Cambridge Environmental Research Consultants

Air Quality Modelling for the London Borough of Islington

Final Report

Prepared for
London Borough of Islington

14th January 2015

CERC

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Contents

1. Summary

The whole of the London Borough of Islington has been declared an Air Quality Management Area due to concentrations of nitrogen dioxide (NO_2) and particulate matter (PM_{10}) exceeding the UK air quality standards. There is particular concern over concentrations of NO_2, PM_{10} and fine particles ($PM_{2.5}$) at Archway; Highbury Corner; Angel; Old Street and Finsbury Park.

Cambridge Environmental Research Consultants (CERC) was commissioned by the London Borough of Islington to carry out air quality modelling for the areas listed above including:

- Modelling showing concentrations in the areas of interest for a 2020 base case;
- Source apportionment, showing the relative contributions of different source groups to pollutant concentrations;
- Modelling emission reduction scenarios for 2020 where i) all buses meet Euro 6 engine standards and ii) all vehicles meet Euro 6 engine standards.

Air quality modelling was carried out using ADMS-Urban (version 3.2.0) with emissions and traffic data from the London Atmospheric Emissions Inventory (LAEI) 2010.

Traffic emissions were calculated using road traffic emission factors and fleet data released in August 2012 by the UK National Atmospheric Emissions Inventory (NAEI), on behalf of the Department for Environment, Food & Rural Affairs (Defra).

Model verification was carried out by comparing measured and modelled concentrations at continuous monitoring sites in Islington for 2012. The modelling shows generally good agreement between the measured and modelled NO_2 and PM_{10} concentrations, indicating that the emissions data and model set-up are appropriate for the area.

Air quality maps of ground level concentrations of NO_2, PM_{10} and $PM_{2.5}$ were created for the areas of interest for the 2020 base case for comparison against air quality standards.

In 2020, the air quality standard of 40 $\mu g/m^3$ for annual average NO_2 concentrations is predicted to be exceeded along many of the major roads in Islington. The air quality standard of 200 $\mu g/m^3$ for the 99.79th percentile of hourly average NO_2 concentrations is predicted to be met for most locations in Islington.

The air quality standards for PM_{10} and $PM_{2.5}$ are predicted to be achieved throughout the borough in 2020.

Source apportionment was carried out to determine the contributions of different source groups to pollutant concentrations at six locations in the borough.

Major roads are predicted to be the major contributor to NO_x concentrations at the source apportionment locations considered, accounting for between 28% and 70% of the predicted concentrations. The highest predicted contribution from major roads sources is predicted at the Finsbury Park source apportionment location.

The major contributions to the road component of the NO_x concentrations are from cars and buses. Cars contribute between 15% and 39% of the road component and buses contribute between 27% and 65% of the road component. The greatest percentage contribution from buses occurs at the Angel site and the greatest percentage contribution from cars occurs at the Archway site.

Background concentrations are the largest contributor to PM_{10} and $PM_{2.5}$ concentrations in the borough, contributing between 73% and 95% to the total concentrations. The next greatest contributor is major roads, accounting for between 4% and 24% of the total. Of the major road compenent, the greatest contributions are from cars (28% to 57%) and buses (9% to 40%).

PM_{10} and $PM_{2.5}$ concentrations resulting from major roads consist of exhaust and non-exhaust components. In 2020, non-exhaust emissions are predicted to account for a larger proportion of the road component than exhaust emissions, for both PM_{10} and $PM_{2.5}$ emissions. Non-exhaust emissions account for between 80% and 89% of PM_{10} concentrations from major roads, and between 58% and 77% of $PM_{2.5}$ concentrations.

Assuming all buses in London meet the EURO 6 emissions standards results in significant decreases in annual average NO_2 concentrations, resulting in smaller areas of exceedence of the air quality objective of 40 $\mu g/m^3$.

Assuming all vehicles in London meet the EURO 6 emissions standards results in further significant decreases in annual average NO_2 concentrations. Exceedences of the air quality objective are no longer predicted at Archway or Highbury, with only small areas of exceedences at busy junctions predicted at Old Street.

2. Introduction

The whole of the London Borough of Islington has been declared an Air Quality Management Area due to concentrations of nitrogen dioxide (NO_2) and particulate matter (PM_{10}) exceeding the UK air quality standards. There is particular concern over concentrations of NO_2, PM_{10} and fine particles ($PM_{2.5}$) at Archway; Highbury Corner; Angel; Old Street; and Finsbury Park.

Cambridge Environmental Research Consultants (CERC) was commissioned by the London Borough of Islington to carry out air quality modelling for the areas listed above including:

- Modelling showing concentrations in the areas of interest for a 2020 base case;
- Source apportionment, showing the relative contributions of different source groups to pollutant concentrations;
- Modelling emission reduction scenarios for 2020 where i) all buses meet Euro 6 engine standards and ii) all vehicles meet Euro 6 engine standards.

This report describes the air quality modelling carried out. The air quality limit values and target values with which the calculated concentrations are compared are presented in Section 3. The emissions data and model set-up are described in Sections 4 and 5. The results of the modelling are then presented: the model verification in Section 6; concentration maps for the 2020 base case in Section 7; source apportionment results in Section 8; and concentration maps for the emission reduction scenarios in Sections 9 and 10. A discussion of the results is presented in Section 11. A description of the ADMS-Urban model is given in Appendix A.

3. Air quality standards

The EU *ambient air quality directive* (2008/50/EC) sets binding limits for concentrations of air pollutants. The directive has been transposed into English legislation as the *Air Quality Standards Regulations 2010*[1], which also incorporates the provisions of the *4th air quality daughter directive* (2004/107/EC).

The Air Quality Standards Regulations 2010 include limit values and target values. The limit values are presented in Table 3.1.

Table 3.1: Air quality limit values

	Value (µg/m³)	Description of standard
NO_2	200	Hourly mean not to be exceeded more than 18 times a calendar year (modelled as 99.79th percentile)
	40	Annual average
PM_{10}	50	24-hour mean not to be exceeded more than 35 times a calendar year (modelled as 90.41st percentile)
	40	Annual average
$PM_{2.5}$	25	Annual average

Note that the limit value for $PM_{2.5}$ includes a margin of tolerance of 20% in June 2008, decreasing on the next 1st January and every 12 months thereafter by equal annual percentages to reach 0% by 1st January 2015. A target value of 25µg/m³ also exists for $PM_{2.5}$.

The short-term standards considered are specified in terms of the number of times during a year that a concentration measured over a short period of time is permitted to exceed a specified value. For example, the concentration of NO_2 measured as the average value recorded over a one-hour period is permitted to exceed the concentration of 200 µg/m³ up to 18 times per year. Any more exceedences than this during a one-year period would represent a breach of the objective.

It is convenient to model objectives of this form in terms of the equivalent percentile concentration value. A percentile is the concentration below which lie a specified percentage of concentration measurements. For example, consider the 98th percentile of one-hour concentrations over a year. Taking all of the 8760 one-hour concentration values that occur in a year, the 98th percentile value is the concentration below which 98% of those concentrations lie. Or, in other words, it is the concentration exceeded by 2% (100 – 98) of those hours, that is, 175 hours per year. Taking the NO_2 objective considered above, allowing 18 exceedences per year is equivalent to not exceeding for 8742 hours or for 99.79% of the year. This is therefore equivalent to the 99.79th percentile value.

[1] http://www.legislation.gov.uk/uksi/2010/1001/contents/made

4. Emissions data

The modelling for this study was based on emissions data taken from the London Atmospheric Emissions Inventory (LAEI) 2010, released by the Greater London Authority (GLA) in 2013.

4.1. Traffic emissions

Traffic flows and speeds for all major roads in London were taken from the LAEI, where data are provided for the years 2012 and 2020. Traffic emissions were calculated using new road traffic emission factors and fleet data released in August 2012 by the UK National Atmospheric Emissions Inventory (NAEI), on behalf of the Department for Environment, Food & Rural Affairs (Defra). The NAEI emissions factors include speed-emissions data for NO_x based on the COPERT 4 version 8.1 software tool[2]. The emissions data include primary NO_2 emission factors for each vehicle type resulting in accurate road-by-road NO_x and NO_2 emission rates.

Brake, tyre and road-wear emissions were calculated using emission factors in the 2009 EMEP/EEA emissions inventory guidebook[3]. Resuspension emission factors were taken from a report produced by TRL Limited on behalf of Defra[4].

For the emission reductions scenarios, major road emissions were recalculated assuming that:

i. All buses in London met Euro 6 emission standards; and
ii. All vehicles in London met Euro 6 emission standards.

All major roads within 1500 metres of Islington were modelled in detail, with all other roads in London modelled as part of a 1-kilometre resolution grid source. Figure 4.1 shows the major roads in Islington and also the areas of interest modelled in more detail.

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2 http://www.emisia.com/copert/General.html

3 EMEP/EEA air pollutant emissions inventory guidebook – 2009 Technical report no. 9/2009 http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

4 Road vehicle non-exhaust particulate matter: final report on emission modelling, TRL Limited Project Report PPR110 http://uk-air.defra.gov.uk/reports/cat15/0706061624_Report2__Emission_modelling.PDF

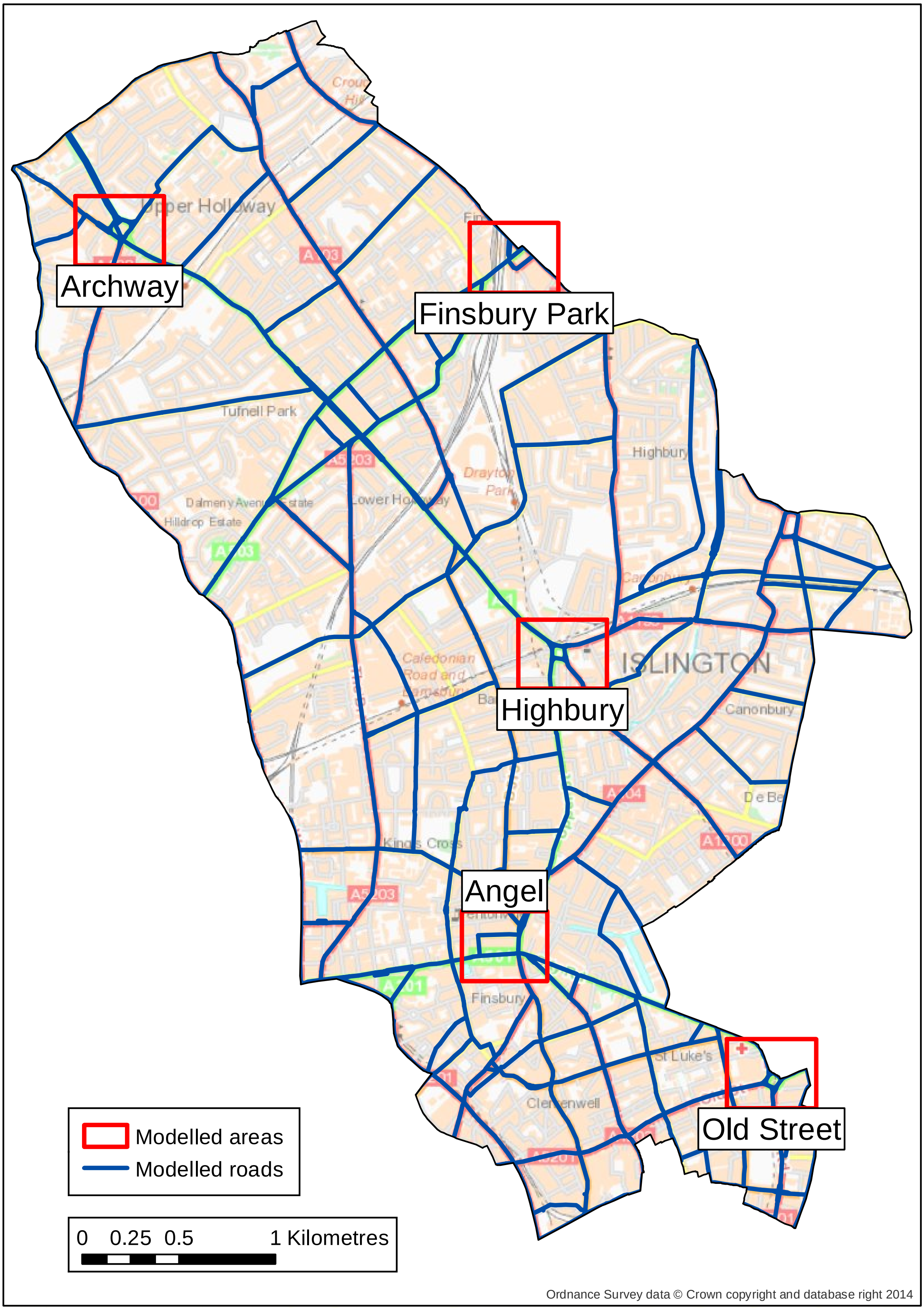

Figure 4.1: Major roads and modelled areas of interest in the London Borough of Islington

4.1.1. Daily traffic variation

The variation of traffic flow during the day was taken into account by applying a set of diurnal profiles to the road emissions. These profiles were taken from the report *Air pollution and emissions trends in London*[5] used in the compilation of the LAEI, and are shown in Figure 4.2.

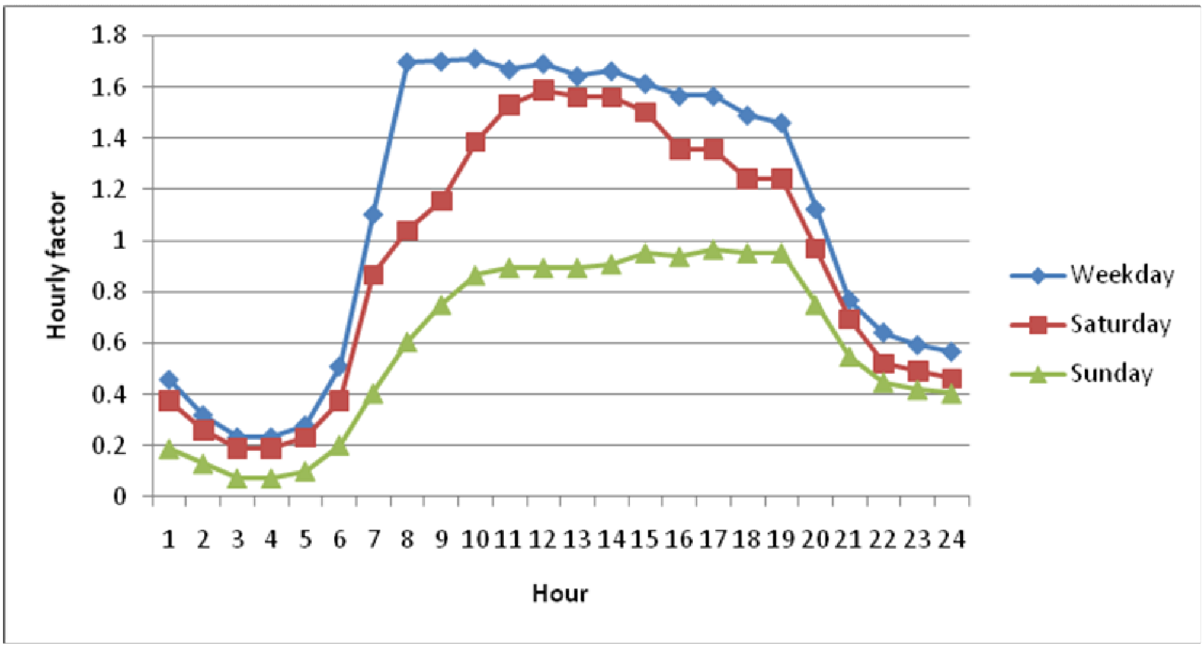

Figure 4.2: Diurnal profiles for Central London

4.2. Industrial sources

Due to their high emission rates, the following industrial sources have been included explicitly in the modelling:

- South East London Combined Heat and Power (SELCHP) plant, approximately 5 km southeast of Islington; and
- Citigen CHP in the south of the borough.

4.3. Other emissions

Emission rates for all other sources were taken from the LAEI and modelled as aggregated 1-kilometre resolution grid sources covering the whole of London.

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[5] *Air pollution and emissions trends in London*, King's College London, Environmental Research Group and Leeds University, Institute for Transport studies
http://www.airquality.co.uk/reports/cat05/1004010934_MeasurementvsEmissionsTrends.pdf

5. Model set-up

Modelling was carried out using the ADMS-Urban[6] model (version 3.2.0). The model uses the detailed emissions data described in Section 4 together with a range of other input data to calculate the dispersion of pollutants. This section summarises the data and assumptions used in the modelling.

5.1. Surface roughness

A length scale parameter called the surface roughness length is used in the model to characterise the study area in terms of the effects it will have on wind speed and turbulence, which are key factors in the modelling. A value of 1 metre was used in the modelling.

The difference in land use at Heathrow compared to the study area was taken into account by entering a different surface roughness for the meteorological site. See Section 5.3 for further details.

5.2. Monin-Obukhov Length

In urban and suburban areas a significant amount of heat is emitted by buildings and traffic, which warms the air within and above a city. This is known as the urban heat island and its effect is to prevent the atmosphere from becoming very stable. In general, the larger the urban area the more heat is generated and the stronger the effect becomes.

In the ADMS-Urban model, the stability of the atmosphere is represented by the Monin-Obukhov parameter, which has the dimension of length. In very stable conditions it has a positive value of between 2 metres and 20 metres. In near neutral conditions its magnitude is very large, and it has either a positive or negative value depending on whether the surface is being heated or cooled by the air above it. In very convective conditions it is negative with a magnitude of typically less than 20 metres.

The effect of the urban heat island is that, in stable conditions, the Monin-Obukhov length will never fall below some minimum value; the larger the city, the larger the minimum value. A value of 75 metres was used in the modelling.

[6] http://www.cerc.co.uk/environmental-software/ADMS-Urban-model.html

5.3. Meteorological data

Meteorological data from Heathrow for the year 2012 were used in the modelling. A summary of the data is given in Table 5.1. Figure 5.1 shows a wind rose giving the frequency of occurrence of wind from different directions for a number of wind speed ranges.

The difference in land use at Heathrow compared to the study area was taken into account by entering a different surface roughness for the meteorological site. The surface roughness for Heathrow was set to 0.1 m, compared to 1 m for Central London. In addition, a minimum Monin-Obukhov length of 30 m was used for Heathrow, compared to 75 m used for Central London.

Table 5.1: Summary of meteorological data

	Minimum	Maximum	Mean
Temperature (°C)	-7.3	30.0	11.1
Wind speed (m/s)	0	15.5	4.2
Cloud cover (oktas)	0	8	4.8

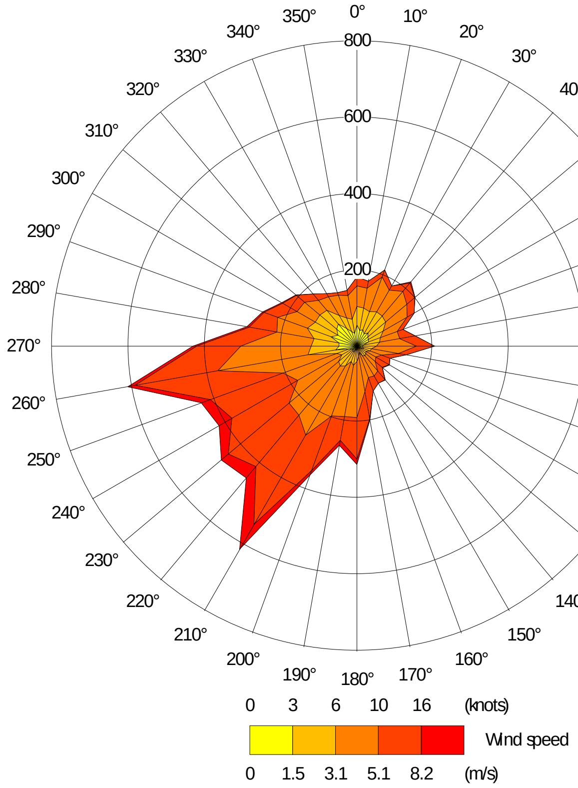

Figure 5.1: Wind rose for Heathrow, 2012

5.4. NO_x chemistry and background data

Nitrogen dioxide (NO_2) results from direct emissions from combustion sources together with chemical reactions in the atmosphere involving NO_2, nitric oxide (NO) and ozone (O_3). The combination of NO and NO_2 is referred to as nitrogen oxides (NO_x).

The chemical reactions taking place in the atmosphere were taken into account in the modelling using the Generic Reaction Set (GRS) of equations. These use hourly average background concentrations of NO_x, NO_2 and O_3, together with meteorological and modelled emissions data to calculate the NO_2 concentration at a given point.

All emissions of NO_x and NO_2 from within the city are included in the modelling. Hourly background data for these pollutants and ozone were input to the model to represent the concentrations in the air being blown into the city. These data were obtained from rural monitoring sites around the city as described in Section 5.4.1.

5.4.1. Background data for 2012

NO_x, NO_2 and O_3 concentrations from Rochester, Harwell, Lullington Heath and Wicken Fen were input to the model, the monitored concentration used for each hour depending upon the wind direction for that hour, as shown in Figure 5.2.

Two sources of PM_{10} and $PM_{2.5}$ background data were used for the modelling. For hours for which the wind direction was from the west, rural PM_{10} and $PM_{2.5}$ data from Harwell were used, and for hours for which the wind direction was from the east, rural PM_{10} and $PM_{2.5}$ measurements from Rochester were used.

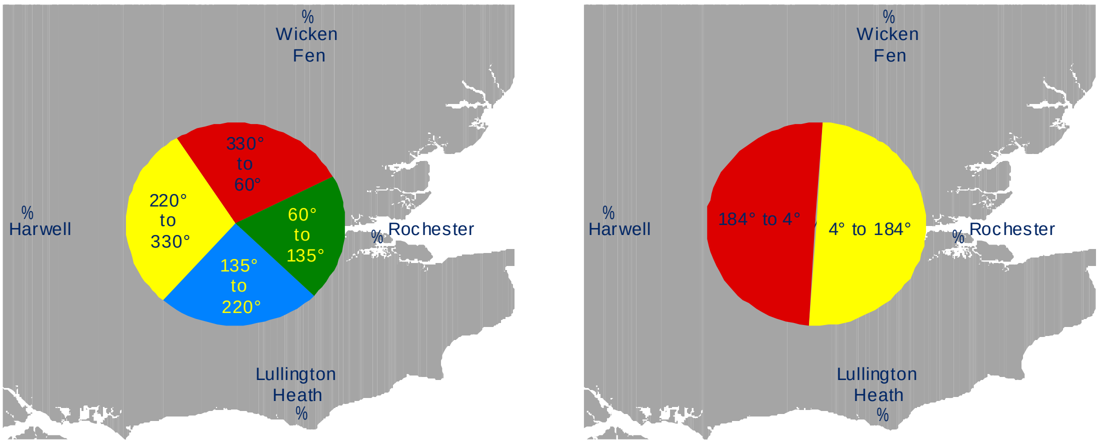

Figure 5.2 Wind direction segments used to calculate background concentrations for NO_x, NO_2 and O_3 (left) and PM_{10} and $PM_{2.5}$ (right)

Table 5.2 summarises the annual statistics of the resulting background concentrations used in the modelling for 2012.

Table 5.2: Background concentrations for 2012 (µg/m^3)

	NO_x	NO_2	O_3	PM_{10}	$PM_{2.5}$
Annual average	13.4	9.3	53.2	18.0	12.8
99.79th percentile of hourly average	117.9	58.4	125.1	-	-
90.41st percentile of 24-hour average	-	-	-	30.4	23.4

5.4.2. Background data for 2020

When modelling 2020 scenarios, the same background data used for 2012 was used in order to provide a conservative estimate of background concentrations.

6. Model verification

The first stage of a modelling study is to model a current case in order to verify that the input data and model set-up are representative for the area. This was carried out by calculating hourly average concentrations of NO_2 at the sites of the continuous monitors and diffusion tubes in Islington and comparing the measured and modelled concentrations. At the automatic monitoring sites, concentrations of PM_{10} were also calculated, and compared with measured concentrations.

The London Borough of Islington had two continuous monitors in operation in 2012. Both sites measured NO_x, NO_2, and PM_{10}; Table 6.1 summarises their locations. In addition to the continuous monitors, the London Borough of Islington operates 21 diffusion tubes at roadside and urban background locations across the borough, monitoring annual average NO_2 concentrations. Table 6.2 shows the locations of the diffusion tubes. Figure 6.1 shows the locations of the continuous and diffusion tube monitoring sites.

For the urban background sites BUS1 and BUS2, the LAEI does not include the Metroline bus garage adjacent to these sites. Due to the omission of these significant local emissions sources, good agreement between modelled and monitored concentrations for these locations was not expected.

Table 6.1: Continuous monitor locations

Site name	Site type	Location	Distance to kerb	Height (m)
Arsenal (continuous monitor)	Urban Background	531328, 186067	N/A	2
Holloway Road (continuous monitor)	Roadside	530697, 185742	3	2

Table 6.2: Islington diffusion tube locations

Site type	Site name	Location (m)	Distance to exposure (m)	Height (m)
Roadside	Caledonian Road	530718, 183584	0.5	2
	Roseberry Avenue	531336, 182599	0.5	
	City Road	532566, 182735	0.5	
	Old Street	532577, 182429	0.5	
	Highbury Corner	531669, 184743	0.5	
	Balls Pond Road	532820, 184816	0.5	
	Holloway Road	531034, 185349	0.5	
	Junction Road	529202, 186093	0.5	
	Archway Close	529392, 186844	0.5	
Urban Background	Percy Circus	530901, 182855	1	
	Myddleton Square	531317, 182998	1	
	Arran Walk	532303, 184460	1	
	Sotheby Road	532252, 185983	1	
	Highbury Fields	531755, 185454	1	
	Lady Margaret Road	529325, 185813	1	
	Zoffany Park	529881, 187022	1	
	Elthome Park	529987, 187342	1	
	Turle Road	530469, 186891	1	
	Waterloo Terrace	531625, 184100	1	
	Bus 1	529521, 186443	1	
	Bus 2	529618, 186558	1	

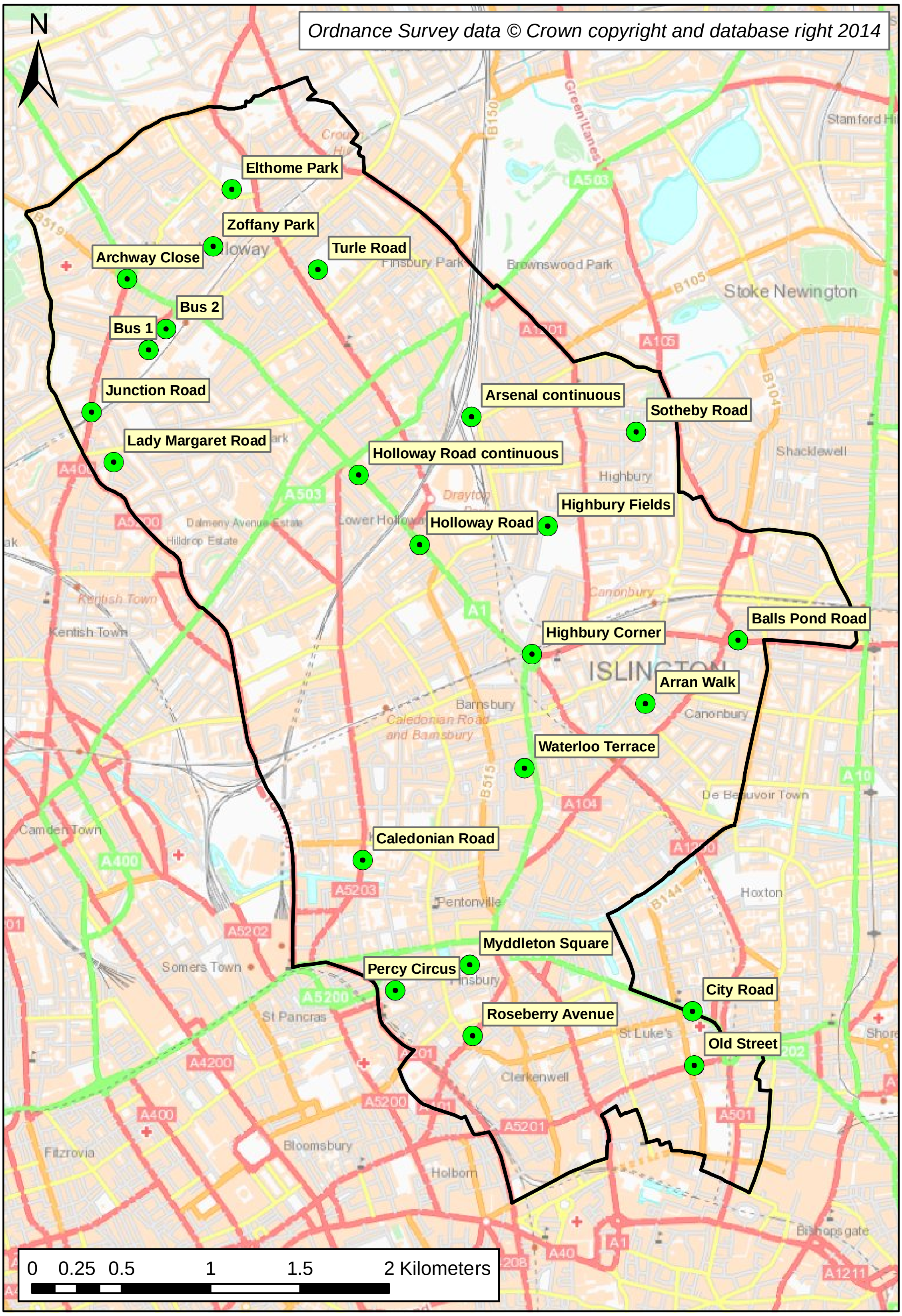

Figure 6.1: Monitoring sites in Islington

6.1. NO_2 verification

Table 6.3 shows the monitored and modelled annual average concentrations of NO_2 for 2012 at the continuous monitoring sites and diffusion tube locations, together with the modelled concentrations expressed as a percentage of the measured concentrations. A value of zero would indicate perfect agreement between measured and modelled data, with positive values indicating that the model is over-predicting concentrations and negative values showing model under-prediction. Exceedences of the air quality standard of 40µg/m³ for annual average NO_2 are highlighted in bold.

Table 6.3: Measured and modelled annual average concentrations of NO_2 for 2012

Site	Monitored	Modelled	% difference
Arsenal (continuous monitor)	36.0	31.2	-13.3
Holloway Road (continuous monitor)	**55.0**	**45.6**	-17.1
Caledonian Road	**50.0**	**43.5**	-13.1
Roseberry Avenue	**58.0**	**56.0**	-3.5
City Road	**52.0**	**49.2**	-5.4
Old Street	**65.0**	**47.5**	-26.9
Highbury Corner	**60.0**	**43.4**	-27.7
Balls Pond Road	**53.0**	**50.4**	-4.8
Holloway Road	**57.0**	**54.8**	-3.9
Junction Road	**45.0**	**44.2**	-1.8
Archway Close	**63.0**	**55.4**	-12.0
Percy Circus	**40.0**	39.0	-2.5
Myddleton Square	36.0	38.2	6.2
Arran Walk	32.0	32.2	0.5
Sotheby Road	28.0	29.8	6.3
Highbury Fields	33.0	30.3	-8.3
Lady Margaret Road	34.0	32.8	-3.5
Zoffany Park	31.0	31.3	0.8
Elthome Park	30.0	30.8	2.8
Turle Road	32.0	30.9	-3.4
Waterloo Terrace	35.0	33.8	-3.4
Bus 1	**52.0**	33.5	-35.6
Bus 2	**40.0**	35.0	-12.4

A scatter plot showing monitored and modelled annual average NO_2 concentrations for 2012 is presented in Figure 6.1.

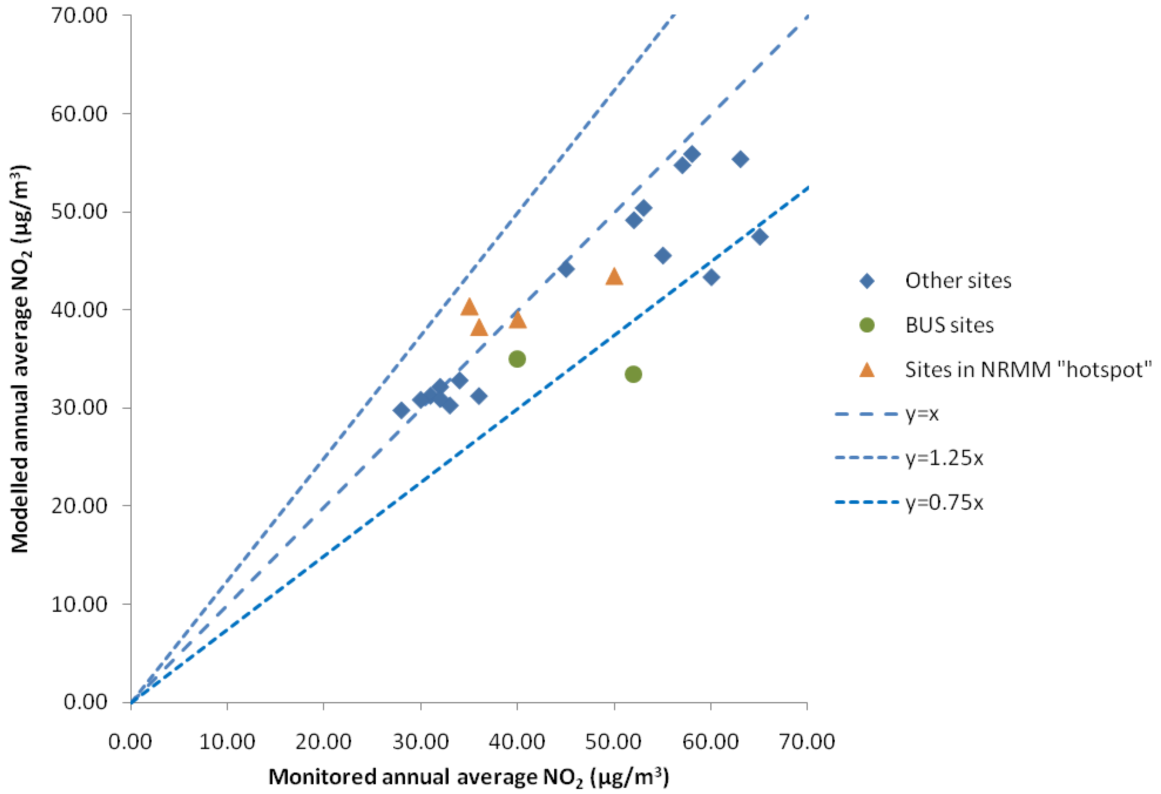

Figure 6.1: Modelled annual average NO_2 concentrations against monitored concentrations for 2012

Overall, the model results correlate well with the monitored data at diffusion tube and continuous monitoring locations for 2012, indicating that the emissions data and model setup are appropriate for the area. Most of the modelled concentrations (65%) lie within 10% of the monitored values; all sites except for BUS1, Old Street, and Highbury corner lie within 25%.

The model under-predicts concentrations at the two diffusion tube locations at the two sites adjacent to the Metroline bus garage in the north of the borough, as the bus garage is not included in the LAEI 2010. These sites are highlighted in green in Figure 6.1.

The LAEI 2010 includes a new emissions source, not quantified in previous versions of the LAEI: Non-Road Mobile Machinery (NRMM). Preliminary work using these new emissions suggests that the calculation methodology results in the production of large pollution "hotspots" in the City of London and the south of Islington. At the monitoring sites lying within this area, highlighted in orange in Figure 6.1 above, the model significantly overpredicted concentrations. In order to account for this inaccuracy, NRMM Construction emissions were removed from the emissions inventory used in this modelling.

6.2. PM_{10} verification

Table 6.4 shows the measured and modelled PM_{10} concentrations at the continuous monitoring sites. The modelled concentrations underpredict the measured values by 10 to 15%.

Table 6.4: Measured and modelled annual average concentrations of PM_{10} for 2012

Site	Monitored	Modelled	% difference
Arsenal (continuous monitor)	24.0	20.4	-15
Holloway Road (continuous monitor)	26.0	23.3	-10

7. 2020 Base case

Ground level concentrations of NO_2, PM_{10} and $PM_{2.5}$ for 2020 were calculated on a grid of receptor points across the whole borough, with a grid resolution of 50 metres. Extra receptor points were added close to the modelled roads, where concentration gradients are highest. For the areas of particular interest, modelling was carried out in more detail, with a resolution of 10 metres with additional points added closest to the roads.

7.1. NO_2 concentrations

Figure 7.1 shows predicted annual average NO_2 concentrations across Islington for the 2020 base case. Figures 7.2a to 7.2e show predicted annual average concentrations for the areas at Archway; Angel; Highbury; Old Street; and Finsbury Park, respectively.

Predicted 99.79th percentile of hourly average NO_2 concentrations across Islington for the 2020 base case are shown in Figure 7.3. Figure 7.4a to 7.4e show the 99.79th percentile of hourly average NO_2 concentrations for areas areas at Archway; Angel; Highbury; Old Street; and Finsbury Park, respectively.

The air quality standard of 40 µg/m^3 for annual average NO_2 concentrations is predicted to be exceeded along many major roads in Islington. The air quality standard of 200 µg/m^3 for the 99.79th percentile of hourly average NO_2 concentrations is predicted to be met for most locations around Islington, with the exception some busy junctions.

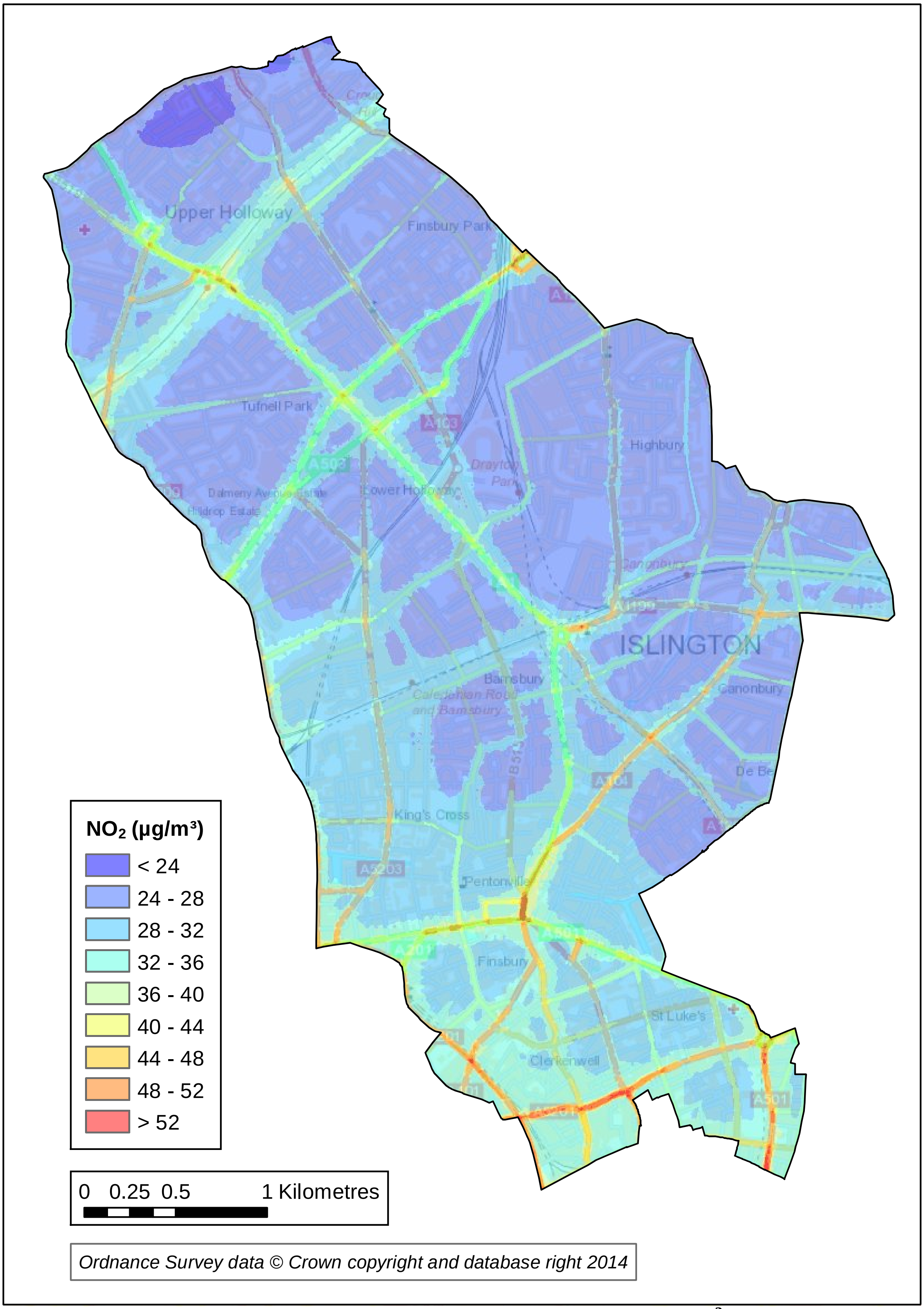

Figure 7.1: Annual average NO_2 concentrations for Islington ($\mu g/m^3$), 2020 base case

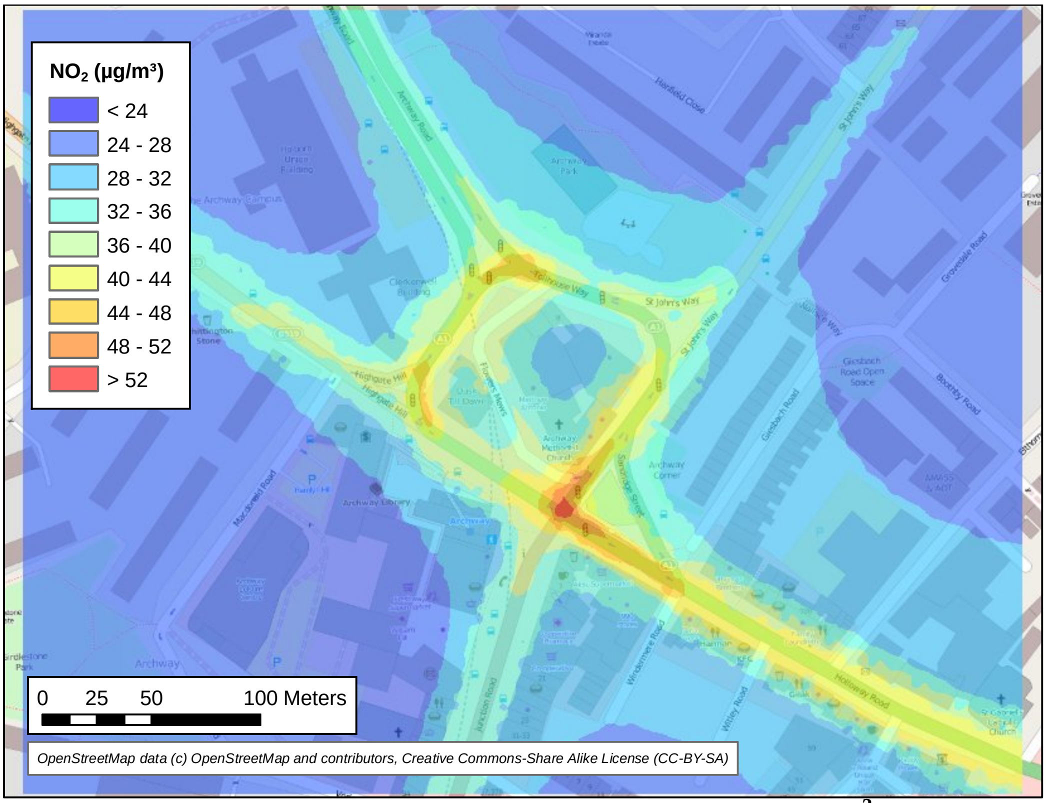

Figure 7.2a: Annual average NO_2 concentrations for Archway ($\mu g/m^3$), 2020 base case

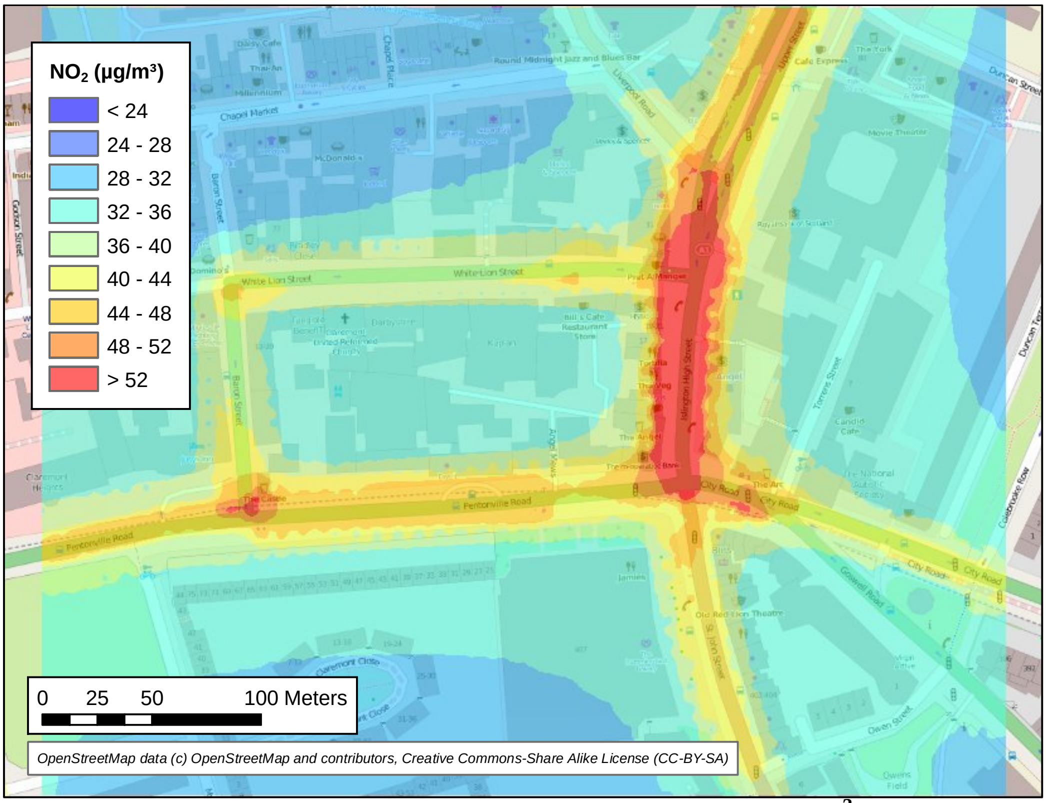

Figure 7.2b: Annual average NO_2 concentrations for Angel ($\mu g/m^3$), 2020 base case

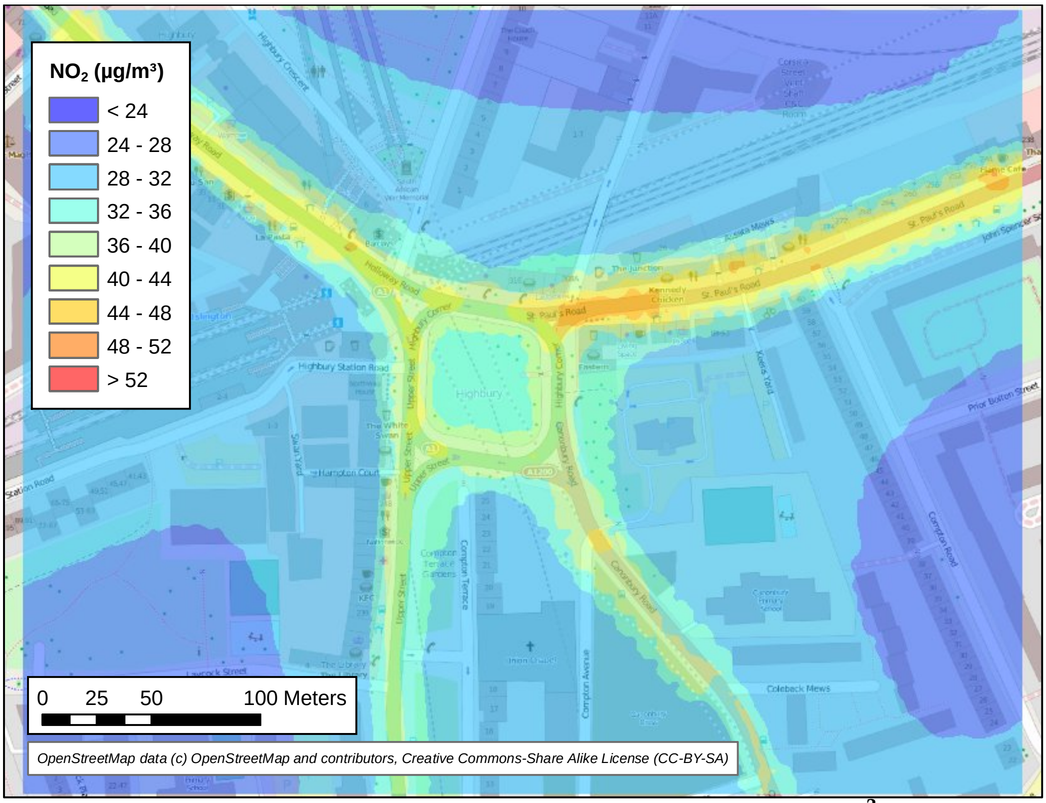

Figure 7.2c: Annual average NO_2 concentrations for Highbury ($\mu g/m^3$), 2020 base case

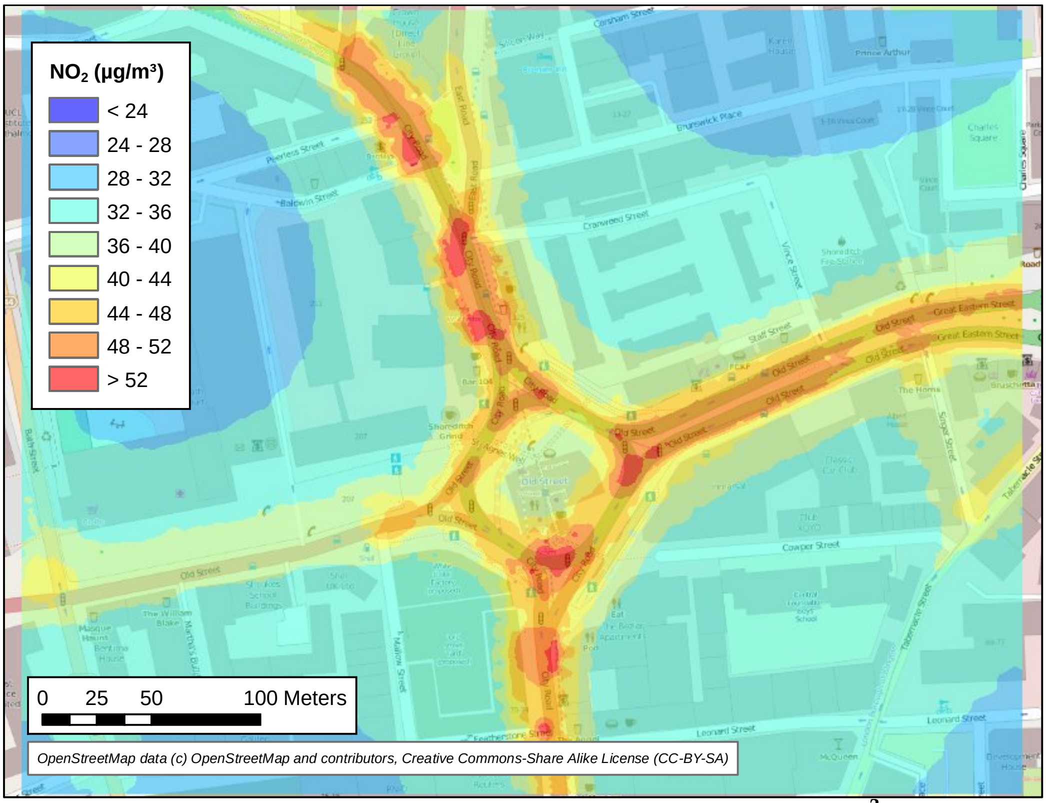

Figure 7.2d: Annual average NO_2 concentrations for Old Street ($\mu g/m^3$), 2020 base case

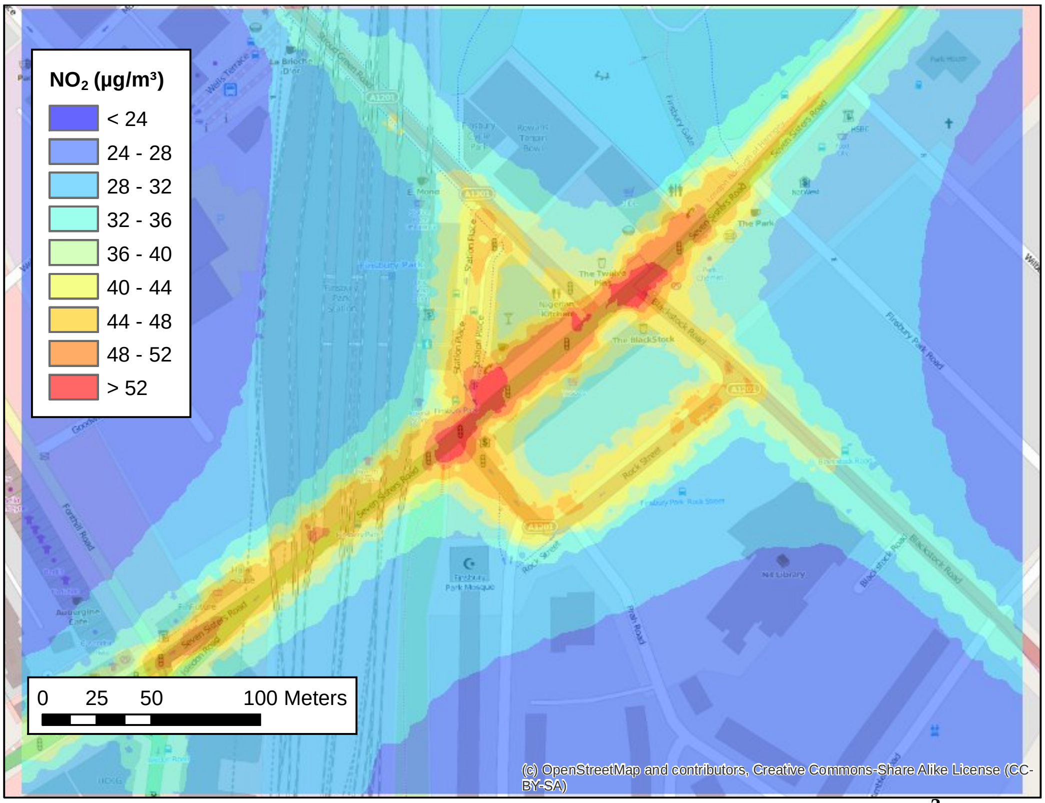

Figure 7.2e: Annual average NO_2 concentrations for Finsbury Park ($\mu g/m^3$), 2020 base case

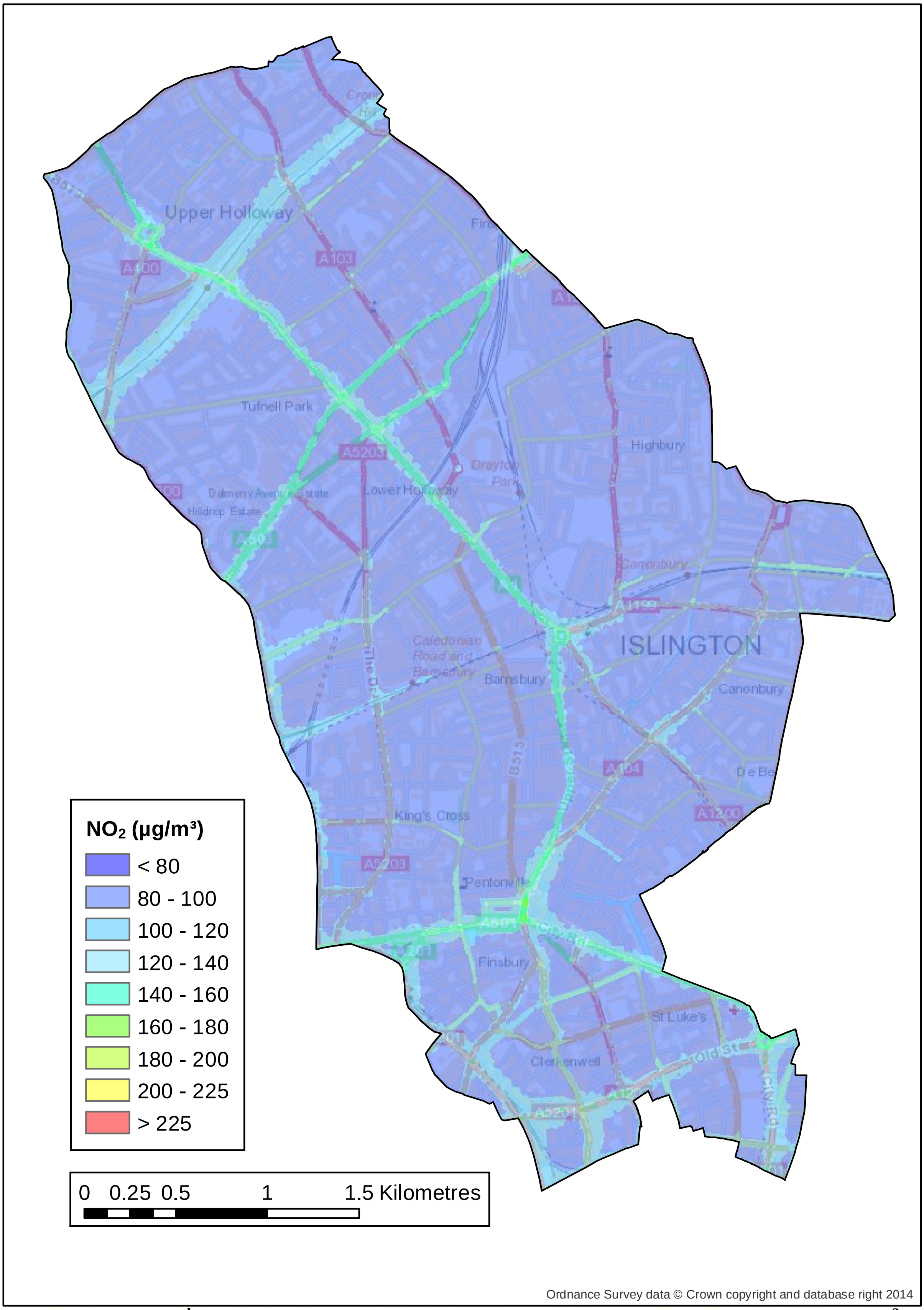

Figure 7.3: 99.79th percentile of hourly average NO_2 concentrations for Islington ($\mu g/m^3$), 2020 base case

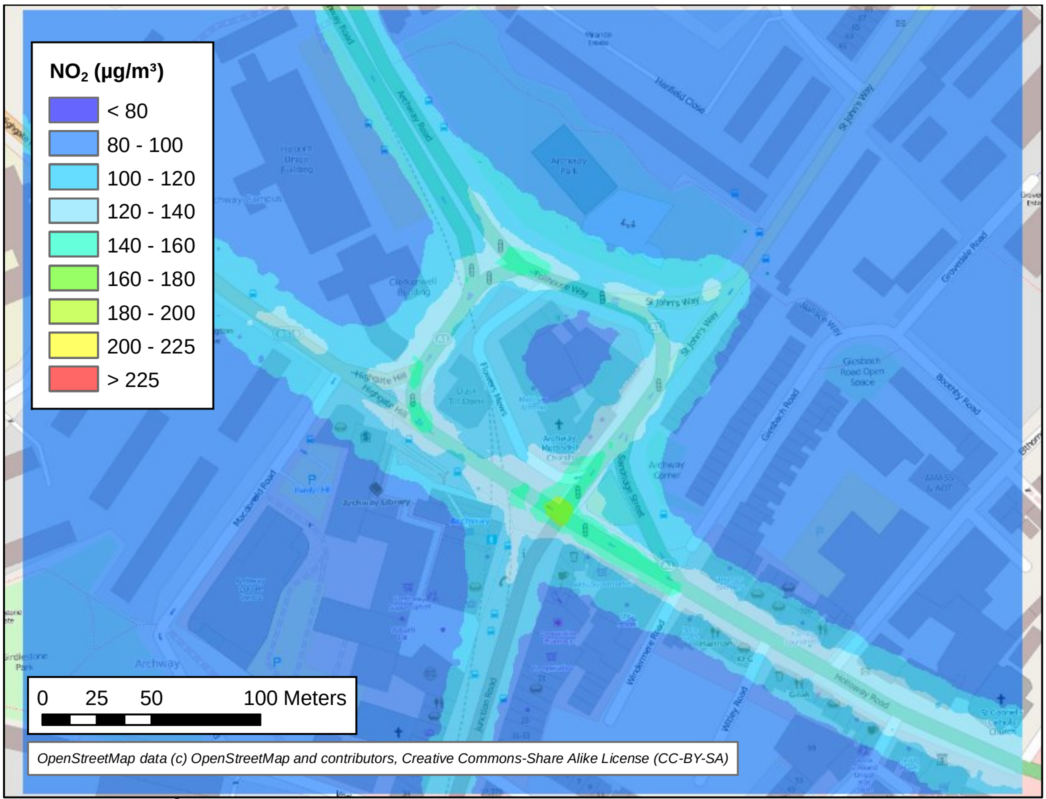

Figure 7.4a: 99.79th percentile of hourly average NO_2 concentrations for Archway (µg/m^3), 2020 base case

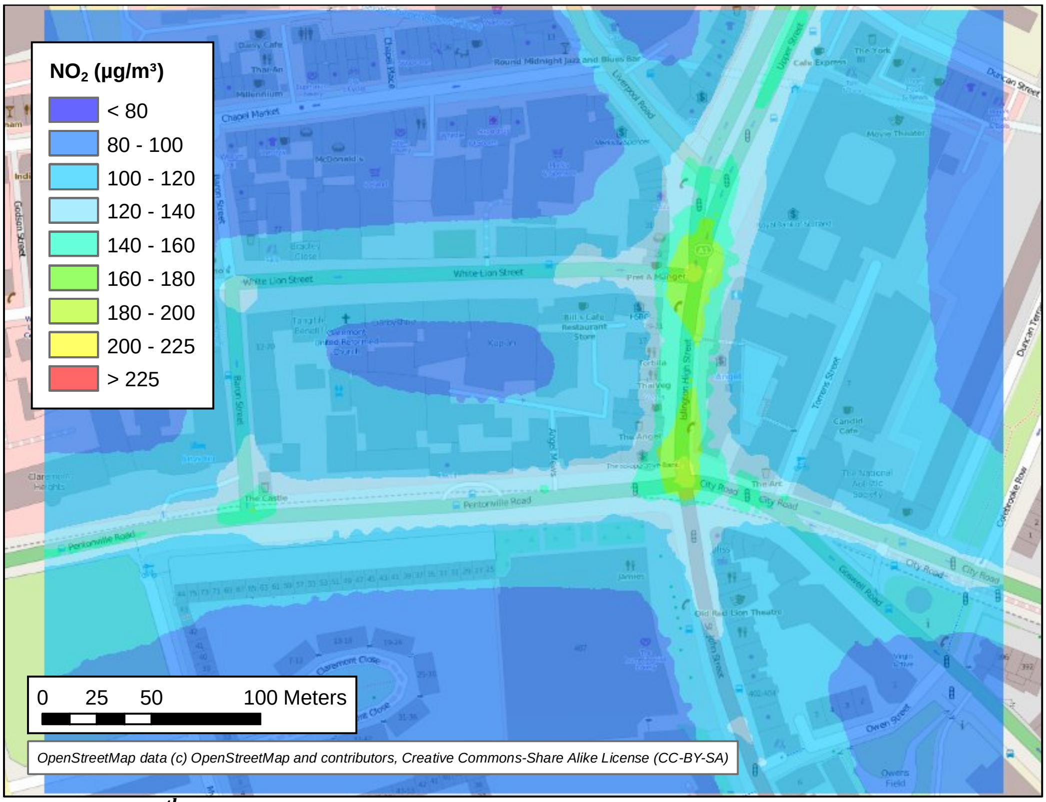

Figure 7.4b: 99.79th percentile of hourly average NO_2 concentrations for Angel (µg/m^3), 2020 base case

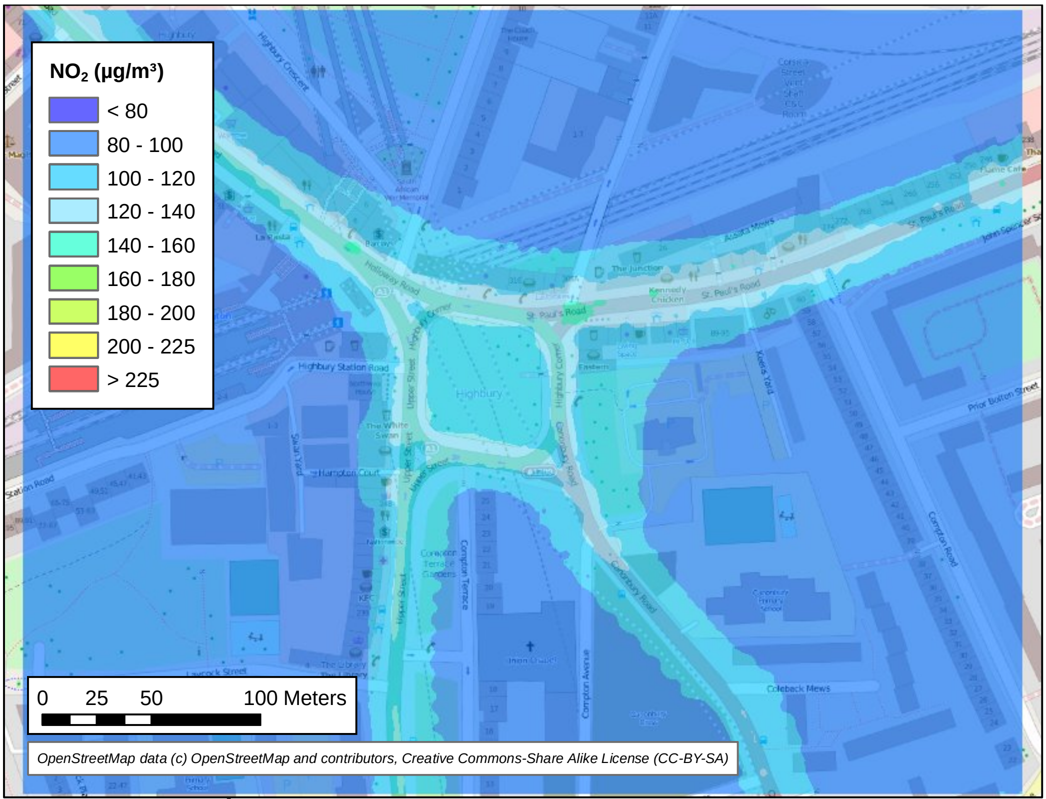

Figure 7.4c: 99.79th percentile of hourly average NO_2 concentrations for Highbury ($\mu g/m^3$), 2020 base case

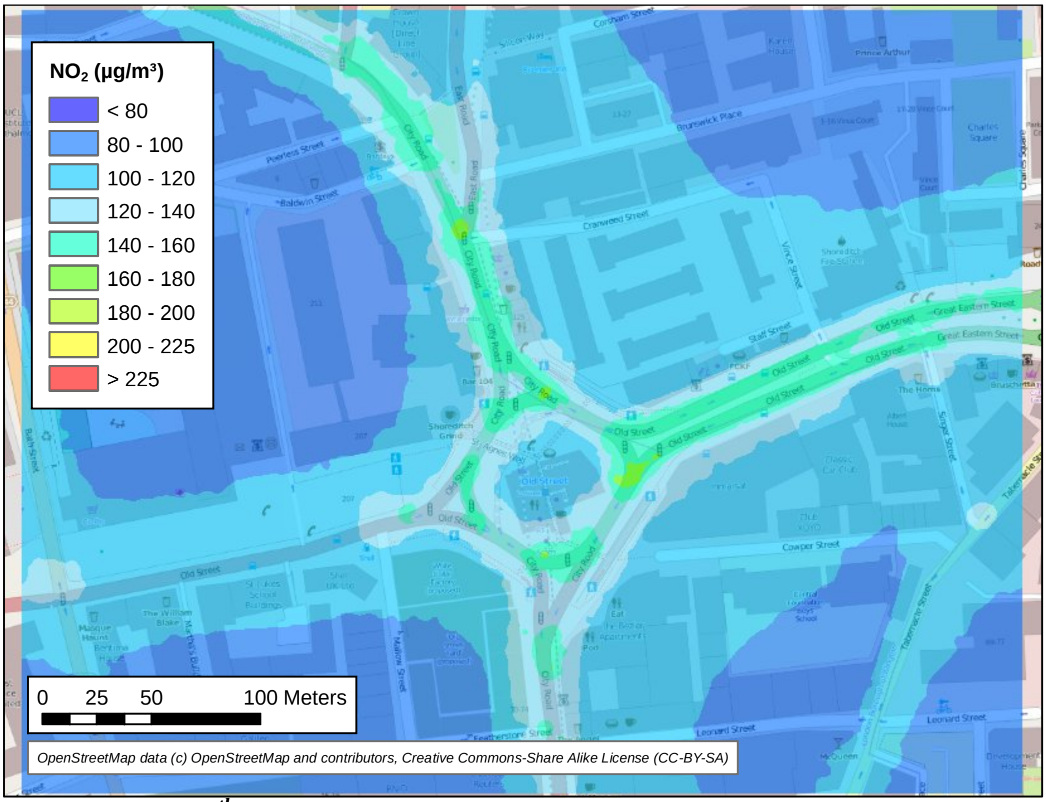

Figure 7.4d: 99.79th percentile of hourly average NO_2 concentrations for Old Street ($\mu g/m^3$), 2020 base case

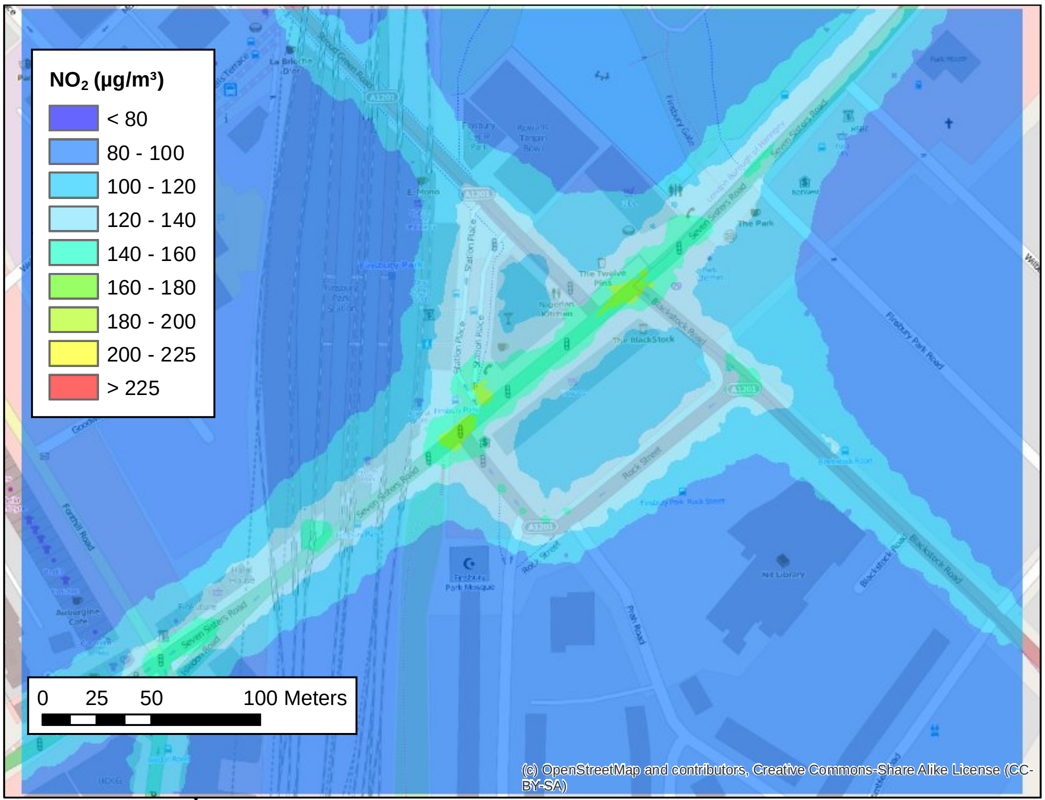

Figure 7.4e: 99.79th percentile of hourly average NO_2 concentrations for Finsbury Park (µg/m^3), 2020 base case

7.2. PM_{10} concentrations

Figure 7.5 shows predicted annual average PM_{10} concentrations across Islington for the 2020 base case. Figure 7.6a to 7.6e show predicted annual average concentrations for the areas around areas at Archway; Angel; Highbury; Old Street; and Finsbury Park, respectively.

Predicted 90.41st percentile of 24-hour average PM_{10} concentrations across Islington for the 2020 base case are shown in Figure 7.7. Figure 7.8a to 7.8e show the 90.41st percentile of 24-hour average PM_{10} concentrations for the areas at Archway; Angel; Highbury; Old Street; and Finsbury Park, respectively.

The air quality standards for PM_{10} are predicted to be achieved throughout Islington.

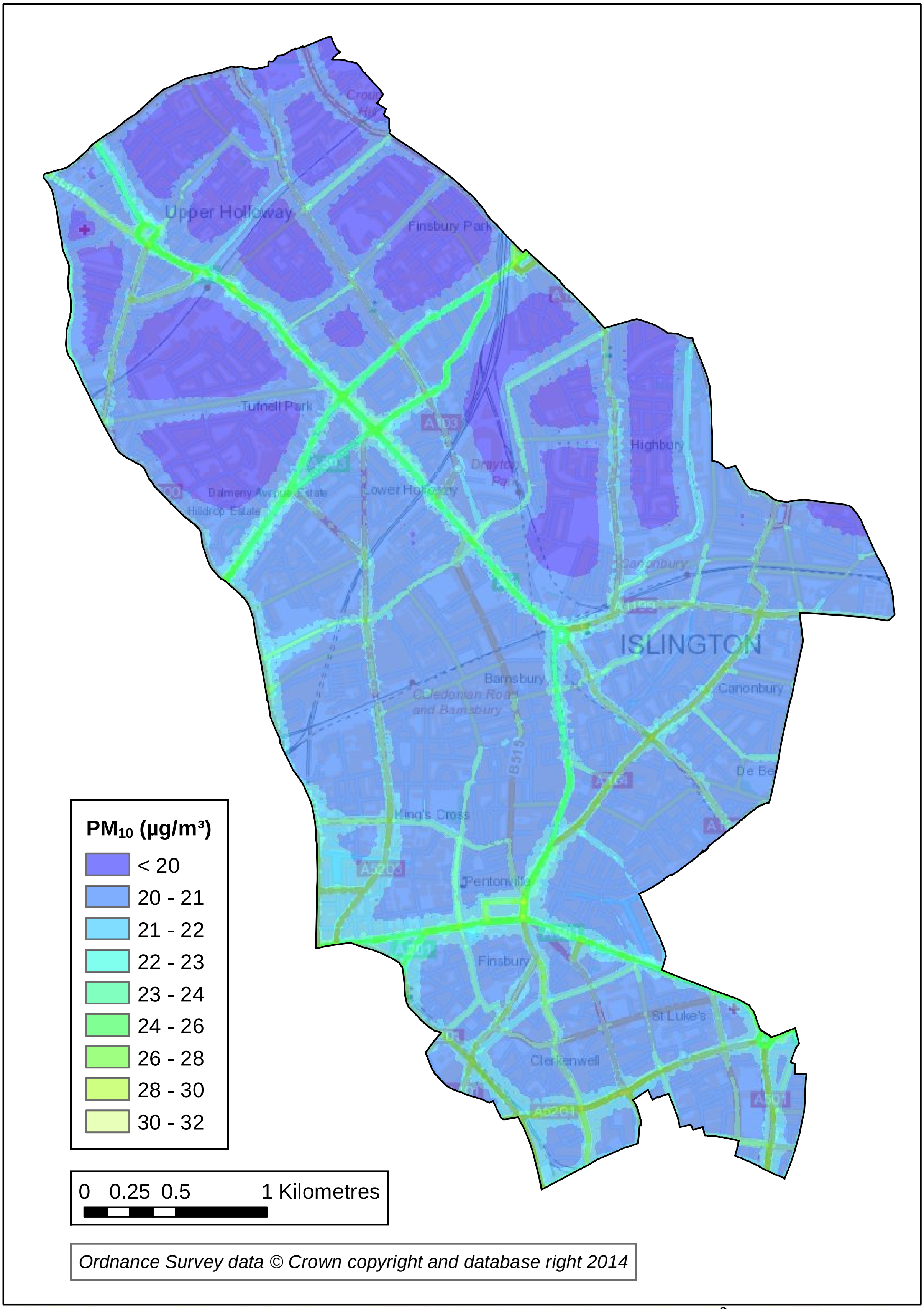

Figure 7.5: Annual average PM_{10} concentrations for Islington ($\mu g/m^3$), 2020 base case

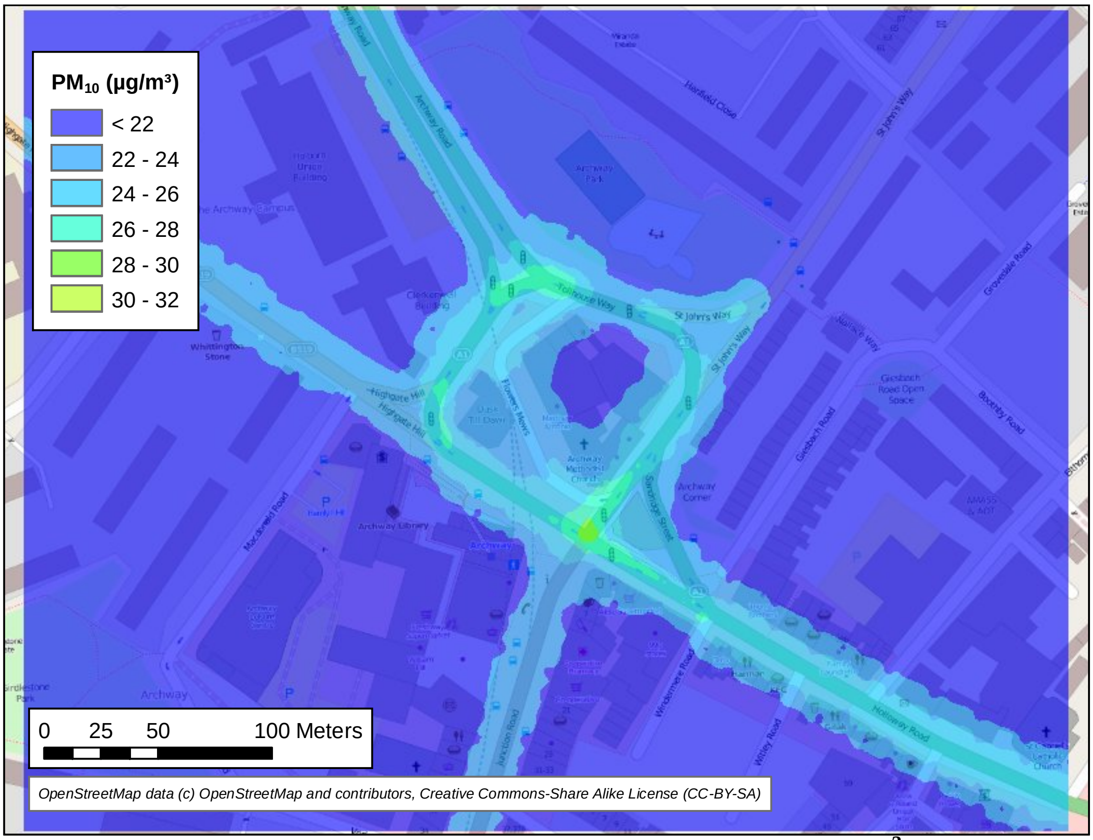

Figure 7.6a: Annual average PM_{10} concentrations for Archway ($\mu g/m^3$), 2020 base case

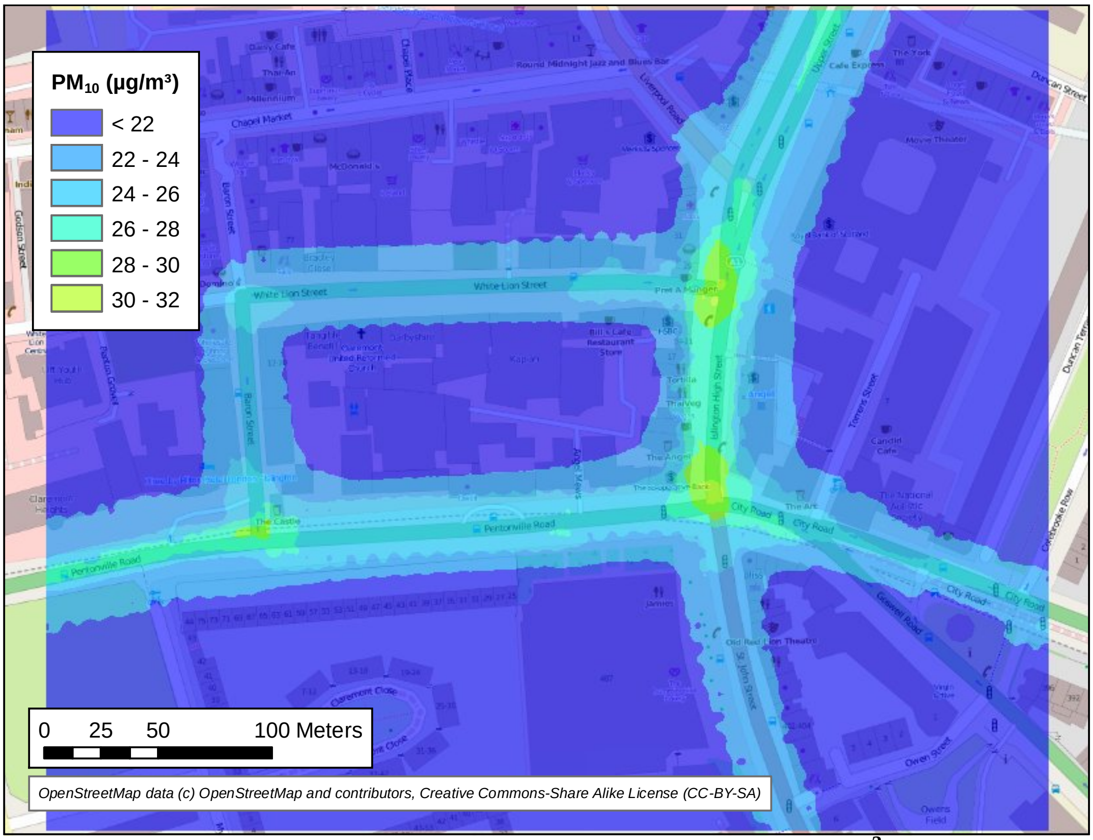

Figure 7.6b: Annual average PM_{10} concentrations for Angel ($\mu g/m^3$), 2020 base case

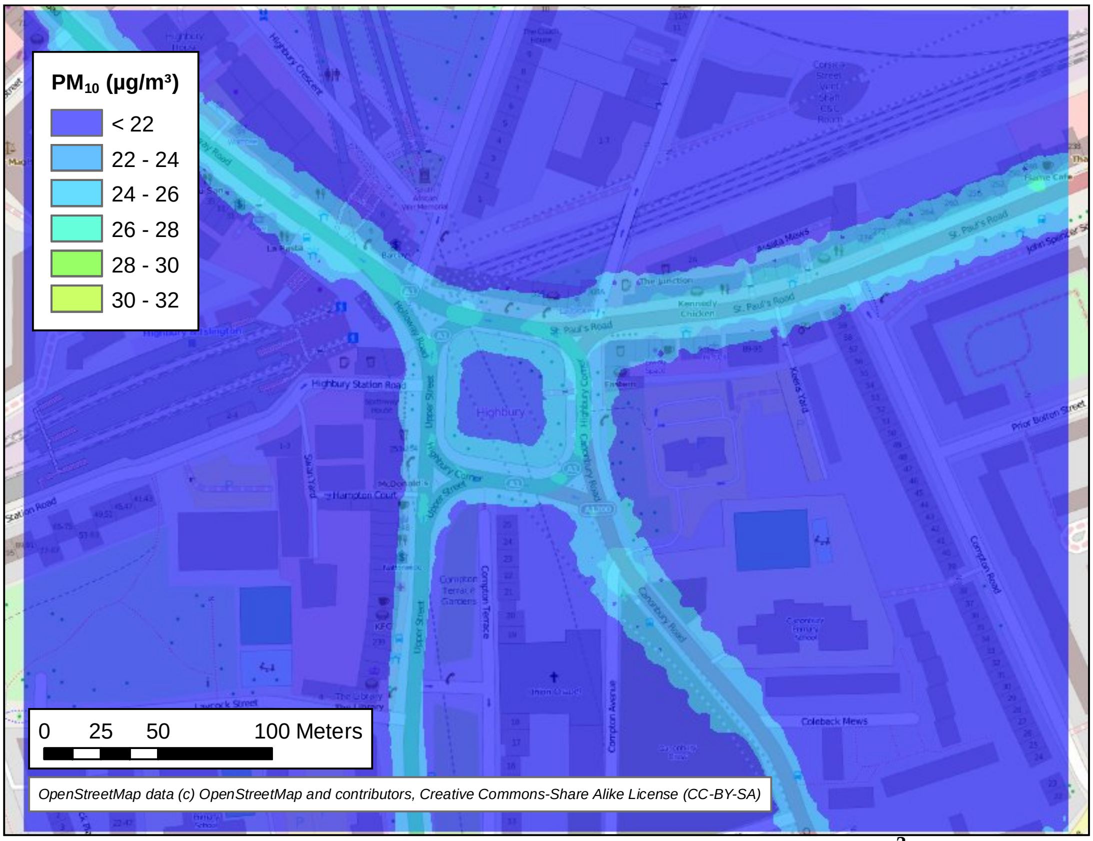

Figure 7.6c: Annual average PM$_{10}$ concentrations for Highbury (µg/m^3), 2020 base case

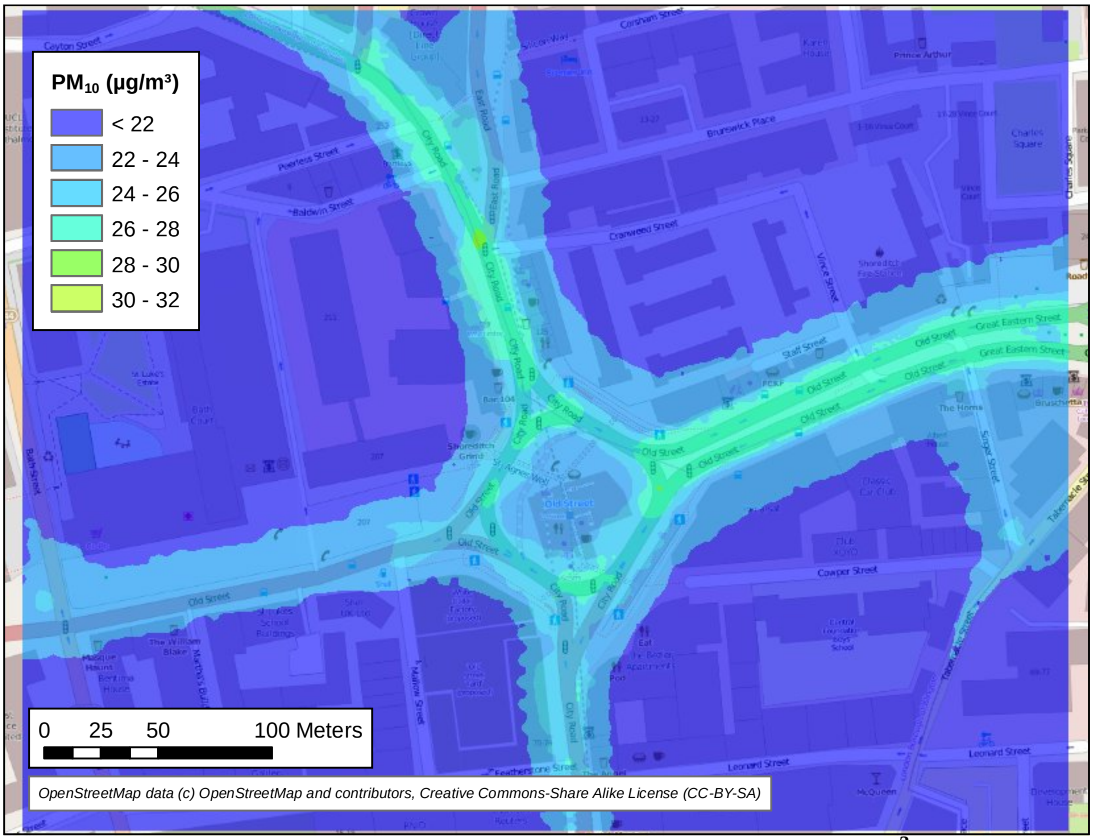

Figure 7.6d: Annual average PM$_{10}$ concentrations for Old Street (µg/m^3), 2020 base case

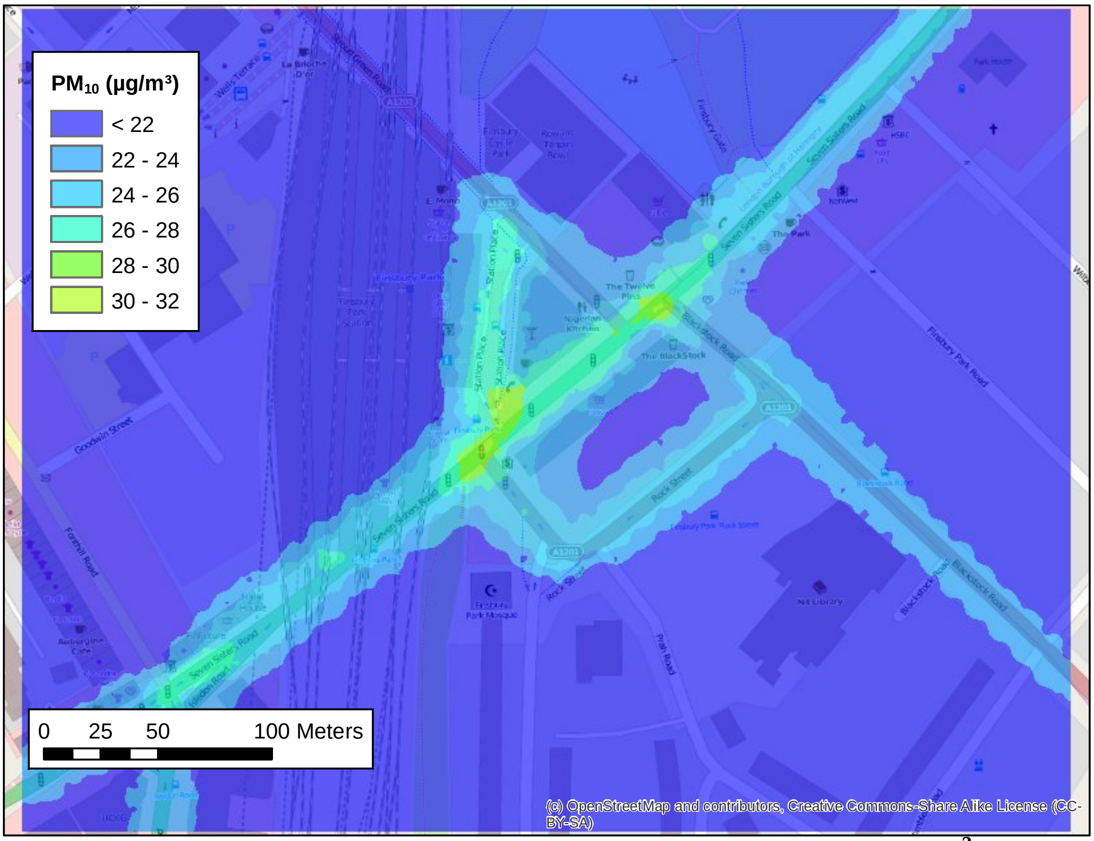

Figure 7.6e: Annual average PM_{10} concentrations for Finsbury Park ($\mu g/m^3$), 2020 base case

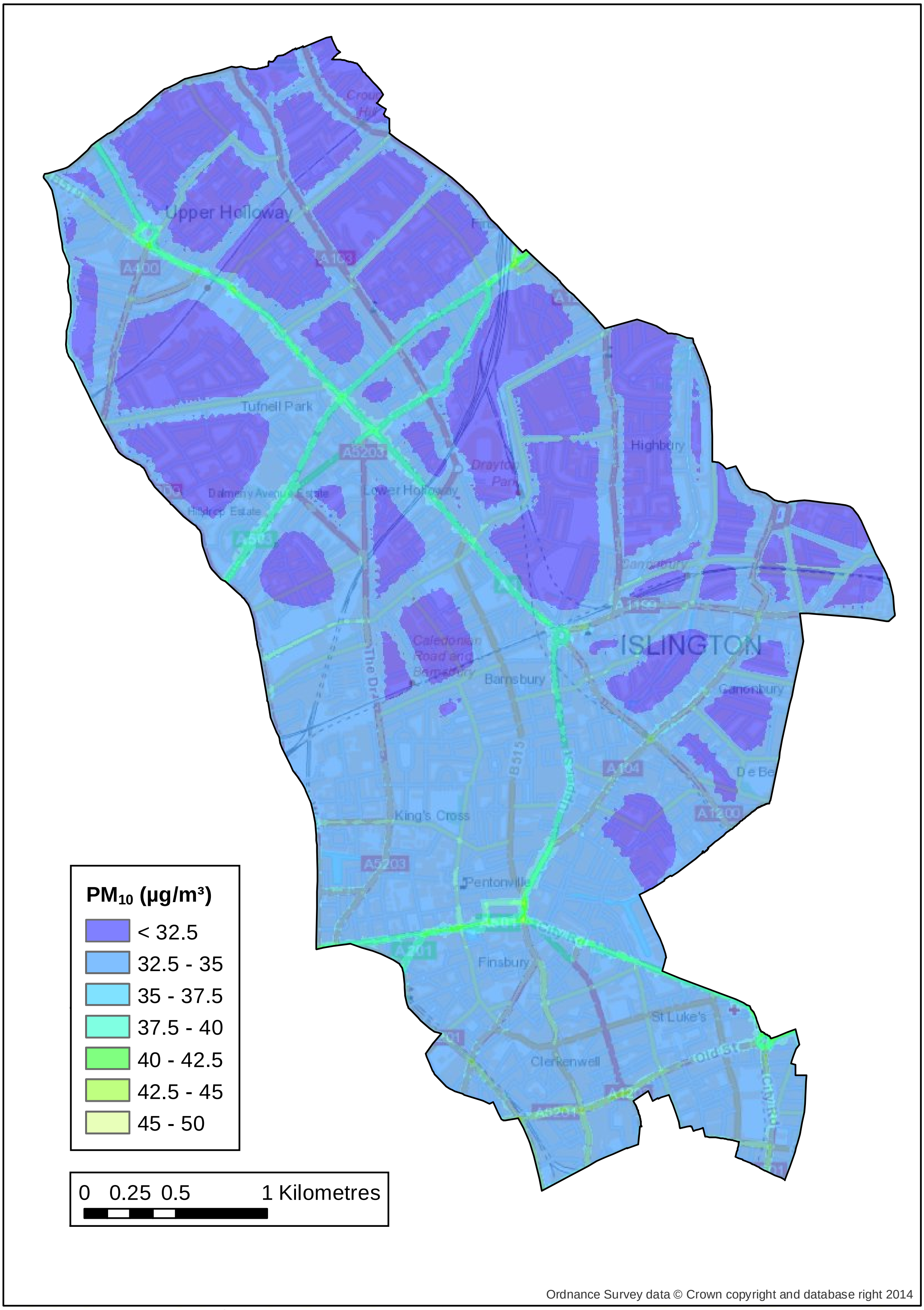

Figure 7.7: 90.41st percentile of 24-hour average PM_{10} concentrations for Islington ($\mu g/m^3$), 2020 base case

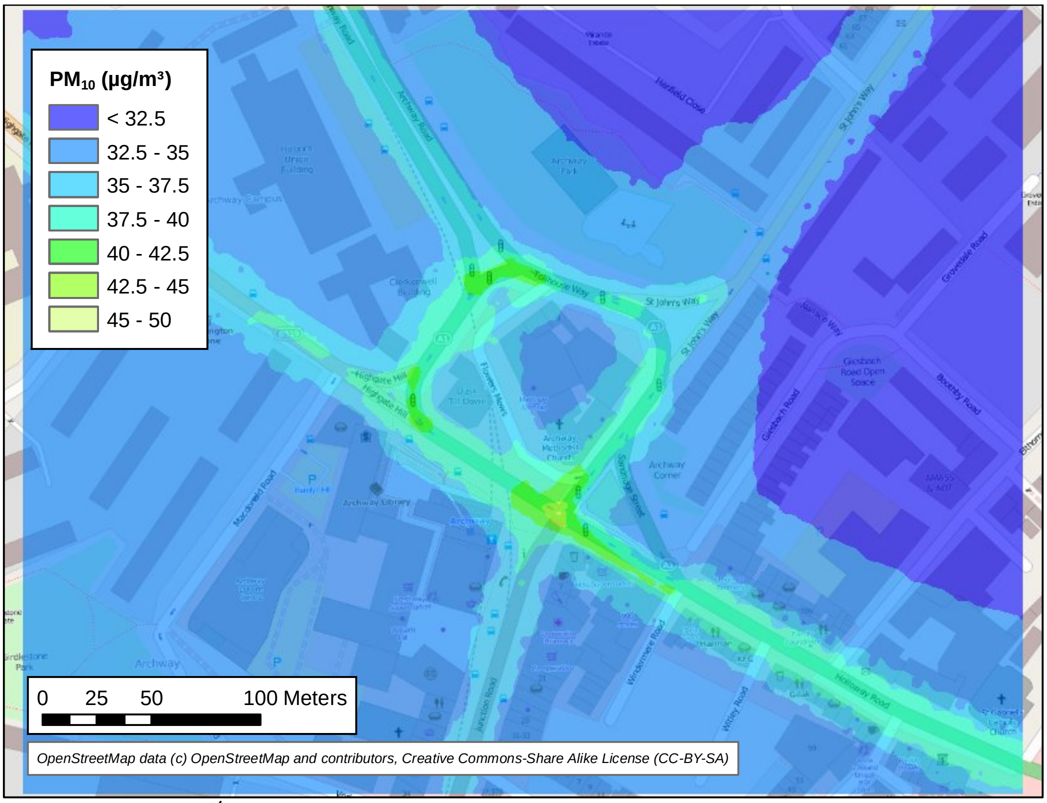

Figure 7.8a: 90.41st percentile of 24-hour average PM_{10} concentrations for Archway ($\mu g/m^3$), 2020 base case

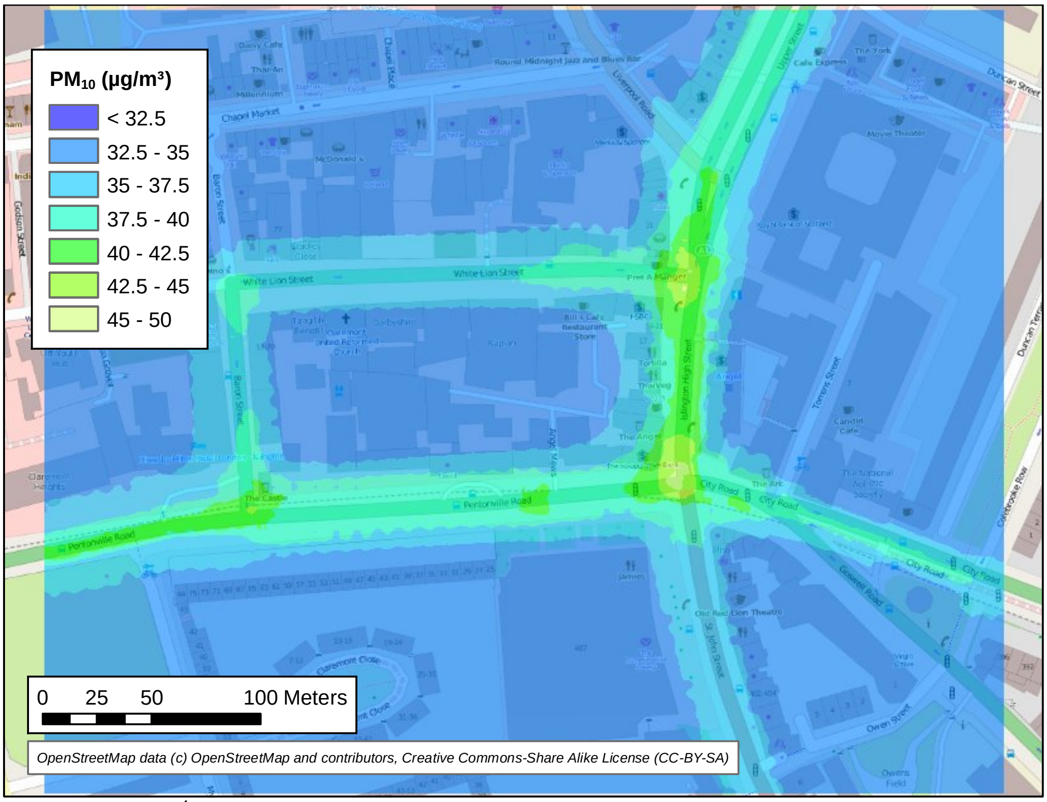

Figure 7.8b: 90.41st percentile of 24-hour average PM_{10} concentrations for Angel ($\mu g/m^3$), 2020 base case

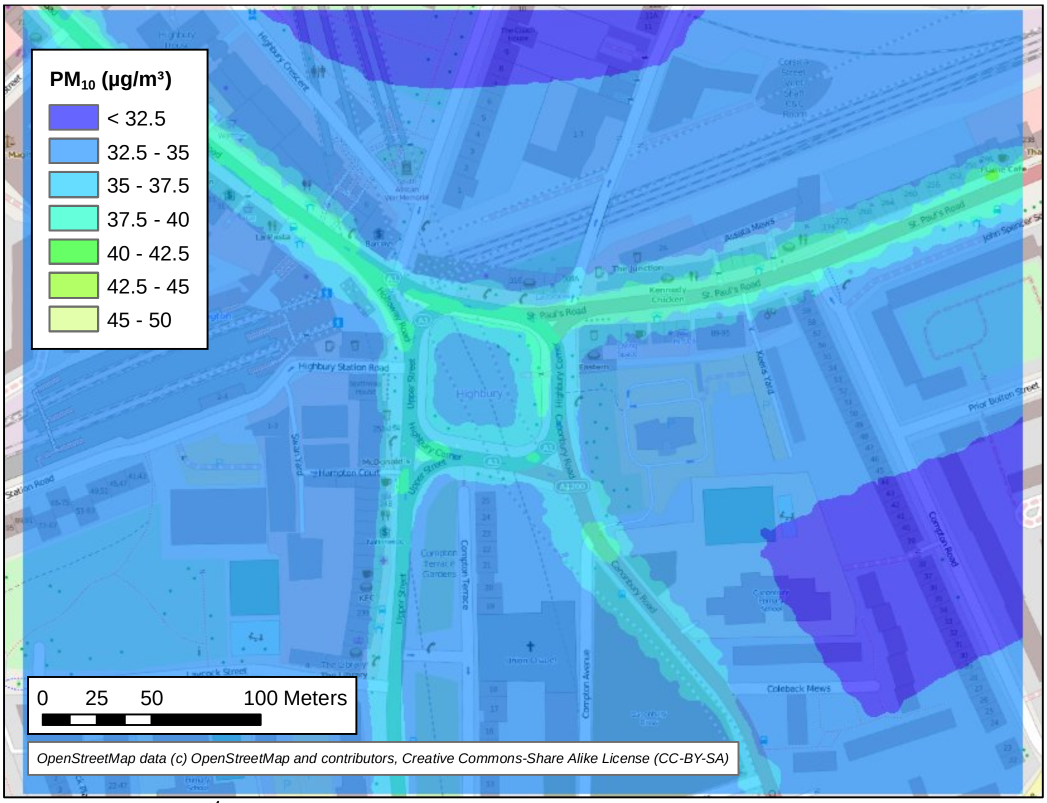

Figure 7.8c: 90.41st percentile of 24-hour average PM_{10} concentrations for Highbury ($\mu g/m^3$), 2020 base case

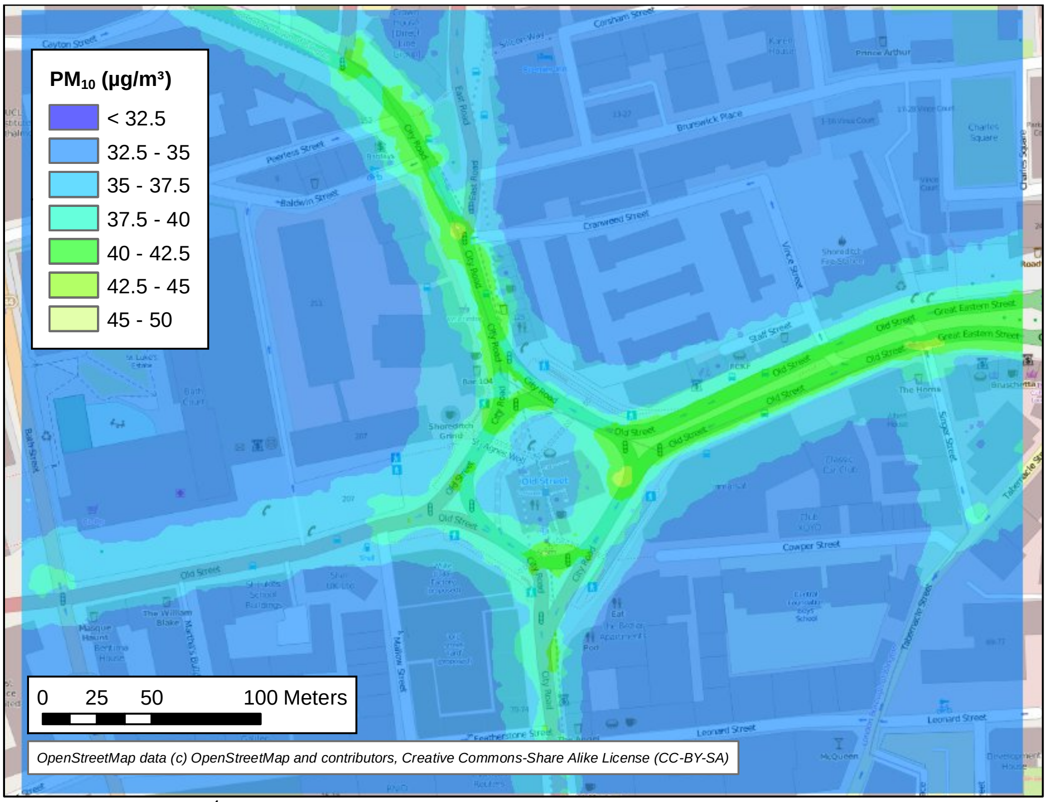

Figure 7.8d: 90.41st percentile of 24-hour average PM_{10} concentrations for Old Street ($\mu g/m^3$), 2020 base case

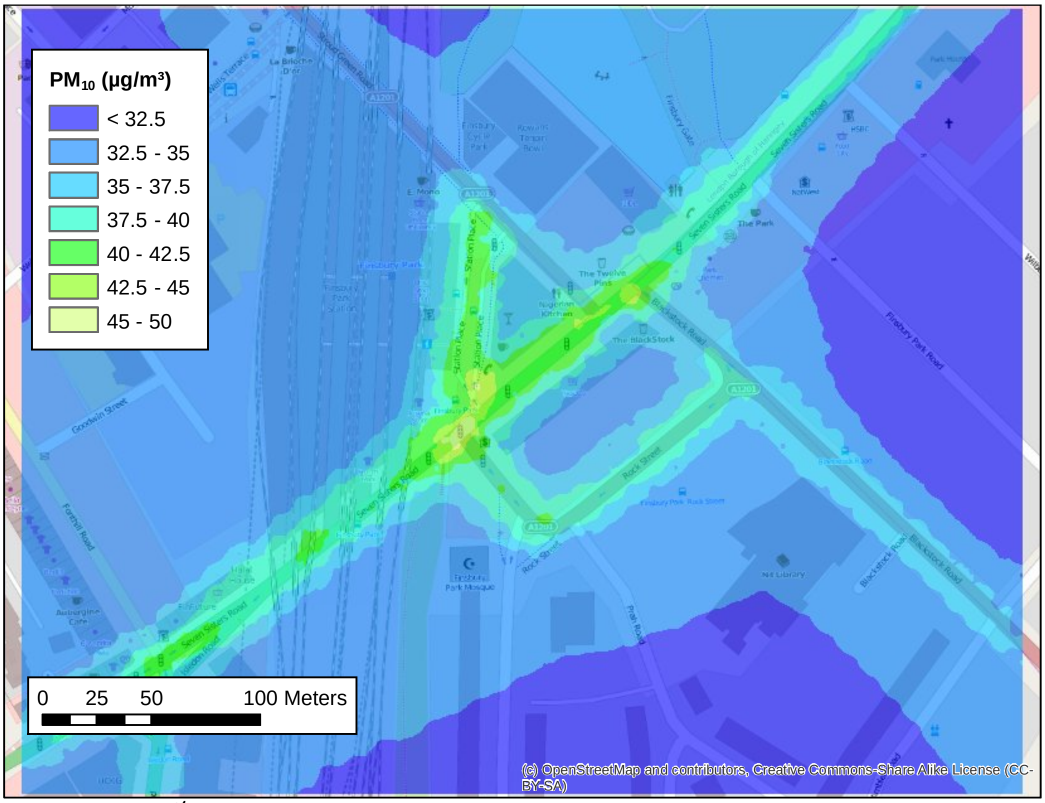

Figure 7.8e: 90.41st percentile of 24-hour average PM_{10} concentrations for Finsbury Park ($\mu g/m^3$), 2020 base case

7.3. $PM_{2.5}$ concentrations

Figure 7.9 shows predicted annual average $PM_{2.5}$ concentrations across Islington for the 2020 base case. Figure 7.10a to 7.10e show predicted annual average concentrations for the areas at Archway; Angel; Highbury; Old Street; and Finsbury Park, respectively.

The air quality standard for $PM_{2.5}$ is predicted to be achieved throughout Islington.

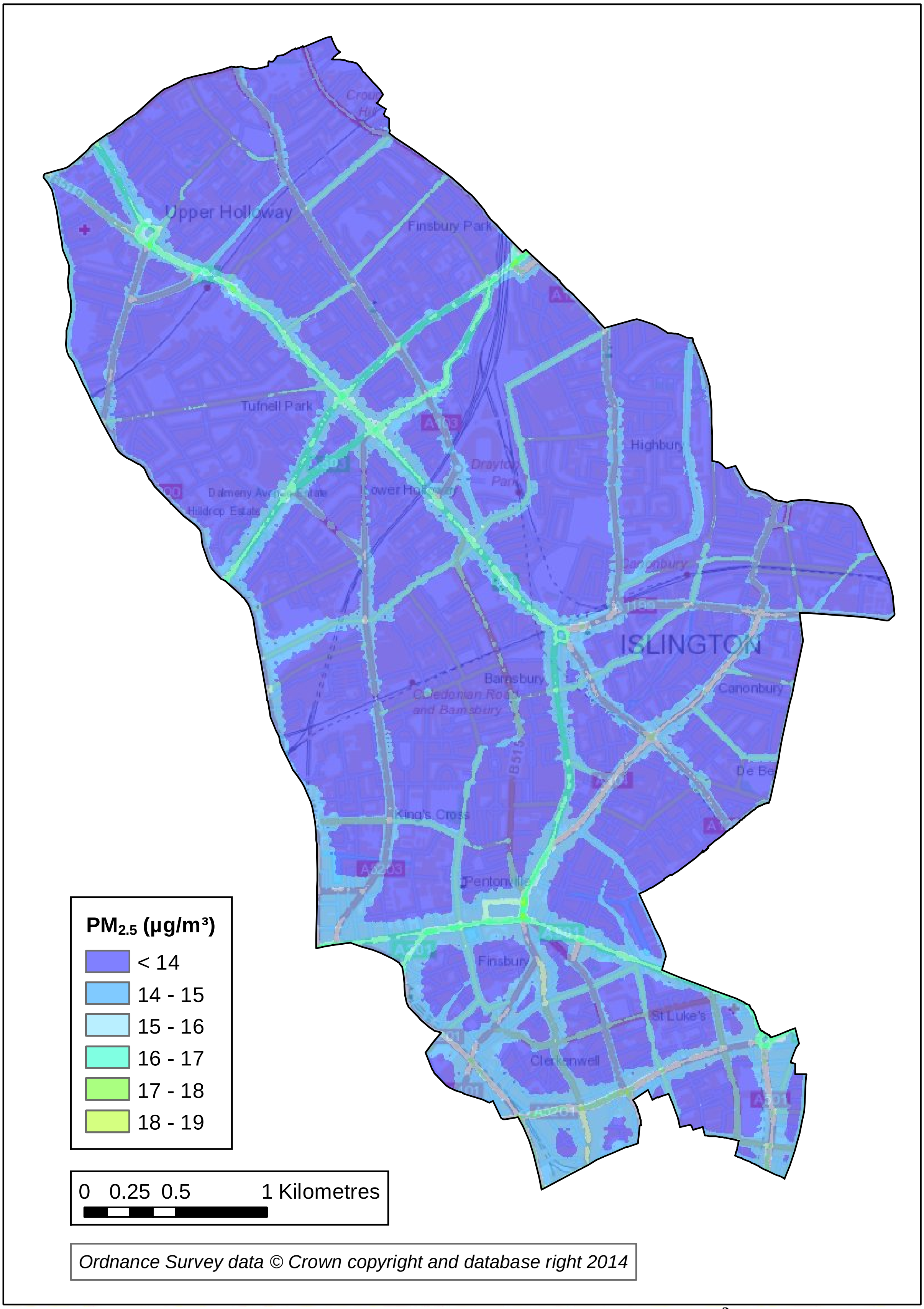

Figure 7.9: Annual average $PM_{2.5}$ concentrations for Islington ($\mu g/m^3$), 2020 base case

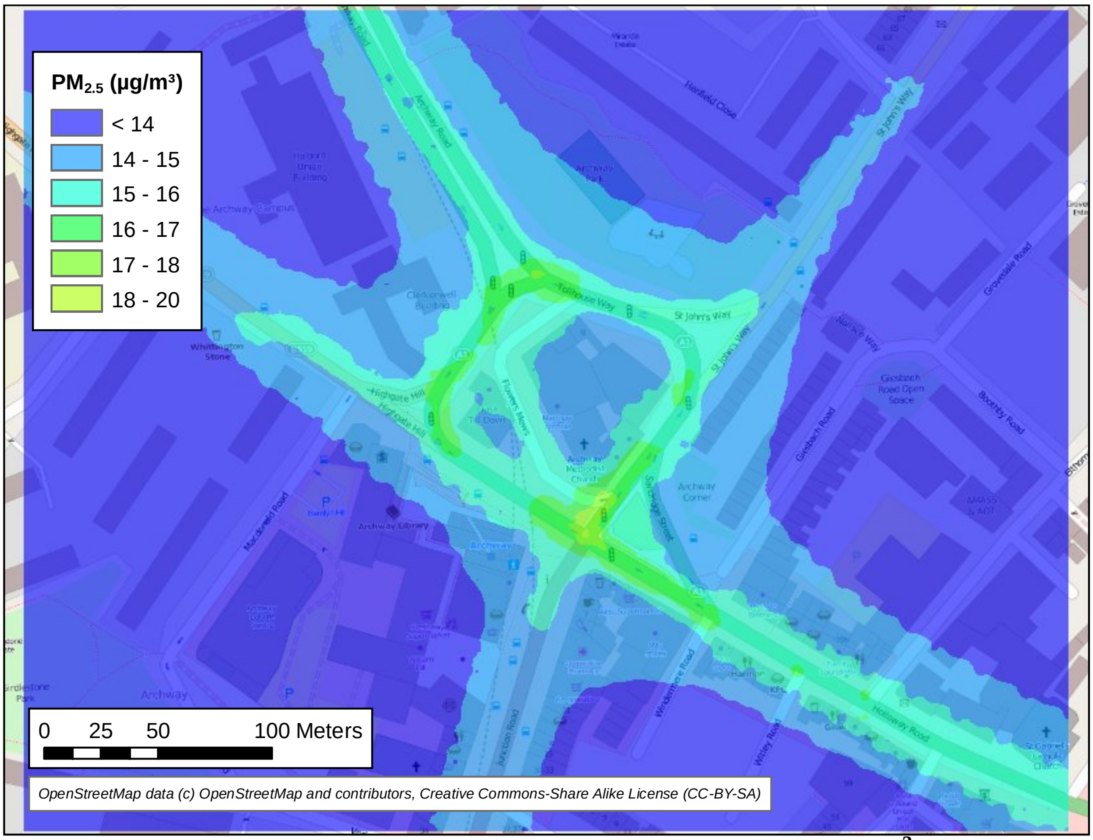

Figure 7.10a: Annual average $PM_{2.5}$ concentrations for Archway ($\mu g/m^3$), 2020 base case

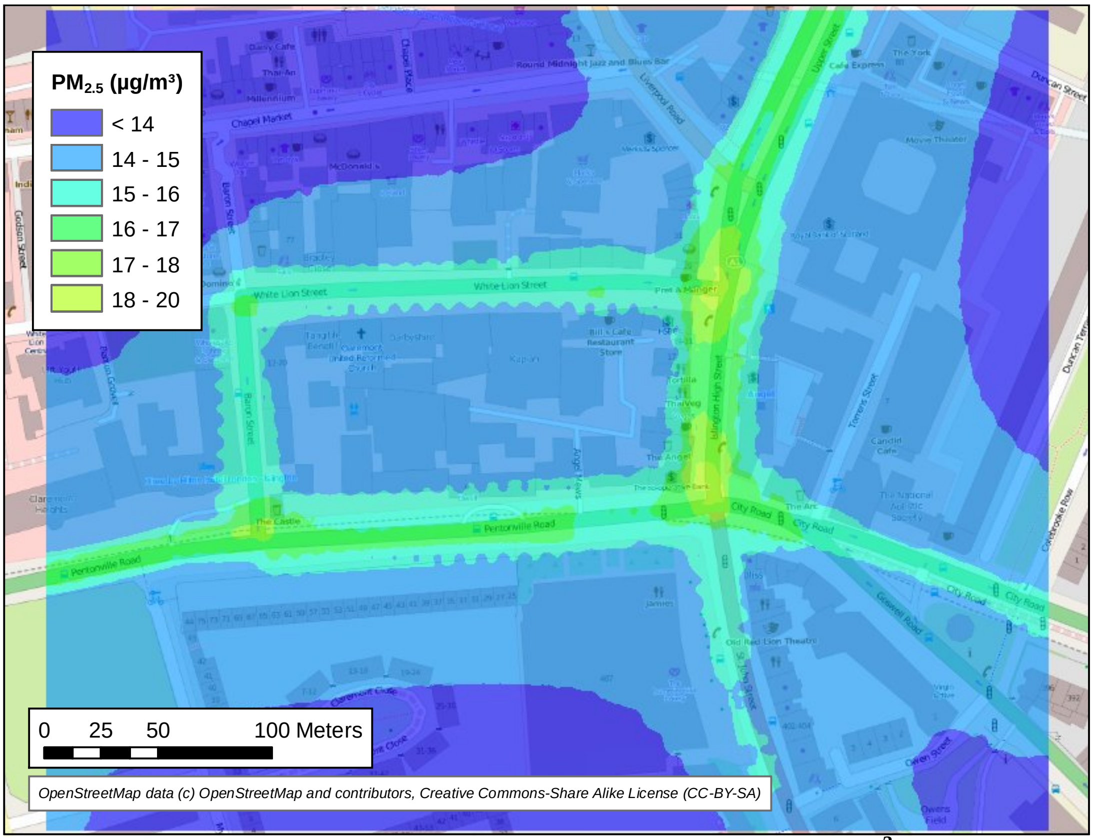

Figure 7.10b: Annual average $PM_{2.5}$ concentrations for Angel ($\mu g/m^3$), 2020 base case

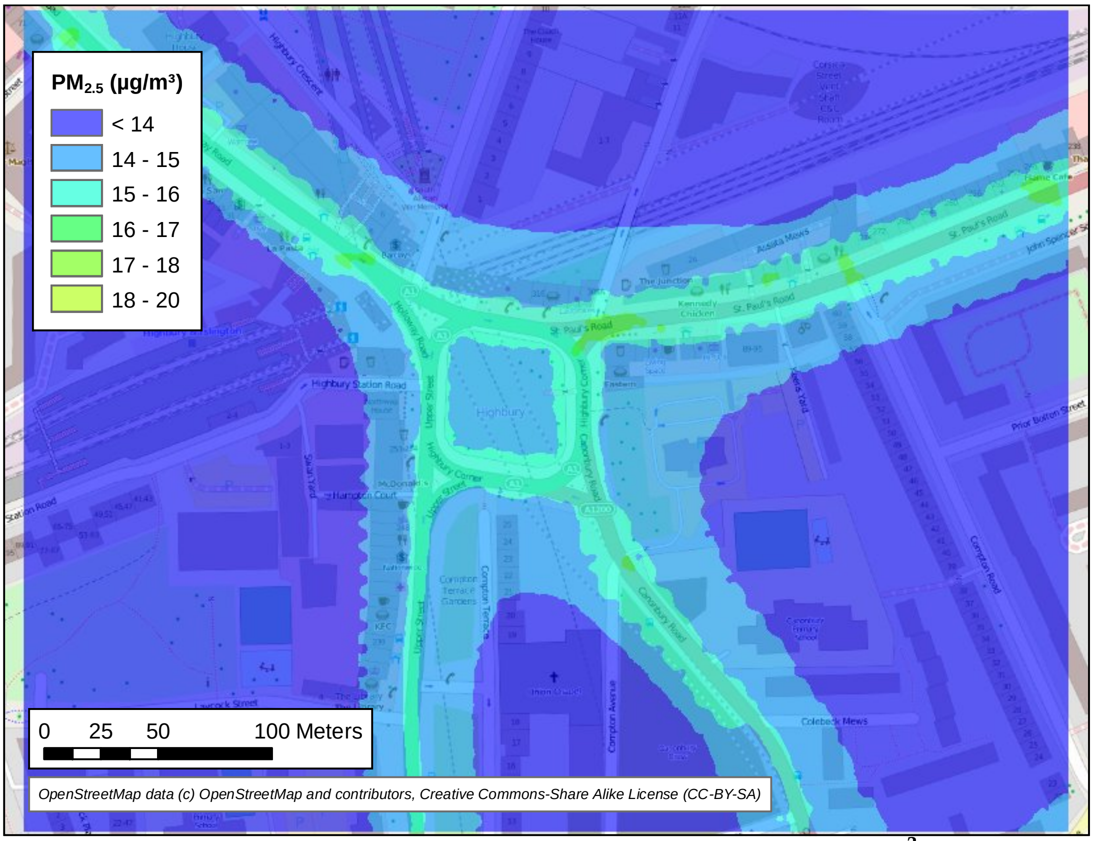

Figure 7.10c: Annual average $PM_{2.5}$ concentrations for Highbury ($\mu g/m^3$), 2020 base case

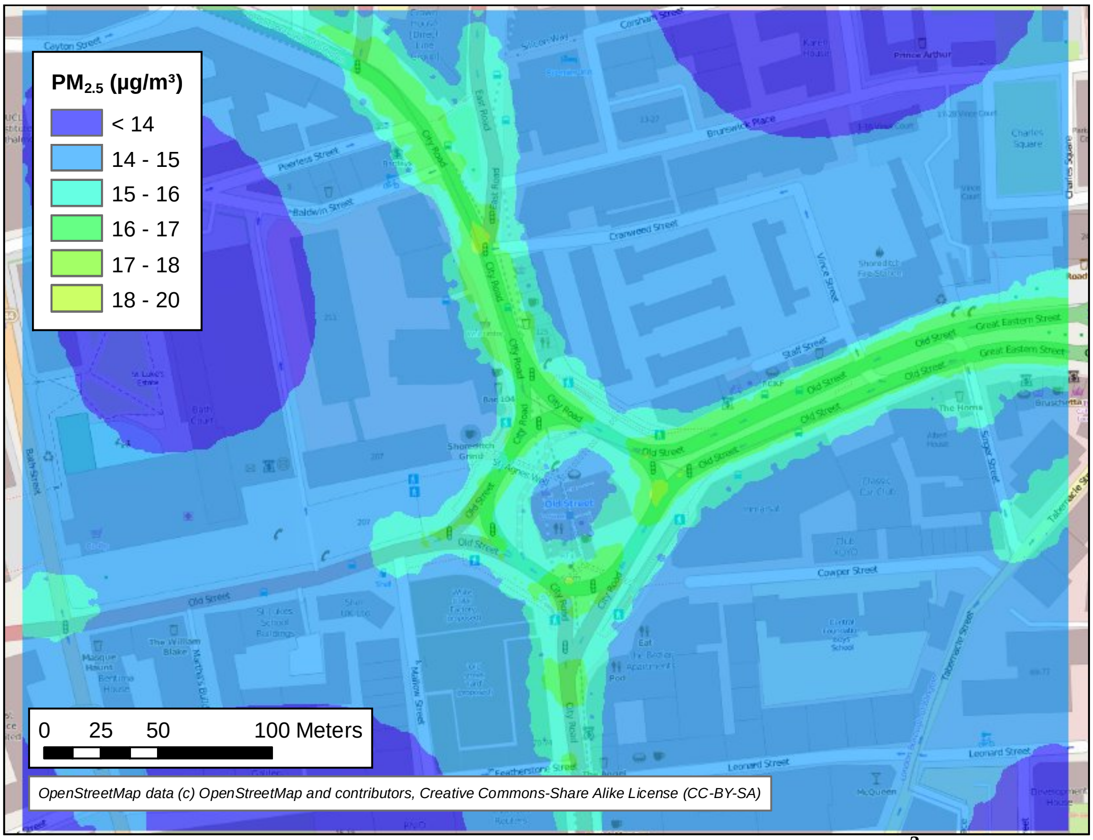

Figure 7.10d: Annual average $PM_{2.5}$ concentrations for Old Street ($\mu g/m^3$), 2020 base case

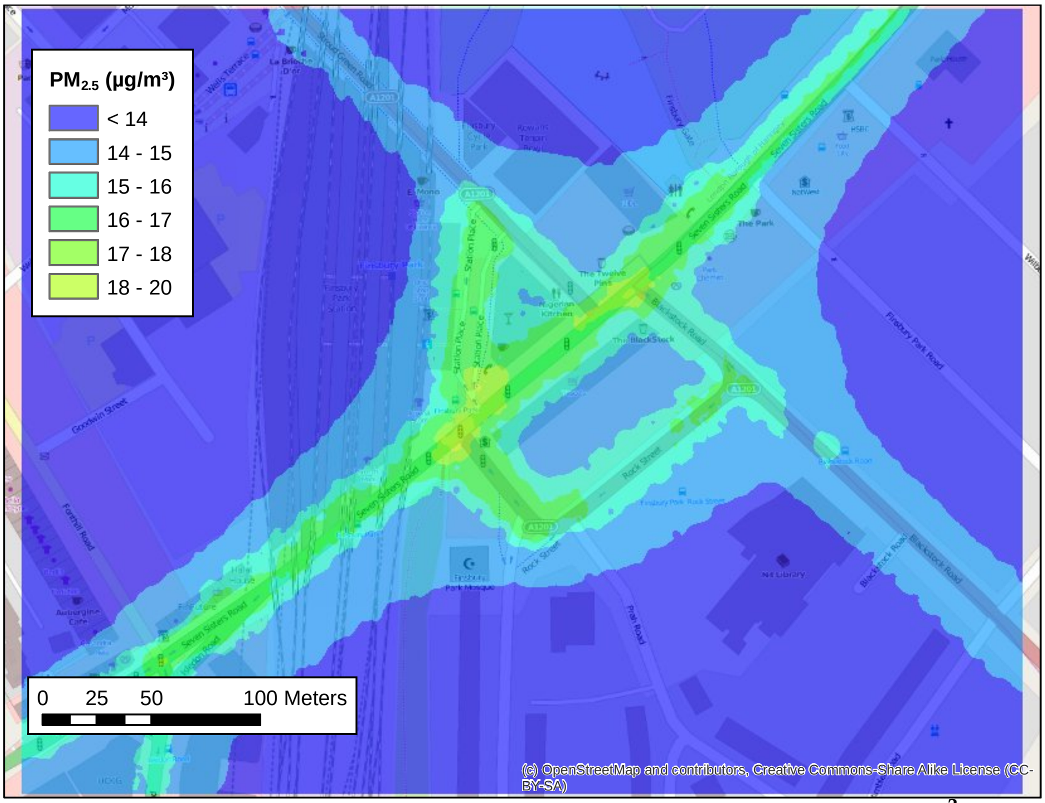

Figure 7.10e: Annual average $PM_{2.5}$ concentrations for Finsbury Park ($\mu g/m^3$), 2020 base case

8. Source apportionment

8.1. Methodology

The concentration of a pollutant at a given point is made up of contributions from numerous sources of different types and, in the case of NO_2, is affected by chemical reactions in the atmosphere. The contribution of different sources will vary depending on the relative locations of the sources and receptor. Modelling was carried out to determine the contribution of different sources at a number of locations across Islington.

The source apportionment locations were provided by the London Borough of Islington and include sites representing the locations of the Nag's Head shopping centre; a road location adjacent to Finsbury Park rail station; a roadside location at Angel; a location 50 metres from the nearest main road near Archway underground station; a roadside location on Old Street; and a roadside location at Highbury Corner. The locations used are presented in Table 8.1 below, and shown in Figure 8.1.

Table 8.1: Islington source apportionment locations used in the study

Receptor name	Location	X(m)	Y(m)
SA1	Finsbury Park	531419	186757
SA2	Nags Head Shopping centre	530536	185953
SA3	Archway	529216	187120
SA4	Angel	531446	183307
SA5	Old Street	532577	182429
SA6	Highbury Corner	531669	184743

Figure 8.1: Source apportionment receptors

8.2. NO_x source apportionment

The contribution of different source groups to the total NO_2 concentration cannot be determined due to the non-linearity of the chemical reactions which take place in the atmosphere. However, the contribution to the total NO_x concentration can be calculated and these contributions are presented in this section.

The contribution of different source groups to total NO_2 concentrations will be related to the contribution of each group to total NO_x concentrations and the proportion of NO_x emissions emitted as NO_2, known as 'primary NO_2'.

Figure 8.2 shows the contribution of the NO_x emissions generated within Islington and the rest of London, for the year 2020. Figure 8.3 shows the impact of these sources at the receptor locations in the borough.

Figure 8.4 shows the contribution of each major source group to the total NO_x emissions from within Islington, for the year 2020. The contribution of these sources to the total NO_x concentrations at the set of receptor locations is shown in Figure 8.5.

Figure 8.6 shows the contribution of each vehicle type to the total road traffic NO_x emissions within Islington for the year 2020 and Table 8.2 shows percentage primary NO_2 emissions for each vehicle type. The contribution of these vehicle types to the total NO_x concentrations at the set of receptor locations is shown in Figure 8.7.

Source apportionment of NO_x concentrations at the set of receptor locations, for the year 2020, is summarised in Tables 8.3 and 8.4.

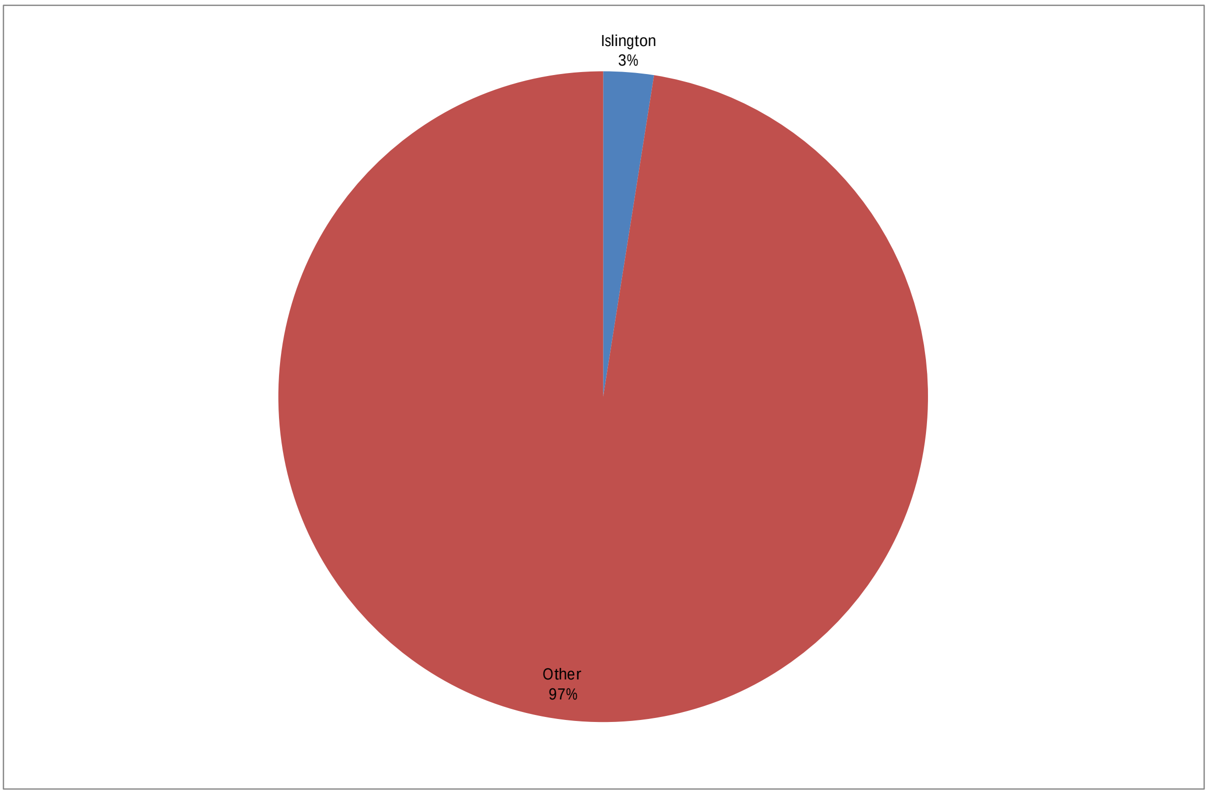

Figure 8.2: NO_x emissions by location of source

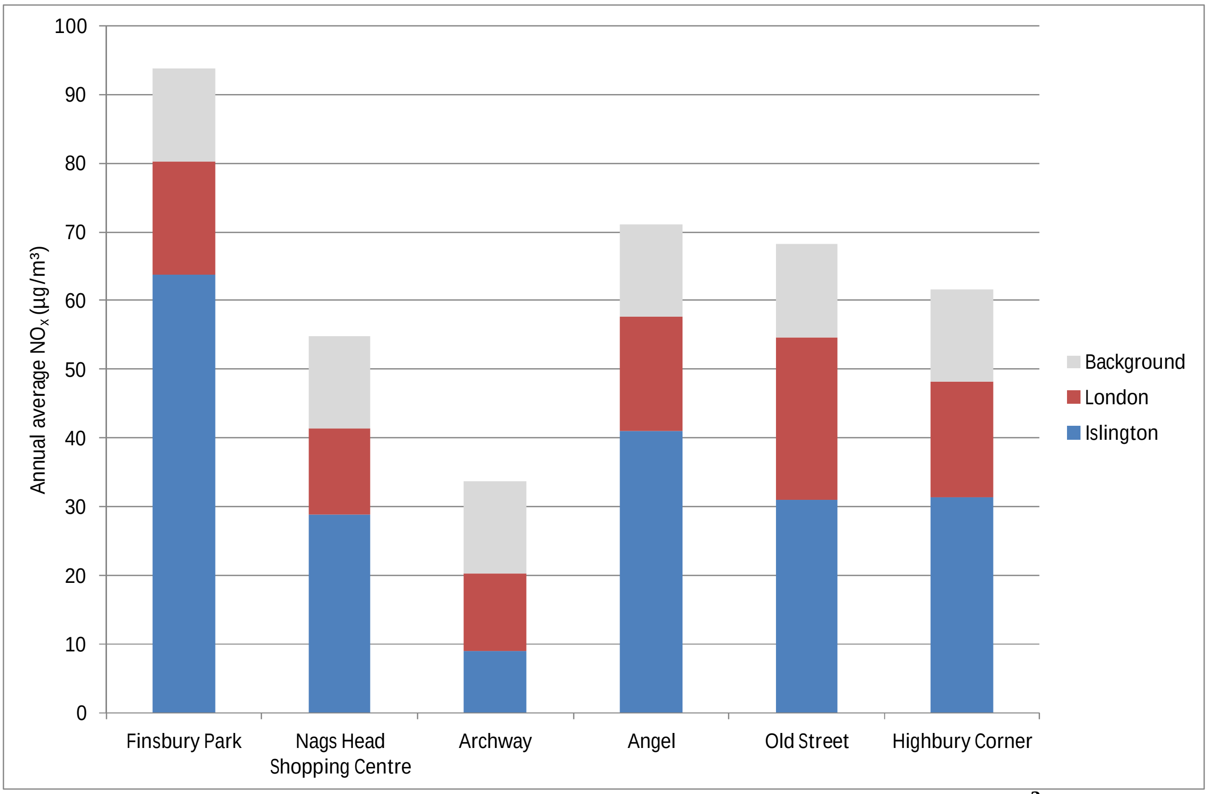

Figure 8.3: Total NO_x concentrations apportioned by location of source ($\mu g/m^3$)

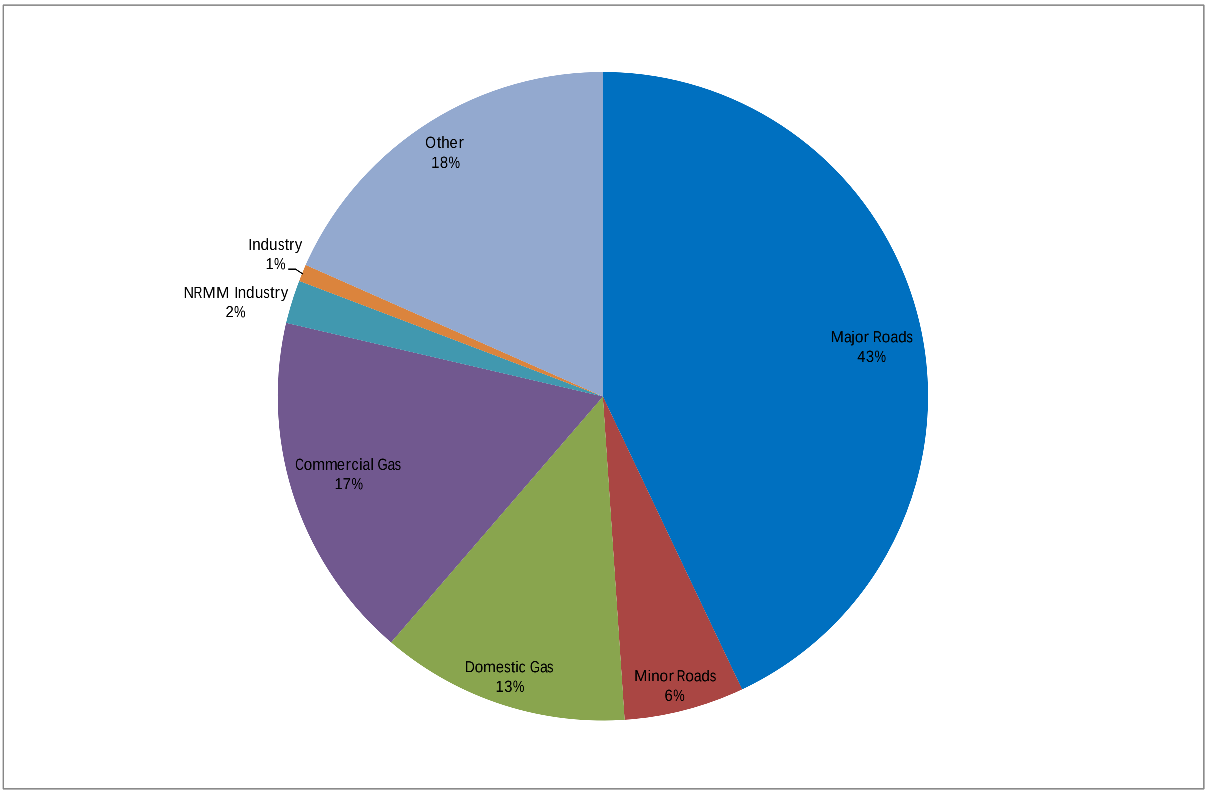

Figure 8.4: Islington NO_x emissions by source type

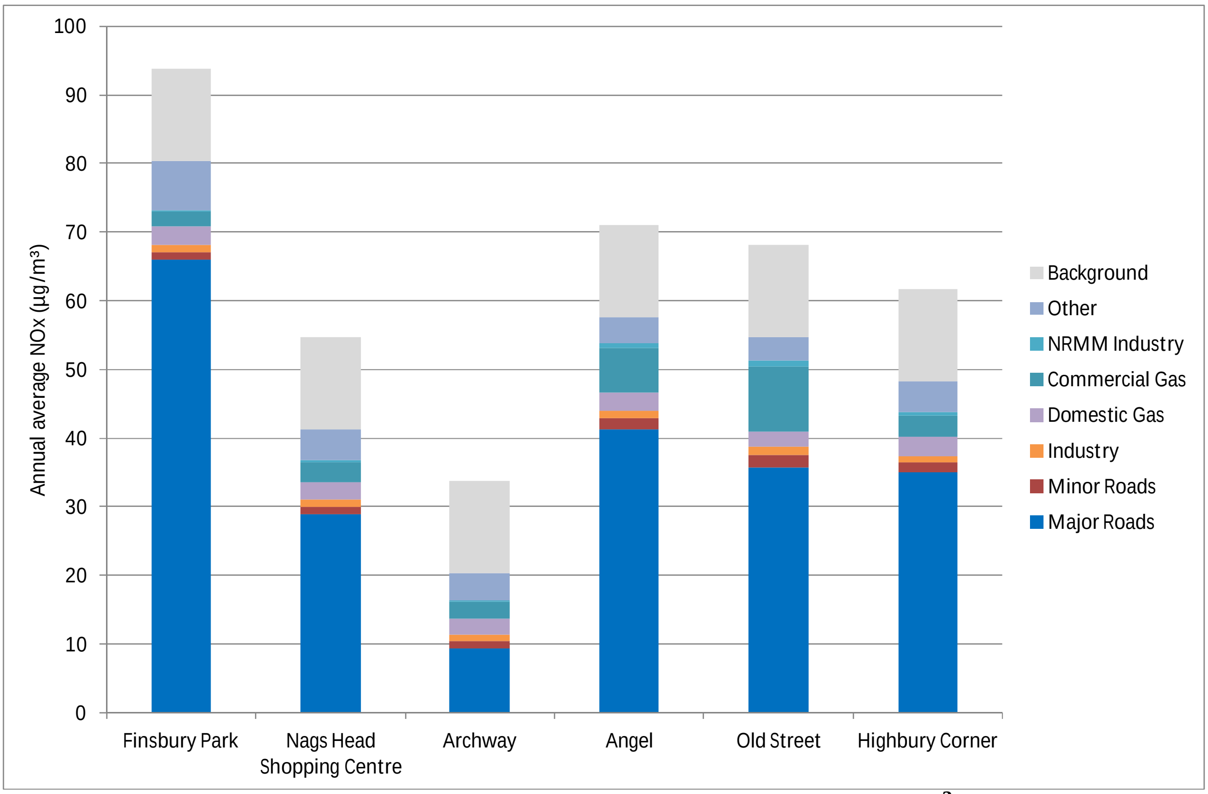

Figure 8.5: Total NO_x concentrations apportioned by source type ($\mu g/m^3$)

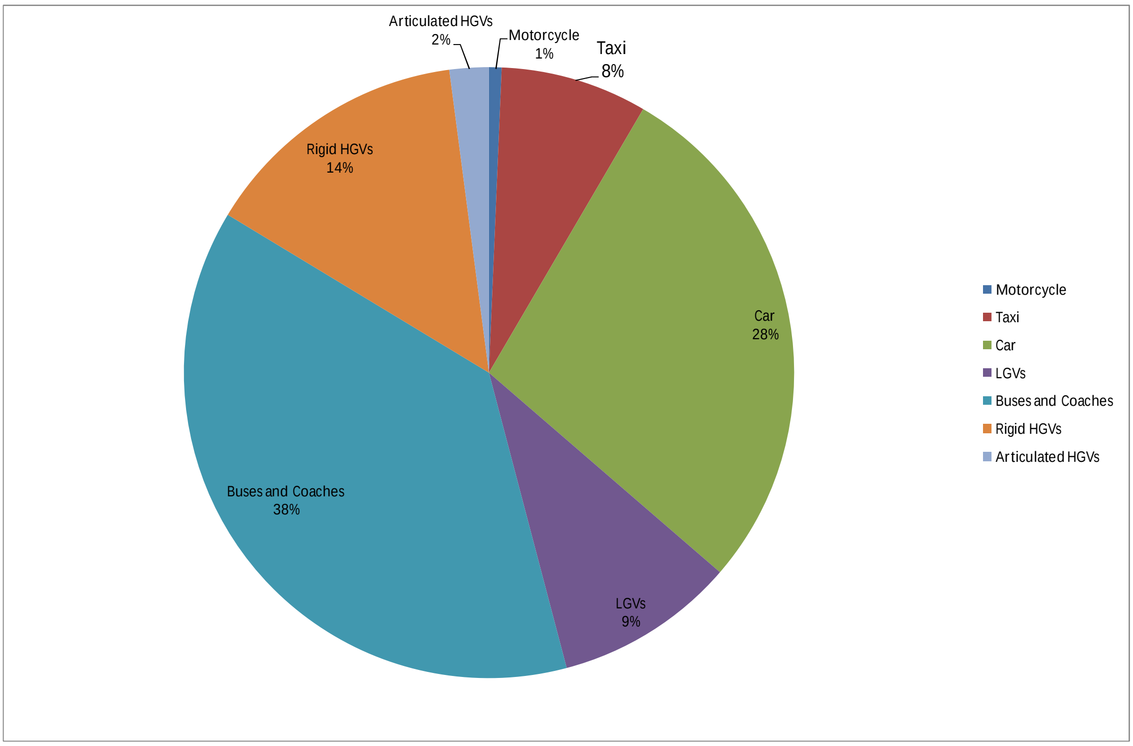

Figure 8.6: Islington road traffic NO_x emissions by vehicle type

Table 8.2: Primary NO_2 percentage for Islington road traffic emissions by vehicle type

Motorcycles	Cars	Taxis	LGV	Buses & Coaches	Rigid	Articulated	All Vehicles
4.0	33.8	43.2	37.7	12.9	10.7	10.2	22.9

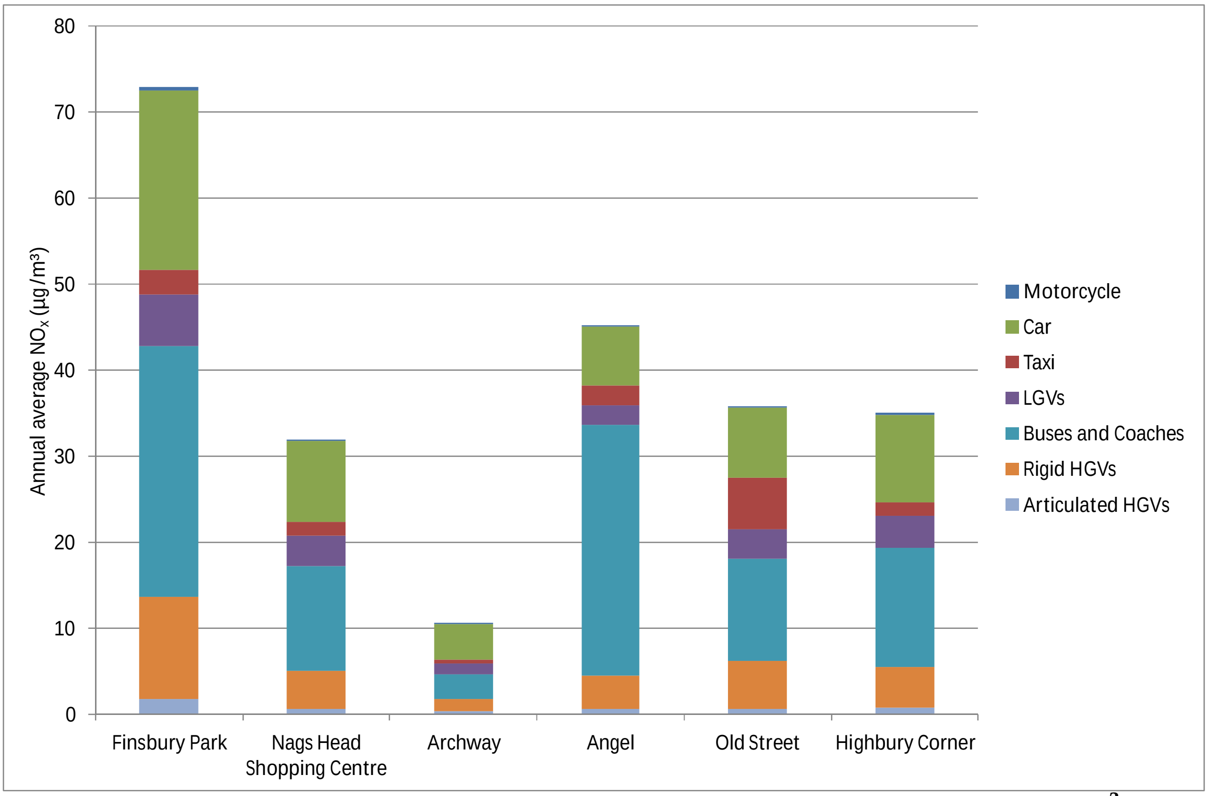

Figure 8.7: NO_x concentrations from major roads apportioned by vehicle type ($\mu g/m^3$)

Table 8.3: Summary of NO_x source apportionment concentrations (µg/m^3) by source group

Source group	Finsbury Park	Nags Head	Archway	Angel	Old Street	Highbury Corner
Major Roads	66.0	28.8	9.4	41.2	35.7	35.0
Minor Roads	1.2	1.2	1.1	1.7	1.9	1.4
Industry	1.0	1.0	0.9	1.1	1.2	1.0
Domestic Gas	2.6	2.6	2.2	2.6	2.2	2.8
Commercial Gas	2.2	2.9	2.6	6.6	9.5	3.1
NRMM Industry	0.3	0.4	0.3	0.7	0.9	0.4
Other	7.0	4.5	3.8	3.7	3.3	4.5
Background	13.4	13.4	13.4	13.4	13.4	13.4
All	93.7	54.7	33.7	71.1	68.1	61.7

Table 8.4: Summary of NO_x source apportionment concentrations (µg/m^3) by vehicle type

Source group	Finsbury Park	Nags Head	Archway	Angel	Old Street	Highbury Corner
Motorcycles	0.3	0.2	0.1	0.2	0.1	0.3
Taxis	2.9	1.5	0.5	2.4	5.9	1.7
Cars	20.9	9.4	4.2	6.8	8.1	10.1
LGVs	6.0	3.7	1.2	2.2	3.4	3.7
Buses	29.2	12.2	2.9	29.3	11.9	13.8
Rigid HGVs	11.8	4.4	1.5	3.8	5.6	4.8
Articulated HGVs	1.8	0.6	0.3	0.6	0.6	0.7

Emissions from sources within Islington represent approximately 2.5% of total NO_x emissions from the LAEI area. The main source of NO_x emissions from Islington are major roads emissions, accounting for 43% of emissions. The main contributors to the major roads emissions are buses and coaches, accounting for 38% of the emissions total, and cars, accounting for 28%.

The contribution of emissions from within Islington contribute between 27% and 68% of total concentrations, with 18% to 35% from emissions from the rest of London and 14% to 40% due to background concentrations from outside London.

Major Roads are predicted to be the major contributor to NO_x concentrations at all locations considered, accounting for between 28% and 70% of the predicted concentrations. The highest predicted contribution from major roads sources is predicted at the Finsbury Park source apportionment location. The major contributions to the road component of the NO_x concentrations are from buses and coaches, and from cars. Cars contribute between 15% and 39% of the road component; buses and coaches contribute between 27% and 65% of the road component. The greatest percentage contribution from buses occurs at the Angel site and the greatest percentage contribution from cars occurs at the Archway site.

8.3. PM_{10} source apportionment

Figure 8.8 shows the contribution of the PM_{10} emissions generated within Islington and the rest of London, for the year 2020. Figure 8.9 shows the impact of these sources at the receptor locations in the borough.

Figure 8.10 shows the contribution of each major source group to the total PM_{10} emissions from within Islington, for the year 2020. The contribution of these sources to the total PM_{10} concentrations at the set of receptor locations is shown in Figure 8.11.

Figure 8.12 shows the contribution of each vehicle type to the total road traffic PM_{10} emissions within Islington for the year. The contribution of these vehicle types to the total PM_{10} concentrations at the set of receptor locations is shown in Figure 8.13.

Vehicles emit particulates not only from their exhausts, but also from brake-wear, tyre-wear, road-wear and resuspension. For the purposes of this source apportionment, these have been attributed to exhaust and non-exhaust groups. Figure 8.22 shows the contribution of the exhaust and non-exhaust emissions to the total road traffic PM_{10} emissions within Islington for the year. The contribution of these vehicle types to the total PM_{10} concentrations at the set of receptor locations is shown in Figure 8.15.

Source apportionment of PM_{10} concentrations at the set of receptor locations, for the year 2020, is summarised in Tables 8.5, 8.6 and 8.7.

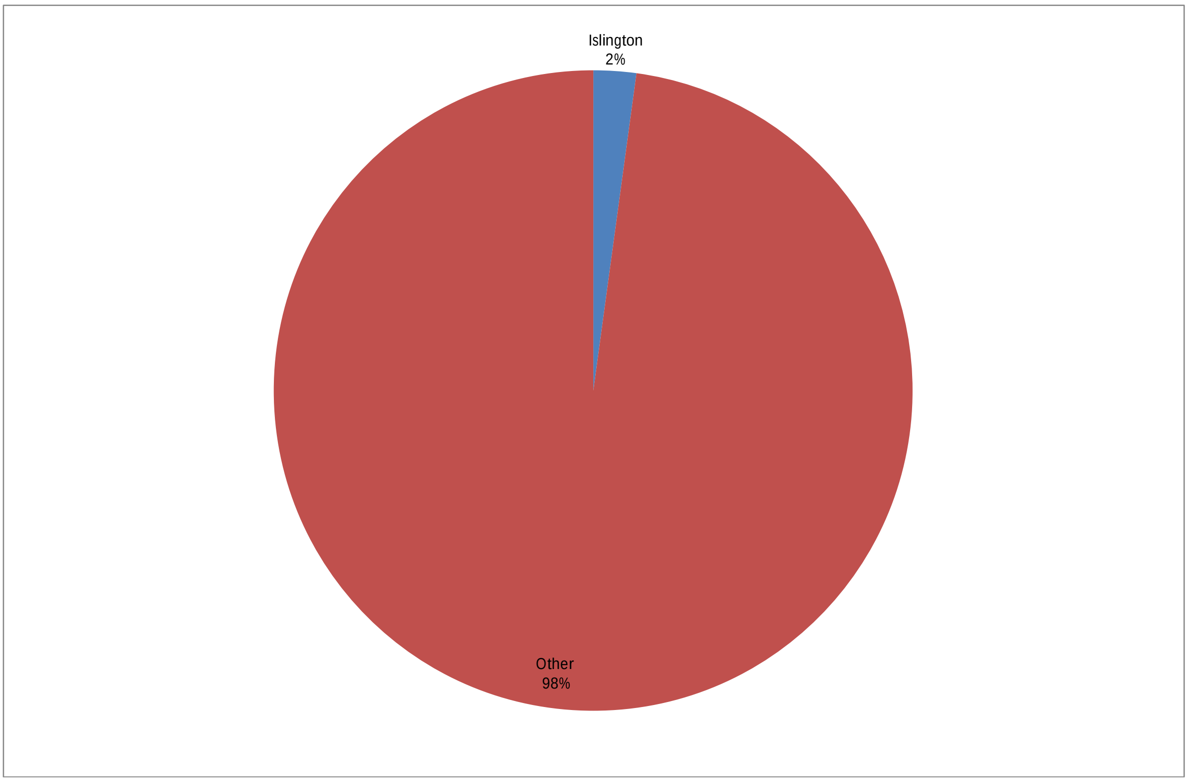

Figure 8.8: PM$_{10}$ emissions by location of source

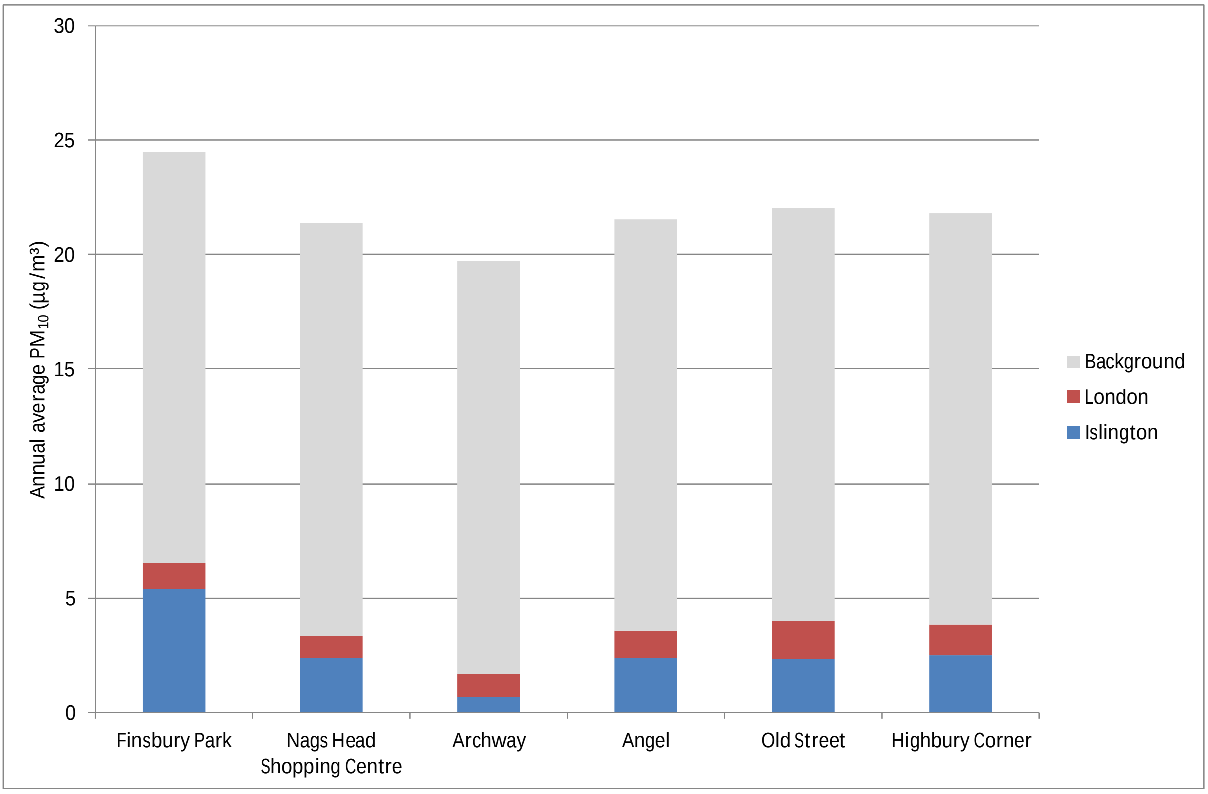

Figure 8.9: Total PM$_{10}$ concentrations apportioned by location of source (µg/m3)

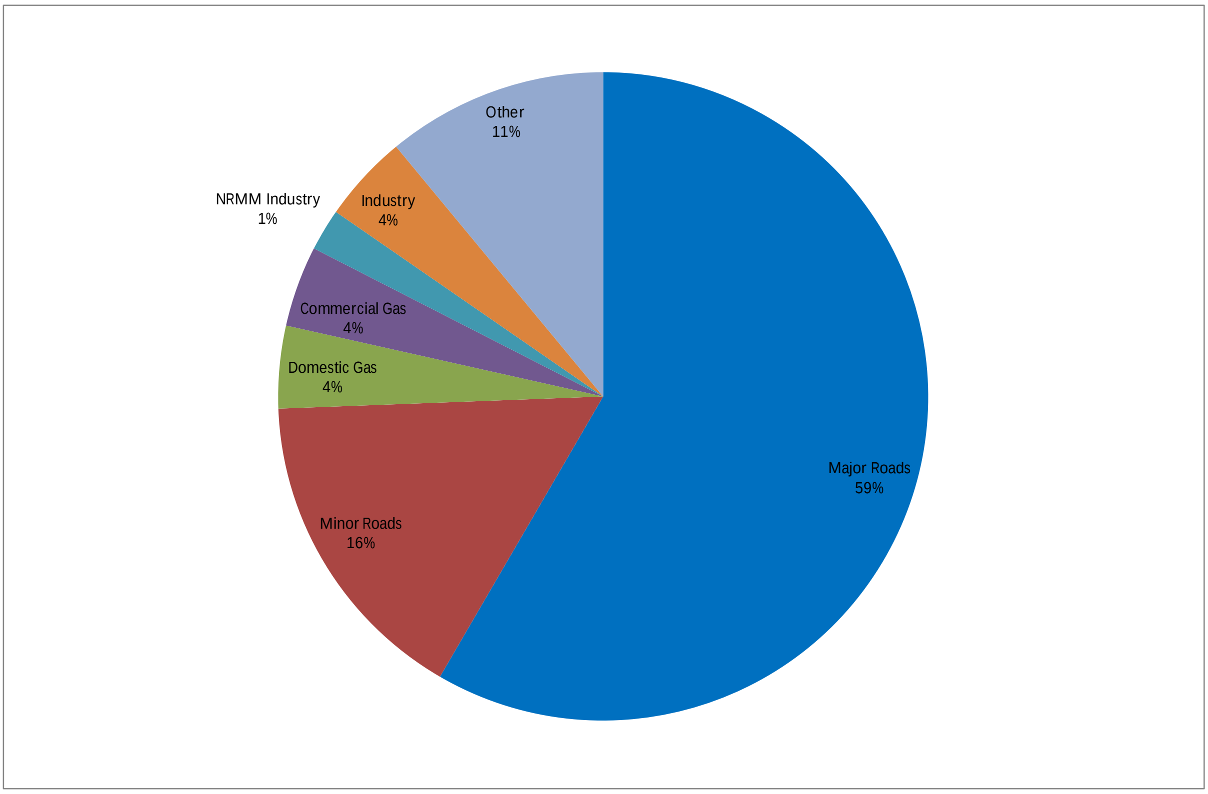

Figure 8.10: Islington PM_{10} emissions by source type

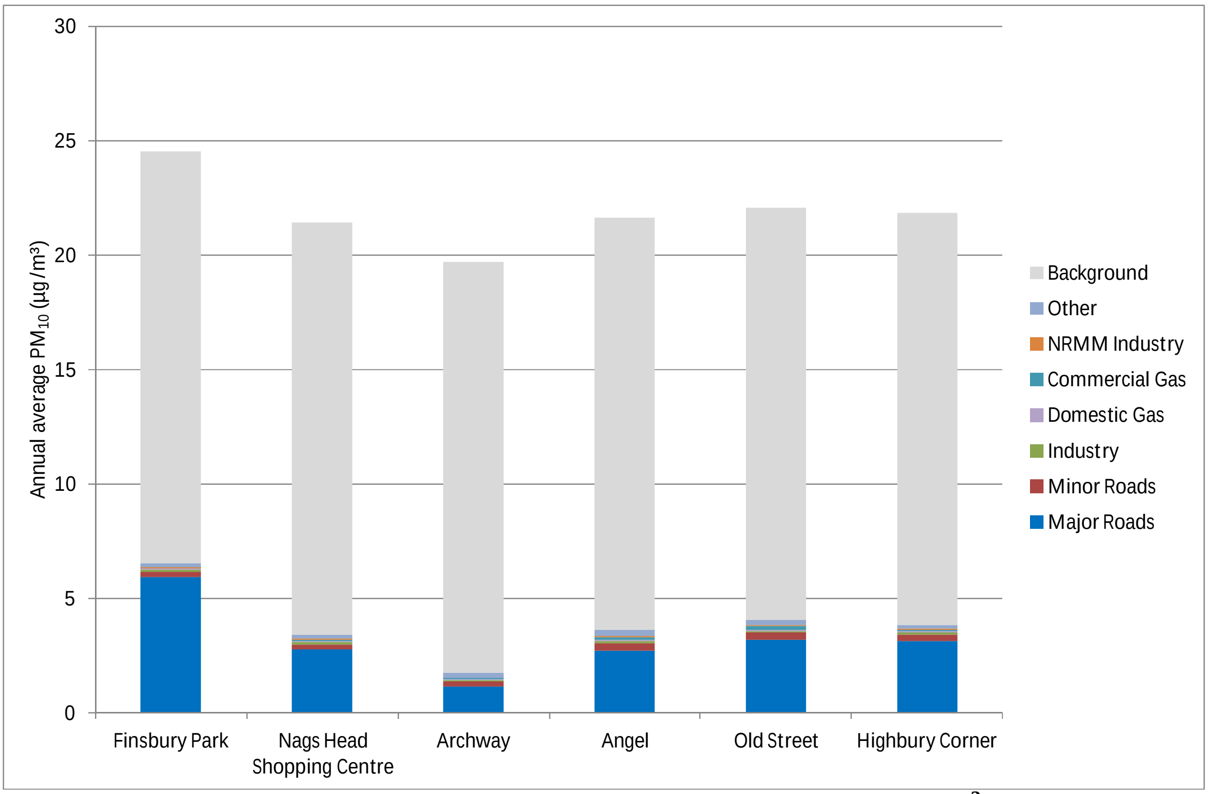

Figure 8.11: Total PM_{10} concentrations apportioned by source type ($\mu g/m^3$)

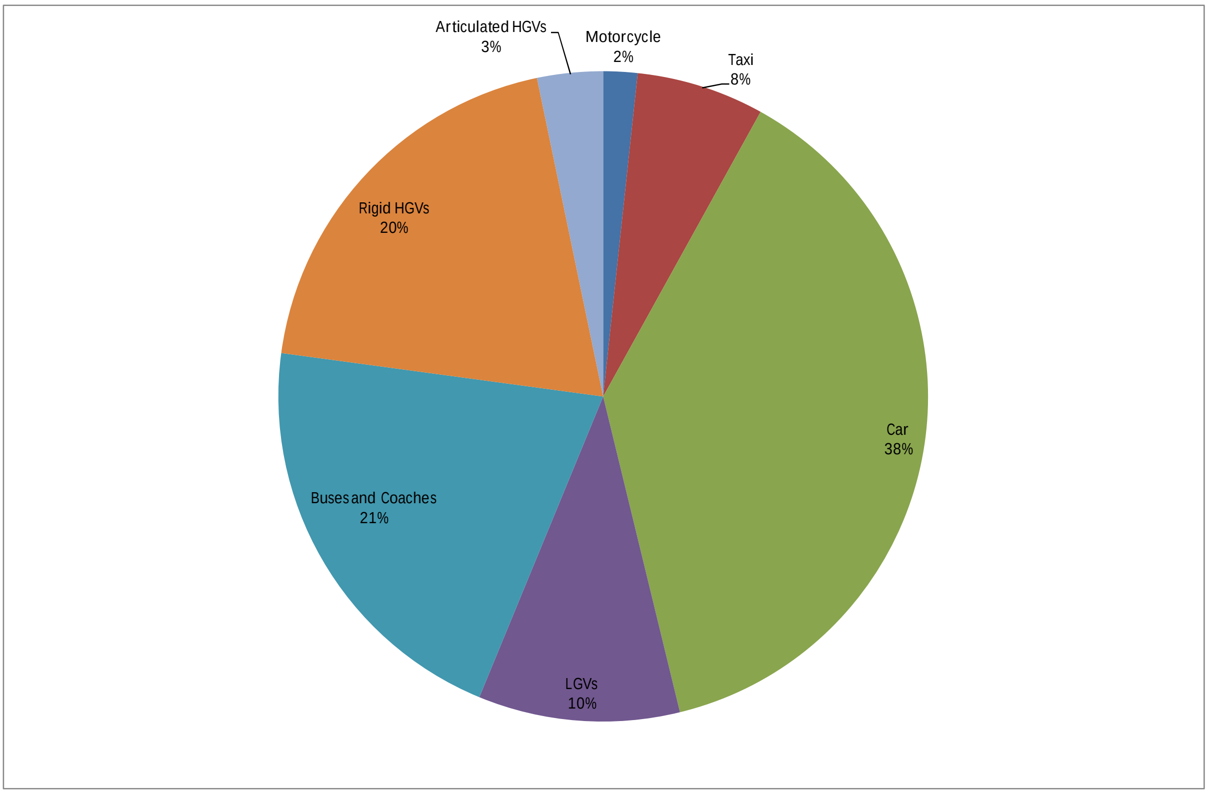

Figure 8.12: Islington road traffic PM_{10} emissions by vehicle type

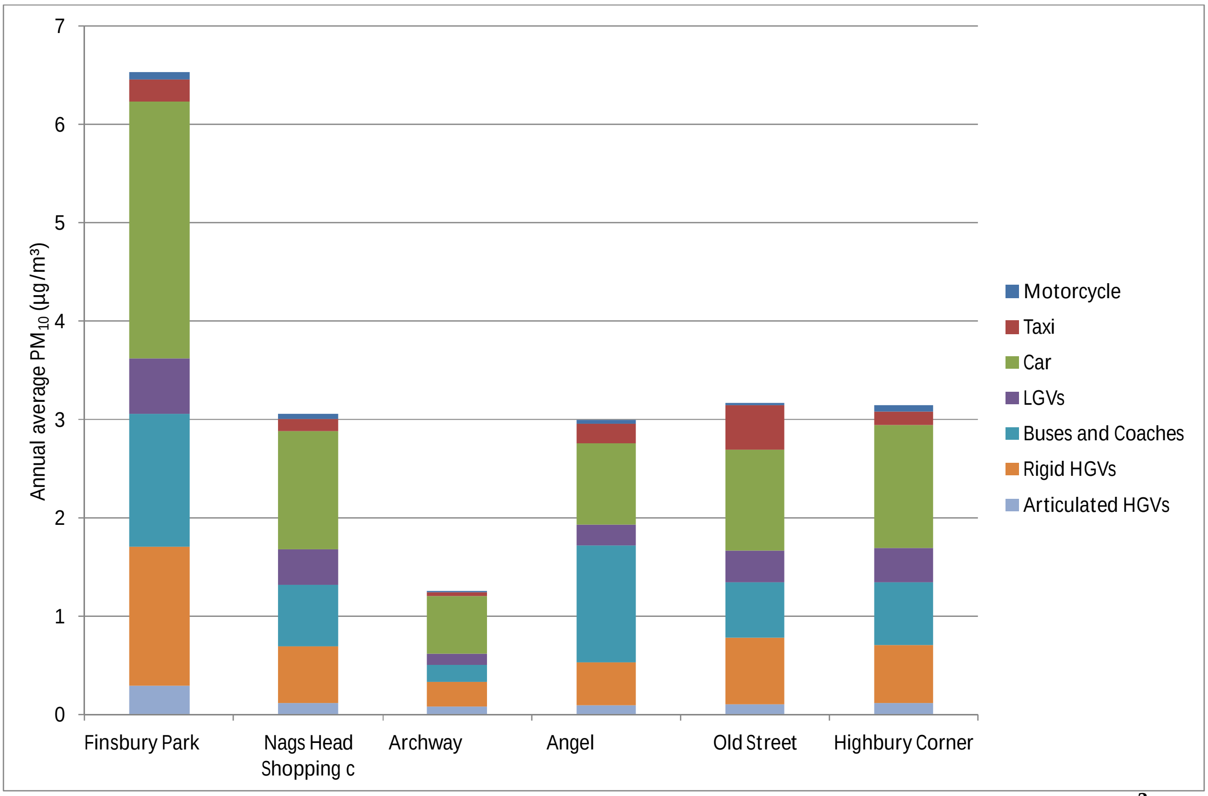

Figure 8.13: PM_{10} concentrations from major roads apportioned by vehicle type (µg/m^3)

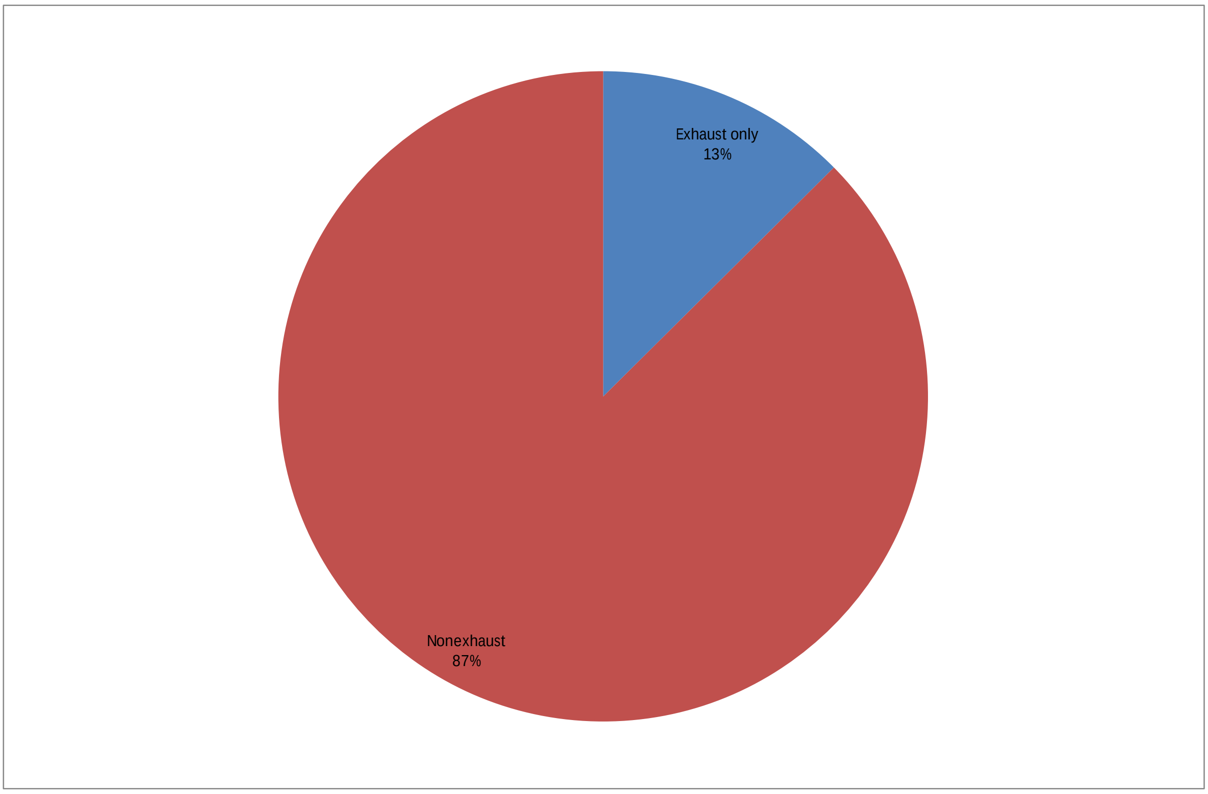

Figure 8.14: Islington road traffic PM_{10} emissions apportioned by emission type

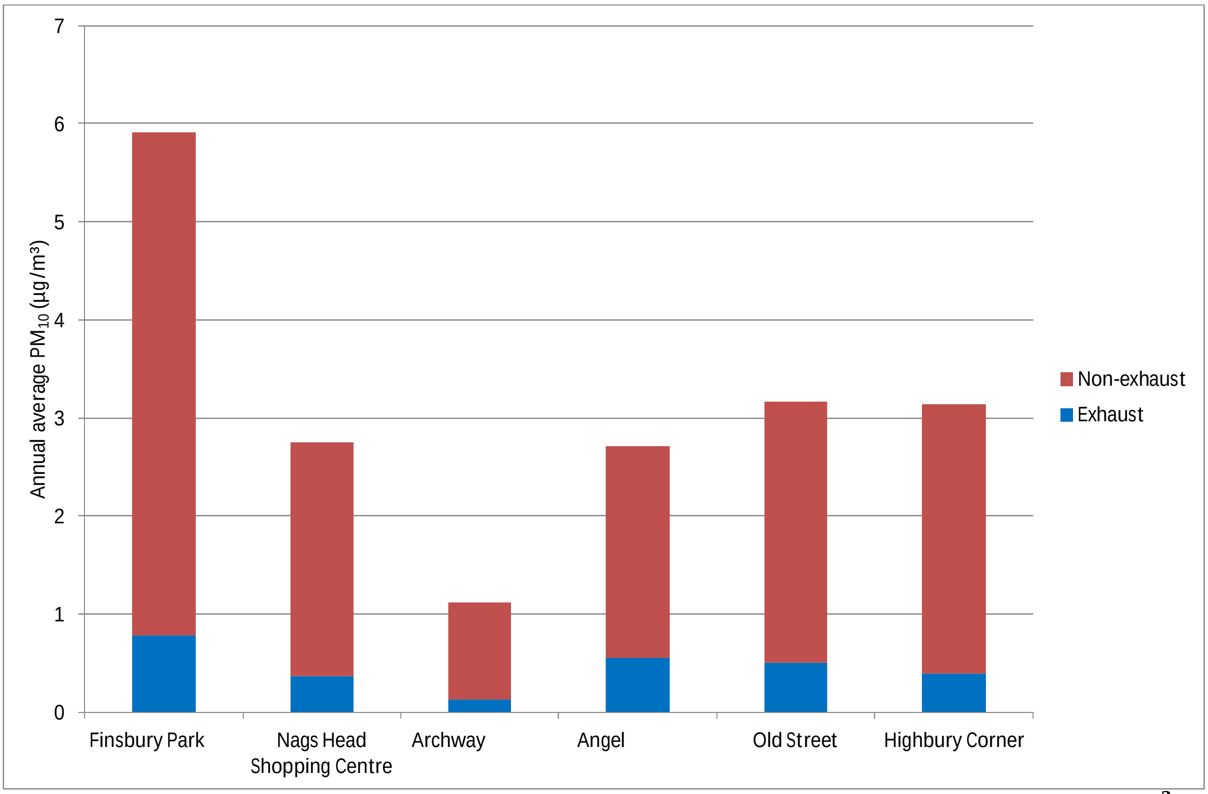

Figure 8.15: PM_{10} concentrations from major roads apportioned by emission type (µg/m^3)

Table 8.5: Summary of PM_{10} concentrations (µg/m^3) by source group

Source group	Finsbury Park	Nags Head Shopping Centre	Archway	Angel	Old Street	Highbury Corner
Major Roads	5.91	2.75	1.12	2.71	3.17	3.14
Minor Roads	0.24	0.25	0.23	0.30	0.32	0.28
Industry	0.08	0.10	0.07	0.14	0.09	0.10
Domestic Gas	0.06	0.06	0.05	0.06	0.05	0.06
Commercial Gas	0.04	0.05	0.04	0.11	0.15	0.05
NRMM Industry	0.02	0.03	0.02	0.05	0.06	0.03
Other	0.18	0.17	0.18	0.25	0.23	0.20
Background	18.0	18.0	18.0	18.0	18.0	18.0
All	24.5	21.4	19.7	21.6	22.1	21.9

Table 8.6: Summary of PM_{10} source apportionment concentrations (µg/m^3) by vehicle type

Source group	Finsbury Park	Nags Head Shopping Centre	Archway	Angel	Old Street	Highbury Corner
Motorcycle	0.07	0.05	0.01	0.04	0.02	0.06
Taxi	0.23	0.12	0.04	0.21	0.45	0.13
Car	2.61	1.21	0.58	0.83	1.02	1.25
LGVs	0.57	0.36	0.12	0.21	0.33	0.35
Buses & Coaches	1.34	0.62	0.17	1.19	0.57	0.65
Rigid HGVs	1.42	0.58	0.25	0.43	0.67	0.58
Articulated HGVs	0.29	0.12	0.07	0.09	0.11	0.12

Table 8.7: Summary of PM_{10} source apportionment concentrations (µg/m^3) by emission type

Source group	Finsbury Park	Nags Head Shopping Centre	Archway	Angel	Old Street	Highbury Corner
Exhaust	0.78	0.37	0.12	0.55	0.51	0.40
Non-exhaust	5.13	2.38	0.99	2.16	2.66	2.74

Emissions from sources within Islington represent approximately 3% of total PM_{10} emissions from the LAEI area. Similarly to NO_x, the main source of PM_{10} emissions from within Islington is major roads, accounting for 59% of emissions. The main contributors to major roads emissions within Islington are buses and coaches, accounting for 34% of the emissions total, and cars, accounting for 29%.

Unlike NO_x concentrations, however, the major contributor to PM_{10} concentrations at all locations is the background concentration, which accounts for between 73% and 91% of the predicted concentrations. The contribution from background is constant across the sites, 18µg/m^3; the variation in percentages reflects the relative contribution of other sources at the sites.

Major roads are the second largest source of PM_{10} concentrations, contributing between 6% and 24% of the total concentrations. The majority (87%) of PM_{10} emissions within Islington are from non-exhaust emissions sources.

The major contributions to the major road component of the PM_{10} concentrations are from cars, and buses and coaches. Cars contribute between 28% and 46% of the road component; buses and coaches contribute between 14% and 40% of the road component. As for NO_x, The greatest percentage contribution from buses occurs at the Angel site and the greatest percentage contribution from cars occurs at the Archway site. Non-exhaust road emissions contribute more to concentrations at the receptor locations than exhaust road emissions, accounting for between 80% and 89% of the road component.

8.4. $PM_{2.5}$ source apportionment

Figure 8.16 shows the contribution of the $PM_{2.5}$ emissions generated within Islington and the rest of London, for the year 2020. Figure 8.17 shows the impact of these sources at the receptor locations in the borough.

Figure 8.18 shows the contribution of each major source group to the total $PM_{2.5}$ emissions from within Islington, for the year 2020. The contribution of these sources to the total $PM_{2.5}$ concentrations at the set of receptor locations is shown in Figure 8.19.

Figure 8.20 shows the contribution of each vehicle type to the total road traffic $PM_{2.5}$ emissions within Islington for the year. The contribution of these vehicle types to the total $PM_{2.5}$ concentrations at the set of receptor locations is shown in Figure 8.21.

Figure 8.22 shows the contribution of exhaust and non-exhaust (road wear, brake wear, tyre wear and resuspension) emissions to the total road traffic $PM_{2.5}$ emissions within Islington for the year. The contribution of these vehicle types to the total $PM_{2.5}$ concentrations at the set of receptor locations is shown in Figure 8.23.

Source apportionment of $PM_{2.5}$ concentrations at the set of receptor locations, for the year 2020, is summarised in Tables 8.8, 8.9 and 8.10.

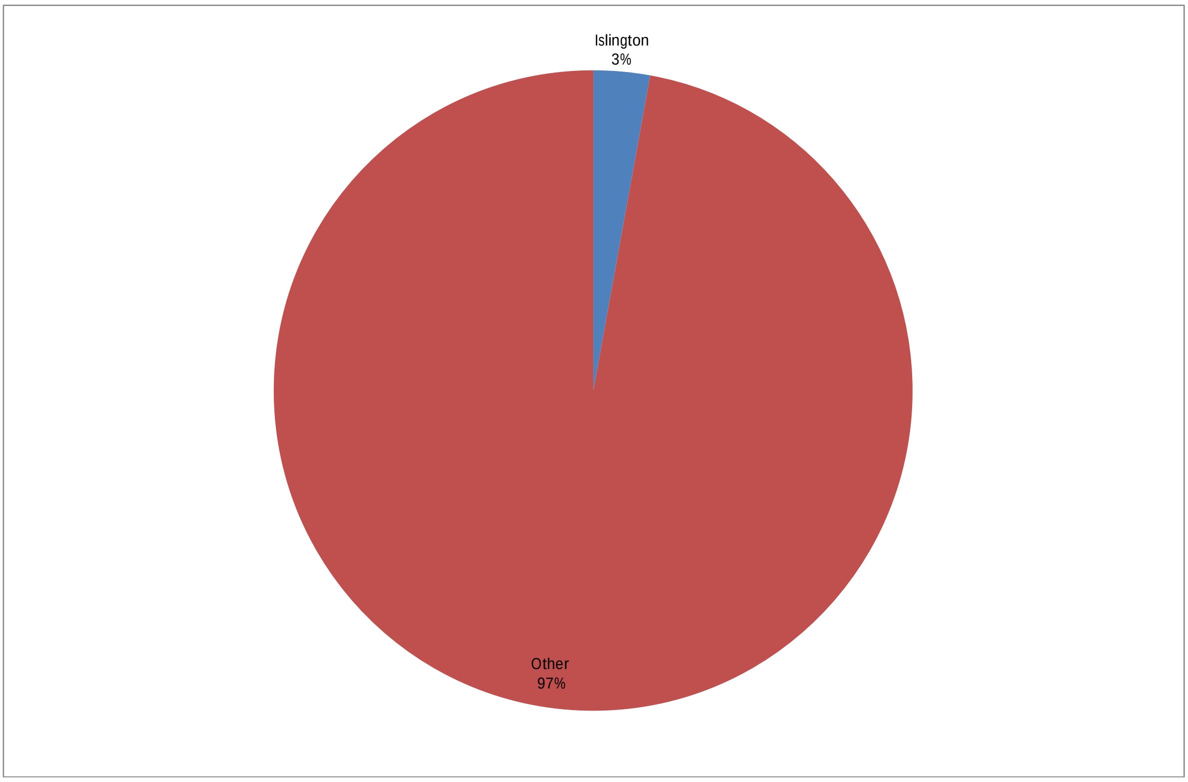

Figure 8.16: PM$_{2.5}$ emissions by location of source

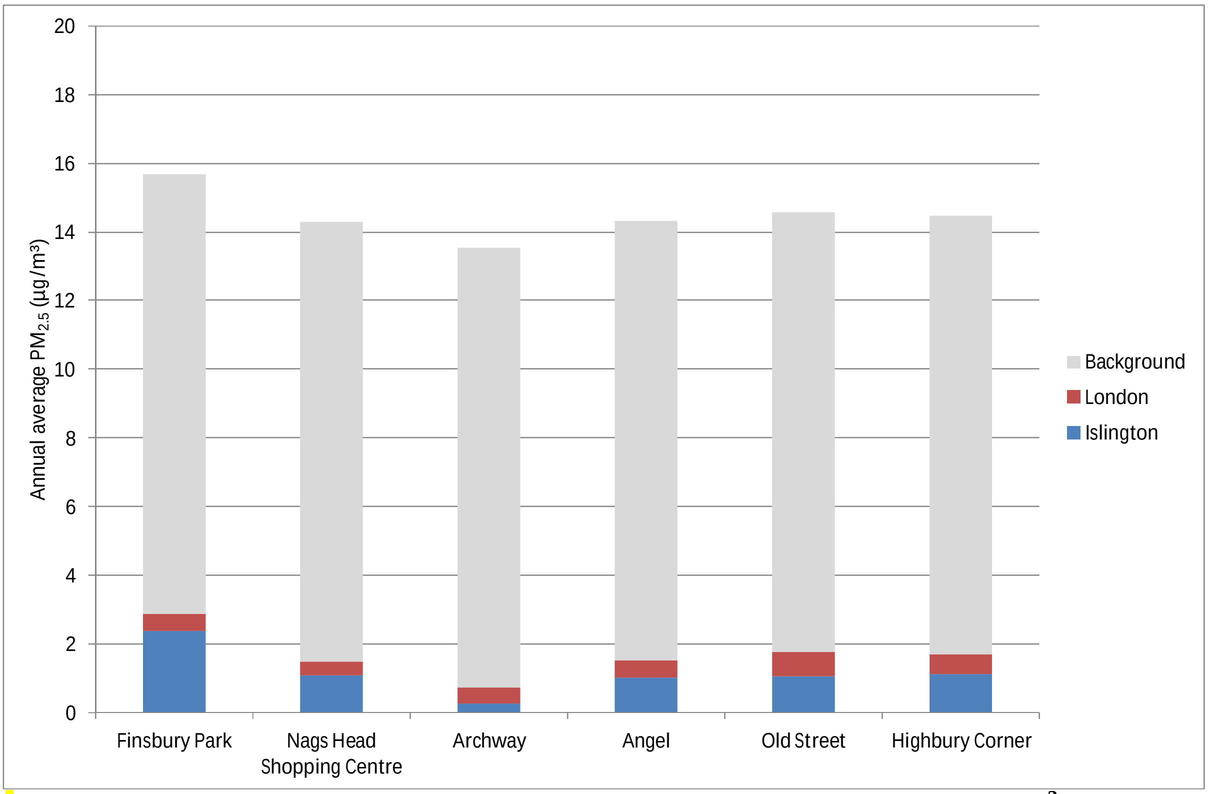

Figure 8.17: Total PM$_{2.5}$ concentrations apportioned by location of source (µg/m^3)

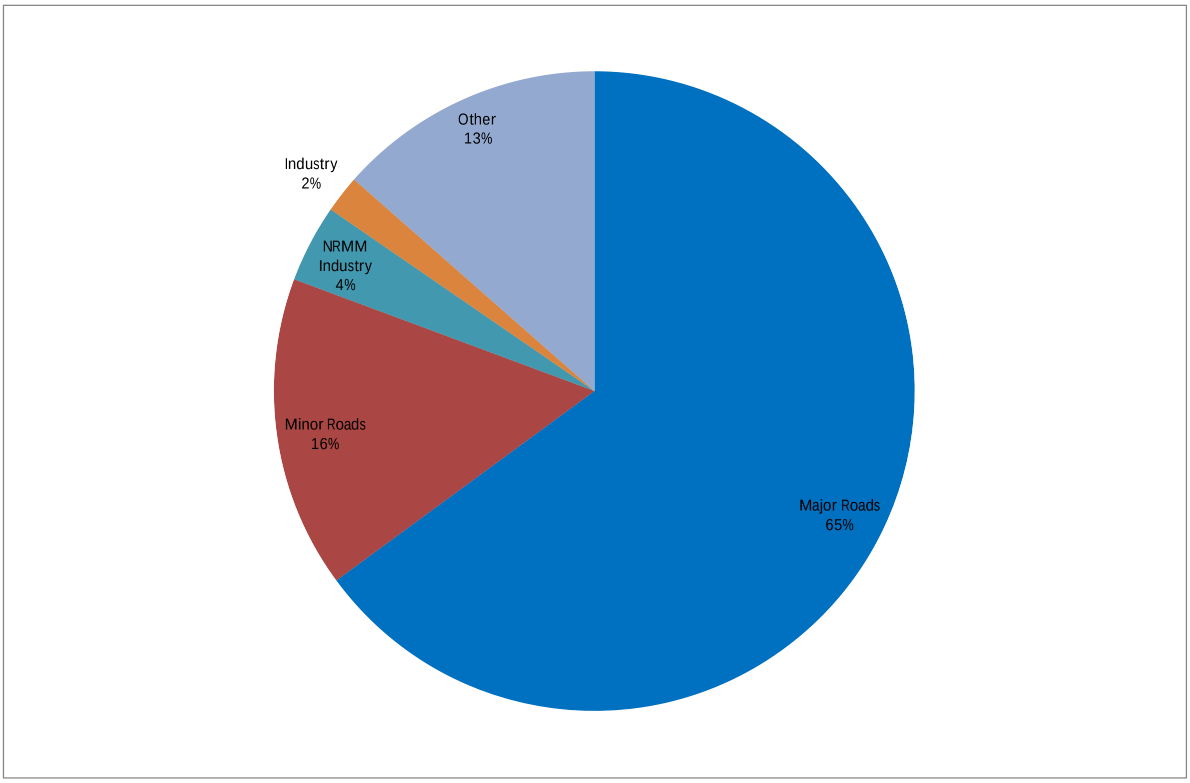

Figure 8.18: Islington $PM_{2.5}$ emissions by source type

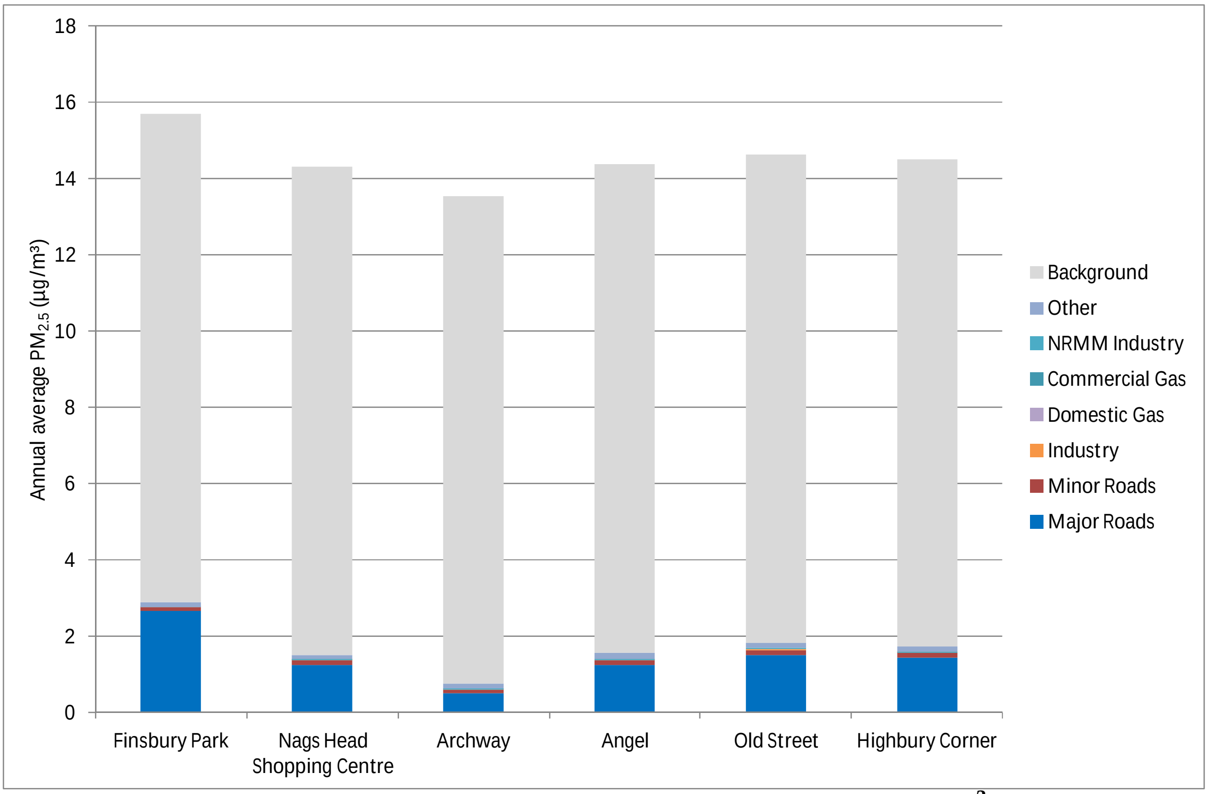

Figure 8.19: Total $PM_{2.5}$ concentrations apportioned by source type (µg/m³)

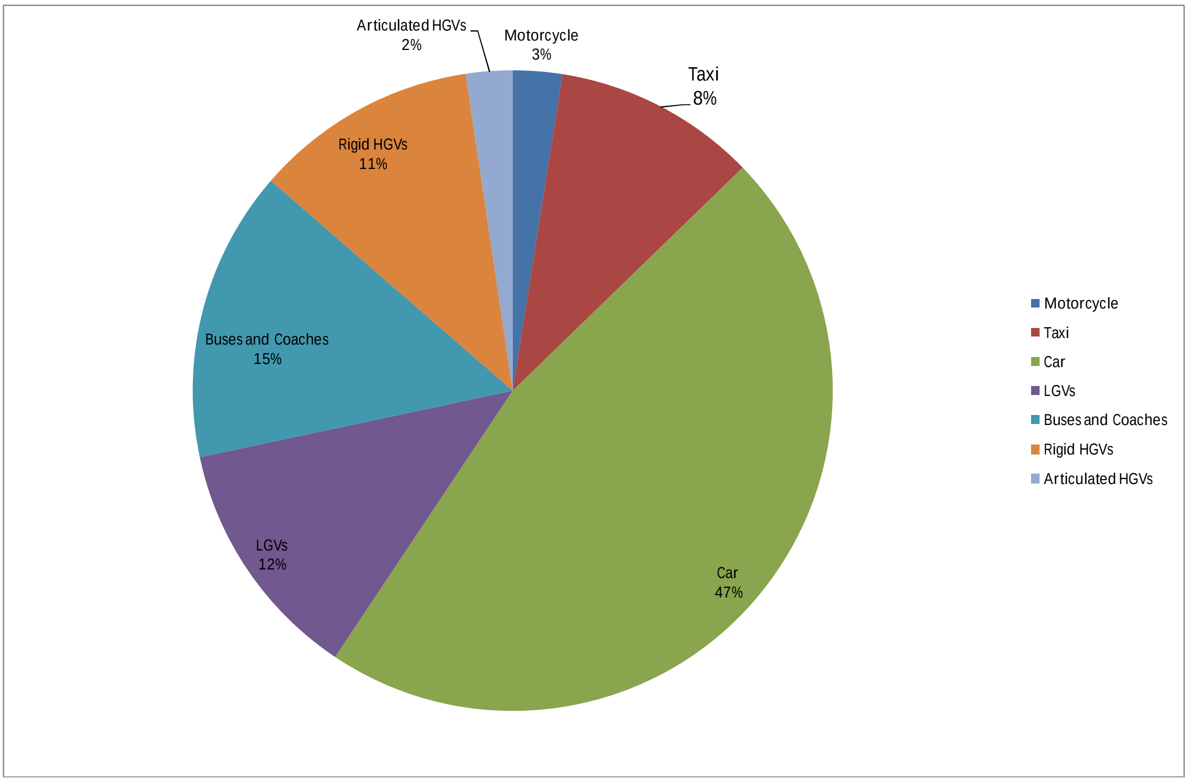

Figure 8.20: Islington road traffic $PM_{2.5}$ emissions by vehicle type

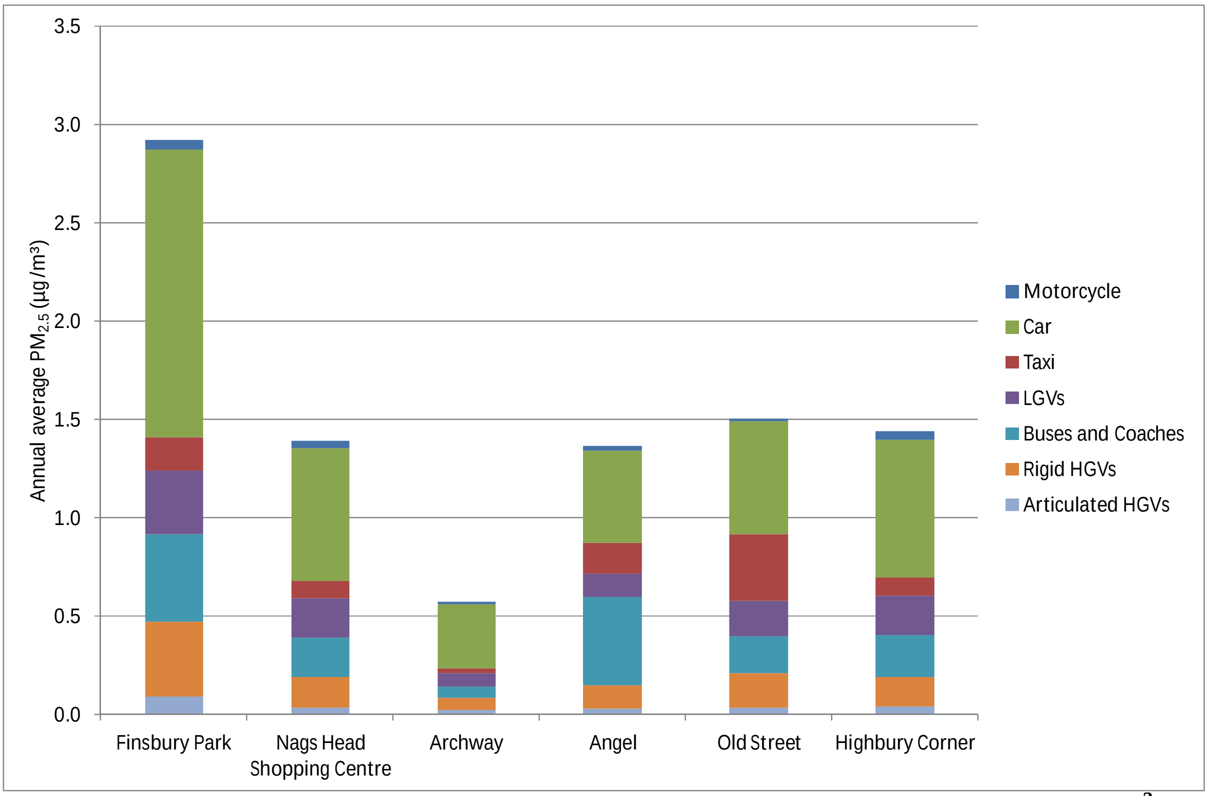

Figure 8.21: $PM_{2.5}$ concentrations from major roads apportioned by vehicle type ($\mu g/m^3$)

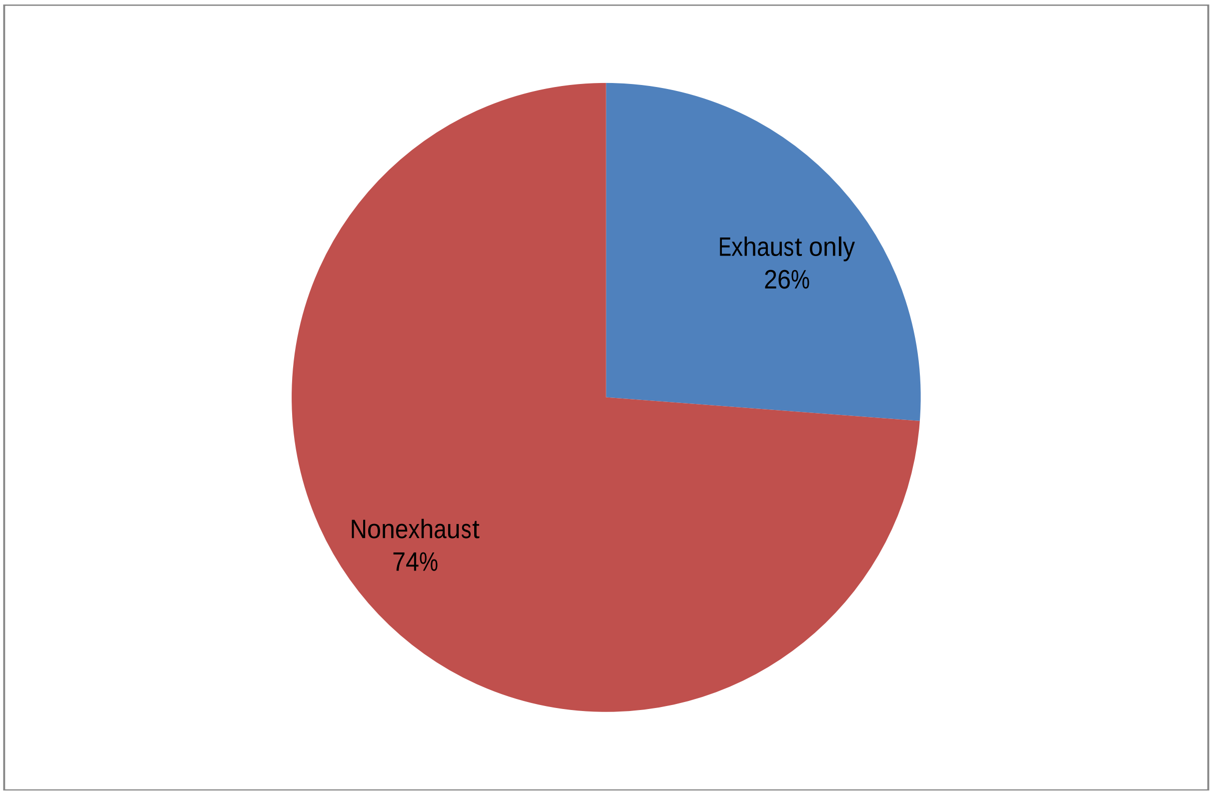

Figure 8.22: Islington road traffic $PM_{2.5}$ emissions apportioned by emission type

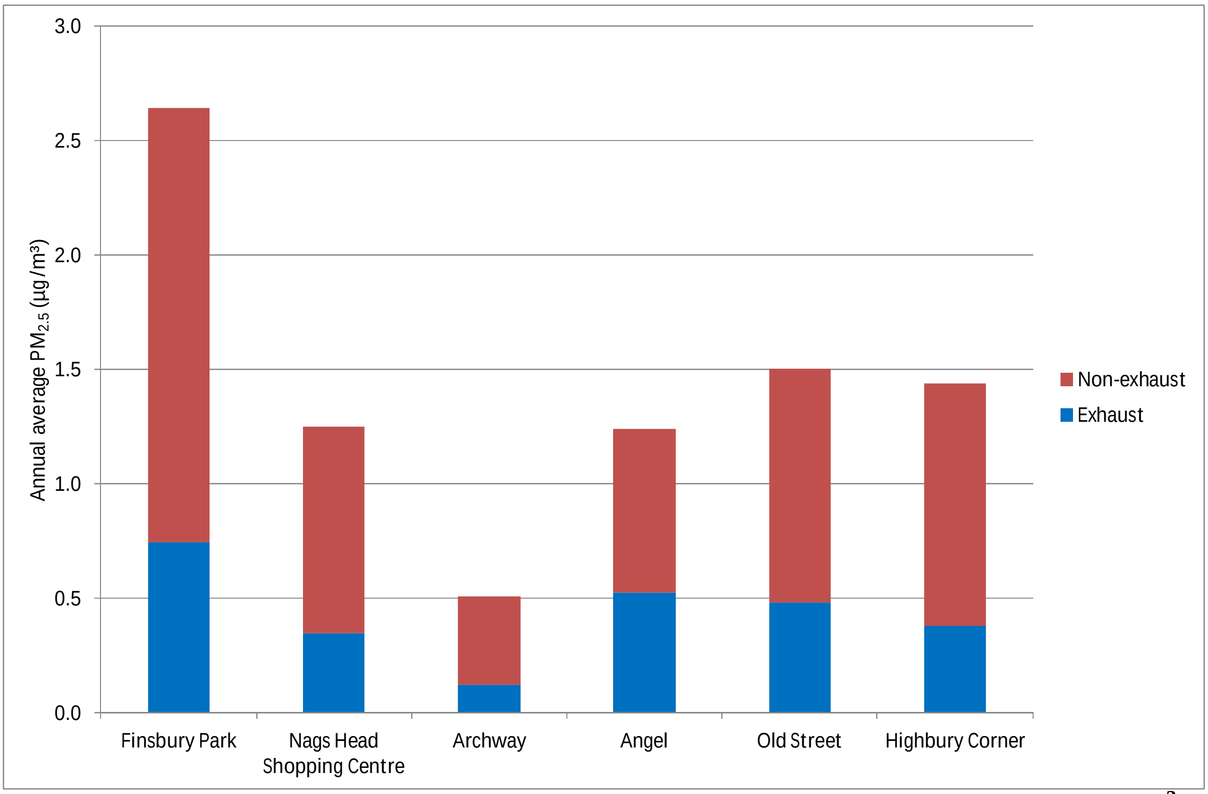

Figure 8.23: $PM_{2.5}$ concentrations from major roads apportioned by emission type (µg/m³)

Table 8.8: Summary of $PM_{2.5}$ concentrations ($\mu g/m^3$) by source group

Source group	Finsbury Park	Nags Head Shopping Centre	Archway	Angel	Old Street	Highbury Corner
Major Roads	2.64	1.25	0.51	1.24	1.50	1.44
Minor Roads	0.10	0.10	0.09	0.12	0.13	0.11
Industry	0.01	0.01	0.01	0.02	0.01	0.01
Domestic Gas	0.00	0.00	0.00	0.00	0.00	0.00
Commercial Gas	0.00	0.00	0.00	0.00	0.00	0.00
NRMM Industry	0.02	0.02	0.01	0.04	0.05	0.02
Other	0.12	0.11	0.12	0.14	0.14	0.12
Background	12.8	12.8	12.8	12.8	12.8	12.8
All	15.7	14.3	13.5	14.4	14.6	14.5

Table 8.9: Summary of $PM_{2.5}$ source apportionment concentrations ($\mu g/m^3$) by vehicle type

Source group	Finsbury Park	Nags Head Shopping Centre	Archway	Angel	Old Street	Highbury Corner
Motorcycles	0.05	0.04	0.01	0.02	0.01	0.04
Taxis	0.17	0.09	0.03	0.16	0.34	0.10
Cars	1.46	0.68	0.33	0.47	0.57	0.70
LGVs	0.32	0.20	0.07	0.12	0.18	0.20
Buses	0.45	0.20	0.05	0.45	0.19	0.21
Rigid HGVs	0.38	0.15	0.06	0.12	0.18	0.15
Articulated HGVs	0.09	0.04	0.02	0.03	0.03	0.04

Table 8.10: Summary of $PM_{2.5}$ source apportionment concentrations ($\mu g/m^3$) by emission type

Source group	Finsbury Park	Nags Head Shopping Centre	Archway	Angel	Old Street	Highbury Corner
Exhaust	0.7	0.3	0.1	0.5	0.5	0.4
Non-exhaust	1.9	0.9	0.4	0.7	1.0	1.1

Emissions from sources within Islington represent approximately 3% of total $PM_{2.5}$ emissions from the LAEI area. As for NO_x and PM_{10}, the main source of $PM_{2.5}$ emissions from within Islington is major roads, accounting for 65% of emissions, a larger proportion than for PM_{10}. The main contributors to major roads emissions within the London Borough of Islington are cars, accounting for 47% of the emissions total.

Similarly to PM_{10} concentrations, the major contributor to $PM_{2.5}$ concentrations at all locations is the ambient background concentration, accounting for between 82% and 95% of the predicted concentrations. The ambient background contributes a larger proportion of $PM_{2.5}$ concentrations than PM_{10} at all modelled locations. The contribution from background is constant across the sites, 12.8µg/m^3; the variation in percentages reflects the relative contribution of other sources at the sites.

Major roads are the second largest source of $PM_{2.5}$ concentrations, contributing between 4% and 17% of the total concentrations.

The major contributions to the road component of the $PM_{2.5}$ concentrations are from cars and buses and coaches. Cars contribute between 34% and 57% of the road component; buses and coaches contribute between 9% and 33% of the road component. As for the other pollutants, the greatest percentage contribution from buses occurs at the Angel site and the greatest percentage contribution from cars occurs at the Archway site, reflecting differences in traffic composition on nearby roads. Non-exhaust road sources contribute more to concentrations at the receptor locations than exhaust road sources, accounting for between 58% and 77% of the road component.

9. Emissions reduction scenario: Euro 6 buses

9.1. NO_2 concentrations

Figures 9.1a to 9.1e show annual average NO_2 concentrations for 2020 assuming all buses in London meet the EURO 6 emissions standards. All other emissions are assumed to remain the same as for the base case.

Annual average NO_2 concentrations are predicted to decrease significantly compared to the base case, with the area exceeding the air quality objective value of 40 µg/m³ reducing in size. However, significant areas of exceedence are still predicted to occur.

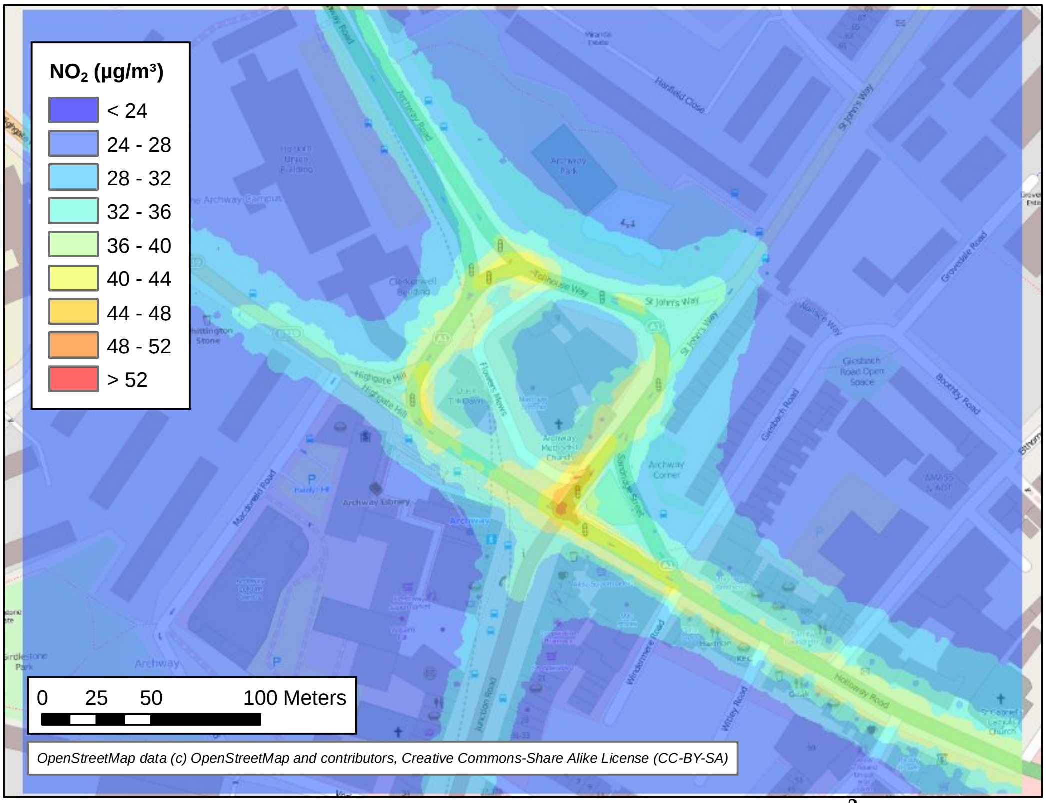

Figure 9.1a: Annual average NO_2 concentrations for Archway (µg/m^3), 2020 Bus Euro 6 Scenario

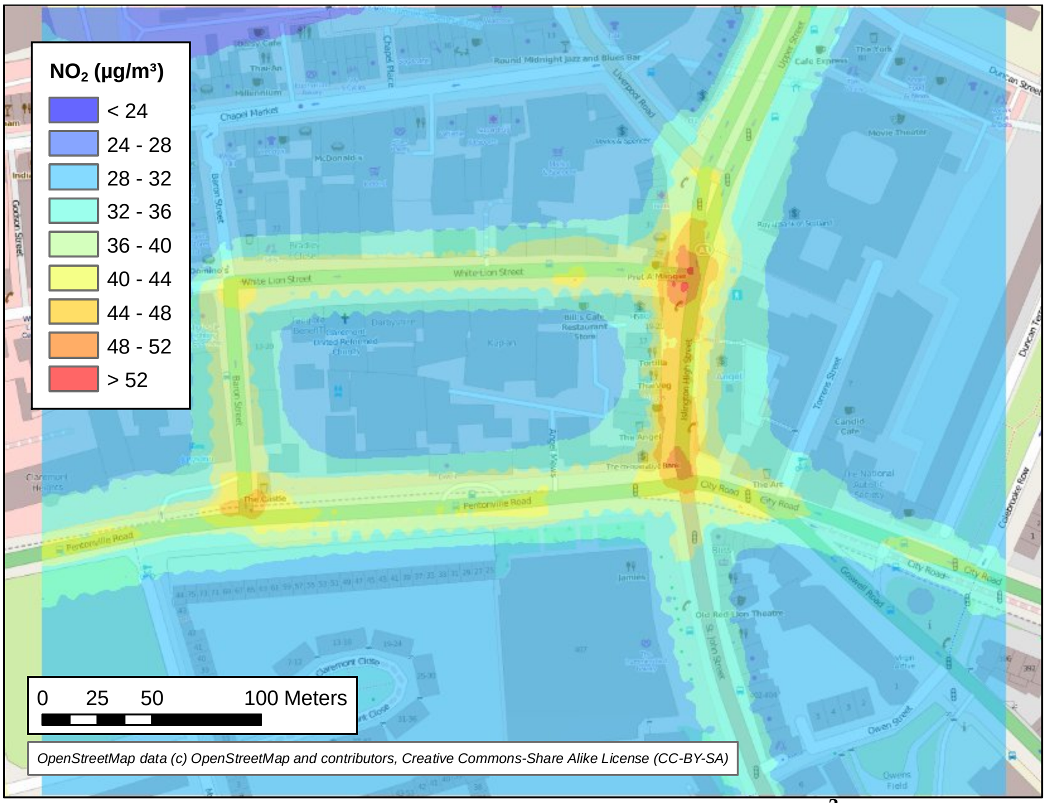

Figure 9.1b: Annual average NO_2 concentrations for Angel ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

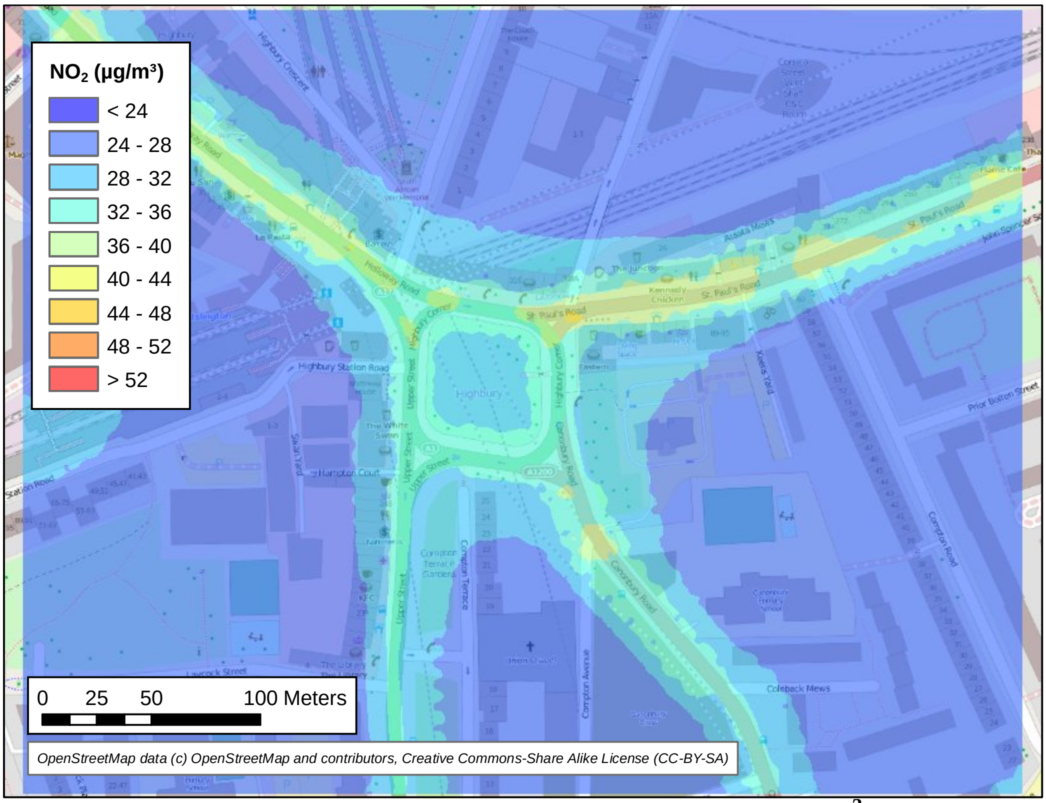

Figure 9.1c: Annual average NO_2 concentrations for Highbury ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

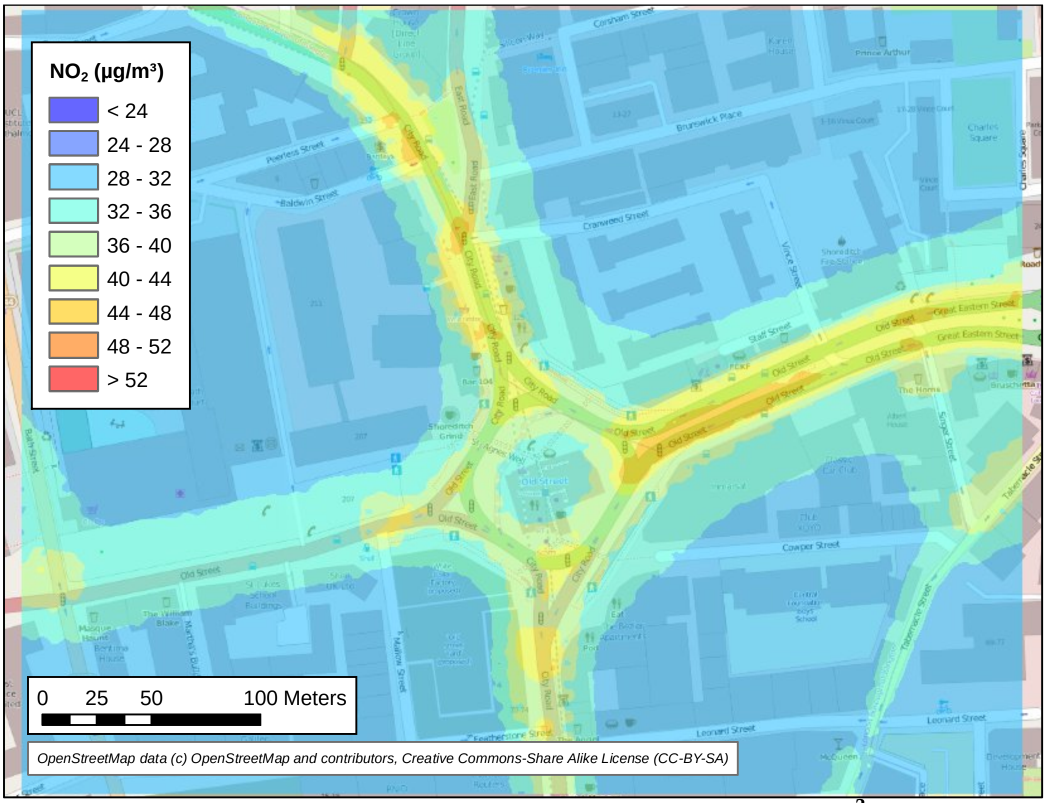

Figure 9.1d: Annual average NO_2 concentrations for Old Street (µg/m^3), 2020 Bus Euro 6 Scenario

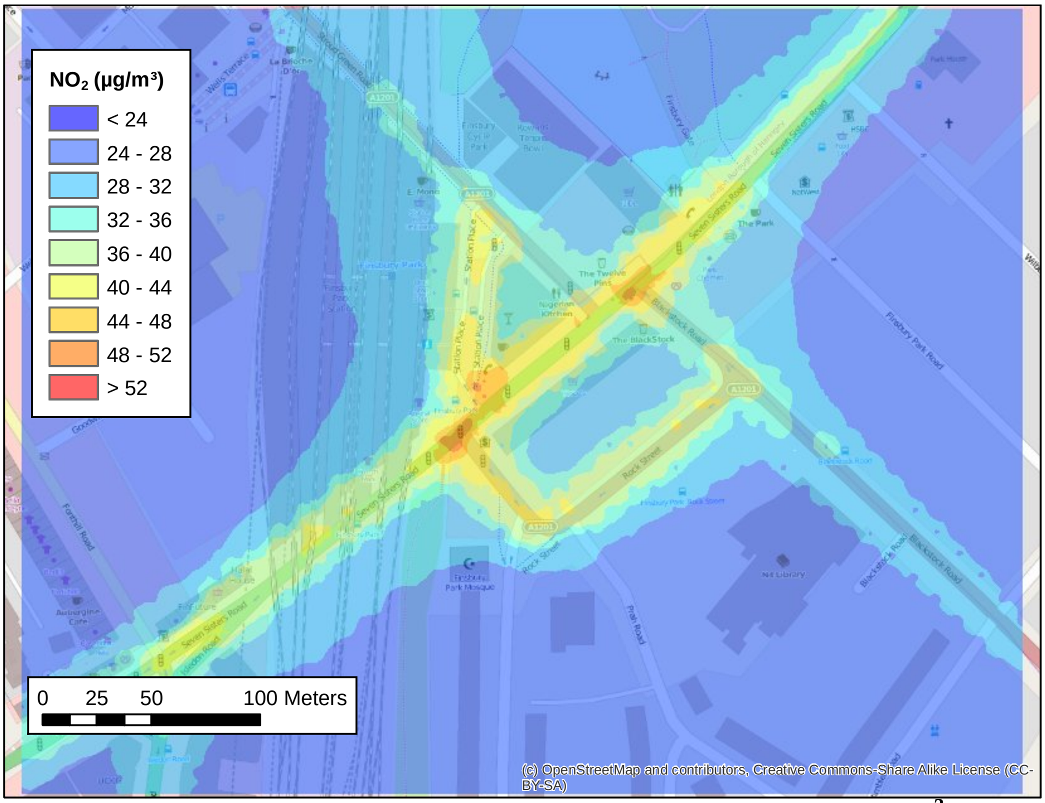

Figure 9.1e: Annual average NO_2 concentrations for Finsbury Park (µg/m^3), 2020 Bus Euro 6 Scenario

9.2. PM_{10} concentrations

Figures 9.2a to 9.2e show annual average PM_{10} concentrations for 2020 assuming all buses in London meet the EURO 6 emissions standards. All other emissions are assumed to remain the same as for the base case.

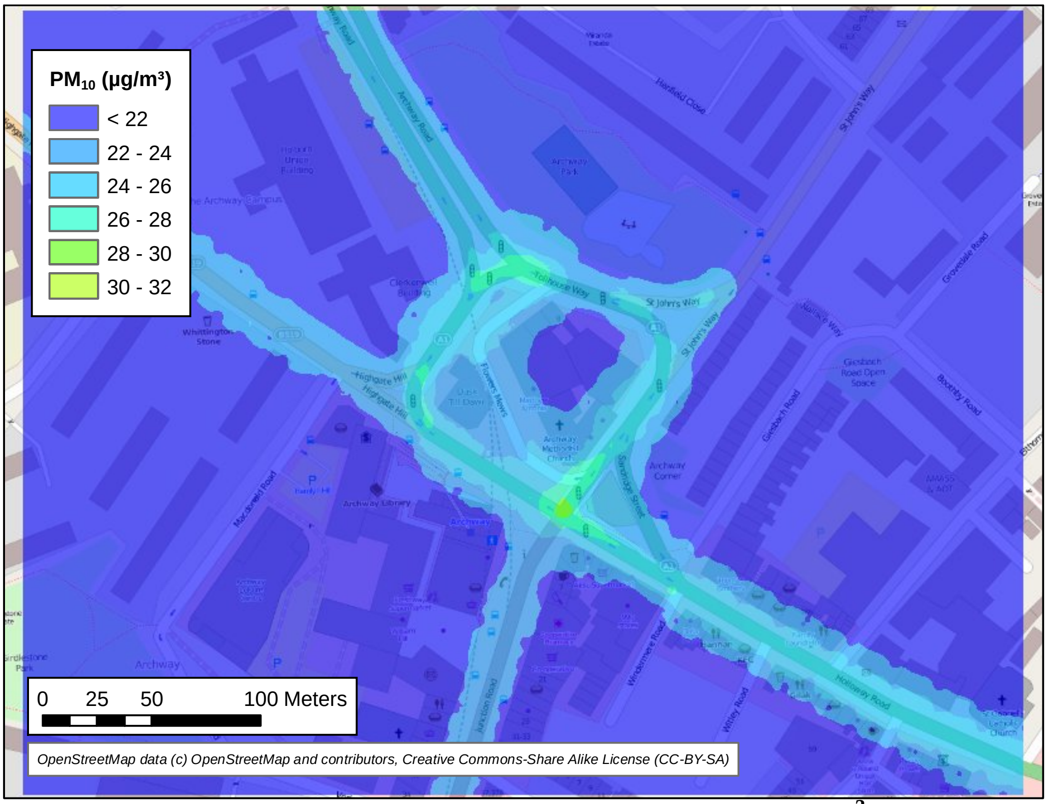

Figure 9.2a: Annual average PM_{10} concentrations for Archway ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

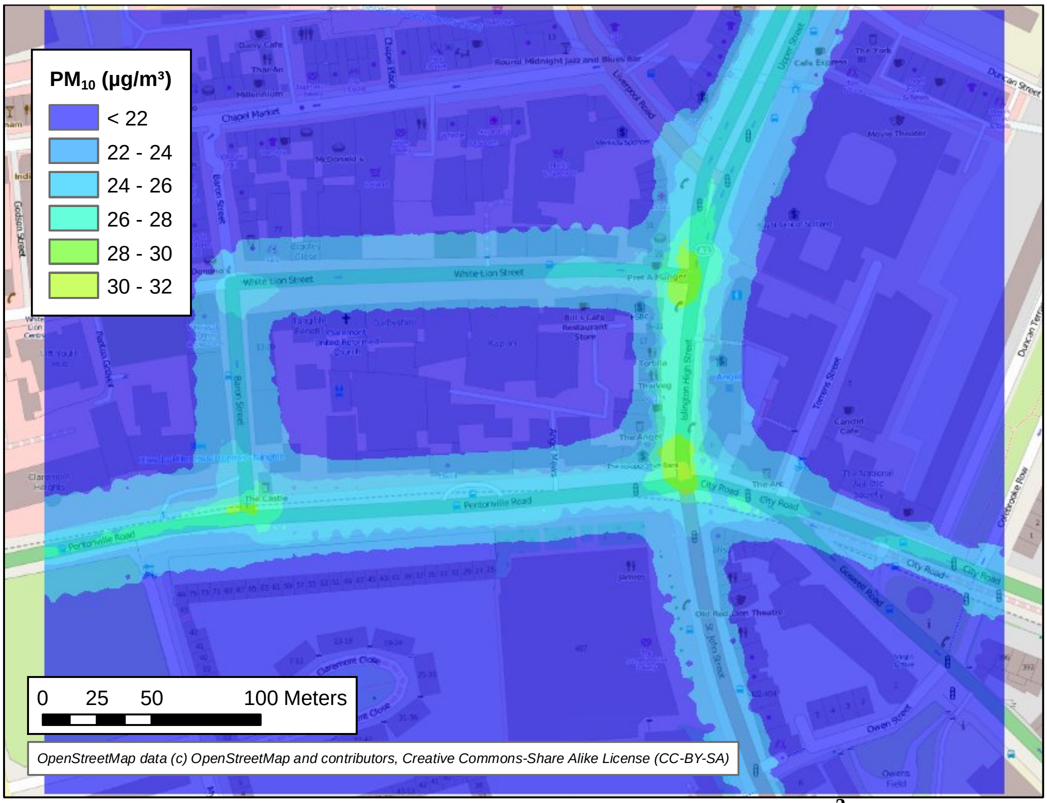

Figure 9.2b: Annual average PM_{10} concentrations for Angel ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

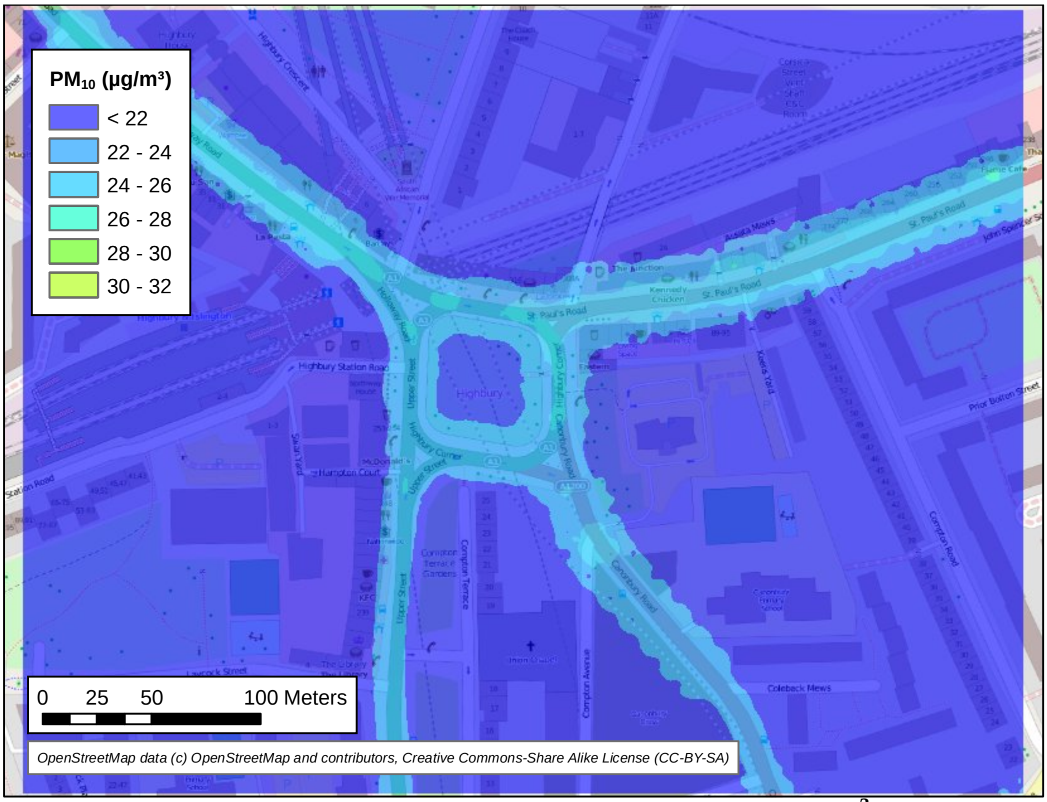

Figure 9.2c: Annual average PM_{10} concentrations for Highbury ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

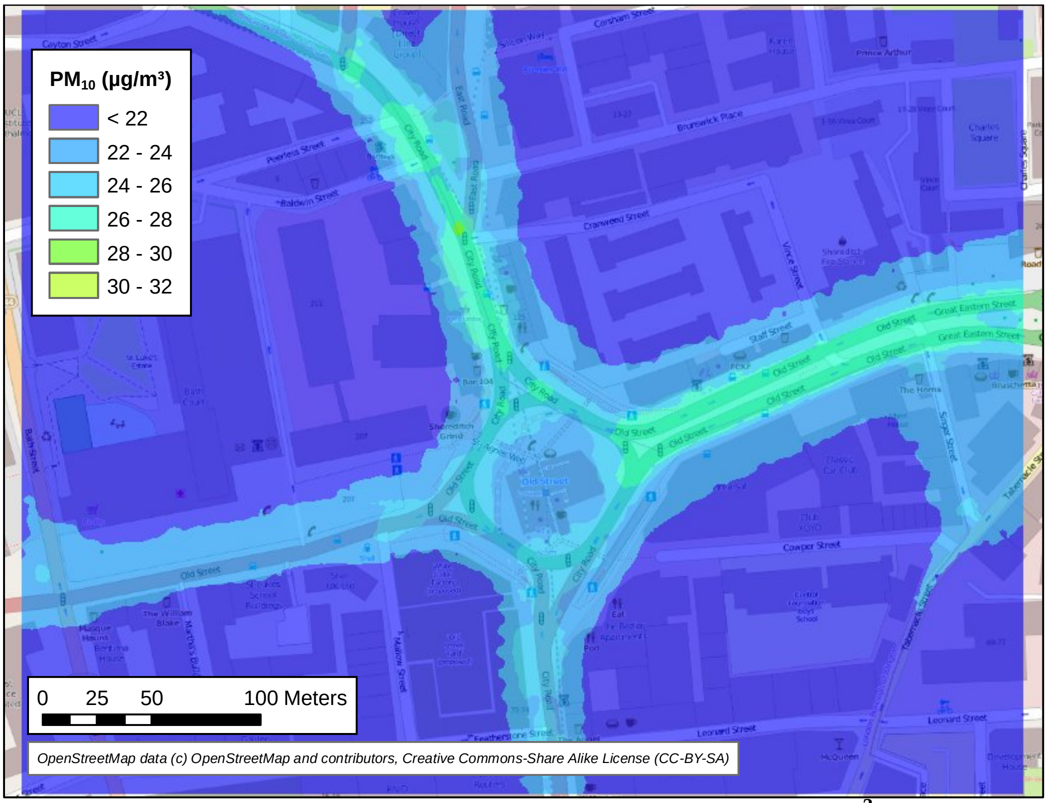

Figure 9.2d: Annual average PM_{10} concentrations for Old Street ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

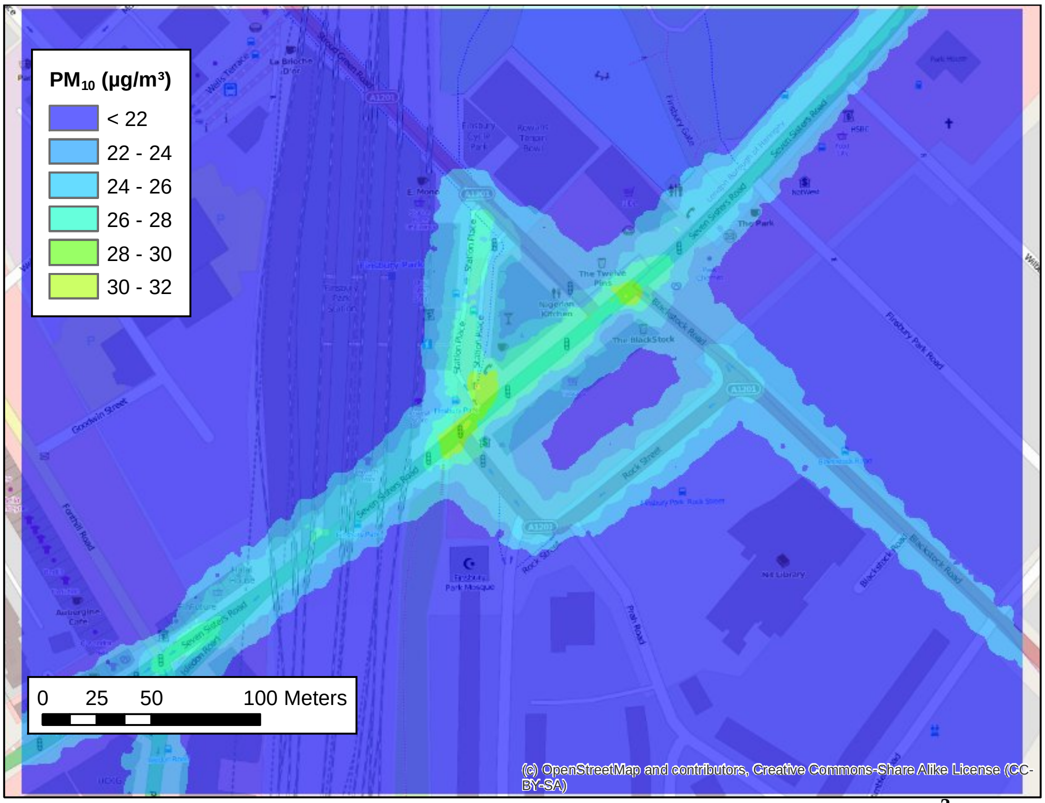

Figure 9.2e: Annual average PM_{10} concentrations for Finsbury Park ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

9.3. $PM_{2.5}$ concentrations

Figures 9.3a to 9.3e show annual average $PM_{2.5}$ concentrations for 2020 assuming all buses in London meet the EURO 6 emissions standards. All other emissions are assumed to remain the same as for the base case.

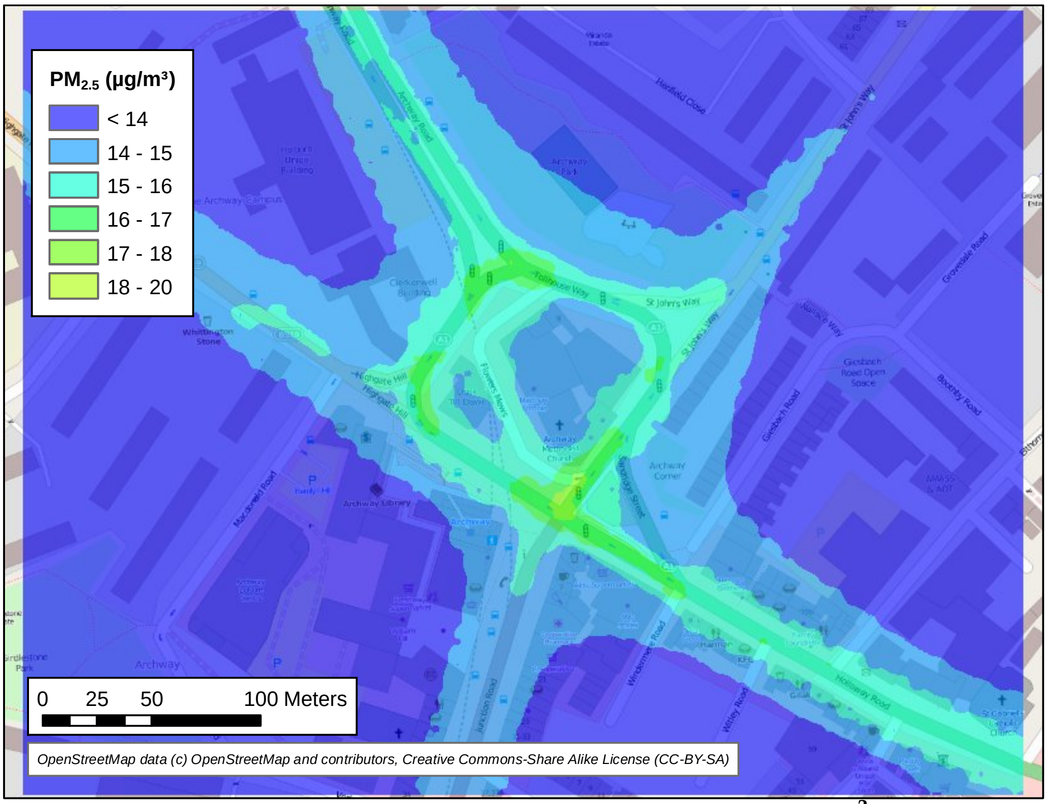

Figure 9.3a: Annual average $PM_{2.5}$ concentrations for Archway ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

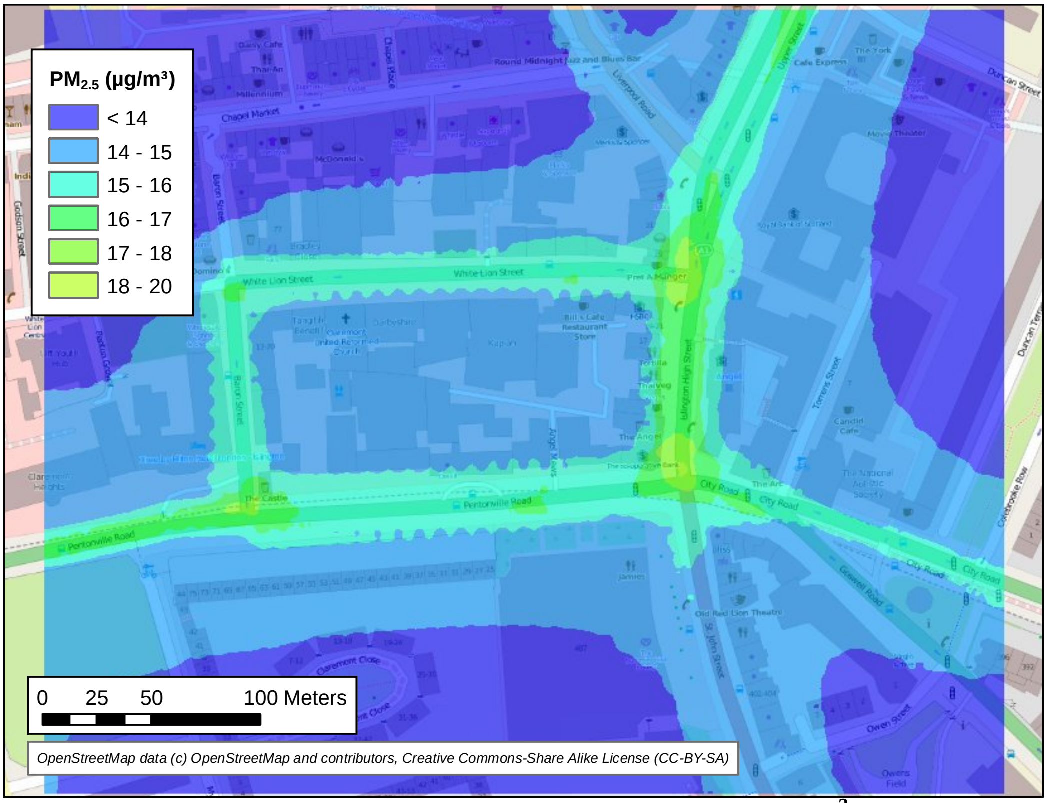

Figure 9.3b: Annual average $PM_{2.5}$ concentrations for Angel ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

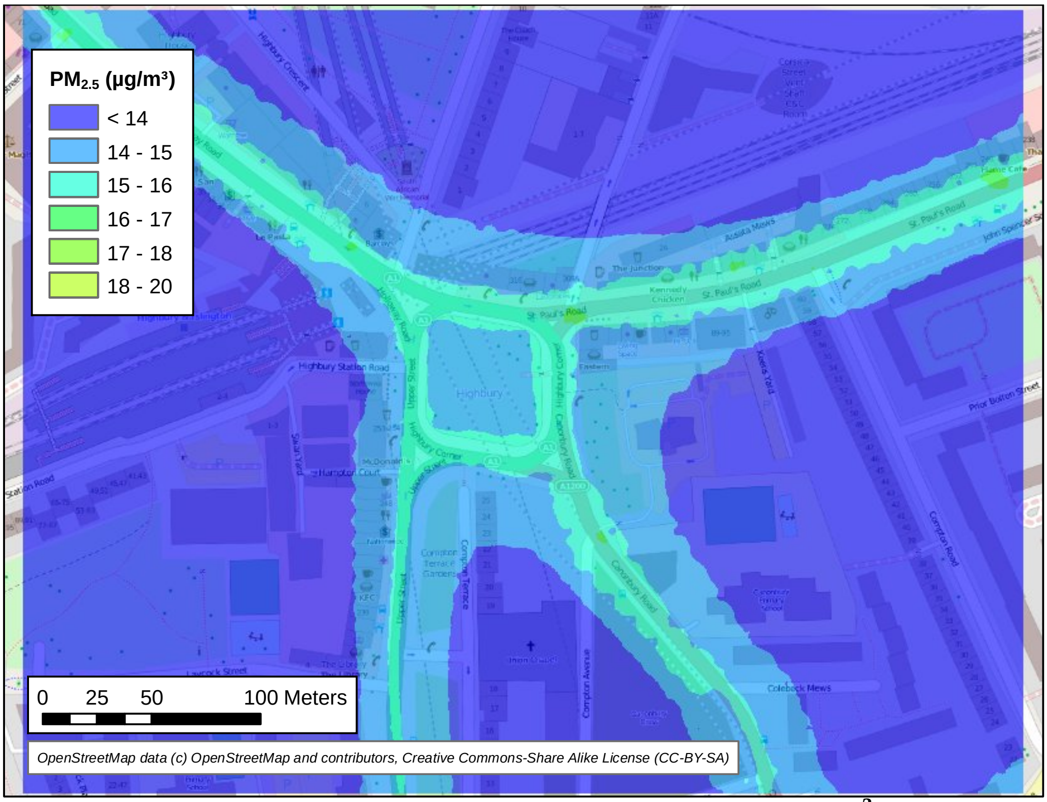

Figure 9.3c: Annual average $PM_{2.5}$ concentrations for Highbury ($\mu g/m^3$), 2020 Bus Euro 6 Scenario

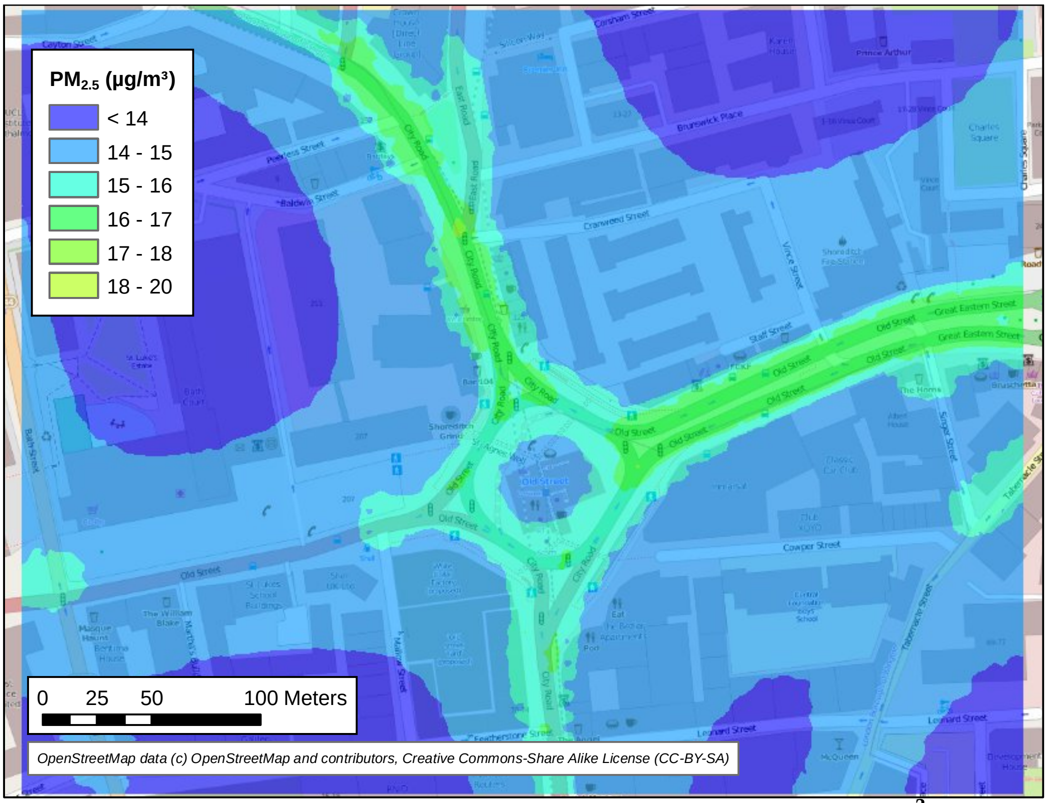

Figure 9.2d: Annual average $PM_{2.5}$ concentrations for Old Street (µg/m^3), 2020 Bus Euro 6 Scenario

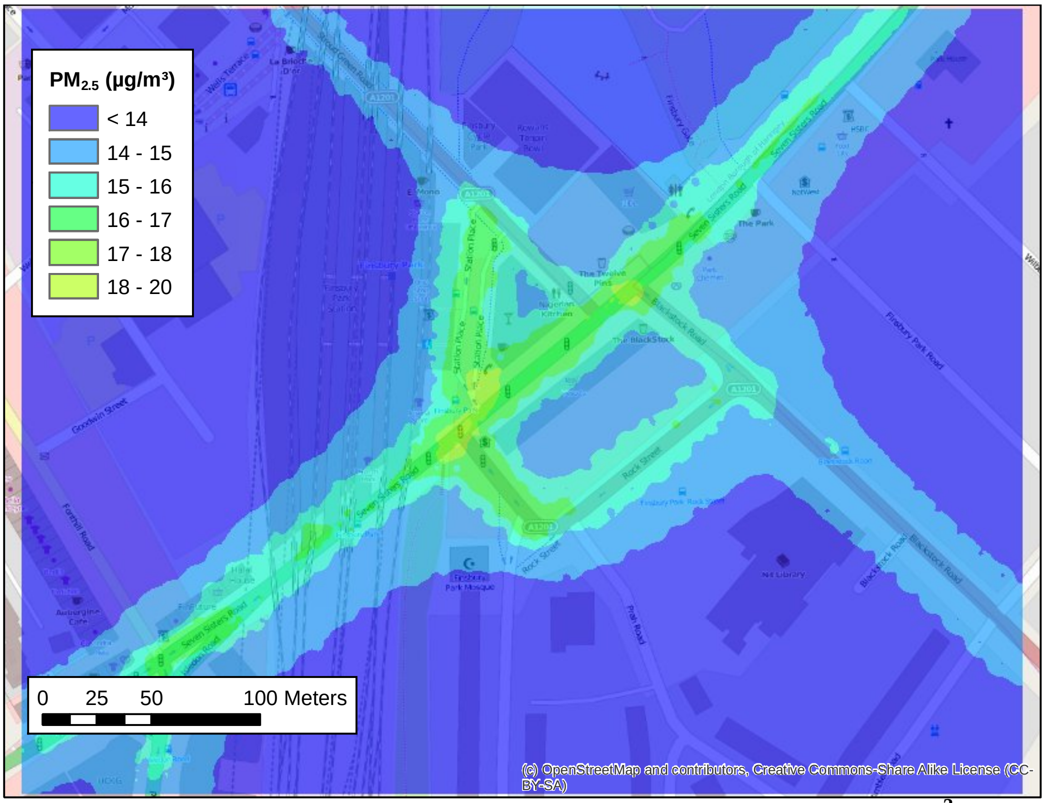

Figure 9.2e: Annual average $PM_{2.5}$ concentrations for Finsbury Park (µg/m^3), 2020 Bus Euro 6 Scenario

10. Emission reduction scenario: all vehicles Euro 6

10.1. NO_2 concentrations

Figures 10.1a to 10.1e show annual average NO_2 concentrations for 2020 assuming all vehicles in London meet the EURO 6 emissions standards. All other emissions are assumed to remain the same as for the base case.

Annual average NO_2 concentrations are predicted to decrease significantly compared to the base case. Exceedences of the air quality objective value of 40 µg/m³ are no longer predicted to occur at Archway and Highbury, with only small areas of exceedence at road junctions predicted at Old Street.

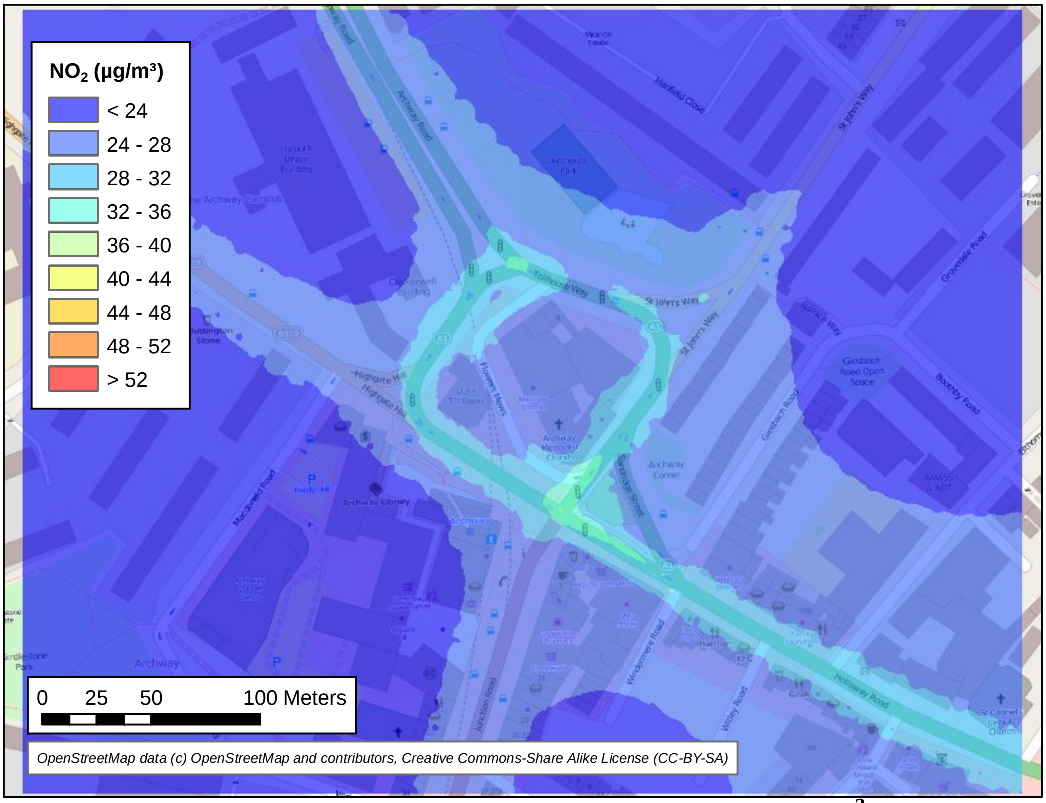

Figure 10.1a: Annual average NO_2 concentrations for Archway (µg/m³), 2020 All vehicles Euro 6 Scenario

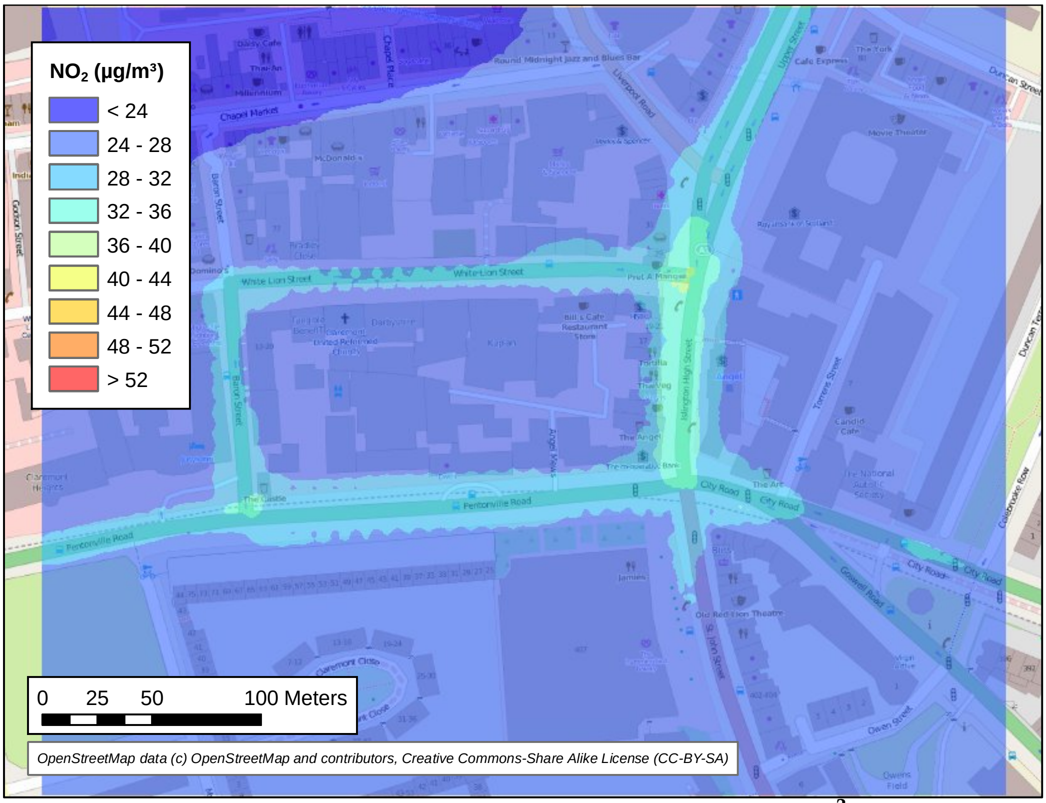

Figure 10.1b: Annual average NO_2 concentrations for Angel (µg/m^3), 2020 All vehicles Euro 6 Scenario

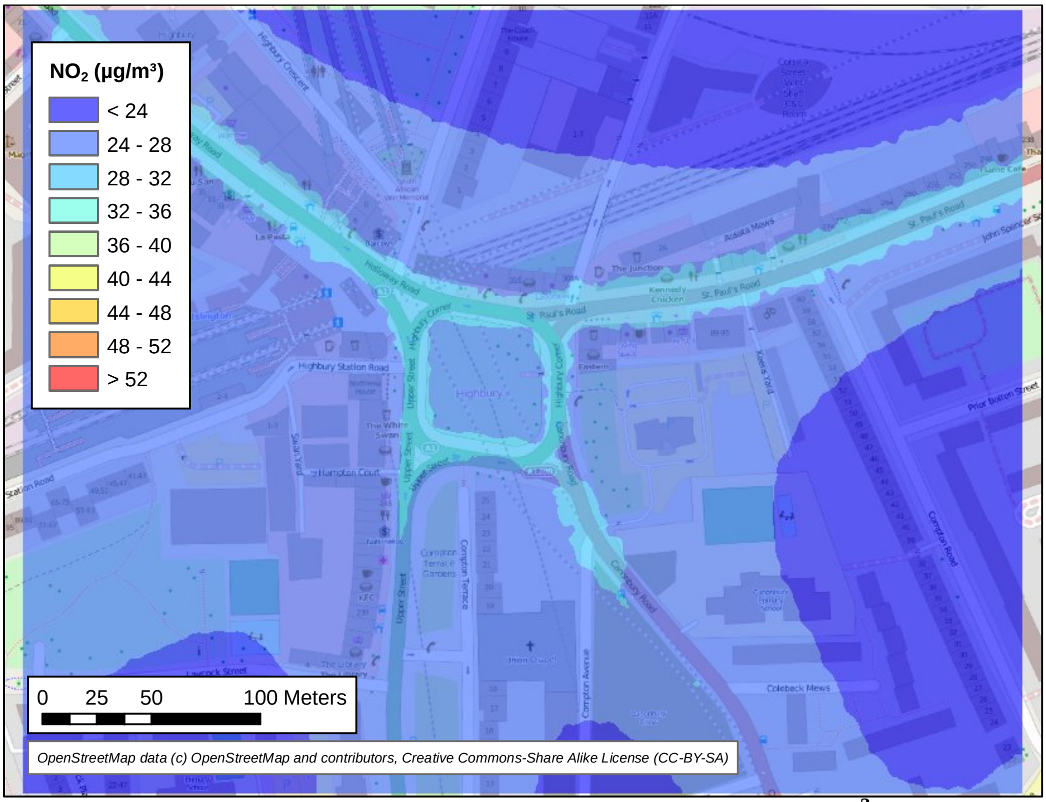

Figure 10.1c: Annual average NO_2 concentrations for Highbury (µg/m^3), 2020 All vehicles Euro 6 Scenario

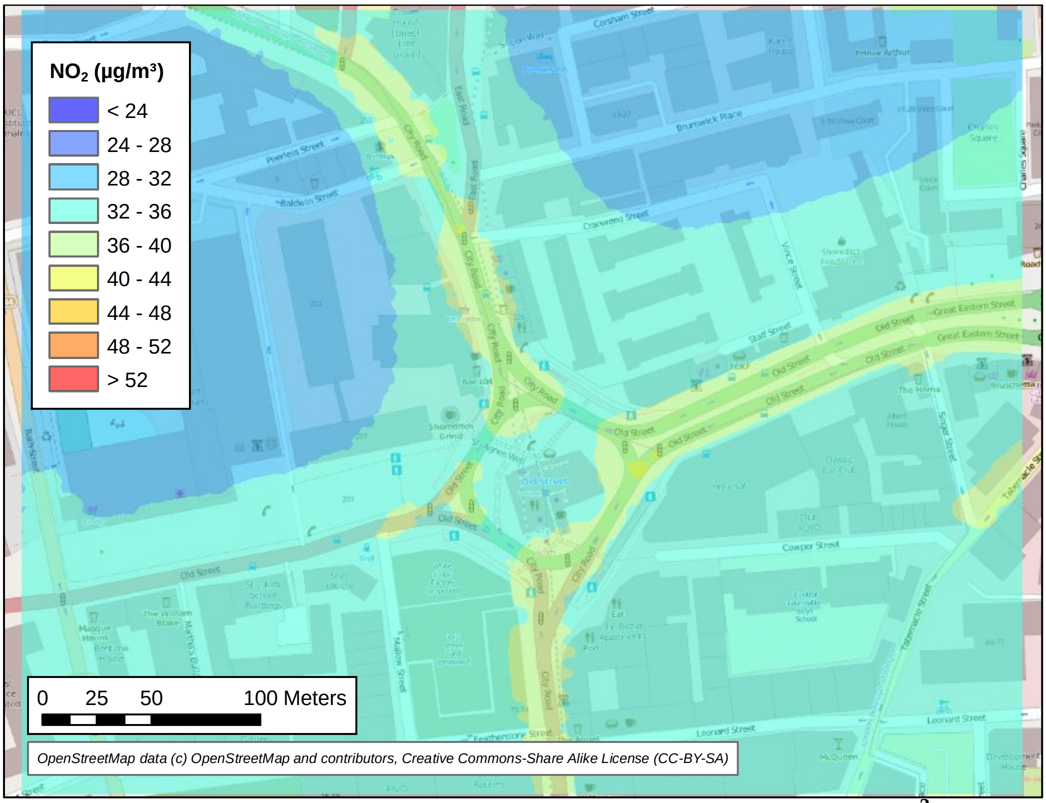

Figure 10.1d: Annual average NO_2 concentrations for Old Street ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

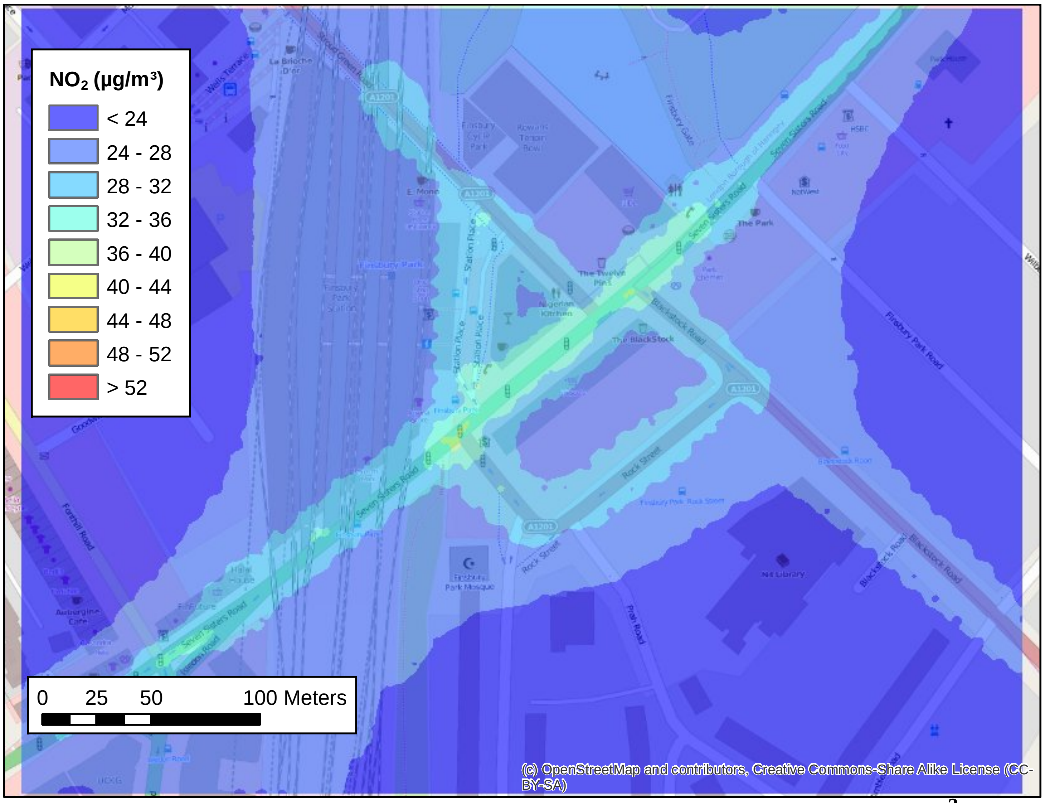

Figure 10.1e: Annual average NO_2 concentrations for Finsbury Park ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

10.2. PM_{10} concentrations

Figures 10.2a to 10.2e show annual average PM_{10} concentrations for 2020 assuming all vehicles in London meet the EURO 6 emissions standards. All other emissions are assumed to remain the same as for the base case.

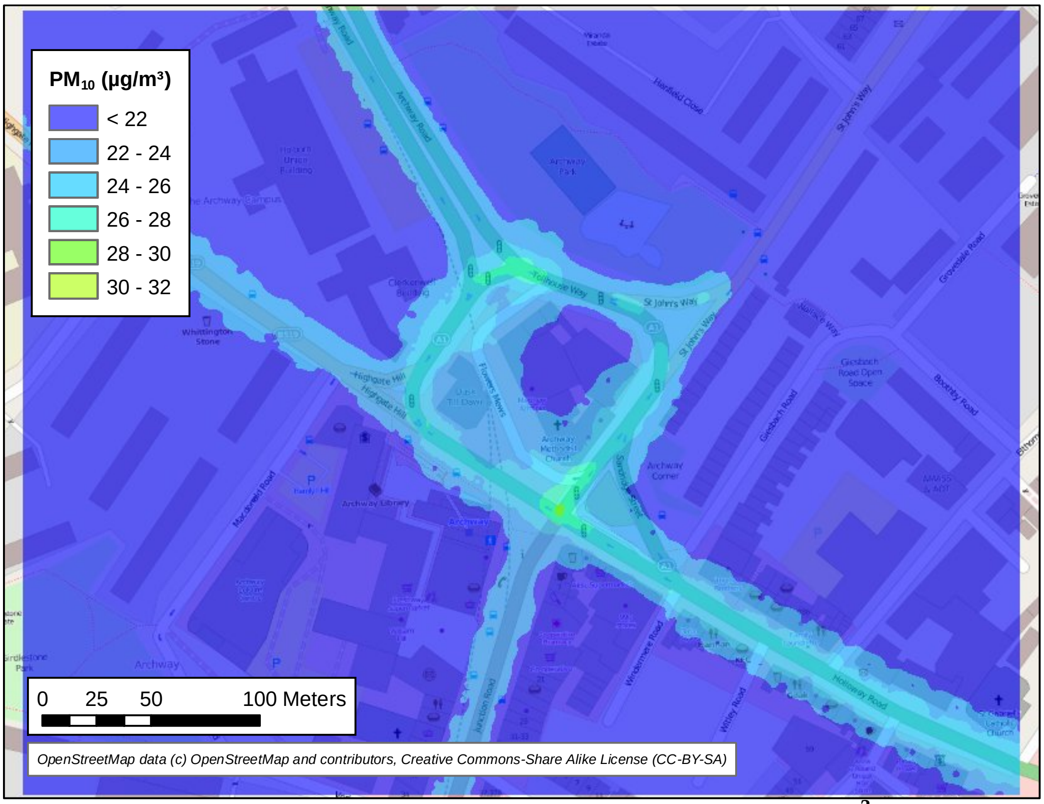

Figure 10.2a: Annual average PM_{10} concentrations for Archway ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

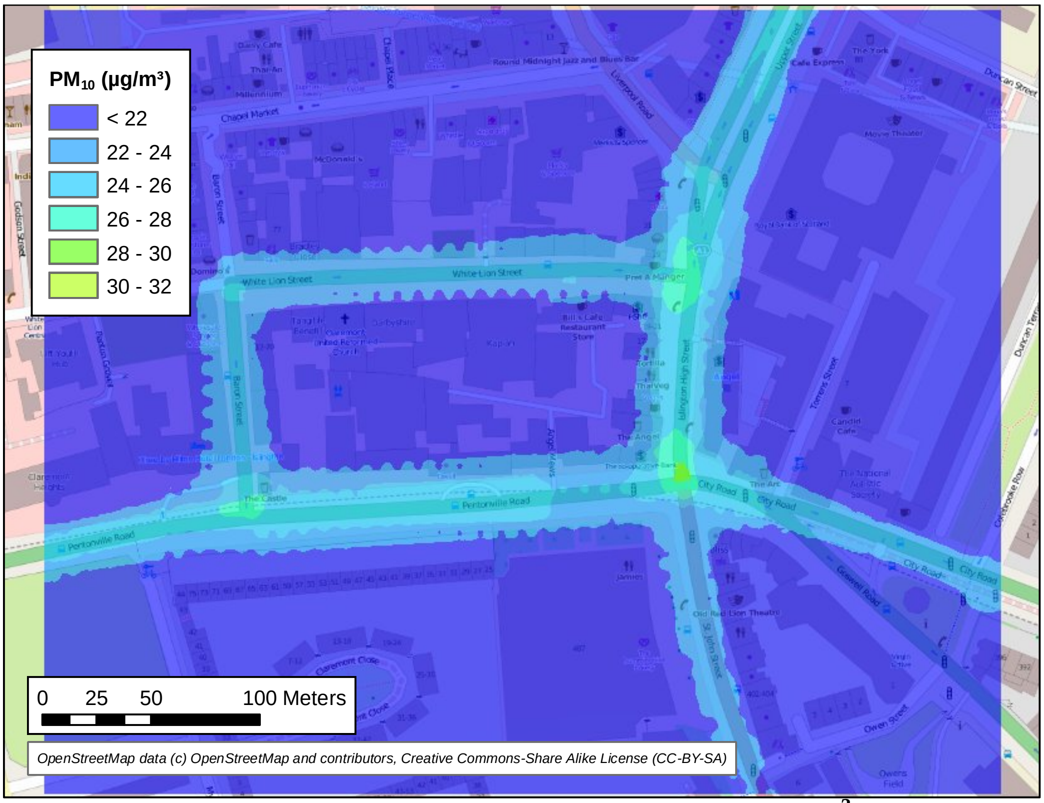

Figure 10.2b: Annual average PM_{10} concentrations for Angel (µg/m^3), 2020 All vehicles Euro 6 Scenario

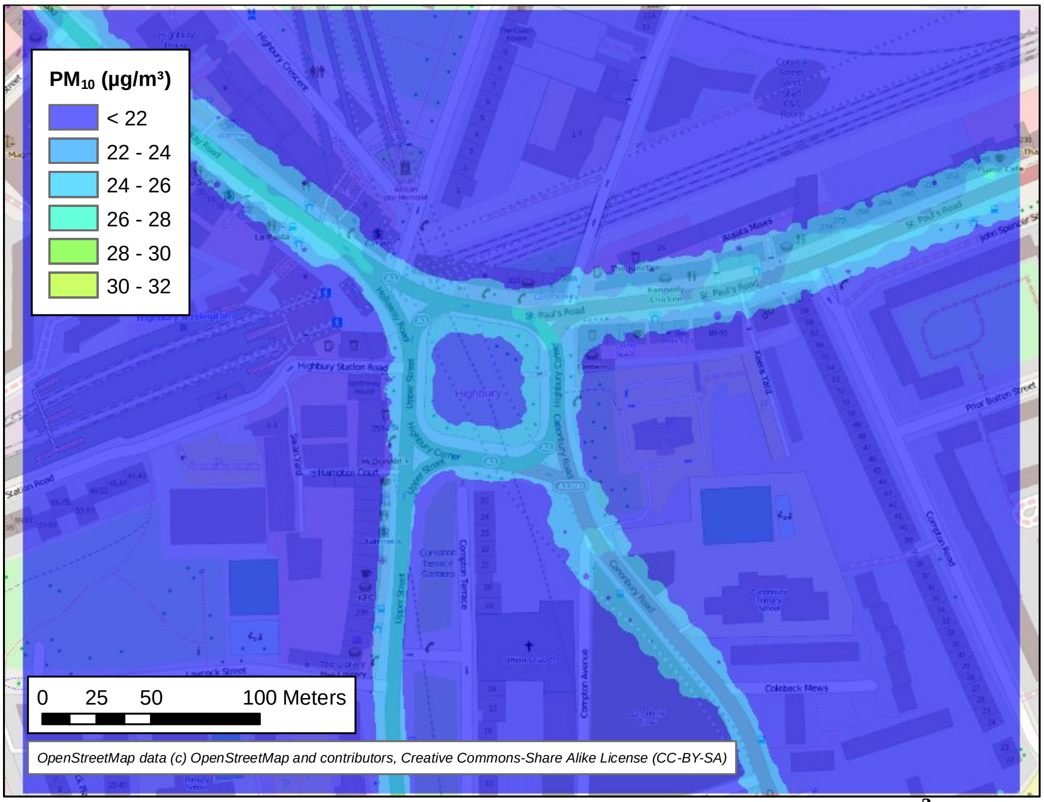

Figure 10.2c: Annual average PM_{10} concentrations for Highbury (µg/m^3), 2020 All vehicles Euro 6 Scenario

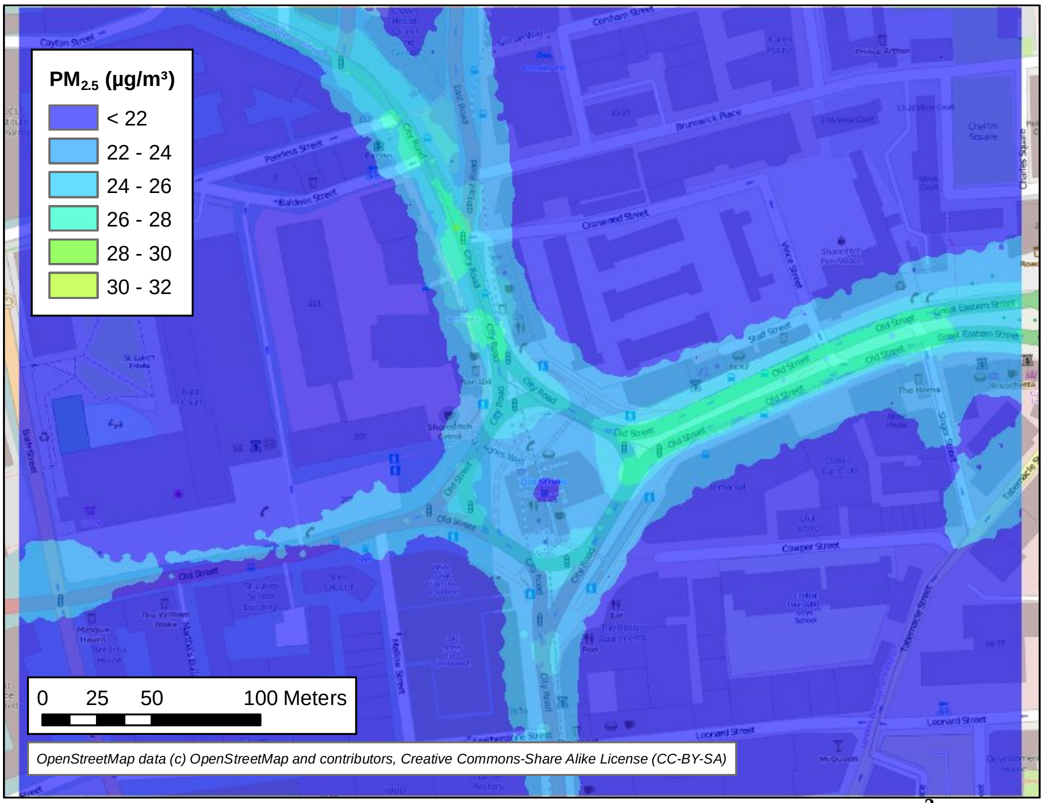

Figure 10.2d: Annual average PM_{10} concentrations for Old Street (µg/m^3), 2020 All vehicles Euro 6 Scenario

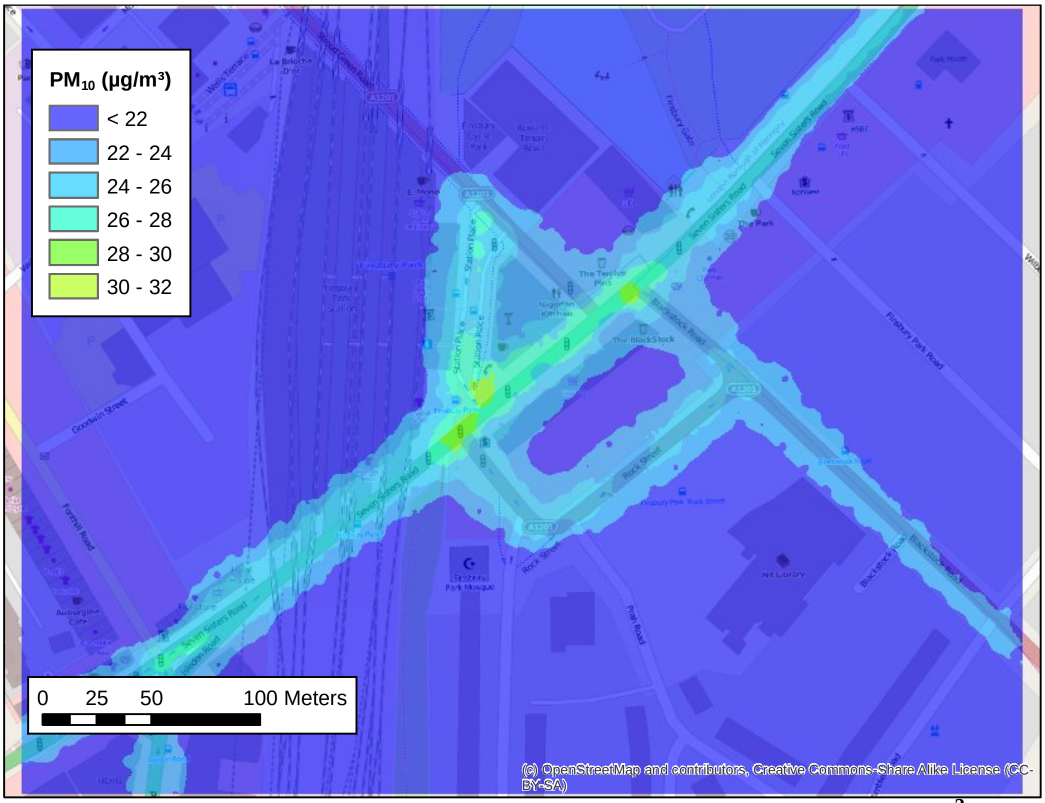

Figure 10.2e: Annual average PM_{10} concentrations for Finsbury Park (µg/m^3), 2020 All vehicles Euro 6 Scenario

10.3. $PM_{2.5}$ concentrations

Figures 10.3a to 10.3e show annual average $PM_{2.5}$ concentrations for 2020 assuming all vehicles in London meet the EURO 6 emissions standards. All other emissions are assumed to remain the same as for the base case.

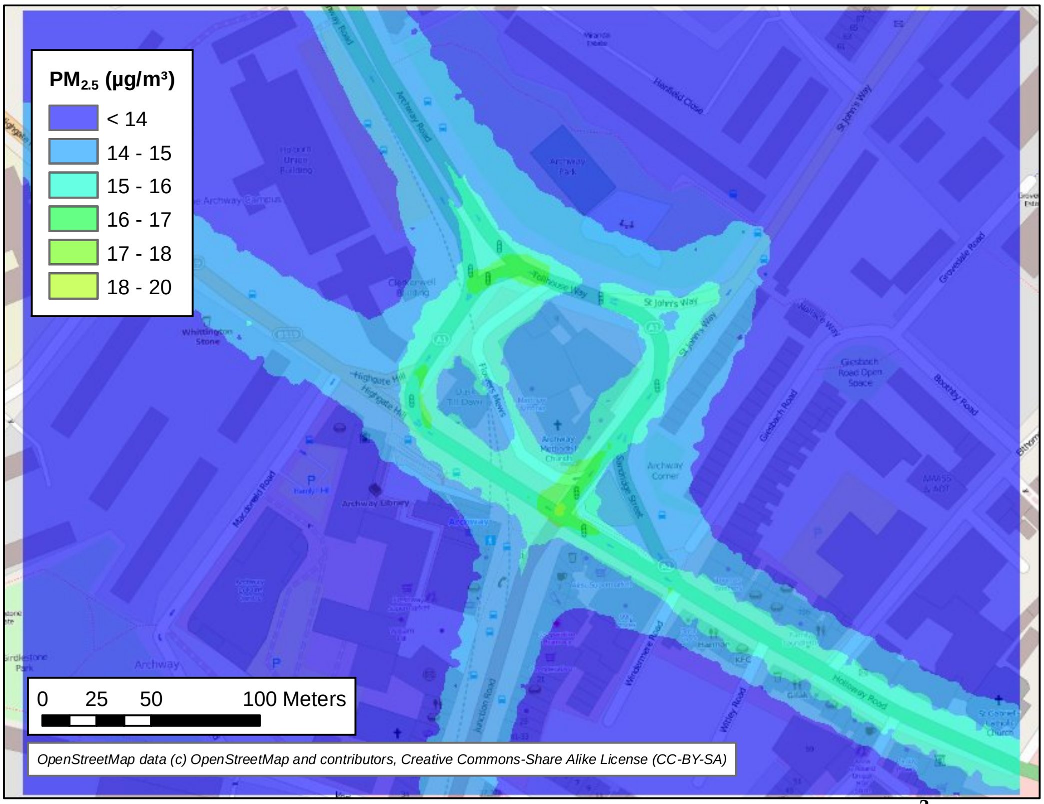

Figure 10.3a: Annual average $PM_{2.5}$ concentrations for Archway ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

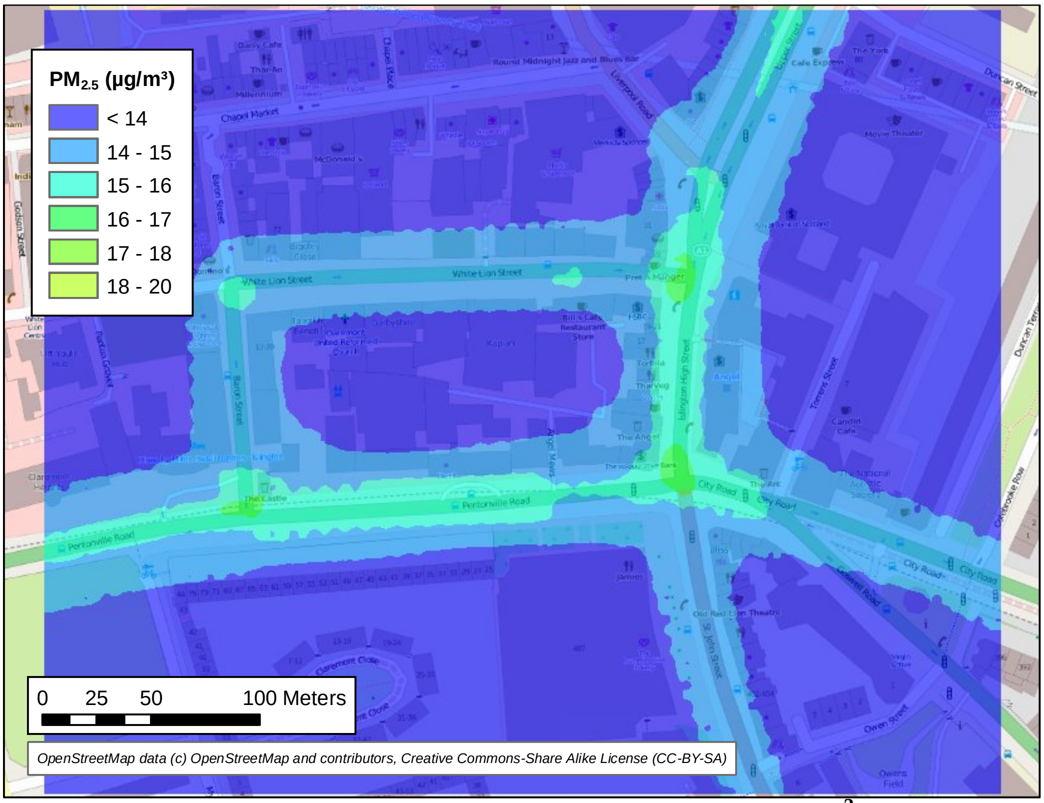

Figure 10.3b: Annual average $PM_{2.5}$ concentrations for Angel ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

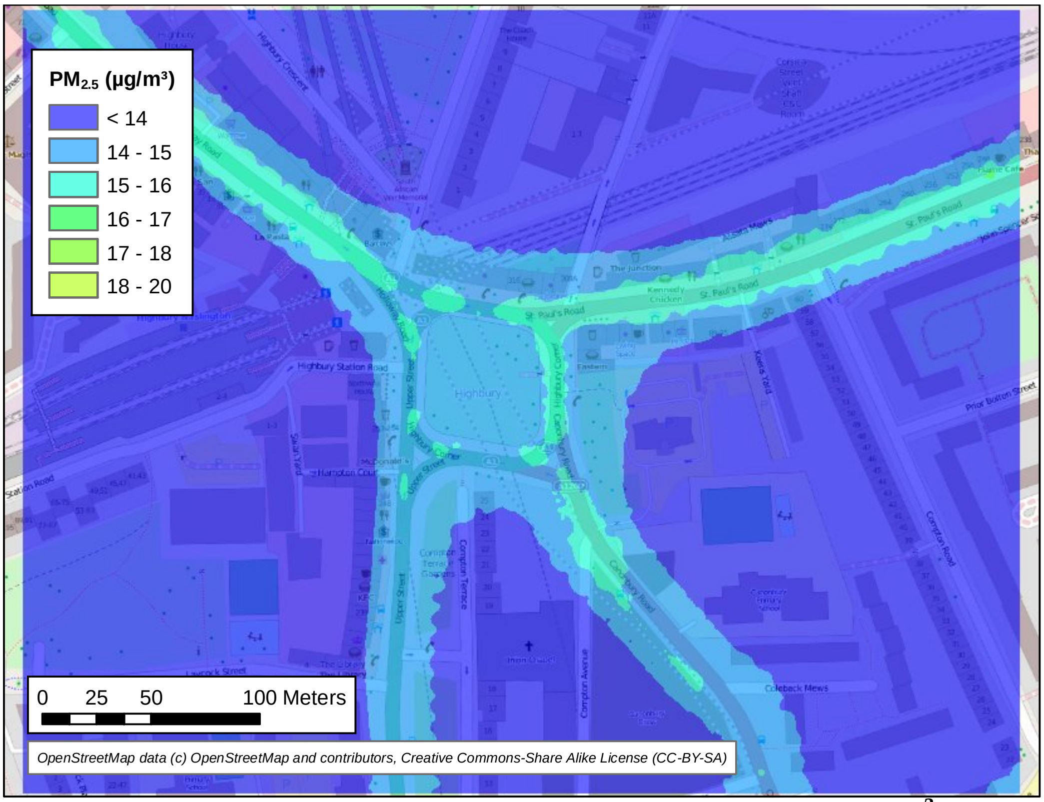

Figure 10.3c: Annual average $PM_{2.5}$ concentrations for Highbury ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

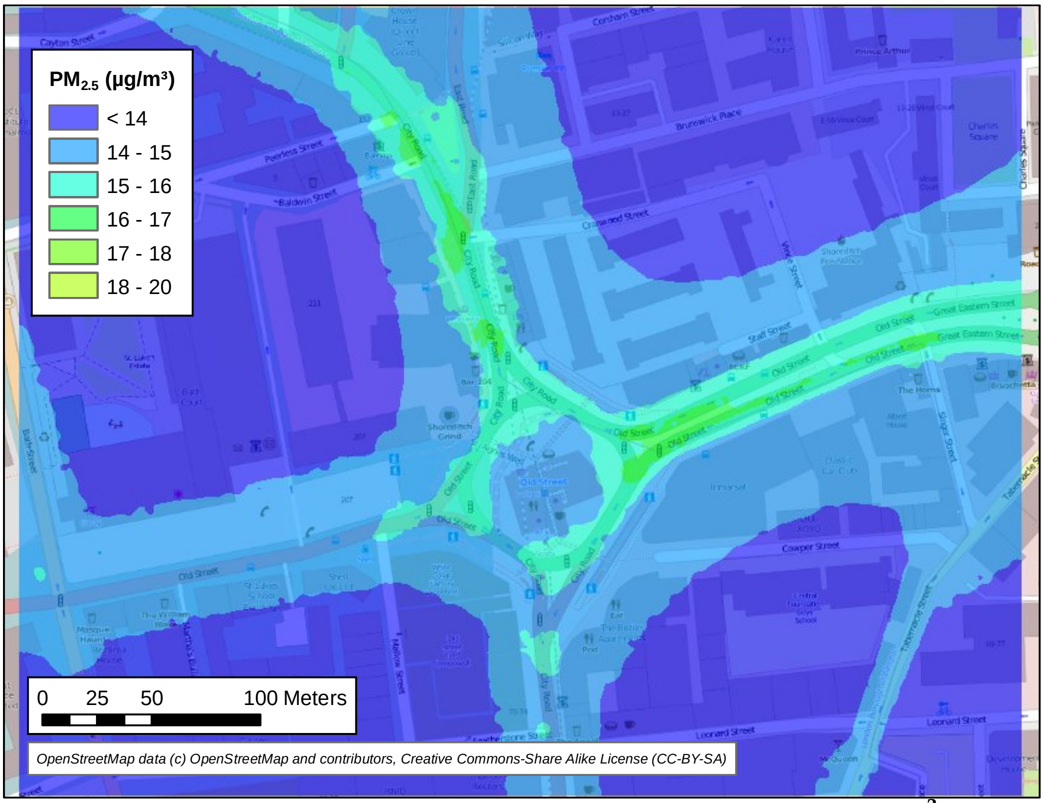

Figure 10.3d: Annual average $PM_{2.5}$ concentrations for Old Street ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

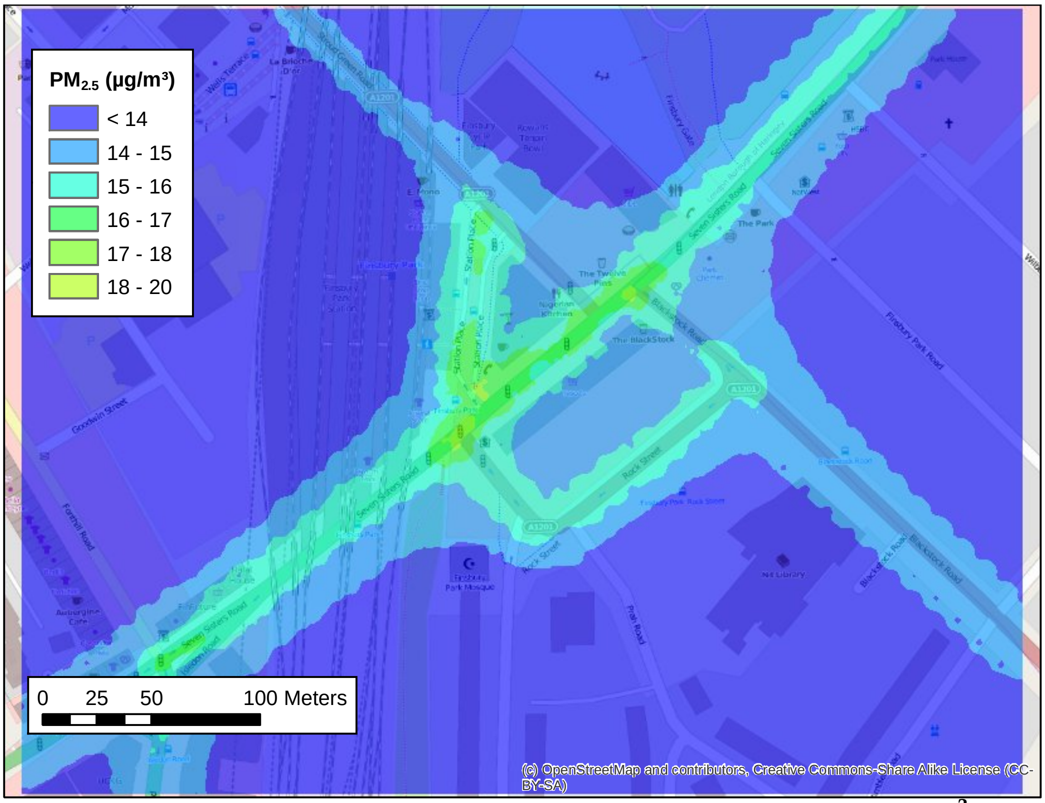

Figure 10.3e: Annual average $PM_{2.5}$ concentrations for Finsbury Park ($\mu g/m^3$), 2020 All vehicles Euro 6 Scenario

11. Discussion

The whole of the London Borough of Islington has been declared an Air Quality Management Area due to concentrations of NO_2 and PM_{10} exceeding the UK air quality standards. There is particular concern over concentrations of NO_2, PM_{10} and $PM_{2.5}$ at Archway; Highbury Corner; Angel; Old Street; and Finsbury Park.

Model verification was carried out by comparing measured and modelled concentrations at continuous monitoring sites in Islington for 2012. The modelling shows generally good agreement between the measured and modelled NO_2 and PM_{10} concentrations indicating that the emissions data and model set-up are appropriate for the area.

Air quality maps of ground level concentrations of NO_2, PM_{10} and $PM_{2.5}$ were created for the areas of interest for a 2020 base case for comparison against air quality standards.

In 2020, the air quality standard of 40 $\mu g/m^3$ for annual average NO_2 concentrations is predicted to be exceeded along many of the major roads in Islington. The air quality standard of 200 $\mu g/m^3$ for the 99.79th percentile of hourly average NO_2 concentrations is predicted to be met for most locations in Islington.

The air quality standards for PM_{10} and $PM_{2.5}$ are predicted to be achieved throughout the borough in 2020.

Source apportionment was carried out at six locations in the borough to determine the main contributors to pollutant concentrations at a set of locations. Major roads are predicted to be the major contributor to NO_x concentrations at the source apportionment locations considered, accounting for between 28% and 70% of the predicted concentrations. The highest predicted contribution from major roads sources is predicted at the Finsbury Park source apportionment location. For PM_{10} and $PM_{2.5}$, the main contributor to modelled concentrations is the background concentration. Major roads are the main emission source for modelled concentrations originating from Islington.

The major contributions to the road component of pollutant concentrations are those from buses and coaches and cars for all pollutants. For all pollutants, the greatest percentage contribution from buses occurs at the Angel site and the greatest percentage contribution from cars occurs at the Archway site, reflecting differences in traffic composition on nearby roads.

Cars contribute between 15% and 39% of the road component of NO_x concentrations; buses and coaches contribute between 27% and 65% of the road component. Cars contribute between 28% and 46% of the road component of PM_{10} emissions; buses and coaches contribute between 14% and 40%. For $PM_{2.5}$ concentrations, Cars contribute between 34% and 57% of the road component; buses and coaches contribute between 9% and 33% of the road component.

Non-exhaust emissions account for a larger proportion of the road component than exhaust emissions for both PM_{10} and $PM_{2.5}$. Non-exhaust emissions account for between 80% and 89% of PM_{10} concentrations, and between 47% and 77% of $PM_{2.5}$ concentrations.

Assuming all buses in London meet the EURO 6 emissions standards results in significant decreases in annual average NO_2 concentrations, resulting in smaller areas of exceedence of the air quality objective of 40 µg/m^3.

Assuming all vehicles in London meet the EURO 6 emissions standards results in further significant decreases in annual average NO_2 concentrations. Exceedences of the air quality objective are no longer predicted at Archway or Highbury, with only small areas of exceedences at busy junctions predicted at Old Street.

APPENDIX A: Summary of ADMS-Urban

ADMS-Urban is a practical air pollution modelling tool, which has been developed to provide detailed predictions of pollution concentrations for all sizes of study area. The model can be used to look at concentrations near a single road junction or over a region extending across the whole of a major city. ADMS-Urban has therefore been extensively used for the Review and Assessment of Air Quality carried out by Local Authorities in the UK. The following is a summary of the capabilities and validation of ADMS-Urban. More details can be found on the CERC web site at www.cerc.co.uk.

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS), which has been developed to investigate the impacts of emissions from industrial facilities. ADMS-Urban allows full characterisation of the wide variety of emissions in urban areas, including an extensively validated road traffic emissions model. It also boasts a number of other features, which include consideration of:

- the effects of vehicle movement on the dispersion of traffic emissions;
- the behaviour of material released into street-canyons;
- the chemical reactions occurring between nitrogen oxides, ozone and Volatile Organic Compounds (VOCs);
- the pollution entering a study area from beyond its boundaries;
- the effects of complex terrain on the dispersion of pollutants; and
- the effects of a building on the dispersion of pollutants emitted nearby.

More details of these features are given below.

Studies of extensive urban areas are necessarily complex, requiring the manipulation of large amounts of data. To allow users to cope effectively with this requirement, ADMS-Urban has been designed to operate in the widely familiar PC environment, under Microsoft Windows 7, Windows Vista or XP. The manipulation of data is further facilitated by the possible integration of ADMS-Urban with a Geographical Information System (GIS) such as MapInfo or ArcGIS, and with the CERC Emissions Inventory Toolkit, EMIT.

Dispersion Modelling

ADMS-Urban uses boundary layer similarity profiles in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the ground. This has significant advantages over earlier methods in which the dispersion parameters did not vary with height within the boundary layer.

In stable and neutral conditions, dispersion is represented by a Gaussian distribution. In convective conditions, the vertical distribution takes account of the skewed structure of the vertical component of turbulence. This is necessary to reflect the fact that, under convective conditions, rising air is typically of limited spatial extent but is balanced by descending air extending over a much larger area. This leads to higher ground-level concentrations than would be given by a simple Gaussian representation.

Emissions

Emissions into the atmosphere across an urban area typically come from a wide variety of sources. There are likely to be industrial emissions from chimneys as well as emissions from road traffic and domestic heating systems. To represent the full range of emissions configurations, the explicit source types available within ADMS-Urban are:

- **Industrial points**, for which plume rise and stack downwash are included in the modelling.
- **Roads**, for which emissions are specified in terms of vehicle flows and the additional initial dispersion caused by moving vehicles is also taken into account.
- **Areas**, where a source or sources is best represented as uniformly spread over an area.
- **Volumes**, where a source or sources is best represented as uniformly spread throughout a volume.

In addition, sources can also be modelled as a regular grid of emissions. This allows the contributions of large numbers of minor sources to be efficiently included in a study while the majority of the modelling effort is used for the relatively few significant sources.

ADMS-Urban can be used in conjunction with CERC's Emissions Inventory Toolkit, EMIT, which facilitates the management and manipulation of large and complex data sets into usable emissions inventories.

Presentation of Results

For most situations ADMS-Urban is used to model the fate of emissions for a large number of different meteorological conditions. Typically, meteorological data are input for every hour during a year or for a set of conditions representing all those occurring at a given location. ADMS-Urban uses these individual results to calculate statistics for the whole data set. These are usually average values, including rolling averages, percentiles and the number of hours for which specified concentration thresholds are exceeded. This allows ADMS-Urban to be used to calculate concentrations for direct comparison with existing air quality limits, guidelines and objectives, in whatever form they are specified.

ADMS-Urban can be integrated with the ArcGIS or MapInfo GIS to facilitate both the compilation and manipulation of the emissions information required as input to the model and the interpretation and presentation of the air quality results provided.

Complex Effects - Street Canyons

The *Operational Street Pollution Model (OSPM)*[7], developed by the Danish National Environmental Research Institute (NERI), has been incorporated within ADMS-Urban.

[7] Hertel, O., Berkowicz, R. and Larssen, S., 1990, 'The Operational Street Pollution Model (OSPM).' *18th International meeting of NATO/CCMS on Air Pollution Modelling and its Applications.* Vancouver, Canada, pp741-749.

The OSPM uses a simplified flow and dispersion model to simulate the effects of the vortex that occurs within street canyons when the wind-flow above the buildings has a component perpendicular to the direction of the street. The model takes account of vehicle-induced turbulence. The model has been validated against Danish and Norwegian data.

Complex Effects - Chemistry

ADMS-Urban includes the *Generic Reaction Set (GRS)*[8] atmospheric chemistry scheme. The original scheme has seven reactions, including those occurring between nitrogen oxides and ozone. The remaining reactions are parameterisations of the large number of reactions involving a wide range of Volatile Organic Compounds (VOCs). In addition, an eighth reaction has been included within ADMS-Urban for the situation when high concentrations of nitric oxide (NO) can convert to nitrogen dioxide (NO_2) using molecular oxygen.

In addition to the basic GRS scheme, ADMS-Urban also includes a trajectory model[9] for use when modelling large areas. This permits the chemical conversions of the emissions and background concentrations upwind of each location to be properly taken into account.

Complex Effects – Terrain and Roughness

Complex terrain can have a significant impact on wind-flow and consequently on the fate of dispersing material. Primarily, terrain can deflect the wind and therefore change the route taken by dispersing material. Terrain can also increase the levels of turbulence in the atmosphere, resulting in increased dilution of material. This is of particular significance during stable conditions, under which a sharp change with height can exist between flows deflected over hills and those deflected around hills or through valleys. The height of dispersing material is therefore important in determining the route it takes. In addition areas of reverse flow, similar in form and effect to those occurring adjacent to buildings, can occur on the downwind side of a hill.

Changes in the surface roughness can also change the vertical structure of the boundary layer, affecting both the mean wind and levels of turbulence.

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[8] Venkatram, A., Karamchandani, P., Pai, P. and Goldstein, R., 1994, 'The Development and Application of a Simplified Ozone Modelling System.' *Atmospheric Environment,* Vol 28, No 22, pp3665-3678.

[9] Singles, R.J., Sutton, M.A. and Weston, K.J., 1997, 'A multi-layer model to describe the atmospheric transport and deposition of ammonia in Great Britain.' In: *International Conference on Atmospheric Ammonia: Emission, Deposition and Environmental Impacts. Atmospheric Environment*, Vol 32, No 3.

The ADMS-Urban Complex Terrain Module models these effects using the wind-flow model FLOWSTAR[10]. This model uses linearised analytical solutions of the momentum and continuity equations, and includes the effects of stratification on the flow. Ideally hills should have moderate slopes (up to 1 in 2 on upwind slopes and hill summits, up to 1 in 3 in hill wakes), but the model is useful even when these criteria are not met. The terrain height is specified at up to 16,500 points that are interpolated by the model onto a regular grid of up to 128 by 128 points. The best results are achieved if the specified data points are regularly spaced. FLOWSTAR has been extensively tested with laboratory and field data.

Regions of reverse flow are treated by assuming that any emissions into the region are uniformly mixed within it. Material then disperses away from the region as if it were a virtual point source. Material emitted elsewhere is not able to enter reverse flow regions.

Complex Effects - Buildings

A building or similar large obstruction can affect dispersion in three ways:

1. It deflects the wind flow and therefore the route followed by dispersing material;
2. This deflection increases levels of turbulence, possibly enhancing dispersion; and
3. Material can become entrained in a highly turbulent, recirculating flow region or cavity on the downwind side of the building.

The third effect is of particular importance because it can bring relatively concentrated material down to ground-level near to a source. From experience, this occurs to a significant extent in more than 95% of studies for industrial facilities.

The buildings effects module in ADMS-Urban has been developed using extensive published data from scale-model studies in wind-tunnels, CFD modelling and field experiments on the dispersion of pollution from sources near large structures. It operates out to a distance of about 30 building heights from the building and has the following stages:

(i) A complex of buildings is reduced to a single rectangular block with the height of the dominant building and representative streamwise and crosswind lengths.
(ii) The disturbed flow field consists of a recirculating flow region in the lee of the building with a diminishing turbulent wake downwind, as shown in Figure A1.
(iii) Concentrations within the well-mixed recirculating flow region are uniform and based upon the fraction of the release that is entrained.
(iv) Concentrations further downwind in the main wake are the sum of those from two plumes: a ground level plume from the recirculating flow region and an elevated plume from the non-entrained remainder.

[10] Carruthers D.J., Hunt J.C.R. and Weng W-S. 1988. 'A computational model of stratified turbulent airflow over hills – FLOWSTAR I.' Proceedings of Envirosoft. In: *Computer Techniques in Environmental Studies*, P. Zanetti (Ed) pp 481-492. Springer-Verlag.

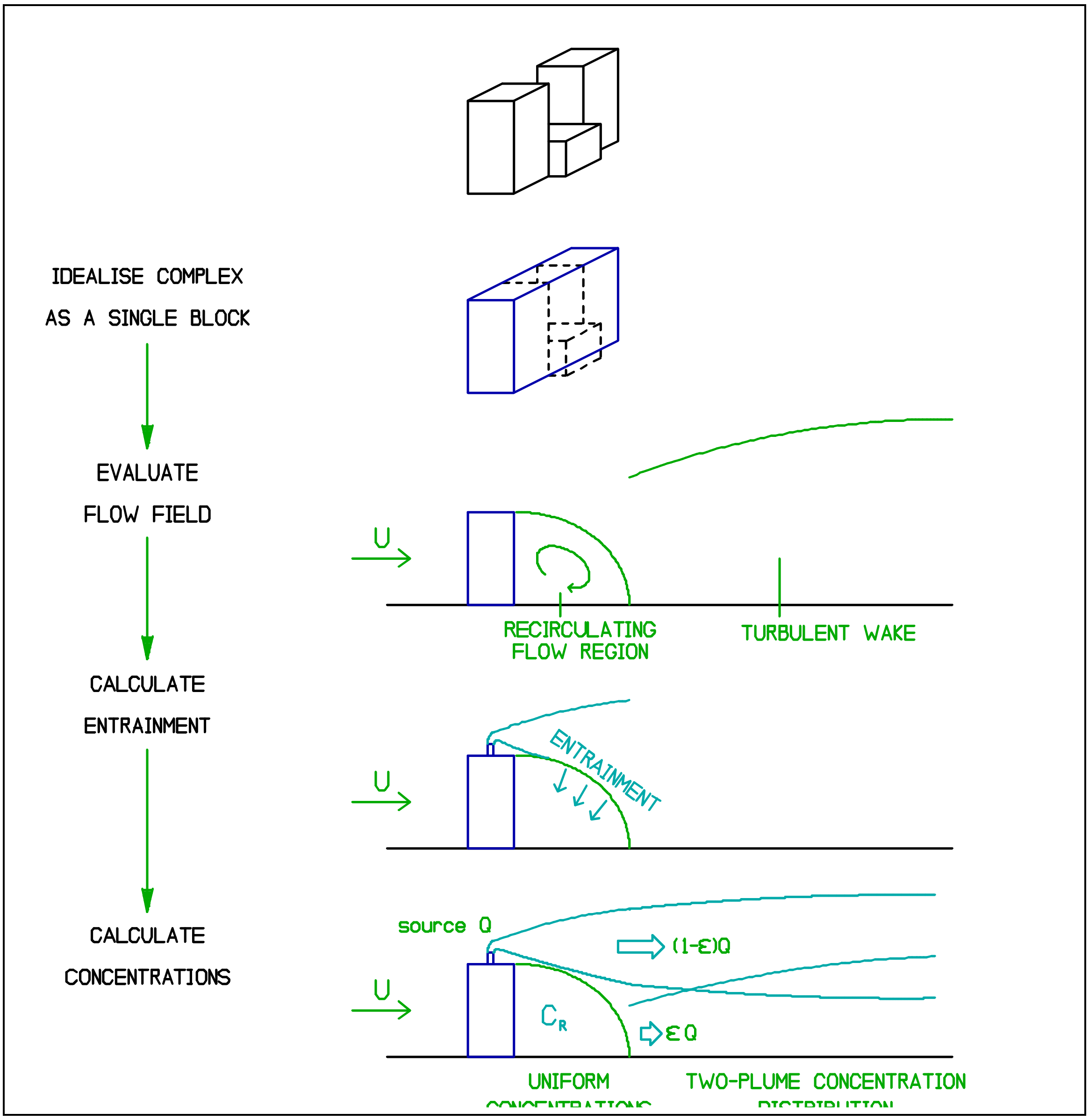

Figure A1: Stages in the modelling of building effects

Data Comparisons – Model Validation

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS), which is used throughout the UK by industry and the Environment Agency to model emissions from industrial sources. ADMS has been subject to extensive validation, both of individual components (e.g. point source, street canyon, building effects and meteorological pre-processor) and of its overall performance.

ADMS-Urban has been extensively tested and validated against monitoring data for large urban areas in the UK, including Central London and Birmingham, for which a large scale project was carried out on behalf of the DETR (now DEFRA).

Further details of ADMS-Urban and model validation, including a full list of references, are available from the CERC web site at www.cerc.co.uk.