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# *Air quality modelling to support the Runnymede Local Plan*

Final report

*Prepared for*
Runnymede Borough Council

*4th May 2018*

CERC

## Report Information

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# Contents

# 1 Summary

Runnymede Borough Council is preparing a Local Plan to guide development in the Borough until 2036. CERC was commissioned to carry out air dispersion modelling to identify the baseline air quality profile across the area, and to assess two future (2036) scenarios, with and without proposed developments in the Runnymede Local Plan in place.

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

The main source of air pollution in Runnymede is road traffic emissions from major roads. The Council has declared two Air Quality Management Areas (AQMAs) due to annual average $NO_2$ concentrations exceeding the Air Quality Objective: along the M25, including an extended area at Egham; and Addlestone town centre.

Air quality modelling was carried out using ADMS-Urban (version 4.2.0) air quality modelling software, using meteorological data from the Met Office Heathrow weather station.

Traffic flow data derived from traffic models for the area surrounding the Borough was provided by the Council, augmented with traffic flow and speed data from the London Atmospheric Emissions Inventory (LAEI) 2013. Minor road emissions were derived from the LAEI and the UK National Atmospheric Emissions Inventory (NAEI) 2015.

Traffic emissions were calculated using road traffic emission factors and fleet data using the Emission Factor Toolkit version 8.0.1, published by Defra. Additional scaling factors were applied to $NO_x$ emissions based on real-world emissions data; scaling factors from the LAEI were applied to non-exhaust particulate emissions. Resuspension emissions were also calculated.

All other emissions and traffic data were taken from the LAEI and NAEI where applicable.

Modelled concentrations for 2015 show exceedences of the Air Quality Objective of 40µg/m³ for annual average $NO_2$ concentrations; no exceedences of other relevant Air Quality Objectives are predicted. Modelled annual mean $NO_2$ concentrations for 2015 exceed 40µg/m³ along the M25, and at building façades on London Street and Windsor Street in Chertsey.

In both the modelled 2036 scenarios, no exceedences of any relevant Air Quality Objectives are predicted at any locations across Runnymede. This reflects a large decrease in $NO_2$ concentrations arising from reductions in traffic exhaust emissions due to predicted improvements in engine technology.

The implementation of the Runnymede Local Plan gives rise to a spatially complex pattern of air quality impacts. Decreases in concentration are seen in the Addlestone AQMA, and along roads where exceedences are predicted in 2015 in Addlestone and Chertsey. The largest increases in pollutant concentrations are seen near St. Peter's Hospital to the west of Chertsey, where a new residential development is proposed; these increases do not bring concentrations close to the Air Quality Objectives. Small increases in pollutant concentrations are seen along Motorways and some trunk roads.

The health impact of air quality on health in Runnymede was assessed by calculating the number of attributable deaths and corresponding life-years lost due to concentrations of $PM_{2.5}$ and $NO_2$ following the methodology described in the report *Understanding the Health Impacts of Air Pollution in London*[1]. Using this approach, the combined health impacts of $NO_2$ and $PM_{2.5}$ in 2015 were calculated to be 1065 life-years lost. In 2036, without the implementation of the Local Plan, the impact was calculated to be 929 life-years lost; with the implementation of the Local Plan, the impact was calculated to be the loss of 928 life-years. This very small change reflects the low concentrations predicted across the Borough, and the fact that local decreases in traffic emissions are offset by increases in other areas in the Borough.

Following the completion of the modelling study, the date of implementation of the Runnymede Local Plan was changed to 2030. In the modelled 2036 scenarios, published data for 2030 or earlier was used for all inputs except traffic activity, due to the absence of emission factors or emissions inventory data in the UK for years after 2030. It is expected that traffic flows will increase slightly between 2030 and 2036 due to regional traffic growth, and that the effects of the implementation of the Local Plan will not change significantly depending on the year. As such, the results in this report are likely to provide a slightly conservative estimate of predicted concentrations in 2030. As no exceedences of the relevant Air Quality Objectives were predicted in the 2036 scenarios, it is reasonable to predict that no exceedences of the Air Quality Objectives would be predicted for 2030 with the Local Plan in place.

[1] https://www.london.gov.uk/sites/default/files/HIAinLondon_KingsReport_14072015_final_0.pdf

# 2 Introduction

Runnymede Borough Council (the Council) is preparing a Local Plan to guide development in the Borough until 2036. The Plan includes a number of residential developments, as shown in Figure 2.1, in addition to some commercial developments, with related transport infrastructure changes.

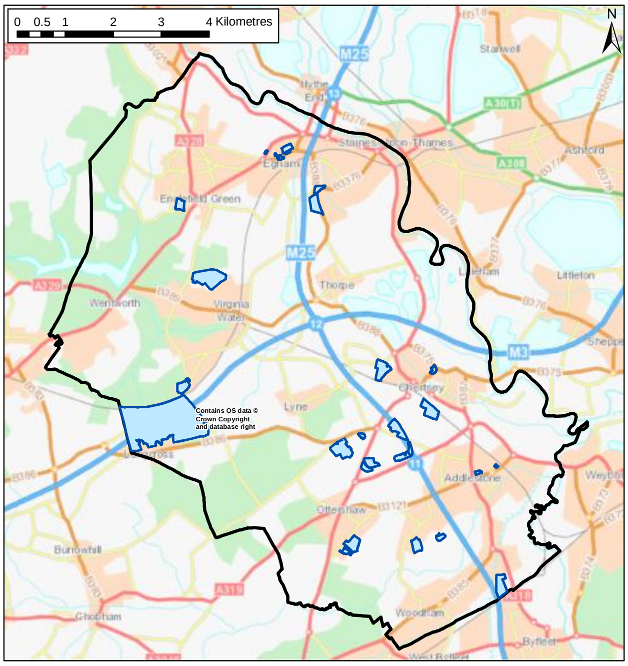


***Figure 2.1: Local plan proposed development areas***

The main source of air pollution in Runnymede is road transport, and the addition of additional homes and changes to transport infrastructure will lead to changes in the magnitude and location of these emissions. As such, CERC was commissioned to carry out air dispersion modelling to support the plan, using traffic model data provided by the Council.

Three scenarios were modelled:

1. A 2015 scenario, in order to establish a baseline for air quality;
2. A 2036 scenario without the implementation of the Runnymede Local Plan; and
3. A 2036 scenario with the implementation of the Runnymede Local Plan.

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

The air quality limit values and target values with which the calculated concentrations are compared are presented in Section 3. Section 4 summarises local air quality in Runnymede. The model setup and emissions data are described in Sections 5 and 6. The results of the modelling are then presented: the model verification in Section 7; the concentration maps for 2015 in Section 8, and the results for 2036 in Section 9. Calculations of health impacts are described in Section 10. A discussion of the results is presented in Section 11.

# 3 Air quality standards and guidance

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*[2], 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***

| | Value (µg/m³) | Description of standard | Date to be achieved by and maintained thereafter |
|---|---|---|---|
| **$NO_2$** | 200 | Hourly mean not to be exceeded more than 18 times a year (modelled as 99.79th percentile) | 31-12-2005 |
| | 40 | Annual average | 31-12-2005 |
| **$PM_{10}$** | 50 | 24-hour mean not be exceeded more than 35 times a year (modelled as 90.41st percentile) | 31-12-2004 |
| | 40 | Annual average | 31-12-2004 |
| **$PM_{2.5}$** | 25 | Annual average | 2020 |

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.

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

# 4 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.

The Council has declared two Air Quality Management Areas (AQMAs) due to annual average $NO_2$ concentrations exceeding the Air Quality Objective: along the M25, including an extended area at Egham; and Addlestone town centre.

The Council operates diffusion tubes at 32 locations across the Borough as of 2016; in 2015, diffusion tubes were operated at 31 locations, although year-round monitoring was only carried out at 24 of these. Figure 4.1 presents the locations of the diffusion tubes and AQMAs.

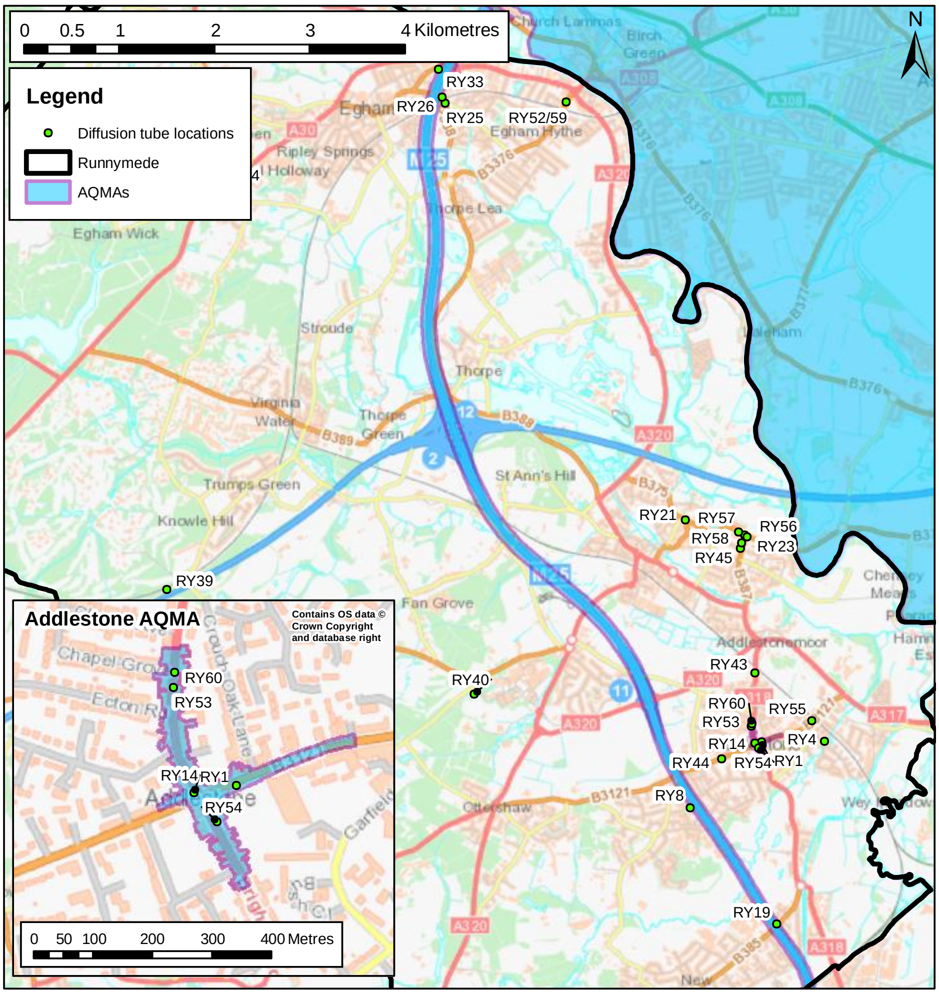


*Figure 4.1: Diffusion tube locations*

Table 4.1 presents the monitored annual average concentrations for 2015. These data were taken from Runnymede Borough Council's 2015 Air Quality Annual Status Report (ASR). A bias adjustment factor of 0.97 has been applied to the raw values. Exceedences of the Air Quality Objective of 40µg/m³ for annual average $NO_2$ concentrations are highlighted in bold. Note that, although there are 25 diffusion tube locations, RY52 and RY59 are co-located.

***Table 4.1: Monitored annual average $NO_2$ concentrations at Runnymede diffusion tubes, 2015 (µg/m$^3$)***

| Site ID | Site Name | Location | Height (m) | Distance to kerb (m) | Concentration (µg/m³) |
|---|---|---|---|---|---|
| RY1 | Civic Centre, Station Road, Addlestone | 505065, 164613 | 2.3 | 2 | 39.1 |
| RY4 | Riverside Sheltered Housing, Piston Close, Addlestone | 505727, 164624 | 2 | 5 | 19.6 |
| RY8 | Ongar Place First School, Milton Road, Addlestone | 504325, 163940 | 1.9 | 21 | 22.0 |
| RY14 | 1 Church Road, Addlestone | 504991, 164601 | 2.3 | 2 | 48.6 |
| RY19 | 78 Woodham Lane, New Haw | 505227, 162701 | 2 | 2.5 | 34.3 |
| RY21 | London Street/Heriot Road junction, Chertsey | 504265, 166941 | 2 | 1 | 32.1 |
| RY23 | 37 Bridge Road, Chertsey | 504888, 166786 | 2.2 | 1 | **42.2** |
| RY25 | 1 Pooley Green Road, Egham | 501748, 171316 | 2.3 | 13 | 28.2 |
| RY26 | Railway crossing, Vicarage Road, Egham | 501715, 171382 | 2.2 | 2.5 | **41.0** |
| RY33 | 46 The Avenue, Egham | 501679, 171676 | 2.1 | 15 | 32.4 |
| RY34 | St. Judes Rd Englefield Green | 499328, 170695 | 2.3 | 1 | 25.1 |
| RY39 | Chobham Lane, Longcross, near Kitsmead Lane roundabout | 498827, 177217 | 1.8 | 10 | 25.1 |
| RY40 | Homewood Park, Stonehill | 502052, 165119 | 2.5 | 68 | 17.0 |
| RY43 | 114 Chertset Cl, Addlestone | 504996, 165339 | 2.3 | 2 | 34.5 |
| RY44 | 87 Church Road, Addlestone | 504622, 164433 | 2.4 | 2 | 23.3 |
| RY45 | 27/29 Weir Road, Chertsey | 504844, 166648 | 2.3 | 2 | 37.2 |
| RY52 | 12 Thorpe Road, Egham | 503011, 171333 | 2.3 | 2 | 34.0 |
| RY53 | 1-22 Wyvern Place, High St, Addlestone | 504960, 164778 | 2.4 | 2 | 39.2 |
| RY54 | 23 Brighton Road, Addlestone | 505036, 164554 | 2.3 | 2 | 36.4 |
| RY55 | 158 Station Road, Addlestone | 505592, 164840 | 2.3 | 0.2 | 35.9 |
| RY56 | 34/36 Bridge Road, Chertsey | 504911, 166766 | 2.3 | 1 | **48.7** |
| RY57 | Opposite Knightsmead, on Bridge Road, Chertsey | 504826, 166819 | 2.3 | 2 | 36.7 |
| RY58 | 39 Weir Road, Chertsey | 504859, 166701 | 2.3 | 2 | 33.4 |
| RY59 | 12 Thorpe Road, Egham | 503011, 171333 | 2.3 | 1 | 34.0 |
| RY60 | Renaissance flats, High Street, Addlestone | 504962, 164803 | 2.4 | 2 | 38.8 |

# 5 Air quality modelling

## 5.1 Modelling software

All modelling was carried out using ADMS-Urban[3] version 4.2, developed by CERC. This model allows the effects of wider urban areas on local air quality to be taken into account, allowing the effect of emissions from London to be included in the model.

## 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. The modelling used a roughness length of 0.75 metres, which represents built-up areas.

The difference in land use at the meteorological site compared to the study area was taken into account by entering a different surface roughness for the meteorological site. See Section 5.4 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-Airport 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 Heathrow in 2015 was used for all modelled scenarios, including future years. Table 5.1 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 5.1: Summary of meteorological data***

| Year | % of hours used | Parameter | Minimum | Maximum | Mean |
|---|---|---|---|---|---|
| 2015 | 99.6 | Temperature (°C) | -4.2 | 33.7 | 11.0 |
| | | Wind speed (m/s) | 0 | 16.5 | 4.1 |
| | | Cloud cover (oktas) | 0 | 8 | 3.4 |

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 shows a wind rose for the site showing the frequency of occurrence of wind from different directions for a number of wind speed ranges.

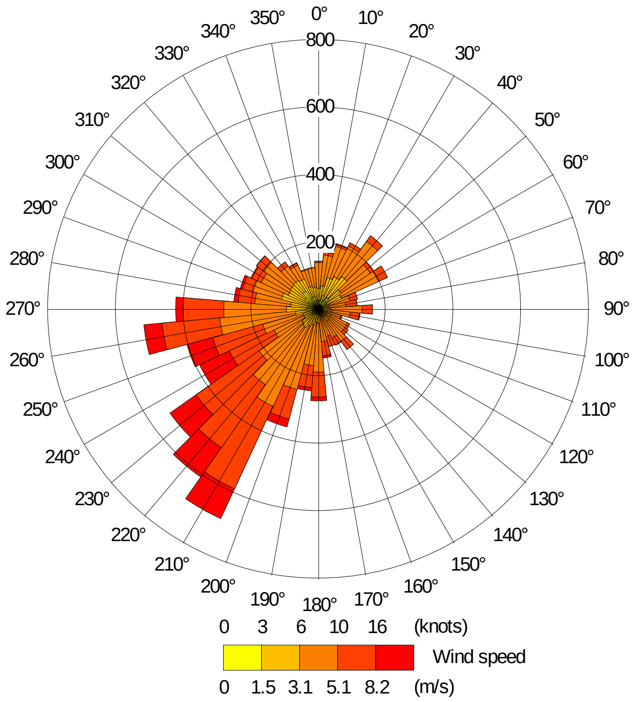


***Figure 5.1: Wind rose for Heathrow 2015***

## 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. $NO_x$, $NO_2$ and $O_3$ concentrations from Rochester, Harwell, Lullington Heath and Wicken Fen for 2013 were input to the model, the monitored concentration used for each hour depending upon the wind direction for that hour, as shown in Figure 5.2.

Two sites measuring $PM_{10}$, $PM_{2.5}$, and $SO_2$ background data were used for the modelling. For hours with westerly winds, data from Harwell were used, and for hours for which the wind direction was from the east, measurements from Rochester were used.

$NO_x$, $NO_2$ and $O_3$ Concentrations obtained in this manner were scaled to match the lowest concentrations given for Runnymede in the 2015 background maps published by Defra.

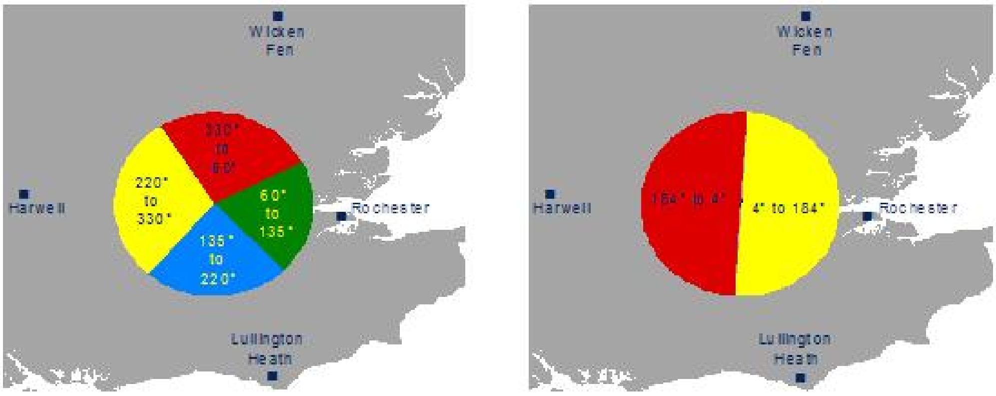


***Figure 5.2: Wind direction segments used to calculate background concentrations for $NO_x$, $NO_2$ and $O_3$ (left) and $PM_{10}$, $PM_{2.5}$ and $SO_2$ (right)***

Table 5.2 summarises the annual statistics of the resulting background concentrations used in the modelling for 2013.

***Table 5.2: Summary of 2015 background data used in the modelling (μg/m$^3$)***

| **Statistic** | **$NO_x$** | **$NO_2$** | **$O_3$** | **$PM_{10}$** | **$PM_{2.5}$** | **$SO_2$** |
|---|---|---|---|---|---|---|
| Annual average | 15.2 | 11.3 | 55.2 | 14.7 | 8.4 | 1.4 |
| 99.79$^{th}$ percentile of hourly average | 70.7 | 48.6 | 118.1 | - | - | - |
| 90.41$^{st}$ percentile of 24-hour average | - | - | - | 24.3 | 17.7 | 2.9 |

## 5.7 Street canyons

The advanced street canyon modelling 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, provided by the Council.

# 6 Emissions

Emission inventories were compiled for each of the three scenarios modelled, using CERC's EMIT emissions inventory tool, version 3.4.

## 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 $NO_x$ and $NO_2$ were calculated from traffic flows using EFT v8.0.1 emission factors based on Euro vehicle emissions categories. These emission factors include speed-emissions data for $NO_x$ using emission factors equivalent to COPERT 5 [4]. As the EFT only includes emission factors for years up to 2030, emission factors for 2030 were used in the 2036 scenarios, representing a conservative estimate of vehicle emissions.

The EfT v8.0.1 uses fleet data separated by the regions and road types in Table 6.1. London roads were classified by region as shown in Figure 6.1, with the M25 treated separately. Roads outside the LAEI region were classified as 'Non-London Urban', except for Motorways, which were classified as 'Non-London Motorway'.

***Table 6.1: EfT v8.0.1 emission factor regions***

| Area | Regions |
|---|---|
| Non-London | Urban / Rural / Motorway |
| London | Central / Inner / Outer / Motorway (M25 only) |

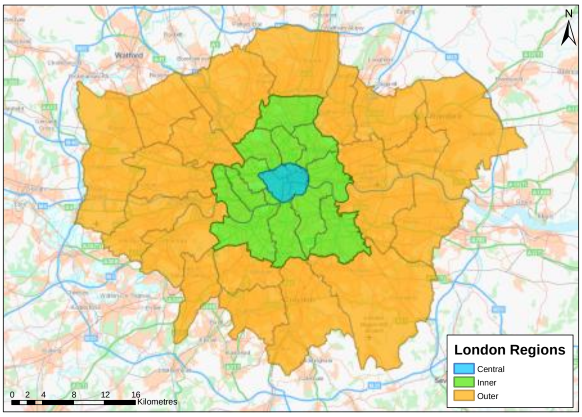


***Figure 6.1: London regions***

[4] http://www.emisia.com/copert/General.html

Note that there is large uncertainty surrounding the current emissions estimates of $NO_x$ from all vehicle types, in particular diesel vehicles, in these factors; refer to, for example, an AQEG report from 2007 [5] and a Defra report from 2011 [6]. In order to address this discrepancy, the $NO_x$ emission factors were modified based on recently published Remote Sensing Data (RSD)[7] for vehicle $NO_x$ emissions in London. Scaling factors were applied to each vehicle category and speed.

Brake, tyre and road-wear emissions were and scaled using empirically-derived factors used in the London Atmospheric Emissions Inventory (LAEI) 2013. Resuspension emission factors were taken from a report produced by TRL Limited on behalf of Defra[8].

### 6.1.2 Activity data

As Runnymede lies on the southwestern edge of London, a single dataset combining traffic flow data from the London Atmospheric Emissions Inventory (LAEI) 2013 and the provided Runnymede traffic model data was generated, using the Runnymede traffic model data preferentially where available. Road emissions from the area outside the LAEI and traffic model areas were obtained from the National Atmospheric Emissions Inventory (NAEI).

The resulting model regions are shown in Figure 6.2.

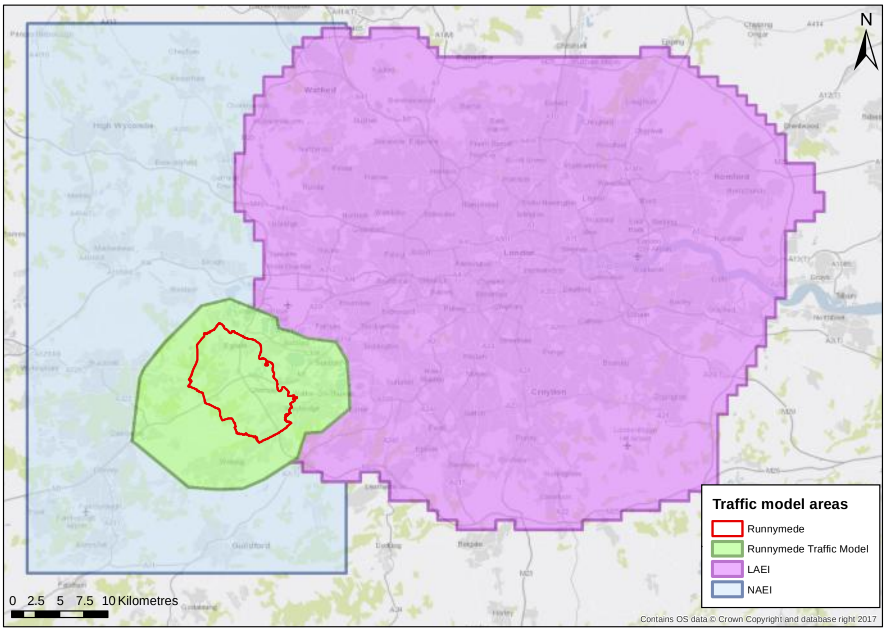


***Figure 6.2: Traffic activity data zones***

[5] Trends in primary nitrogen dioxide in the UK
[6] Trends in $NO_x$ and $NO_2$ emissions and ambient measurements in the UK
[7] 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.
[8] 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

In the Runnymede traffic model, traffic flows for peak times were provided, divided into cars, LGVs, HGVs, and buses. These peak flows were converted to Annual Average Daily Traffic flows (AADTs) using a representative factor for the area provided by the Council. Motorcycle flows were calculated from car flows using the average ratio between the two in DfT traffic counts in the Borough. Using this approach, motorcycle flows were assumed to be 1.1% of car flows for all roads.

### 6.1.3 Speed data

For road links in both the LAEI and Runnymede traffic model networks, average speeds from the LAEI were used in preference to modelled speeds from the Runnymede traffic model, as these were only provided for peak times and were therefore not representative of traffic speeds under normal flow conditions.

For roads in the Runnymede traffic model network area where no speed data were available in the LAEI, general assumptions were made for road speed using national traffic flow speed data published by the DfT[9]; these assumptions are presented in Table 6.2.

***Table 6.2: Traffic speeds outside the development area, from DfT traffic speed statistics***

| Road Type | Traffic type | Speed (km/hr) |
|---|---|---|
| Motorway | Free-flowing (main) | 71 |
| | Free-flowing (slip) | 48 |
| | Congested | 20 |
| Urban Road | Free-flowing | 50 |
| | Congested | 20 |

Speeds within 75m of major junctions (classified based on total AADT input and average input AADT per arm) were reduced to 20 kph, following LAQM.TG(16)[10].

### 6.1.4 Minor roads

In the Runnymede traffic model data area, minor roads emissions were assumed to be 5% of the NAEI total road traffic emissions for each grid square, reflecting the roads coverage in the provided traffic model data.

In the LAEI area, emissions were calculated using the emission factors described in Section 6.2, combined with LAEI statistics for total distance travelled along minor roads on a 1km grid basis, categorised by vehicle type.

[9] https://www.gov.uk/government/statistics/free-flow-vehicle-speeds-in-great-britain-2015
[10] https://laqm.defra.gov.uk/documents/LAQM-TG16-February-18-v1.pdf

### 6.1.5 Time-varying emissions

The variation of traffic flow during the day was taken into account by applying a set of diurnal profiles to the road emissions. National average diurnal profiles, published by the DfT, were used.[11] These profiles are shown in Figure 6.3. These profiles were applied to all major roads in the modelling area and grid sources, representing emissions of minor roads, and other emissions, aggregated on 1-km square basis, as described in Section 6.2.

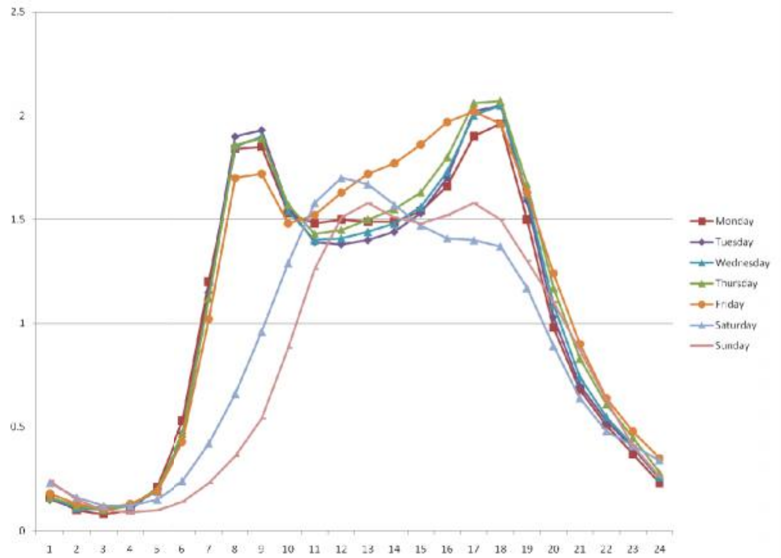


*Figure 6.3: Diurnal profiles used for roads and grid sources*

## 6.2 Other emissions

Emissions from other sources across the LAEI area were taken from the LAEI. Emissions from rail were modelled as road sources with an emission height of 4m, with rail sources running through the Runnymede area extended from the LAEI region; emissions from all other source types were modelled as an aggregated grid source with a resolution of 1km, matching the resolution in the LAEI. Emissions from sources outside the LAEI area were taken from the National Atmospheric Emissions Inventory (NAEI) 2015 for all modelled scenarios as a conservative assumption.

Domestic emissions from residential developments in the Local Plan were calculated using NAEI emission factors for domestic combustion of natural gas 2015, combined with mean estimates of domestic gas consumption per dwelling figures published by the Department for Business, Energy and Industrial Strategy[12]; this approach provides a conservative estimate of emissions for 2036.

Note that emissions from elevated sources arising from Heathrow were not modelled, in order to prevent overestimation of ground level concentrations.

[11] https://www.gov.uk/government/statistical-data-sets/tra03-motor-vehicle-flow
[12] https://www.gov.uk/government/collections/sub-national-gas-consumption-data

# 7 Model verification

The first stage of a modelling study is to model a current case in order to verify that the input data and model set-up are 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 2015.

Table 7.1 and Figure 7.1 present the monitored and modelled concentrations of $NO_2$ at the 24 diffusion tube monitoring sites operated in Runnymede.

The modelled annual average $NO_2$ concentrations correlate strongly with the monitored data. This suggests that the modifications made to the model setup are sensible and lends confidence to the prediction of future concentrations.

Note that there is a significant degree of variance in the verification data; the underpredicting sites tend to be located on busy junctions, for example RY56 which is located on the busy junction between Weir Road and Bridge Road. Underprediction at these sites may reflect a greater degree of congestion on this junction than is recommended for modelling by the LAQM.TG(16) guidance. The model overpredicts at a number of sites with low data capture for 2015; at a number of these sites data capture is best in months where concentrations tend to be low.

The verification indicates that the model set-up and emissions are suitable for the situation considered and lends confidence to the predictions of future concentrations.

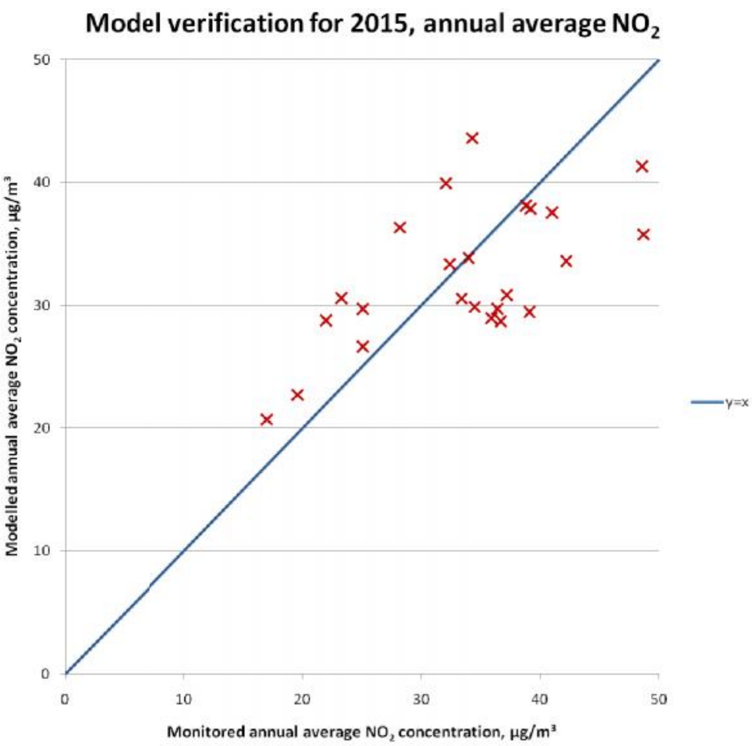


***Figure 7.1: Measured and modelled annual average $NO_2$ concentrations***

***Table 7.1: Model verification, annual average $NO_2$, 2015. The ratio of monitored to modelled results is presented, with the blue-red scale representing model underprediction (blue) to overprediction (red)***

| Site ID | Site Name | Concentration, µg/m³ | | Modelled / Monitored Ratio |
|---|---|---|---|---|
| | | Mon | Mod | |
| RY1 | Civic Centre, Station Road, Addlestone | 39.1 | 29.5 | 75.3% |
| RY4 | Riverside Sheltered Housing, Piston Close, Addlestone | 19.6 | 22.7 | 116.0% |
| RY8 | Ongar Place First School, Milton Road, Addlestone | 22.0 | 28.8 | 130.8% |
| RY14 | 1 Church Road, Addlestone | 48.6 | 41.3 | 85.0% |
| RY19 | 78 Woodham Lane, New Haw | 34.3 | 43.6 | 127.1% |
| RY21 | London Street/Heriot Road junction, Chertsey | 32.1 | 39.9 | 124.5% |
| RY23 | 37 Bridge Road, Chertsey | 42.2 | 33.6 | 79.6% |
| RY25 | 1 Pooley Green Road, Egham | 28.2 | 36.3 | 128.9% |
| RY26 | Railway crossing, Vicarage Road, Egham | 41.0 | 37.6 | 91.6% |
| RY33 | 46 The Avenue, Egham | 32.4 | 33.3 | 102.9% |
| RY34 | St. Judes Rd Englefield Green | 25.1 | 26.6 | 106.1% |
| RY39 | Chobham Lane, Longcross, near Kitsmead Lane roundabout | 25.1 | 29.7 | 118.3% |
| RY40 | Homewood Park, Stonehill | 17.0 | 20.7 | 121.9% |
| RY43 | 114 Chertset Cl, Addlestone | 34.5 | 29.9 | 86.6% |
| RY44 | 87 Church Road, Addlestone | 23.3 | 30.6 | 131.3% |
| RY45 | 27/29 Weir Road, Chertsey | 37.2 | 30.8 | 82.9% |
| RY52 | 12 Thorpe Road, Egham | 34.0 | 33.8 | 99.6% |
| RY53 | 1-22 Wyvern Place, High St, Addlestone | 39.2 | 37.9 | 96.6% |
| RY54 | 23 Brighton Road, Addlestone | 36.4 | 29.7 | 81.6% |
| RY55 | 158 Station Road, Addlestone | 35.9 | 29.0 | 80.7% |
| RY56 | 34/36 Bridge Road, Chertsey | 48.7 | 35.8 | 73.4% |
| RY57 | Opposite Knightsmead, on Bridge Road, Chertsey | 36.7 | 28.7 | 78.3% |
| RY58 | 39 Weir Road, Chertsey | 33.4 | 30.6 | 91.5% |
| RY59 | 12 Thorpe Road, Egham | 34.0 | 33.8 | 99.6% |
| RY60 | Renaissance flats, High Street, Addlestone | 38.8 | 38.1 | 98.3% |

# 8 2015 baseline results

## 8.1 Concentration contours

Contour plots showing modelled concentrations across the output area for the 2015 baseline, on a 10m resolution, are presented below. Plots showing areas of interest in detail are also provided.

Modelled annual mean $NO_2$ concentrations for 2015 indicate exceedences of the Air Quality Objective of 40µg/m³ along the M25, and small areas of exceedence at some junctions inside the M25, including at building façades on London Street and Windsor Street in Chertsey.

Concentrations close to the Air Quality Objective for annual average $NO_2$ concentrations are predicted within the Addlestone AQMA; however, no exceedences of the objective are predicted at locations of relevant exposure. As such, given the uncertainty in the model input data and results, there is a significant possibility of concentrations exceeding the standard at these locations.

Additionally, concentrations within 10% of the Objective occur at building façades along St Ann’s Road in Chertsey, and at building façades on The Avenue in Egham, adjacent to the M25.

Modelled hourly $NO_2$ concentrations do not exceed the Air Quality Objective (200µg/m³ for more than 18 hours per year) at any locations of relevant exposure across Runnymede. Concentrations exceeding the standard are predicted along the M25.

The entirety of the area is predicted to be compliant with the Air Quality Objective of 40 µg/m³ for $PM_{10}$ in 2015. Furthermore, no exceedences of the Air Quality Objective of 50µg/m³ for 24-hour average $PM_{10}$ are predicted in Runnymede.

Concentrations exceed the World Health Organisation (WHO) guideline for annual average $PM_{10}$ of 20µg/m$^3$ along the M25 and at a number of junctions, including those in the Addlestone AQMA.

No exceedences of the Air Quality Objective of 25µg/m³ for annual average $PM_{2.5}$ concentrations are predicted for 2015.

### 8.1.1 $NO_2$

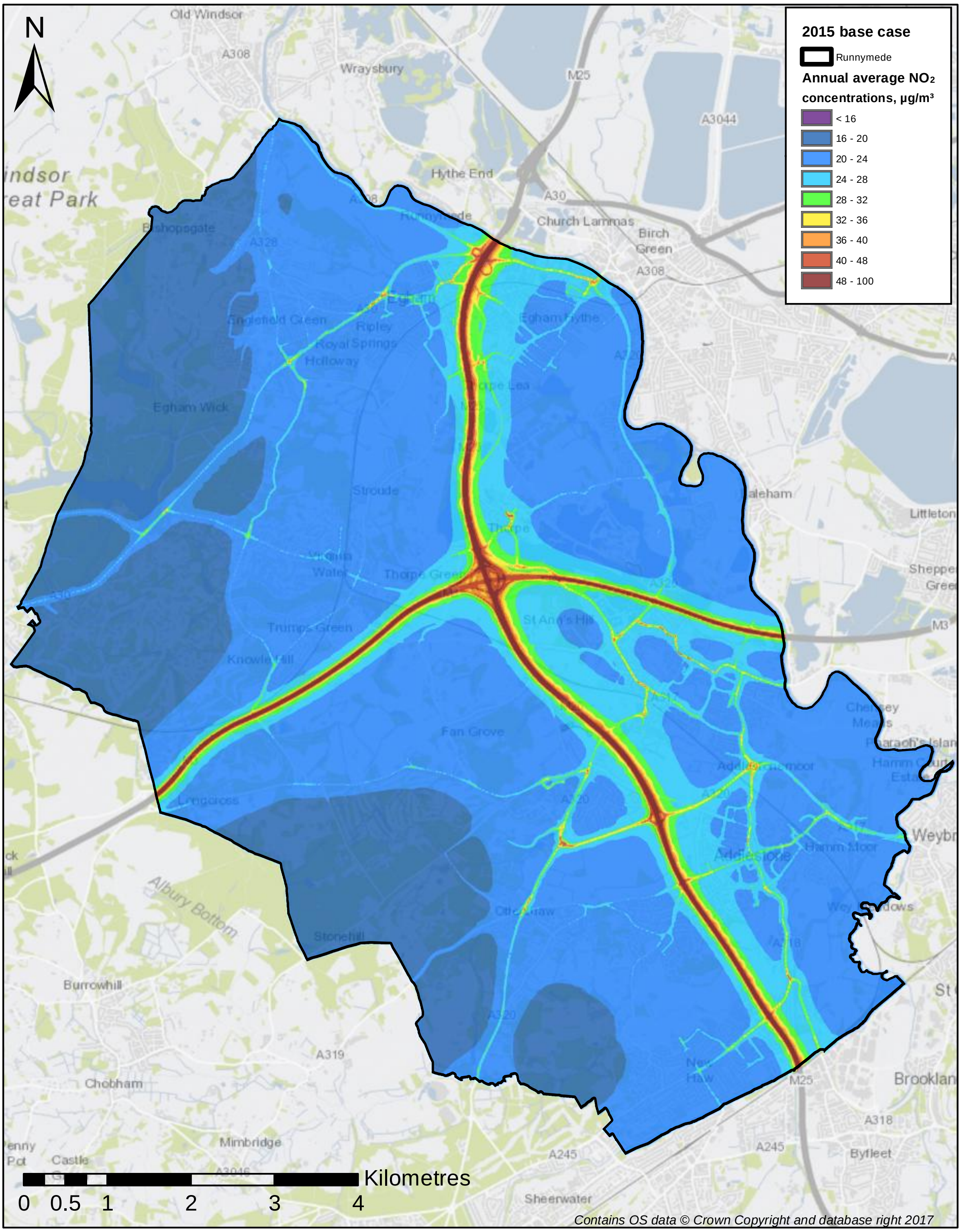


***Figure 8.1: Annual mean $NO_2$ concentrations, 2015 baseline (µg/m³)***

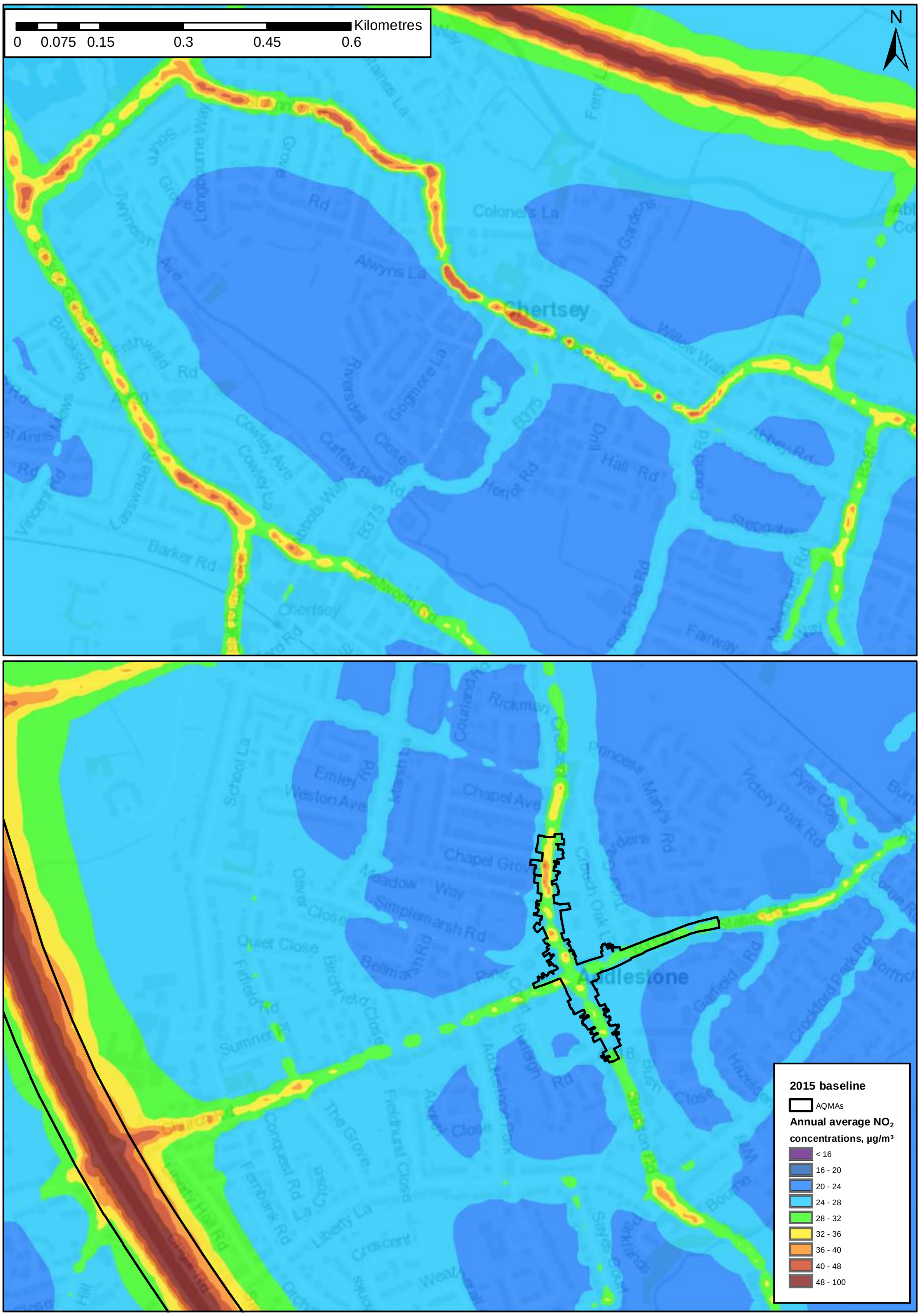


***Figure 8.2: Annual mean $NO_2$ concentrations, 2015 baseline, Addlestone (below) and Chertsey (above) (µg/m³)***

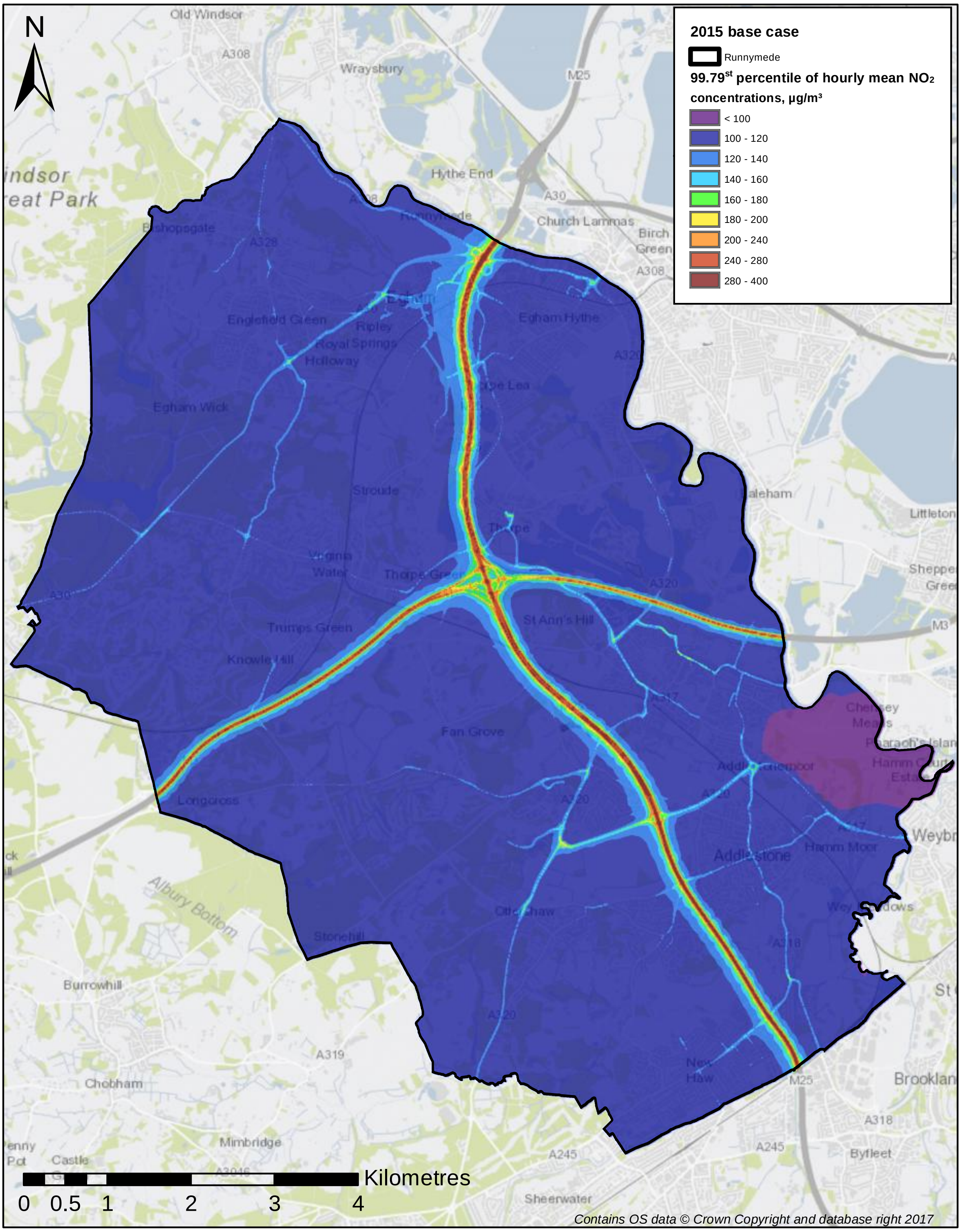


*Figure 8.3: 99.79th percentile of hourly mean $NO_2$ concentrations, 2015 baseline (µg/m³)*


***Figure 8.4: 99.79th percentile of hourly mean $NO_2$ concentrations, 2015 baseline, Addlestone (below) and Chertsey (above) (µg/m³)***

## 8.1.2 $PM_{10}$

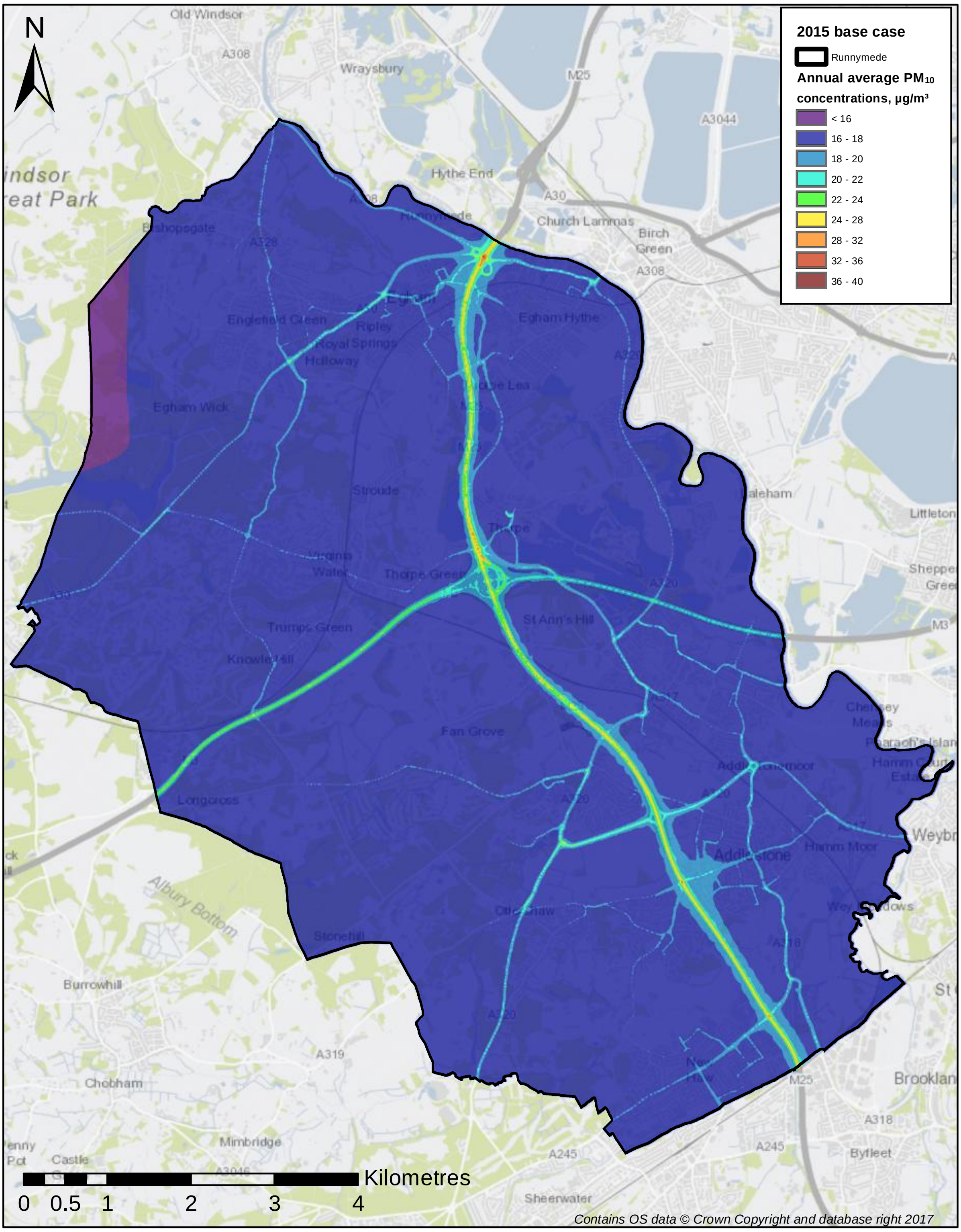


*Figure 8.5: Annual mean $PM_{10}$ concentrations, 2015 baseline (µg/m³)*

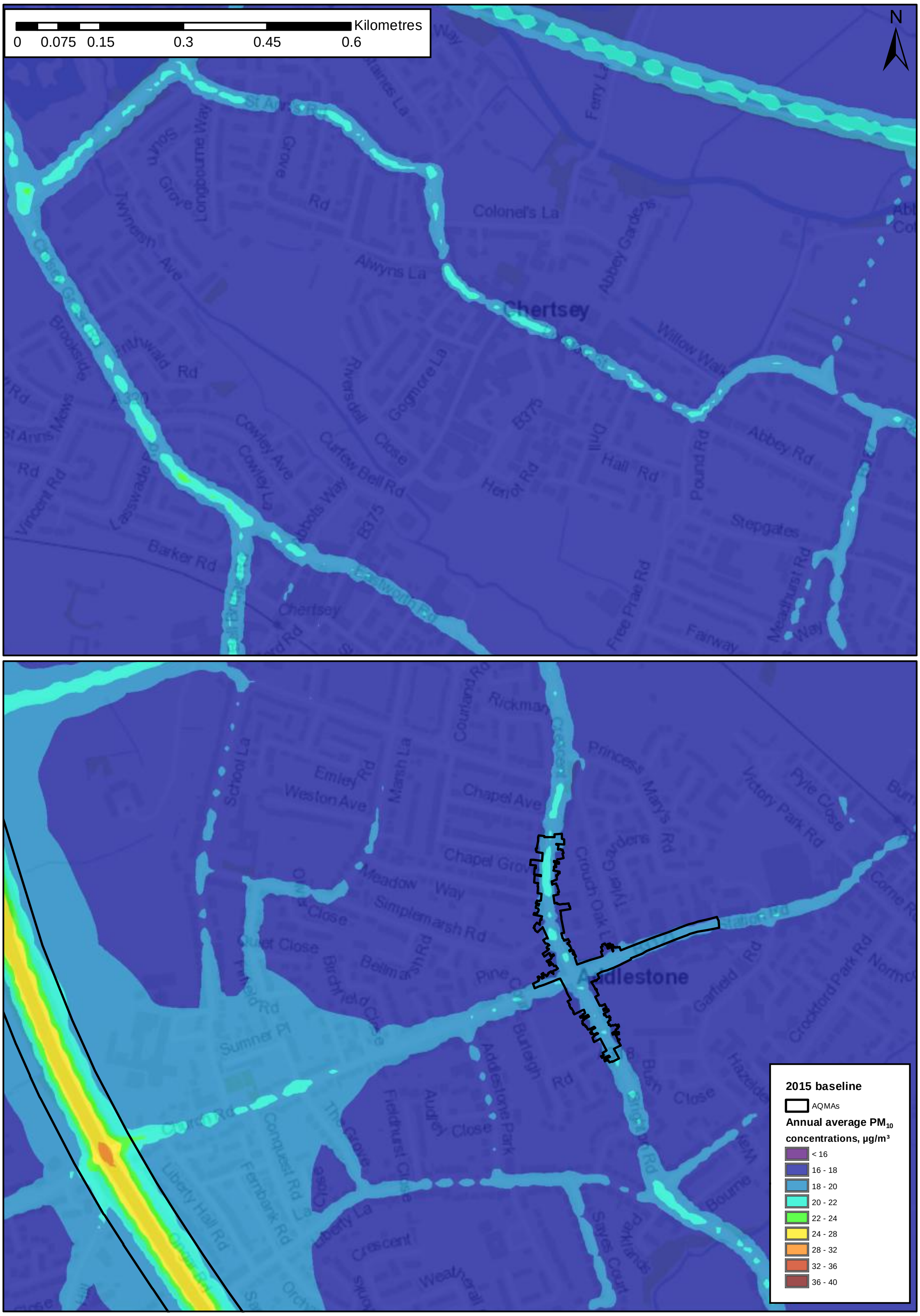


***Figure 8.6: Annual mean $PM_{10}$ concentrations, 2015 baseline, Addlestone (below) and Chertsey (above) (µg/m³)***

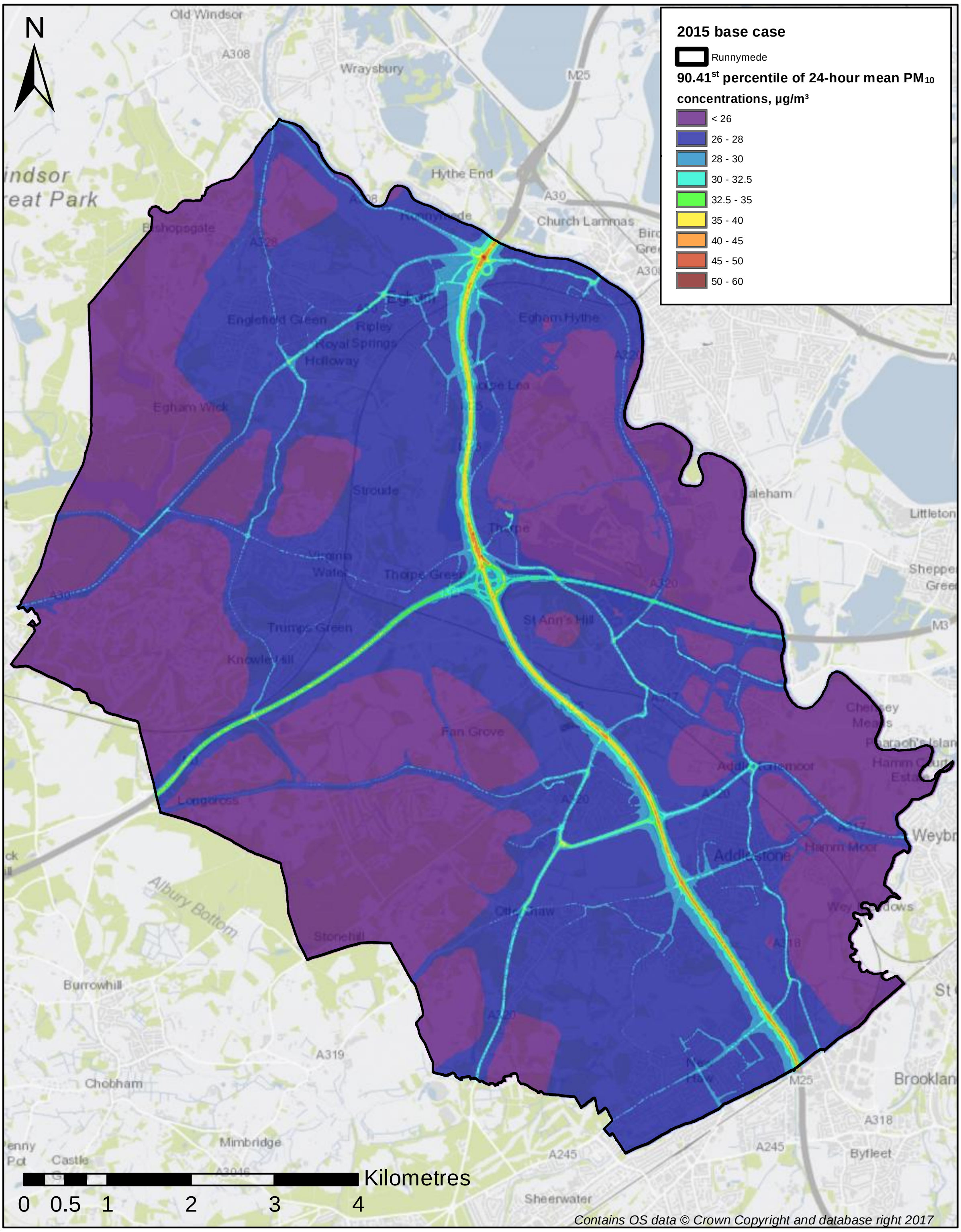


***Figure 8.7: 90.41st percentile of 24-hourly mean $PM_{10}$ concentrations, 2015 baseline (µg/m³)***

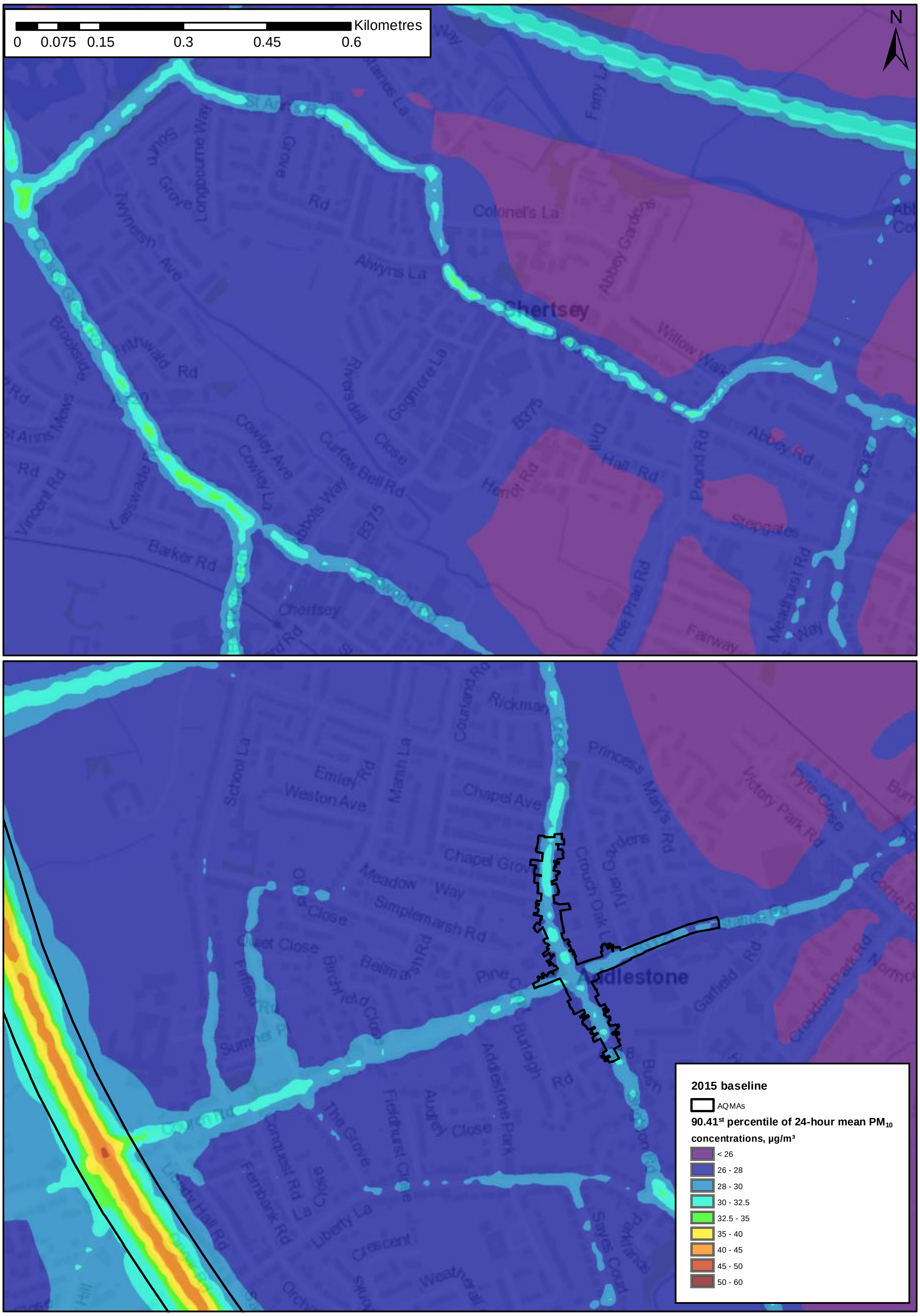


***Figure 8.8: 90.41st percentile of 24-hourly mean $PM_{10}$ concentrations, 2015 baseline, Addlestone (below) and Chertsey (above) (µg/m³)***

## 8.1.3 $PM_{2.5}$

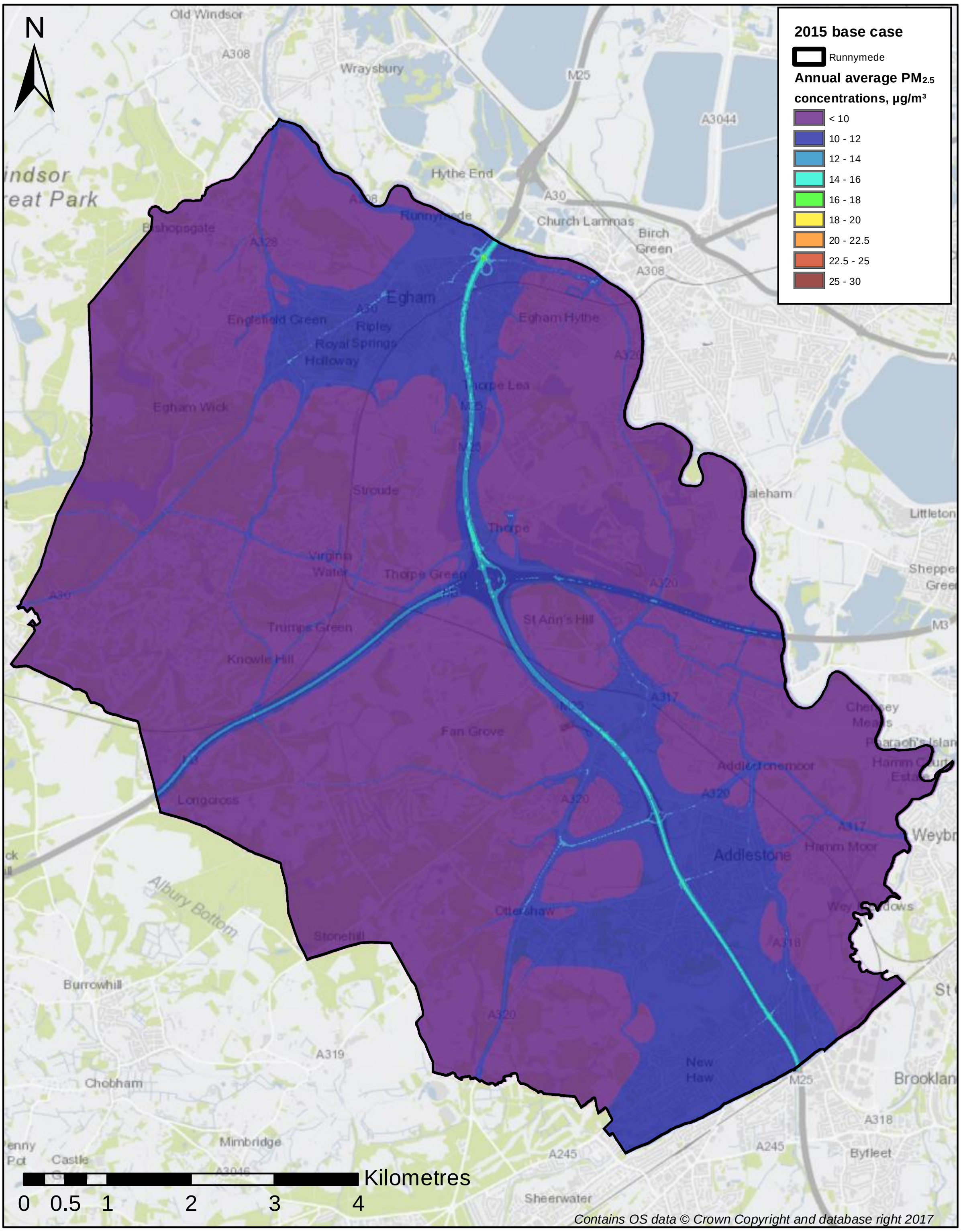


*Figure 8.9: Annual mean $PM_{2.5}$ concentrations, 2015 baseline (µg/m³)*

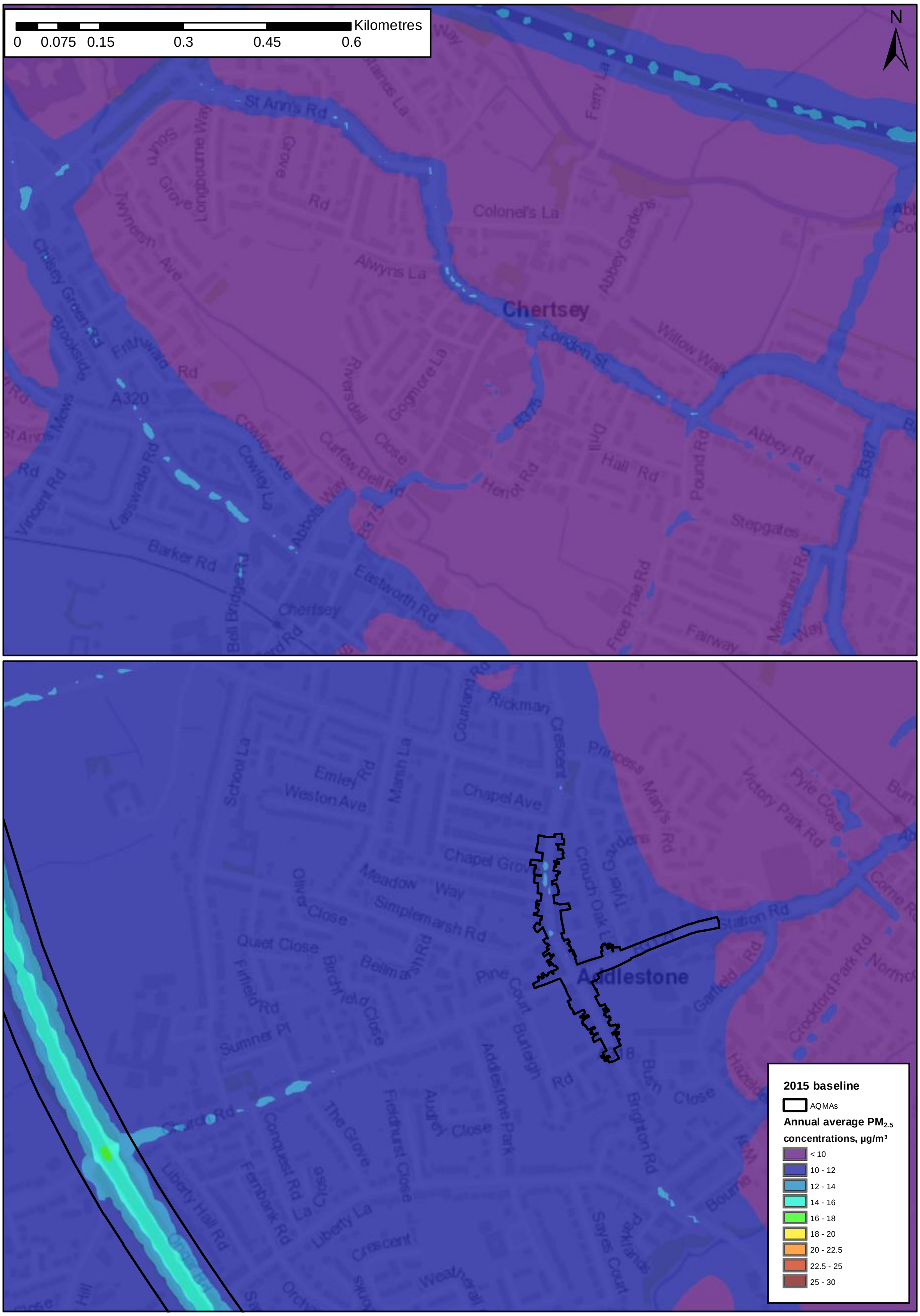


***Figure 8.10: Annual mean $PM_{2.5}$ concentrations, 2015 baseline, Addlestone (below) and Chertsey (above) ($\mu g/m^3$)***

# 9 2036 results

Contour plots showing modelled concentrations across the output area for the two scenarios for 2036, on a 10m resolution, are presented below. Difference plots are also presented, where appropriate, in order to allow the impacts of the Local Plan to be clearly identified.

## 9.1 Concentration contours

### 9.1.1 Annual average $NO_2$

Figures 9.1 and 9.2 present annual average $NO_2$ concentrations across the whole of Runnymede for the without Local Plan and with Local Plan scenarios, respectively. Figure 9.3 presents the difference between the modelled scenarios, and Figure 9.4 shows this difference at areas of interest.

No exceedences of the Air Quality Objective of 40µg/m³ for annual average $NO_2$ concentrations are predicted across the model area in either 2036 scenario, including along the M25, where the maximum predicted concentration is 39µg/m³. Note that, while this is within 10% of the standard, and is subject to model uncertainty, concentrations within 10% of the objective are not predicted at any locations of relevant exposure. This reflects the significant decreases in total $NO_x$ and $NO_2$ emissions associated with the improvement in vehicle technologies and emissions forecasted for 2036, and is not related to any changes proposed in the Local Plan.

Increases of 0.1-0.2 µg/m³ are predicted within proposed developments in the Local Plan. As this is below 0.5% of the Air Quality Objective, these effects can be considered negligible. However, it should be noted that these predictions are based on a uniform emission rate across the area; the precise location and nature of any boilers at these sites is likely lead to substantially different local concentrations at these sites.

Traffic flow changes associated with the Local Plan are spatially complex, and as such lead to both increases and decreases in annual average $NO_2$ concentrations in different areas. Broadly speaking, significant increases in concentrations are seen along roads in the portion of Chertsey southwest of the M25, and along motorways and trunk roads in the area; changes of a smaller magnitude are seen on smaller roads within Addlestone and Chertsey, with the majority of changes being decreases. These changes are shown in Figure 9.4.

The maximum increases in roadside concentrations occur in the St. Peter's Hospital area, and are caused by traffic routing changes and additional demand associated with the St. Peter's Hospital residential development. Combined with the effects of emissions from the development itself, increases in annual average $NO_2$ concentrations of up to 2µg/m³ are seen along Silverlands Close, with similar increases seen along private roads currently associated with the hospital.

Annual average $NO_2$ concentrations along the M25 and M3 are predicted to increase by a maximum of 0.2µg/m³, reflecting increased usage in the Local Plan scenario.

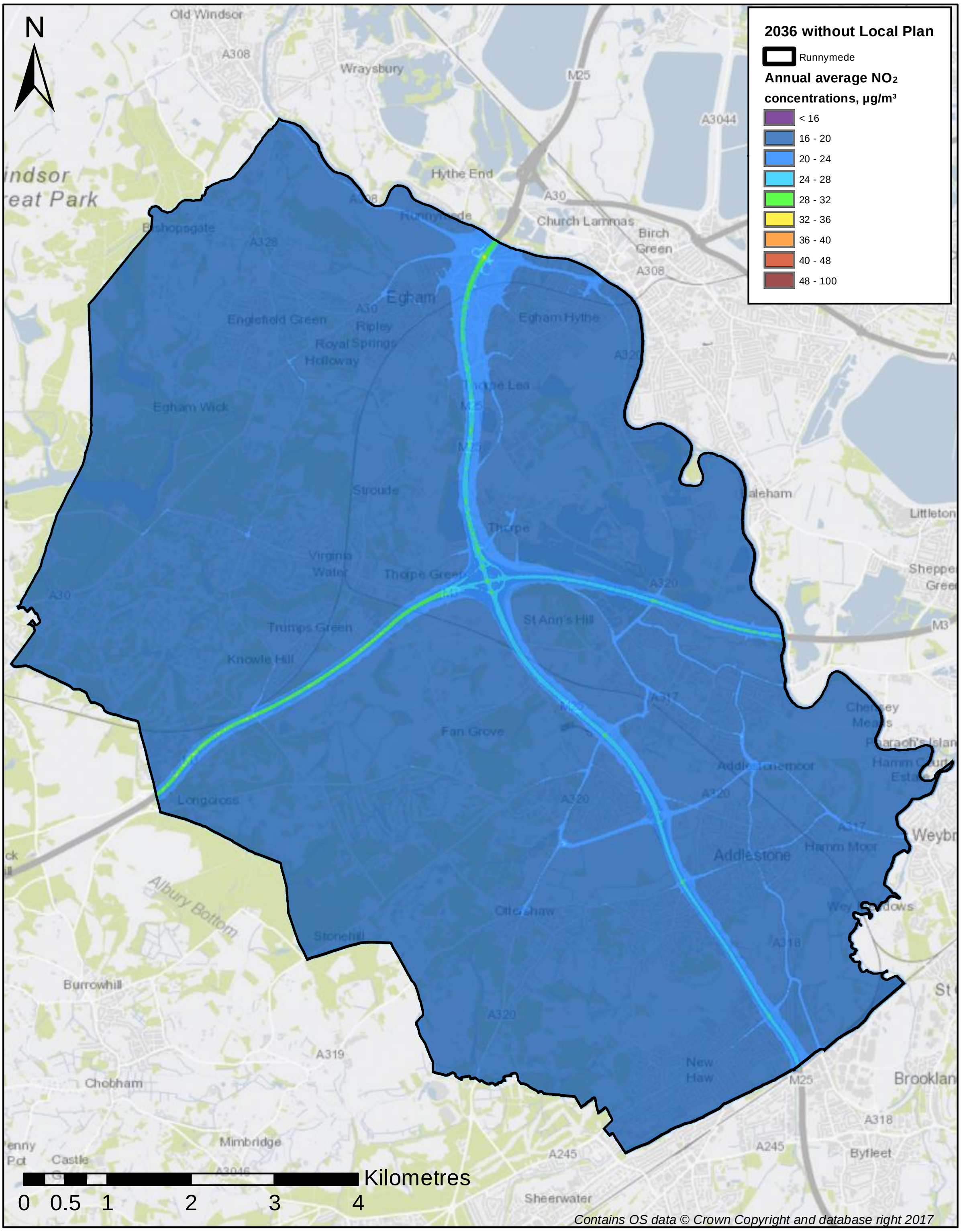


***Figure 9.1: Annual mean $NO_2$ concentrations without the Local Plan in 2036 (µg/m³)***

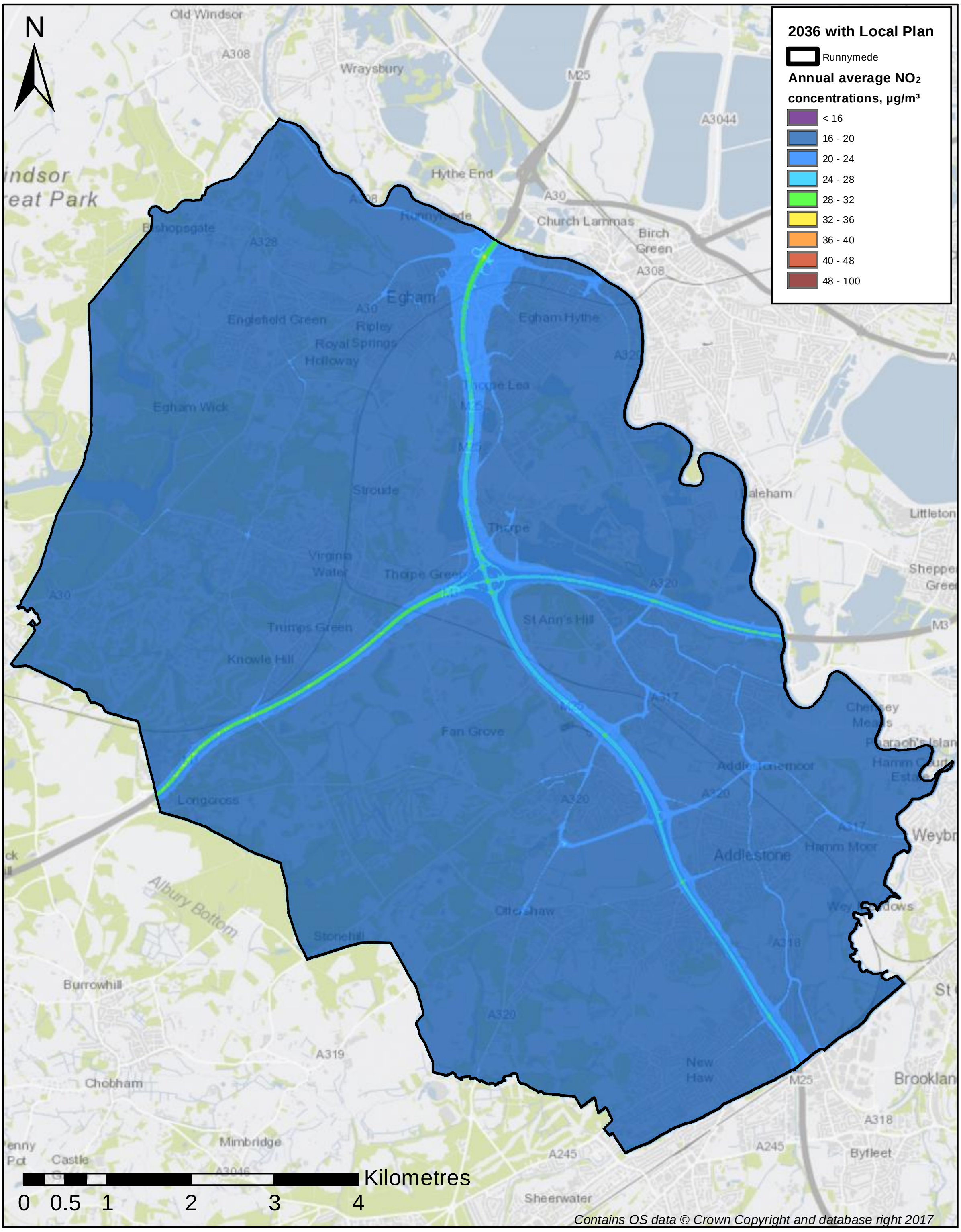


***Figure 9.2: Annual mean $NO_2$ concentrations with the Local Plan in 2036 (µg/m³)***

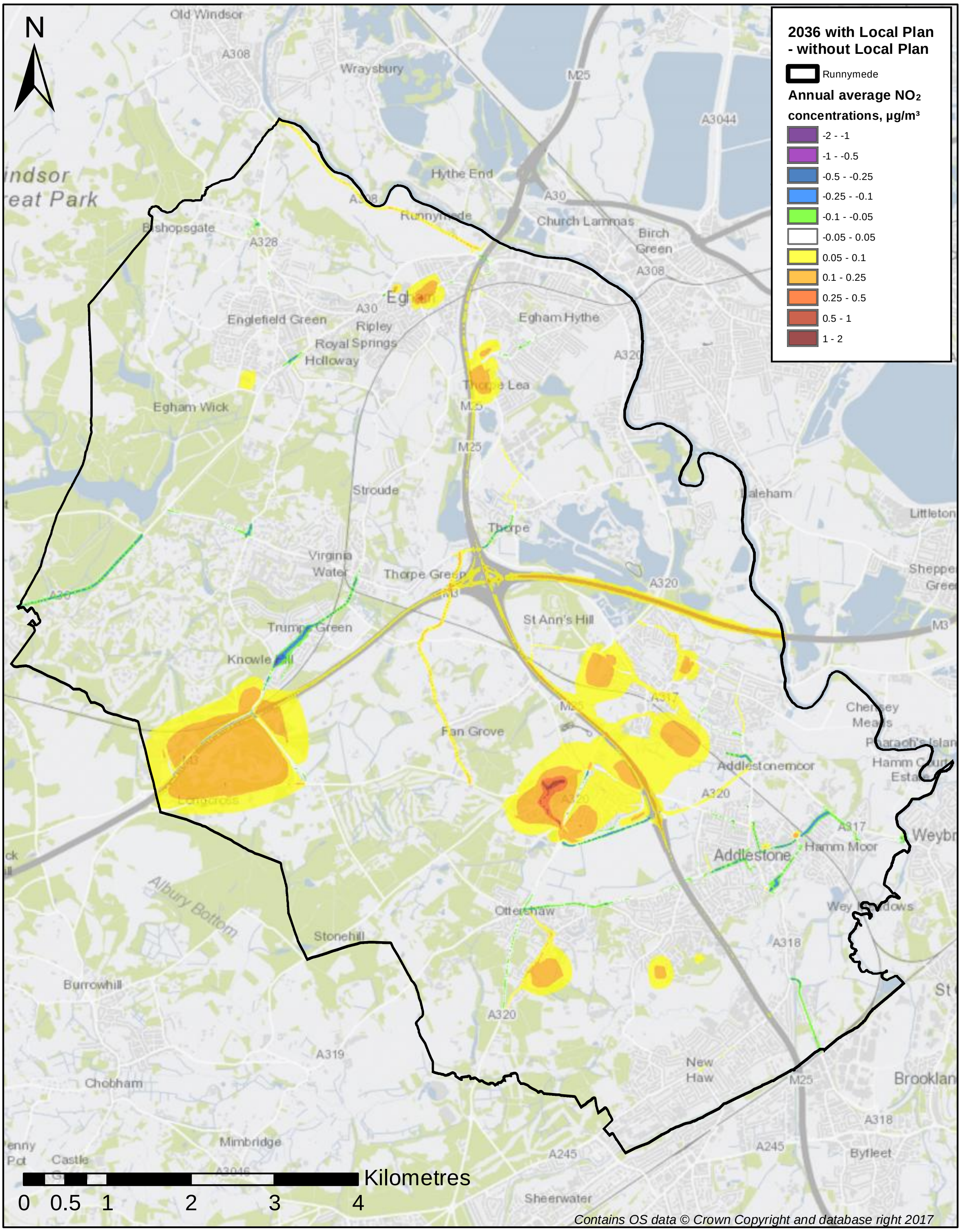


*Figure 9.3: Difference between annual mean $NO_2$ concentrations with and without the Local Plan, 2036 («g/m$^3$)*


***Figure 9.4: Difference between annual mean $NO_2$ concentrations with and without the Local Plan, 2036, Addlestone (below) and Chertsey (above) («g/m$^3$)***

### 9.1.2 Hourly average $NO_2$

Figures 9.5 and 9.6 present the 99.79th percentile of hourly average $NO_2$ concentrations across the whole of Runnymede for the without Local Plan and with Local Plan scenarios, respectively.

No exceedences of the Air Quality Objective for hourly average $NO_2$ concentrations are predicted. As for annual average concentrations, the maximum predicted concentrations occur along the M25, but are significantly below the standard. As such, no difference plots have been produced for this statistic, as any changes are insignificant.

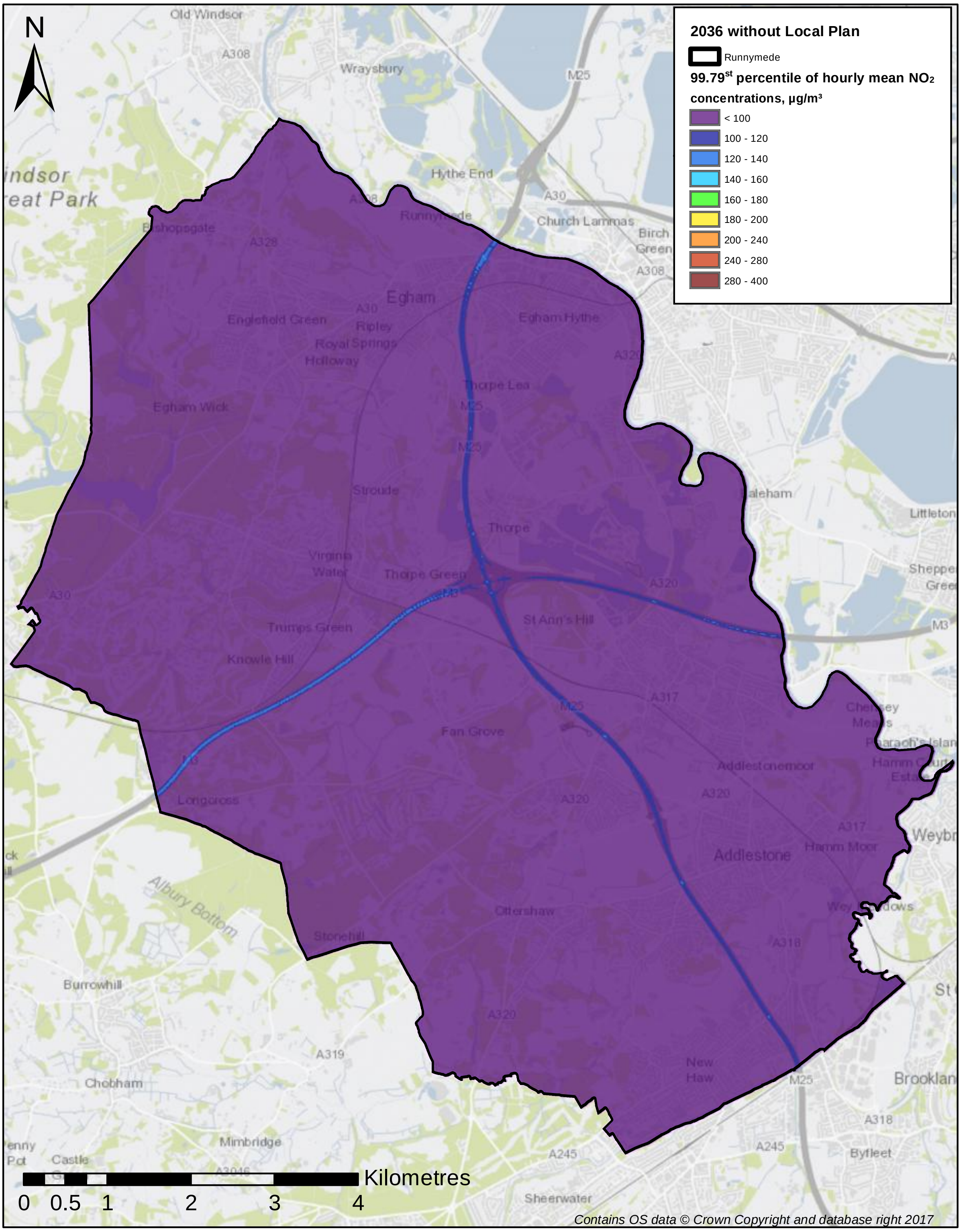


***Figure 9.5: 99.79$^{th}$ percentile of hourly mean $NO_2$ concentrations without the Local Plan in 2036 (µg/m³)***

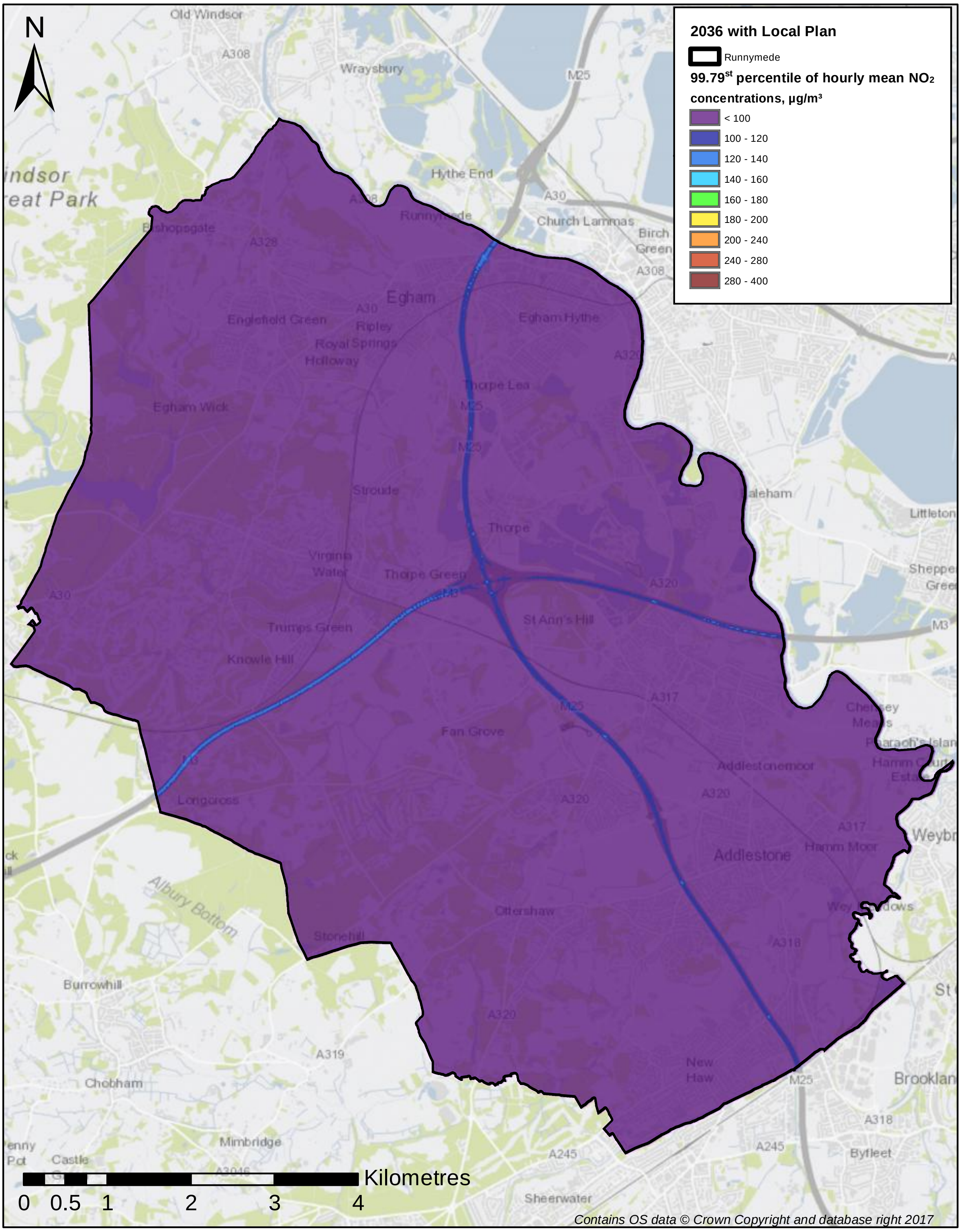


***Figure 9.6: 99.79$^{th}$ percentile of hourly mean $NO_2$ concentrations with the Local Plan in 2036 (µg/m³)***

### 9.1.3 Annual average $PM_{10}$

Figure 9.7 and Figure 9.8 present annual average $PM_{10}$ concentrations across the whole of the Borough, for the without and with Local Plan scenarios respectively; Figure 9.9 shows the change between the two scenarios, and Figure 9.10 presents the change at areas of interest.

As seen with $NO_2$ concentrations, particulate concentrations decrease significantly between 2015 and 2036. However, this decrease is not as great owing to the proportion of particulate emissions from non-exhaust traffic sources, which are not affected by improving engine technology. No exceedences of the Air Quality Objective of 40µg/m³ for annual average $PM_{10}$ concentrations are predicted across the area in either 2036 scenario.

Annual average $PM_{10}$ concentrations show a similar pattern of increases and decreases to annual average $NO_2$ concentrations with the implementation of the Local Plan. Small decreases (up to 0.8µg/m³) are seen along roads in Addlestone, Chertsey, and Virginia Water, while small increases (up to 0.1µg/m³) are seen along Motorways and some trunk roads across Runnymede. Increases of 1µg/m³ are seen along roads associated with the St. Peter's Hospital residential development.

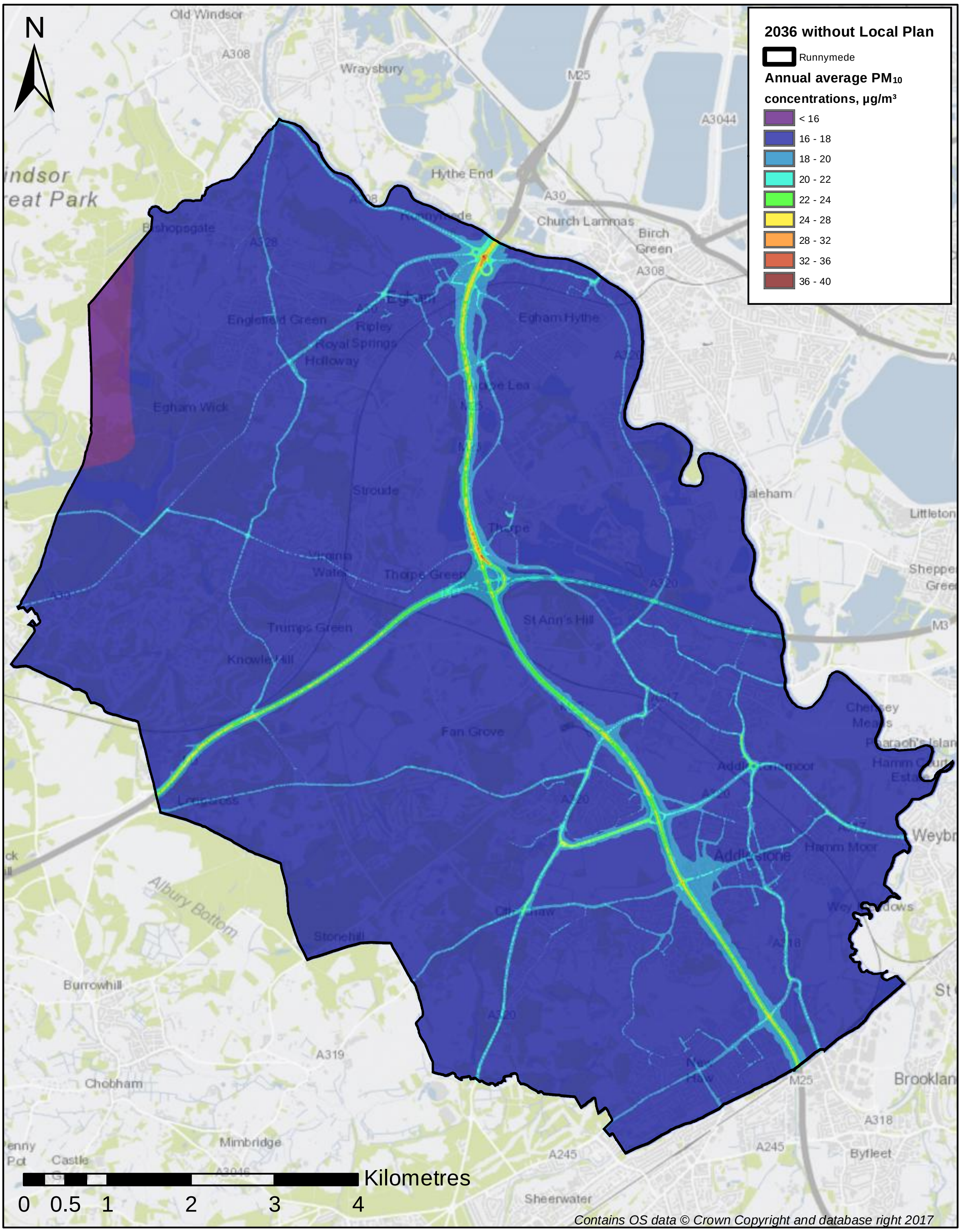


***Figure 9.7: Annual mean $PM_{10}$ concentrations without the Local Plan in 2036 (µg/m³)***

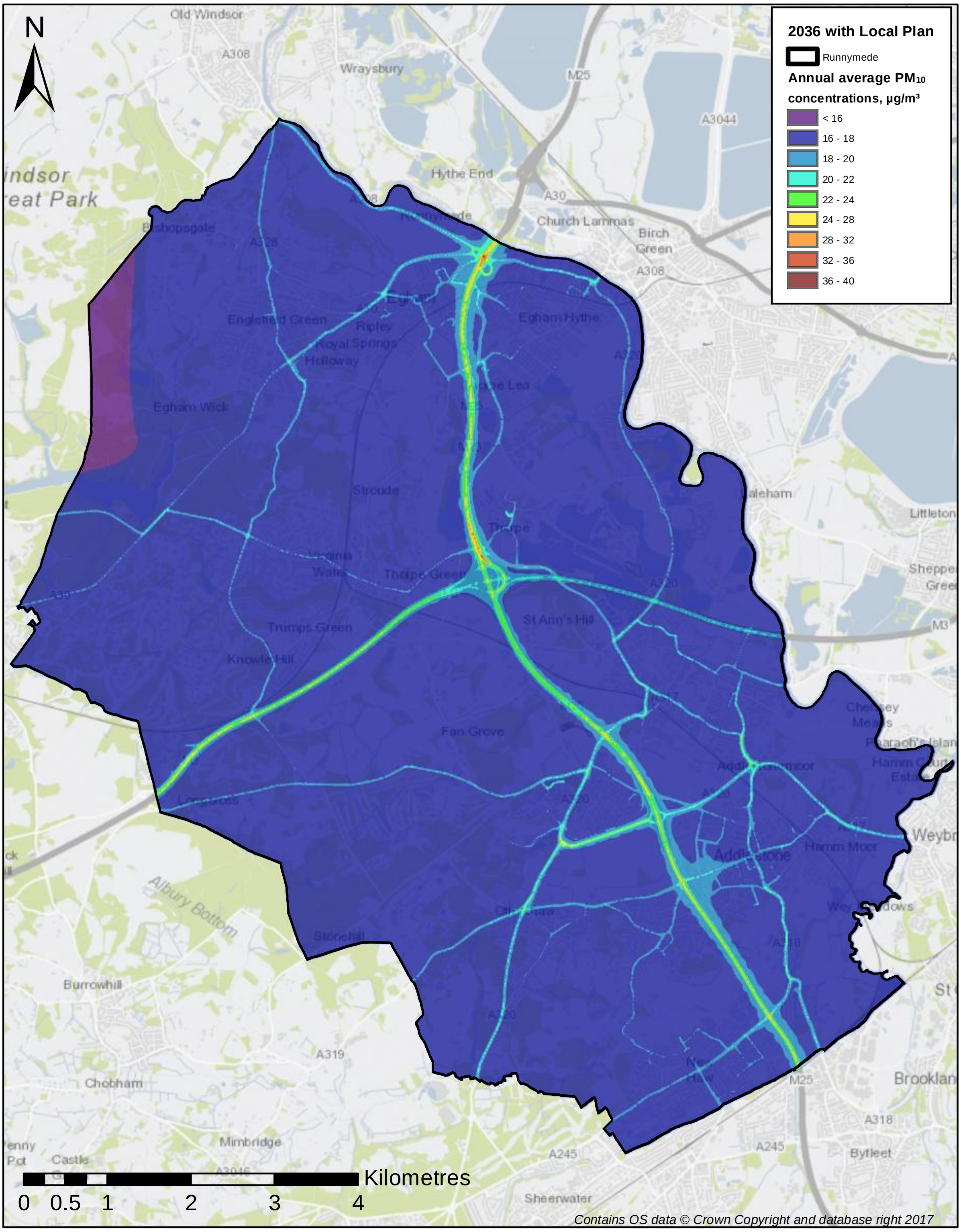


***Figure 9.8: Annual mean $PM_{10}$ concentrations with the Local Plan in 2036 (µg/m³)***

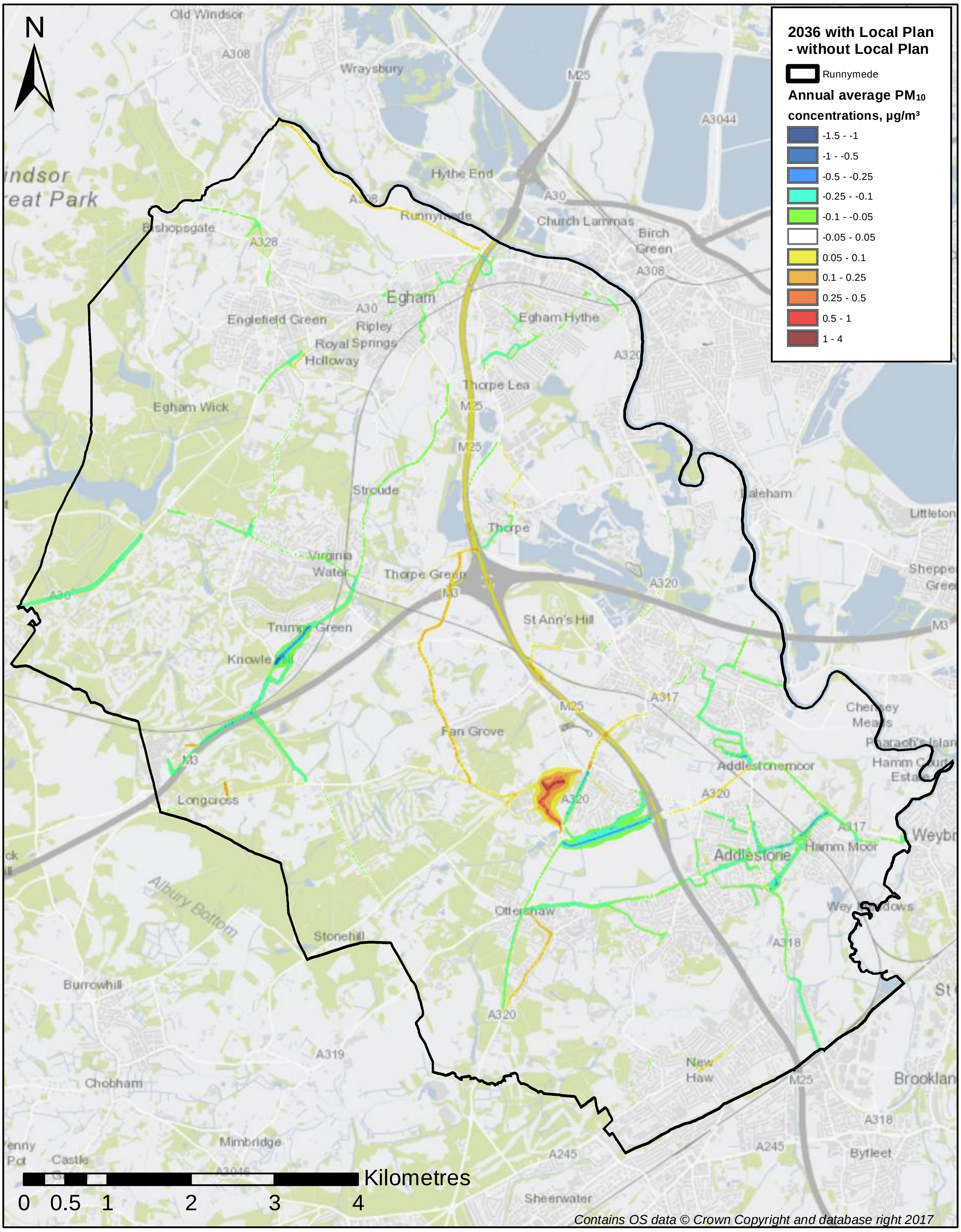


*Figure 9.9: Difference between annual mean PM$_{10}$ concentrations with and without the Local Plan, 2036 («g/m$^3$)*

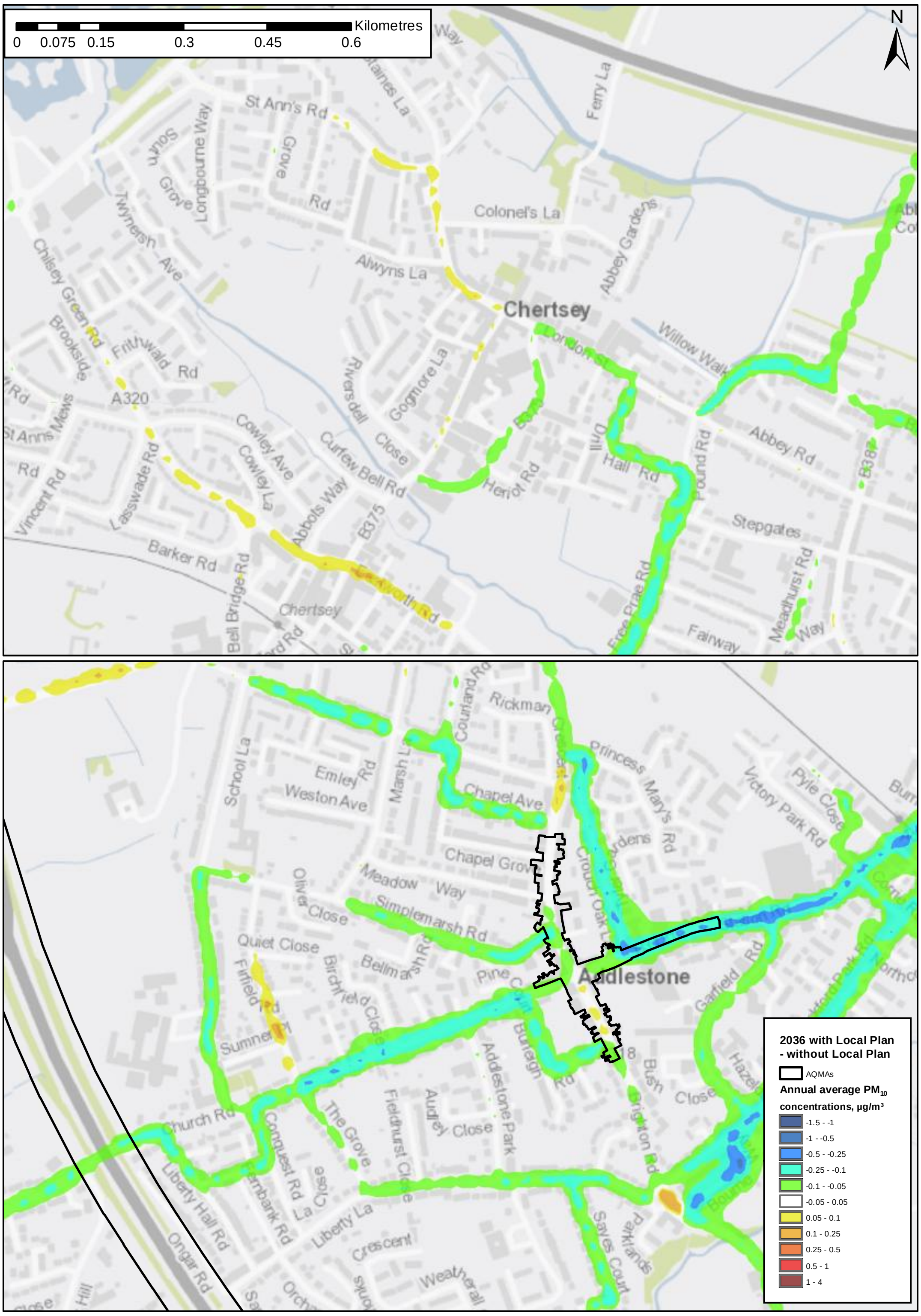


***Figure 9.10: Difference between annual mean $PM_{10}$ concentrations with and without the Local Plan, 2036, Addlestone (below) and Chertsey (above) («g/$m^3$)***

### 9.1.4 24-hourly average $PM_{10}$

Figure 9.11 presents the 90.41st percentile of 24-hourly average $PM_{10}$ concentrations across the whole of Runnymede for the no Local Plan scenario, and Figure 9.12 presents the same statistic for the with Local Plan scenario; Figure 9.13 shows the difference between the two, with Figure 9.14 presenting the Addlestone and Chertsey areas.

No exceedences of the Air Quality Objective for 24-hour average concentrations are predicted in either scenario. 24-hour average $PM_{10}$ concentrations change following the same pattern as annual average concentrations with the implementation of the Local Plan.

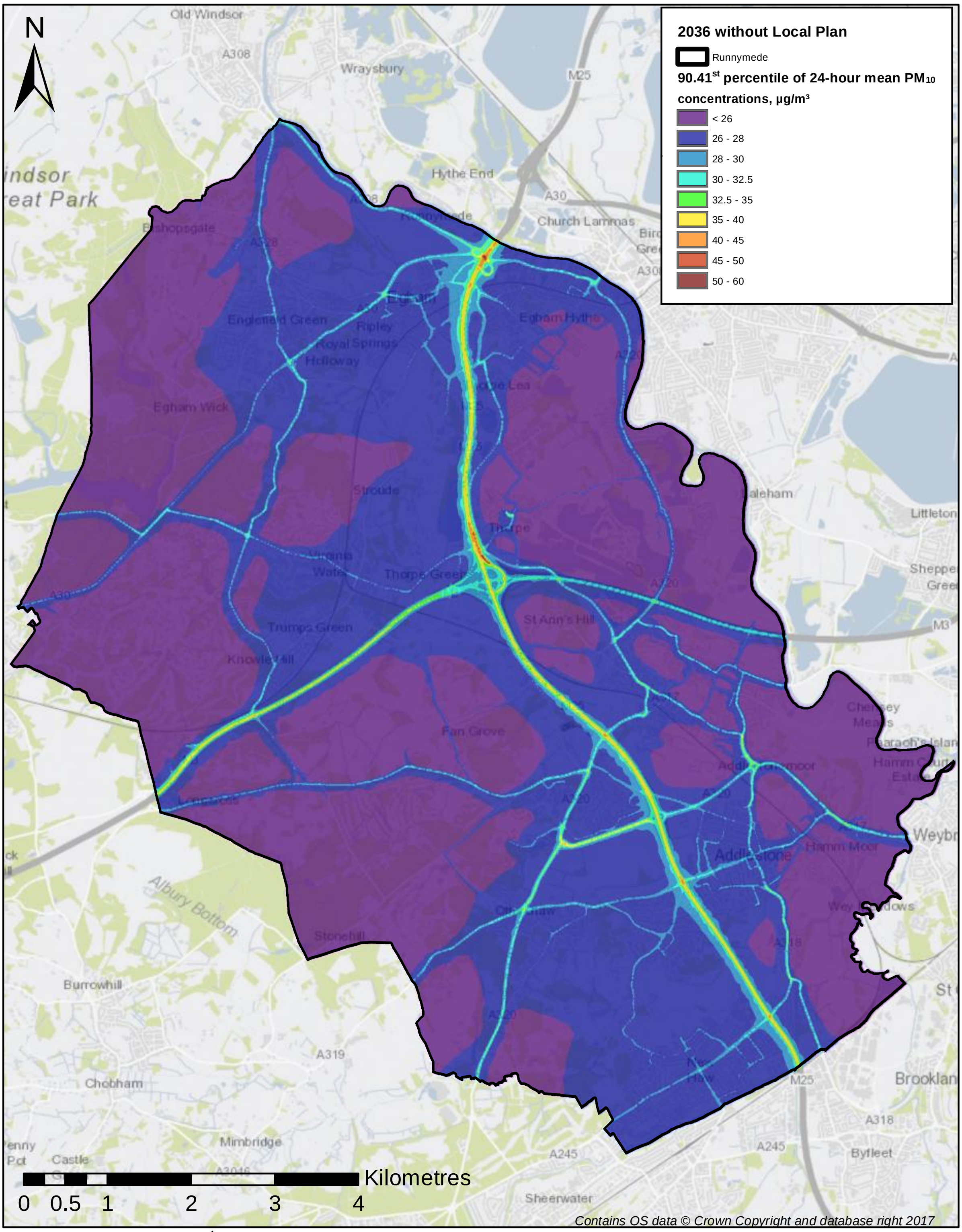


***Figure 9.11: 90.41st percentile of 24-hour mean $PM_{10}$ concentrations without the Local Plan in 2036 (µg/m³)***

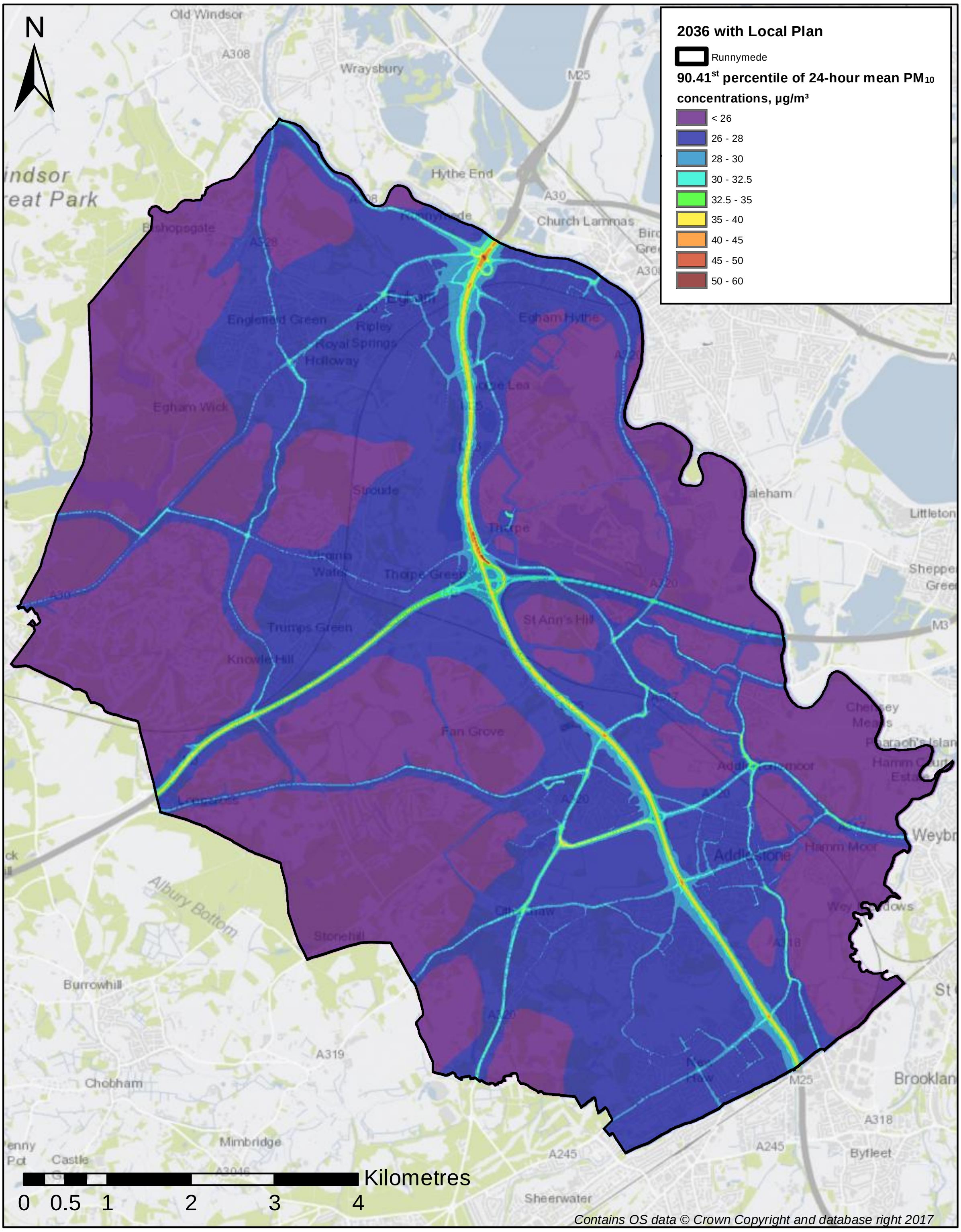


***Figure 9.12: 90.41$^{st}$ percentile of 24-hour mean $PM_{10}$ concentrations with the Local Plan in 2036 (µg/m³)***

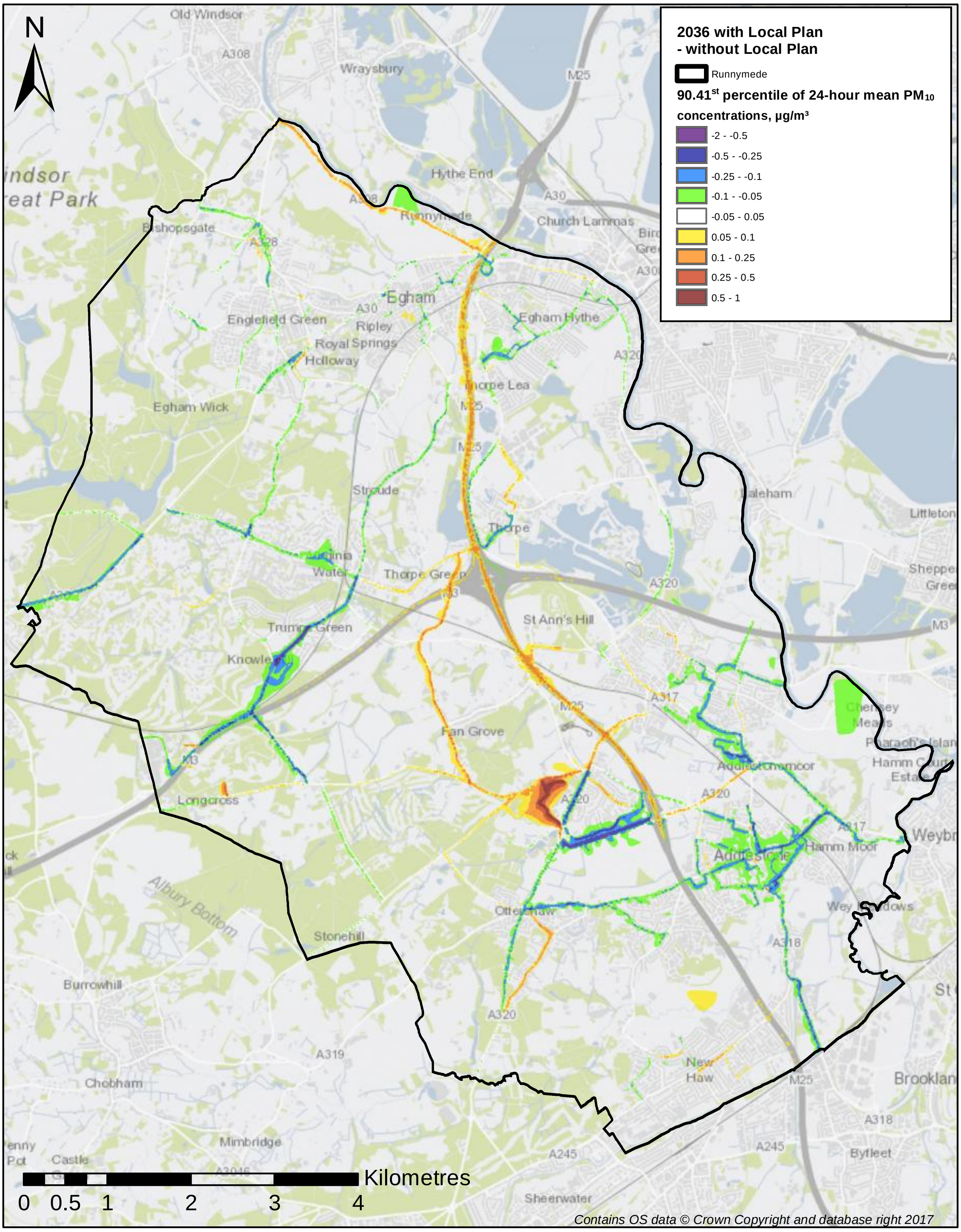


***Figure 9.13: Difference between 90.41$^{st}$ percentile of 24-hour mean $PM_{10}$ concentrations with and without the Local Plan, 2036 («g/m$^3$)***

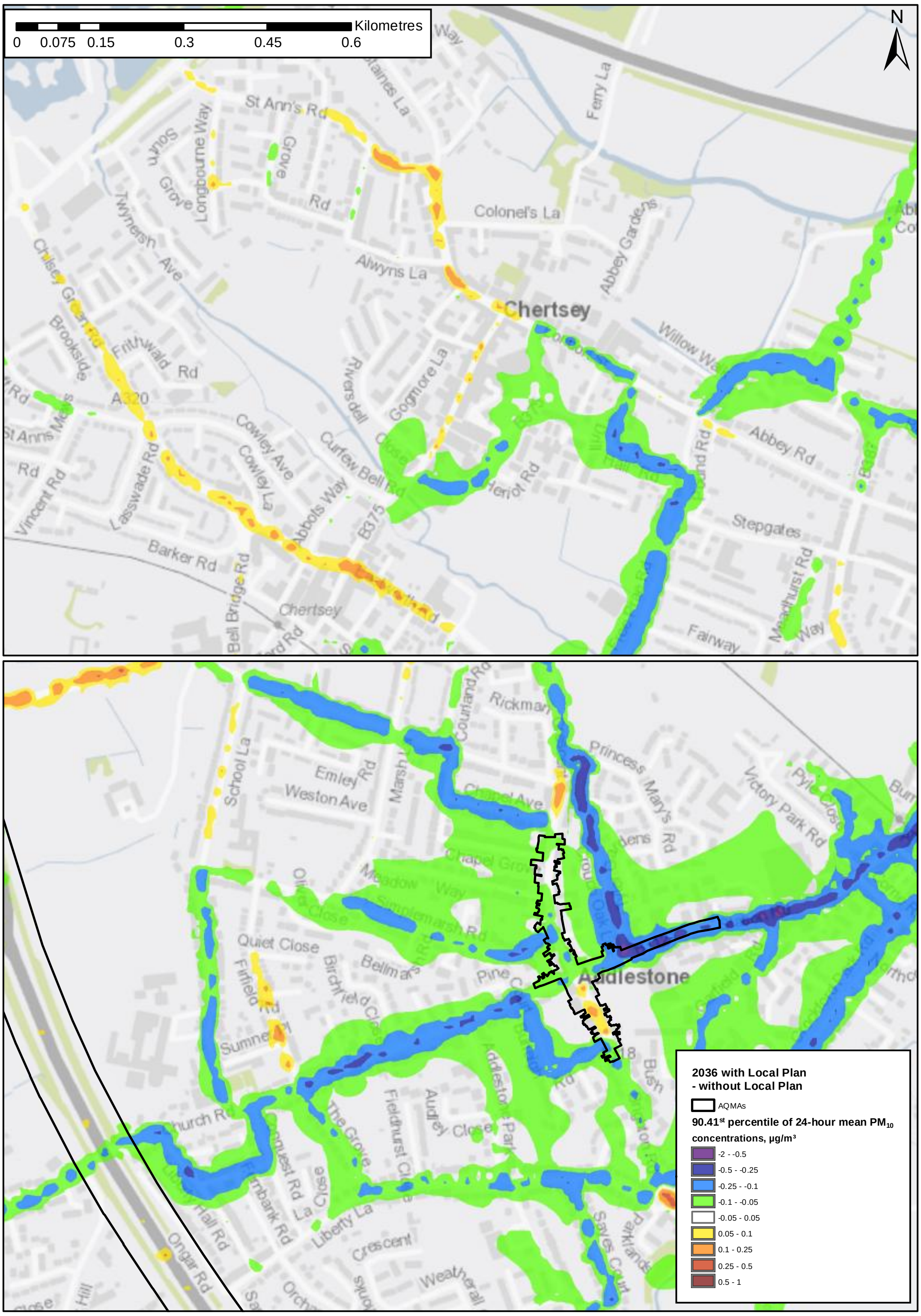


***Figure 9.14: Difference between 90.41$^{st}$ percentile of 24-hour mean $PM_{10}$ concentrations with and without the Local Plan, 2036, Addlestone (below) and Chertsey (above) («g/m$^3$)***

### 9.1.5 Annual average $PM_{2.5}$

Figures 9.15 and 9.16 present the annual average $PM_{2.5}$ concentrations for the without Local Plan and with Local Plan scenarios, respectively. Figure 9.17 presents the difference in concentration between the two scenarios, and Figure 9.18 presents the difference in the Addlestone and Chertsey areas. No exceedences of the Air Quality Objective for annual average $PM_{2.5}$ concentrations are predicted in either 2036 scenario.

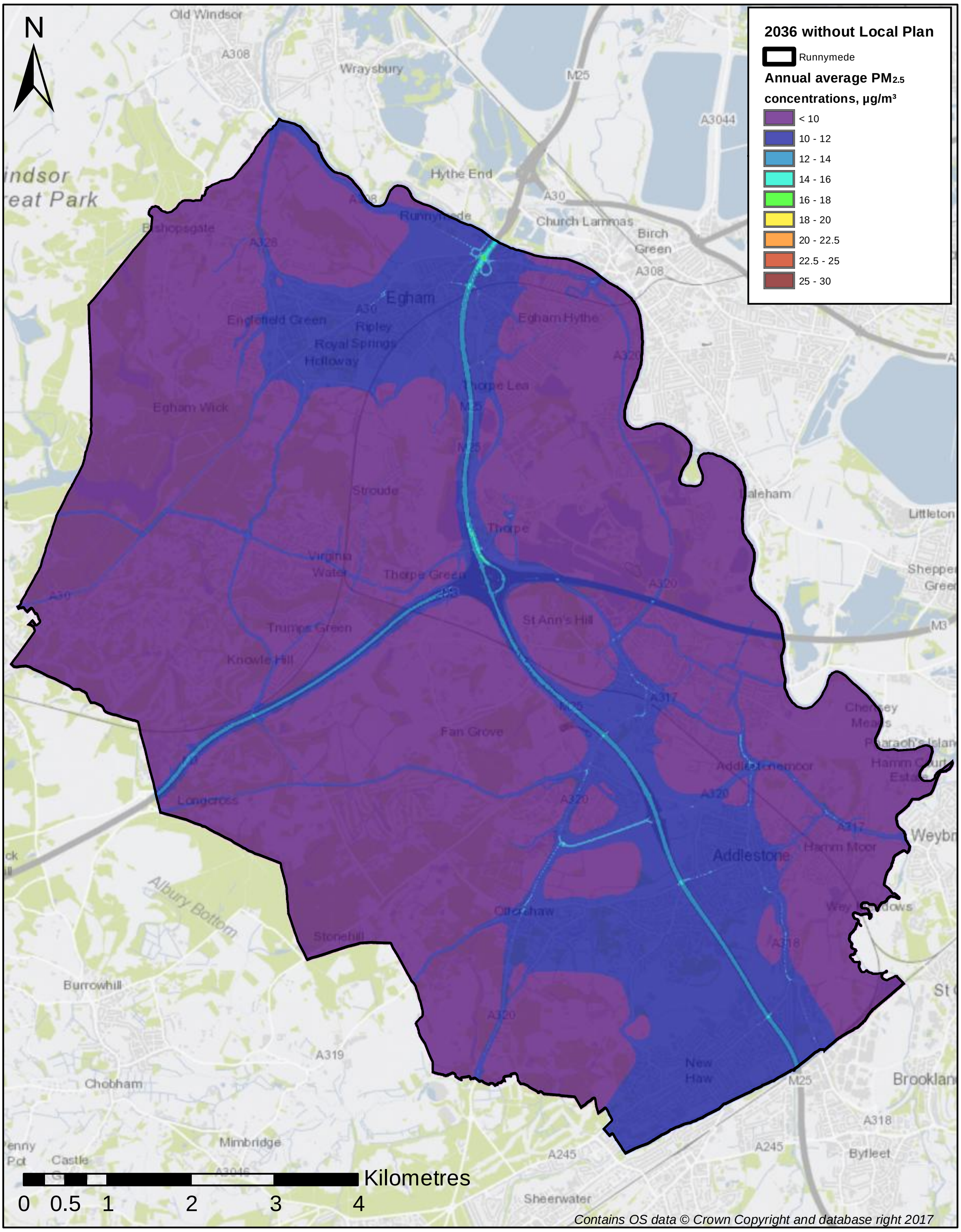

*Figure 9.15: Annual mean $PM_{2.5}$ concentrations without the Local Plan in 2036 (µg/m³)*

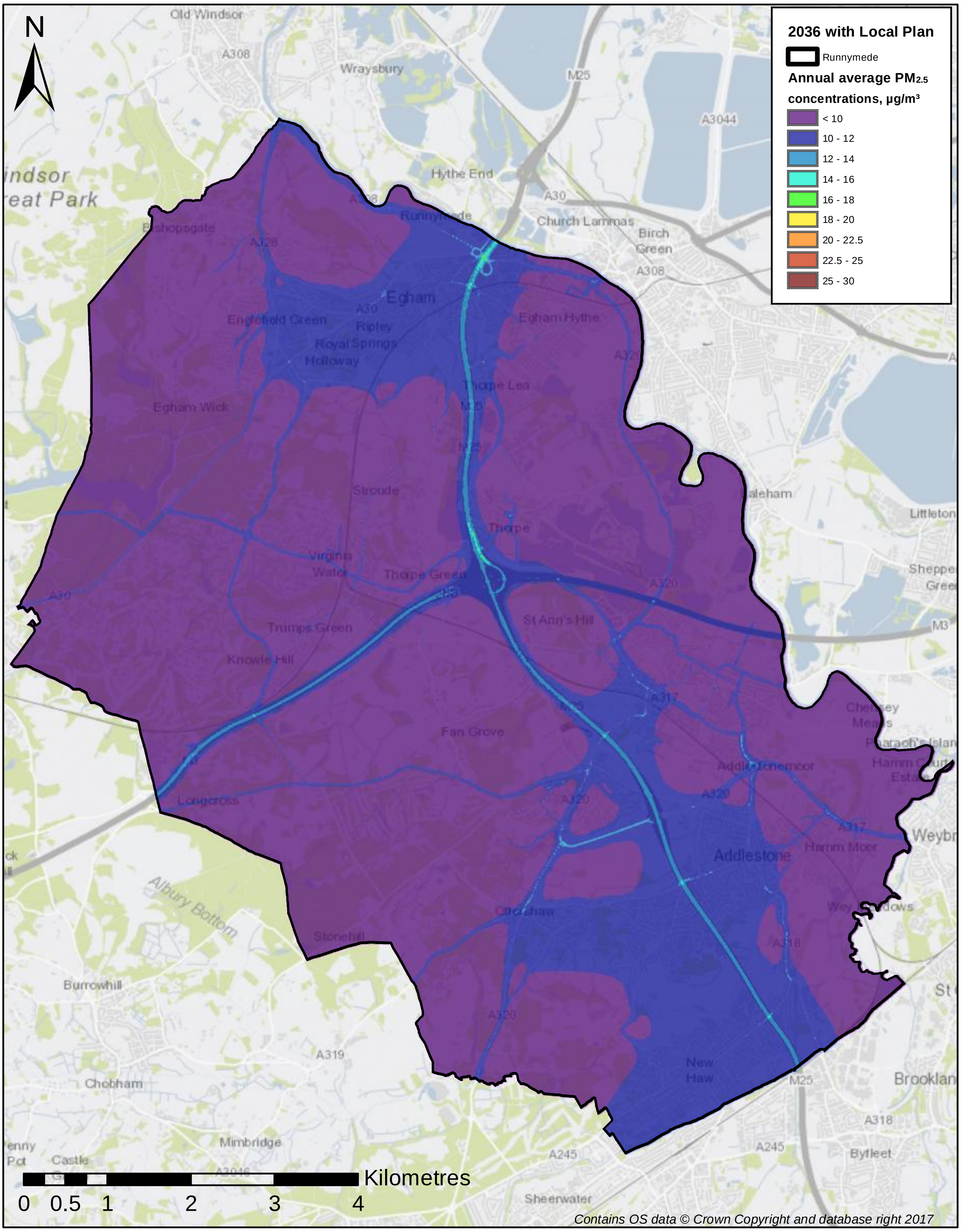


*Figure 9.16: Annual mean $PM_{2.5}$ concentrations with the Local Plan in 2036 (µg/m³)*

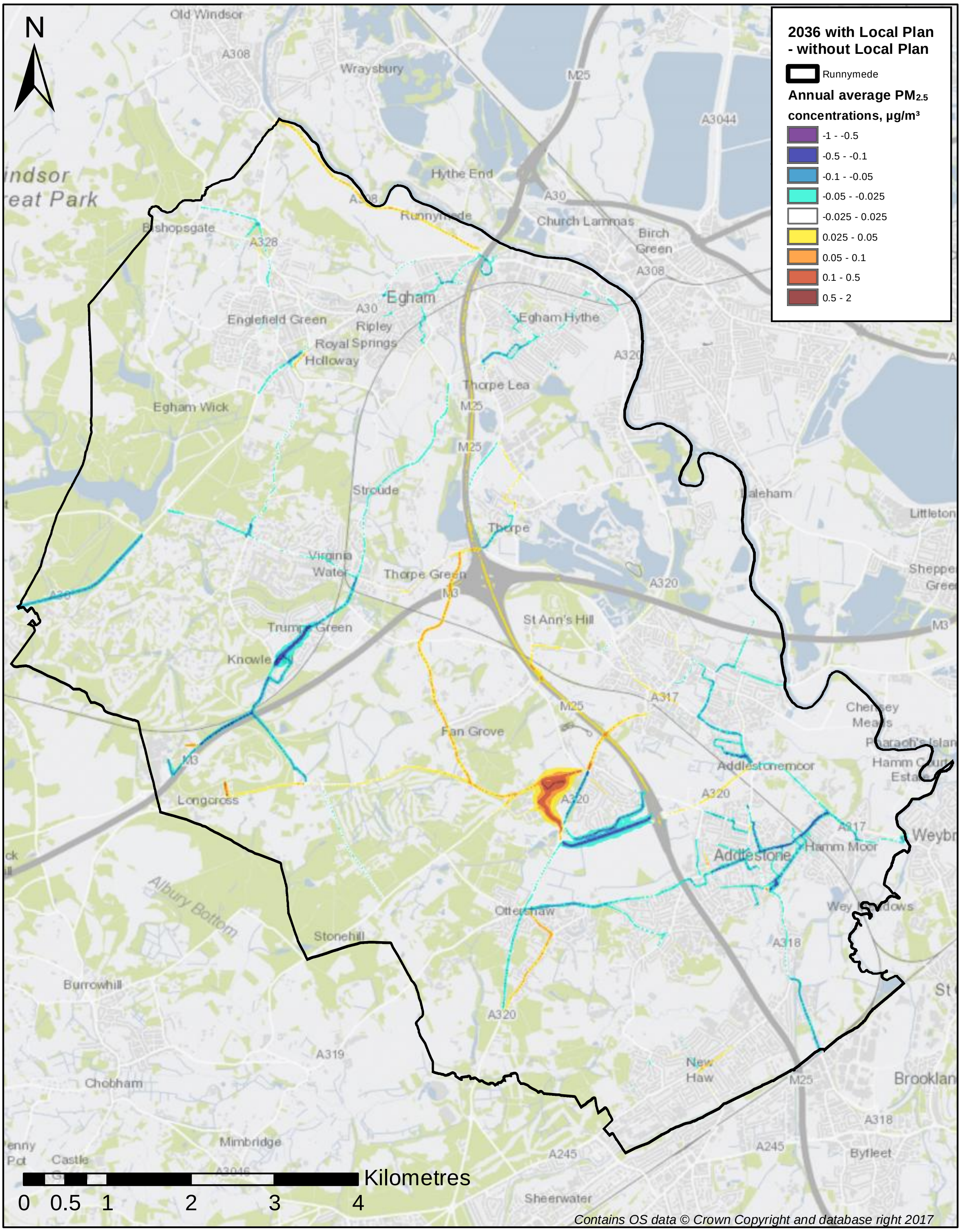


***Figure 9.17: Difference between annual mean $PM_{2.5}$ concentrations with and without the Local Plan, 2036 («g/m$^3$)***

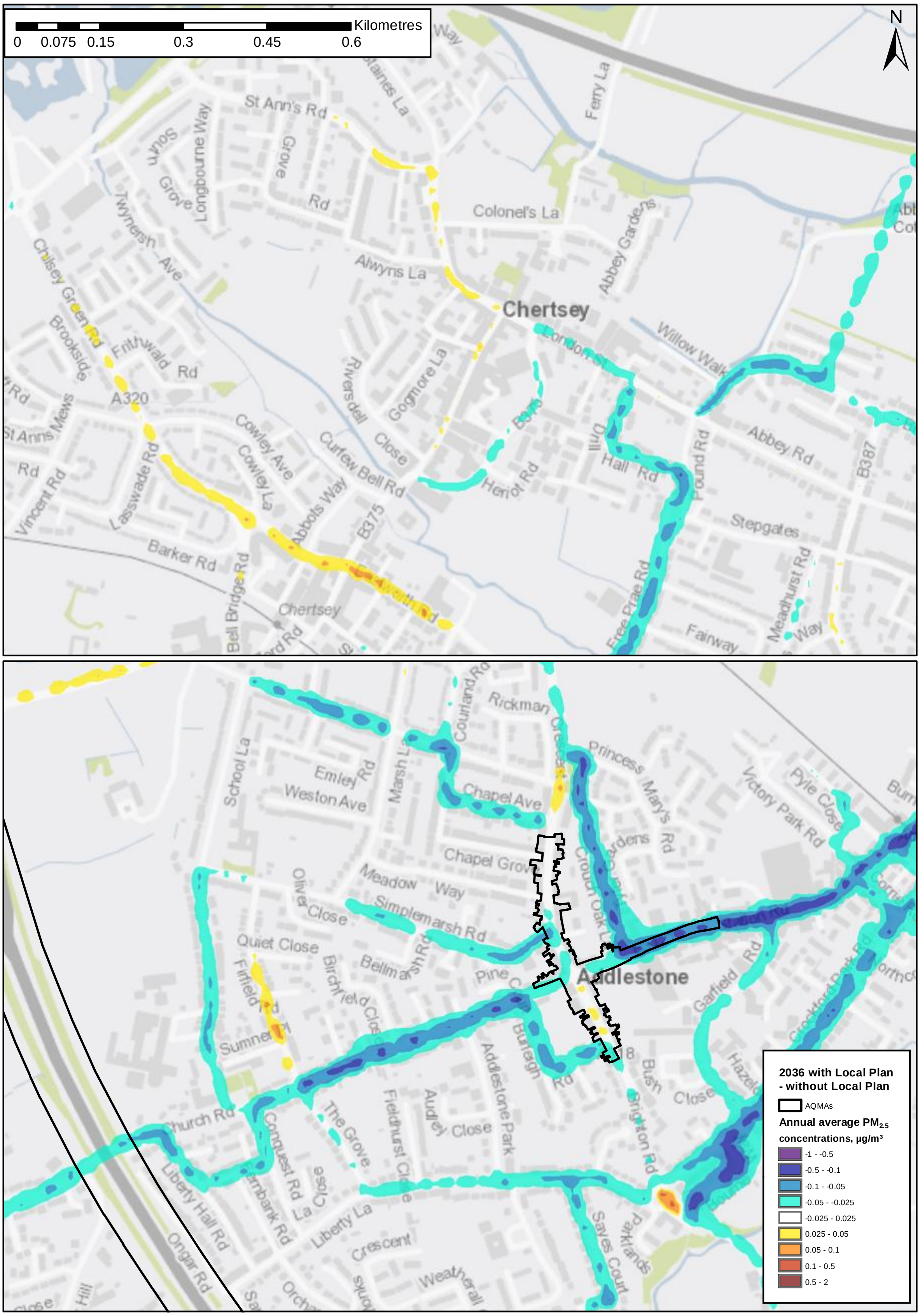


*Figure 9.18: Difference between annual mean $PM_{2.5}$ concentrations with and without the Local Plan, 2036, Addlestone (below) and Chertsey (above) («g/m$^3$)*

# 10 Health impact calculations

The health impact of air quality on health in Runnymede was assessed by calculating the number of attributable deaths and corresponding life-years lost due to concentrations of $PM_{2.5}$ and $NO_2$. These calculations follow the method described in the report *Understanding the Health Impacts of Air Pollution in London*[13]. They are based on the reported relative risk to mortality of a change in long term $NO_2$ and $PM_{2.5}$ concentrations as shown in Table 10.1. There is potential overlap between the effects of $NO_2$ and $PM_{2.5}$ on health; a relative risk for $NO_2$ removing potential overlap is also provided.

***Table 10.1: Relative risk of mortality due to change in long-term concentrations***

| **Pollutant** | **Relative risk (per 10 µg/m³ change in long-term average concentration)** |
|---|---|
| **$PM_{2.5}$** | 1.06 |
| **$NO_2$** | 1.055 |
| **$NO_2$ (no overlap)** | 1.039 |

Runnymede is split into 52 Lower Layer Super Output Areas (LSOA). Population and death data by 5-year age group and gender were obtained for each LSOA from the Office for National Statistics. Overall data for Runnymede are given in Table 10.2.

***Table 10.2: Population and death data for Runnymede***

| | **Male** | **Female** |
|---|---|---|
| **Population** | 42354 | 44535 |
| **Deaths** | 357 | 379 |

Contour plots of pollutant concentrations were used to calculate population-weighted annual mean concentrations of $PM_{2.5}$ and $NO_2$ for each LSOA for each scenario. The overall population-weighted annual mean concentrations for Runnymede are given in Table 10.3.

***Table 10.3: Population-weighted annual mean concentrations for Runnymede***

| **Scenario** | **$PM_{2.5}$** | | **$NO_2$** | |
|---|---|---|---|---|
| | **Male** | **Female** | **Male** | **Female** |
| **2015** | 10.05 | 10.05 | 23.8 | 23.7 |
| **2036 no Local Plan** | 10.05 | 10.05 | 18.7 | 18.7 |
| **2036 with Local Plan** | 10.04 | 10.05 | 18.7 | 18.7 |

[13] https://www.london.gov.uk/sites/default/files/HIAinLondon_KingsReport_14072015_final_0.pdf

The relative risk for each LSOA, pollutant, gender and scenario was calculated as

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

where R is the relative risk as given in Table 10.1 and c is the population-weighted annual mean concentration.

The attributable fraction was then calculated as

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

The attributable deaths were calculated by multiplying the attributable fraction by the number of deaths in each age group over 30 in each LSOA. The total number of deaths attributable to air pollution in the Runnymede area presented in Table 10.4.

***Table 10.4: Total attributable deaths to pollutant concentrations in Runnymede***

| **Scenario** | **$PM_{2.5}$** | | **$NO_2$** | | **$NO_2$ (no overlap)** | |
|---|---|---|---|---|---|---|
| | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** |
| **2015** | 19.8 | 21.5 | 41.4 | 45.9 | 30.1 | 33.4 |
| **2036 no Local Plan** | 19.8 | 21.5 | 33.1 | 36.1 | 24.0 | 26.2 |
| **2036 with Local Plan** | 19.8 | 21.5 | 33.1 | 36.1 | 24.0 | 26.2 |

The total loss in life-years due to air pollution has been calculated by multiplying the attributable deaths in each age group by the corresponding expected remaining life-expectancy for the age group. These life expectancy data were obtained from the South East Public Health Observatory Life Expectancy Health Calculator[14]. Table 10.5 presents the calculated total life-years lost due to air pollution in Runnymede.

***Table 10.5: Total life-years lost due to air pollution in Runnymede***

| **Scenario** | **$PM_{2.5}$** | | **$NO_2$** | | **$NO_2$ (no overlap)** | |
|---|---|---|---|---|---|---|
| | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** |
| **2015** | 199 | 220 | 419 | 469 | 305 | 341 |
| **2036 no Local Plan** | 199 | 220 | 333 | 370 | 242 | 268 |
| **2036 with Local Plan** | 199 | 219 | 334 | 370 | 242 | 268 |

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

# 11 Discussion

Modelled annual average $NO_2$ concentrations for 2015 exceed the Air Quality Objective of 40µg/m³. No exceedences of the Air Quality Objective of 200µg/m³ for hourly average $NO_2$ concentrations, or the Air Quality Objectives for $PM_{10}$ and $PM_{2.5}$, are predicted.

Modelled annual mean $NO_2$ concentrations (µg/m³) for 2015 exceed 40µg/m³ along the M25, and at building façades on London Street and Windsor Street in Chertsey. Modelled concentrations are above the Air Quality Objective at pavement locations in Egham, Addlestone and Chertsey; however, these locations are not relevant for exposure.

Concentrations close to the Air Quality Objective for annual average $NO_2$ concentrations are predicted within the Addlestone AQMA; however, no exceedences of the objective are predicted at locations of relevant exposure. As such, given the uncertainty in the model input data and results, there is a significant possibility of concentrations exceeding the standard at these locations. Additionally, concentrations within 10% of the Objective occur at building façades along St Ann's Road in Chertsey, and at building façades on The Avenue in Egham, adjacent to the M25.

The health impact of air quality on health in Runnymede was assessed by calculating the number of attributable deaths and corresponding life-years lost due to concentrations of $PM_{2.5}$ and $NO_2$ following the methodology described in the report *Understanding the Health Impacts of Air Pollution in London*[15]. Using this approach, the combined health impacts of $NO_2$ and $PM_{2.5}$ were calculated to be 1065 life-years lost.

In both the modelled 2036 scenarios, no exceedences of any relevant Air Quality Objectives are predicted at any location in Runnymede. This reflects a large decrease in $NO_2$ concentrations between 2015 and 2036, arising from reductions in traffic exhaust emissions due to predicted improvements in engine technology. While concentrations of $PM_{10}$ and $PM_{2.5}$ do not decrease by the same extent, due to the importance of non-exhaust emissions for these pollutants, concentrations do not exceed the standards in 2015, and as such do not exceed in 2036.

The implementation of the Runnymede Local Plan gives rise to a spatially complex pattern of changes in air quality impacts. Decreases in concentration are seen in the Addlestone AQMA, and along roads where exceedences are predicted in 2015 in Addlestone and Chertsey. In the event that vehicle technology does not make the improvements currently predicted, these changes may be significant, but currently both scenarios are predicted to be significantly below the standard. The largest increases in pollutant concentrations are seen near St. Peter's Hospital to the west of Chertsey; these increases do not bring concentrations close to the Air Quality Objectives. Small increases in pollutant concentrations are seen along Motorways and some trunk roads.

Health impacts were not calculated to differ significantly between the two scenarios: without the implementation of the Local Plan, the impact was calculated to be 929 life-years lost;

[15] https://www.london.gov.uk/sites/default/files/HIAinLondon_KingsReport_14072015_final_0.pdf

with the implementation of the Local Plan, the impact was the loss of 928 life-years. This reflects the low concentrations predicted across the Borough, and the fact that local decreases in traffic emissions are offset by increases in other areas in the Borough.

Following the completion of the modelling study, the date of implementation of the Runnymede Local Plan was changed to 2030. In the modelled 2036 scenarios, published data for 2030 or earlier was used for all inputs except traffic activity, due to the absence of emission factors or emissions inventory data in the UK for years after 2030. It is expected that traffic flows will increase slightly between 2030 and 2036 due to regional traffic growth, and that the effects of the implementation of the Local Plan will not change significantly depending on the year. As such, the results in this report are likely to provide a slightly conservative estimate of predicted concentrations in 2030. As no exceedences of the relevant Air Quality Objectives were predicted in the 2036 scenarios, it is reasonable to predict that no exceedences of the Air Quality Objectives would be predicted for 2030 with the Local Plan in place.

# 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)*[16], 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)*[17] 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[18] 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.

[16] 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.
[17] 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.
[18] 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[19]. 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.

[19] 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.

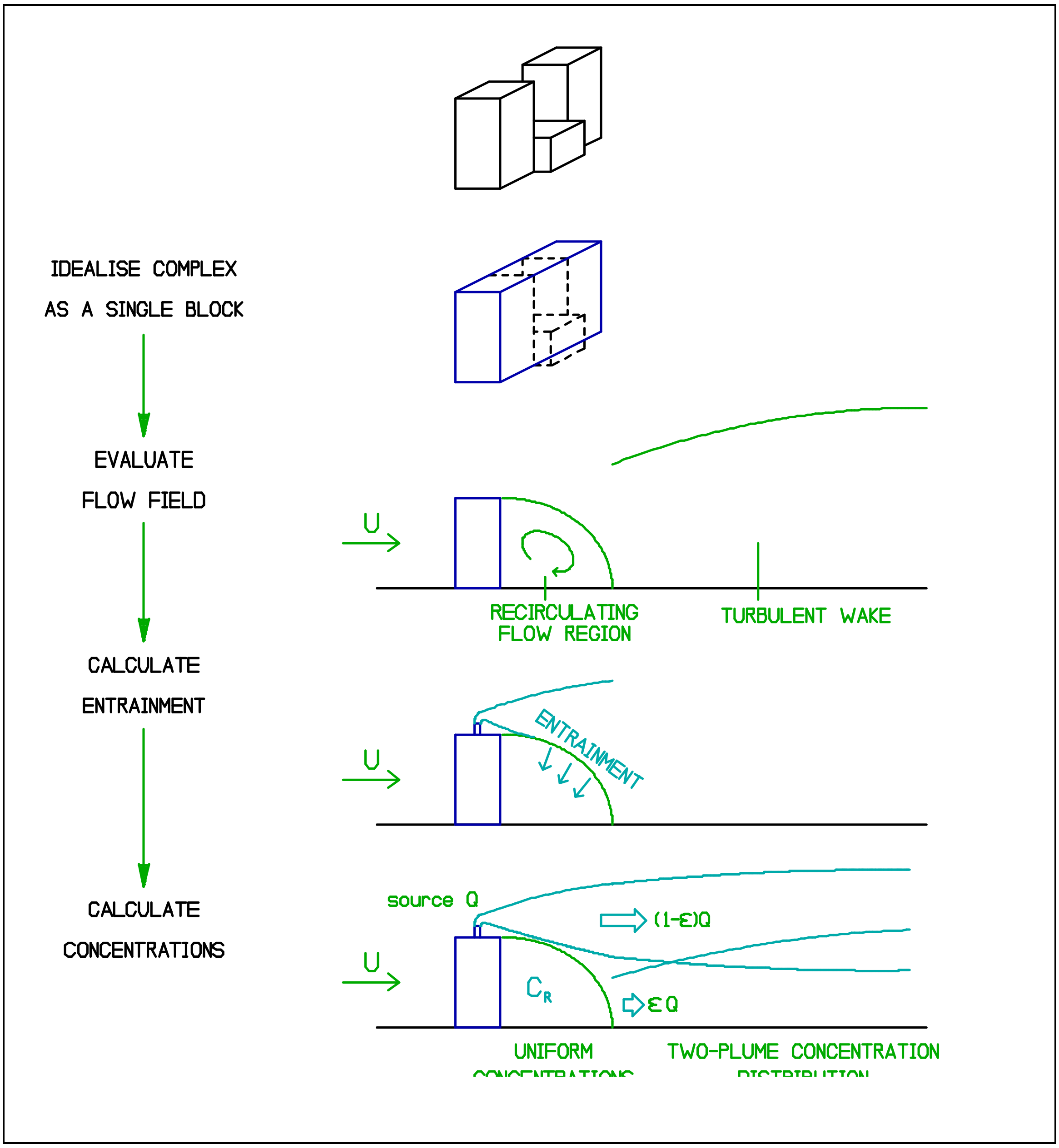


***Figure A3.1: Stages in the modelling of building effects***

***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.