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Air quality modelling
to support the Brentwood Local Plan

Final report

Prepared for
Brentwood Borough Council

8th July 2021

CERC

Report Information

CERC Job Number:	FM1322
Job Title:	Air quality modelling to support the Brentwood Local Plan
Prepared for:	Brentwood Borough Council
Report Status:	Final
Report Reference:	FM1322/R3/21
Issue Date:	8th July 2021
Author(s):	Matthew Williams
Reviewer(s):	Sarah Strickland

Issue	Date	Comments
1	28/05/21	Draft report – Phase 1
2	01/07/21	Draft report – Phase 2
3	08/07/21	Final report

Main File(s):	FM1322_Brentwood_CERC_ 08Jul21.pdf

Contents

1 Summary

Brentwood Borough Council is preparing a Local Plan to guide development in the Borough until 2033. CERC was commissioned to carry out dispersion modelling to identify the baseline air quality profile across the area and to assess air quality for a 2033 Reference Case and a 2033 Local Plan Case.

The aim of the modelling is to ascertain whether or not the development associated with the Local Plan has the potential to cause air quality issues, i.e. approaching or exceeding air quality standards for nitrogen dioxide (NO_2) or particulate matter (PM_{10} and $PM_{2.5}$).

The main source of air pollution in Brentwood is road traffic emissions from major roads. The Council has declared three Air Quality Management Areas (AQMAs) due to annual average NO_2 concentrations exceeding the Air Quality Objective.

The air quality modelling was carried out with ADMS-Urban (version 5.0) dispersion modelling software, using meteorological data from the Andrewsfield meteorological station.

Road traffic data comprised traffic counts for 2019 for major roads in the borough and modelled changes in traffic flows for the 2033 Reference and Local Plan cases. Road traffic emissions input to the dispersion model were calculated using the Emission Factor Toolkit (EFT) version 10.1, published by Defra. The EFT data were adjusted based on Remote Sensing Data to better reflect vehicle emissions in real-world conditions. Emissions data for all other sources of pollutants were taken from the NAEI.

Detailed model verification was carried out by comparing modelled concentrations against monitored data across Brentwood for the year 2019, with iterative improvements to the model set-up to ensure acceptable agreement between modelled and monitored concentrations.

The model verification showed generally good agreement between measured and modelled concentrations, with modelled annual average NO_2 concentrations falling within 10% of the measured values at 58% of the monitoring sites, and within 25% of the measured values at 91% of the monitoring sites.

For the 2019 baseline, with the exception of some locations close to major roads, the air quality objectives are met throughout the borough. There are modelled exceedences of the annual mean NO_2 objective of 40 $\mu g/m^3$ along the M25, the A12, the A127 and at Wilson's Corner. Exceedences of short-term NO_2 and PM_{10} and $PM_{2.5}$ objectives are less extensive.

Between 2019 and 2033, emissions from vehicle exhausts are expected to decrease due to improving vehicle technology, with a corresponding reduction in background concentrations. However, for PM_{10} and $PM_{2.5}$ the majority of emissions from road traffic is due to non-exhaust emissions, namely brake, tyre and road-wear. Non-exhaust emissions are related to vehicle sizes, numbers and speed, and are therefore expected to increase as traffic grows.

By 2033, concentrations of NO_2 are expected to decrease compared to 2019 levels. In particular, all exceedences of the Air Quality Objectives for NO_2 concentrations are predicted to disappear. PM_{10} and $PM_{2.5}$ concentrations away from major roads are predicted to decrease but, along major roads, concentrations are predicted to remain similar to 2019 levels; the extent of exceedences of the objectives for PM_{10} and $PM_{2.5}$ concentrations is not predicted to change significantly.

The addition of emissions from vehicles and domestic and commercial combustion due to the Local Plan developments increases concentrations slightly along the main roads, in particular along the A127. Assessment of the significance of these changes using the IAQM guidance shows that the changes are *negligible* at all locations with relevant exposure. The impact in intervening years may vary depending on when each development is completed and other local factors.

For 2019, air pollution is estimated to cost between about 500 and 700 life years in the borough. In 2033, this has reduced to between about 375 and 600 life years, with no significant difference between the reference case and the Local Plan case.

2 Introduction

Brentwood Borough Council (the Council) is preparing a Local Plan to guide development in the Borough until 2033.

The main source of air pollution in Brentwood is road transport from major roads; implementation of a Local Plan can lead to changes in the magnitude and location of these emissions. CERC was commissioned to carry out air dispersion modelling to identify the baseline air quality profile across the area and to assess air quality for a 2033 Reference Case and a 2033 Local Plan Case.

The aim of the modelling is to ascertain whether or not the development associated with the Local Plan has the potential to cause air quality issues, i.e. approaching or exceeding air quality objectives for nitrogen dioxide (NO_2) or particulate matter (PM_{10} and $PM_{2.5}$).

The air quality objectives with which the calculated concentrations are compared are presented in Section 3. Section 4 describes the modelled area and summarises local air quality across Brentwood. The model setup and emissions data are described in Sections 5 and 6, respectively.

The results of the modelling are then presented: the model verification in Section 7; and baseline concentrations in Section 8. Section 9 presents the modelled concentrations for 2033 and Section 10 shows the results of the mortality burden calculations. A discussion of the results is presented in Section 11 and a summary of the ADMS-Urban model is included as Appendix A.

3 Air quality standards and guidance

3.1 Air quality standards for the protection of human health

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 NO_2, PM_{10} and $PM_{2.5}$ Air Quality Objectives are presented in Table 3.1.

Table 3.1: Air quality objectives (µg/m³)

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

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 200µg/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.

Table 3.2 gives examples from the Defra TG(16) guidance of where the air quality objectives should apply.

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

Table 3.2: Examples of where the Air Quality Objectives should apply

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, hospitals, care homes etc	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties Kerbside sites (as opposed to locations at the building 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.	Kerbside sites where the public would not be expected to have regular access.

3.2 Significance Criteria

The significance of the air quality impacts as a result of the Local Plan was assessed using The Environmental Protection UK (EPUK) and Institute of Air Quality Management (IAQM) guidance for Land-Use Planning & Development Control[2].

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 3.1 (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.

Table 3.3: 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

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

4 Modelled area

4.1 Local air quality

The Local Air Quality Management (LAQM) process, as set out in Part IV of the Environment Act (1995), the Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007 and the relevant Policy and Technical Guidance documents places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the Air Quality Objectives are likely to be achieved. Where exceedences are considered likely, the local authority must then declare an Air Quality Management Area (AQMA) and prepare an Air Quality Action Plan (AQAP) setting out the measures it intends to put in place in pursuit of the objectives.

Brentwood Council has declared three AQMAs due to high NO_2 concentrations:

- AQMA 2: Parts of Brook Street, Brentwood and the A12.
- AQMA4: Parts of Warescot Road, Hurstwood Avenue and Ongar Road, Brentwood and the A12.
- AQMA7: Parts of Ongar Road, Ingrave Road, High Street and Shenfield Road, Brentwood in proximity to Wilsons Corner (the junction of the A128 and A1203).

Concentrations of NO_2 in the borough are measured using 33 diffusion tubes; the locations of these monitors are shown in Figure 4.1.

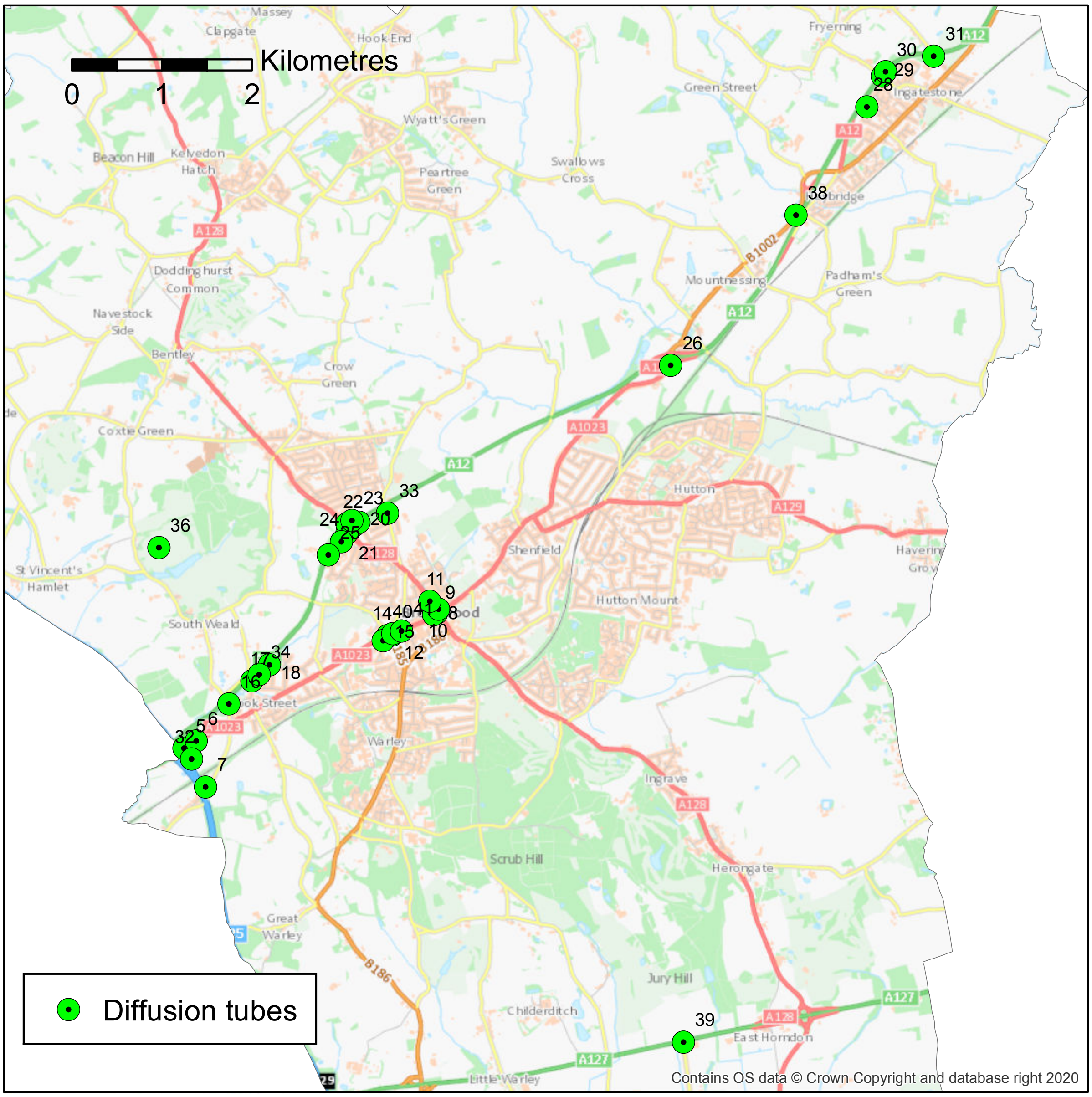


Figure 4.1: Diffusion tubes in Brentwood

Table 4.1 presents the monitored annual average NO_2 concentrations for Brentwood in 2018 and 2019. Exceedences of the Air Quality Objective of 40 µg/m³ for annual average NO_2 concentrations are highlighted in **bold**.

Monitoring data presented in this section was provided by Brentwood Council, with diffusion tube concentrations presented as bias-adjusted values.

Table 4.1: Monitored annual average NO_2 concentrations at Brentwood, 2018 and 2019

Site ID	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m³)	
				2018	2019
BRW 5	Telegraph pole at end of Brook Street	2.5	1.3	39.6	**42.1**
BRW 6	Freeway Cottage, 63 Brook Street	2.5	1.3	34.2	32.6
BRW 7	13 Nags Head Lane - on fence trellis	2.5	15.6	25.1	23.8
BRW 8	3 High Street - front facade	2.5	9.8	33.9	35.1
BRW 9	Caffe Uno, High Street - front facade	2.5	8.1	31.9	31.0
BRW 10	5/7 Ongar Road - lamp-post	2.5	3.2	36.4	33.6
BRW 11	36 Ongar Road - front facade	2.5	5.7	31.1	30.5
BRW 12	Corner of Kings Road/Hart Street/High Street	2.5	2.1	26.9	26.2
BRW 14	145 High Street - front facade	2.5	2.6	31.9	29.6
BRW 15	4 Westbury Road - downpipe on corner of house	2.5	6.9	20.5	19.7
BRW 16	24 Wingrave Crescent - rear boundary fence	2.5	25.1	28.1	27.3
BRW 17	51 Spital Lane - side garden	2.5	9.3	26.0	26.6
BRW 18	46 Selwood Road - rear garden tree stump	2.5	20	23.4	22.5
BRW 19	61 Warescot Road - front facade	2.5	10.4	26.8	26.7
BRW 20	76 Warescot Road - lamp-post	2.5	0.2	32.3	31.9
BRW 21	316 Ongar Road - side gatepost	2.5	8.2	23.7	23.7
BRW 22	339 Ongar Road - front facade	2.5	7.1	30.3	30.0
BRW 23	12 Hurstwood Avenue - front facade	2.5	8.2	33.3	33.5
BRW 24	Highwood Close - lamp-post	2.5	1	23.8	24.6
BRW 25	65 Greenshaw - lamp-post	2.5	21.4	28.5	26.7
BRW 26	289 Chelmsford Road - telegraph pole	2.5	2.1	26.4	26.7
BRW 28	Ingatestone Junior School, The Furlongs - playground pergola	2.5	37	28.3	28.4
BRW 29	1 Trimble Close - lamp-post	2.5	11	24.6	24.5
BRW 30	8 Trimble Close - rear facade	2.5	9.5	26.4	26.9
BRW 31	New Road, Ingatestone - telegraph pole	2.5	18.7	28.3	25.9
BRW 32	The Poplars, Brook Street	2.5	45	29.7	28.5
BRW 33	108 Doddinghurst Road - front facade	2.5	16.3	22.1	22.6
BRW 34	La Clarentet, Talbrook - carport	2.5	2.7	22.9	23.4
BRW 36	Lincolns Lane - background	2.5	0.6	15.9	16.0
BRW 38	58 Roman Road	2.5	26.3	18.5	19.1
BRW 39	Thorndon Avenue/A127	2.5	2.2	27.1	25.7
BRW 40	131 High St - lamp-post	2.5	1	39.2	36.9
BRW 41	88 High St - lamp- post	2.5	1	39.2	38.4

5 Air quality modelling

5.1 Modelling software

All modelling was carried out using ADMS-Urban[3] version 5.0, developed by CERC. This model allows the effects of wider urban areas on local air quality to be taken into account.

5.2 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 roughness length of 0.5m was used for the dispersion site throughout the modelling, representing open suburbia.

The difference in land use at the meteorological station compared to the study area was taken into account by entering a different surface roughness for the meteorological station. See Section 0 for further details.

5.3 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 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. 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 minimum Monin-Obukhov length of 30 m was used in the modelling.

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

5.4 Meteorological data

A year of hourly sequential meteorological data measured at Andrewsfield, approximately 30 km north of Brentwood, for the year 2019, was used for model verification and subsequent modelling.

Table 5.1 summarises the meteorological data from Andrewsfield. To take account of the different surface characteristics at Andrewsfield, compared to the modelled area, a surface roughness of 0.1 m was assumed for the meteorological station.

Table 5.1: Summary of meteorological data

Year	% of hours used	Parameter	Minimum	Maximum	Mean
2019	98.7	Temperature (°C)	-6.2	34.5	10.6
		Wind speed (m/s)	0	17.5	4.1
		Cloud cover (oktas)	0	8	4.5

The ADMS meteorological pre-processor, written by the UK Met Office, uses the data provided to calculate the parameters required by the program. Figure 5.1 presents a wind rose showing the frequency of occurrence of wind from different directions for a number of wind speed ranges for Andrewsfield.

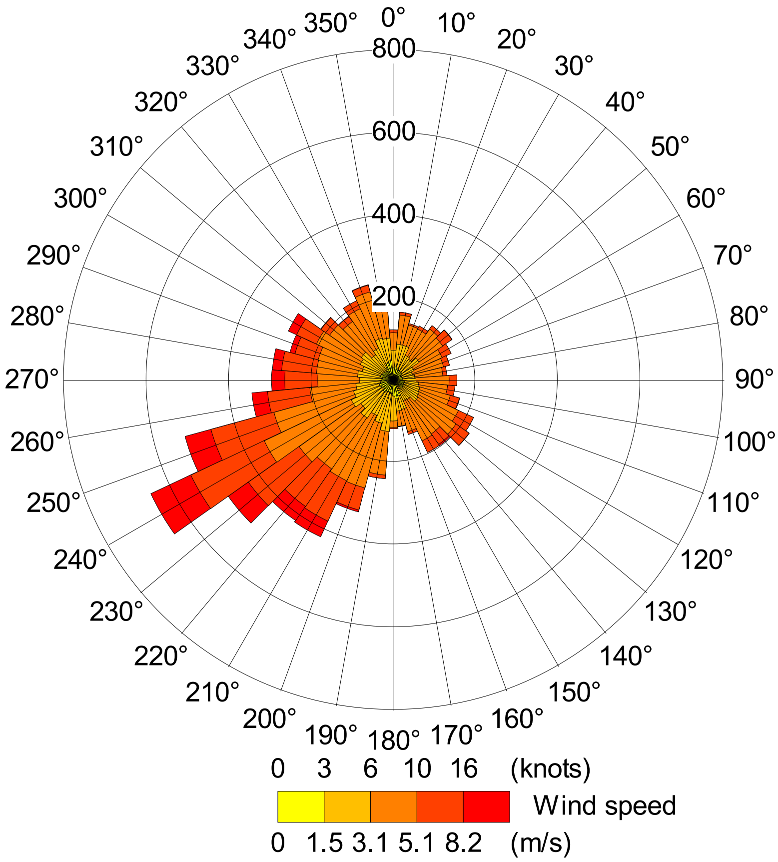


Figure 5.1: Wind rose for Andrewsfield 2019

5.5 Chemistry

The ADMS-Urban explicit chemistry scheme was used to model the interconversion between NO and NO_2, using wind dependent background concentrations derived from AURN rural monitoring sites. This approach allows for direct model verification against monitored concentrations for NO_x and NO_2, with simultaneous consideration of source dependent primary NO_2.

5.6 Background data

Hourly background data for the modelled pollutants and sulphur dioxide and ozone were input to the model to represent the concentrations in the air being blown into the area. NO_x, NO_2, SO_2, PM_{10}, $PM_{2.5}$ and O_3 concentrations from Rochester Stoke, Wicken Fen, Breckland East Wretham for 2019 were input to the model, the monitored concentration used for each hour taken from the upwind monitoring site. The monitoring sites used for each wind direction are given in Table 5.2.

Table 5.2: Background monitoring site used for each wind direction

Wind direction	NO_x, NO_2, SO_2 & O_3	PM_{10}	$PM_{2.5}$
100° – 270°	Rochester	Rochester	Rochester
280° - 90°	Wicken Fen	Breckland	Rochester

Projections of background concentrations for 2033 were based on Local Air Quality Management background air pollution maps, published by Defra[4]. The maps provide annual average background concentrations on a 1 km by 1 km grid square basis, with projections up to the year 2030. The 2030 background maps were used to project the 2019 background concentrations to the year 2033 at each of the monitoring sites.

Table 5.3 summarises the annual statistics for background data used for the modelling, calculated using wind data from Andrewsfield.

Table 5.3: Summary of background data used in the modelling (µg/m³)

Year	Statistic	NO_x	NO_2	O_3	PM_{10}	$PM_{2.5}$	SO_2
2017	Annual average	14.1	11.0	52.5	14.4	10.8	2.4
	99.79th percentile of hourly average	138.7	67.4	150.6	-	-	-
	90.41st percentile of 24-hour average	-	-	-	25.4	22.5	5.8
2019	Annual average	10.0	7.9	55.1	13.3	9.9	2.4
	99.79th percentile of hourly average	105.2	53.1	153.1	-	-	-
	90.41st percentile of 24-hour average	-	-	-	23.4	21.2	5.8

[4] https://uk-air.defra.gov.uk/data/laqm-background-home

5.7 Street canyons

The advanced street canyon module option in ADMS-Urban was used to modify the dispersion of pollutants from a road source according to the presence and properties of canyon walls on one or both sides of the road. Building footprint and height information was taken from OS Mastermap data. Some additional barriers were added to the Mastermap data, for instance fences along some of the main roads which would affect the dispersion of pollutants.

6 Emissions

Emission inventories were compiled for each of the scenarios modelled, using CERC's EMIT[5] emissions inventory tool, version 3.7.

6.1 Road transport

Emissions from road transport were calculated using an activity data approach, whereby Annual Average Daily Traffic flows (AADTs) for each road link were combined with emission factors and speed data to calculate emissions for each road link on a vehicle-by-vehicle basis. This methodology is described below.

6.1.1 Emission factors

Traffic emissions of NO_x, NO_2, PM_{10} and $PM_{2.5}$ were calculated from traffic flows using EFT v10.1 emission factors based on Euro vehicle emissions categories. This dataset includes speed-emissions data that are based COPERT 5.3[6] emission factors. EFT v10.1 include exhaust, brake, tyre and road wear for PM_{10} and $PM_{2.5}$; resuspension emission factors were taken from a report produced by TRL Limited on behalf of Defra[7]. The vehicle fleet compositions in the EFT only extend up to the year 2030; the emissions calculations used for these calculations were the England Urban vehicle fleet compositions for 2019 and 2033 included in the EFT.

Note that there is large uncertainty surrounding the current emissions estimates of NO_x from all vehicle types, in particular diesel vehicles. In order to address this discrepancy, the NO_x emission factors were modified based on published Remote Sensing Data (RSD)[8] for vehicle NO_x. Scaling factors were applied to each vehicle category and speed.

6.1.2 Traffic flows

6.1.3 2019 traffic flows

For the 2019 base year, traffic flows were taken from traffic counts carried out by the Department for Transport (DfT), Highways England and Brentwood Borough Council. The locations of these counts are shown in Figure 6.1. These were supplemented with data from the London Atmospheric Emissions Inventory for the roads on the western edge of the borough. Where there were gaps in the data coverage, estimates of traffic flows were made based on the

[5] http://cerc.co.uk/environmental-software/EMIT-tool.html
[6] http://www.emisia.com/copert/General.html
[7] 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
[8] 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.

traffic flows on neighbouring roads. Figure 6.2 shows a map of the modelled roads with the thickness of the roads scaled by annual average daily total (AADT) traffic flow.

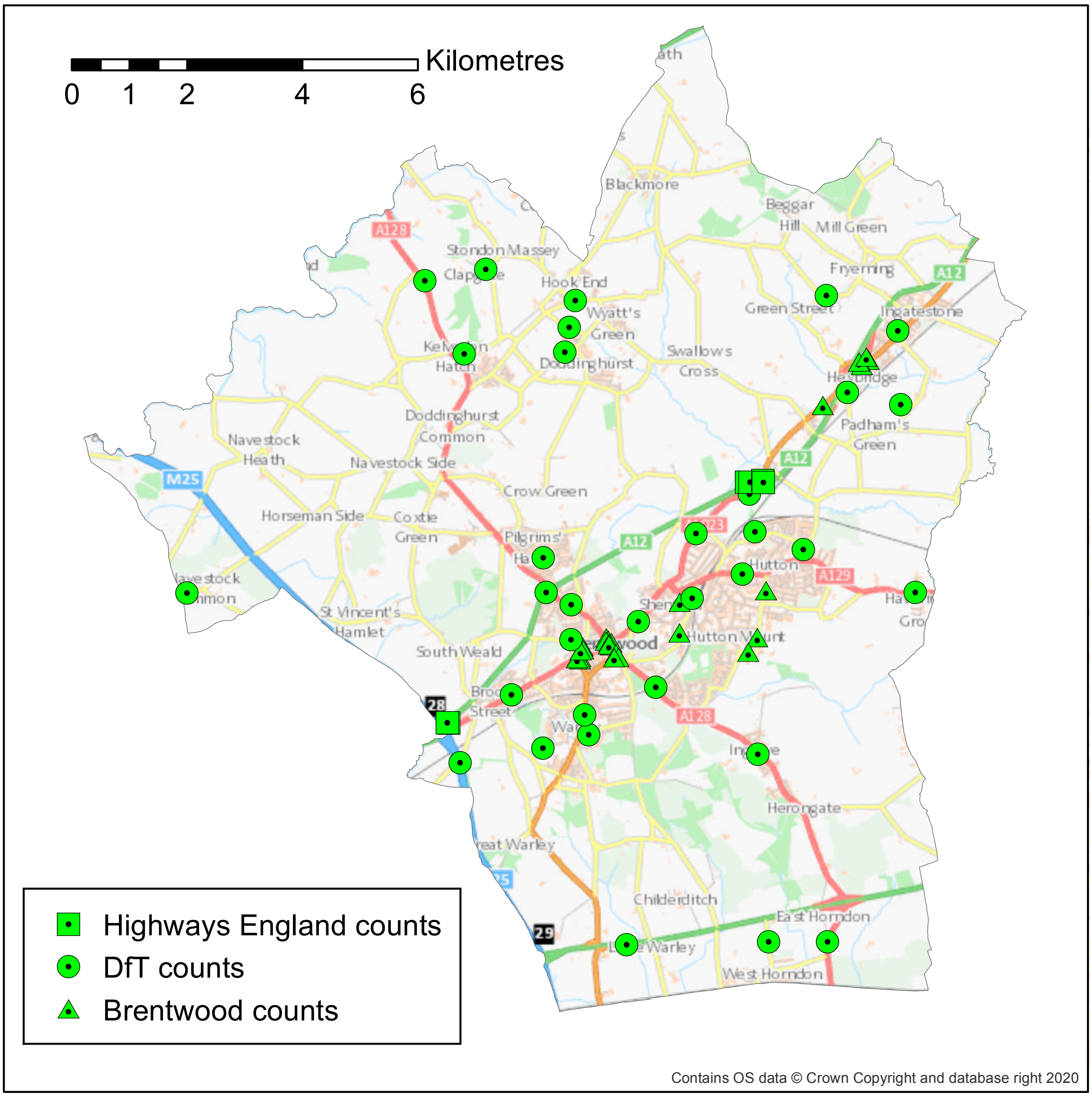


Figure 6.1: Traffic count locations

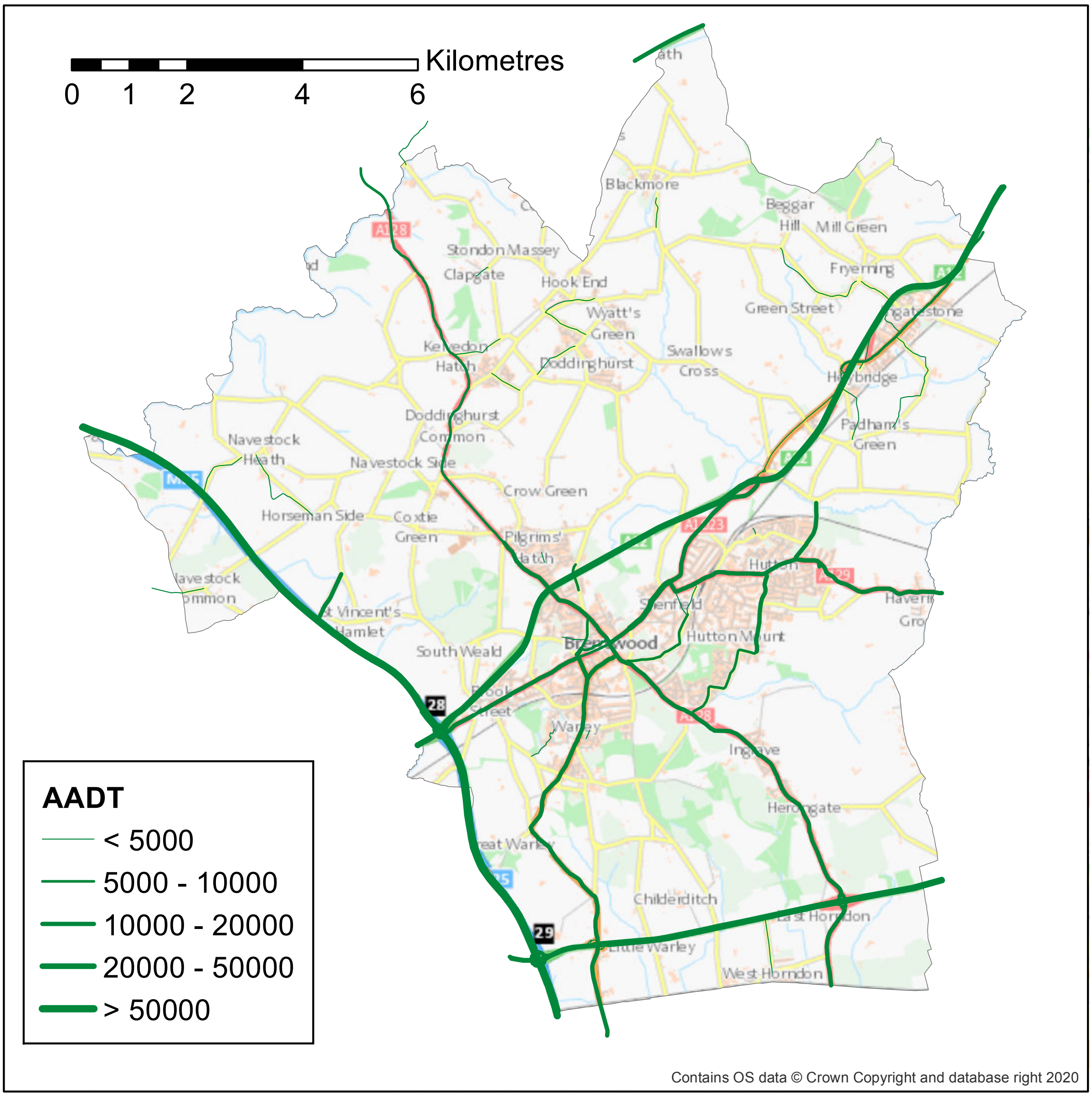


Figure 6.2: Annual average daily total traffic flows for 2019 baseline

6.1.4 2033 traffic flows

Two sets of traffic flows were provided for 2033:

- The increase in traffic between 2019 and the 2033 reference case; and
- The increase in traffic flows due to the Local Plan policies.

The data were provided in the form of AM and PM peak total flows. These were converted to AADTs using the daily profile described in Section 6.1.6. The breakdown of traffic flows by vehicle type was assumed to be the same as for 2019.

The traffic data for 2033 included traffic counts for all major roads in the borough; not all of these roads had data available for 2019. Only those roads for which data were available for both 2019 and 2033 were modelled explicitly; the change in total traffic emissions on these roads was applied to the gridded minor road emissions (see Section 6.2) to represent the growth in traffic on the rest of the road network.

6.1.5 Traffic speeds

Average traffic speeds were taken from the data provided for the future baseline scenario. Speeds were provided for each direction; the average of the speeds in each direction was used in the modelling. The speeds were assumed to remain the same for all modelled scenarios. Figure 6.3 shows the average speeds used in the modelling.

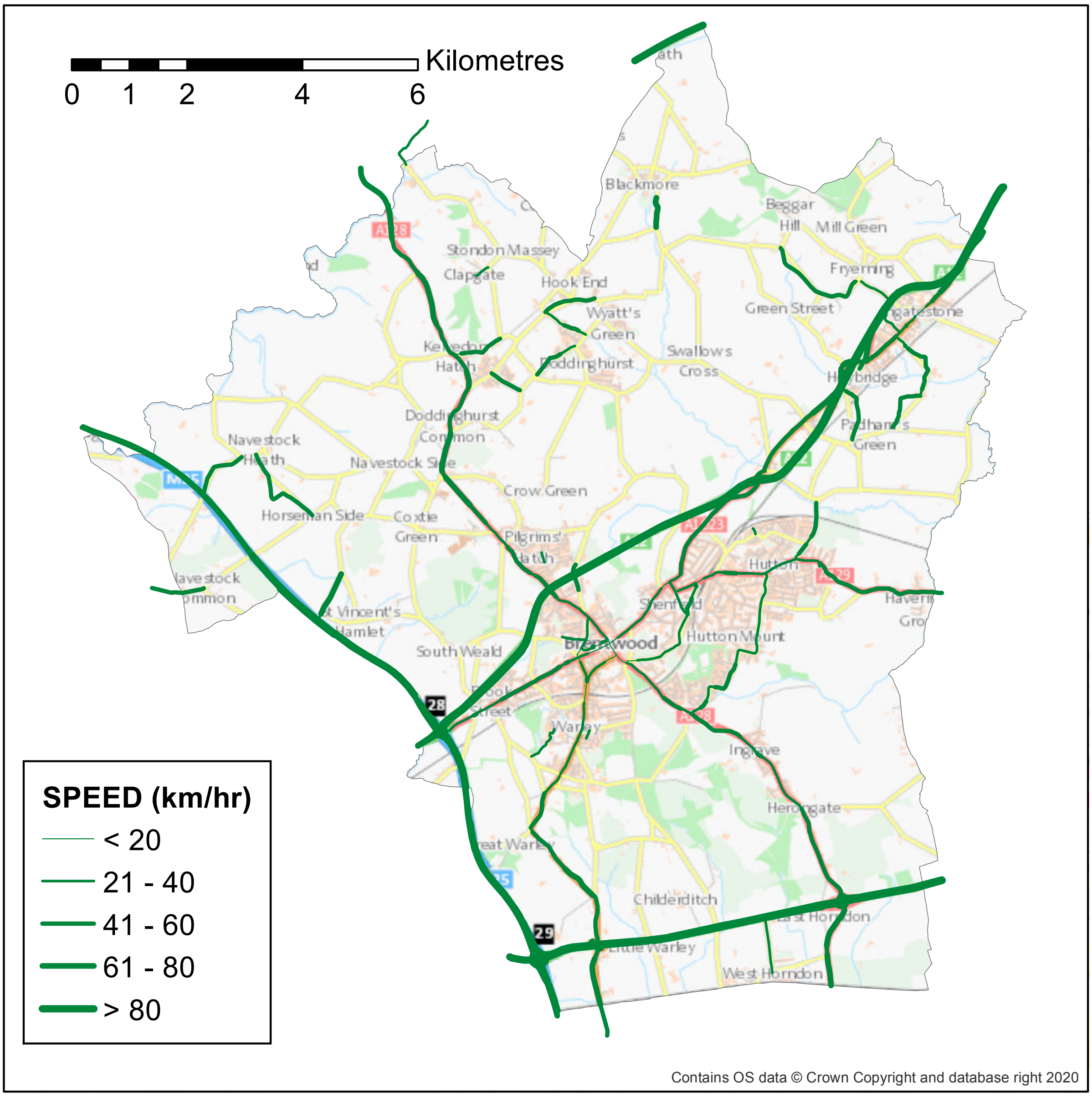


Figure 6.3: Average speeds for 2019 baseline

6.1.6 Time-varying emissions

The variations of traffic flows during the day were taken into account by applying a diurnal profile to the road emissions. The profile based on the average traffic distribution on all roads in Great Britain, as published by the DfT.[9] The profile, shown in Figure 6.4, was applied to all modelled roads for all scenarios.

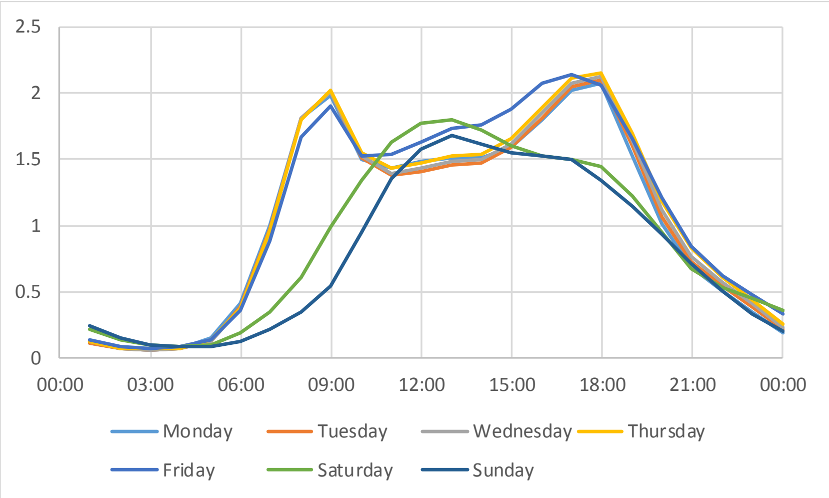


Figure 6.4: Diurnal emission factor profile used for road sources

An hourly profile for grid sources, which are described in Section 6.2., was derived from typical variations by source type taken from European Monitoring and Evaluation Programme (EMEP) data and the total local emissions for each source type. This profile is shown in Figure 6.5.

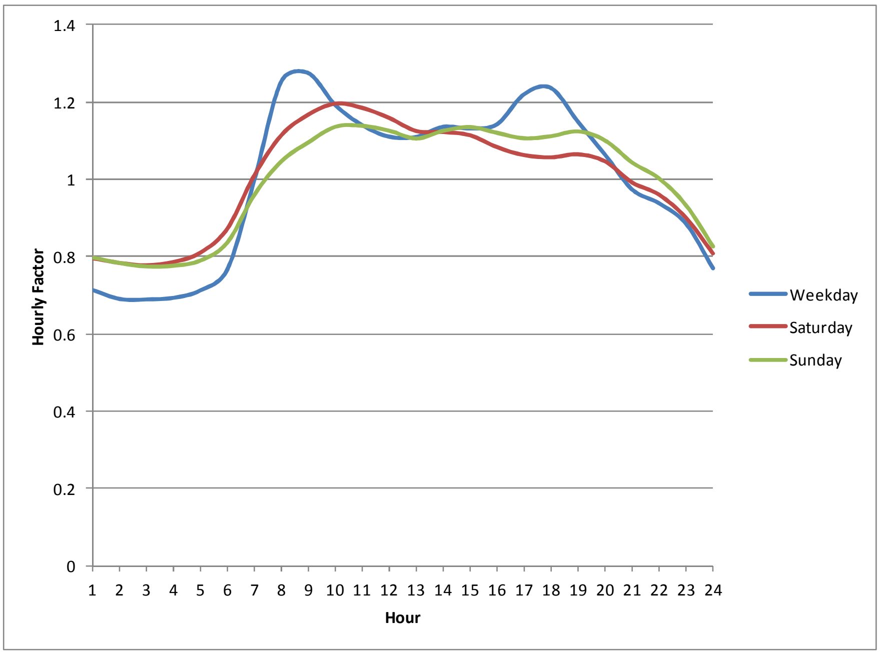


Figure 6.5: Diurnal profiles grid sources

[9] https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra

6.2 Other emissions

Emissions from other sources across the modelling domain, including domestic emissions and minor roads, were taken from the National Atmospheric Emissions Inventory (NAEI) 2018. Emissions from all other source types were modelled as an aggregated grid source with a resolution of 1 km.

All emissions were assumed to remain the same for all scenarios, apart from minor roads which were scaled by the same ratio as the calculated major road emissions.

6.3 Local Plan sites

Emissions from commercial and domestic developments expected as part of the Local Plan were included for the 2033 Local Plan scenario. The domestic emissions were calculated based on the number of units and the commercial emissions were calculated based on the area of floor space assigned to each development.

Emission factors were obtained from the NAEI and a representative energy demand was obtained from the Department of Energy and Climate Change (DECC) Energy demand benchmarks. A value of 200 kWh per square metre per year was used for the calculation of commercial emissions and a value of 10,000 kWh per year was used for the calculation of domestic emissions, based on an average of the energy demand benchmarks for different types of houses, as shown in Table 6.1.

Table 6.1: DECC Energy demand benchmarks[10]

Type	Energy demand (kWh/year)
Flat	6218
Terrace	8371
Semi	10306
Detached	15459
Average	10089

For commercial emissions, the floorspace was assumed to be 40% of the development area and an average gas use of 158 kWh/m^2 taken from DECC energy statistics[11].

The emissions were modelled as 1-km resolution grid sources, consistent with the modelling of current domestic and commercial emissions.

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/379052/EED_regs_-_benchmark_heat_demand_paper_-_261114_.pdf

[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/416369/non_domestic_national_energy_efficiency_data_framework_energy_statistics_2006-12.pdf

Table 6.2: Local Plan sites

Name	Site ref	No. of dwellings	Employment area (ha)	Floorspace (m^2)
East Horndon Hall	E13	-	5.5	22000
Dunton Hills Garden Village	R01	2750	5.5	22000
Land at Priests Lane, Brentwood	R19	45	-	-
Land north of Shenfield	R03	825	2	8000
Ford Headquarters and Council Deport, Warley - southern Site	R04	325	2	8000
Land at Crescent Drive, Shenfield	R18	35	-	-
The Eagle and Child Public House, Shenfield	R20	20	-	-
Land off Stocks Lane, Kelvedon Hatch	R24	30	-	-
West Horndon Industrial Estate	R02	580	2	8000
Westbury Road car park, Brentwood	R11	45	-	-
Chatham Way car park, Brentwood	R13	31	-	-
Land Hunter House, Brentwood	R12	48	-	-
Land east of Nags Head Lane, Brentwood	R06	125	-	-
Childerditch Industrial Estate	E12		20.64	82560
William Hunter Way car park, Brentwood	R14	300	-	-
Wates Way Industrial Estate, Ongar Road, Brentwood	R15	80	-	-
Land north of Wollard Way, Blackmore	R25	30	-	-
Land adjancent to Ingatestone by-pass (part bounded by Roman Road, south of flyover)	R22	57	-	-
Land north of Orchard Piece, Blackmore	R26	20	-	-
Land off Doddinghurst Road, Pilgrims Hatch and Brentwood	R16 R17	200	-	-
Ford Headquarters and Council Depot - Northern Site	R05	148	-	-
Land off Warley Hill, Warley	R09	43	-	-
Brentwood railway station car park	R10	100	-	-
Sow & Grown Nursery, Ongar Road, Pilgrams Hatch	R07	38	-	-
Brentwood Enterprise Park (M25 Works Site at A127/M25 junction 29)	E11	-	25.85	103400
Brizes Corner Field, Blackmore Road, Kelvedon Hatch	R23	23	-	-
Land at Mascalls Lane, Warley	R08	9	-	-
Land adjacent to Ingatestone by-pass (part bounded by Roman Road)	E08	-	2.06	8240
Ingatestone Garden Centre, Roman Road, Ingatestone	R21	161	-	-
Codham Hall Farm	E10	-	9.6	38400

7 Model verification

The first stage of a modelling assessment is to model a current case in order to verify that the input data and model set-up are appropriate for the area, by comparing measured and modelled concentrations for local monitoring locations. The monitor locations used for this purpose are described in Section 4. Concentrations were calculated at these monitoring locations for 2019.

The model verification involves an iterative process to improve the model set-up, for better agreement between measured and modelled concentrations.

Figure 7.1 and Table 7.1 present the monitored and modelled annual average NO_2 concentrations at the 33 diffusion tubes operated in Brentwood. Figure 7.2 shows a map of a comparison of the modelled and measured concentrations.

Discrepancies between measured and modelled concentrations will always be present in modelling assessments. These can be due to uncertainties in measured concentrations, traffic flows, traffic speeds, other sources such as idling traffic, or local dispersion effects not included in the model.

Modelled annual average NO_2 concentrations are within 10% of the measured value at 19 of the 33 monitoring sites (58%) and within 25% at 30 of the sites (91%). This shows that the model setup and input data are generally appropriate for the borough. There is some underprediction of NO_2 concentrations along Brentwood High Street; at the seven monitoring sites here the modelled concentrations range between 78% and 101% of the measured values.

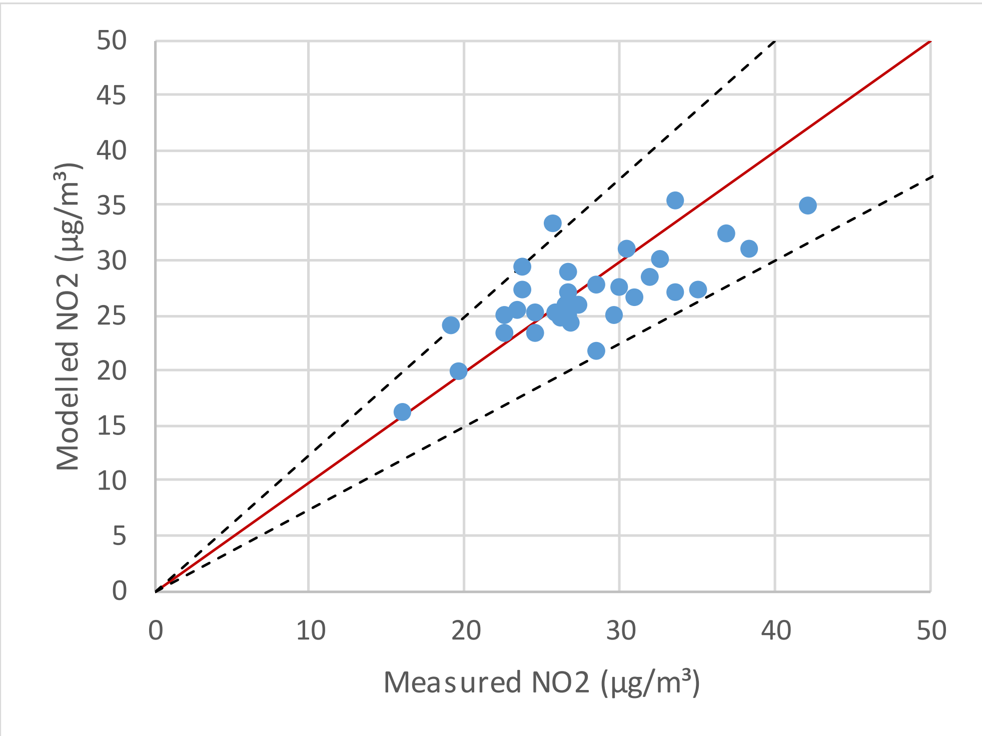


Figure 7.1: Measured and modelled annual average NO_2 concentrations at diffusion tubes and continuous monitors throughout Brentwood, 2019 ($\mu g/m^3$)

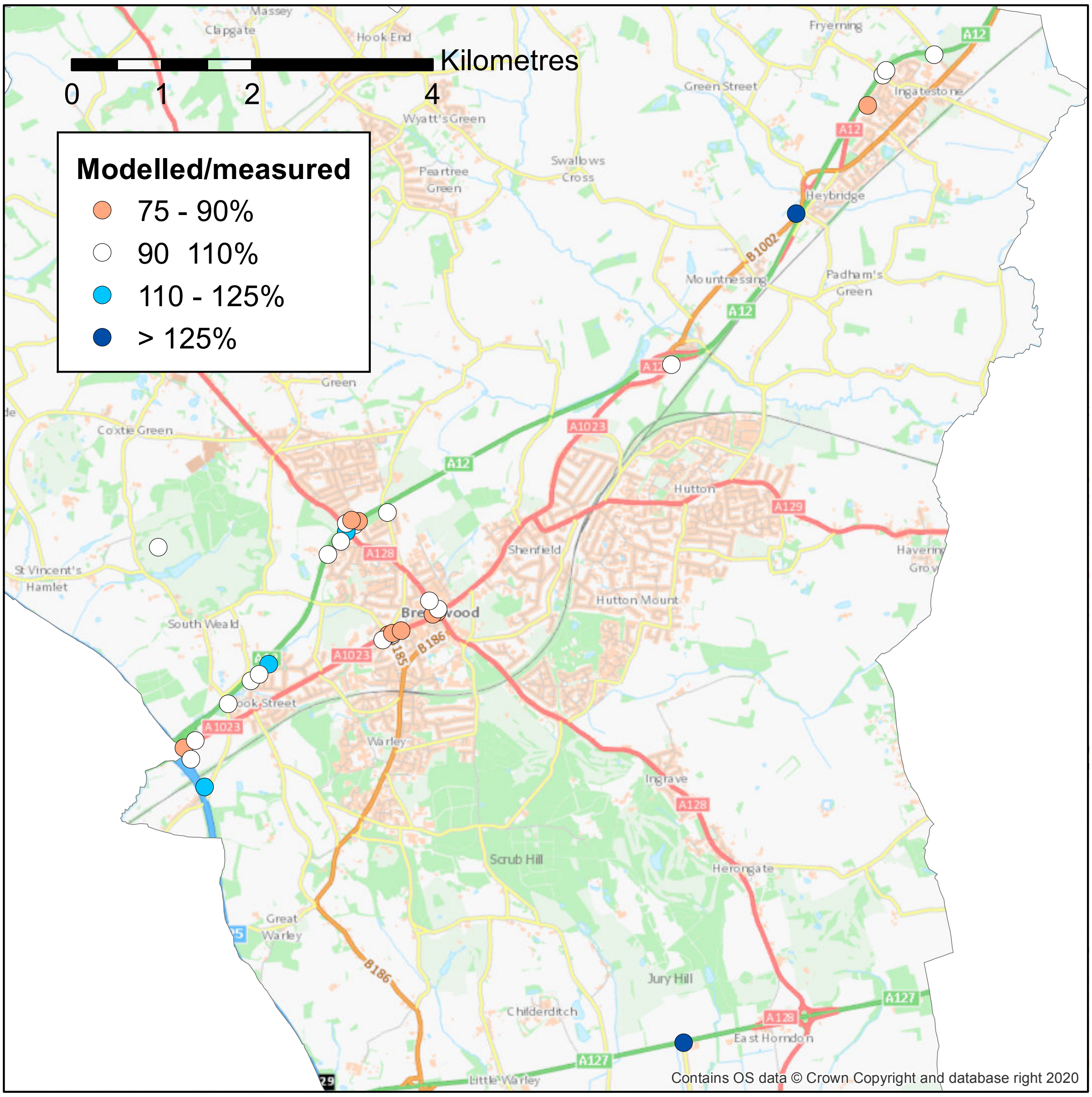


Figure 7.2: Monitoring sites showing comparison of modelled to measured annual average NO_2 concentrations

Table 7.1: Model verification, annual average NO_2, 2019

Site ID	Concentration, µg/m³		Modelled / Monitored Ratio
	Measured	Modelled	
BRW 5	**42.1**	35.1	83%
BRW 6	32.6	30.1	92%
BRW 7	23.8	29.6	124%
BRW 8	35.1	27.4	78%
BRW 9	31.0	26.8	87%
BRW 10	33.6	35.6	106%
BRW 11	30.5	31.1	102%
BRW 12	26.2	24.9	95%
BRW 14	29.6	25.0	84%
BRW 15	19.7	20.0	102%
BRW 16	27.3	26.1	96%
BRW 17	26.6	26.1	98%
BRW 18	22.5	25.0	111%
BRW 19	26.7	27.3	102%
BRW 20	31.9	28.7	90%
BRW 21	23.7	27.4	116%
BRW 22	30.0	27.6	92%
BRW 23	33.5	27.1	81%
BRW 24	24.6	23.6	96%
BRW 25	26.7	29.2	109%
BRW 26	26.7	25.1	94%
BRW 28	28.4	22.0	77%
BRW 29	24.5	25.5	104%
BRW 30	26.9	24.4	91%
BRW 31	25.9	25.4	98%
BRW 32	28.5	28.0	98%
BRW 33	22.6	23.5	104%
BRW 34	23.4	25.7	110%
BRW 36	16.0	16.3	102%
BRW 38	19.1	24.3	127%
BRW 39	25.7	33.4	130%
BRW 40	36.9	32.5	88%
BRW 41	38.4	31.2	81%

8 2019 baseline concentrations

This section comprises borough-wide air quality maps, for comparison against Air Quality Objectives for NO_2, PM_{10} and $PM_{2.5}$.

Contour plots of pollutant concentrations were generated using a model output on a 100 m regular grid across the region, along with additional output points along modelled roads to capture the steep concentration gradients at roadside. These model-calculated concentrations are used to generate 10 m resolution air quality maps in GIS software, using the Natural Neighbour interpolation method.

In the air quality maps, exceedences of the Air Quality Objective are shown in yellow, and pollutant concentrations below the objectives are shown in blue and green.

Figure 8.1 shows a map of the modelled annual mean NO_2 concentrations across Brentwood for 2019. Modelled concentrations show exceedences of the 40 $\mu g/m^3$ annual mean NO_2 objective along the M25, the A12, the A127 and at Wilson's Corner.

Figure 8.2 shows a map of the modelled 99.79th percentile of hourly mean NO_2 concentrations across Brentwood for 2019. The only modelled exceedences of the 200 $\mu g/m^3$ objective are along short stretches of the M25 and A12 where walls and barriers create street canyon effects; there is no relevant public exposure at these locations.

Figure 8.3 shows a map of the modelled annual mean PM_{10} concentrations across Brentwood for 2019. The only modelled exceedences of the 40 $\mu g/m^3$ objective are along the M25.

Figure 8.4 shows a map of the modelled 90.41st 24-hourly mean PM_{10} concentrations across Brentwood for 2019. The only modelled exceedences of the 50 $\mu g/m^3$ objective are limited to stretches of the M25 and the A12.

Figure 8.5 presents a contour plot of the modelled annual mean $PM_{2.5}$ concentrations across Brentwood for 2019. The only modelld exceedences of the 25 $\mu g/m^3$ objective are limited to stretches of the M25 and the A12.

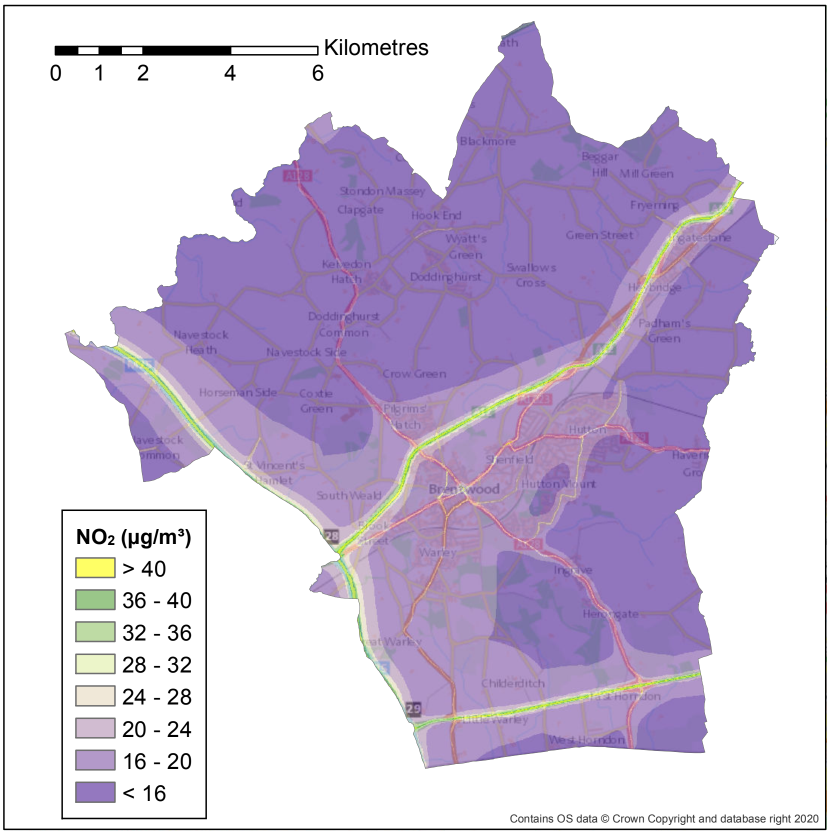


Figure 8.1: Annual mean NO_2 concentrations for Brentwood, 2019 (µg/m³)

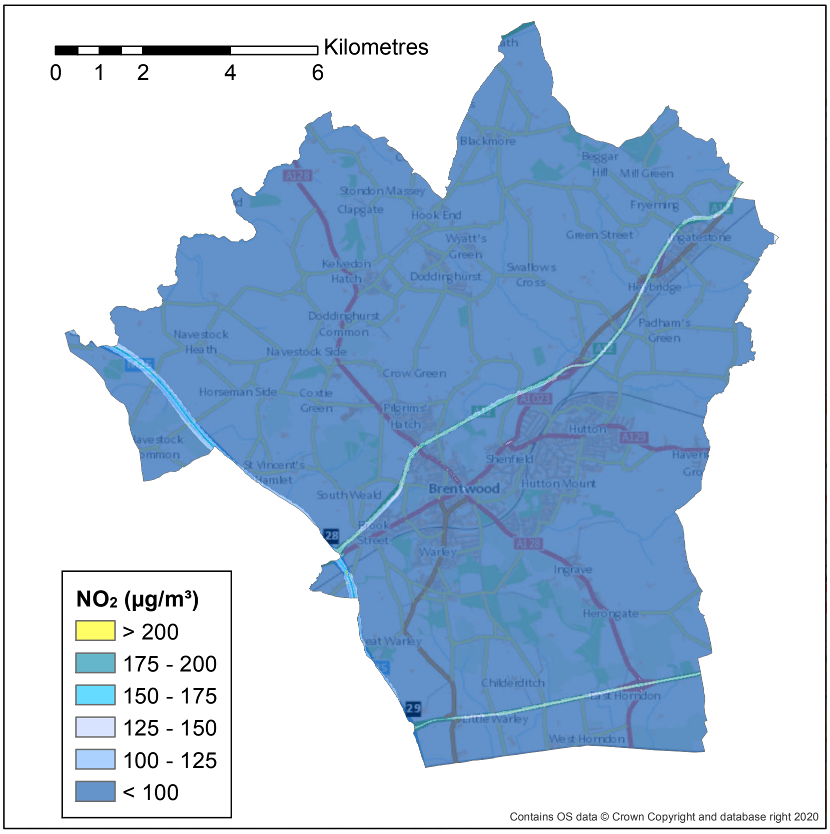


Figure 8.2: 99.79th percentile of hourly NO_2 concentrations for Brentwood, 2019 (µg/m³)

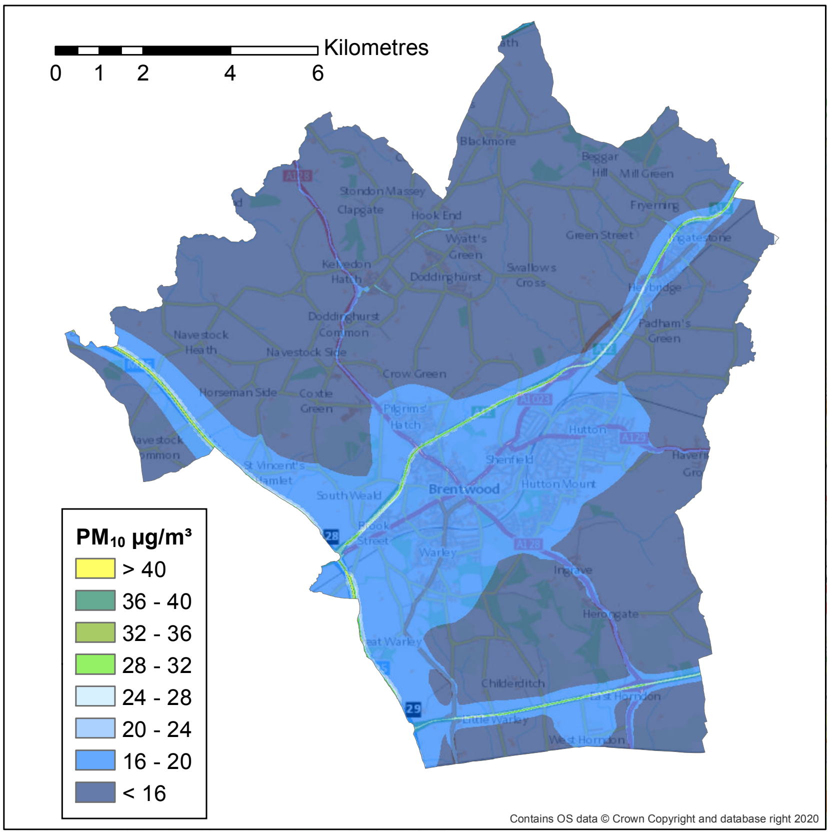


Figure 8.3: Annual mean PM_{10} concentrations for Brentwood, 2019 (µg/m³)

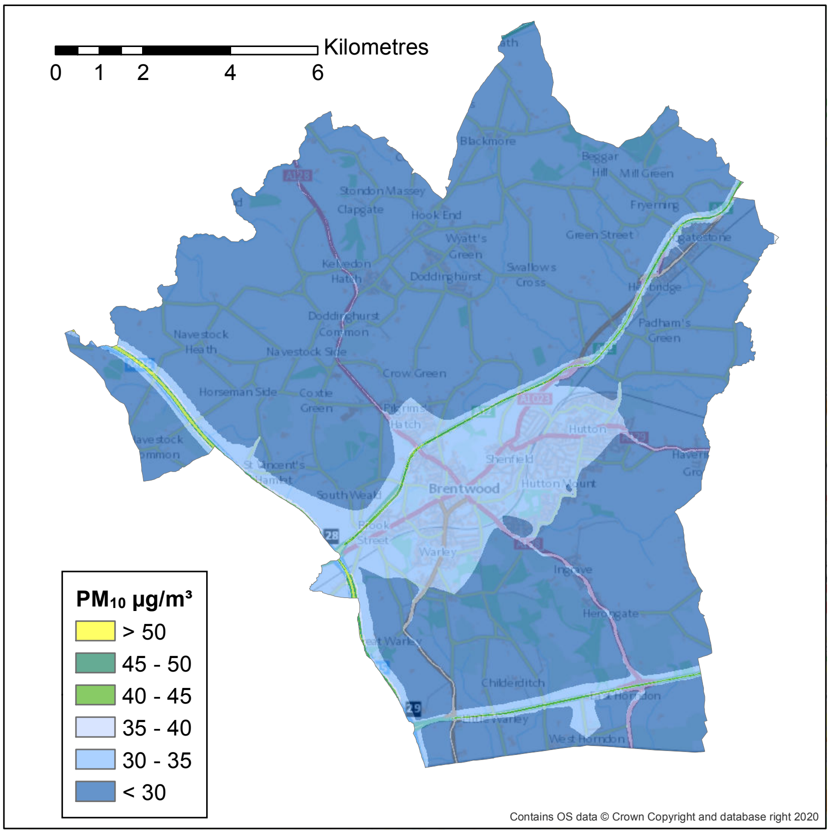


Figure 8.4: 90.41st percentile of daily mean PM_{10} concentrations for, 2019 (µg/m³)

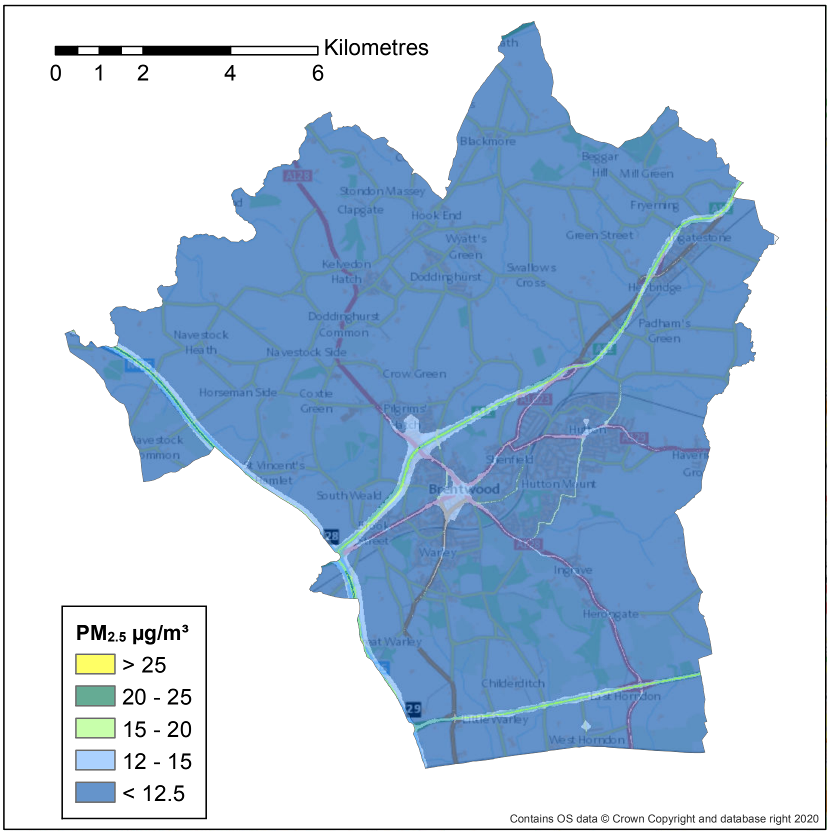


Figure 8.5: Annual mean $PM_{2.5}$ concentrations for Brentwood, 2019 (µg/m³)

9 2033 concentrations

9.1 Concentration maps

This section comprises borough-wide air quality maps for the two 2033 scenarios, for comparison against air quality objectives for NO_2, PM_{10} and $PM_{2.5}$.

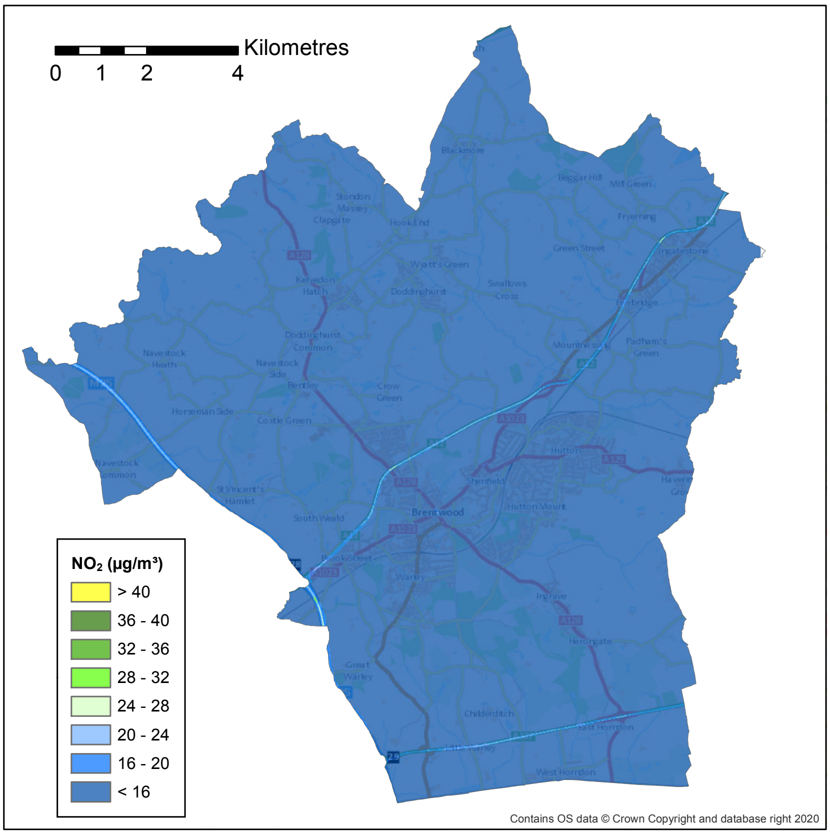
As for the 2019 scenario, contour plots of pollutant concentrations were generated using a model output on a 100 m regular grid across the region, along with additional output points along modelled roads to capture the steep concentration gradients at roadside. These modelled concentrations are used to generate 10 m resolution air quality maps in GIS software, using the Natural Neighbour interpolation method.

In the air quality maps, exceedences of the air quality objective are shown in yellow, and pollutant concentrations below objectives are shown in blue and green.

Figure 9.1 and Figure 9.2 shows maps of the modelled annual average and 99.79th percentile of hourly average NO_2 concentrations across Brentwood for the 2033 Reference Case and 2033 Local Plan Case. The modelled concentrations for both cases are significantly lower than for 2019 and there are no predicted exceedences of the Air Quality Objectives for either case.

Figure 9.3 and Figure 9.4 show maps of the modelled annual average and 90.41st percentile of daily average PM_{10} concentrations across Brentwood for the 2033 Reference Case and 2033 Local Plan Case. Away from the major roads the 2033 concentrations are lower than for 2019, but along the major roads the concentrations are not significantly different to those for 2019. The extent of the modelled exceedences for 2019 and the two 2033 scenarios are not significantly different, limited to stretches of the main roads in each case.

Figure 9.5 presents a contour plot of the modelled annual mean $PM_{2.5}$ concentrations across Brentwood for the 2033 Reference Case and 2033 Local Plan Case. The only modelled exceedences of the 25 µg/m^3 objective are limited to stretches of the M25 for both cases.



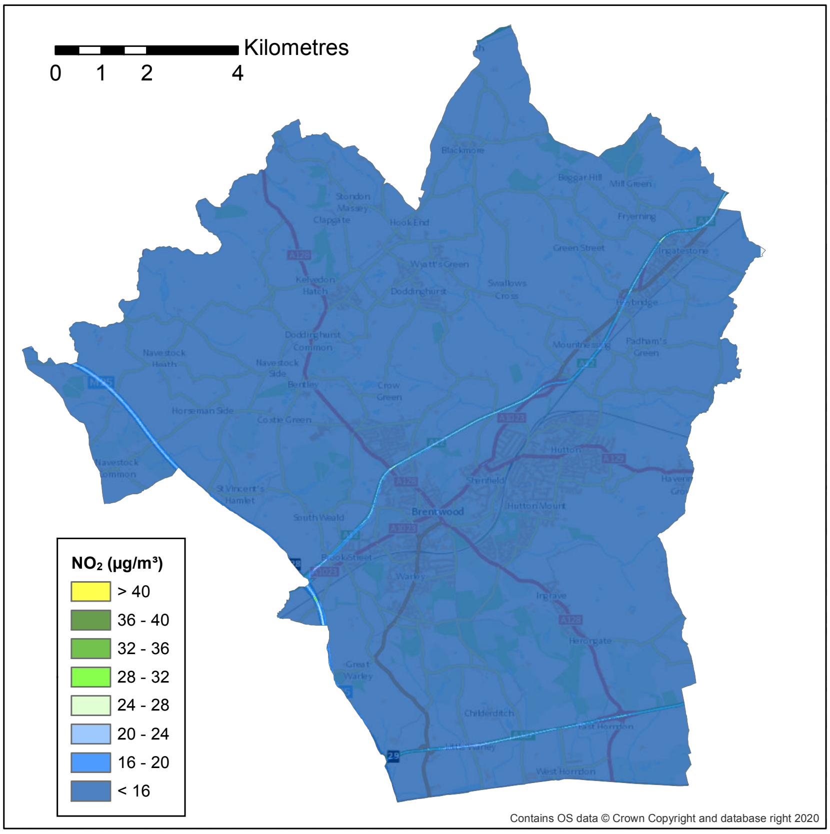


Figure 9.1: Modelled annual average NO_2 concentration for 2033 Reference Case (top) and 2033 with Local Plan (bottom)

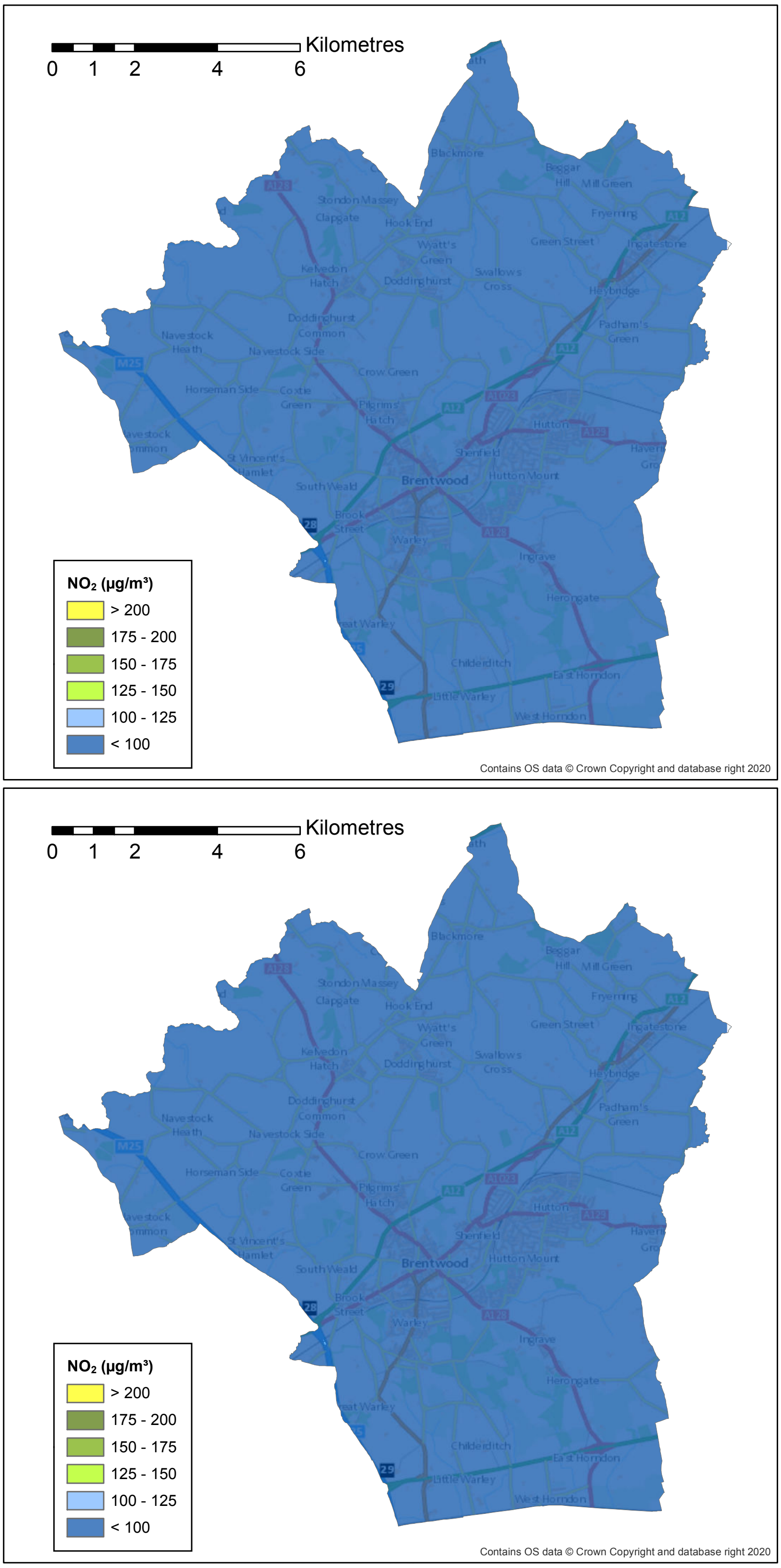
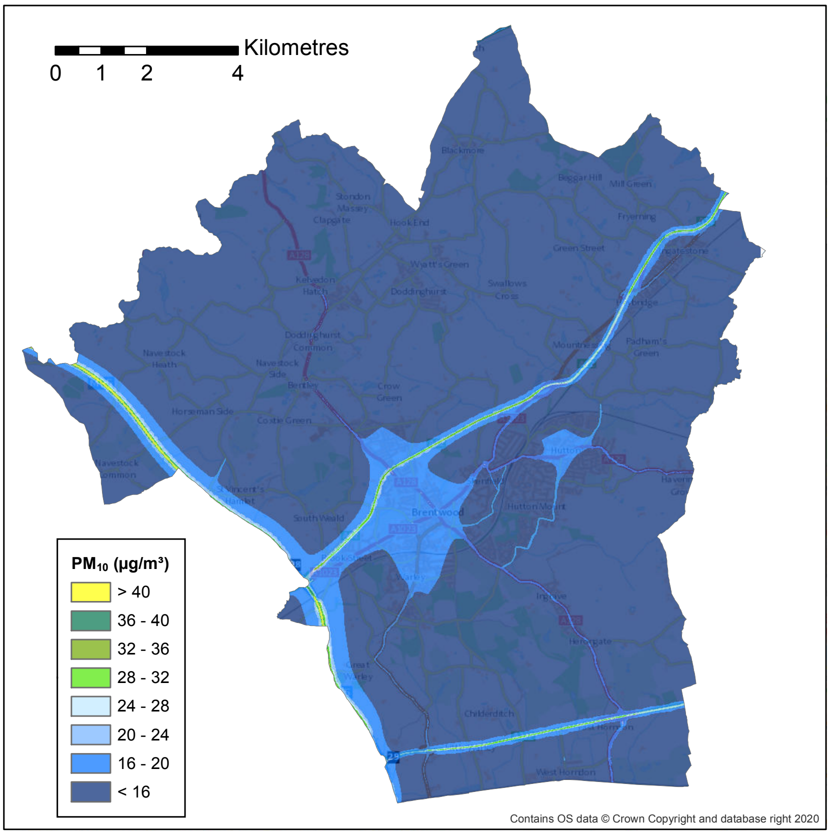


Figure 9.2: Modelled 99.79th percentile of hourly NO_2 concentration for 2033 Reference Case (top) and 2033 with Local Plan (bottom)



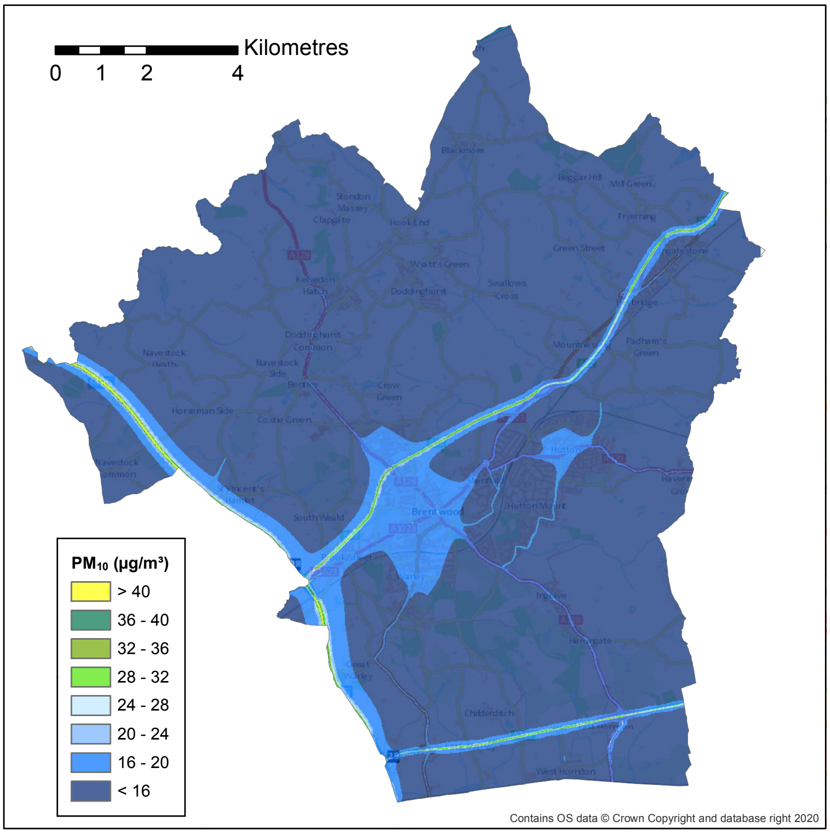


Figure 9.3: Modelled annual average PM_{10} concentration for 2033 Reference Case (top) and 2033 with Local Plan (bottom)

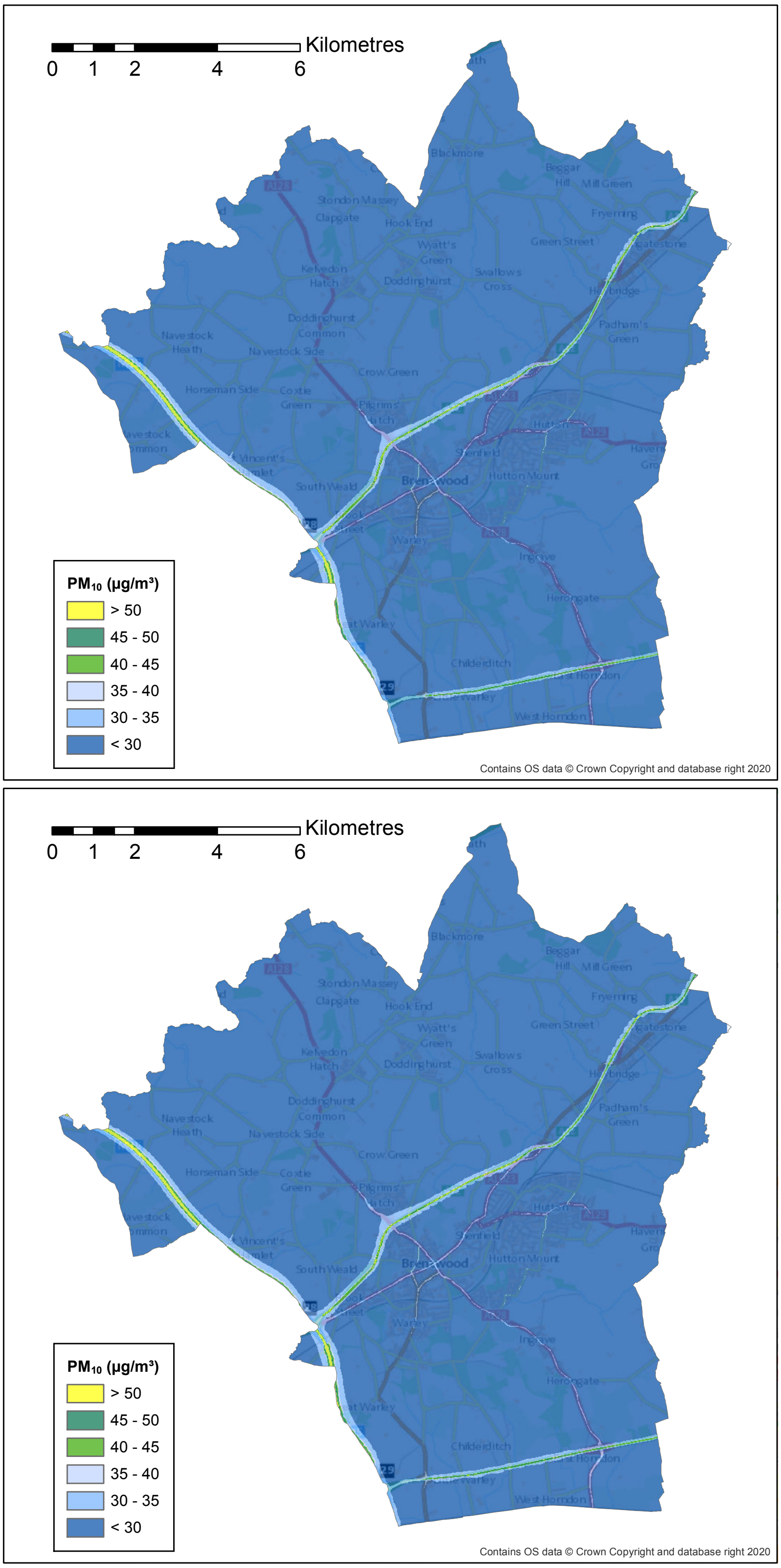


Figure 9.4: Modelled 90.41st percentile of daily average PM_{10} concentration for 2033 Reference Case (top) and 2033 with Local Plan (bottom)

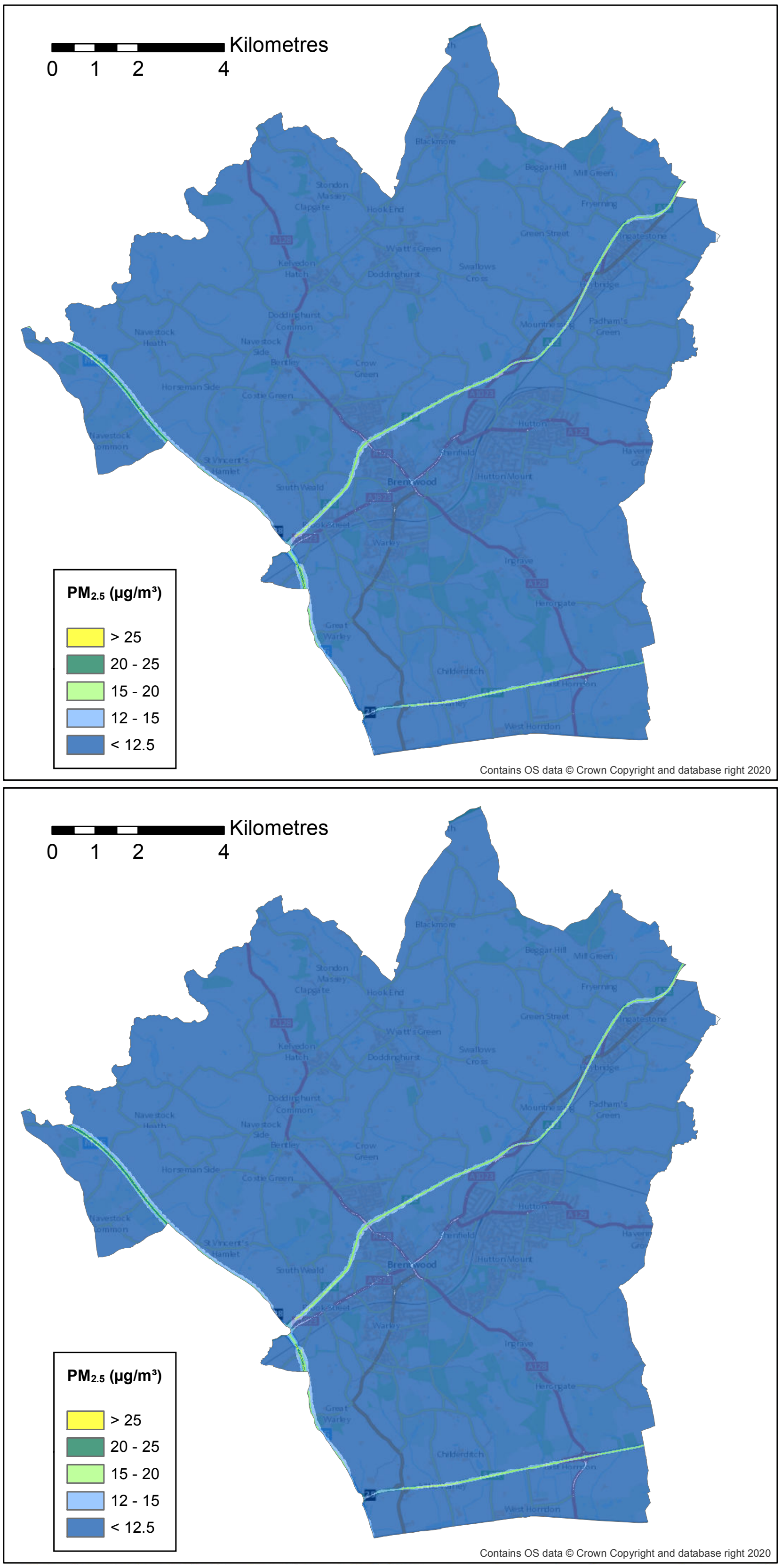


Figure 9.5: Modelled annual average $PM_{2.5}$ concentration for 2033 Reference Case (top) and 2033 with Local Plan (bottom)

9.2 Difference plots

Difference plots were calculated by subtracting the modelled annual average concentrations for the 2033 Reference Case from the 2033 Local Plan Case. The resulting concentrations are shown as maps: areas coloured red show an increase in concentrations; and areas with no colour show no significant change in concentrations. The colour scale used in the difference plots reflects the percentage change criteria used for IAQM EPUK significance assessments; a change of less than 0.5% of the standard is generally considered to be negligible.

Figure 9.6 to Figure 9.8 show the modelled change in annual average NO_2, PM_{10} and $PM_{2.5}$ concentrations between the 2033 Reference Case and the 2033 Local Plan Case. In the majority of the modelled area, the concentrations change by less than 0.5% of the relevant limit values. The greatest changes are seen for NO_2 along the A127, where concentrations increase by between 1% and 5% of the 40 µg/m³ objective.

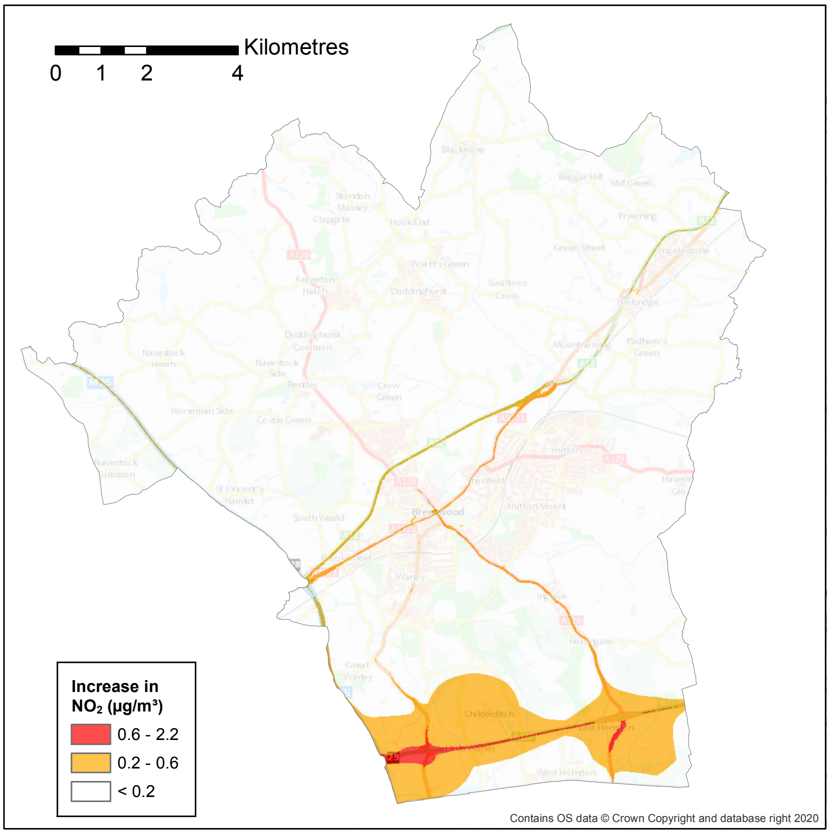


Figure 9.6: Change in annual average NO_2 concentration due to Local Plan

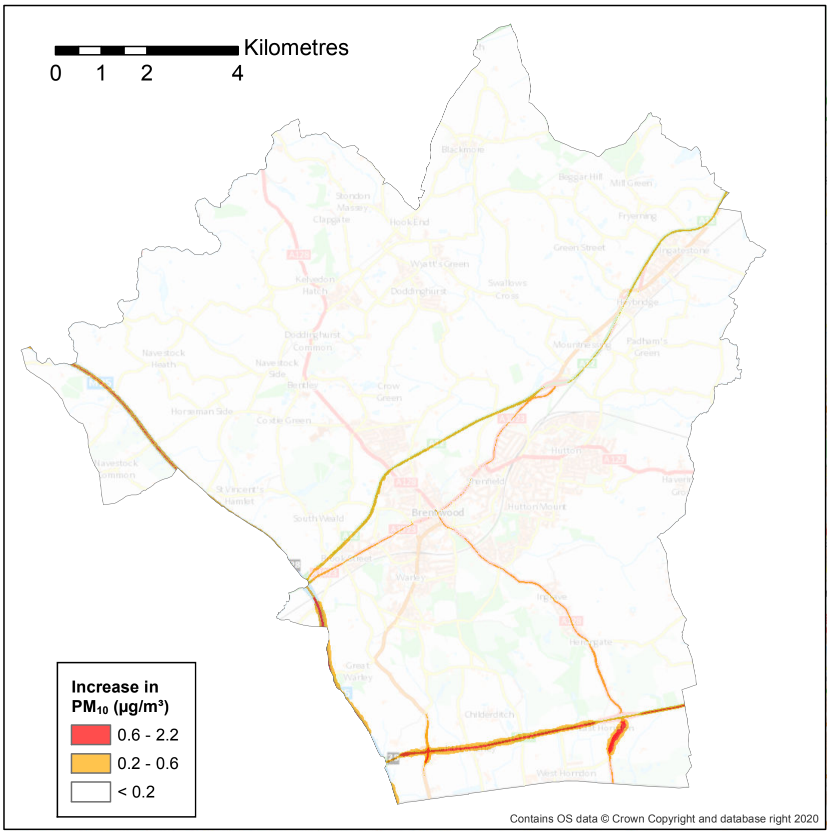


Figure 9.7: Change in annual average PM_{10} concentration due to Local Plan

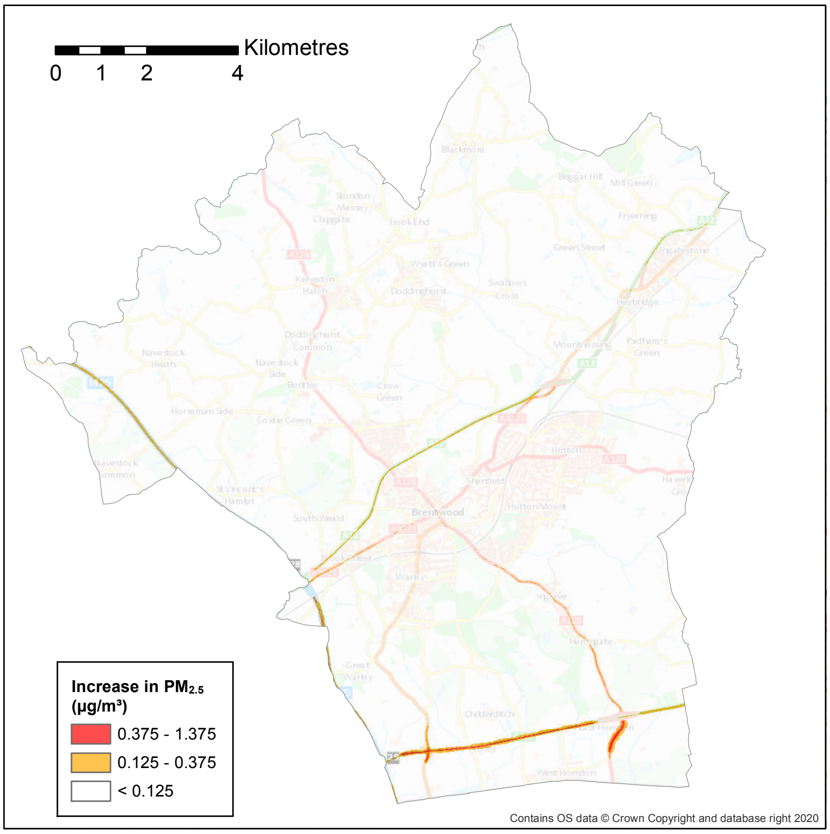


Figure 9.8: Change in annual average $PM_{2.5}$ concentration due to Local Plan

9.3 Significance assessment

The modelled annual average NO_2, PM_{10} and $PM_{2.5}$ concentrations and the calculated change in concentrations were used to assess the significance of the air quality impacts due to the Local Plan, based on the IAQM guidance described in Section 3.2. These show that, for all areas with relevant exposure, the change in concentrations is *negligible*; the only areas with changes with greater significance than this are limited to the road carriageways.

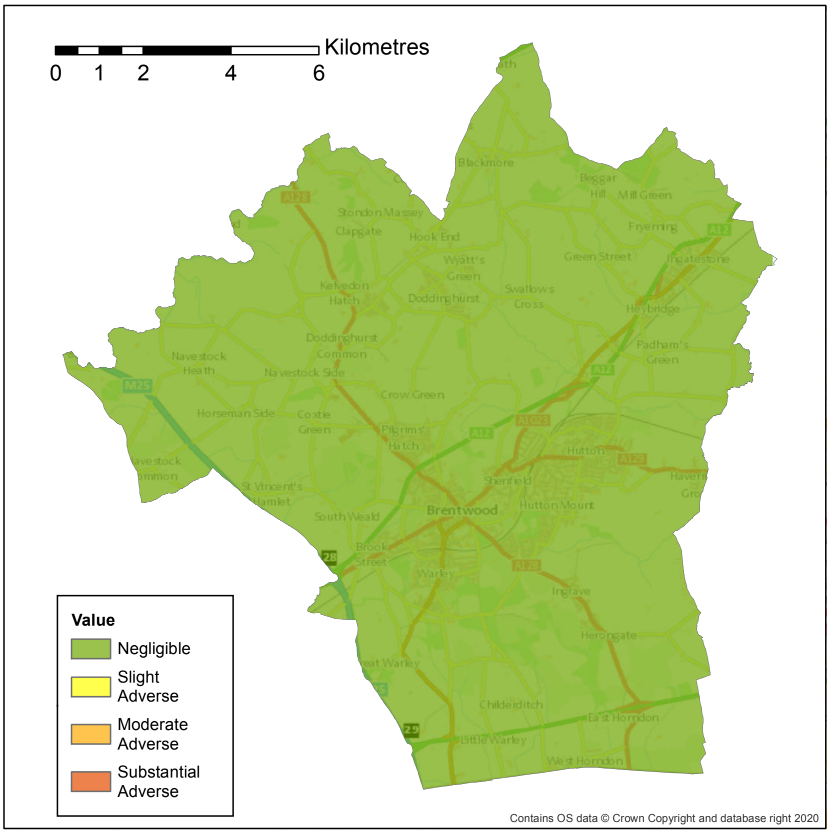


Figure 9.9: Significance of change in NO_2 concentrations

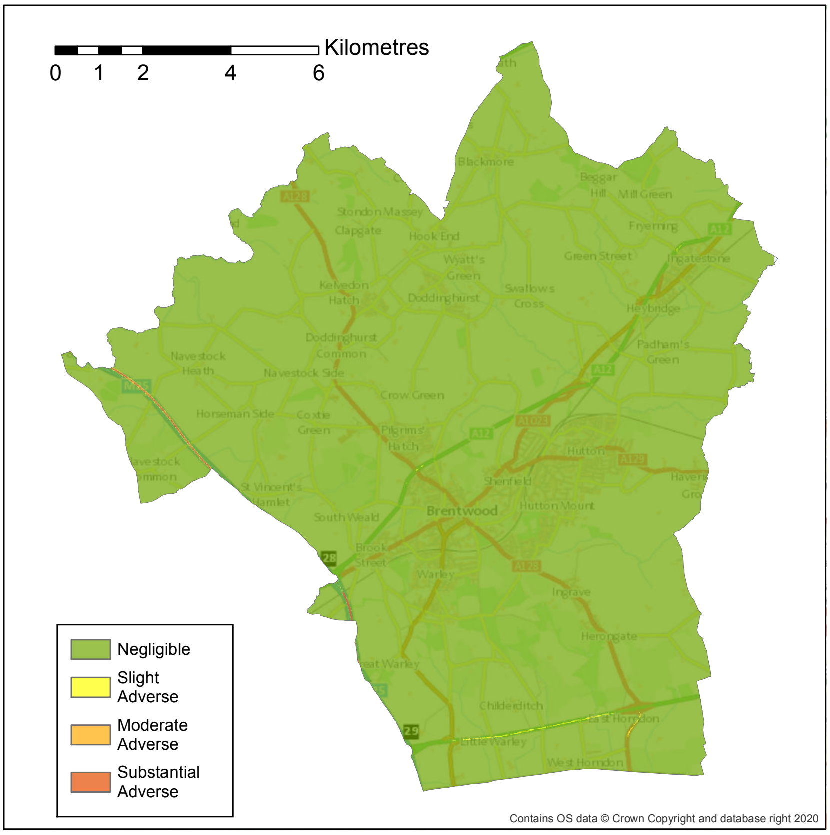


Figure 9.10: Significance of change in PM_{10} concentrations

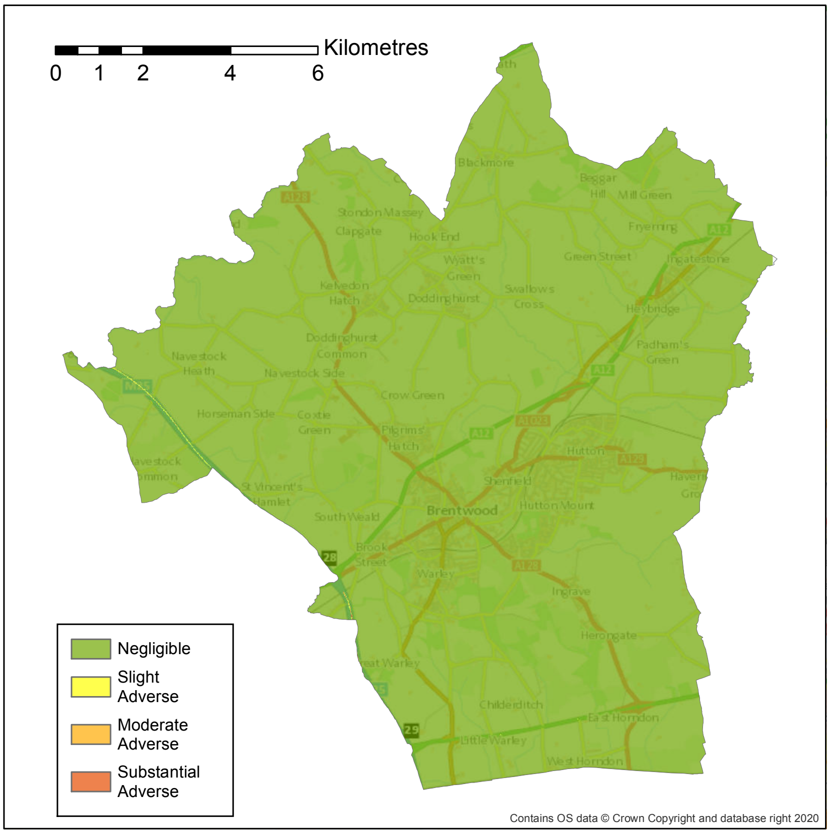


Figure 9.11: Significance of change in $PM_{2.5}$ concentrations

10 Mortality burden

The concentrations presented in Sections 8 and 9 were used to calculate the number of deaths in the borough attributable to air pollution and the associated life-years lost.

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)*[12]. 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*[13] 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 10.1 with the results from the two pollutants added for each study.

Table 10.1: Coefficients for use in burden calculations

Pollutant	Unadjusted coefficient	Jerrett et al (2013)	Fischer et al (2015)	Beelen et al (2014)	Crouse et al (2015)
NO_2	1.023	1.019	1.016	1.011	1.020
$PM_{2.5}$	1.06	1.029	1.033	1.053	1.019

Mortality burdens calculations were carried out for Lower Layer Super Output Areas (LSOAs), each representing an area with a population of approximately 1,500. The Office for National Statistics (ONS) publishes population[14] and death[15] data split by age for each LSOA.

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 10.1, and *c* is the average pollutant concentration for that LSOA calculated from the concentration contour maps.

[12] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf
[13] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf
[14] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates
[15] 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 Brentwood 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 life expectancy data are taken from the Public Health England Life Expectancy Calculator[16], which uses ONS population and deaths data as input.

Table 10.2 to Table 10.4 present the mortality burden associated with NO_2 and $PM_{2.5}$ concentrations by ward for 2019, the 2033 Reference Case and 2033 Local Plan Case.

The range of values given for attributable deaths and life years lost for each pollutant were derived from the minimum and maximum values for each of the individual pollutants across the four studies.

For 2019, air pollution is estimated to cost between about 500 and 700 life years in the borough. In 2033, this reduces to between about 375 and 600 life years, with no significant difference between the reference case and the Local Plan case.

Table 10.2: Attributable deaths and life years lost by ward for 2019

Ward	NO_2		$PM_{2.5}$		Total life years lost
	Attributable deaths	Life years lost	Attributable deaths	Life years lost	
Brentwood North	0.5 - 0.9	7 - 13	1.3 - 3.6	18 - 49	31 - 56
Brentwood South	0.4 - 0.6	5 - 10	1 - 2.8	15 - 40	25 - 46
Brentwood West	1.2 - 2.2	14 - 24	1.4 - 3.8	17 - 47	42 - 61
Brizes and Doddinghurst	1.3 - 2.3	17 - 31	1.5 - 4	19 - 51	50 - 69
Herongate, Ingrave and West Horndon	1.2 - 2.2	14 - 24	0.9 - 2.4	8 - 23	33 - 36
Hutton Central	1.2 - 2.1	15 - 27	0.6 - 1.7	9 - 24	36 - 39
Hutton East	0.7 - 1.3	7 - 12	0.6 - 1.7	9 - 25	22 - 32
Hutton North	0.5 - 0.9	7 - 13	1.4 - 3.7	16 - 44	29 - 51
Hutton South	0.5 - 0.9	7 - 13	0.7 - 1.8	9 - 24	21 - 31
Ingatestone, Fryerning and Mountnessing	1.3 - 2.3	16 - 28	1.2 - 3.2	16 - 44	45 - 60
Pilgrims Hatch	1.1 - 2	13 - 23	1.4 - 3.8	16 - 42	39 - 55
Shenfield	1 - 1.8	13 - 24	1.1 - 3.1	10 - 28	34 - 42
South Weald	1 - 1.9	10 - 17	0.4 - 1.1	6 - 16	23 - 25
Tipps Cross	0.9 - 1.6	13 - 23	0.7 - 2	11 - 29	34 - 42
Warley	0.5 - 1	8 - 14	1.4 - 3.8	15 - 41	30 - 49
Total	**13.3 - 23.9**	**165 - 297**	**15.8 - 42.4**	**196 - 529**	**493 - 694**

[16] https://fingertips.phe.org.uk/.../PHE%20Life%20Expectancy%20Calculator.xlsm

Table 10.3: Attributable deaths and life years lost by ward for 2033 Reference Case

Ward	NO_2		$PM_{2.5}$		Total life years lost
	Attributable deaths	Life years lost	Attributable deaths	Life years lost	
Brentwood North	0.3 - 0.6	5 - 9	1.2 - 3.3	17 - 45	26 - 50
Brentwood South	0.2 - 0.4	3 - 6	1 - 2.6	14 - 37	20 - 41
Brentwood West	0.8 - 1.4	9 - 15	1.3 - 3.5	16 - 43	32 - 52
Brizes and Doddinghurst	0.8 - 1.4	11 - 19	1.4 - 3.7	17 - 47	37 - 58
Herongate, Ingrave and West Horndon	0.8 - 1.5	9 - 16	0.8 - 2.2	8 - 21	24 - 30
Hutton Central	0.8 - 1.4	10 - 18	0.6 - 1.6	8 - 22	26 - 32
Hutton East	0.5 - 0.9	5 - 8	0.6 - 1.6	8 - 23	17 - 27
Hutton North	0.3 - 0.6	5 - 9	1.3 - 3.4	15 - 41	24 - 45
Hutton South	0.3 - 0.6	5 - 9	0.6 - 1.6	8 - 22	17 - 27
Ingatestone, Fryerning and Mountnessing	0.8 - 1.5	10 - 18	1.1 - 3	15 - 41	33 - 51
Pilgrims Hatch	0.7 - 1.3	9 - 16	1.3 - 3.5	15 - 39	30 - 48
Shenfield	0.6 - 1.2	9 - 16	1 - 2.8	10 - 26	25 - 35
South Weald	0.6 - 1.2	6 - 11	0.4 - 1	5 - 15	16 - 21
Tipps Cross	0.6 - 1.1	8 - 15	0.7 - 1.8	10 - 27	25 - 35
Warley	0.4 - 0.7	6 - 10	1.3 - 3.5	14 - 38	24 - 44
Total	**8.7 - 15.6**	**108 - 194**	**14.5 - 39.1**	**181 - 487**	**375 - 595**

Table 10.4: Attributable deaths and life years lost by ward for 2033 with Local Plan

Ward	NO_2		$PM_{2.5}$		Total life years lost
	Attributable deaths	Life years lost	Attributable deaths	Life years lost	
Brentwood North	0.3 - 0.6	5 - 9	1.2 - 3.3	17 - 45	26 - 50
Brentwood South	0.2 - 0.4	3 - 6	1 - 2.6	14 - 37	20 - 41
Brentwood West	0.8 - 1.4	9 - 16	1.3 - 3.5	16 - 43	32 - 52
Brizes and Doddinghurst	0.8 - 1.4	11 - 19	1.4 - 3.7	17 - 47	37 - 58
Herongate, Ingrave and West Horndon	0.8 - 1.5	9 - 16	0.8 - 2.2	8 - 21	24 - 30
Hutton Central	0.8 - 1.4	10 - 18	0.6 - 1.6	8 - 22	26 - 32
Hutton East	0.5 - 0.9	5 - 8	0.6 - 1.6	8 - 23	17 - 27
Hutton North	0.3 - 0.6	5 - 9	1.3 - 3.4	15 - 41	24 - 45
Hutton South	0.3 - 0.6	5 - 9	0.6 - 1.6	8 - 22	17 - 27
Ingatestone, Fryerning and Mountnessing	0.8 - 1.5	10 - 18	1.1 - 3	15 - 41	34 - 51
Pilgrims Hatch	0.7 - 1.3	9 - 16	1.3 - 3.5	15 - 39	30 - 48
Shenfield	0.6 - 1.2	9 - 16	1 - 2.8	10 - 26	25 - 35
South Weald	0.7 - 1.2	6 - 11	0.4 - 1	5 - 15	16 - 21
Tipps Cross	0.6 - 1.1	8 - 15	0.7 - 1.8	10 - 27	25 - 35
Warley	0.4 - 0.7	6 - 10	1.3 - 3.5	14 - 38	24 - 44
Total	**8.7 - 15.7**	**108 - 195**	**14.5 - 39.2**	**181 - 488**	**376 - 596**

11 Discussion

Air quality modelling for Brentwood was carried out using ADMS-Urban (version 5.0) dispersion modelling software to calculate concentrations of NO_2, PM_{10} and $PM_{2.5}$ across the borough for 2019, for a 2033 Reference Case and a 2033 Local Plan Case. The modelling used meteorological data from the Andrewsfield meteorological station and background pollutant concentrations data from rural air quality monitoring stations.

Road traffic emissions input to the dispersion model were calculated from traffic counts using the Emission Factor Toolkit (EFT) version 10.1, published by Defra. The EFT data were adjusted based on Remote Sensing Data to better reflect vehicle emissions in real-world conditions. Emissions data for all other sources of pollutants were taken from the NAEI.

Detailed model verification was carried out by comparing modelled concentrations against monitored data across Brentwood for the year 2019, with iterative improvements to the model set-up to ensure acceptable agreement between modelled and monitored concentrations.

The model verification showed generally good agreement between measured and modelled concentrations, with modelled annual average NO_2 concentrations falling within 10% of the measured values at 58% of the monitoring sites, and within 25% of the measured values at 91% of the monitoring sites.

For the 2019 baseline, with exception of some locations close to major roads, the Air Quality Objectives are met throughout the borough. There are modelled exceedences of the annual mean NO_2 objective of 40 $\mu g/m^3$ along the M25, the A12, the A127 and at Wilson's Corner. Exceedences of short-term NO_2 and PM_{10} and $PM_{2.5}$ objectives are less extensive.

Between 2019 and 2033, emissions from vehicle exhausts are expected to decrease due to improving vehicle technology, with a corresponding reduction in background concentrations. However, for PM_{10} and $PM_{2.5}$ the majority of emissions from road traffic is due to non-exhaust emissions, namely brake, tyre and road-wear. Non-exhaust emissions are related to vehicle sizes, numbers and speed, and are therefore expected to increase as traffic grows.

By 2033, concentrations of NO_2 are expected to decrease compared to 2019 levels. In particular, all exceedences of the Air Quality Objectives for NO_2 concentrations are predicted to disappear. PM_{10} and $PM_{2.5}$ concentrations away from major roads are predicted to decrease but, along major roads, concentrations are predicted to remain similar to 2019 levels; the extent of exceedences of the objectives for PM_{10} and $PM_{2.5}$ concentrations is not predicted to change significantly.

The addition of emissions from vehicles and domestic and commercial combustion due to the Local Plan developments increases concentrations slightly along the main roads, in particular along the A127. Assessment of the significance of these changes using the IAQM guidance shows that the changes are *negligible* at all locations with relevant exposure. The impact in intervening years may vary depending on when each development is completed and other local factors.

For 2019, air pollution is estimated to cost between about 500 and 700 life years in the borough. In 2033, this reduces to between about 375 and 600 life years, with no significant difference between the reference case and the Local Plan case.

There are a number of uncertainties in the modelling, including: the lack of traffic data for some roads; uncertainties over the future vehicle fleet composition and future background concentrations; and exact details of the Local Plan Developments. However, given the data available, the modelled concentrations are likely to give a good representation of air quality in 2033 and the relative impact of the Local Plan developments.

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 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. 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

ADMS-Urban includes two options for modelling the effects of street canyons:
1. The *basic* street canyon option uses the *Operational Street Pollution Model (OSPM)*[17], developed by the Danish National Environmental Research Institute (NERI). 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.
2. The *advanced* street canyon option modifies the dispersion of pollutants from a road source according to the presence and properties of canyon walls on one or both sides of the road. It differs from the basic canyon option in the following ways:
(i) It can consider a wide range of canyon geometries, including tall canyons and asymmetric canyons;
(ii) The modelled concentrations vary with height within the canyon;
(iii) Emissions can be restricted only to the carriageway with no emissions on pedestrian areas; and
(iv) Concentrations both inside and outside a particular street canyon are affected.

Complex Effects - Chemistry

ADMS-Urban includes the *Generic Reaction Set (GRS)*[18] 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[19] 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.

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[17] 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.
[18] 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.
[19] 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.

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.

The ADMS-Urban Complex Terrain Module models these effects using the wind-flow model FLOWSTAR[20]. 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. FLOWSTAR has been extensively tested with laboratory and field data.

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 in 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.

[20] 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.

(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.

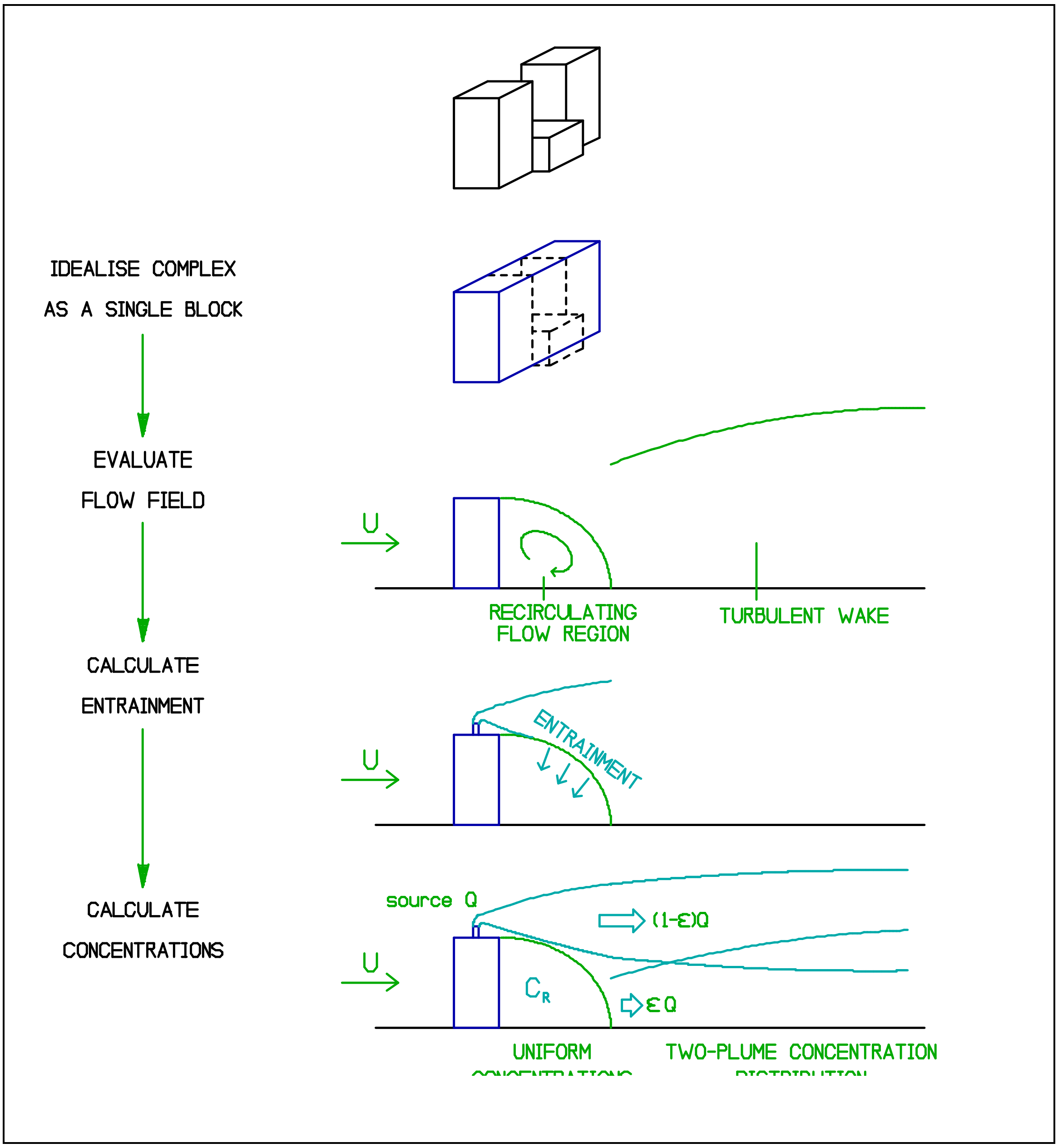

Figure A.1: Stages in the modelling of building effects

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 website at www.cerc.co.uk.