0.026	0.016	0.007	0.055
Option 1	406	0.005	0.003	0.003	0.005	0.006	0.007	0.029	0.075	0.115	0.084	0.074	0.072	0.097	0.077	0.101	0.111	0.130	0.109	0.089	0.043	0.033	0.026	0.015	0.007	0.055
Option 1	615	0.002	0.001	0.001	0.001	0.003	0.007	0.027	0.052	0.075	0.047	0.037	0.035	0.025	0.033	0.032	0.033	0.029	0.030	0.028	0.017	0.011	0.008	0.004	0.004	0.023
Option 1	616	0.002	0.001	0.001	0.001	0.004	0.007	0.028	0.050	0.074	0.048	0.040	0.034	0.026	0.034	0.033	0.034	0.030	0.029	0.028	0.018	0.011	0.008	0.005	0.004	0.023
		Percentage Reduction in NOx Emissions (%)																								
% Reduction	405	32%	51%	63%	54%	55%	45%	54%	61%	53%	55%	59%	61%	60%	59%	59%	66%	65%	68%	64%	55%	47%	35%	5%	-31%	50%
% Reduction	406	30%	51%	61%	60%	57%	42%	54%	61%	50%	54%	59%	60%	59%	59%	59%	66%	64%	68%	64%	55%	50%	39%	12%	-1%	51%
% Reduction	615	92%	94%	93%	93%	89%	92%	92%	89%	83%	89%	90%	91%	92%	91%	91%	91%	92%	92%	92%	93%	93%	94%	94%	93%	91%
% Reduction	616	92%	95%	94%	94%	90%	92%	92%	89%	83%	89%	90%	91%	92%	90%	91%	91%	92%	92%	92%	93%	93%	94%	94%	93%	92%

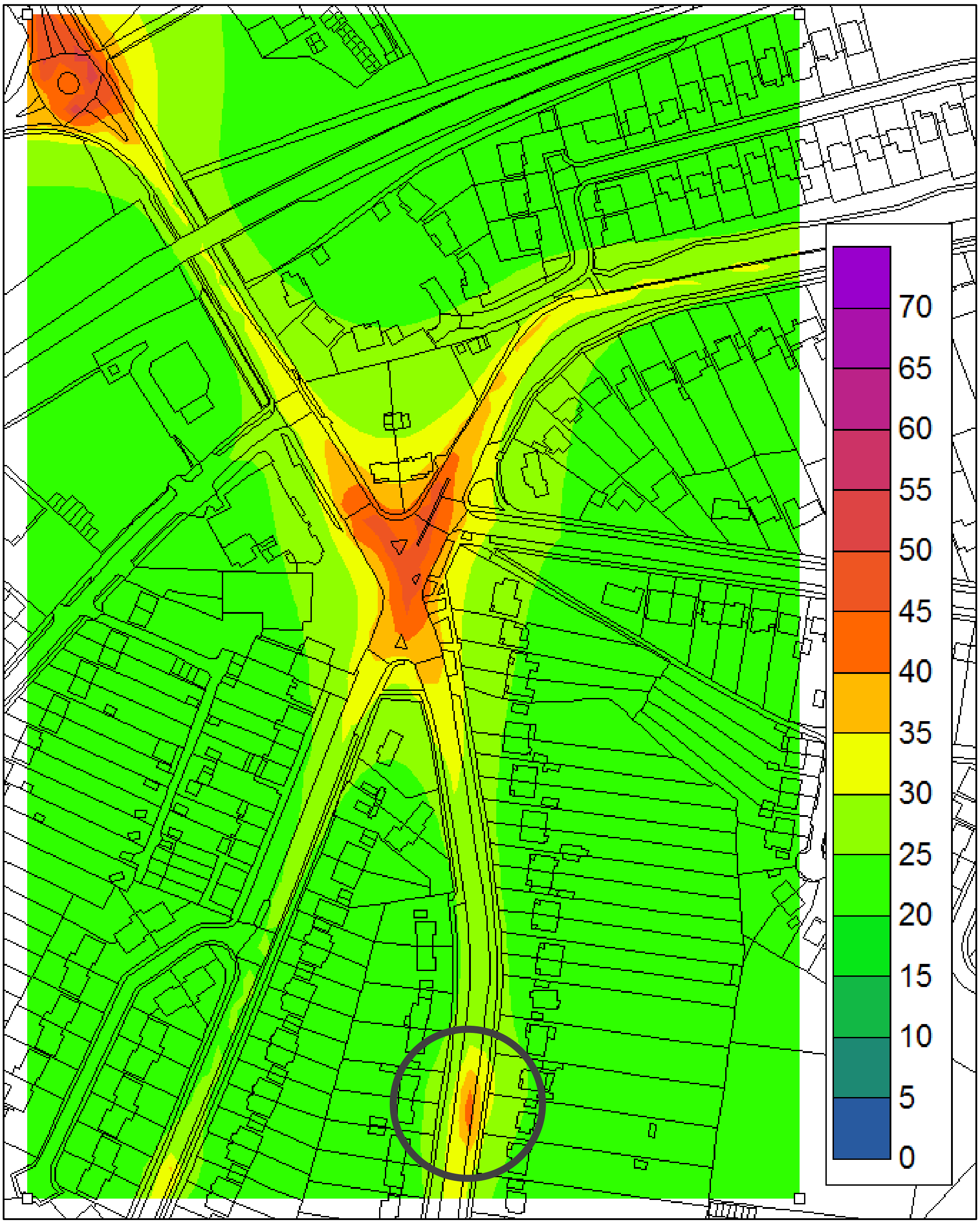

Figure 29: Option 1 Predicted Annual Mean NO_2 ($\mu g/m^3$)

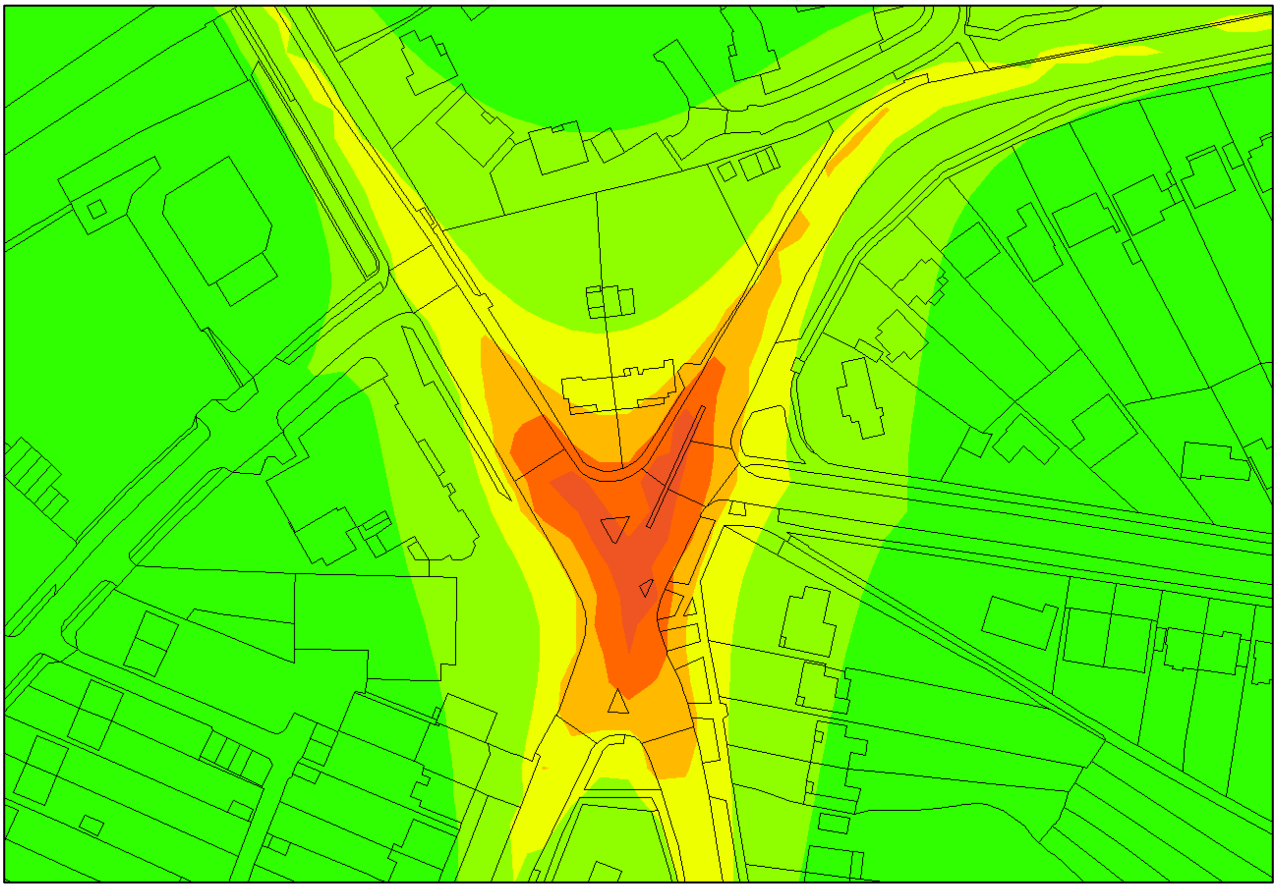

Figure 30: Option 1 Predicted Annual Mean NO_2 (µg/m^3) – Just at Junction

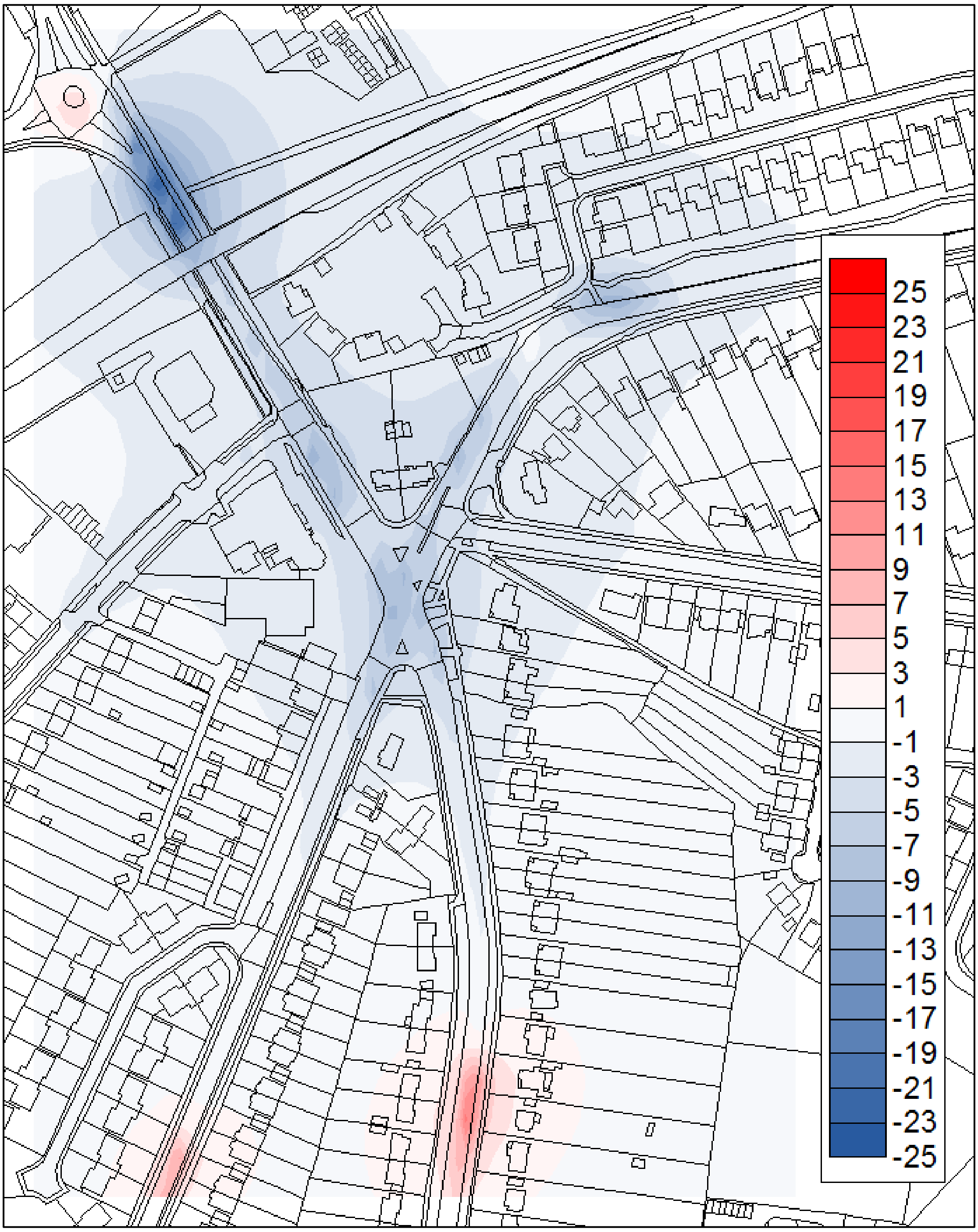

Figure 31: Change in Predicted Annual Mean NO_2 (µg/m^3) between Option 1 and Base Case

Option 2 – Removal of the Southbound Left-hand Lane of Reigate Road

7.8 The second traffic management option that has been explored is the removal of the southbound left-hand lane of Reigate Road (north of the junction). Figure 32 shows the total predicted NO_2 concentration around the junction in both the base case and with Option 2. At the corner of Driftways Cottage, and at the circled receptor to the northwest of the AQMA, the objective exceedences are removed. The objective is predicted to continue to be exceeded in the Crossways part of the AQMA. The objective level is caused to be exceeded by Option 2 at two receptors to the east of the junction, but there is no relevant exposure in this area.

7.9 Figure 33 shows the predicted change in total concentrations at all modelled receptors. Predicted concentrations at some receptors increase by <2 μg/m^3, while some reduce by <2 μg/m^3. The changes are much smaller than predicted with Option 1. The results are also tabulated in Appendix A1.

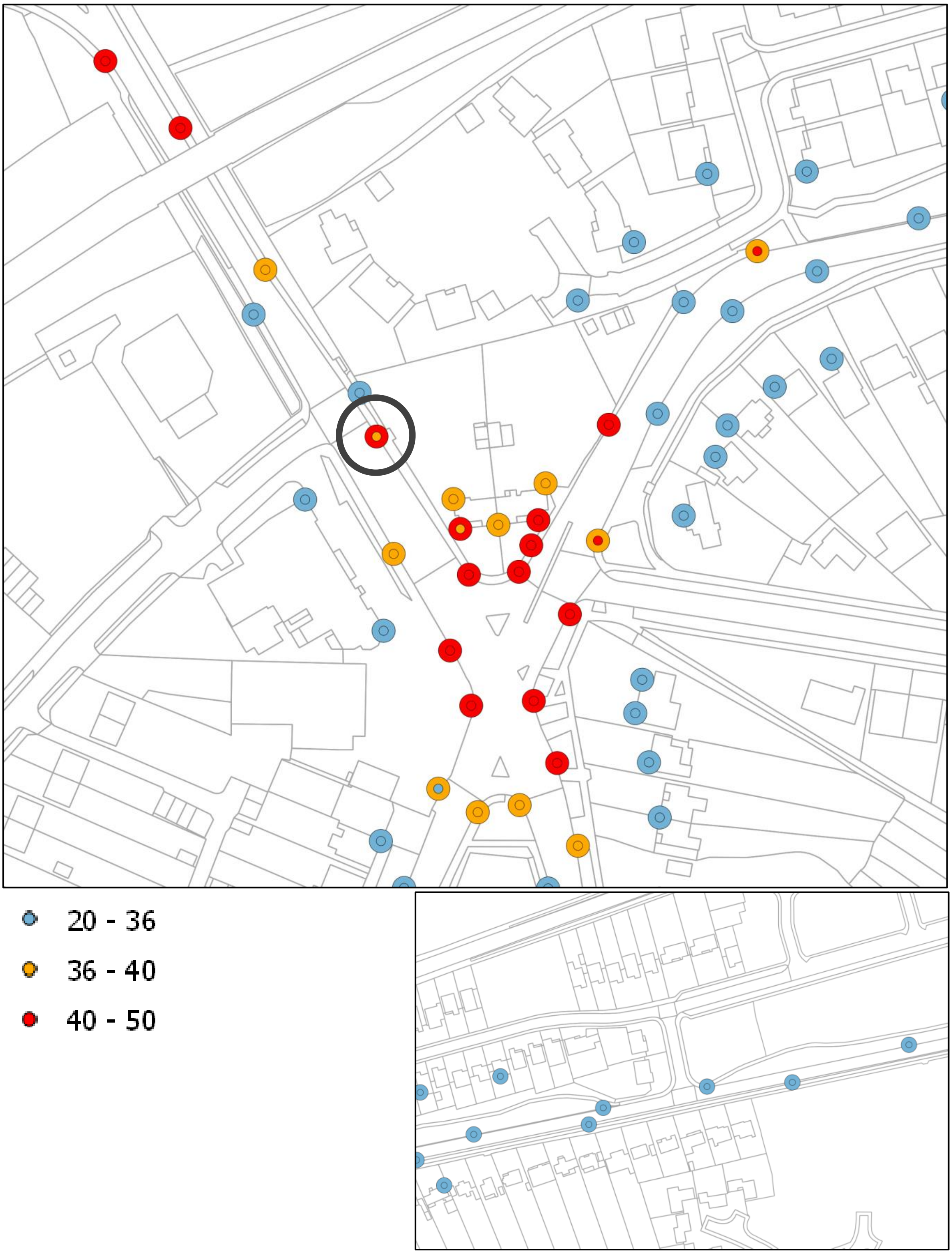

Figure 32: **Predicted Annual Mean NO_2 in the Base Case (Big Circles) and under Option 2 (Small Circles) ($\mu g/m^3$)**

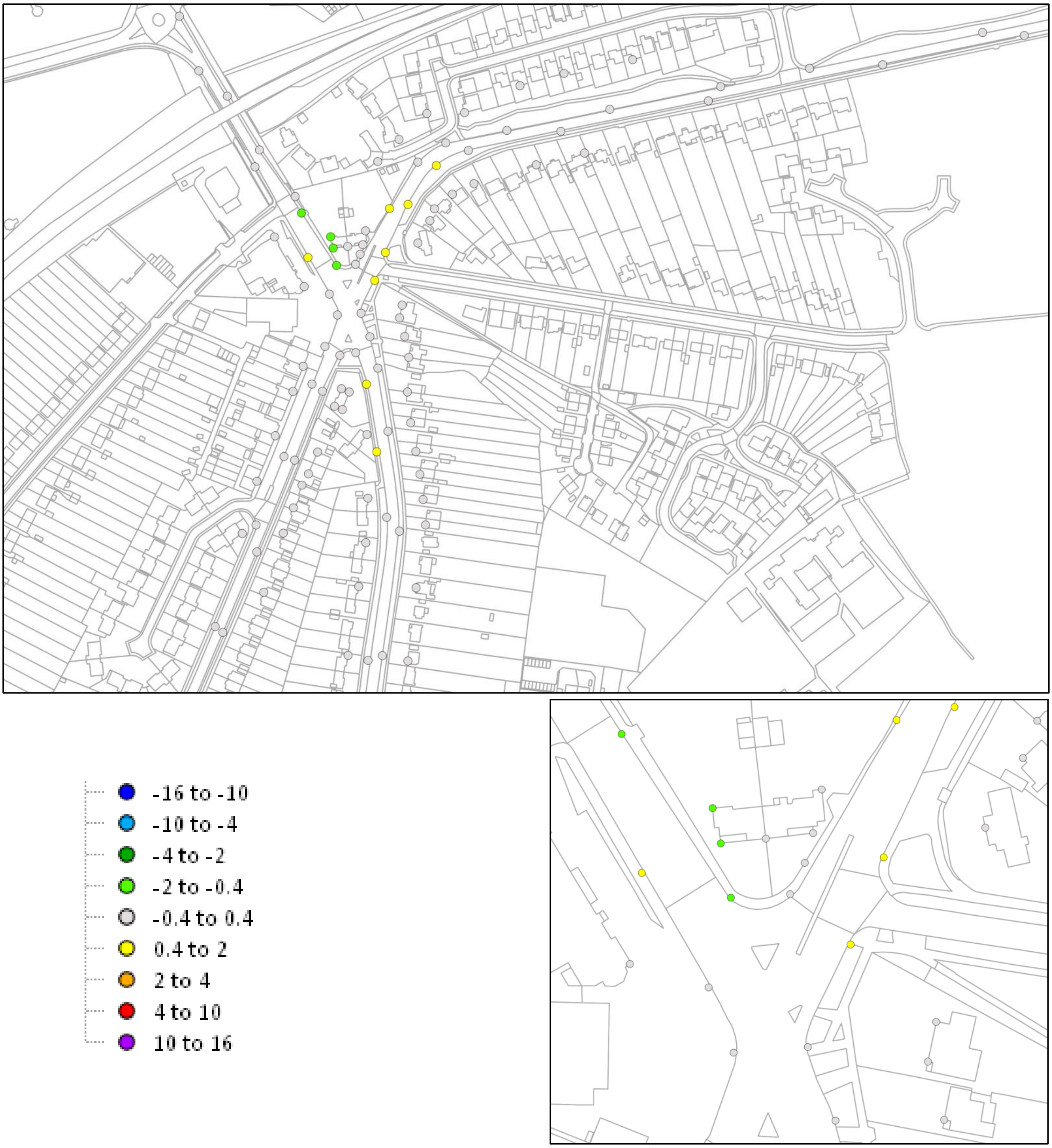

Figure 33: Change in Predicted Annual Mean NO_2 (µg/m^3) between Option 2 and the Base Case

Option 3 – Extended Green Traffic Light

7.10 The final traffic management option that has been explored extends the length of time that the junction traffic lights stay green for Reigate Road. Figure 34 shows the total predicted NO_2 concentration around the junction in both the base case and with Option 3. At two receptors along Fir Tree Road (circled in Figure 34) the objective level is caused to be exceeded by Option 3, but there is no relevant exposure at these locations. The objective exceedences within the AQMA are not removed by Option 3.

7.11 Figure 35 shows the change in total concentrations at all modelled receptors. Some receptors increase by <2 $\mu g/m^3$, while some reduce by <2 $\mu g/m^3$. The reductions are close to the junction while the increases are away from the AQMA, but the changes are much smaller than with Option 1. The results are tabulated in Appendix A1.

7.12 Figure 36, Figure 37 and Figure 38 show the isopleths of predicted concentrations for Option 3. Figure 38, in particular, shows the localised nature of the predicted changes.

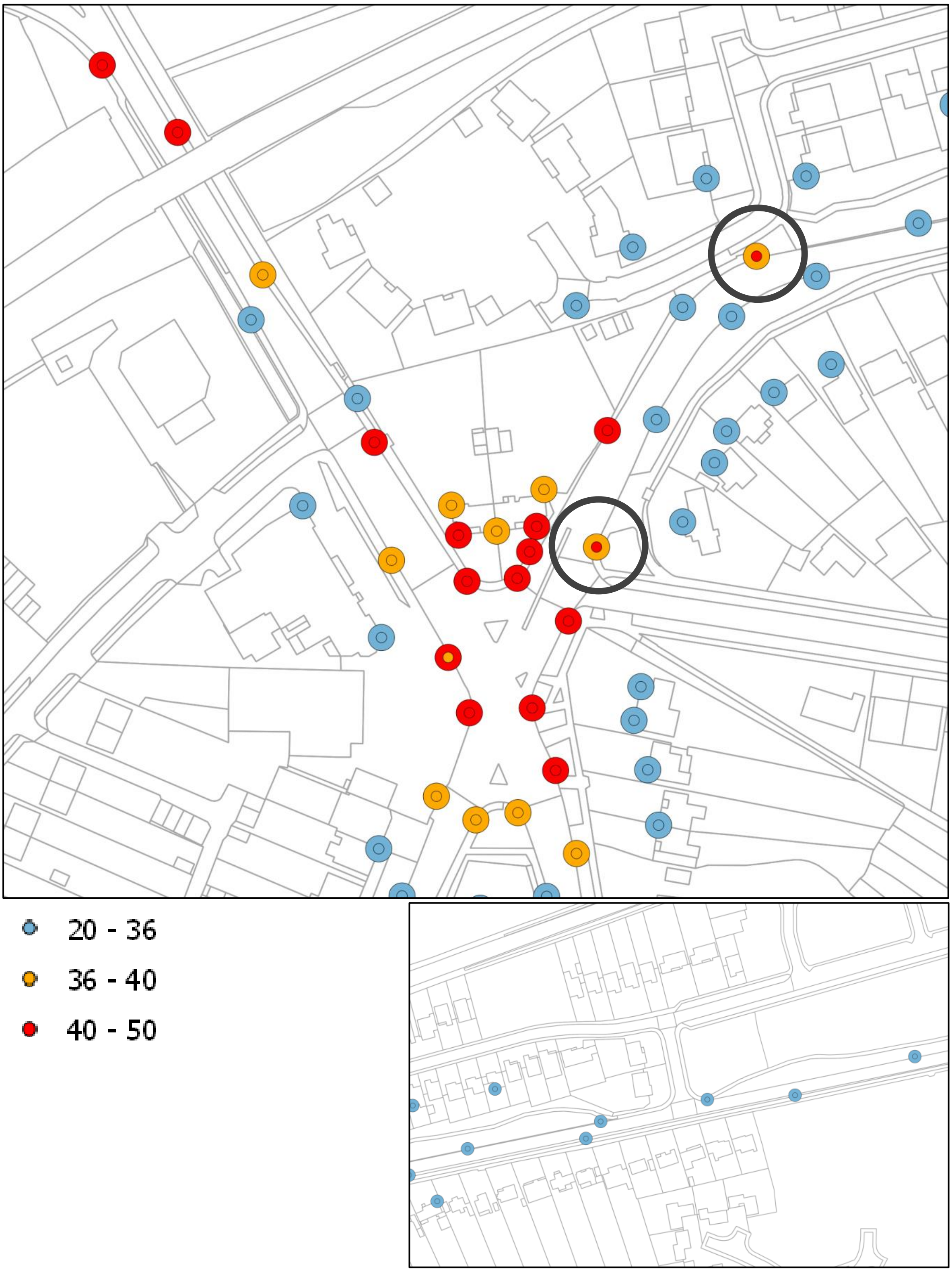

Figure 34: Predicted Annual Mean NO_2 in the Base Case (Big Circles) and under Option 3 (Small Circles) ($\mu g/m^3$)

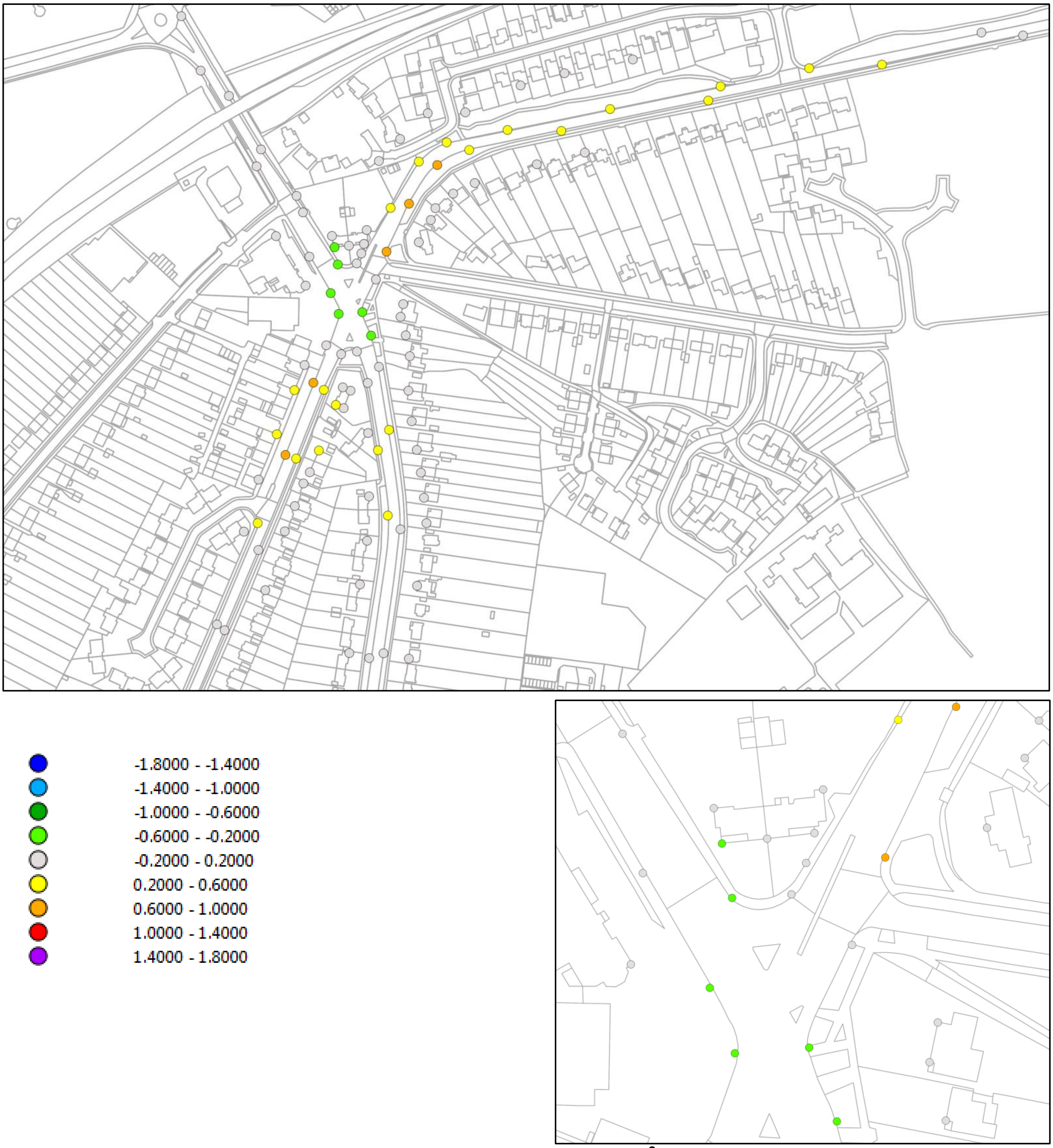

Figure 35: Change in Predicted Annual Mean NO_2 (µg/m^3) between Option 3 and the Base Case

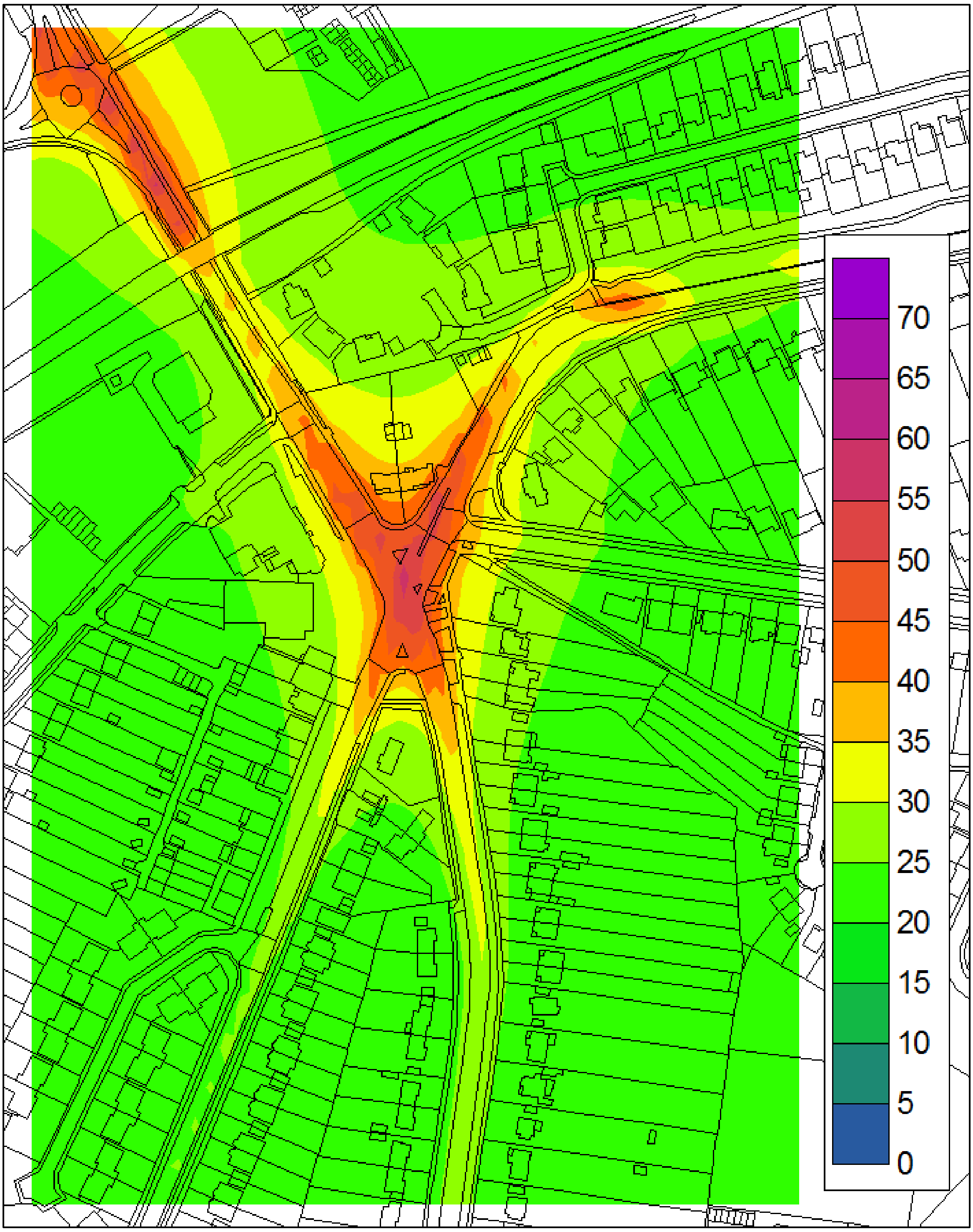

Figure 36: Option 3 Predicted Annual Mean NO_2 ($\mu g/m^3$) – Whole Study Area

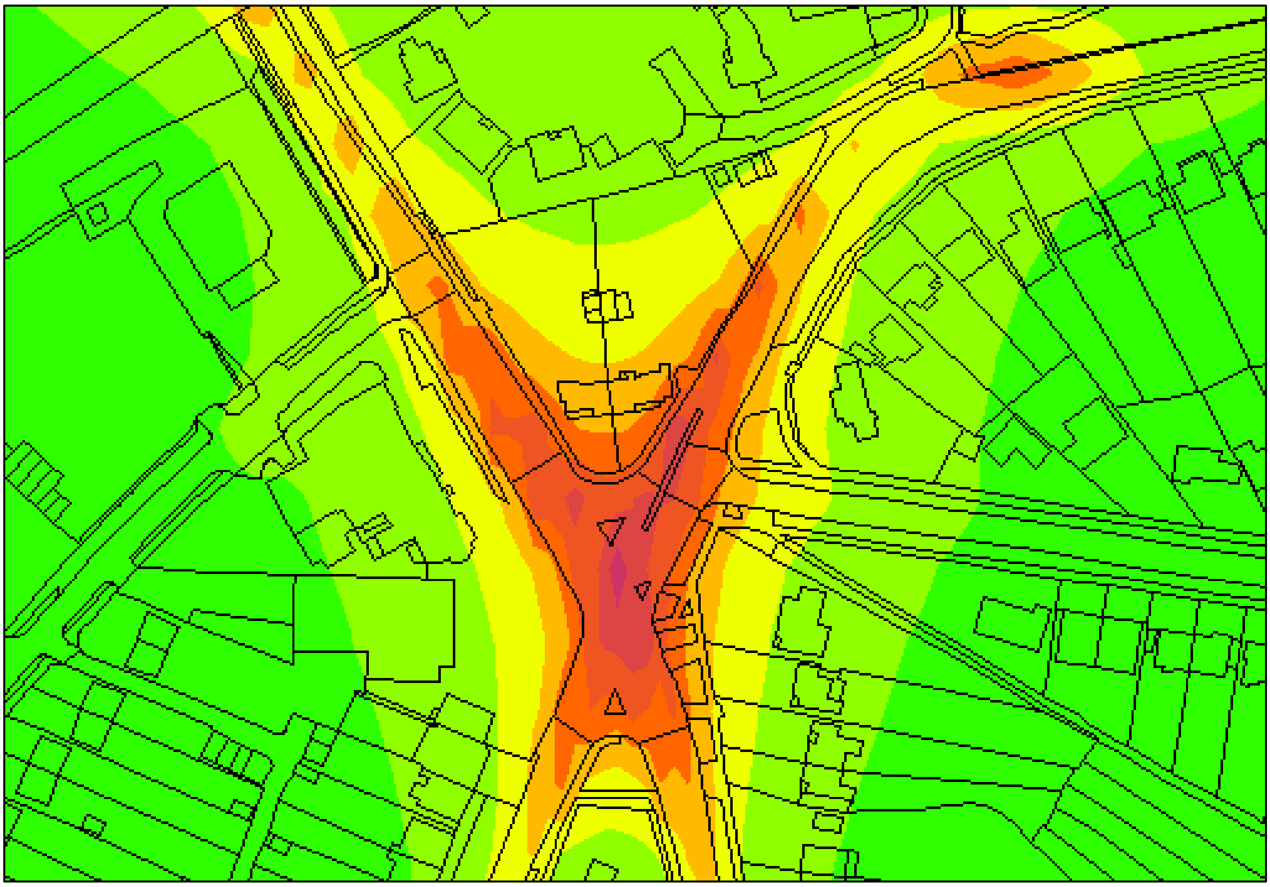

Figure 37: Option 3 Predicted Annual Mean NO_2 ($\mu g/m^3$) – Just at Junction

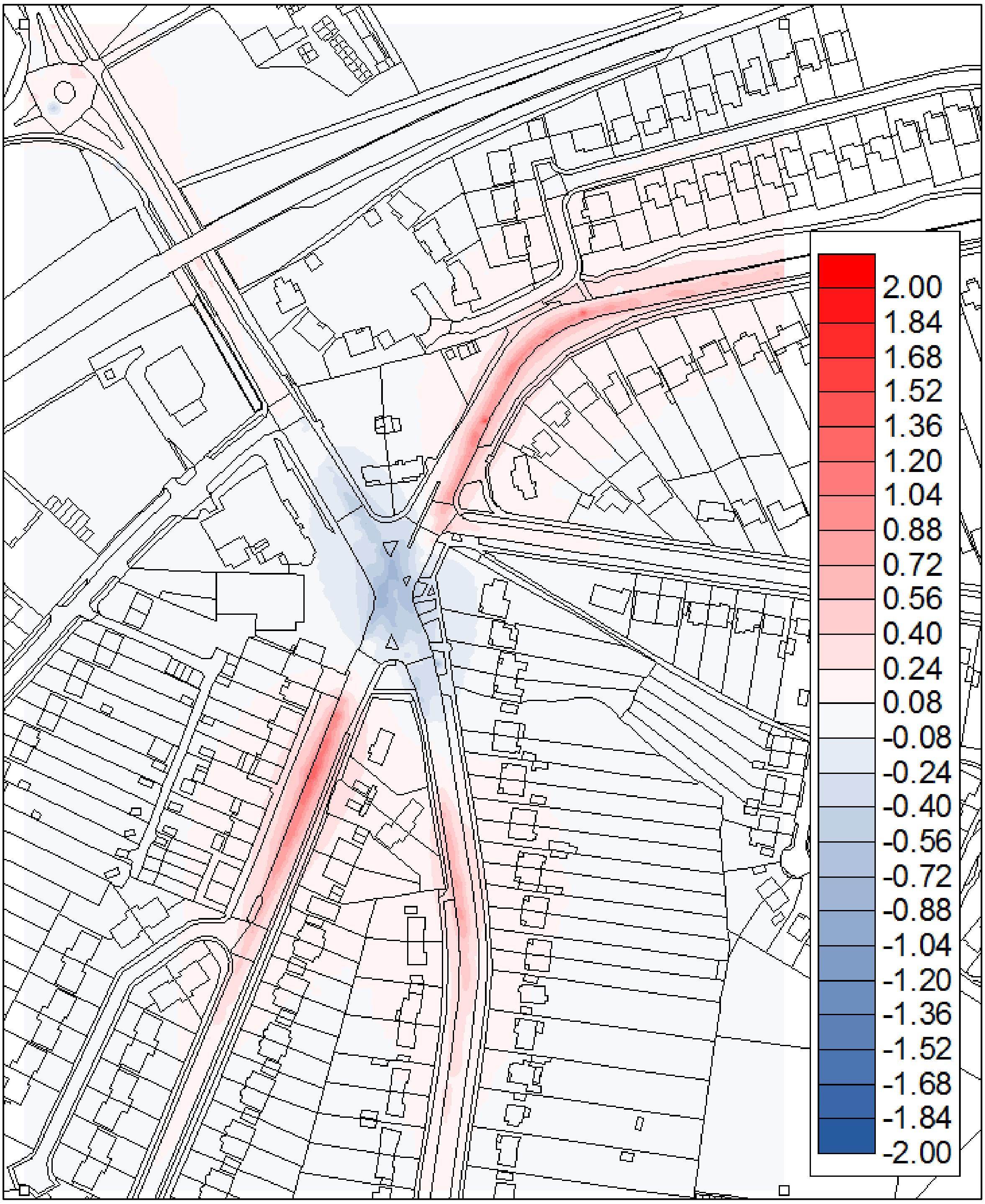

Figure 38: Change in Predicted Annual Mean NO_2 (µg/m^3) between Option 3 and Base Case – Whole Study Area

Summary and Discussion of Traffic Management Tests

Discussion of the Results

7.13 All three options investigated are predicted to reduce concentrations in some locations and to increase them in others. An important point is that there is no relevant exposure to traffic pollution in some parts of the study area. Options which improve concentrations at residential properties at the expense of increased concentrations in locations with no exposure will, on balance, improve the air quality to which residents are exposed. Furthermore, options which remove the objective exceedences within the AQMA can be said to achieve the aim of the study, even if this is at the expense of increased concentrations at other residential properties where concentrations are below the objectives.

7.14 Of the three options, Option 1 (20 mph zone) is predicted to have the most beneficial impacts on air quality both within the AQMA and elsewhere within the study area. It is also predicted to cause the greatest increases in concentrations, but these are in a few isolated locations where traffic is predicted to accelerate out from the 20 mph zone. The predicted changes associated with Option 1 are appreciable: it is predicted to reduce NOx emissions on some road sections by more than 90%; to reduce annual mean NO_2 concentrations in some locations by more than 10 $\mu g/m^3$; and to remove the need for the Drift Bridge AQMA.

Potential Benefits of the Chosen Assessment Method in Identifying the Predicted Changes

7.15 If the modelling had been carried out using traditional, average-speed based, techniques, then the predictions would have shown an adverse effect within the AQMA of imposing a 20 mph zone. This is because, as the average vehicle speed reduces from 30 mph to 20 mph, the EFT suggests that emissions should increase (Figure 39). The reason why the results from this study show the opposite effect is that slow average speeds can be achieved in many different ways. The higher emissions at slow speeds shown in Figure 39 relate mainly to the degree of acceleration assumed for that speed. By smoothing the traffic flow, it is assumed that the amount of acceleration will be reduced. It is only through using instantaneous emission factors that the effects of any of the three options considered in this report can be considered with any degree of accuracy.

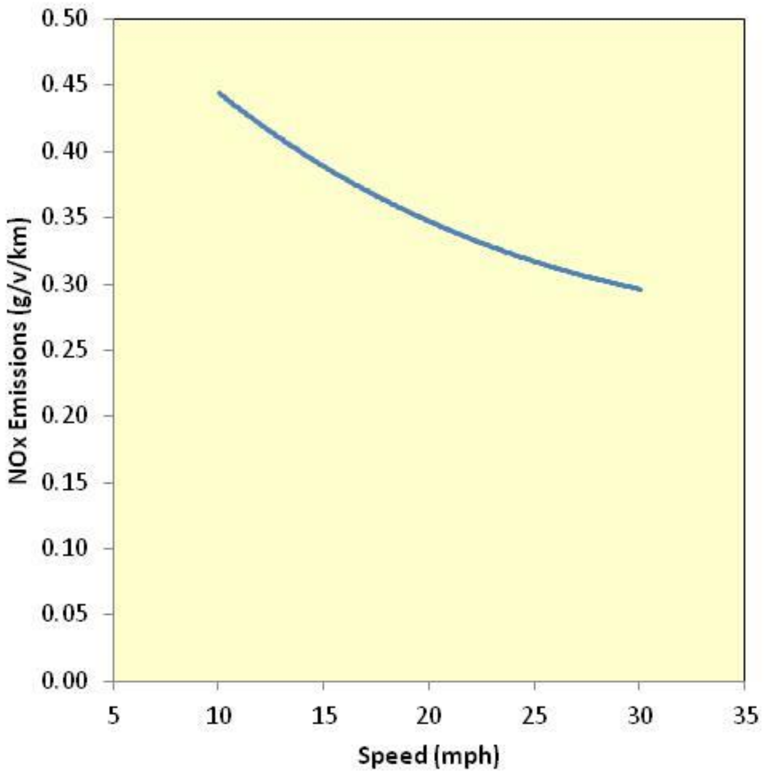

Figure 39: Average-Speed Emission Curve for a Typical Passenger Car from the EFT[3]

Potential Disbenefits of the Chosen Assessment Method in Identifying the Predicted Changes

7.16 The discussion above should not be taken to imply that the results predicted in this study should be relied upon without question. Just as average-speed based modelling has its limitations, there are significant uncertainties associated with the predicted results. The key difference between using instantaneous emission factors and average-speed emission factors for a study such as this rests in the way in which emissions from idling and acceleration phases are treated. AIRE predicts minimal emissions from idling vehicles, and appreciable emissions from accelerating vehicles. It is well known that some micro-simulation traffic models can misrepresent acceleration rates, and while it is understood that S-Paramics handles acceleration more accurately than some other traffic models, given the sensitivity of the results to acceleration, the potential for erroneous results must be recognised.

7.17 The conclusions relating to traffic management options are also entirely dependent upon how well the traffic model reflects the average effects of each option; and then how well these effects are then simulated in the emissions model. Anecdotal evidence is that different drivers respond very differently to the introduction of a new 20 mph zone.

7.18 Ultimately, while a large number of studies have been carried out across the UK from which to estimate the likely reliability of average-speed model results, there are no other published studies which have followed the same methodology as set out here from which to estimate how reliable the current findings may be. SIAS Ltd., who publishes both the S-Paramics and AIRE models, has advised that the large predicted reductions in emissions associated with Option 1 are explicable by the smoothing predicted within the models. Thus, while the predicted results should be viewed with a sensible degree of caution, there is no apparent reason why they should be discounted.

Other Common Issues with Using Instantaneous Emission Factors

7.19 Instantaneous vehicle emission factors are sometimes used to calculate total emissions across a study area, and these totals are occasionally used to indicate the likely changes in air quality. As it happens, the total emissions data in Table 6 reflect the large predicted receptor-specific concentration reductions. Total emissions are, however, predicted to increase in both Options 2 and 3, even though both options would bring about reduced concentrations within the AQMA. It is thus considered inappropriate to use study-area average emissions as an indicator of location-specific concentration changes.

Table 6: Total Predicted NOx Emissions Across the Study Area

Scenario	NOx Emissions (kt/yr)
Baseline	81.0
Option 1	74.0
Option 2	81.8
Option 3	81.7

The micro-simulation traffic modelling which under-pins this work considered 24-hours of a typical weekday, as well as Saturdays and Sundays. Micro-simulation traffic modelling often only covers peak hours. It is always preferable to predict annual mean concentrations using full 24-hour periods of traffic modelling. This can be demonstrated using the subset of data from Table 5, which has been re-processed in Table 7 to show the proportion of the weekday road-NOx that is emitted during each hour of a weekday. On these links, the AM and PM peak hours contribute less than 20% of the total weekday emissions (and will contribute less to the annual total emissions). Those periods which are thus not very significant in traffic models (since they are of limited importance in terms of road capacity) are of appreciable importance in terms of air quality. Perhaps more importantly, the relative contribution of each hour to the total, changes appreciably between the baseline and Option 1. Thus, the standard approach of calculating daily-average flows from peak-hour data using fixed scaling factors would not accurately represent the effect of the traffic management options being considered. This limitation is very common when traffic models are used to inform air quality assessments.

Table 7: Proportion of Weekday Road NOx Emitted Each Hour on Four Link Sections under Two Scenarios

	Link	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16	hr17	hr18	hr19	hr20	hr21	hr22	hr23	hr24
Baseline	405	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	1.9%	5.8%	7.4%	5.6%	5.4%	5.4%	7.2%	5.5%	7.6%	10%	11%	11%	7.5%	3.0%	1.9%	1.2%	0.5%	0.2%
	406	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	1.9%	5.8%	6.9%	5.6%	5.5%	5.5%	7.3%	5.8%	7.6%	10%	11%	11%	7.5%	3.0%	2.0%	1.3%	0.5%	0.2%
	615	0.4%	0.2%	0.3%	0.2%	0.5%	1.6%	5.8%	7.9%	7.9%	7.3%	6.7%	6.6%	5.3%	6.2%	6.1%	6.2%	6.2%	6.3%	6.2%	4.7%	3.0%	2.3%	1.3%	0.9%
	616	0.4%	0.2%	0.3%	0.2%	0.6%	1.6%	5.8%	7.9%	7.8%	7.5%	6.7%	6.7%	5.3%	6.1%	6.2%	6.2%	6.1%	6.2%	6.1%	4.6%	3.0%	2.2%	1.3%	0.9%
Option 1	405	0.4%	0.2%	0.3%	0.4%	0.5%	0.5%	2.1%	5.6%	8.7%	6.3%	5.6%	5.3%	7.2%	5.6%	7.8%	8.6%	10%	8.4%	6.9%	3.3%	2.5%	2.0%	1.2%	0.5%
	406	0.4%	0.2%	0.2%	0.4%	0.5%	0.5%	2.2%	5.7%	8.7%	6.4%	5.6%	5.5%	7.4%	5.9%	7.7%	8.4%	9.9%	8.3%	6.8%	3.3%	2.5%	2.0%	1.1%	0.5%
	615	0.4%	0.2%	0.2%	0.2%	0.6%	1.3%	5.0%	9.6%	14%	8.7%	6.8%	6.5%	4.6%	6.1%	5.9%	6.1%	5.4%	5.5%	5.2%	3.1%	2.0%	1.5%	0.7%	0.7%
	616	0.4%	0.2%	0.2%	0.2%	0.7%	1.3%	5.1%	9.1%	14%	8.7%	7.3%	6.2%	4.7%	6.2%	6.0%	6.2%	5.5%	5.3%	5.1%	3.3%	2.0%	1.5%	0.9%	0.7%

8 Conclusions

8.1 The use of micro-simulation traffic modelling and instantaneous emission factors can give appreciably different results from those predicted using more traditional methods. In particular, concentrations predicted using instantaneous emission factors vary across the study area to a much greater extent than those predicted using average-speed-based emission factors. This is to be expected given the basis of both emissions models.

8.2 The two long-term roadside monitoring sites in the study area do not provide a robust basis for claiming that the instantaneous-based model performs more accurately than the average-speed-based model, but the instantaneous-based model certainly gives a more detailed picture and allows the effects of options to be tested which would not be possible using an average-speed-based model.

8.3 If the detailed picture of concentrations provided by AIRE is correct, then it has significant implications for the use of average-speed emissions factors in dispersion modelling studies. One important point is that, since AIRE predicts that road-NOx concentrations will vary appreciably along the length of a road, while average-speed models do not, then the precise location of a monitoring site will determine how well the model results compare with the measurements. This may, in turn, determine the adjustment factor that is applied to the results over the whole study area.

8.4 Of the options tested, the imposition of a 20 mph speed restriction is predicted to have the greatest benefits. This option is predicted to remove the need for the AQMA. This finding is of interest, given that the average-speed-based emission factors predict a worsening of air quality associated with this measure.

9 References

Carslaw, D., Beevers, S., Westmoreland, E. and Williams, M. (2011) *Trends in NOx and NO2 emissions and ambient measurements in the UK*, [Online], Available: uk-air.defra.gov.uk/reports/cat05/1108251149_110718_AQ0724_Final_report.pdf.

CERC (2011) *Developments in Dispersion Modelling over Different Spatial Scales: Presentation ot UK DMUG 2011*, [Online].

Defra (2007) *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland*, Defra.

Defra (2009) *Review & Assessment: Technical Guidance LAQM.TG(09)*, Defra.

Defra (2014a) *Defra Air Quality Website*, [Online], Available: http://www.defra.gov.uk/environment/quality/air/airquality/.

Defra (2014b) *Local Air Quality Management (LAQM) Support*, [Online], Available: http://laqm.defra.gov.uk/.

Directive 2008/50/EC of the European Parliament and of the Council (2008).

Newcastle City Council (2005) 'Further Assessment of Air Quality in Newcastle City Centre, the Quayside, and Jesmond Road'.

RBBC (2007) *Further Assessment of Air Quality at the Junction of the A2022 and A240 (Drift Bridge)*.

RBBC (2011) *Progress Report (2011) on Air Quality within the Borough of Reigate and Banstead*.

The Air Quality (England) (Amendment) Regulations, 2002, Statutory Instrument 3043 (2002), HMSO.

The Air Quality Regulations, 2000, Statutory Instrument 928 (2000), HMSO.

The Air Quality Standards Regulations 2010 (No. 1001) (2010), HMSO.

WHO (2013) *Review of Evidence on Health Aspects of Air Pollution - REVIHAAP Project Technical Report*, [Online], Available: http://www.euro.who.int/__data/assets/pdf_file/0004/193108/REVIHAAP-Final-technical-report-final-version.pdf?ua=1.

A1 Tabulated Results

Table A1.1: Predicted Annual Mean Road-NOx at Specific Receptors

Receptor	Grid Coordinate	1-hour AIRE	1-hour EFT	1-hour EFT Adjusted	5-minute AIRE	1-hour Standard	1-hour Standard Adjusted	Option 1	Option 2	Option 3
R1	523092,159668	6.5	14.0	18.7	6.5	11.5	16.7	6.8	6.6	6.6
R2	523099,159668	9.1	14.5	19.4	9.0	11.1	16.1	9.5	9.1	9.1
R3	523126,160208	66.7	33.4	44.9	66.5	32.9	48.0	62.3	67.1	67.1
R4	523138,160172	52.4	31.7	42.5	52.2	24.7	36.0	19.4	52.5	52.6
R5	523239,159682	9.6	24.8	33.3	9.6	17.4	25.3	11.3	9.7	9.7
R6	523247,159681	13.3	27.7	37.2	13.2	20.2	29.5	15.8	13.3	13.3
R7	523853,160237	6.7	3.6	4.8	6.7	7.5	11.0	6.5	6.8	6.8
R8	523114,159724	5.8	11.9	15.9	5.8	9.1	13.3	6.8	5.8	5.8
R9	523128,159737	11.9	18.3	24.6	11.8	13.0	18.9	14.8	12.0	11.9
R10	523149,159800	7.3	15.8	21.3	7.2	12.8	18.6	14.8	7.4	7.5
R11	523155,159797	11.1	17.2	23.1	11.1	12.8	18.7	30.6	11.3	11.3
R12	523157,160155	60.4	47.3	63.5	60.0	34.1	49.8	21.8	60.6	60.8
R13	523177,159868	7.7	14.3	19.2	7.7	11.1	16.1	7.6	7.9	8.3
R14	523176,160107	21.5	28.2	37.9	21.4	21.2	30.9	13.6	21.9	21.7
R15	523177,159850	11.4	17.0	22.9	11.3	13.3	19.4	11.1	11.6	11.8
R16	523179,160119	36.3	47.2	63.4	36.1	34.4	50.1	23.7	37.2	36.5
R17	523195,159914	11.6	16.7	22.5	11.6	12.9	18.8	10.3	12.2	13.1

Receptor	Grid Coordinate	1-hour AIRE	1-hour EFT	1-hour EFT Adjusted	5-minute AIRE	1-hour Standard	1-hour Standard Adjusted	Option 1	Option 2	Option 3
R18	523202,159912	15.3	17.2	23.1	15.2	12.9	18.8	12.7	15.7	16.2
R19	523207,160077	46.7	45.2	60.7	46.4	37.2	54.3	31.0	41.5	46.5
R20	523211,160047	41.2	28.5	38.2	41.0	30.2	44.1	28.4	43.7	40.9
R21	523214,159962	23.4	18.3	24.5	23.3	14.8	21.5	18.2	23.8	25.0
R22	523221,159958	27.6	20.0	26.8	27.5	15.2	22.1	19.9	28.1	28.6
R23	523223,159987	36.4	19.2	25.7	36.1	17.5	25.5	26.3	36.1	36.4
R24	523226,160022	46.5	29.9	40.1	46.3	34.9	50.9	31.8	46.6	45.8
R25	523231,160008	55.8	29.1	39.1	55.5	28.9	42.1	36.0	55.5	54.4
R26	523230,160042	64.7	46.4	62.2	64.2	45.9	66.9	54.5	61.4	63.6
R27	523233,159982	43.1	22.2	29.8	42.9	19.8	28.9	27.5	43.2	43.1
R28	523243,160042	61.6	36.9	49.5	61.2	37.4	54.6	49.8	61.9	61.1
R29	523243,159983	43.2	27.2	36.6	42.9	24.1	35.2	32.4	43.7	42.9
R30	523247,160010	73.5	37.9	50.8	73.1	35.4	51.7	51.8	73.3	71.9
R31	523250,159962	29.9	27.0	36.3	29.7	22.1	32.2	24.4	31.0	29.7
R32	523253,159994	52.2	31.6	42.4	51.8	29.4	42.9	35.8	52.2	51.4
R33	523251,159778	9.0	22.1	29.6	9.0	15.6	22.8	14.1	9.2	9.3
R34	523256,160032	53.1	29.8	40.0	52.8	26.5	38.6	42.3	54.3	53.5
R35	523257,159917	14.0	22.0	29.6	14.0	15.5	22.7	12.6	14.9	14.8
R36	523258,159973	37.9	31.1	41.7	37.6	27.2	39.6	28.3	38.3	37.4
R37	523261,159781	15.7	31.4	42.2	15.6	22.5	32.9	27.0	15.9	15.9

Receptor	Grid Coordinate	1-hour AIRE	1-hour EFT	1-hour EFT Adjusted	5-minute AIRE	1-hour Standard	1-hour Standard Adjusted	Option 1	Option 2	Option 3
R38	523263,160050	46.3	31.7	42.6	46.0	29.9	43.5	37.0	48.4	48.2
R39	523264,159873	11.9	24.5	32.9	11.8	17.9	26.0	12.3	12.5	12.6
R40	523265,159931	23.5	30.8	41.4	23.3	22.1	32.2	19.1	24.3	23.9
R41	523266,160080	52.9	35.9	48.2	52.6	28.8	42.0	35.1	54.1	53.7
R42	523272,159864	17.4	30.2	40.5	17.2	21.0	30.6	16.7	17.8	17.8
R43	523278,160082	32.6	30.2	40.5	32.4	26.4	38.4	23.5	34.3	34.1
R44	523285,160111	27.8	30.9	41.5	27.5	22.9	33.5	27.5	28.5	28.5
R45	523297,160108	23.6	30.4	40.8	23.5	22.4	32.6	18.9	24.8	25.1
R46	523303,160123	45.9	32.7	43.9	45.6	24.4	35.6	26.5	46.6	46.7
R47	523319,160118	25.3	26.6	35.7	25.2	20.1	29.3	15.9	26.2	26.4
R48	523344,160132	33.1	33.8	45.4	32.9	25.2	36.8	22.8	33.7	33.8
R49	523380,160131	14.9	23.5	31.5	14.8	17.5	25.6	12.3	15.4	15.7
R50	523413,160146	24.1	32.9	44.2	24.0	24.3	35.4	21.3	24.6	24.7
R51	523479,160151	11.7	22.2	29.9	11.7	16.6	24.2	11.3	12.2	12.4
R52	523487,160161	22.3	32.3	43.4	22.1	23.7	34.5	21.1	22.7	22.8
R53	523546,160173	19.5	32.2	43.3	19.3	23.6	34.4	52.0	19.9	20.1
R54	523595,160176	9.6	21.6	29.0	9.5	16.4	23.8	13.2	9.9	10.1
R55	523662,160197	17.8	31.6	42.4	17.7	22.8	33.2	20.0	18.1	18.2
R56	523690,160195	9.0	21.0	28.2	9.0	15.9	23.2	10.2	9.3	9.4
R57	523858,160230	5.1	2.8	3.8	5.1	4.4	6.4	5.0	5.2	5.2

Receptor	Grid Coordinate	1-hour AIRE	1-hour EFT	1-hour EFT Adjusted	5-minute AIRE	1-hour Standard	1-hour Standard Adjusted	Option 1	Option 2	Option 3
R58	523285,160057	21.0	14.4	19.4	21.0	12.9	18.9	15.7	21.6	21.4
R59	523274,160015	21.4	13.8	18.6	21.4	12.0	17.5	15.6	21.6	21.2
R60	523273,160007	21.4	14.2	19.0	21.4	12.3	17.9	15.5	21.6	21.2
R61	523276,159994	17.9	13.2	17.7	17.9	11.1	16.3	13.2	18.1	17.8
R62	523279,159980	15.0	12.7	17.1	15.0	10.3	15.0	11.5	15.2	14.9
R63	523278,159957	12.9	13.7	18.4	12.9	10.1	14.7	10.5	13.3	13.0
R64	523239,159957	16.7	14.6	19.6	16.6	11.7	17.0	13.0	17.1	16.9
R65	523234,159959	17.6	14.3	19.3	17.6	11.5	16.8	13.4	18.0	18.0
R66	523234,159945	12.7	12.4	16.7	12.7	9.5	13.8	10.2	13.1	13.1
R67	523229,159948	13.7	12.6	17.0	13.7	9.7	14.1	10.9	14.1	14.2
R68	523218,159917	8.6	10.2	13.7	8.6	7.5	10.9	7.4	8.9	9.0
R69	523251,159929	12.3	16.3	21.8	12.3	11.7	17.1	10.7	13.0	12.7
R70	523212,159902	7.4	9.6	12.9	7.4	7.0	10.2	6.7	7.6	7.8
R71	523280,159937	10.7	13.7	18.4	10.7	9.7	14.1	9.1	11.1	11.0
R72	523283,159917	9.1	13.2	17.8	9.1	9.2	13.4	8.2	9.4	9.4
R73	523286,159902	8.1	12.8	17.2	8.1	8.8	12.8	7.7	8.4	8.4
R74	523288,159885	7.4	12.4	16.7	7.4	8.4	12.3	7.6	7.6	7.7
R75	523290,159868	6.6	11.7	15.7	6.6	7.9	11.5	7.6	6.8	6.8
R76	523284,159826	6.2	12.0	16.1	6.2	8.1	11.8	12.3	6.3	6.4
R77	523278,159777	5.4	11.2	15.0	5.4	7.5	11.0	8.3	5.5	5.5

Receptor	Grid Coordinate	1-hour AIRE	1-hour EFT	1-hour EFT Adjusted	5-minute AIRE	1-hour Standard	1-hour Standard Adjusted	Option 1	Option 2	Option 3
R78	523207,159895	7.1	9.5	12.8	7.1	7.0	10.2	6.5	7.3	7.4
R79	523202,159880	6.2	9.1	12.2	6.2	6.7	9.7	6.0	6.4	6.5
R80	523195,159863	5.6	8.7	11.6	5.6	6.4	9.3	5.8	5.7	5.8
R81	523182,159823	4.5	7.4	10.0	4.5	5.4	7.9	5.8	4.5	4.6
R82	523167,159863	5.4	9.2	12.3	5.4	6.9	10.0	5.6	5.6	5.7
R83	523208,159974	16.8	11.5	15.5	16.8	9.8	14.3	12.5	17.0	17.2
R84	523201,159957	12.4	10.3	13.9	12.3	8.3	12.0	9.6	12.6	12.9
R85	523190,159928	8.1	9.1	12.2	8.1	6.9	10.1	6.8	8.4	8.7
R86	523177,159897	5.9	8.3	11.1	5.9	6.2	9.1	5.4	6.1	6.3
R87	523209,160027	23.7	15.7	21.1	23.7	16.3	23.8	17.5	24.2	23.6
R88	523189,160061	18.6	15.3	20.5	18.5	13.1	19.1	12.0	19.2	18.5
R89	523228,160053	47.1	33.6	45.1	46.9	34.1	49.7	36.9	44.7	46.5
R90	523238,160054	41.9	27.5	37.0	41.7	27.0	39.3	32.3	41.5	41.6
R91	523248,160055	50.8	29.8	40.0	50.6	29.2	42.6	39.3	51.2	50.8
R92	523250,160065	40.6	25.5	34.2	40.4	24.2	35.3	29.7	41.0	40.7
R93	523227,160061	40.1	29.6	39.8	40.0	29.4	42.9	29.5	38.4	39.8
R94	523293,160071	18.3	13.8	18.5	18.3	12.0	17.4	13.4	18.8	18.7
R95	523296,160079	17.7	14.1	18.9	17.7	11.9	17.4	12.9	18.2	18.1
R96	523308,160089	14.6	12.6	16.9	14.7	10.2	14.9	10.7	15.1	15.0
R97	523322,160096	12.3	11.2	15.1	12.3	8.9	12.9	9.0	12.7	12.6

Receptor	Grid Coordinate	1-hour AIRE	1-hour EFT	1-hour EFT Adjusted	5-minute AIRE	1-hour Standard	1-hour Standard Adjusted	Option 1	Option 2	Option 3
R98	523364,160109	8.7	9.5	12.8	8.7	7.2	10.5	6.7	9.0	9.0
R99	523396,160117	7.2	9.0	12.1	7.2	6.7	9.7	5.9	7.4	7.4
R100	523272,160126	15.3	13.3	17.9	15.3	10.4	15.1	11.2	15.6	15.6
R101	523291,160143	13.6	11.9	15.9	13.6	9.1	13.3	9.6	13.8	13.8
R102	523316,160144	17.0	14.5	19.4	17.0	10.9	15.9	10.8	17.3	17.4
R103	523353,160162	10.7	11.0	14.8	10.7	8.2	12.0	7.8	11.0	11.0
R104	523382,160170	8.8	10.2	13.6	8.8	7.5	10.9	6.9	9.0	9.0
R105	523428,160179	7.3	9.7	13.0	7.3	7.1	10.3	6.4	7.5	7.5
R106	523251,159886	7.3	12.5	16.8	7.3	8.7	12.8	7.4	7.7	7.7
R107	523250,159856	6.2	11.7	15.7	6.1	8.1	11.8	7.6	6.4	6.4
R108	523245,159827	5.5	11.1	14.9	5.5	7.6	11.1	9.2	5.6	5.7
R109	523238,159781	4.9	10.6	14.2	4.8	7.2	10.5	7.7	4.9	5.0

A2 Examples of Model Verification

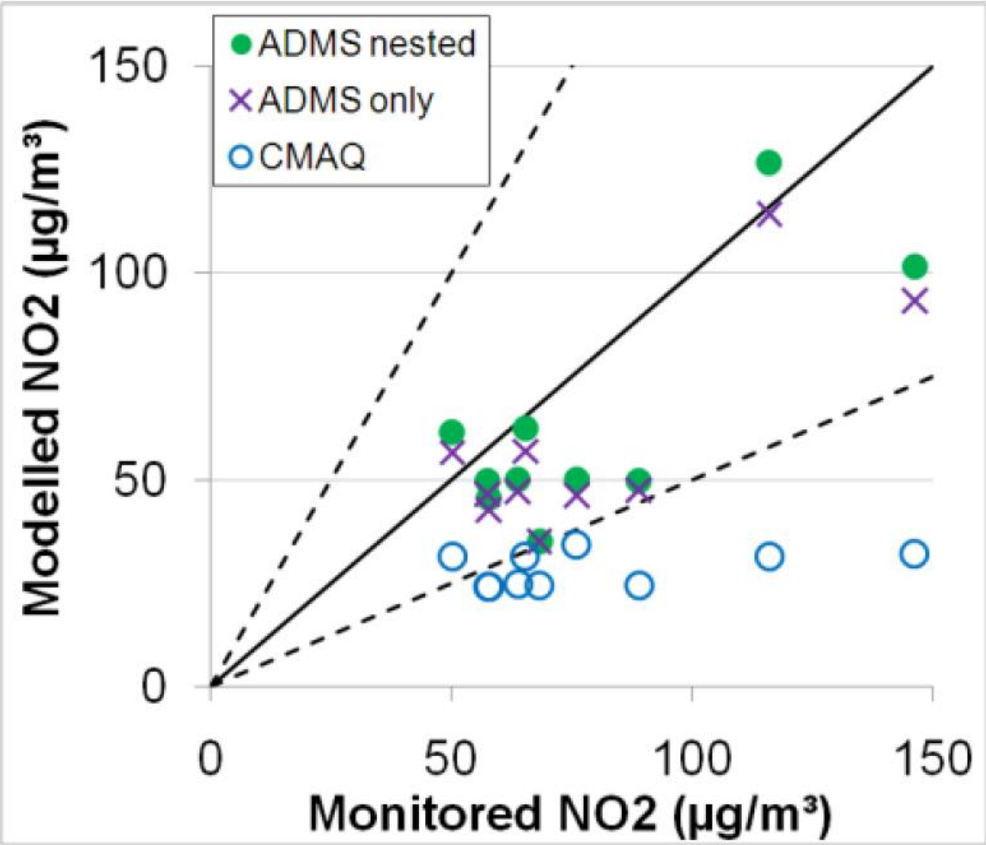

Figure A2.1: Example of Verification Plot - Comparison of Modelled and Measured NO_2 at Roadside and Kerbside Monitoring Sites – Comparing Three Model Set-ups (CERC, 2011)

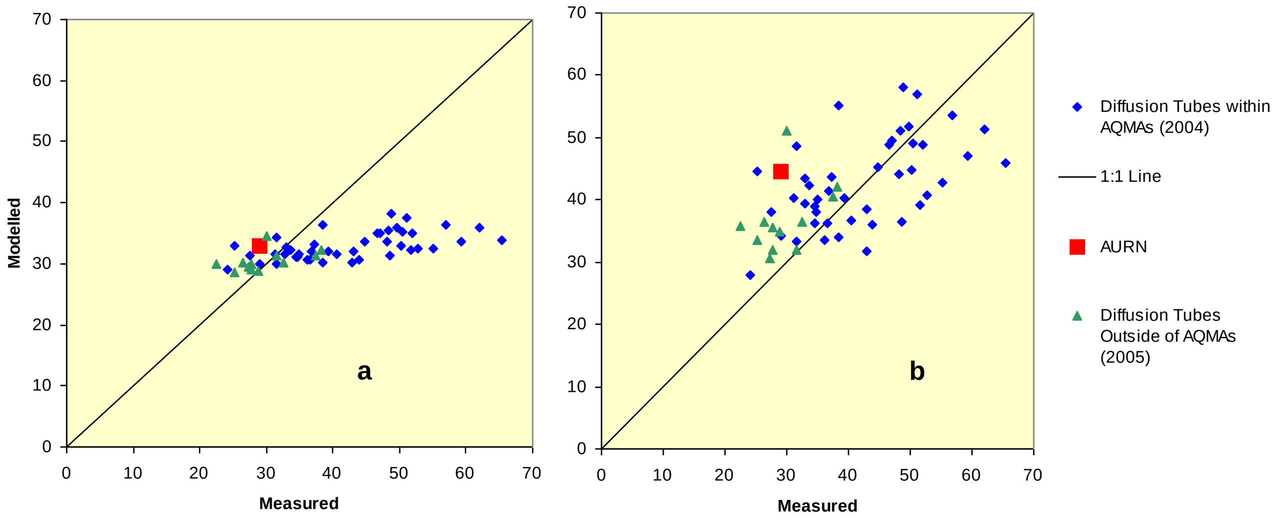

Figure A2.2: Example of Verification Plot - Modelled vs Measured Annual Mean Nitrogen Dioxide Concentrations, a) before adjustment a and b) after verification and adjustment (µg/m^3) (Newcastle City Council, 2005)