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Dulwich Streetspace Air Quality Modelling (June 2021 traffic monitoring)

Draft report

Prepared for
London Borough of Southwark

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CERC

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Contents

1. Executive Summary

Southwark Council commissioned Cambridge Environmental Research Consultants Ltd (CERC) to carry out air quality modelling to assess the impact of three Low Traffic Neighbourhoods (LTNs) in Dulwich.

Two scenarios, pre-scheme and post-scheme, were modelled to assess the current air quality impact of the Dulwich LTNs, based on June 2021 traffic monitoring. Concentrations of NO_2, PM_{10} and $PM_{2.5}$ were modelled for assessment against national air quality objectives.

For both scenarios, the air quality objectives are met throughout the scheme area with the exception of two areas, which are predicted to exceed the air quality objective of 40 $\mu g/m^3$ for annual average NO_2 concentrations: approximately 100 m section of Lordship Lane between East Dulwich Grove and East Dulwich Road; and junctions for Half Moon Lane and Norwood Road close to Herne Hill railway station. The area exceeding the air quality objective is not predicted to increase in the post-scheme scenario, as no change in traffic flows is assumed on these road sections between scenarios.

The expected change in concentrations due to the implementation of the LTNs were assessed using significance criteria from Environmental Protection UK (EPUK) and Institute of Air Quality Management (IAQM) guidance for Land-Use Planning & Development Control. This is a widely used method for assessing air quality impacts for planning purposes.

Using the EPUK IAQM criteria, the changes in concentrations at school locations in the scheme area are classed as *Negligible*.

For the majority of building façade locations along scheme roads, the changes in concentration are classed as *Negligible*. Non-negligible impacts at building façade locations are predicted for annual average NO_2 concentrations in areas shown in Figure 1.1. Areas where *Beneficial* impacts (air quality improves) or *Adverse* impacts (air quality worsens) are predicted include:

- *Moderate Beneficial and Slight Beneficial* impacts on Grove Vale, from Vale End to Elsie Road and Ondine Road to East Dulwich Road
- *Slight Beneficial* impact on Melbourne Grove, for an 80 m section of road from the junction with Grove Vale
- *Slight Beneficial* impact on Calton Avenue, from Court Lane to Woodwarde Road
- *Slight Adverse* impact on East Dulwich Grove, from Lordship Lane to Matham Grove

All ground-level building façades were included in the assessment, regardless of whether the locations are relevant for long-term exposure; annual average air quality objectives only apply to locations such as residential settings, hospitals and schools; they are not relevant for retail premises.

Using modelled annual average NO_2 and $PM_{2.5}$ concentrations, local mortality burdens were calculated using the approach set out in Appendix A of the Public Health England guidance *Estimating local mortality burdens associated with particulate air pollution (April 2014)*; the approach used concentration response function (CRF) pairs for NO_2 and $PM_{2.5}$ from the 2018

COMEAP report *Associations of long-term average concentrations of nitrogen dioxide with mortality.*

The health impacts of air pollution in the scheme area are calculated to be in the range of 132 and 164 life-years lost, which equates to an economic cost of between £5 million and £8 million. The LTN scheme is predicted to have a marginal positive impact on health, in the range of 0.1 and 0.2 life-years, equating to an economic benefit of between £5,000 and £9,000.

1.1. Summary of model set-up

A model set-up for 2019 was modified to include traffic and emissions data for 2021 (based on June 2021 traffic data), to provide an estimate of the current air quality impact of the scheme. The model set-up was based on recent modelling for LTN assessments in the neighbouring borough of Lambeth. Due to project timescales, the model set-up was not verified against local monitoring, however comparison against monitoring data will follow, in order to inform the uncertainty in the conclusions of the assessment. Note the model for Lambeth was extensively verified against borough-wide monitoring, including locations near Dulwich.

Pollutant emissions from vehicles were calculated using activity data from traffic monitoring sites located within the LTN areas and on the boundary roads. Traffic data were provided for pre-scheme and post-scheme scenarios. For other roads in the area, London Atmospheric Emissions Inventory (LAEI 2016) data were used, adjusted to 2019 using DfT traffic counts.

These data were used with emission factors taken from the latest Department for Environment, Food and Rural Affairs (Defra) Emission Factor Toolkit (EFT v 10.1), modified to account for emission factor uncertainty in urban driving conditions. Emission calculations for the scheme scenarios used road traffic fleet projections for 2021, in order to represent the current air quality impact of the LTNs. Baseline modelling using 2019 road traffic emissions was also carried out.

The South East London CHP Energy Facility industrial source was explicitly included in the modelling. Emission rates for all other sources were taken from the LAEI 2016 and modelled as aggregated grid sources for the whole of London.

The modelling used meteorological data from Heathrow Airport and background pollutant data obtained from rural monitoring sites. The Advanced Street Canyon and Urban Canopy options in ADMS-Urban were used to take into account the impact of buildings on the dispersion of pollutants.

The variation in emissions during the day was taken into account by applying a set of diurnal profiles to the road and grid sources. These profiles consider higher emissions during peak /congested periods but will not consider detailed localised changes in the variation in emissions due to the implementation of the scheme. The absence of very detailed local emissions variation in the model set-up is not expected to affect the conclusions of the assessment.

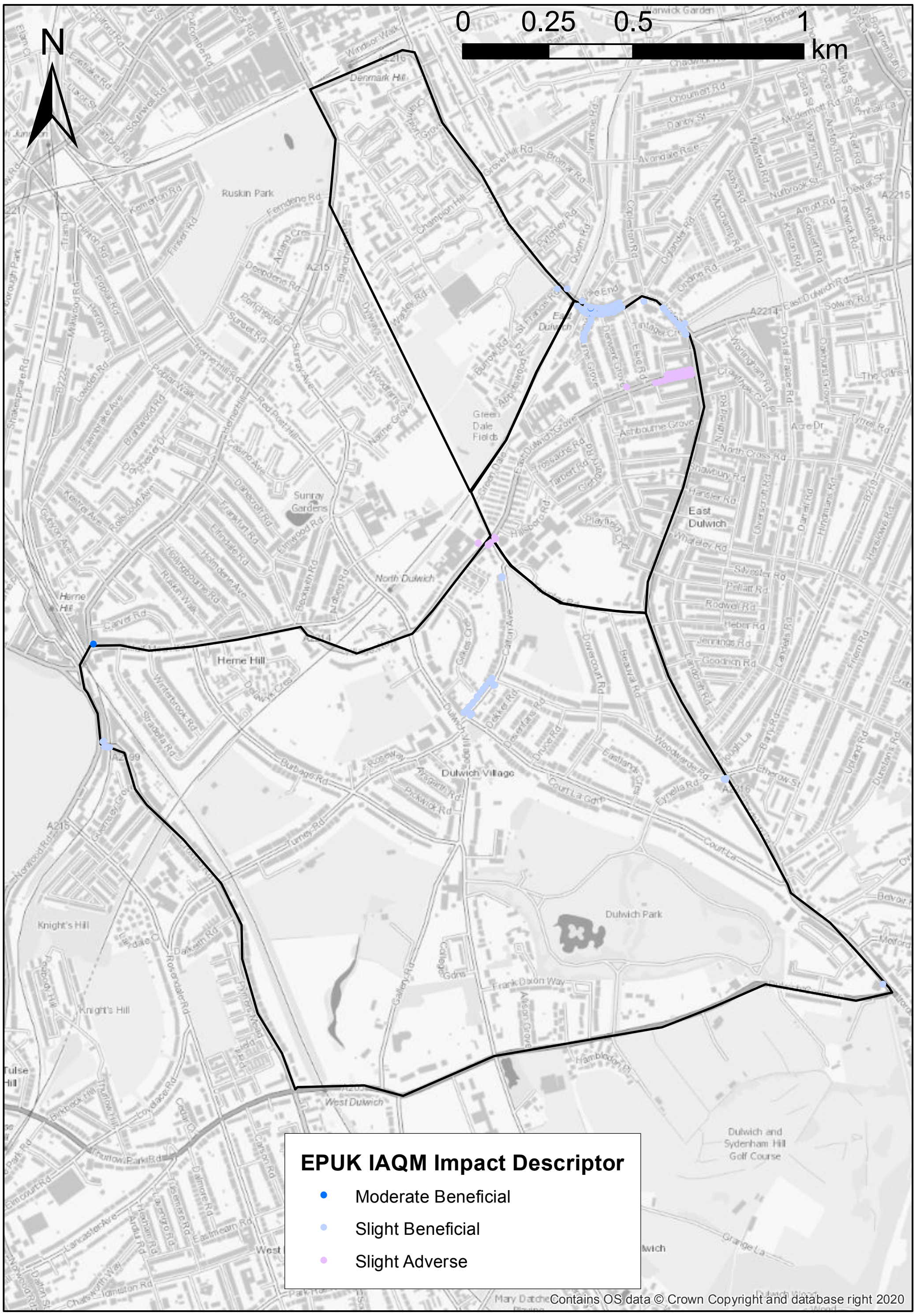

Figure 1.1: Impact descriptors for change in annual average NO_2 concentrations at building façade locations for the Dulwich LTN schemes

2. Introduction

Low Traffic Neighbourhoods (LTNs) involve the closure of residential roads to motor vehicles at specific locations. With significantly less traffic in residential areas, LTNs become far easier and attractive to walk and cycle in, with improved air quality amongst a range of benefits; however, they also have the potential to worsen traffic and hence air quality on boundary roads.

Southwark Council commissioned Cambridge Environmental Research Consultants Ltd (CERC) to carry out an air quality modelling to assess the impact of three LTNs in Dulwich:

- Dulwich Village
- East Dulwich
- Champion Hill

The model set-up is based on recent modelling for LTN assessments in the neighbouring borough of Lambeth. This was modified for the Dulwich LTN schemes to model two scenarios, pre-scheme and post-scheme, using road traffic emission factors for 2021. These scenarios are expected to provide the best estimate for the impact of the LTN schemes on current air quality levels.

Due to project timescales the model set-up was not verified against local air quality monitoring, however comparison against local monitoring will follow to inform the uncertainty in the conclusions of the assessment. Note the model for Lambeth was extensively verified against borough-wide monitoring, including a number of locations near Dulwich.

This report describes the air quality modelling based on traffic monitoring from June 2021. The format of the report is largely the same as *Dulwich Streetspace Air Quality Modelling* final report dated 12th August 2021, that uses data based on April 2021 traffic monitoring.

Section 3 presents the air quality standards, with which the calculated concentrations are compared, and Section 4 provides the criteria used to carry out the impact magnitude assessment of the LTN schemes. A summary of the site location and a review of existing air quality data are given in Section 5. The model set-up and emissions data are summarised in Sections 6 and 7. Section 8 presents modelled concentrations for the pre-scheme and post-scheme scenarios and air pollution mortality burden calculations are shown in Section 9. A discussion of the results is provided in Section 10. Appendix A includes a description of ADMS-Urban as a modelling tool.

3. Air quality standards

The EU *Ambient Air Quality Directive* (2008/50/EC) sets binding limits for concentrations of air pollutants, which take into account the effects of each pollutant on the health of those who are most sensitive to air quality. The Directive has been transposed into English legislation as the *Air Quality Standards Regulations 2010* [1] [2], which also incorporates the provisions of the *Fourth Daughter Directive* (2004/107/EC).

The *Air Quality Standards Regulations 2010* include limit values and target values. Local authorities are required to work towards air quality objectives. In doing so, they assist the Government in meeting the limit values. The limit values are presented in Table 3.1.

Table 3.1: Air quality objectives (μg/m^3)

	Value	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

The short-term objectives, i.e. those measured hourly or over 24 hours, 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/m^3 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. It is important to note that modelling exceedences of short term averages is generally not as accurate as modelling annual averages.

[1] http://www.legislation.gov.uk/uksi/2010/1001/contents/made
[2] Note limit and target values are not affected by *The Air Quality Standards (Amendments) Regulation 2016*.

Table 3.2 gives examples from the London Local Air Quality Management technical guidance (LLAQM.TG(19))[3] of where the air quality objectives should apply. Note that this table differs from the equivalent table in Defra's national (outside London) guidance, LAQM. TG(16), includes clarifications that the annual average objective applies to school playgrounds and the grounds of hospitals and care homes.

Table 3.2: Examples of where the air quality objectives should apply, as provided in the technical guidance LLAQM.TG(19)

Averaging period	**Objectives should apply at:**	**Objectives should generally not apply at:**
Annual average	All locations where members of the public might be regularly exposed. Building facades of residential properties, schools (including all of playgrounds), hospitals (and their grounds), care homes (and their grounds) etc.	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
24-hour mean	All locations where the annual mean objective would apply, together with hotels. Gardens of residential properties (where relevant for public exposure e.g. seating or play areas)	Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
Hourly average	All locations where the annual mean and 24-hour mean objectives apply and: Kerbside sites (for example pavements of busy shopping streets). Those parts of car parks, bus stations and railway stations etc. Which are not fully enclosed, where members of the public might reasonably be expected to spend one hour or longer. Any outdoor locations where members of the public might reasonably expected to spend one hour or longer.	Kerbside sites where the public would not be expected to have regular access.

[3] https://www.london.gov.uk/sites/default/files/llaqm_technical_guidance_2019.pdf

4. Significance criteria

The significance of the air quality impacts as a result of the LTN schemes was assessed using The Environmental Protection UK (EPUK) and Institute of Air Quality Management (IAQM) guidance for Land-Use Planning & Development Control[4].

The impact magnitude criteria presented in the EPUK and IAQM guidance can be applied to any Air Quality Assessment Level (AQAL), such as the air quality objectives considered in this assessment.

Table 4.1 (reproduced from Table 6.3 of the document) sets out the impact descriptors for annual average NO_2 and particulate concentrations. A concentration decrease of 0.5% or more from the baseline is considered a *Beneficial* impact and an increase of 0.5% or more is considered an *Adverse* impact. The equivalent concentrations ranges when comparing annual average NO_2 air quality objective of 40 µg/m^3 are shown in Table 4.2.

Table 4.1: Impact descriptors

Long term average concentration at receptor in assessment year	**% change in concentration relative to Air Quality Assessment level (AQAL)**			
	1	2-5	6-10	>10
75% or less of AQAL	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Slight	Moderate	Moderate
95-102% of AQAL	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Moderate	Moderate	Substantial	Substantial
110% or more of AQAL	Moderate	Substantial	Substantial	Substantial

Note percentages used in defining these descriptors are rounded to the nearest whole number

Table 4.2: Impact descriptor concentration ranges for annual average NO_2

Annual average NO_2 concentration at receptor in assessment year (µg/m^3)	**Change in concentration (µg/m^3)**			
	0.2 – 0.6	0.6 – 2.2	2.2 – 4.2	≥ 4.2
Less than 30.2	Negligible	Negligible	Slight	Moderate
30.2 – 37.8	Negligible	Slight	Moderate	Moderate
37.8 – 41.0	Slight	Moderate	Moderate	Substantial
41.0 – 43.8	Moderate	Moderate	Substantial	Substantial
43.8 or more	Moderate	Substantial	Substantial	Substantial

[4] Land-Use Planning & Development Control: Planning for Air Quality (January 2017) http://www.iaqm.co.uk/text/guidance/air-quality-planning-guidance.pdf

5. Site location and local air quality

5.1. Site location

Figure 5.1 shows the locations of the three Low Traffic Neighbourhoods (LTNs) within the London Borough of Southwark.

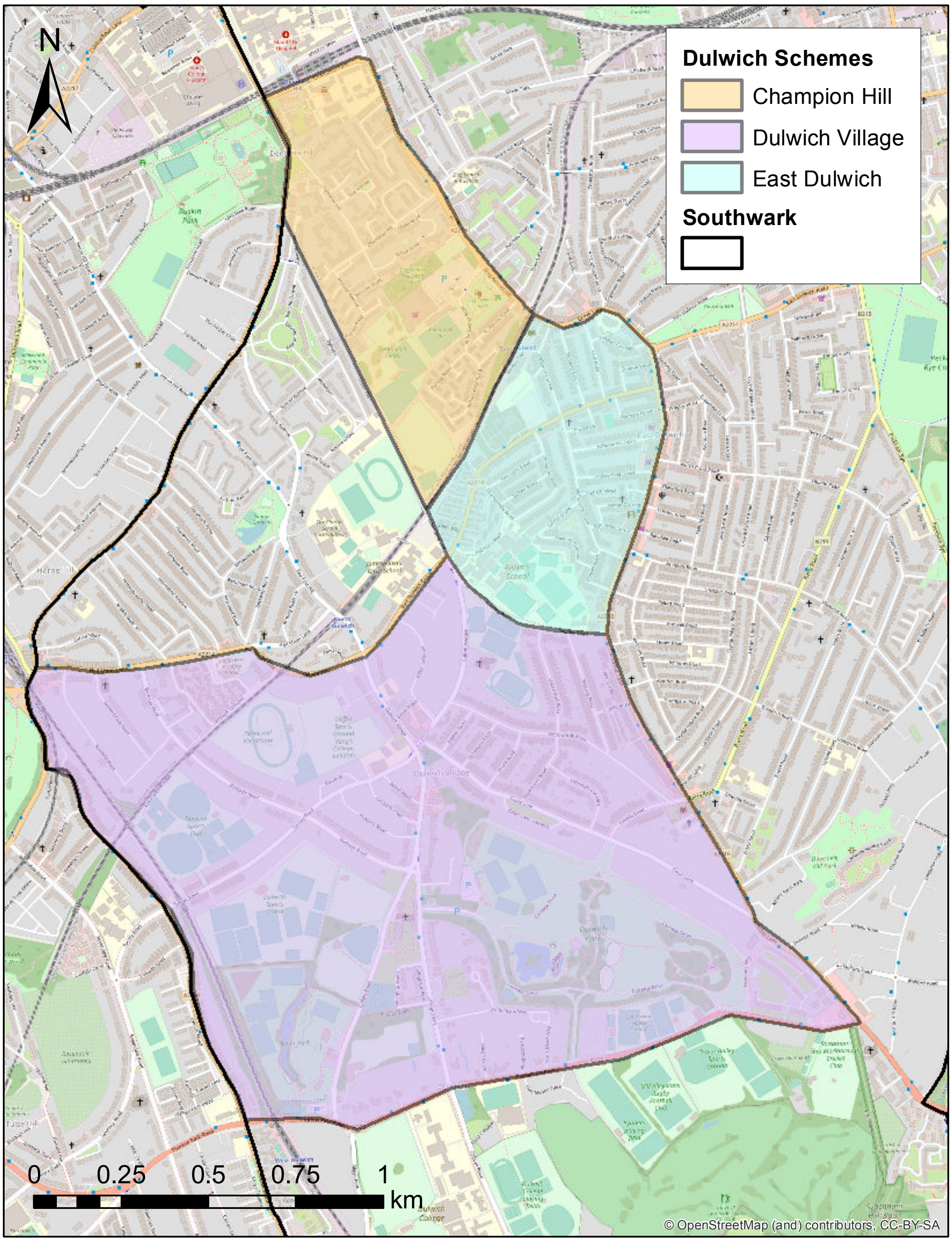

Figure 5.1: Location map of Low Traffic Neighbourhoods

5.2. Local Air Quality Management

Part IV of the Environment Act 1995[5] prescribes the Local Air Quality Review and Assessment process for local authorities. The Review and Assessment process requires local authorities to review local air quality and assess whether or not air quality objectives will be achieved. If it is predicted that these will not be achieved, an Air Quality Management Area must be designated and an Air Quality Action Plan put in place to improve air quality to acceptable levels.

Southwark Council declared the northern part of the borough as an Air Quality Management Area (AQMA) in 2003, due to concentrations of NO_2 and PM_{10} exceeding the air quality objectives. The AQMA encompasses the entire northern part of the borough, extending from Rotherhithe to Walworth and Camberwell and up to the boundary on the River Thames. All three Dulwich LTN schemes are within Southwark's AQMA.

5.3. Air quality monitoring

This section presents a summary of the monitoring sites operational in Southwark in the year 2019, showing air quality levels prior to the Covid-19 pandemic. Data for continuous monitoring sites were taken from Southwark Council's 2019 Air Quality Annual Status Report. In addition, Southwark Council provided details of diffusion tube monitoring and Council commissioned AQMesh pods.

In 2019, Southwark measured air pollutant concentrations at three automatic monitoring sites, providing hour by hour measurements of NO_2 and PM_{10}, and at 82 diffusion tube locations, providing monthly measurements of NO_2.

The three automatic monitoring sites comprise two roadside locations and one background location, Table 5.1 provides details of the automatic monitoring sites. None of these monitors are located in the scheme area; the nearest automatic monitor is SW5 Old Kent Road, located approximately 2.4 km north-east of the scheme area. Southwark Council's automatic monitoring network was expanded in late 2020 and 2021, adding three additional monitoring locations including the South Circular Road site in July 2021. This site is located on a boundary road of the scheme area.

There were 19 diffusion tubes in the vicinity of the Dulwich LTN schemes. All of these diffusion tube sites are classed as kerbside locations. Details of these diffusion tubes are provided in Table 5.2 and their locations are shown in Figure 5.2.

Air pollutant concentrations were also measured at nine AQMesh pods in Southwark, as part of the *Breathe London* project[6]. None of these pods were located in Dulwich LTN scheme areas. Southwark Council provided data for a Council commissioned AQMesh pods on East Dulwich Grove and Lordship Lane.

[5] http://www.legislation.gov.uk/ukpga/1995/25/pdfs/ukpga_19950025_en.pdf
[6] https://data.london.gov.uk/dataset/breathe-london-aqmesh-pods

Table 5.1: Summary of automatic monitoring sites in Southwark

Site ID	Site name	Site type	Pollutants monitored	Location (X, Y)	Distance to kerb of nearest road (m)	Height (m)
SWK 5	Old Kent Road	Roadside	NO_2 and PM_{10}	534844, 177515	5	2
SWK 6	Elephant & Castle	Urban background	NO_2, O_3 and PM_{10}	531884, 178835	25	3.5
SWK 8	Tower Bridge Road	Roadside	NO_2	533488, 179804	4	1.7

Table 5.2: Summary of Southwark diffusion tubes in the vicinity of the Dulwich LTN schemes

Site ID	Site name	Site type	Location (X, Y)	Distance to kerb of nearest road (m)	Height (m)
SDT 9	Dulwich Common	Kerbside	533470, 173204	0.5	2.5
SDT 10	Adjacent to 2 Village Way	Kerbside	532940, 174392	0.5	2.5
SDT 53	Lamppost (2074 - 25) Adjacent entrance to Edward Alleyn Club, Burbage Road	Kerbside	532668, 173998	0	2.5
SDT 95	Court Lane	Kerbside	533700, 173892	0.5	2.5
SDT 97	Barry Road	Kerbside	533940, 173998	0.5	2.5
SDT 98	Junction with Underhill Road South Circular Road	Kerbside	534503, 173251	0.5	2.5
SDT 100	Post adjacent to 1d Calton Avenue	Kerbside	533159, 174191	0.5	2.5
SDT 101	Lamppost 307/19 Adjacent to 91 Herne Hill	Kerbside	532303, 174756	0.5	2.5
SDT 114	Lamppost 1 Goose Green / East Dulwich Road	Kerbside	533799, 175324	0.5	2.5
SDT 136	Lamppost 2160/12 adjacent to Dog Kennel Hill School	Kerbside	533232, 175775	0.5	2.5
SDT 137	Lamppost 2136/18 at the junction adjacent to Champion Hill	Kerbside	532987, 175568	0.5	2.5
SDT 138	Lamppost 2127 11 Pytchley Road	Kerbside	533364, 175561	0.5	2.5
SDT 139	Lamppost 2139 29 Grove Lane	Kerbside	533030, 176022	0.5	2.5
SDT 140	Post near Dog Kennel Hill school entrance Dog Kennel Hill	Kerbside	533221, 175715	0.5	2.5
SDT 145	Lamppost 2544L08 Croxted Road	Kerbside	532777, 172711	0.5	2.5
SDT 146	Lamppost 423-23 Croxted Road	Kerbside	532486, 173535	0.5	2.5
SDT 151	Lamppost 2300 - L01 Junction of Townley Road & Lordship Lane	Kerbside	533660, 174480	0.5	2.5
SDT 152	Lamppost 2300 - L19 Townley Road	Kerbside	533245, 174655	0.5	2.5
SDT 153	Lamppost 2292 - L27 Dulwich Village	Kerbside	533123, 173780	0.5	2.5

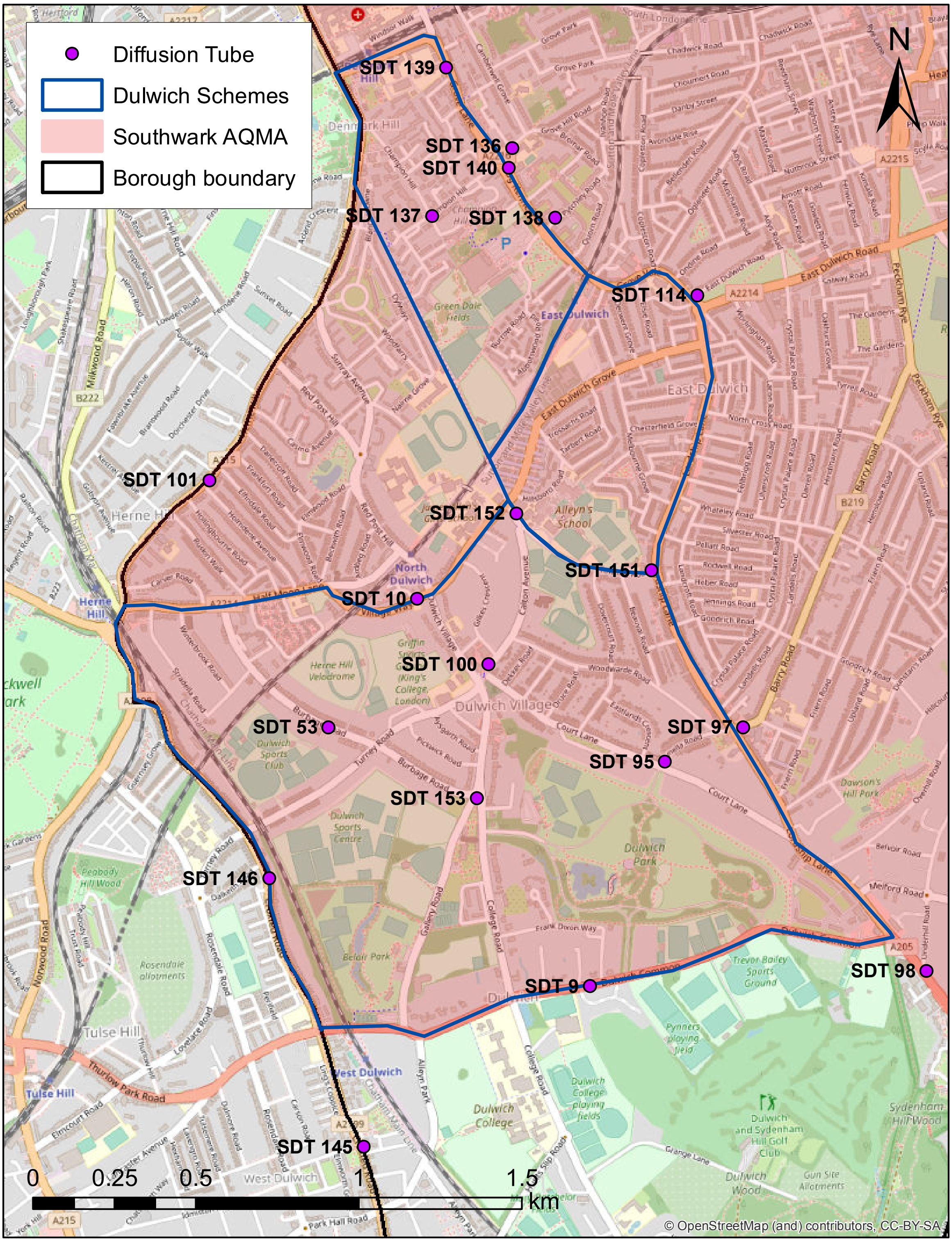

Figure 5.2: Southwark monitoring sites in the vicinity of the Dulwich LTN schemes

5.3.1. NO_2 concentrations

Table 5.3 shows the annual average NO_2 concentrations measured by the automatic monitors for the years 2016 to 2019 and Table 5.4 shows the number of recorded hourly average NO_2 concentrations exceeding 200 µg/m³. Exceedences of the annual average air quality objective of 40 µg/m³ and exceedences of hourly averages over the permitted 18 hours per year are shown in **bold**.

The continuous monitoring shows an improvement in air quality in Southwark between 2016 and 2019; no exceedences of the NO_2 air quality objectives were measured at these sites in 2019.

Latest measurements from the Council's continuous monitoring sites are available from the London Air Quality Network[7] run by the ERG Imperial College London. Note that 2021 measurements on this website are currently unratified and subject to change in 2022. NO_2 measurements from the South Circular Road monitoring site from the date of first measurements (24th July 2021) to present (4th August 2021) show an average concentration of 19 µg/m³ and a maximum hourly concentration of 56 µg/m³, which is well below the hourly average exceedence threshold of 200 µg/m³. Note that NO_2 levels are usually lower in the summer when compared to the winter.

Table 5.5 shows average NO_2 concentrations measured by diffusion tubes for the years 2019 and 2020, and the first six months of 2021. The values for 2019 and 2020 are fully ratified and bias adjusted, whereas 2021 values are raw values that are subject to change in 2022, when the measurements will be ratified and bias adjusted.

In 2019, the annual average NO_2 air quality objective was exceeded at three diffusion tube locations in the vicinity of the Dulwich LTN scheme area. The air quality objective was not exceeded at diffusion tube locations in 2020. The NO_2 concentrations in 2020 were between 20% and 50% lower than 2019 concentrations, in part due to the reduced traffic flows associated with Covid-19 pandemic lockdown measures.

The six-month average concentrations for 2021 are similar to 2019 levels, but it should be noted that these are raw concentrations before ratification and bias adjustment. For context, the bias adjustment factors applied to 2019 and 2020 concentrations are respectively 0.91 and 0.81 i.e. 9% and 19% lower than the raw concentrations.

Southwark Council provided hourly average measurements from AQMesh pods on East Dulwich Grove from 18th May to 19th June 2017 and from 18th May to 24th July 2021. Comparing the same periods in 2017 and 2021 shows average NO_2 concentrations were 33 µg/m³ in 2017 and 23 µg/m³ in 2021. For these periods, the maximum hourly average concentrations were 67 µg/m³ and 52 µg/m³, in 2017 and 2021 respectively; over the two-month period in 2021, the maximum hourly average concentration was 56 µg/m³. The change in concentrations at this AQMesh pod location is in line with continuous monitor and diffusion tube measurements.

[7] https://www.londonair.org.uk/LondonAir/Default.aspx

Data was provided for an AQ Mesh pod on Lordship Lane from 18th May 2021 to 27th July 2021. Over this period the average NO_2 concentration was 33 µg/m³ and the maximum hourly average concentration was 110 µg/m³.

Table 5.3: Annual average NO_2 concentrations at automatic monitors (µg/m³)

Site ID	Site Name	Site Type	2016	2017	2018	2019
SWK5	Old Kent Road	Roadside	**53**	**42**	**41**	35
SWK6	Elephant & Castle	Urban Background	39	34	32	30
SWK8	Tower Bridge Road	Roadside	-	-	-	39

Table 5.4: Number of hours with NO_2 > 200 µg/m³ at automatic monitors

Site ID	Site Name	Site Type	2016	2017	2018	2019
SWK5	Old Kent Road	Roadside	1	0	0	0
SWK6	Elephant & Castle	Urban Background	0	0	0	0
SWK8	Tower Bridge Road	Roadside	-	-	-	0

Table 5.5: Average NO_2 concentrations at diffusion tube sites (µg/m³)

Site ID	Site Name	2019[a]	2020[b]	2021[c]
SDT 9	Dulwich Common	**42**	30	**44**
SDT 10	Adjacent to 2 Village Way	29	20	30
SDT 53	Lamppost (2074 - 25) Adjacent entrance to Edward Alleyn Club, Burbage Road	24	17	23
SDT 95	Court Lane	26	17	24
SDT 97	Barry Road	**41**	24	30
SDT 98	Junction with Underhill Road South Circular Road	**48**	34	**48**
SDT 100	Post adjacent to 1d Calton Avenue	34	17	22
SDT 101	Lamppost 307/19 Adjacent to 91 Herne Hill	35	24	33
SDT 114	Lamppost 1 Goose Green / East Dulwich Road	33	23	33
SDT 136	Lamppost 2160/12 adjacent to Dog Kennel Hill School	34	20	29
SDT 137	Lamppost 2136/18 at the junction adjacent to Champion Hill	25	16	26
SDT 138	Lamppost 2127 11 Pytchley Road	31	25	33
SDT 139	Lamppost 2139 29 Grove Lane	33	24	36
SDT 140	Post near Dog Kennel Hill school entrance Dog Kennel Hill	31	23	32
SDT 145	Lamppost 2544L08 Croxted Road	25	20	26
SDT 146	Lamppost 423-23 Croxted Road	30	21	28
SDT 151	Lamppost 2300 - L01 Junction of Townley Road & Lordship Lane	29	19	29
SDT 152	Lamppost 2300 - L19 Townley Road	32	19	25
SDT 153	Lamppost 2292 - L27 Dulwich Village	27	17	29

[a] 2019 annual average, fully ratified and bias adjusted using a factor of 0.91
[b] 2020 annual average, fully ratified and bias adjusted using a factor of 0.81
[c] Six-month average for the first half of 2021, unratified values without bias adjustment. Subject to change in 2022

5.3.2. PM_{10} concentrations

Table 5.6 shows the measured annual average PM_{10} concentrations at the automatic monitors for the four years 2016 to 2019 and Table 5.7 shows the number of measured daily average PM_{10} concentrations which exceeded 50 µg/m³. There were no exceedences of the annual average air quality standard of 40 µg/m³ or hourly averages over the permitted 35 days per year measured at either of the monitoring sites.

Table 5.6: Annual average PM_{10} concentrations at automatic monitors (µg/m³)

Site ID	Site Name	Site Type	2016	2017	2018	2019
SWK5	Old Kent Road	Roadside	24	22	22	24
SWK6	Elephant & Castle	Urban Background	26	19	20	17

Table 5.7: Number of hours with PM_{10} > 50 µg/m³ at automatic monitors

Site ID	Site Name	Site Type	2016	2017	2018	2019
SWK5	Old Kent Road	Roadside	18	19	8	2
SWK6	Elephant & Castle	Urban Background	21	1	2	14

5.3.3. $PM_{2.5}$ concentrations

Breathe London AQ Mesh pods measured $PM_{2.5}$ concentrations at locations in Southwark in 2019, primarily in the north of the borough. A roadside site located on Tower Bridge Road measured an exceedence of the annual average air quality standard of 25 µg/m³. At all other pod locations the monitored annual averages ranged between 7.2 µg/m³ (urban background location on Brook Drive) and 19.4 µg/m³ (kerbside location on Camberwell Road).

6. Model set-up

Modelling was carried out using the ADMS-Urban [8] model (version 5.0.0.1). The model uses the detailed emissions data described in Section 7, 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.

6.1. 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 m was used to represent the modelled area, representing the built-up nature of the area.

6.2. 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.

6.3. Urban canopy flow

The ADMS-Urban spatially-varying urban canopy flow option calculates changes in the vertical profiles of velocity and turbulence caused by the presence of buildings in an urban area, allowing the flow field within urban areas to be characterised on a neighbourhood-by-neighbourhood basis. The velocity and turbulence profiles are displaced by the building height, and flow within the building canopy is slowed by the buildings. Note that modelling spatially-varying urban canopy flow does not influence the urban heat island calculations described in Section 6.2.

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

6.4. Street canyons

The presence of buildings either side of a road can introduce street canyon effects that result in pollutants becoming trapped, leading to increased pollutant concentrations. Street canyon effects were taken into account using the ADMS Advanced Canyon option, which makes use of detailed information for roadside buildings.

6.5. Meteorological data

A year of hourly sequential meteorological data measured at Heathrow in 2019 was used in the modelling. Table 6.1 shows the proportion of useable data and Table 6.2 summarises the data used in the modelling. To take account of the different surface characteristics at Heathrow, a surface roughness of 0.2 m was used for the meteorological site.

Table 6.1: Hours of meteorological data used in the modelling

Total number of hours used	8760
Number of hours with missing data	94
Percentage of hours used	98.9%

Table 6.2: Summary of meteorological data

	Minimum	Maximum	Mean
Temperature (°C)	-4.4	37.2	11.9
Wind speed (m/s)	0	16.5	4.0
Cloud cover (oktas)	0	8	5

The ADMS meteorological pre-processor, written by the Met Office, uses the data provided to calculate the parameters required by the program. Figure 6.1 shows a wind rose for the site showing the frequency of occurrence of wind from different directions for a number of wind speed ranges.

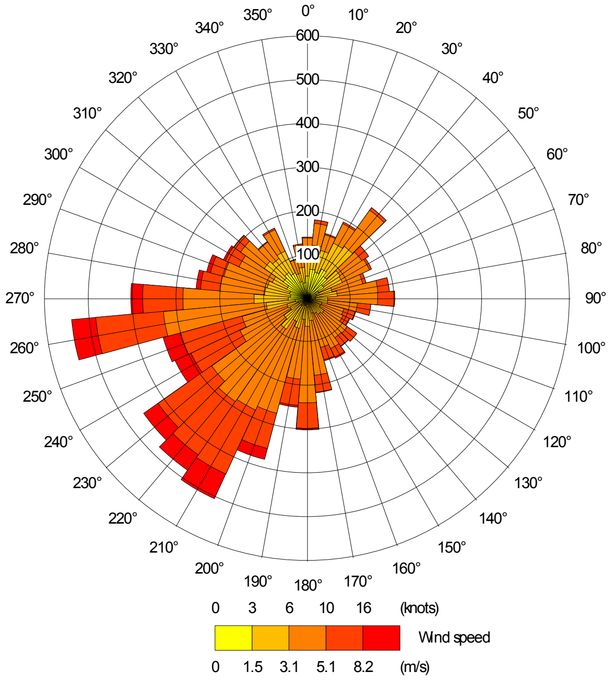

Figure 6.1: Wind rose for Heathrow 2019

6.6. Background data

The air entering from outside of London contains a concentration of each pollutant being modelled. These background concentrations were estimated using measured data from the monitoring sites at Wicken Fen, Chilbolton Observatory, Lullington Heath and Rochester Stoke.

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.

Hourly background data were input to the model to represent the concentrations in the air being blown into the city. NO_x, NO_2, O_3 and SO_2 concentrations were obtained from Rochester, Chilbolton Observatory, Lullington Heath and Wicken Fen. PM_{10}, $PM_{2.5}$ concentrations were obtained from Rochester and Chilbolton Observatory. The monitored concentration used for each hour is based upon the wind direction for that hour , as shown in Figure 6.2.

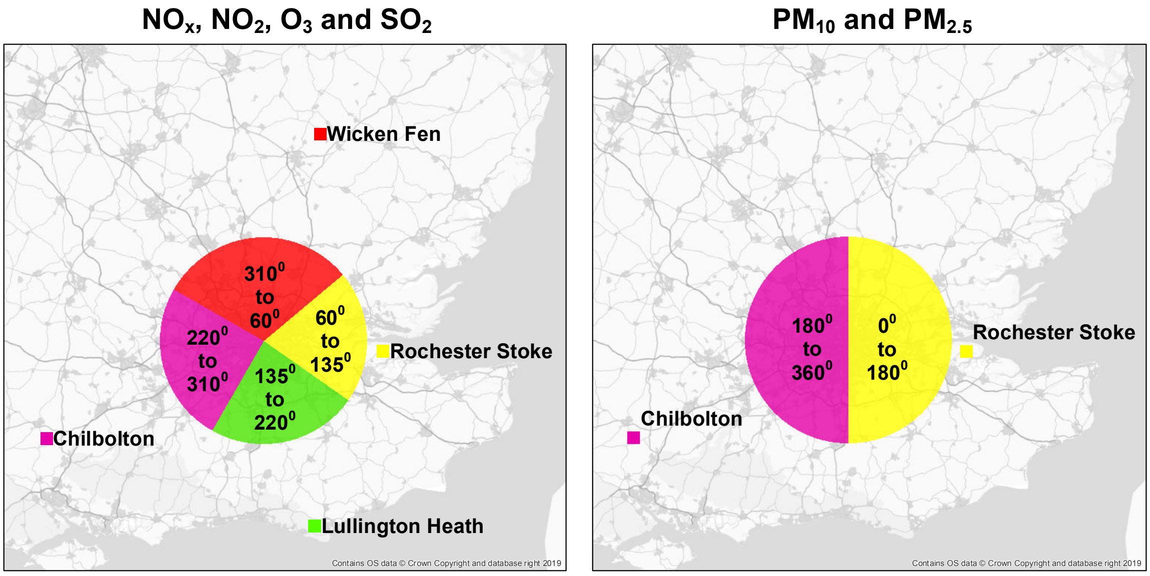

Figure 6.2: Wind direction segments used to calculate background concentrations

Table 6.3 summarises the annual statistics of the resulting background concentrations used in the modelling.

Table 6.3: Summary of 2019 background data used in the modelling (µg/m³)

Statistic	NO_x	NO_2	O_3	PM_{10}	$PM_{2.5}$	SO_2
Annual average	9.1	7.3	55.1	13.4	9.5	0.9
Maximum	175	107	205	272	191	12

7. Emissions data

Emissions inventories for oxides of nitrogen (NO_x), nitrogen dioxide (NO_2) and particulates (PM_{10} and $PM_{2.5}$) were compiled in CERC's emissions inventory toolkit, EMIT.

7.1. Traffic data

As part of the monitoring programme for Dulwich LTNs, data collection of traffic flows was carried out at 23 survey sites using Automatic Traffic Counters (ATCs). The ATC sites are located within the LTN areas, as well as on the immediate boundary roads that surround the LTN areas. Traffic flow data for the ATC sites was provided by SYSTRA.

Compared to the April 2021 traffic monitoring, the June 2021 data includes an additional ATC site called Lordship Lane Central. This ATC is located near the junction of Lordship Lane and Ashbourne Grove. Data from the site was assumed to be representative of traffic flows on Lordship Lane between East Dulwich Grove and Eynella Road.

Calculated flow data was provided for each ATC site for pre and post-scheme scenarios in AADT (Annual Average Daily Traffic) format, based on SYSTRA's pre-implementation and June 2021 post-implementation traffic monitoring.

The ATC traffic data were split into Motorcycles, Cars, LGV and HGV flows. To match the eleven vehicle categories used for emission calculations, Car flows were split into Cars and Taxis and HGV flows were split into Bus, Rigid HGV and Articulated HGV flows. The vehicle split was taken from LAEI 2016 data.

Traffic data for the remaining explicitly modelled roads used LAEI 2016 traffic data projected using borough-average growth factors derived from Department for Transport (DfT) traffic counts.

Figure 7.1 shows the network of explicitly modelled roads in the scheme area. Scheme roads use ATC site traffic flows and all other roads use LAEI 2016 traffic data. To maintain detail at junctions, the major roads in this network were mapped onto LAEI geometry.

Major roads within 1500 m of the scheme area were modelled in detail and emissions from other minor roads and more distant major roads were modelled as a part of the aggregated grid source described in Section 7.7. The widths for all roads were based on OS Mastermap data.

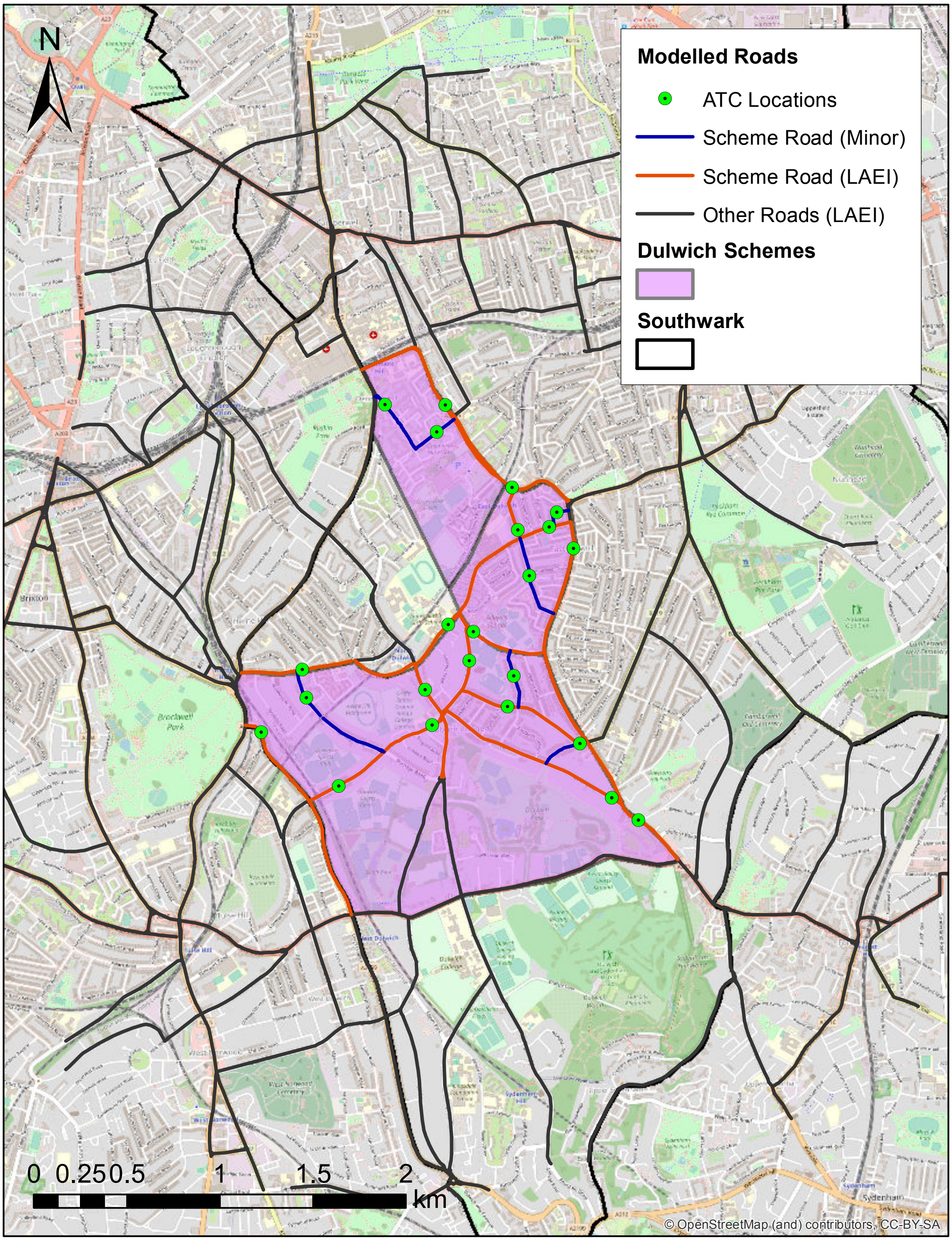

Figure 7.1: Map of explicitly modelled roads

7.2. Traffic speeds

Road speeds for pre-scheme and post-scheme scenarios were provided at each ATC site. On scheme roads where LAEI 2016 speed data were also available, the lower of the two speeds was used for each link, to maintain a good level of speed detail at junctions.

Where only ATC speeds were available, these speeds were used for the entire length of the road link. For other major roads (non-scheme), LAEI 2016 speeds were used.

On minor roads, the following speed assumptions were used for the emission calculations[9]:

- 11 km/h in Central London;
- 19 km/h in Inner London; and
- 31 km/h in Outer London.

These speeds were the basis of road traffic emission calculations. The variation of emissions across a day was considered by applying the time-varying emission profiles shown in Section 7.5.

7.3. Traffic emission factors

Traffic emissions of NO_x, NO_2 and PM_{10} were calculated from traffic flows and speeds using EFT v10.1 published by Defra[10]. This dataset comprises speed-emissions emission factors based on Euro vehicle emissions categories.

Note that there is uncertainty surrounding the current emissions estimates of NO_x in these factors. In order to address this discrepancy, the NO_x emission factors were modified based on published Remote Sensing Data (RSD) [11] [12] for vehicle NO_x emissions. Scaling factors were applied to each vehicle category and Euro standard.

Concentrations of PM_{10} at roadside locations are affected by brake, tyre and road-wear, and concentrations of PM_{10} are also affected by resuspension. With the exception of resuspension, these non-exhaust road traffic emissions were calculated using EFT v10.1 emission factors. Resuspension emission factors were taken from a report produced by TRL Limited on behalf of Defra [13].

[9] https://www.london.gov.uk/questions/2019/19767
[10] https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html
[11] Carslaw, D and Rhys-Tyler, G 2013: New insights from comprehensive on-road measurements of NO_x, NO_2 and NH_3 from vehicle emission remote sensing in London, UK. *Atmos. Env.* **81** pp 339–347.
[12] Davison, J., Rose, R.A., Farren, N.J., Wagner, R.L., Murrells, T.P. and Carslaw, D.C., 2021. Verification of a National Emission Inventory and Influence of On-road Vehicle Manufacturer-Level Emissions. Environmental Science & Technology, 55(8), pp.4452-4461.
[13] *Road vehicle non-exhaust particulate matter: final report on emission modelling*, TRL Limited Project Report PPR110
https://uk-air.defra.gov.uk/assets/documents/reports/cat15/0706061624_Report2__Emission_modelling.PDF

7.4. Road traffic fleet assumptions

The EFT v10.1 uses fleet data separated by the regions and road types. London roads were classified by region using definitions provided in LAEI 2016, shown in Figure 7.2, with the M25 treated separately (London Motorway fleet). For non-GLA roads within the M25, Outer London fleet data were used.

The borough of Southwark forms part of Inner London. With the exception of the bus fleet assumptions outlined in Section 7.4.1, the Inner London fleets were used, in line with the regions defined in the LAEI. This is expected to give a good representation of the fleet on a borough-wide basis but may not be representative of the fleet operating on particular roads.

Pre-scheme and post-scheme scenarios were modelled using road traffic fleet assumptions for 2021. In addition, a baseline model for 2019 was set-up using 2019 fleet data.

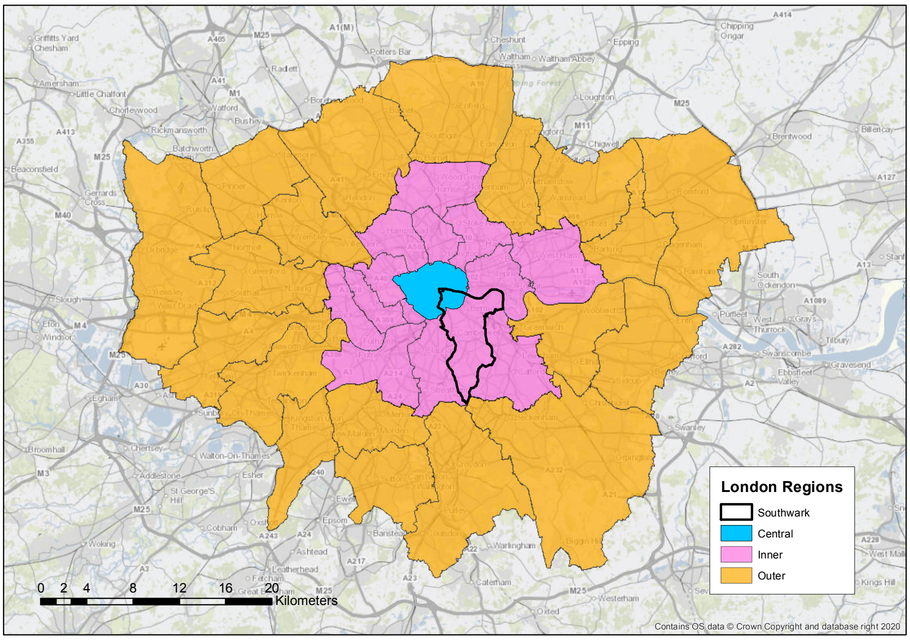

Figure 7.2: London regions

7.4.1. Bus fleet assumptions

Bus fleet projections in EFT 10.1 are shown in Figure 7.3. The projections for 2019 assume 100% buses operating in Central London, 77% in Inner London and 66% in Outer London are Euro VI or better. The projections show a step change in 2020, where all buses across London become Euro VI or better.

According to TfL's bus fleet audit[14], by the end of the 2018/2019 financial year, 77.5% of buses across the whole of London were Euro VI standard or better, increasing to 93.4% by the end of 2019/2020.

To account for the accelerated uptake of newer bus technology, the following assumptions were applied to the modelled bus fleet for 2019:

- Use an average of the respective EFT 2019 and 2020 bus projections for roads in Inner and Outer London; and
- For Central London, use the EFT projection without modifications for 2019 since it is in line with TfL's bus fleet audit.

For 2021 emissions, the EFT fleet for 2021 was used without modifications.

[14] https://tfl.gov.uk/corporate/publications-and-reports/bus-fleet-data-and-audits

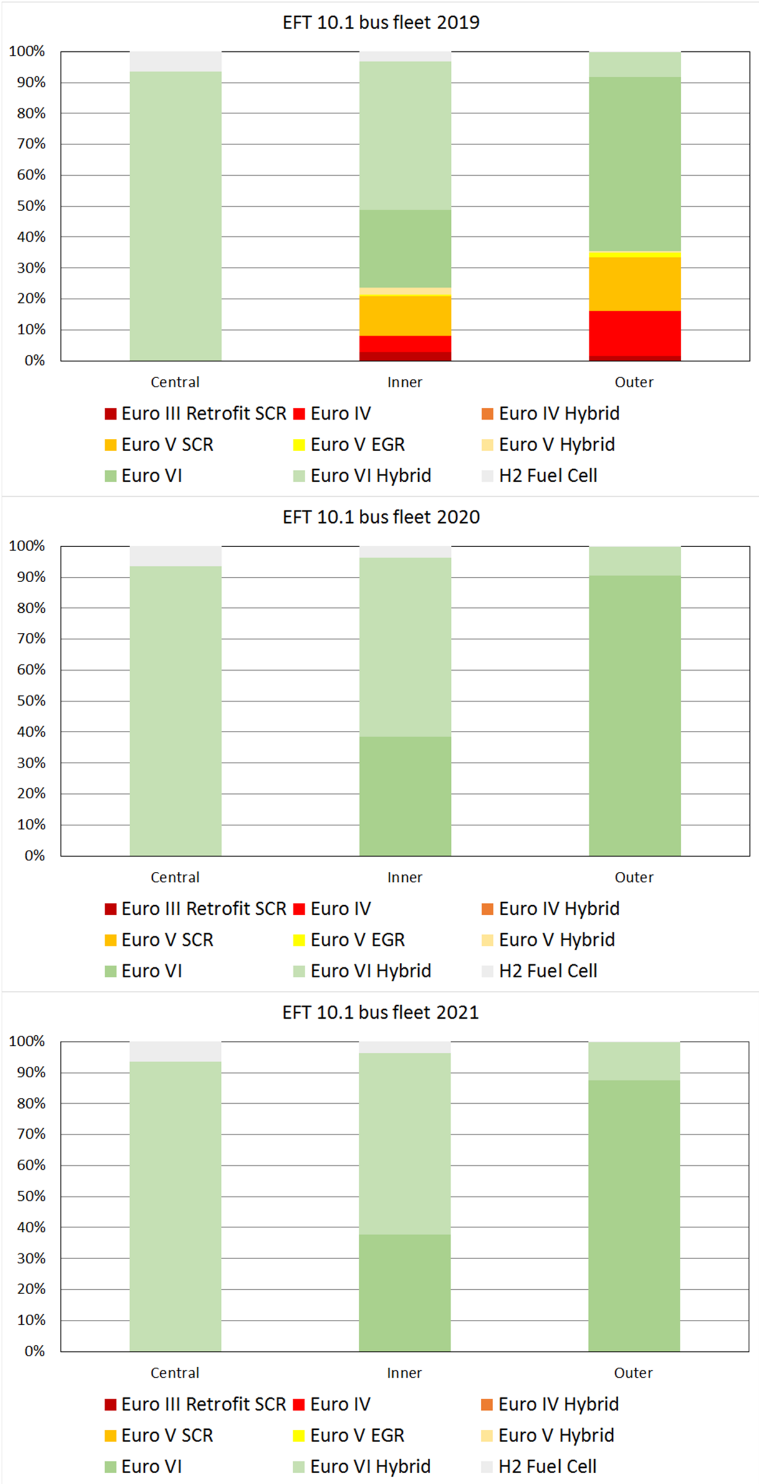

Figure 7.3: EFT 10.1 bus fleet projections for London regions for 2019 (top), 2020 (middle) and 2021 (bottom). Projections for Central, Inner and Outer London are shown.

7.5. Time-varying emissions profiles

The variation in emissions during the day was taken into account by applying a set of diurnal profiles to the road and grid sources. Time-varying emissions profiles were based on road traffic emissions in *Air pollution and emissions trends in London* [15], used in the compilation of the LAEI, and are shown in Figure 7.4.

These emission profiles are expected to capture the changes in traffic volume, composition and speed throughout the day. In the absence of more detailed data, these profiles were used for all scheme roads in both the pre-scheme and post-scheme scenarios. Although the use of the same profile may underestimate the impact of additional peak time congestion on boundary roads with the scheme in place, this assumption is not expected to affect the overall conclusions of the assessment.

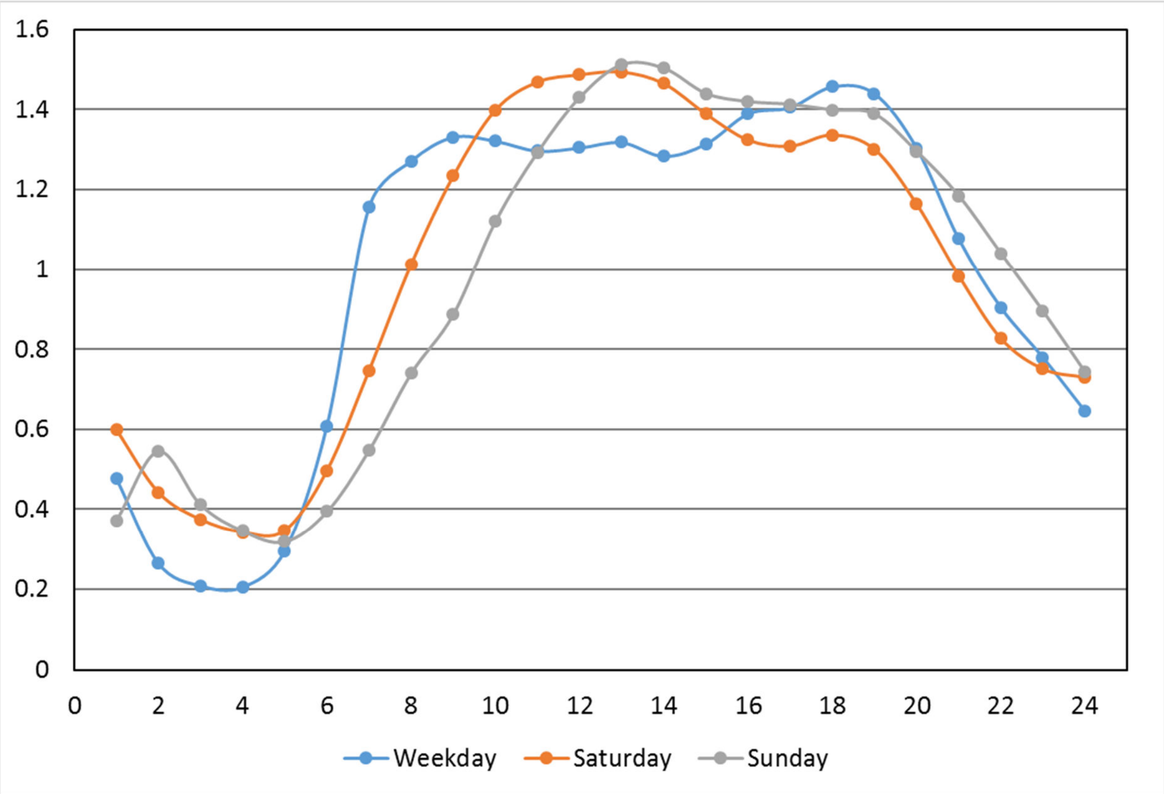

Figure 7.4: Diurnal profiles for road traffic emissions

Profiles for grid sources, as described in Section 7.7, were derived from European Monitoring and Evaluation Programme (EMEP) emissions data, and are shown in Figure 7.5.

[15] *Air pollution and emissions trends in London*, King's College London, Environmental Research Group and Leeds University, Institute for Transport studies https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1004010934_MeasurementvsEmissionsTrends.pdf

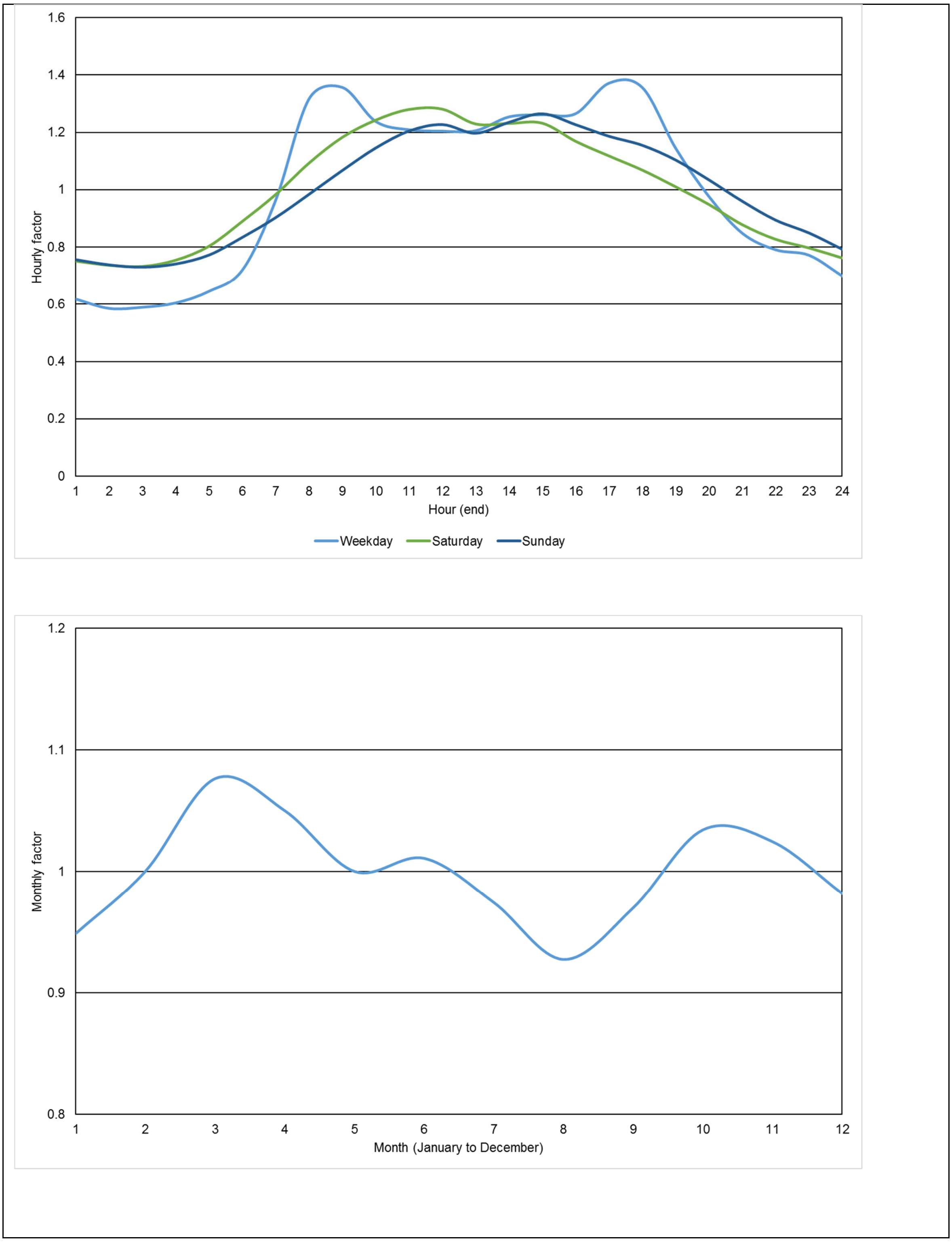

Figure 7.5: Diurnal (top) and monthly profiles (bottom) for grid source emissions

7.6. Industrial sources

One industrial source was explicitly included in the modelling due to its proximity to the scheme area and relatively high emission rates. The model parameters for South East London Combined Heat and Power (SEL CHP) are summarised in Table 7.1. The source is located in north Lewisham, approximately 3 km north-east of the scheme area.

Stack parameters were estimated based on the type of source and emission rates were obtained from the LAEI 2016, for the grid square in which the industrial source is located (535500, 178500).

Table 7.1: SEL CHP model parameters and emission rates

Location (x, y)	Height (m)	Diameter (m)	Exit velocity (m/s)	Temperature (°C)	NO_2 (g/s)	NO_x (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
535700, 178120	61	1.6	13.7	134	1.0	20.0	0.1	0.1

7.7. Other emissions

Emission rates for all other sources were taken from the LAEI 2016 and modelled as aggregated 1-kilometre resolution grid sources covering the whole of London.

Hourly and monthly emissions profiles for the grid sources were derived from European Monitoring and Evaluation Programme (EMEP) emissions data and are shown in Section 7.5.

8. Modelled concentrations

This section presents modelled NO_2, PM_{10} and $PM_{2.5}$ concentrations for the pre-scheme and post-scheme scenarios.

As described in the previous section, the modelling uses road traffic emissions calculated using fleet projections for 2021 and scheme traffic data based on monitoring from June 2021. All other model inputs are for 2019, including meteorological and background (contribution from outside London).

8.1. School locations

Concentrations were calculated at school locations in the scheme area chosen by Southwark Council. Figure 8.1 provides the locations of the schools and Table 8.1 provides the average modelled roadside façade(s) concentrations for schools or, where the nearby roads are not modelled explicitly, a single location representing the centre of the school.

Modelled concentrations of NO_2, PM_{10} and $PM_{2.5}$ at these school locations are all below the relevant air quality objectives.

The change in annual average NO_2 concentrations between the post-scheme and pre-scheme scenarios range between a 2.1 $\mu g/m^3$ reduction (5% of air quality objective) and a 1.3 $\mu g/m^3$ increase (3% of air quality objective). For 17 out of 24 school locations, the change in concentration represents 1% or less of the annual average NO_2 air quality objective.

The changes in annual average PM_{10} and $PM_{2.5}$ concentrations are small, representing up to 1% of the relevant air quality objective.

Using the EPUK IAQM significance criteria matrix reproduced in Table 4.1, the impact of the scheme at all school locations, for all pollutants, is classed as *Negligible*.

In addition to small changes in concentrations, this significance classification represents the relatively low pollution concentrations across the scheme area. At all but one of the school locations, long term average concentrations fall into the *75% or less of AQAL* category of the significance criteria matrix.

Table 8.1: Average modelled concentrations at roadside façades of selected schools (µg/m³)

ID	School	Modelled Road	Pre-Scheme					Post-Scheme				
			Annual average NO_2	99.79th %ile of 1-hour NO_2	Annual average PM_{10}	90.41st %ile of 24-hour PM_{10}	Annual average $PM_{2.5}$	Annual average NO_2	99.79th %ile of 1-hour NO_2	Annual average PM_{10}	90.41st %ile of 24-hour PM_{10}	Annual average $PM_{2.5}$
1	Goose Green Primary and Nursery School	GROVE VALE	29.7	104	19.8	35.6	13.1	29.0	102	19.7	35.5	13.0
2	Alleyn's School	EAST DULWICH GROVE	27.4	100	19.3	34.8	12.7	28.1	101	19.4	35.0	12.8
		TOWNLEY ROAD	25.1	96	18.8	34.2	12.5	24.9	97	18.8	34.1	12.5
3	Bessemer Grange Primary School	*School centre point*	23.5	94	18.2	33.5	12.3	23.5	94	18.3	33.5	12.3
4	The Charter School North Dulwich	*School centre point*	23.4	93	18.2	33.4	12.2	23.4	93	18.2	33.4	12.2
5	Dog Kennel Hill School	DOG KENNEL HILL	28.4	103	19.5	35.0	12.9	28.0	102	19.5	34.9	12.9
		GROVE HILL ROAD	26.1	97	18.8	34.0	12.6	26.1	97	18.8	34.0	12.6
6	Dulwich College	COLLEGE ROAD	23.4	96	17.8	32.7	12.0	23.4	96	17.8	32.7	12.0
		DULWICH COMMON	24.8	100	18.1	32.8	12.1	24.7	100	18.1	32.8	12.1
7	Dulwich Hamlet Junior School	DULWICH VILLAGE	26.4	98	18.6	34.0	12.4	26.0	97	18.5	33.9	12.4
		TURNEY ROAD	24.5	97	18.3	33.6	12.3	24.2	96	18.3	33.5	12.3
8	Dulwich Village Church of England Infants' School	DULWICH VILLAGE	25.5	98	18.5	33.9	12.4	25.4	98	18.5	33.9	12.4
9	Harris Primary Academy East Dulwich	LORDSHIP LANE	29.0	102	20.1	35.8	13.1	29.2	102	20.1	35.7	13.1

ID	School	Modelled Road	Pre-Scheme					Post-Scheme				
			Annual average NO_2	99.79th %ile of 1-hour NO_2	Annual average PM_{10}	90.41st %ile of 24-hour PM_{10}	Annual average $PM_{2.5}$	Annual average NO_2	99.79th %ile of 1-hour NO_2	Annual average PM_{10}	90.41st %ile of 24-hour PM_{10}	Annual average $PM_{2.5}$
10	Heber Primary School	*School centre point*	22.4	92	18.1	33.4	12.1	22.4	92	18.1	33.4	12.1
11	Judith Kerr Primary School	HALF MOON LANE	24.1	95	18.1	33.5	12.3	24.1	95	18.2	33.5	12.2
		VILLAGE WAY	24.1	96	18.3	33.7	12.3	24.0	96	18.3	33.7	12.3
12	St Anthony's Catholic Primary School	BARRY ROAD	26.0	96	18.8	34.0	12.4	25.9	96	18.8	34.0	12.4
13	James Allen's Girls' School	EAST DULWICH GROVE	27.0	100	19.2	34.4	12.7	27.6	102	19.3	34.5	12.8
14	The Charter School East Dulwich	EAST DULWICH GROVE	26.6	101	19.2	34.5	12.7	27.5	103	19.4	34.7	12.8
		MELBOURNE GROVE	25.9	97	18.9	34.3	12.7	23.8	94	18.5	33.9	12.5
15	Under the Willow Nursery	*School centre point*	22.8	92	17.7	32.7	12.0	22.9	92	17.8	32.7	12.0
16	Nelly's Nursery	CROXTED ROAD	24.9	97	18.3	33.5	12.2	24.4	95	18.0	33.2	12.1
		TURNEY ROAD	24.3	96	18.0	32.9	12.1	23.4	93	17.8	32.7	12.0
17	EDG Nursery	EAST DULWICH GROVE	28.3	102	19.5	35.6	12.9	29.6	106	19.8	36.0	13.1

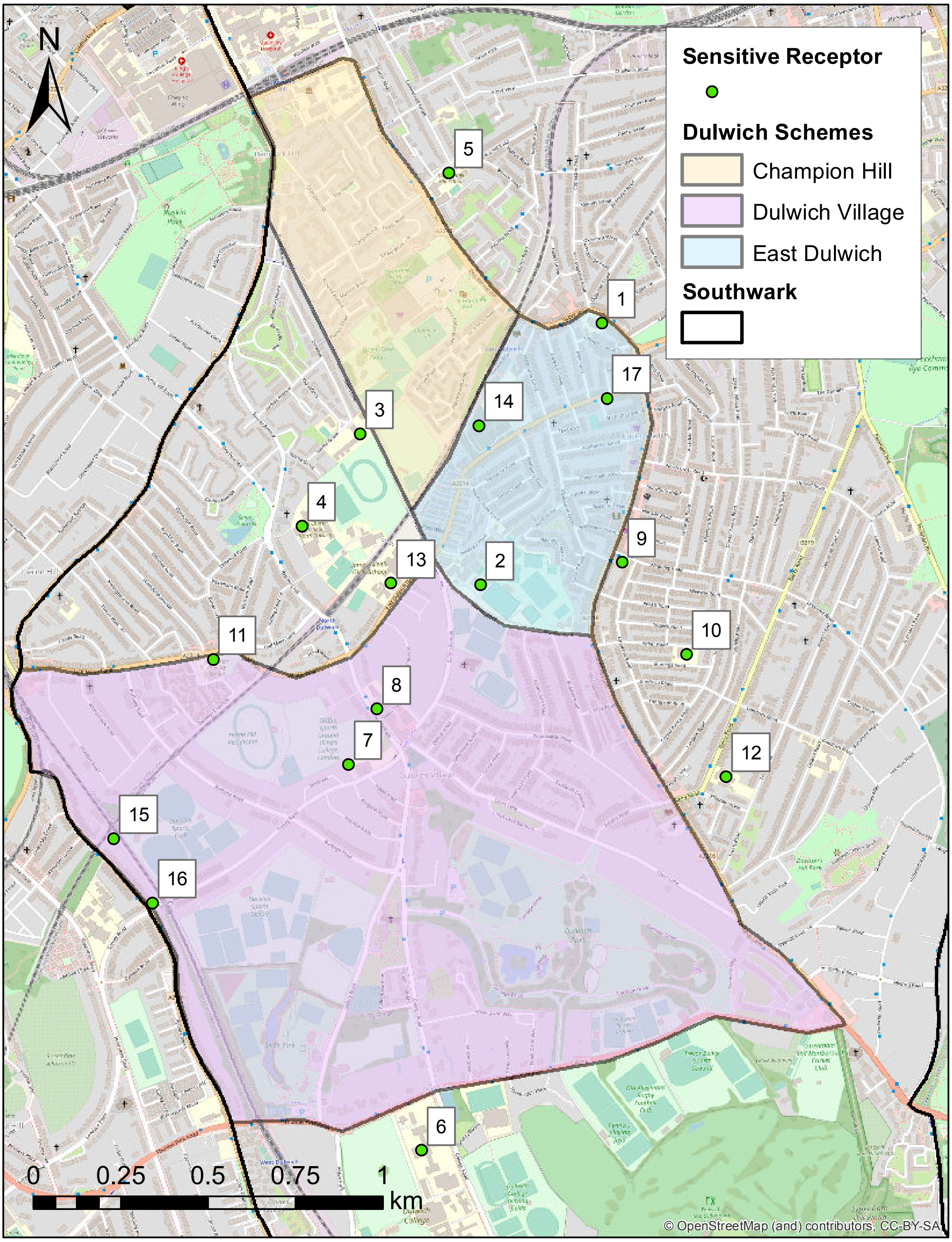

Figure 8.1: Locations of modelled sensitive receptors

8.2. Contour maps

Concentrations were calculated on a regular grid of receptors on a 50 m resolution and a dense network of roadside, kerbside and building façade points. The additional set of receptors was used to represent the steep concentration gradient from the roadside to the building facades. The model output was used to generate 5 m resolution contour maps across the scheme area using the natural neighbour interpolation method.

Figure 8.2 and Figure 8.3 show modelled annual average NO_2 concentrations for the pre-scheme and post-scheme scenarios. These maps use the same colour scale as the GLA's LAEI 2016 concentration maps.

Modelled annual average NO_2 concentrations meet the air quality objective of 40 µg/m³ throughout the scheme area, with the exception of some locations close to busy road junctions. Modelled concentrations exceed the air quality objective along Lordship Lane, between East Dulwich Grove and East Dulwich Road, and junctions of Half Moon Lane and Norwood Road, close to Herne Hill railway station.

For context, Figure 8.4 shows modelled annual average NO_2 concentrations from a 2019 baseline model, using 2019 road traffic emission factors and pre-scheme traffic flows. Comparing this figure against the scheme scenarios that use 2021 traffic emission factors, provide an indication of the expected change in concentrations due to recent changes in the traffic fleet composition, partly driven by measures such as the Ultra Low Emission Zone. The area exceeding the annual average NO_2 air quality objective in 2019 is a much wider extent than for the scheme scenarios, encompasses the length of most major roads in the scheme area.

Figure 8.5 and Figure 8.6 show the modelled 99.79th percentile of hourly average NO_2 concentrations for the pre-scheme and post-scheme scenarios. Modelled concentrations meet the air quality objective of 200 µg/m³ across the scheme area.

Figure 8.7 and Figure 8.8 shows the modelled annual average PM_{10} concentrations for the pre-scheme and post-scheme scenarios. Modelled concentrations meet the air quality objective of 40 µg/m³ across the scheme area.

Figure 8.9 and Figure 8.10 shows the modelled 90.41st percentile of 24-hour average PM_{10} concentrations for the pre-scheme and post-scheme scenarios. Modelled concentrations meet the air quality objective of 50 µg/m³ across the scheme area.

Figure 8.11 and Figure 8.12 show modelled annual average $PM_{2.5}$ concentrations for the pre-scheme and post-scheme scenarios. Modelled concentrations meet the air quality objective of 25 µg/m³ across the scheme area.

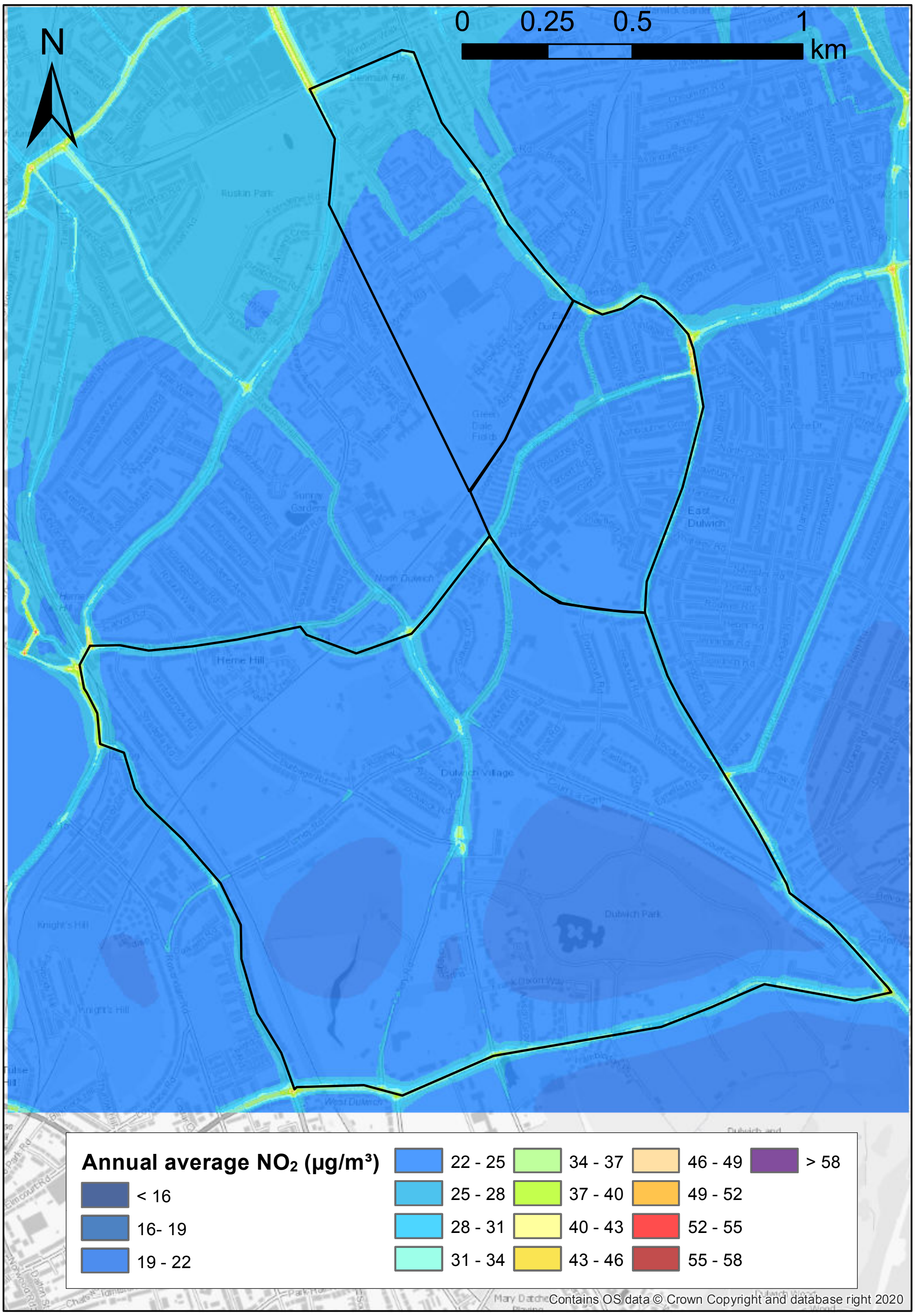

Figure 8.2: Pre-scheme annual average NO_2 concentrations

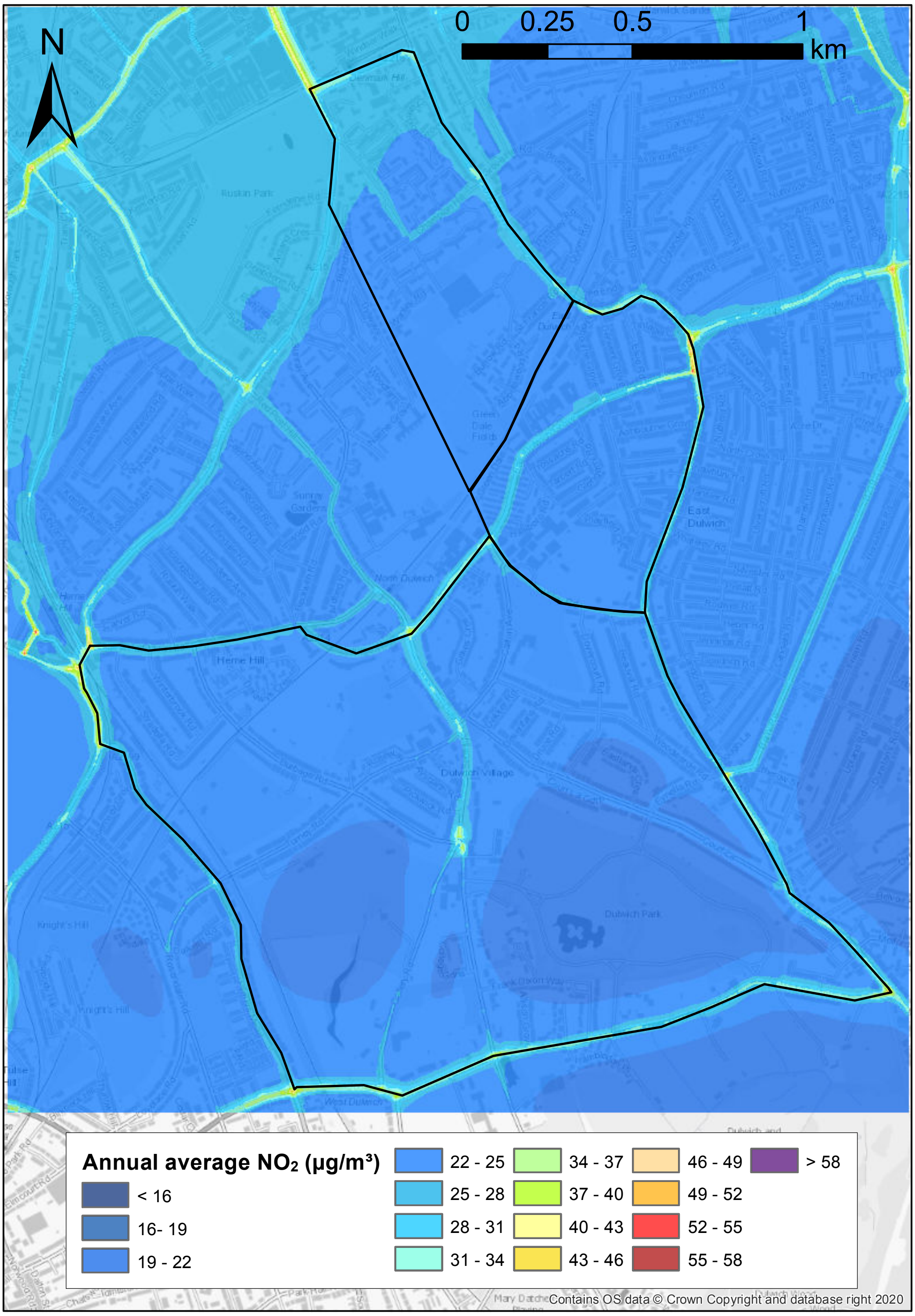

Figure 8.3: Post-scheme annual average NO_2 concentrations

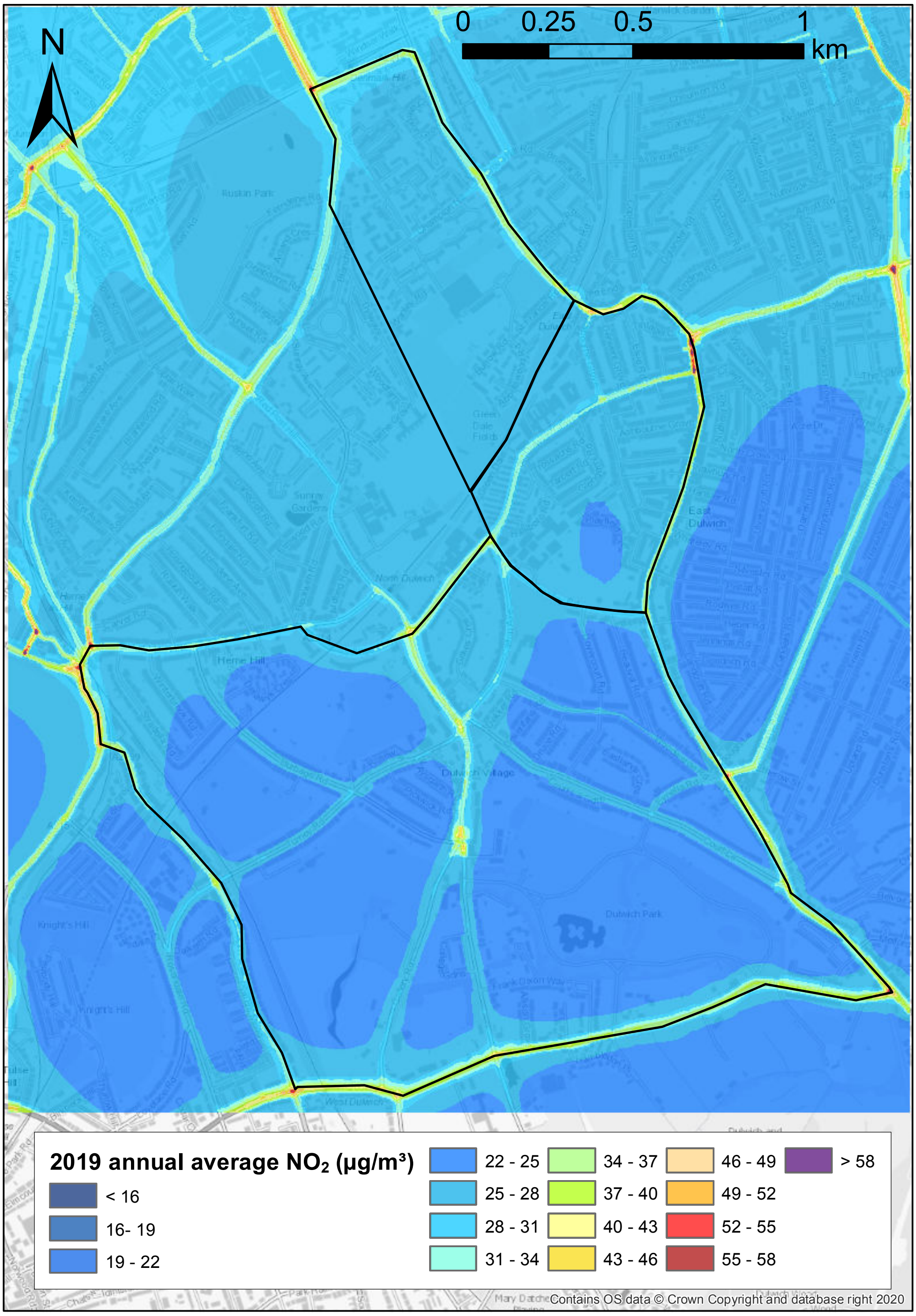

Figure 8.4: 2019 annual average NO_2 concentrations

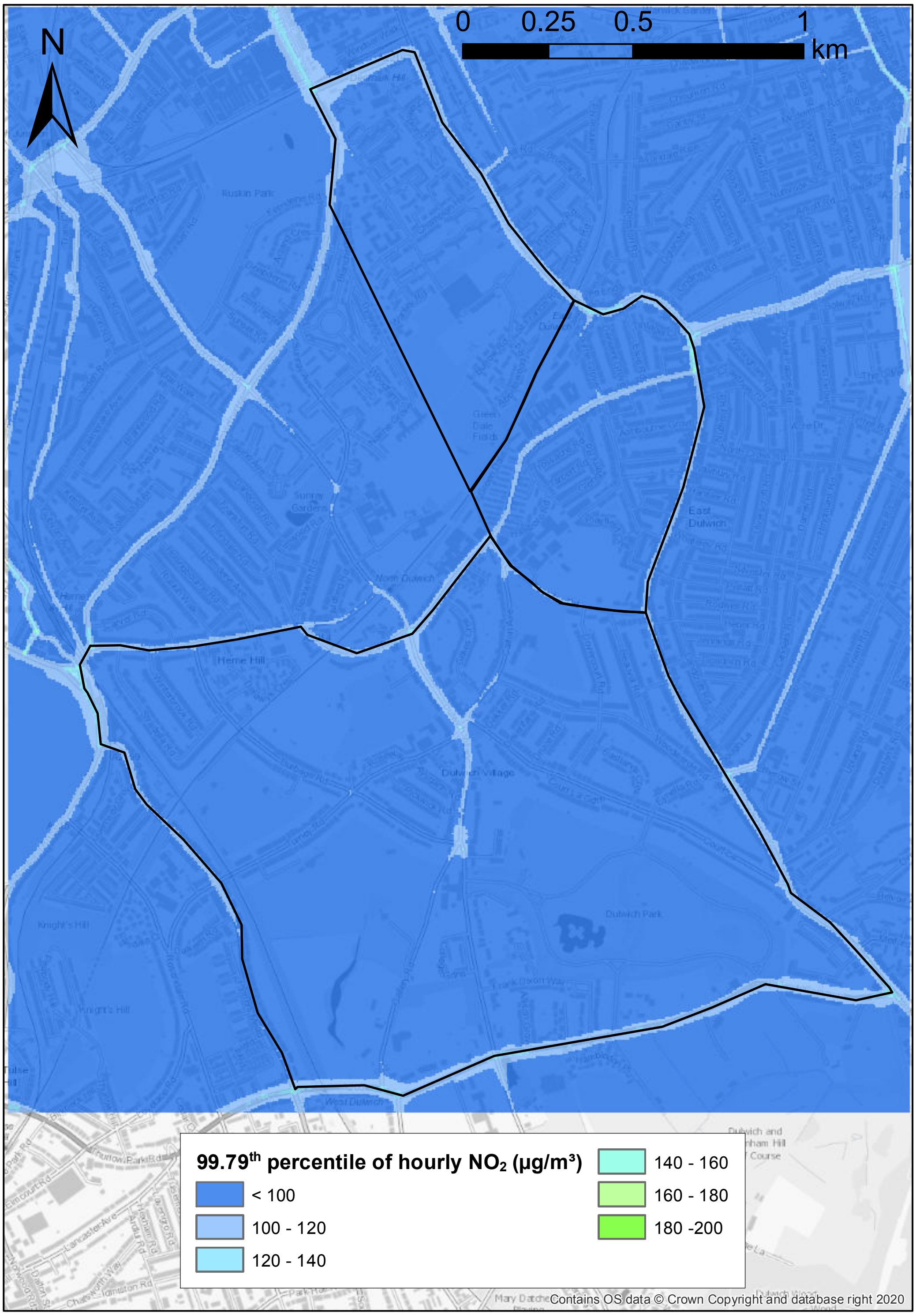

Figure 8.5: Pre-scheme 99.79th percentile of hourly average NO_2 concentrations

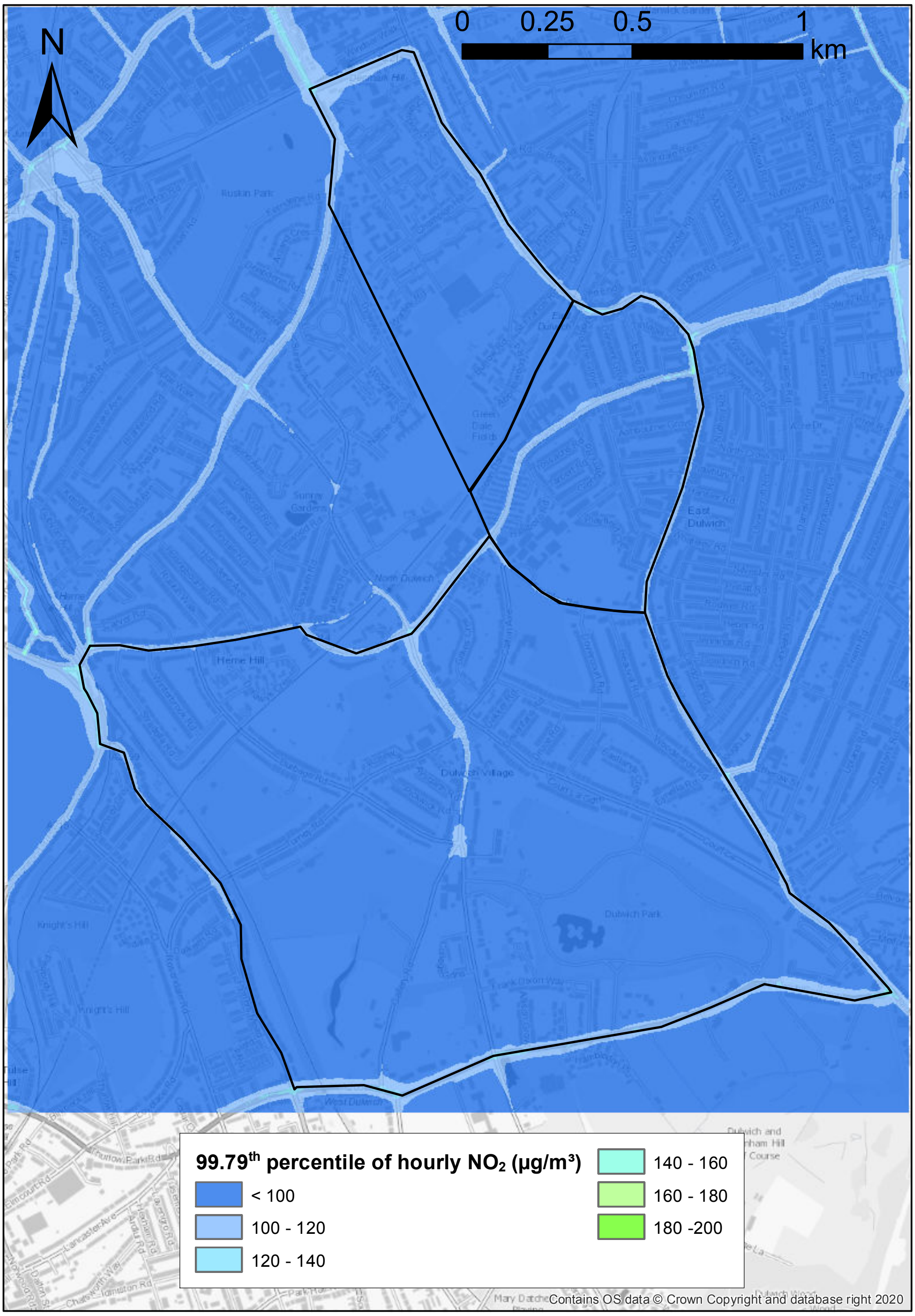

Figure 8.6: Post-scheme 99.79th percentile of hourly average NO_2 concentrations

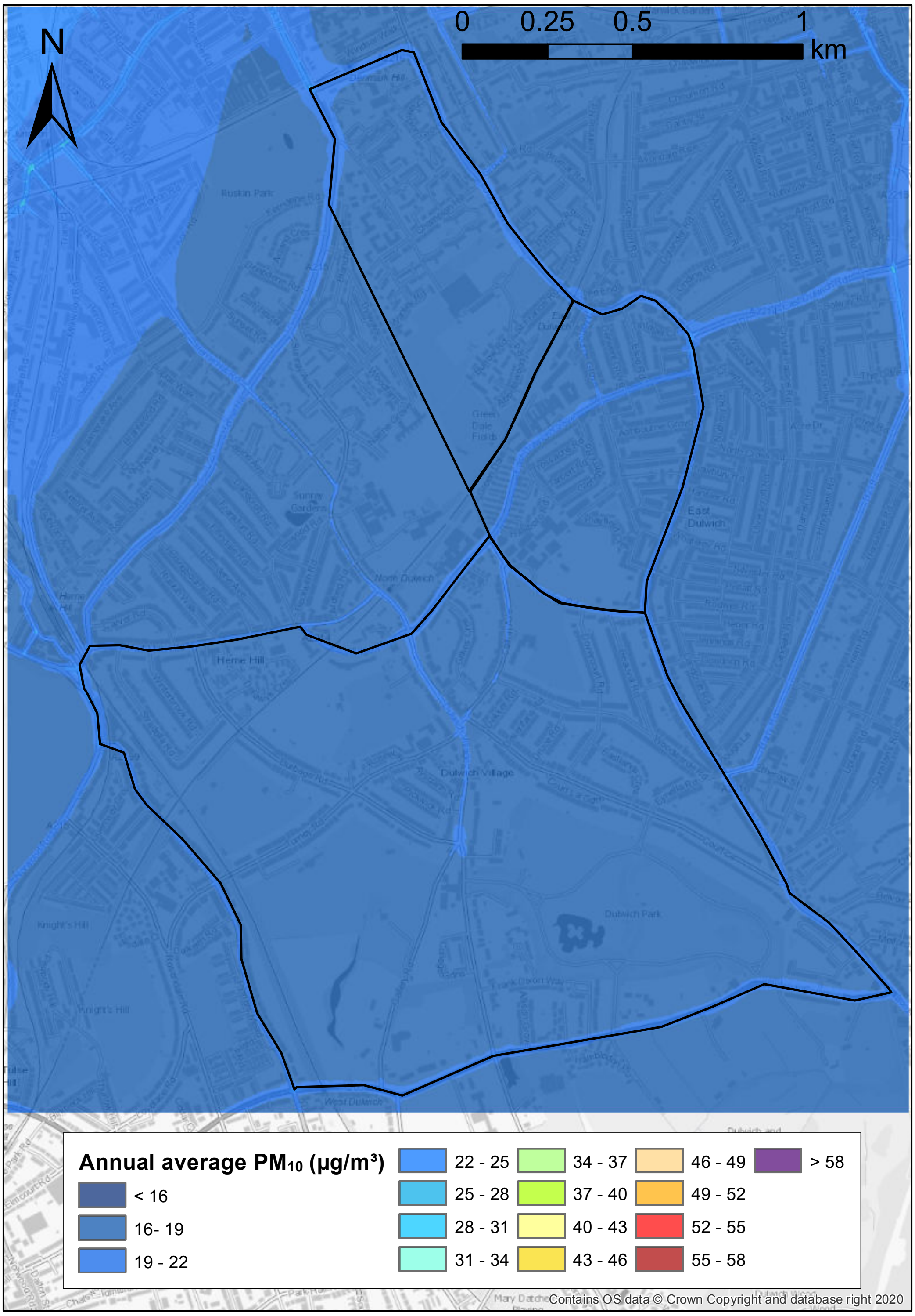

Figure 8.7: Pre-scheme annual average PM_{10} concentrations

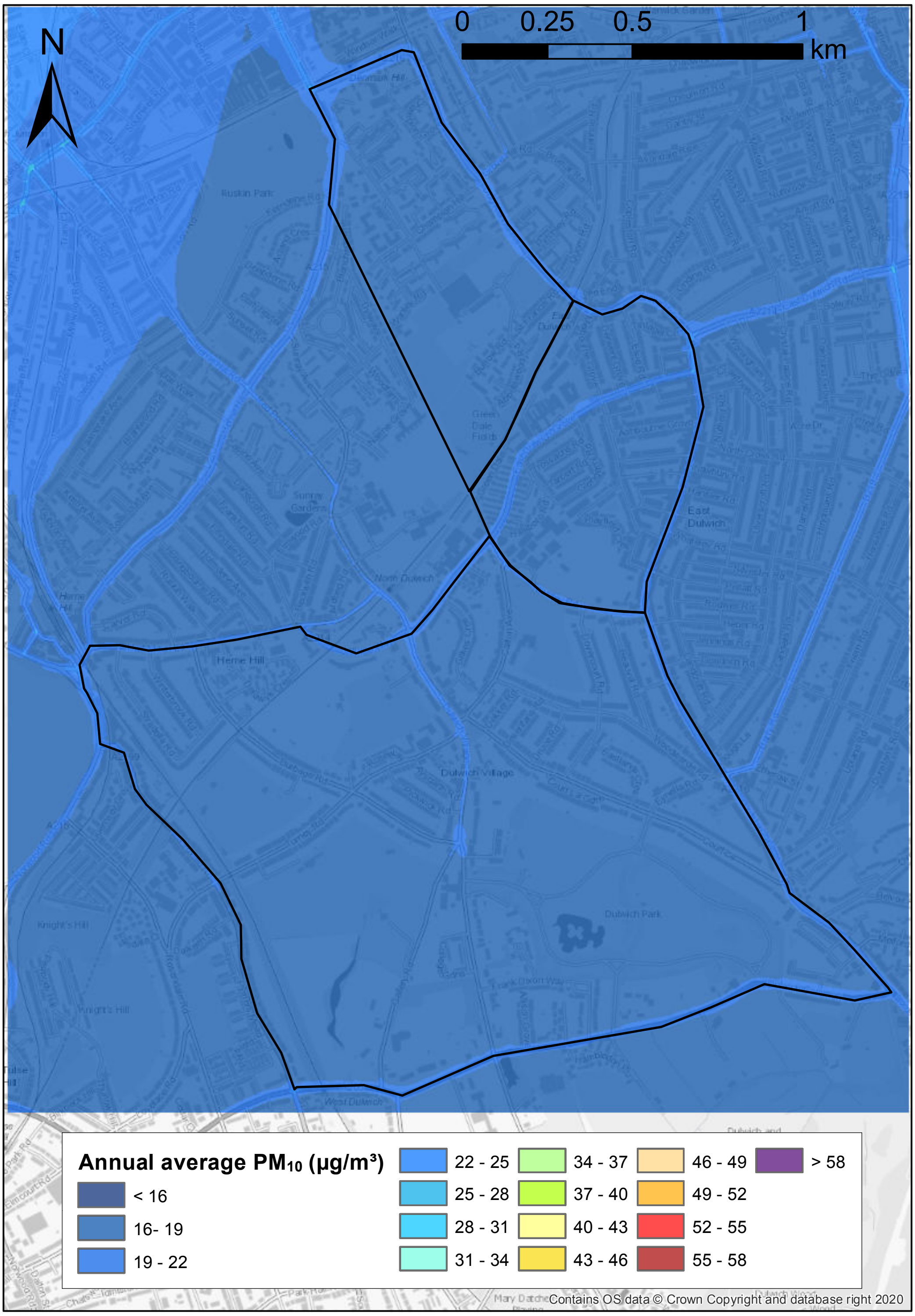

Figure 8.8: Post-scheme annual average PM_{10} concentrations

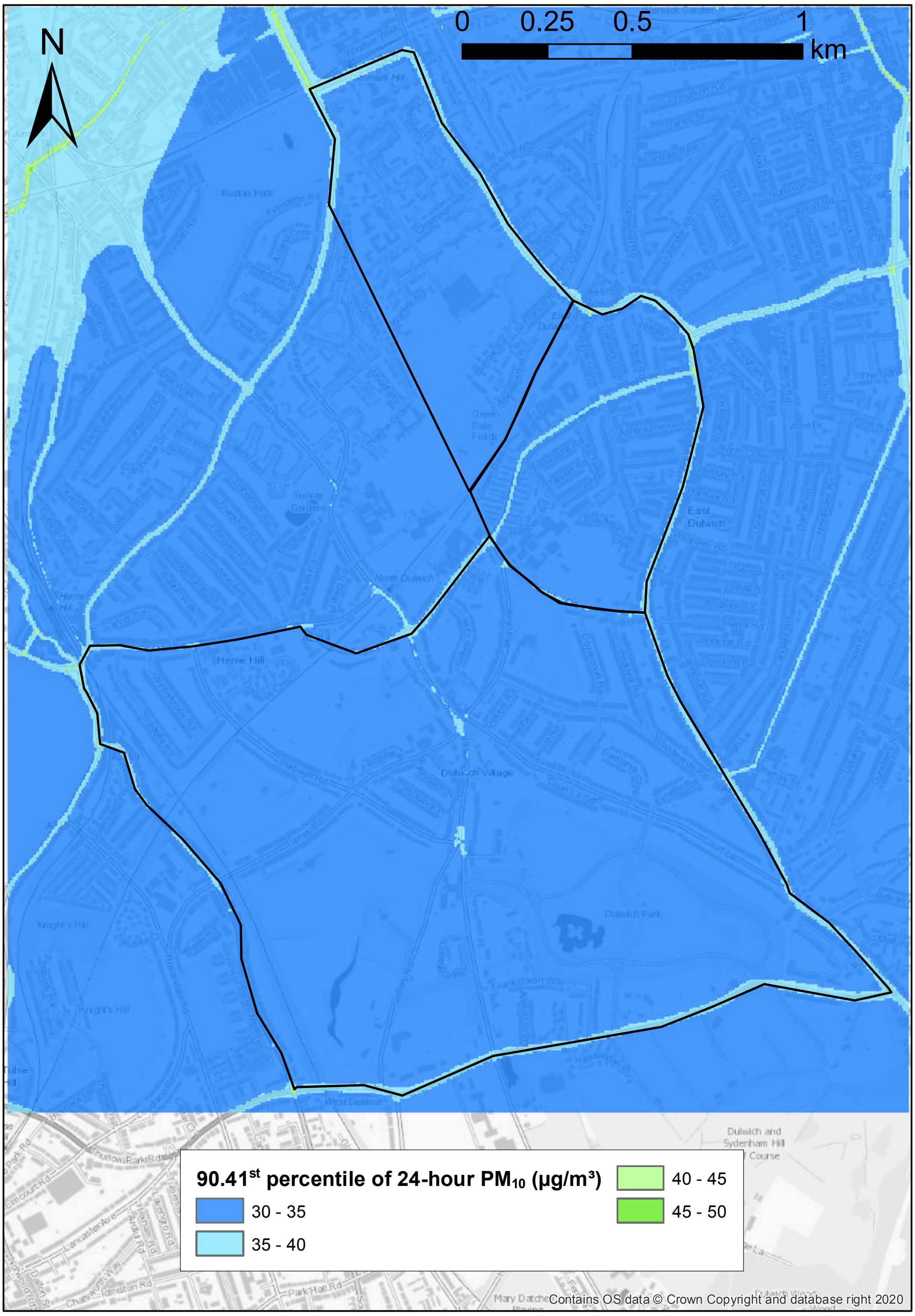

Figure 8.9: Pre-scheme 90.41st percentile of 24-hour average PM_{10} concentrations

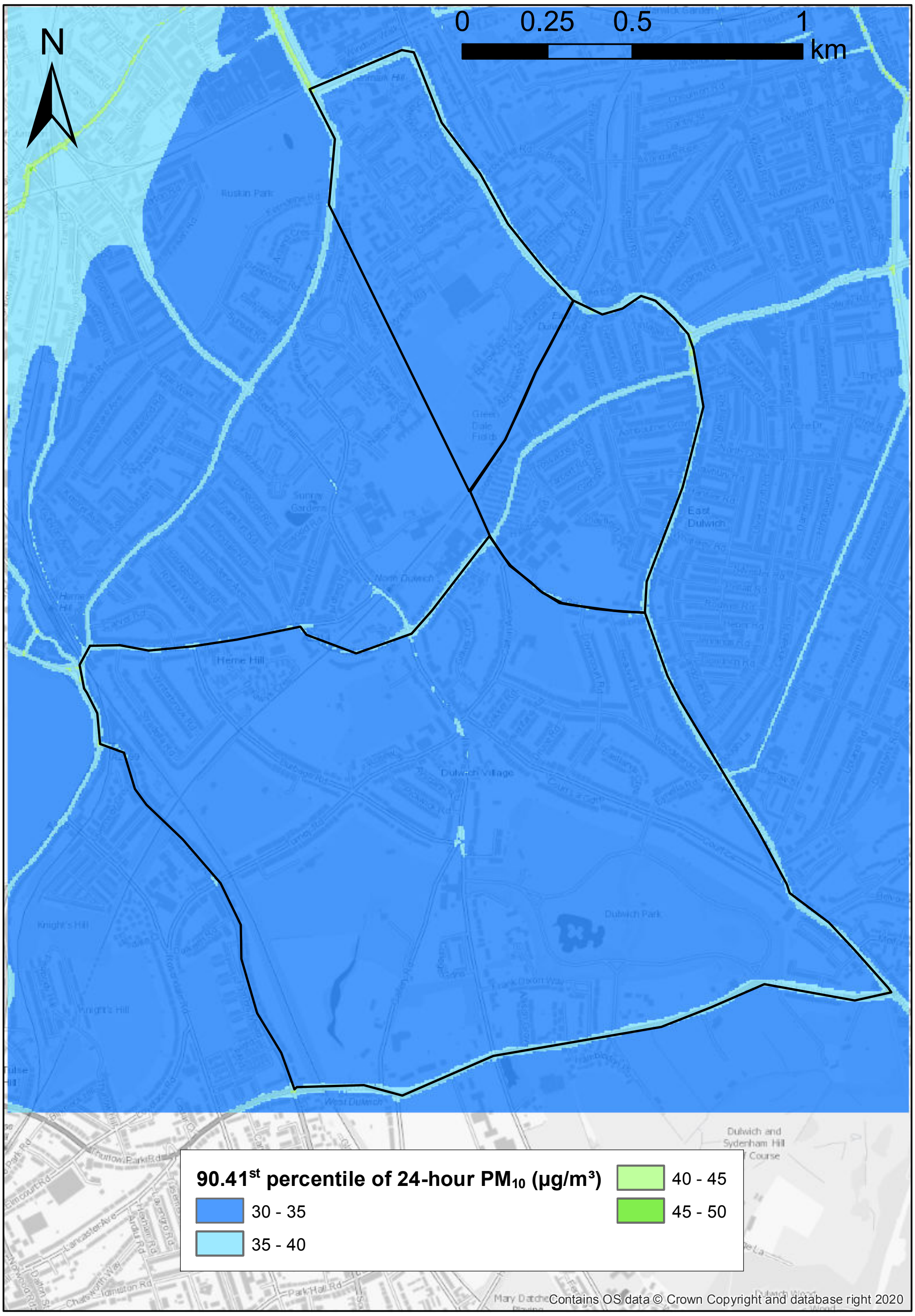

Figure 8.10: Post-scheme 90.41st percentile of 24-hour average PM_{10} concentrations

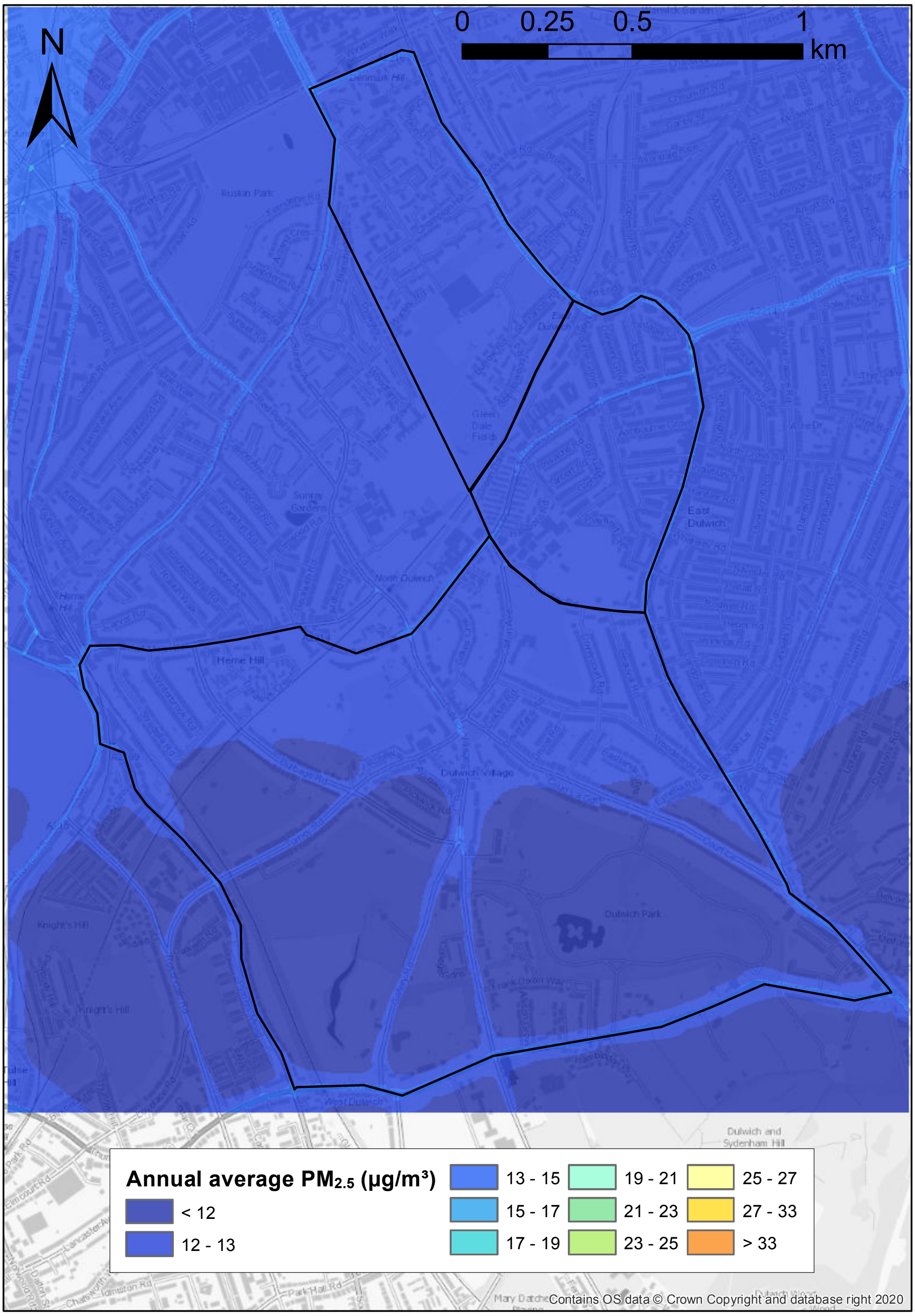

Figure 8.11: Pre-scheme annual average $PM_{2.5}$ concentrations

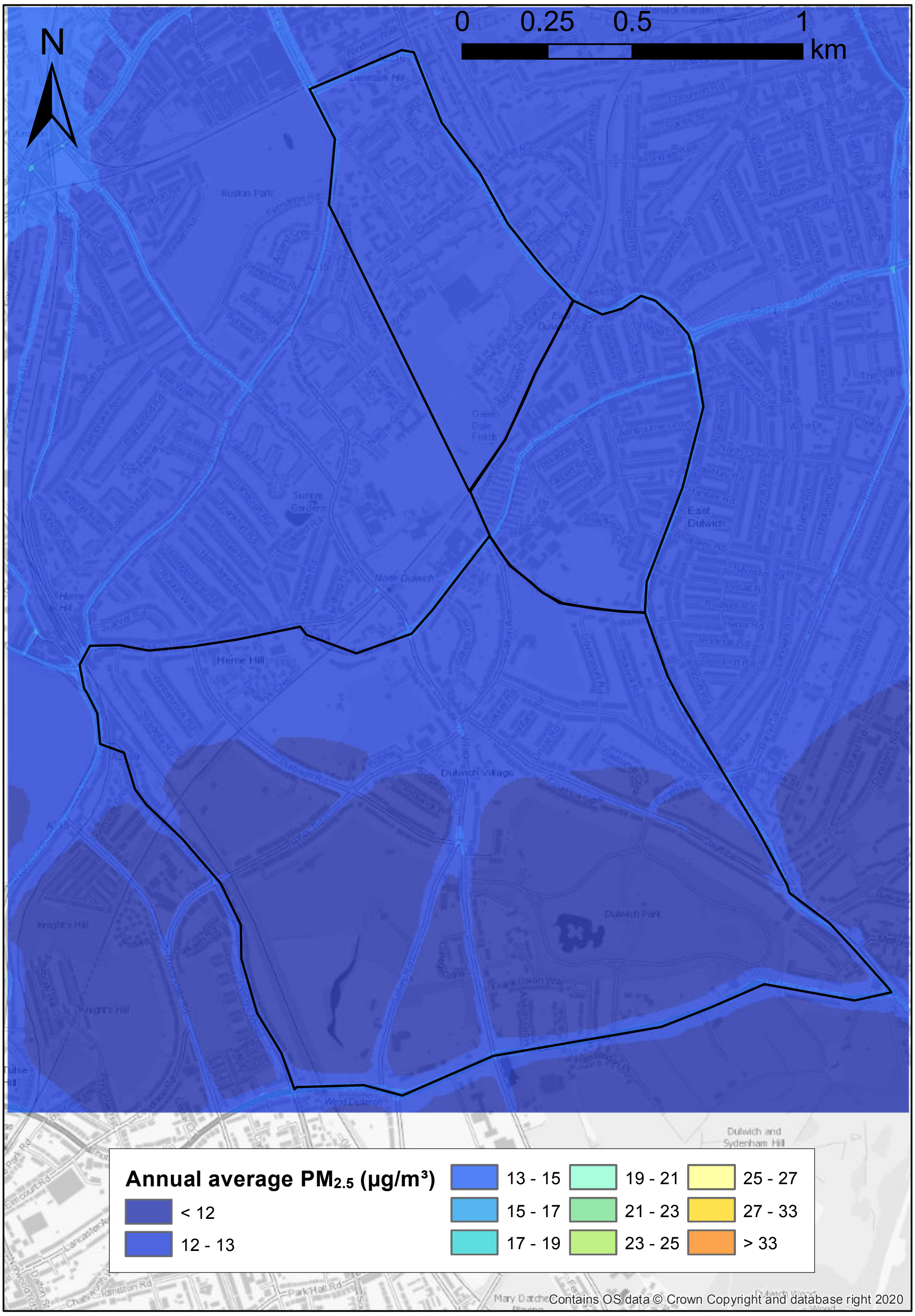

Figure 8.12: Post-scheme annual average $PM_{2.5}$ concentrations

8.3. Significance criteria maps

Figure 8.13 and Figure 8.14 show pre-scheme and post-scheme annual average NO_2 concentrations coloured by long term concentration bands used in the EPUK IAQM significance criteria described in Section 4.

A difference plot showing the predicted change in annual average NO_2 concentrations due to the scheme is shown in Figure 8.15, using a colour scale reflecting the percentage change used in the EPUK IAQM significance criteria.

This difference plot was calculated by subtracting the modelled annual average concentrations of the pre-scheme scenario from the post-scheme scenario. The resulting concentrations are shown on a map where: areas coloured purple show an increase in concentrations with the scheme in place; areas coloured blue show a decrease in concentrations; and areas with no colour show no significant change in concentrations.

Annual average NO_2 concentrations for the majority of the scheme area fall into the lowest *75% or less of AQAL* long term concentration band, the exception being some locations close to busy roads. For most of the scheme area, concentrations are predicted to change by 5% or less of the air quality objective of 40 $\mu g/m^3$. As a consequence, the impact descriptor for the scheme is classed as *Negligible* for the majority of the scheme area.

The EPUK IAQM significance criteria are intended for the assessment of air quality impacts at locations relevant for long term exposure. Therefore, the model results were used to assess the air quality impacts at ground-floor building façade locations along scheme roads. As some of these buildings may represent retail premises, not all of the building façade locations assessed will be relevant long term exposure.

Table 8.2 and Table 8.3 summarise average concentrations at building façade locations along key scheme roads. It reflects the relatively low pollution concentrations away from the kerbside of busy roads in the area. At building façade locations, increases in annual average NO_2 concentrations due to the scheme are up to 2.0 $\mu g/m^3$, or 5% of the air quality objective. Reductions in concentrations are up to 3.6 $\mu g/m^3$, or 9% of the air quality objective.

This is confirmed by Figure 8.16 which shows impact descriptors for only those building façade locations where a significant impact is predicted, i.e. locations of where the impact is negligible are omitted.

Areas where *Beneficial* or *Adverse* impacts are predicted include:

- *Moderate Beneficial and Slight Beneficial* impacts on Grove Vale, from Vale End to Elsie Road and Ondine Road to East Dulwich Road
- *Slight Beneficial* impact on Melbourne Grove, for an 80 m section of road from the junction with Grove Vale
- *Slight Beneficial* impact on Calton Avenue, from Court Lane to Woodwarde Road
- *Slight Adverse* impact on East Dulwich Grove, from Lordship Lane to Matham Grove

Due to significantly lower concentrations, relative to the relevant air quality objectives, the impact of the predicted changes in annual average PM_{10} and $PM_{2.5}$ concentrations are classed as *Negligible* throughout the scheme area.

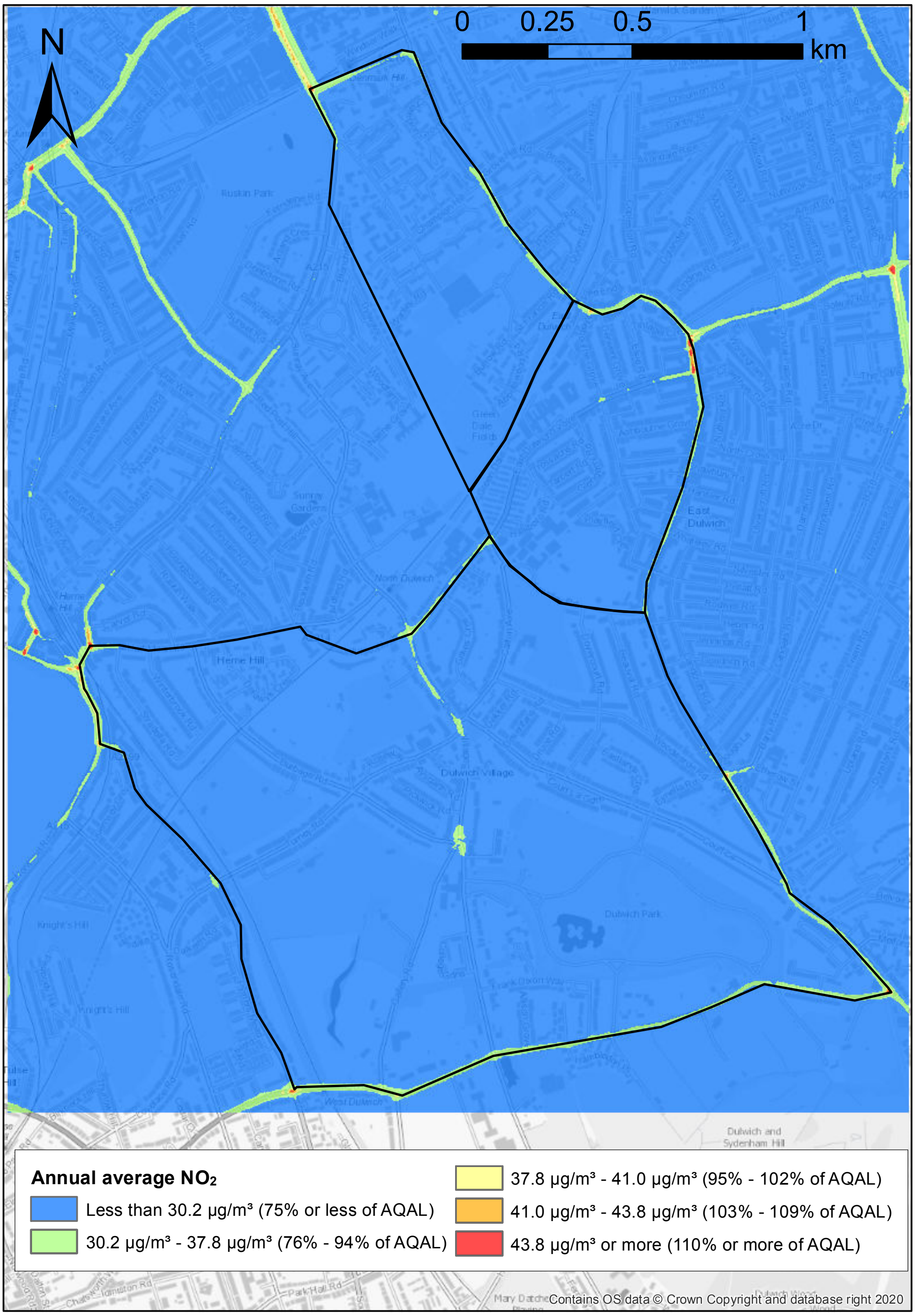

Figure 8.13: Pre-scheme annual average NO_2 concentrations categorised by AQAL levels used in EPUK IAQM significance criteria calculations

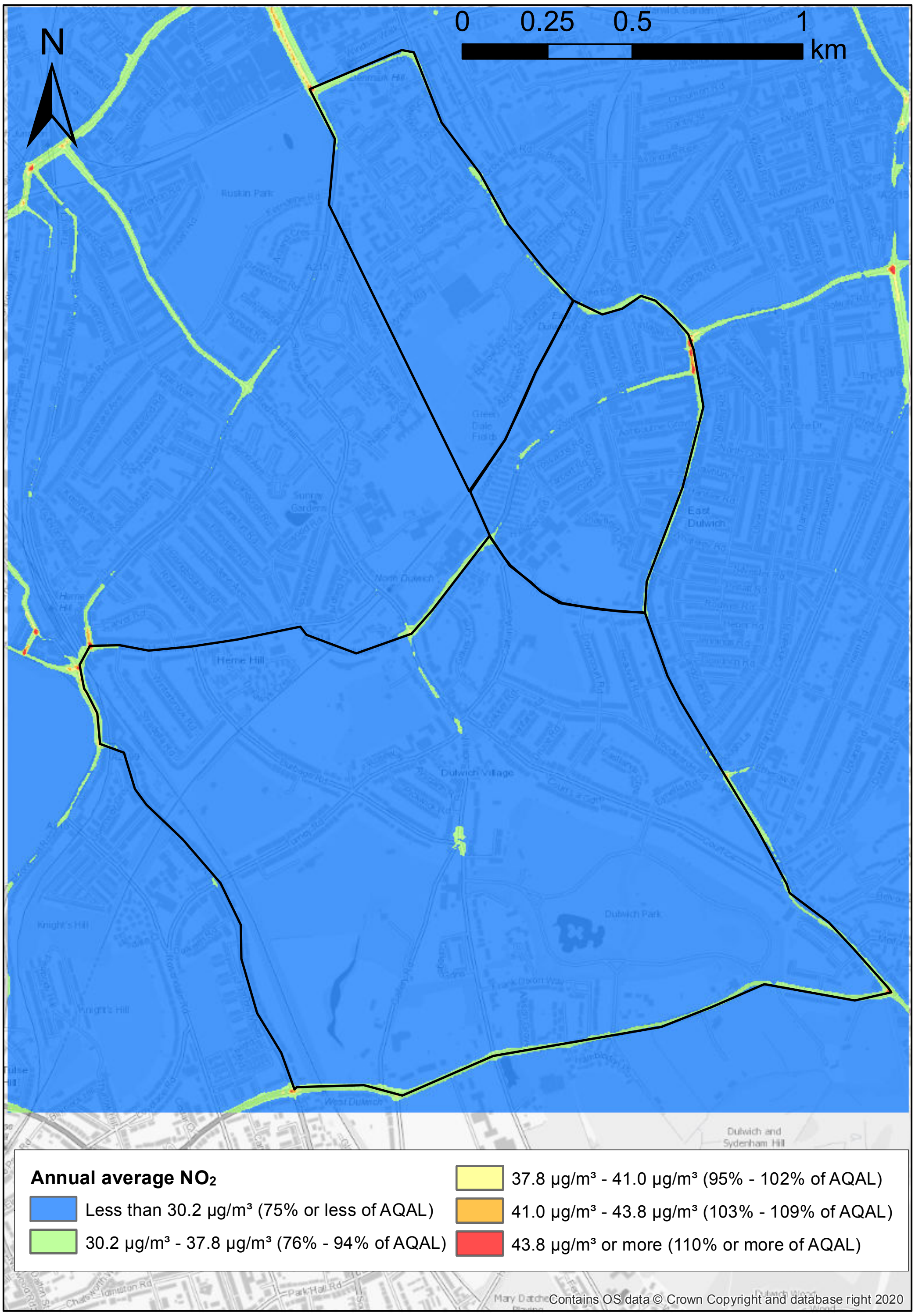

Figure 8.14: Post-scheme annual average NO_2 concentrations categorised by AQAL levels used in EPUK IAQM significance criteria calculations

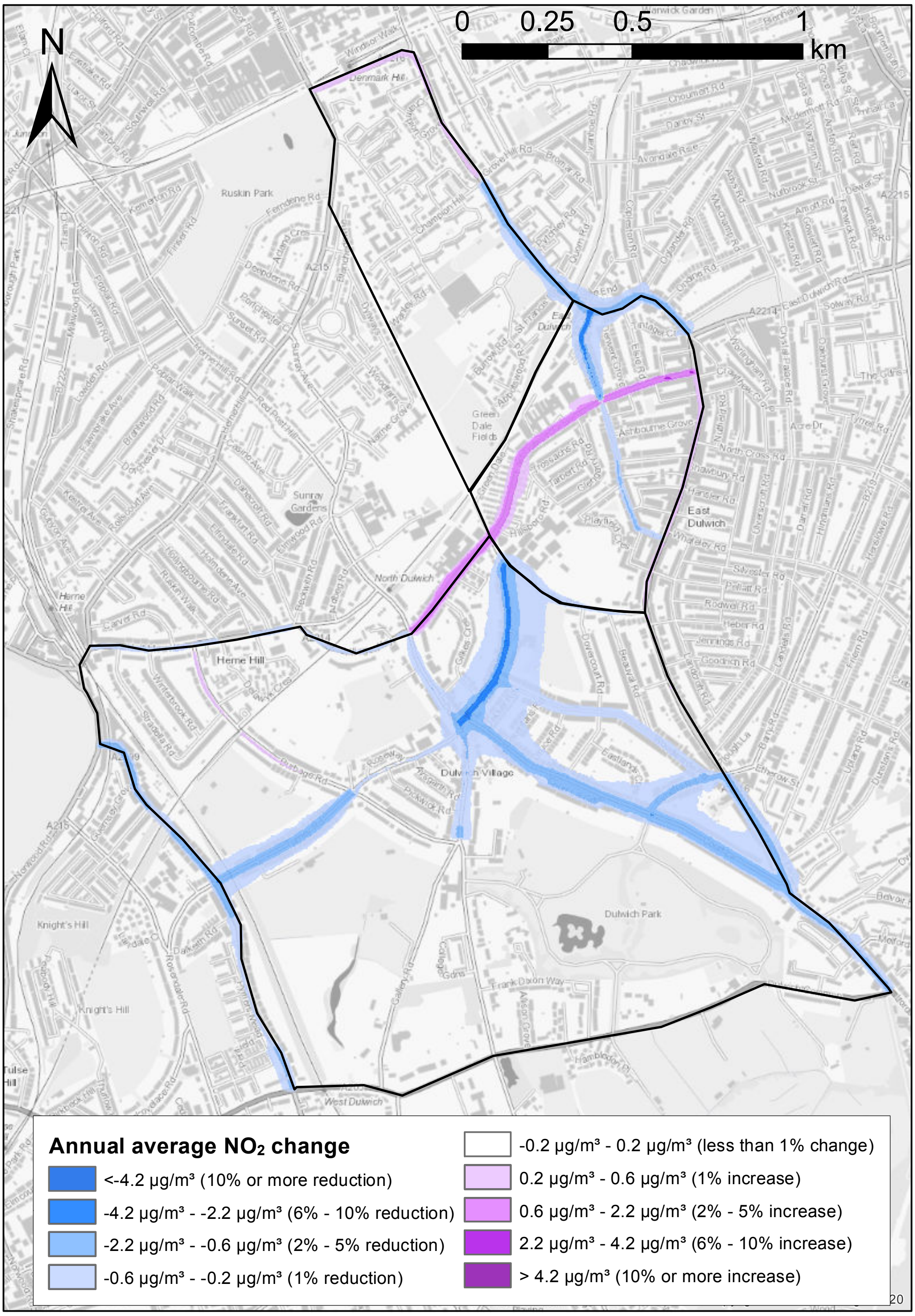

Figure 8.15: Difference plot (post-scheme minus pre-scheme) of annual average NO_2 concentrations, coloured by EPUK IAQM significance criteria concentration change bands

Table 8.2: Predicted annual average NO_2, PM_{10} and $PM_{2.5}$ concentrations at building façades along Dulwich Village, East Dulwich Grove, Half Moon Lane and Village Way

Air quality metric	Scenario	Statistic	Dulwich Village	East Dulwich Grove	Half Moon Lane	Village Way
Annual average NO_2	Pre-Scheme	Average	26.5	27.5	26.1	25.4
		Minimum	24.4	24.7	24.0	24.2
		Maximum	30.1	31.9	41.8	30.0
	Post-Scheme	Average	26.1	28.2	26.0	25.3
		Minimum	23.7	24.9	24.0	24.2
		Maximum	30.0	33.8	41.6	30.0
	Change[1]	Average	-0.4	0.8	-0.1	-0.1
		Minimum[2]	-1.8	-1.5	-0.2	-0.1
		Maximum[3]	0.4	2.0	0.0	0.0
Annual average PM_{10}	Pre-Scheme	Average	18.6	19.3	18.6	18.6
		Minimum	18.1	18.7	18.1	18.3
		Maximum	19.5	20.2	21.2	19.8
	Post-Scheme	Average	18.6	19.5	18.6	18.6
		Minimum	18.1	18.7	18.1	18.3
		Maximum	19.5	20.5	21.3	19.8
	Change[1]	Average	-0.1	0.2	0.0	0.0
		Minimum[2]	-0.4	-0.3	0.0	0.0
		Maximum[3]	0.1	0.4	0.1	0.1
Annual average $PM_{2.5}$	Pre-Scheme	Average	12.4	12.8	12.5	12.5
		Minimum	12.1	12.5	12.2	12.3
		Maximum	12.9	13.3	13.8	13.0
	Post-Scheme	Average	12.4	12.9	12.5	12.5
		Minimum	12.1	12.5	12.2	12.3
		Maximum	12.9	13.5	13.8	13.0
	Change[1]	Average	0.0	0.1	0.0	0.0
		Minimum[2]	-0.2	-0.2	0.0	0.0
		Maximum[3]	0.0	0.2	0.0	0.0

[1] Post-scheme concentrations minus pre-scheme concentrations
[2] Minimum change represents the largest reduction in pollutant concentrations
[3] Maximum change represents the largest increase in pollutant concentrations or the smallest reduction

Table 8.3: Predicted annual average NO_2, PM_{10} and $PM_{2.5}$ concentrations at building façades along Burbage Road, Croxted Road, Grove Vale and Lordship Lane

Air quality metric	Scenario	Statistic	Burbage Road	Croxted Road	Grove Vale	Lordship Lane Central[4]	Lordship Lane South[5]
Annual average NO_2	Pre-Scheme	Average	23.6	25.7	31.1	28.5	27.3
		Minimum	22.9	24.0	26.1	24.8	23.6
		Maximum	26.6	29.4	39.2	33.1	36.9
	Post-Scheme	Average	23.6	25.3	30.2	28.6	26.8
		Minimum	22.9	23.8	25.8	24.8	23.5
		Maximum	26.6	28.5	37.2	33.4	36.5
	Change[1]	Average	0.1	-0.4	-0.9	0.1	-0.5
		Minimum[2]	0.0	-1.4	-3.6	-0.4	-1.5
		Maximum[3]	0.2	-0.1	-0.2	0.4	-0.2
Annual average PM_{10}	Pre-Scheme	Average	18.0	18.5	20.3	19.8	18.9
		Minimum	17.8	17.9	18.9	18.7	17.9
		Maximum	18.6	19.6	22.5	20.9	21.2
	Post-Scheme	Average	18.0	18.3	20.2	19.8	18.8
		Minimum	17.8	17.8	18.8	18.6	17.9
		Maximum	18.7	19.2	22.2	20.9	21.1
	Change[1]	Average	0.0	-0.2	-0.1	0.0	0.0
		Minimum[2]	0.0	-0.4	-0.6	-0.2	-0.2
		Maximum[3]	0.1	-0.1	0.0	0.0	0.0
Annual average $PM_{2.5}$	Pre-Scheme	Average	12.1	12.3	13.3	12.9	12.5
		Minimum	12.0	12.0	12.6	12.4	12.0
		Maximum	12.5	12.8	14.5	13.5	13.6
	Post-Scheme	Average	12.2	12.2	13.3	12.9	12.5
		Minimum	12.0	12.0	12.6	12.4	12.0
		Maximum	12.5	12.7	14.3	13.5	13.6
	Change[1]	Average	0.0	-0.1	-0.1	0.0	0.0
		Minimum[2]	0.0	-0.2	-0.4	-0.1	-0.1
		Maximum[3]	0.0	0.0	0.0	0.0	0.0

[1] Post-scheme concentrations minus pre-scheme concentrations
[2] Minimum change represents the largest reduction in pollutant concentrations
[3] Maximum change represents the largest increase in pollutant concentrations or the smallest reduction
[4] Between East Dulwich Grove and Eynella Road
[5] Between Eynella Road and Dulwich Common

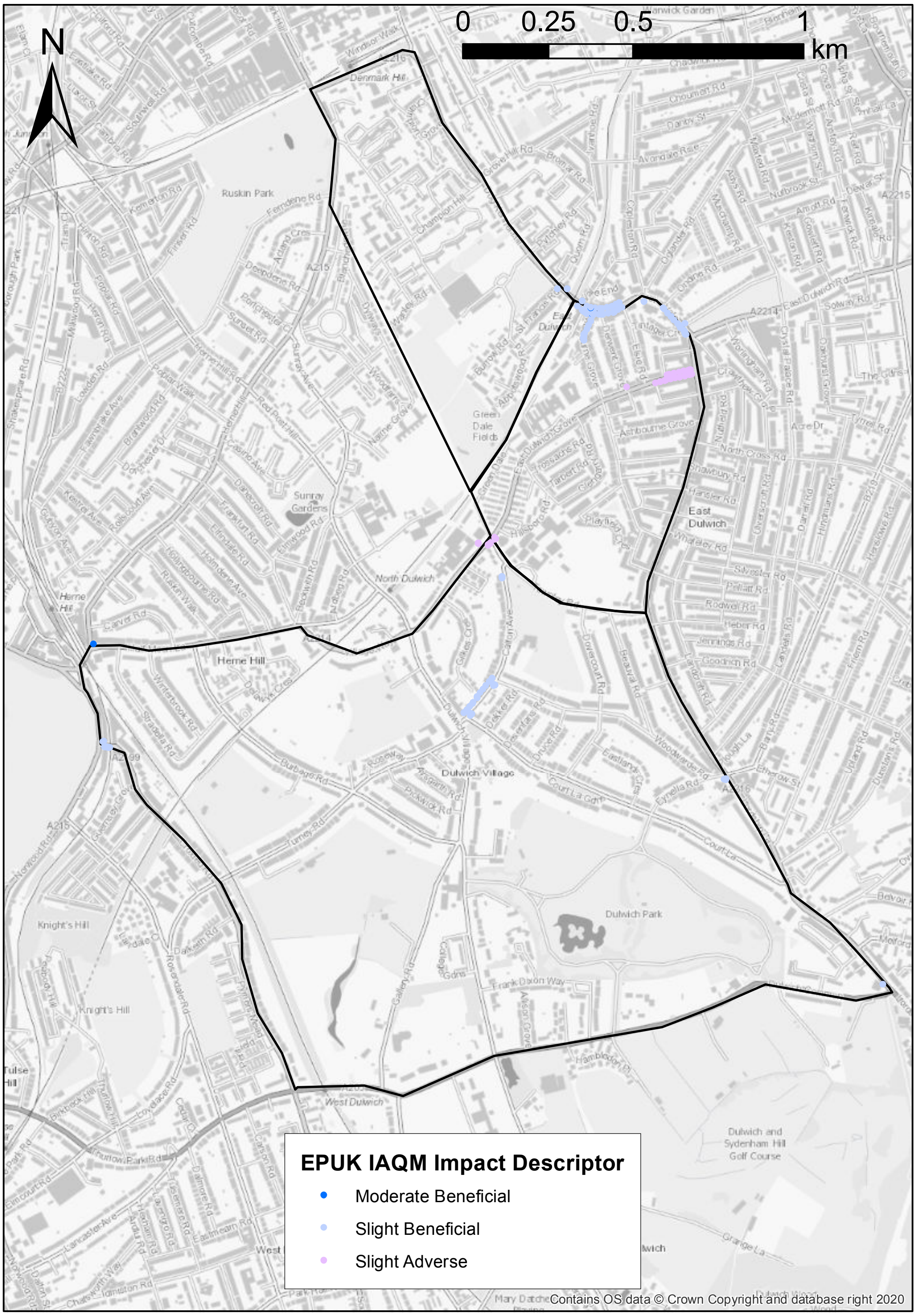

Figure 8.16: EPUK IAQM mpact descriptors for change in annual average NO_2 concnetrations at building façade locations

9. Local mortality burden of air pollution

This section summarises local mortality burden of air pollution calculations. It includes the calculation of the number of deaths attributable to air pollution, the associated life-years lost and economic cost. The calculations were carried out for the pre-scheme and post-scheme scenarios in order to estimate the health impact of the scheme.

The mortality burden is assessed using the approach set out in Appendix A of the Public Health England guidance *Estimating local mortality burdens associated with particulate air pollution (April 2014)*[16]. This guidance uses concentration response functions (CRFs) which relate the increased risk of mortality to a given change in pollutant concentrations; specifically, it assumes that an increment of 10 µg/m³ in the annual concentration of $PM_{2.5}$ will increase the mortality risk by 6%.

The mortality burden of air quality will actually be a consequence of exposure to both NO_2 and $PM_{2.5}$. The 2018 COMEAP report *Associations of long-term average concentrations of nitrogen dioxide with mortality*[17] recommends revised CRFs for anthropogenic $PM_{2.5}$ and NO_2 which are adjusted from the single-pollutant CRFs to avoid double counting air quality effects from different pollutants. The report recommends using pairs of CRFs for $PM_{2.5}$ and NO_2 taken from four studies, as shown in Table 9.1, with the results from the two pollutants added for each study.

Table 9.1: Coefficients for use in burden calculations

Pollutant	Jerrett et al (2013)	Fischer et al (2015)	Beelen et al (2014)	Crouse et al (2015)
NO_2	1.019	1.016	1.011	1.020
$PM_{2.5}$	1.029	1.033	1.053	1.019

Mortality burden calculations were carried out for Lower Layer Super Output Areas (LSOAs), each representing an area with a population of approximately 1,500. There are 14 LSOAs covering the scheme area. The Office for National Statistics (ONS) publishes population[18] and death[19] data split by age for each LSOA; data for 2019 were used for the calculations.

For each LSOA, the relative risk for each pollutant is calculated as

$$RR(c) = R^{c/10}$$

where *R* is the relative risk, as given in Table 9.1, and *c* is the average pollutant concentration for that LSOA calculated from the concentration contour maps, presented in Section 8.2.

[16] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf
[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf
[18] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates
[19] https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/009235numberofdeathsregisteredineachlowersuperoutputareabysexandagedeathsregisteredin2017

The attributable fraction is then calculated as

$$AF = (RR-1)/RR$$

The number of attributable deaths in each LSOA was then calculated by multiplying the attributable fraction by the number of deaths over 30 years of age. The total number of attributable deaths for the scheme area is the sum of the attributable deaths in each LSOA.

The total loss in life-years due to air pollution for each LSOA was calculated by multiplying the attributable deaths for each 5-year age band by the corresponding expected life expectancy for each age group. The 2017–2019 life expectancy data for Southwark were taken from the ONS[20].

The economic cost is calculated by multiplying the life-years lost by a value for a life year lost. The recommended value in the Defra guidance[21] of £42,780 at 2017 prices. The economic costs were calculated at 2017 and 2021 prices assuming a 2% annual uplift, in line with Defra recommendations for damage costs appraisals[22].

Table 9.2 summarises mortality burden estimates for the pre-scheme and post-scheme scenarios. For the scheme area between 7 and 10 deaths are attributable to air pollution, equivalent to between 132 and 164 life-years lost. The economic costs range between £5 million and £8 million.

The calculated mortality burden for the post-scheme scenario is slightly lower than the pre-scheme scenario, indicating that the scheme provides a marginal benefit of between 0.2% and 0.3%. This is a reduction in life-years lost of between 0.1 and 0.2 life-years (one to three life-months), equivalent to an economic 'saving' of between £5,000 and £9,000.

[20] https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/datasets/lifeexpectancyestimatesallagesuk
[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770649/impact-pathway-approach-guidance.pdf
[22] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance

Table 9.2: Summary of mortality burden calculations for scheme area

Scenario	Metric	Air pollution burden coefficients			
		Beelan *et al* (2014)	**Crouse *et al* (2015)**	**Fischer *et al* (2015)**	**Jerrett *et al* (2013)**
Pre-scheme	Attributable Deaths	9.54	7.75	8.45	8.74
	Life-years lost	163.7	133.2	145.2	150.1
	Economic cost (£, 2017 prices)	7,002,004	5,699,066	6,211,444	6,423,126
	Economic cost (£, 2021 prices)	7,579,194	6,168,852	6,723,467	6,952,598
Post-scheme	Attributable Deaths	9.53	7.74	8.44	8.73
	Life-years lost	163.5	133.0	145.0	150.0
	Economic cost (£, 2017 prices)	6,996,171	5,690,796	6,204,255	6,414,939
	Economic cost (£, 2021 prices)	7,572,881	6,159,901	6,715,685	6,943,737
Difference	Attributable Deaths	-0.01	-0.01	-0.01	-0.01
	Life-years lost	-0.1	-0.2	-0.2	-0.2
	Economic cost (£, 2017 prices)	-5,833	-8,269	-7,189	-8,187
	Economic cost (£, 2021 prices)	-6,314	-8,951	-7,782	-8,861

10. Discussion and conclusions

Southwark Council commissioned Cambridge Environmental Research Consultants Ltd (CERC) to carry out air quality modelling to assess the impact three Low Traffic Neighbourhoods (LTNs) in Dulwich.

Two scenarios, pre-scheme and post-scheme, were modelled to assess the current air quality impact of the Dulwich LTNs. These scenarios were based on June 2021 traffic monitoring.

Concentrations of NO_2, PM_{10} and $PM_{2.5}$ were modelled for assessment against national air quality objectives. Concentrations were calculated at school locations and on a grid of receptor points, to generate pollution maps for the scheme area.

For both scenarios, the air quality objectives are met throughout the scheme area with the exception of two small areas, predicted to exceed the air quality objective of 40 $\mu g/m^3$ for annual average NO_2 concentrations. The area exceeding is not predicted to increase in the post-scheme scenario, when compared against the pre-scheme scenario. The modelled concentrations based on 2021 traffic emissions predict smaller areas exceeding the air quality objective when compared to the 2019 baseline model.

Typically, pollution levels across the scheme are relatively low; with the exception of roadside locations concentrations are 75% or less than the air quality objectives. The largest predicted changes in concentrations due to the scheme are predicted at roadside locations; at locations relevant for long term exposure the predicted changes in concentrations are much lower.

Using the EPUK IAQM significance criteria, the predicted changes in concentrations at school locations in the scheme area are classed as *Negligible*. In addition, for the majority of building façade locations along scheme roads the predicted changes in concentrations are classed as *Negligible*. The EPUK IAQM criteria identifies four main areas where the model predicted improvement in air quality at building façades is classed as significant, and one area where the predicted worsening of air quality is classed as significant.

Air pollution mortality burden calculations estimate that the Dulwich LTN schemes have a marginal positive health impact.

APPENDIX A: Summary of ADMS-Urban

ADMS-Urban is a scientifically advanced but practical air pollution modelling tool, which has been developed to provide high resolution calculations of pollution concentrations for all sizes of study area relevant to the urban environment. 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 is used worldwide to assess air quality impact for a wide range of planning and policy studies, incorporating elements such as Low Emission Zones, traffic management, clean vehicle technologies and modal shift. In the UK, it is used extensively for air quality review and assessment carried out by local government.

The following is a summary of the capabilities and validation of ADMS-Urban. More details can be found on the CERC web site[23].

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 includes 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;
- the effects of the urban canopy on the dispersion of pollutants; and
- the effects of a building on the dispersion of pollutants emitted nearby.

Further details of these features are provided 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 runs in Windows 10 and Windows 8 environments. The manipulation of data is further facilitated by the ADMS-Urban Mapper, which allows for the visualisation and manipulation of geospatial information, and by the CERC Emissions Inventory Toolkit, EMIT.

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

Dispersion Modelling

ADMS and ADMS-Urban use boundary layer similarity profiles to parameterise the variation of turbulence with height within the boundary layer, and the use of a skewed-Gaussian distribution to determine the vertical variation of pollutant concentrations in the plume under convective conditions.

The main dispersion modelling features of ADMS-Urban are as follows:

- ADMS-Urban is an **advanced dispersion model** 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 surface. This method supersedes methods based on Pasquill Stability Categories, as used in, for example, the US models Caline and ISC. Concentrations are calculated hour by hour and are fully dependent on prevailing weather conditions.
- For convective conditions, a **non-Gaussian vertical profile of concentration** allows for the skewed nature of turbulence within the atmospheric boundary layer, which can lead to high concentrations near to the source.
- A **meteorological processor** calculates boundary layer parameters from a variety of input data, typically including date and time, wind speed and direction, surface temperature and cloud cover. Meteorological data may be raw, hourly averaged or statistically analysed data.

Emissions

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

- **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.
- **Industrial points**, for which plume rise and stack downwash are included in the modelling.
- **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

The results from the model can be based on a wide range of averaging times, and include rolling averages. Maximum concentration values and percentiles can be calculated where appropriate meteorological input data have been input to the model. 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 has an integrated Mapper which facilitates 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. ADMS-Urban can also be integrated with ArcGIS or MapInfo.

Complex Effects - Street Canyons

ADMS-Urban incorporates two methods for representing the effect of street canyons on the dispersion of road traffic emissions: a basic canyon method based on the *Operational Street Pollution Model (OSPM)*[24], developed by the Danish National Environmental Research Institute (NERI); and an advanced street canyon module, developed by CERC. The basic canyon model was designed for simple symmetric canyons with height similar to width and assumes that road traffic emissions originate throughout the base of the canyon, i.e. that the emissions are spread across both the road and neighbouring pavements.

The advanced canyon model[25] was developed to overcome these limitations and is our model of choice. It represents the effects of channelling flow along and recirculating flow across a street canyon, dispersion out of the canyon through gaps in the walls, over the top of the buildings or out of the end of the canyon. It can take into account canyon asymmetry and restricts the emissions area to the road carriageway.

Complex Effects - Chemistry

ADMS-Urban includes the *Generic Reaction Set (GRS)*[26] atmospheric chemistry scheme. The original scheme has seven reactions, including those occurring between nitrogen oxides and ozone and 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

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[24] 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.
[25] Hood C, Carruthers D, Seaton M, Stocker J and Johnson K, 2014. *Urban canopy flow field and advanced street canyon modelling in ADMS-Urban.* 16th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Varna, Bulgaria, September 2014.
http://www.harmo.org/Conferences/Proceedings/_Varna/publishedSections/H16-067-Hood-EA.pdf
[26] 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.

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[27] 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

As well as the effect that complex terrain has on wind direction and, consequently, pollution transport, it can also enhance turbulence and therefore increase dispersion. These effects are taken into account in ADMS-Urban using the FLOWSTAR[28] model developed by CERC.

Complex Effects – Urban Canopy

As wind approaches an urban area of relatively densely packed buildings, the wind profile is vertically displaced. The wind speed and turbulence levels are also reduced within the area of buildings. These effects are taken into account in ADMS-Urban by modifying the wind speed and turbulence profiles based on parameters describing the amount and size of buildings within an urban area.

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 and overseas, including London, Birmingham, Manchester, Glasgow, Riga, Cape Town, Hong Kong and Beijing, as part of projects supported by local governments and research organisations. A summary of model validation studies is available online[29]. CERC have co-authored[30] a number of papers presenting results from ADMS-Urban, and other organisations have published the outcomes of their applications of the model[31].

[27] 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.
[28] 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.
[29] www.cerc.co.uk/Validation
[30] www.cerc.co.uk/CERCCoAuthorPublications
[31] www.cerc.co.uk/CERCSoftwarePublications