King's College London

Environmental Research Group

Detailed Assessment of Air Quality

PM_{10} Source Apportionment at Sutton 5, Beddington Lane

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Contents

1. Summary

This report provides a detailed analysis of air pollution measurements made at the Sutton 5 monitoring site. Dispersion modelling was also used to provide an estimate of the likely PM_{10} concentrations over the wider area.

The Sutton 5 monitoring site is located on Beddington Lane, north of several waste management businesses, which are located in Beddington Lane and its side roads. This report compares measured PM_{10} concentrations at the site to the UK Air Quality Strategy (AQS) Objectives / EU Limit Values and quantifies the sources of PM_{10} that affected the monitoring site.

During 2006 the Sutton 5 monitoring site exceeded the EU Limit Value / AQS Objective for PM_{10}. The site measured 50 days when the mean PM_{10} concentrations were above 50 μgm^{-3} TEOM*1.3 compared to the Limit Value of 35 days. It was projected that the site would have measured 55 such days if a pro rata allowance were made for missing measurements. The annual mean objective was not exceeded.

To understand the sources of PM_{10} affecting the site a source apportionment technique was used. The source apportionment model divided the measured concentration of PM_{10} into the following sources:

- Background secondary and natural: background PM_{10} that is not linked to NO_X.
- Background primary: background PM_{10} that is linked to NO_X.
- Local primary: PM_{10} estimated from the elevation in NO_X concentration, above background. This source includes both primary tail pipe PM_{10} and also expected PM_{10} from resuspension, tyre and brake wear sources.
- Local – other: PM_{10} not accounted for by the model. This includes local sources that are not linked to NO_X and also the local sources that may be linked to NO_X but were not expected on the basis of NO_X and PM_{10} relationships derived from other sites in London and the south east, abnormal quantities of resuspended particulate for example.
- TEOM offset - the measurement offset of +3 μgm^{-3} (raw TEOM) applied by the TEOM to all measured mass concentrations.

The uncertainty associated with the calculation of the concentration of local PM_{10} sources was assessed using the GUM (Guide to the Expression of Measurement Uncertainty in Measurement) approach (ISO, 1995).

Source apportionment indicated that 8 (+/- 6, 2σ) μgm^{-3} TEOM *1.3 or 22 (+/- 17, 2σ) % of the PM_{10} measured at the site came from local – other sources. In the absence of this source the site would have achieved the daily mean AQS Objective / EU Limit Value during 2006. This AQS Objective / EU Limit Value would have been met in 2006 with a reduction of around 20 % (5 – 40%) in the mean concentration of local – other PM_{10}.

Clear differences in the mean concentration of local - other PM_{10} were found between weekdays and weekends with the mean concentration being greater on weekdays than on Saturday and Sunday. The mean concentration of local primary and local - other PM_{10} sources exhibited rapid rises at the same time on weekday mornings and it was found that 44% of the changes in the concentration of local – other PM_{10} may be explained by changes in the local primary PM_{10} concentration (averaged by hour of day and day of week). The linkage between these sources suggested that the local – primary PM_{10} was linked to a road traffic source.

Although, the local – other PM_{10} is probably linked to vehicle sources it cannot be completely accounted for by tailpipe emissions and expected mechanical tyre and brake wear. It is therefore likely that the local – other PM_{10} originates from the resuspension of silt from the road surface or direct suspension of material from 'dusty' vehicles. Silt may be carried from waste facilities onto Beddington Lane by vehicles leaving nearby waste facilities. All traffic on Beddington Lane would

have the potential to then resuspend any material deposited on the road. The mean concentration of the local – other PM_{10} from Beddington Lane to the south of the monitoring site was greater than the mean concentration from Beddington Lane to the north of the monitoring site suggesting a gradient in the emission rate of the local – other PM_{10} commensurate with sources of road soiling to the south of the monitoring site.

A comparison of results from Sutton 5 with those in similar locations found that the concentration of local – other PM_{10} was consistent with the monitoring site being several hundred metres from a waste facility.

Dispersion modelling was undertaken of the area for both PM_{10} AQS objectives. The modelling used the KCL model, which has been used extensively for local air quality management purposes. It was refined to incorporate the local – other PM_{10} component identified by source apportionment. On Beddington Lane there is more than one waste facility and to understand the impact from these varying gradients were tested to indicate how concentrations change. A series of scenarios were modelled to test varying emission gradients of local – other PM_{10} and also the sensitivity of assumptions.

The modelling predictions showed that annual mean PM_{10} concentrations exceeded the objective for all scenarios close to the road centre line and junctions. The area exceeding did not extend to areas of relevant public exposure, however, predictions of the number of days greater than 50 μgm^{-3} showed that the AQS objective of 35 days was exceeded for all scenarios and included areas with relevant public exposure on Beddington Lane close to the Sutton 5 site. The predicted number of days at the front facade of a house on the east side of Beddington Lane (close to the Sutton 5 site) was 83 days, which easily exceeds the AQS daily mean objective.

The main finding of changing the emission gradients was to vary the extent of the area that exceeded the AQS objectives. For those areas with steeper emission gradients, concentrations were increased at the road centre line, with the area exceeding reduced in length for both annual mean and daily mean objectives. Close to the Sutton 5 site these changes were very small and did not lead to any changes in the number of houses that exceeded the AQS daily mean objective. At the southern end of Beddington Lane the extent of the area that exceeded varied by up to 300m in length. For three of the scenarios the area that exceeded the daily mean objective approached houses on the western side of Beddington Lane (south of the waste water treatment works). The maximum road length that exceeded was 1.8km

The model results for all scenarios had good agreement with monitored results at the Sutton 5 site. The results of the sensitivity tests of the model indicated that changing the assumption for the local – other PM_{10} sources had little effect on the area that exceeded the AQS objectives.

It is recommended that:

- The findings of this report should be incorporated into the Council's Air Quality Action Plan.

- The Council should work together with the Environment Agency and waste businesses within the Beddington Lane area to reduce the silt deposited on Beddington Lane.

- The Council should continue to monitor concentrations of NO_X and PM_{10} to assess the concentration reductions achieved by any abatement measures installed at the waste facilities. It should however be recognised that the day to day variation in the concentration of local – other PM_{10} and the apparent seasonality exhibited in other studies (e.g. Fuller et al 2007) may confound this assessment in the short – term. This source apportionment study should be repeated annually to quantify changes in local – other PM_{10}.

- A further monitoring site should be installed in Beddington Lane to assess the reduction of local – other PM_{10} with distance from the waste facilities. This would enable better emission rates for the local – other PM_{10} to be determined and therefore better estimates of the area affected could be obtained using dispersion modelling.

- Specific traffic counts for Beddington Lane (both north and south of the Coomber Way roundabout) and Coomber Way would also further aid understanding and dispersion modelling of the area.

- Specific turning count information on the numbers of vehicles using the waste facilities along Beddington Lane and its side roads (including Coomber Way and private access roads) would assist in quantifying the activity of the individual sites.

2. Introduction

This report assists the London Borough of Sutton with its continuing Local Air Quality Management (LAQM) duties through quantifying and understanding PM_{10} in the Beddington Lane area.

The report provides a detailed analysis of air pollution measurements made at the Sutton 5 monitoring site. The Sutton 5 monitoring site was situated on Beddington Lane, north of several waste management businesses, which are located on Beddington Lane and its side roads. The report compares measured PM_{10} concentrations to the UK Air Quality Strategy Objectives and quantifies the sources of PM_{10} that affected the monitoring site.

The report presents an analysis of measurements made from 1st December 2005 to the end of 2006, which included the first full calendar year of measurements.

Results from the source apportionment were used to inform dispersion modelling of the Beddington Lane area.

Previous Air Quality Assessments

As part of its LAQM responsibilities, the London Borough of Sutton completed the previous rounds review and assessment (R&A) of air quality (see the individual reports prepared between 1999 and 2006). These reports presented a staged approach whereby the seven air pollutants in the Government's Air Quality Strategy related to LAQM, were assessed and screened within the Council's area.

Air Quality Management Areas (AQMAs) were declared along the major roads in the Borough due to predicted breaches of the Air Quality Strategy Objectives for NO_2 and PM_{10}. Beddington Lane has also been declared an AQMA due to the combination of nearby waste management sites, dust complaints and relevant exposure.

Reports and other information related to the Council's LAQM responsibilities can be found on the Council's web site at:

http://www.sutton.gov.uk/environment/environmentalhealth/smokeandairpollutioncontrol.htm

3. The site

The Sutton 5 monitoring site is located at a roadside location on the east side of Beddington Lane at the junction with Brookmead Road. Beddington Lane runs approximately northwest to southeast. The monitoring site is in a residential section of Beddington Lane with housing to the south. Further housing lies away from Beddington Lane to the east of the monitoring site accessible off Brookmead Road, along Therepia Lane and further south on Beddington Lane beyond the area shown in Figure 1. Several waste facilities are present to the south of the monitoring site on Beddington Lane and on its side roads and these are more fully described in Section 4. To the north and northeast of Sutton 5 is open common land.

Figure 1 Aerial photograph of the Beddington Lane area. The location of the Sutton 5 monitoring site is indicated by a red arrow.

Figure 2 shows the location of the Sutton 5 monitoring site in relation to nearby housing in Brookmead Road and along Beddington Lane to the southeast.

Figure 2 The Sutton 5 monitoring site looking southeast along Beddington Lane.

4. Site visits

A site visit was undertaken on 5th December 2006, before the source apportionment exercise began. Martin Easton from London Borough of Sutton accompanied Stephen Hedley and Gary Fuller from KCL around the Beddington Lane area and pointed out the location of waste and other industries and also the location of nearby housing.

The range of waste and other dusty industries in the Beddington Lane area is shown in Figure 3 to Figure 7 along with evidence of road silting.

Figure 3 777 Recycling in Coomber Way off Beddington Lane.

Figure 4 RMC concrete batcher in Coomber Way off Beddington Lane.

Figure 5 Substantial silting in Beddington Lane by the entrance to Country Waste Management Ltd (represented as Country Skip Hire Ltd on perimeter signs).

Figure 6 Substantial silting in a bus stop on Beddington Lane to the south of Country Waste Management Ltd.

Figure 7 Skip lorries queuing to enter the Viridor Waste Management landfill off Beddington Lane. Substantial road silting was seen on the access road. This access road lies to the west of Beddington Lane, north of the junction with Coomber Road.

5. Source apportionment method

Air pollution measurements

The Sutton 5 monitoring site was installed on the east site of Beddington Lane at the junction with Brookmead Road and became operational on the 1st December 2005. The sample inlet was approximately 2m above the ground and 5m from the kerb line.

Automatic measurements of PM_{10} were made using the Tapered Element Oscillating Microbalance (TEOM) method. Measurements of NO_X used in this study were made using the chemiluminescent method with automatic equipment subject to fortnightly calibration traceable to National Metrological Standards. All measurements were logged by the instruments themselves and collected by KCL each hour. Measurements from the monitoring site were validated by KCL using the most up to date calibration factors and disseminated in near real time on the LAQN web page (www.londonair.org.uk).

The NO_X and PM_{10} instruments were subject to UKAS accredited audit by the National Physical Laboratory (NPL) twice yearly.

A final measurement data set for December 2005 to the end of 2006 was produced by KCL following retrospective ratification of the measurements using procedures, which exceed the requirements detailed in LAQM TG03 (DEFRA, 2003) and the latest guidance released in 2006. During ratification information from regular calibrations, audits and daily manual validation were used to establish an operational and calibration history of the instruments and the pollution measurements were corrected to establish traceability to National Metrological Standards. Details of the monitoring site and the final dataset may be found at www.londonair.org.uk.

The EU limit value requires PM_{10} to be measured using the gravimetric method. However, the vast majority of PM_{10} measurements in and around London are made using TEOMs. Allen et al., (1997); Smith et al., (1997); Green et al., (2001); Charron et al., (2004) and others have observed that the TEOM produced a lower measurement of PM_{10} than that derived gravimetrically due to greater sampling losses of semi-volatile particulate and particle bound water from the TEOM. A ‘correction’ factor of 1.3 is recommended in the UK for comparison of TEOM PM_{10} measurements with the EU Directive (DETR, 1999). It is recognised that the ‘correction’ factor will depend on PM_{10} particle composition (Charron et al., 2004) and this is therefore likely to lead to inaccuracies when applied to PM_{10} from different sources and to different size fractions of airborne particulate. The application of a consistent 1.3 factor to PM_{10} from all sources is however required to ensure consistency between measured concentrations and the model results and to allow both to be compared to the EU Limit Values and AQS Objectives.

PM_{10} Source apportionment methodology

The PM_{10} modelling methodology described in Fuller et al., (2002) divided PM_{10} by source through analysis of measurements of annual mean NO_X, PM_{10} and $PM_{2.5}$ across a network of monitoring sites. Similar source apportionment techniques have been applied elsewhere in the UK and to a lesser extent in Europe (Deacon et al., 1997; Harrison et al., 1997; APEG 1999; Kukkonen et al., 2001 and Stedman et al., 2001).

Fuller et al., 2002 identified PM_{10} as arising from three source components: primary (associated with NO_X), secondary (mainly the $PM_{2.5}$ not associated with NO_X) and natural (coarse component not associated with NO_X). The model assumed that the secondary and natural components do not vary across the London region (over distances of around 100 km) for medium term averaging periods, a day or more. The total PM_{10} at any monitoring site was therefore a combination of the regional secondary and natural PM_{10} with an additional local primary component from combustion sources. The local primary component from combustion sources was determined from the local NO_X concentration.

The KCL model has been successfully employed elsewhere to determine PM_{10} arising from local non-vehicle sources including building works, road works (Fuller and Green 2004) and an industrial process (Fuller and Tremper 2004). The model has also been successfully applied to source apportion PM_{10} arising in the vicinity of waste handling facilities (Fuller and Baker 2001, Fuller and Hedley 2006, Fuller et al 2007).

This modelling exercise deployed the model in a simplified form where the secondary and natural components were not separated and therefore the co-located measurements of $PM_{2.5}$ required by the full method were not needed. To model the PM_{10} concentration at Sutton 5 the concentration of the regional secondary and natural components was derived from ten background LAQN monitoring sites. These ten background / suburban monitoring sites (termed base sites) were selected because of their proximity to Sutton 5 and their freedom from local non-NO_X sources of PM_{10}. The base sites are listed in Table 2.

Local events that were not associated with NO_X would not be predicted by this model since it had no knowledge of them. Fuller and Green (2004) established that the difference between measured and modelled PM_{10} could be used to quantify the PM_{10} arising from local sources that were not sources of NO_X. The same approach was used for this study to identify both local sources that are not sources of NO_X and local sources that may be linked to NO_X that are not expected on the basis of NO_X and PM_{10} relationships derived from other sites in London and the southeast.

Model Inputs and Outputs

The model was applied separately to measurements of NO_X and PM_{10}, which were averaged in three ways to look at possible characteristics of the local PM_{10} sources at Sutton 5. The following model inputs (and therefore outputs) were chosen:

- Daily mean concentrations for comparison to the EU Limit Value and to identify the dates on which local PM_{10} incidents occurred. Daily mean concentrations of NO_X and PM_{10} were calculated from hourly mean measurements for each day with a daily data capture of greater than 75%.

- Mean concentrations averaged by day of week and hour of day to determine any pattern in concentration of the local non-NO_X PM_{10} source(s). For instance the mean NO_X and PM_{10} measurements for each Wednesday at 13 h were averaged as input data, followed by each Wednesday at 14 h and so on.

- Mean concentrations averaged by wind direction, to create pollution roses, to identify the direction of local PM_{10} source(s), relative to the Sutton 5 site. The selection of appropriate wind direction measurements for Sutton 5 is discussed below. (Care should be taken when interpreting the results of this analysis since equal weighting is given to concentration measurements in each 10 degrees averaging bin. However the wind does not blow with equal frequency from all directions. The apportionment from this analysis cannot therefore be compared directly to the overall apportionment, apportionment of daily mean concentration or that undertaken with respect to day of week and hour of day).

In each case appropriately averaged measurement at the base sites were apportioned between primary and non-primary sources. To undertake this apportionment, the concentration of primary PM_{10} was calculated using the NO_X concentration at each base site and regression gradients as described in Fuller et al., (2002). The modelled total PM_{10} at Sutton 5 and at the test sites was then calculated by adding the mean non-primary PM_{10} from the base sites to the primary PM_{10} calculated from NO_X measurements from each site. The availability of background NO_X and TEOM monitoring sites in south London is poor compared with the availability of local background monitoring sites in previous studies (Fuller and Baker; 2001, Fuller and Hedley 2006, Fuller et al 2007) and the number of base sites was increased from 5 to 10 to minimise the uncertainty associated with the calculation of the source apportioned PM_{10} components.

The source apportionment technique divided the measured concentration of PM_{10} into the following sources:

- **Background secondary and natural** – background PM_{10} that is not linked to NO_X.

- **Background primary** – background PM_{10} that is linked to NO_X.

- **Local primary** – PM_{10} estimated from the elevation in local NO_X concentration, above background. This source includes both primary tail pipe PM_{10} and also expected PM_{10} from resuspension, tyre and brake wear sources determined from average conditions throughout the LAQN, as determined from network wide regressions.

- **Local - other** – PM_{10} not accounted for by the model. This will include local sources that are not linked to NO_X and also the local sources that may be linked to NO_X but were not expected on the basis of NO_X and PM_{10} relationships derived from other sites in London and the south east, abnormal quantities of resuspended particulate for example.

- **TEOM offset** - the measurement offset of +3 μgm^{-3} (raw TEOM) applied by the TEOM to all measured mass concentrations (Patashnick and Rupprecht (1991, 1992, 1996), Rupprecht and Patashnick Co. Inc. (1992), Rupprecht and Patashnick Co. Inc. (1996)) was included as another 'source' within the apportionment scheme. Following the application of the 1.3 'correction' factor this offset had a value of 3.9 μgm^{-3}. Retention of the offset within the model ensured comparability between the source apportionment method and TEOM measurements and enabled the source apportioned TEOM measurements to be compared to the EU Limit Value.

Wind direction measurements

Pollution roses show the mean concentration of pollution averaged according to wind direction.

PM_{10} pollution roses were calculated using mean NO_X and PM_{10} concentration averaged for each 10 degree wind sector. Wind direction is not a scalar quantity but is related to the wind vector. For this reason vector averaged 15 minutes wind direction measurements were used along with contemporaneous pollution measurements.

Wind direction measurements were not available at the Sutton 5 site. Wind direction measurements were therefore taken from the nearby Bexley 2. The Bexley 2 site is in an open location in the grounds of a school in Bexley. The wind vane is located on a mast approximately 8m above ground level. The ability of the wind direction measurements at Bexley 2 to represent those over a wider area were tested by comparing Bexley 2 measurements to those made at Ealing 7. Good agreement was found between the wind direction measurements at the two sites.

Uncertainty Estimates

The method of calculating the local – other PM_{10} relies on the difference between measured and modelled PM_{10}. This difference may however also be due to artefacts arising from uncertainty in the measurement and modelling process.

The uncertainty associated with the calculation of the local – other PM_{10} was assessed using the GUM (Guide to the Expression of Measurement Uncertainty in Measurement) approach (ISO, 1995).

The GUM approach requires a measurement equation to link the output quantity with the various input quantities and then provides a methodology to link the uncertainty in the inputs to the uncertainty in the output. The GUM approach provides two methods for estimating the uncertainty associated with each input quantity: type A estimates from statistical analysis and type B estimates from other methods (e.g. instrument specifications). The data sources for the uncertainty estimates of each of the model inputs are listed Table 1.

Input Source	Source for input uncertainty	Type
TEOM measurement of PM_{10}	Harrison 2006	B
NO_X measurement	KCL 2002	B
Ratio of NO_X to primary PM_{10} concentration	RMA regression of annual mean concentrations from 86 monitoring sites in London and SE see Fuller and Green 2006.	A
Background secondary and natural PM_{10}	Standard deviation of estimates from 10 sites	A

Table 1 Sources for input uncertainty.

The GUM approach assumes that the estimates of the uncertainty associated with each input quantity are considered to be normally distributed about the value of the input quantity. They are therefore approximated as statistical variances and are characterised by their standard deviation. The uncertainty in the input quantities are combined as variances, along with sensitivity coefficients determined from the partial derivative of the measurement equation, with respect to each of the input quantities, to derive a combined standard uncertainty. Additional terms in the calculation of the combined standard uncertainty are required if input quantities are correlated. Finally, the combined standard uncertainty is multiplied by a coverage factor (k) to approximate to a required confidence interval expressed as a number of standard deviations. In this study, a k value of 2 was chosen to approximate to a 95% confidence interval.

Implementation of the GUM uncertainty analysis involved creation of an uncertainty model that was 'run' in parallel to the main model and produced estimates for the uncertainty of each output result. In this way a separate uncertainty estimate was available for each model output e.g. daily mean concentration, diurnal average etc.

In addition to using the GUM model to estimate model uncertainty, the model was also used to predict PM_{10} at six test sites in addition to Sutton 5. The modelled concentrations and estimated uncertainty at the test sites were used to check the validity of the GUM uncertainty estimates and to check for significant model bias. The test sites were selected as the closest roadside sites to Sutton 5. The tests sites are listed in Table 2. Further details of the monitoring sites used in the study can be found on the LAQN web site at www.londonair.org.uk

Site name	Site type
Base Sites	
Bexley 1	Suburban
Bexley 2	Suburban
Ealing 7	Urban background
Greenwich 4	Suburban
Hammersmith & Fulham 2	Urban background
Hounslow 2	Suburban
Kens & Chelsea 1	Urban background
Mole Valley 3	Urban background
Richmond 2	Suburban
Tower Hamlets 1	Urban background
Test Sites	
Croydon 4	Roadside
Crystal Palace 1	Roadside
Greenwich 7	Roadside
Lewisham 2	Roadside
Richmond 1	Roadside
Sutton4	Kerbside

Table 2 Base and test sites used in the source apportionment model

Additionally a sensitivity test was carried out to assess the impact of assuming a worst tail pipe PM_{10} emissions scenario. Emissions rates for HGV vehicles (both fixed and articulated) were examined to determine the highest feasible NO_X: primary PM_{10} emissions ratio. This was then used as a model input instead of the NO_X: primary PM_{10} concentration ratio determined from measurement sites across London and SE England.

6. Source apportionment results

Air pollution measurements 2006

Air pollution measurements for 2006 from the Sutton 5 monitoring site are shown in Table 3. Table 3 also shows measurements at base and test sites. For additional comparison measurements from 3 industrial roadside sites (type 'I' in Table 3) close to waste transfer facilities are shown along with measurements from the Marylebone Road kerbside site. The measurements from Sutton 5 were fully ratified. Measurements from other sites were partially ratified.

Measurements from each monitoring site were compared to the UK AQS Objectives for PM_{10}, which are identical to the EU Limit Values. There are two EU Limit Values for PM_{10}. The first is an assessment of long – term exposure and takes the form of an annual mean concentration which should not exceed 40 μgm^{-3}. The second Limit Value is based on short-term exposure and is expressed in terms of the frequency of pollution episodes; the daily mean concentration of PM_{10} should not exceed 50 μgm^{-3} on more than 35 days per year. As shown in Table 3, the Sutton 5 monitoring site met the annual mean Limit Value. However on the basis of the available measurements the site exceeded the daily mean Limit Value by a substantial margin. As discussed in Section 5 TEOM measurements were multiplied by 1.3 for comparison to the EU Limit Value.

Table 3 is ordered by PM_{10} concentration and clearly indicates the concerns regarding the PM_{10} concentrations at the sites close to waste facilities. Each of these sites exceeded the daily mean EU Limit Value during this period (35 days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3). The EU Limit Value was also exceeded at the Marylebone Road kerbside site. The source apportionment scheme in Fuller et al. (2002), suggests that primary PM_{10} emissions are linked to NO_X and thus high levels of PM_{10} would be expected at Marylebone Road. Such an explanation does not account for the PM_{10} concentrations measured at Brent 5, Bexley 4 and to a lesser extent at Sutton 5; thus a non tail pipe source of PM_{10} obviously affected these sites.

Site	Type	PM10 μgm^{-3} TEOM*1.3				NO_X Annual mean μgm^{-3}
		PM_{10} Capture %	Mean	Daily mean > 50	Full year projected daily mean >50	
Ealing 8	I	99	74	224	226	
Brent 5	I	99	70	191	193	65
Marylebone Road	K	97	47	151	156	161
Bexley 4	I	94	43	106	113	36
Sutton 5	**I**	**92**	**35**	**50**	**55**	**41**
Croydon 4	R	99	53	30	30	53
Greenwich 7	R	99	32	30	30	61
Lewisham 2	R	80	30	21	26	76
Sutton 4	K	98	33	21	21	91
Tower Hamlets 1	U	96	26	18	19	30
Kens & Chelsea 1	U	99	26	16	16	31
Crystal Palace 1	R	88	29	14	16	59
Greenwich 4	S	96	24	12	13	24
Ealing 7	U	39	25	4	10	29
Bexley 2	S	99	25	10	10	27
Bexley 1	S	90	26	9	10	32
Hams & Fulham 2	U	99	25	9	9	31
Richmond 2	S	99	25	9	9	23
Richmond 1	R	94	27	8	9	40
Hounslow 2	S	93	23	4	4	32
Mole Valley 3	U	99	23	4	4	20

Table 3 Measurements of air pollution at Sutton 5 and nearby sites during 2006. Measurements are ordered by the number of days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3.

Type: I = Industrial roadside, K= kerbside, R = roadside, U = urban background, S = suburban.

Comparison of measured and modelled concentrations

Measured and modelled annual mean PM_{10} concentrations at Sutton 5 and each of the roadside test sites are shown in Figure 8. Overall the model performed well at each of the six test sites with measured concentrations close to model predictions and within the uncertainty estimates. Measured annual mean concentrations at Sutton 5 however exceeded the modelled concentrations by 8 µg m^{-3} TEOM*1.3, a margin that exceeded the uncertainty estimate of 6 µg m^{-3} TEOM*1.3, 2σ. A local – other source of PM_{10} was therefore affecting the monitoring site.

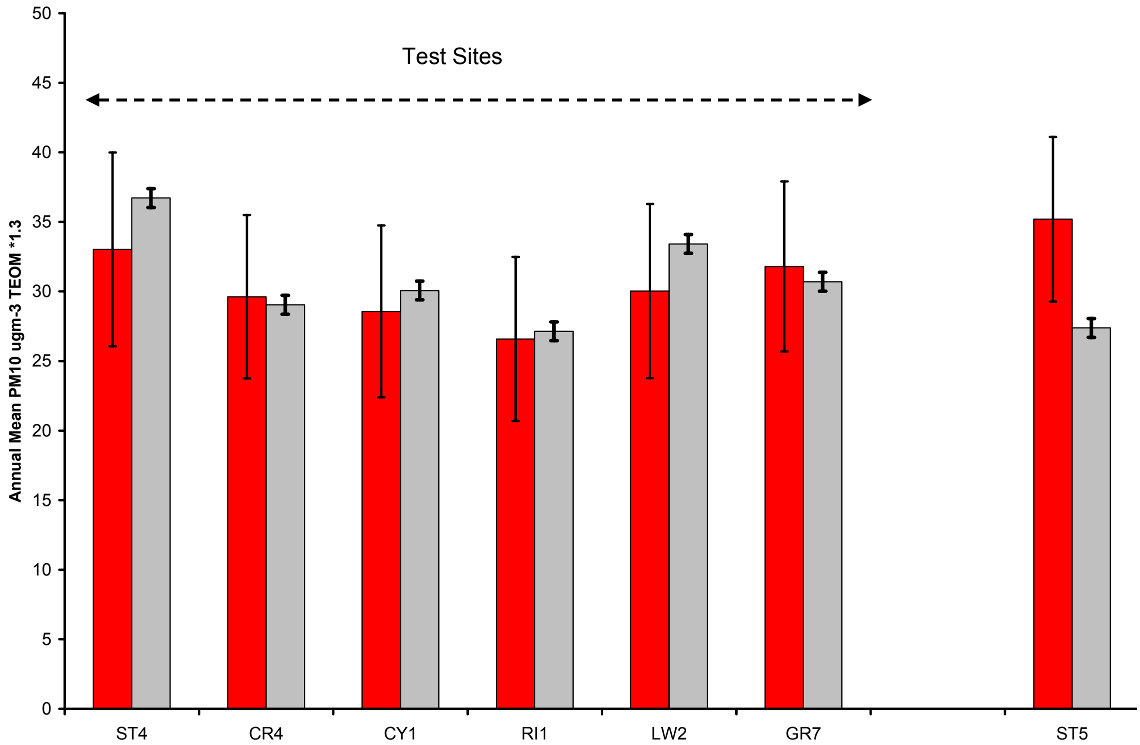

Figure 8 Measured and modelled 2006 annual mean PM_{10} concentrations at Sutton 5 and the 6 roadside test sites. Uncertainty estimates are shown at 2 σ. Measured concentrations are shown grey and modelled concentrations are shown in red.

Source apportionment of mean PM_{10} concentration

Results of the source apportionment of the mean concentration of PM_{10} at Sutton 5 are shown in Figure 9 and Table 4. PM_{10} from background and natural sources made the largest contribution to the mean concentration at the site. The local – other source made the second largest contribution to the mean concentration at the site; 8 (+/- 6, 2σ) µgm^{-3} TEOM *1.3 or 22 (+/- 17, 2σ) %. The model exhibited a slight positive (but non-significant) bias of -5 %. This also resulted in a commensurate under estimate in the concentration of PM_{10} from local – other sources.

All background sources accounted for 66 % and the TEOM offset accounted for a further 11% of the annual mean concentration. The vast majority of the 29% of PM_{10} arising locally was from the local – other source which exceeded the local primary by a factor of greater than 3.

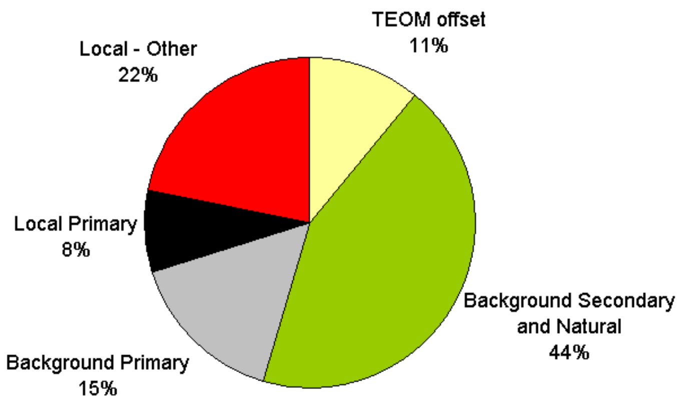

Figure 9 Source apportionment of mean PM_{10} concentration at Sutton 5 during 2006.

Source	Mean concentration μgm^{-3} TEOM *1.3 2006
TEOM offset	4
Background Secondary and Natural	15
Background Primary	5
Local Primary	3
Local - Other	8
Total	**35**

Table 4 Source apportionment of mean PM_{10} concentration at Sutton 5 during 2006.

The ratio of NO_X: primary PM_{10} emissions from the London Atmospheric Emissions Inventory was used to determine a worst case ratio as a sensitivity test. The worst case emitter was found to be a pre-Euro rigid HGV with NO_X: primary PM_{10} of 0.21 μgm^{-3} ppb^{-1} (including an estimate for non-exhaust emissions such as tyre and brake wear) compared with 0.15 μgm^{-3} ppb^{-1} determined from the NO_X: primary PM_{10} concentration ratio at sites across London and southeast England. Use of the worst case ratio in the model reduced the local – other PM_{10} to 19% of the total measured mean concentration, a change of 1 μgm^{-3} TEOM *1.3 but within the uncertainty estimate of 6 μgm^{-3} TEOM *1.3. Local primary PM_{10} increased to 11%, background primary increased to 22% and PM_{10} from background secondary and natural sources reduced to 37%. The ratio of local primary PM_{10} to the total local PM_{10} was 3.8.

Source apportionment of daily mean PM_{10} concentration

The daily mean time series of source apportioned PM_{10} concentration at Sutton 5 is shown in Figure 10. Source apportionment was possible on 247 days during 2006. Source apportionment was not possible on the remaining days due to the absence of NO_X and / or PM_{10} measurements at these times.

It is evident from Figure 10 that the daily mean PM_{10} concentration measured at the site was not constant but varied from day to day. Several different types of pollution episode can be seen in Figure 10.

> A - the daily mean PM_{10} concentration exceeded 50 μgm^{-3} TEOM*1.3 due to the local - other PM_{10}. If the local – other source were not present, the daily mean PM_{10} would not have exceeded the EU Limit value concentration.
>
> B - the combination of background and natural, local and background primary sources caused the daily mean PM_{10} concentration to exceed 50 μgm^{-3} TEOM*1.3. This episode would have affected large parts of London.
>
> C - the background and natural sources alone caused the daily mean PM_{10} concentration to exceed 50 μgm^{-3} TEOM*1.3. This episode would have affected large parts of London.
>
> D – PM_{10} from Guy Fawkes bonfires and fireworks caused the daily mean PM_{10} concentration to exceed 50 μgm^{-3} TEOM*1.3. At this time local non-NO_X sources affected many of the base monitoring sites, therefore the calculation of background secondary and natural PM_{10} became unreliable and the apportionment incurred a high uncertainty.
>
> E – This was a primary pollution episode that affected all of London. PM_{10} concentrations at Sutton 5 approached but did not exceed 50 μgm^{-3} TEOM*1.3. During this episode concentrations of NO_X at many of the background base sites in inner London exceeded the NO_X concentrations at roadside sites in the south London suburbs. This affected the apportionment of primary PM_{10} between background and local sources at Sutton 5. This episode highlighted a potential weakness in the apportionment scheme caused by the absence of input measurements from suitable background sites in suburban south London. This issue is explored further below.

During 2006 the maximum daily mean PM_{10} concentration at Sutton 5 was 95 μgm^{-3} TEOM*1.3 and 3 days had mean concentrations of over 75 μgm^{-3} TEOM*1.3. Daily mean PM_{10} at the site exceeded 50 μgm^{-3} TEOM*1.3 on 50 of the 335 days when PM_{10} measurements were available which equated to a full year estimate of 55 days. If the local other source was removed the daily mean PM_{10} concentration was projected to have exceeded 50 μgm^{-3} TEOM*1.3 on only 10 (9 – 22, 2σ) days during 2006 and the site would have achieved the EU Limit Value / AQS Objective in 2005.

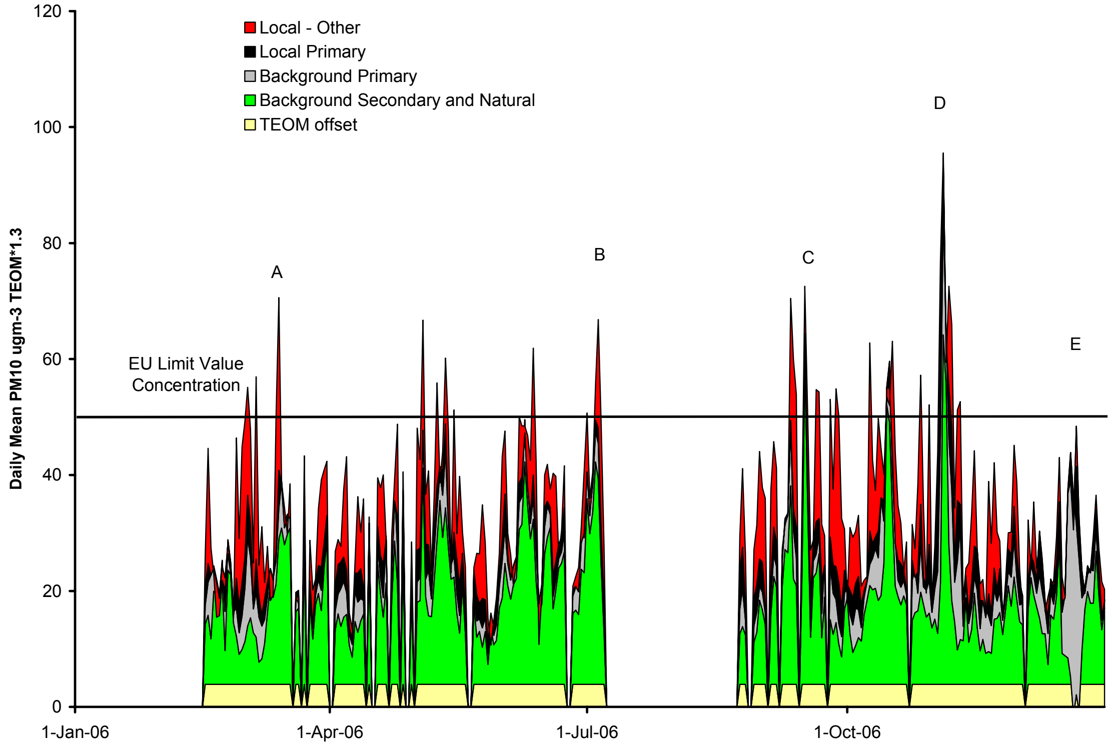

Figure 10 Time series of daily mean PM_{10} concentrations at Sutton 5 during 2006. Different types of pollution episodes are marked A to E and are discussed in the text.

Quantification and characterisation of the local – other PM_{10} is a key objective of the study. Figure 11 shows the daily mean concentration of the local – other PM_{10} with uncertainty is shown at 2σ. The local – other PM_{10} alone did not exceed the EU Limit Value concentration of 50 μgm^{-3} TEOM*1.3. The maximum daily mean concentration of local – other PM_{10} during the study period was 32 +/- 4 μgm^{-3} TEOM*1.3. The source apportionment model produced negative concentrations for the local – other PM_{10} on 43 days during the study period. However, the negative concentration on each of these days was within the expected model uncertainty and these apparent negative concentrations were therefore not significant. The difficulties that the model experienced due to the non-NO_X local sources from Guy Fawkes Night events (episode D) was properly reflected in the uncertainty estimate at this time.

Figure 12 shows the daily mean concentration of local primary PM_{10}. The daily mean concentration of PM_{10} from the local primary source was less than the local - other PM_{10}. The uncertainty model accurately detected the increased uncertainty during episode E from Figure 10 and also during a primary PM_{10} episode at the start of November 2006 near Guy Fawkes Night (episode D). At these times considerable NO_X concentration gradients were present across London. Additionally the NO_X concentration at Sutton 5 was often less than background NO_X concentrations at the base sites. The behaviour of the measured NO_X concentration at Sutton 5 is unsurprising considering the lack of background transport sources around the site; the area is largely surrounded by common land. The absence of nearby background sites that measured both NO_X and PM_{10} meant that background primary concentrations were represented by sites located over a wide area and such model artefacts were inevitable. These artefacts would have affected the apportionment of primary PM_{10} between local and background sources but would have had little effect on the determination of the concentration of local – other PM_{10} as shown by the uncertainty estimates in Figure 11.

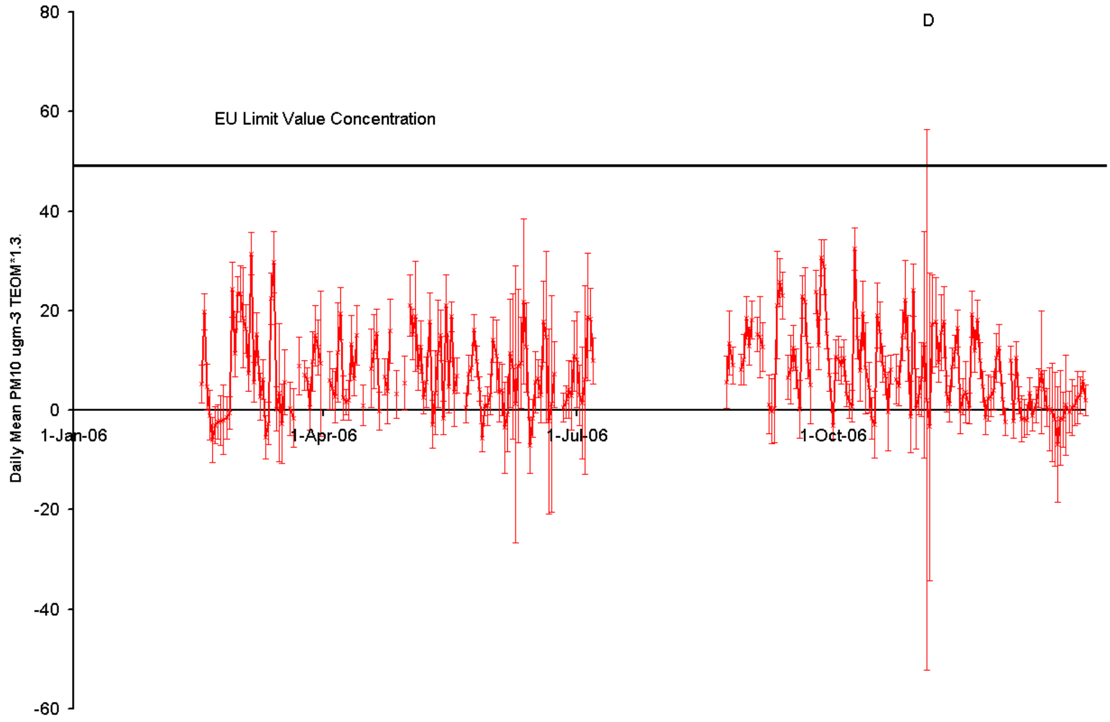

Figure 11 Time series of the modelled daily mean PM_{10} concentration from the local - other source at Sutton 5 during 2006. Uncertainty is shown at 2σ.

Figure 12 Time series of the modelled daily mean PM_{10} concentration from the local primary source at Sutton 5 during 2006. Uncertainty is shown at 2σ.

Source apportionment of PM_{10} concentration averaged by day of week and hour of day

Averaging pollution concentration by day of week and hour of day can provide insight into the behaviour of emissions sources affecting a monitoring site. Figure 13 shows the source-apportioned concentration of PM_{10} at Sutton 5 averaged by day of week and hour of day. Times are shown in GMT (with no correction for BST). Clear differences in the total mean PM_{10} concentration were seen between weekdays and weekends with the total mean concentration being greater on weekdays than on Saturday and Sunday. From concentration minima during hour 3 GMT (hour 4 BST), mean PM_{10} concentrations rose rapidly during hour 5 and 6 GMT (hour 6 and 7 BST) each weekday morning. The timing of the peak concentration was always during normal working hours and concentrations fell rapidly each afternoon. Two peaks were evident on Saturdays albeit a lower concentration compared with that experienced on weekdays. The total mean PM_{10} on Sundays showed comparatively little variation through the day.

The mean concentration of the local – other PM_{10}, averaged by day of week and hour of day is shown in Figure 14. Clear differences in the mean local - other PM_{10} were seen between weekdays and weekends with the local - other concentration being greater on weekdays than on Saturday and Sunday. The local – other PM_{10} was below the detection limit of the model each night however the concentration rose rapidly during hour 6 or 7 GMT (7 or 8 BST) each weekday to peak during working hours.

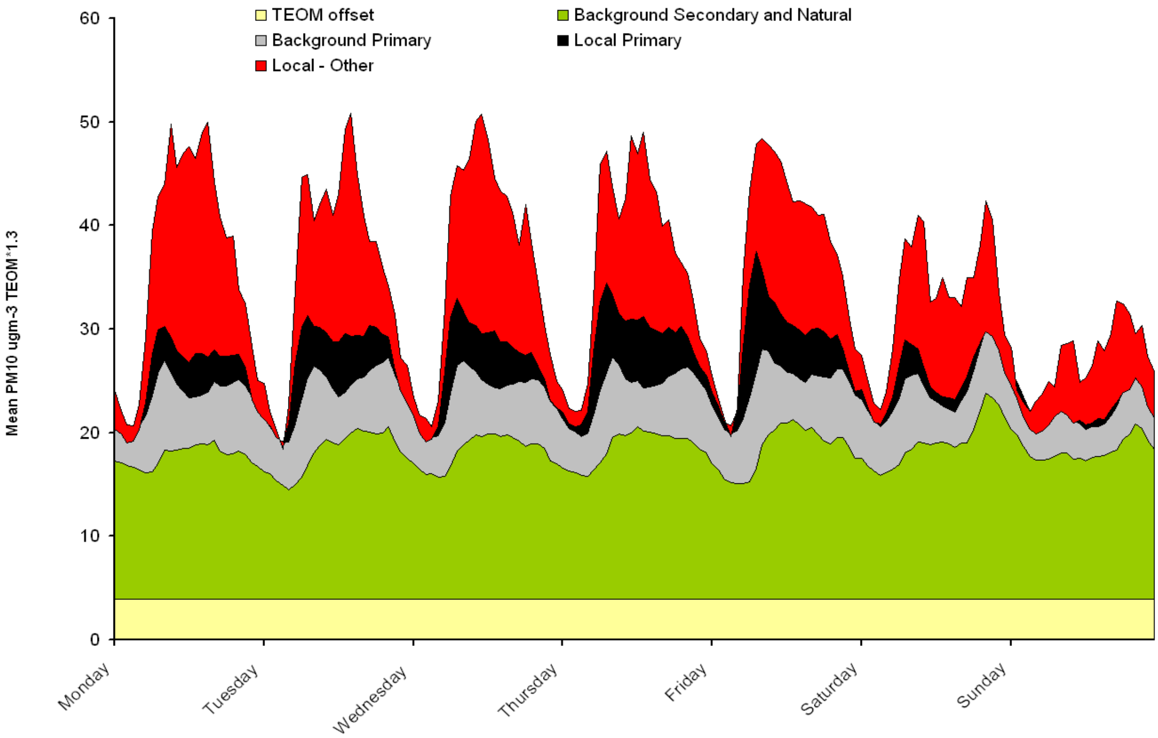

Figure 13 Source apportioned concentrations of PM_{10} at Sutton 5 (2006) averaged by day of week and hour of day. Times were based on GMT.

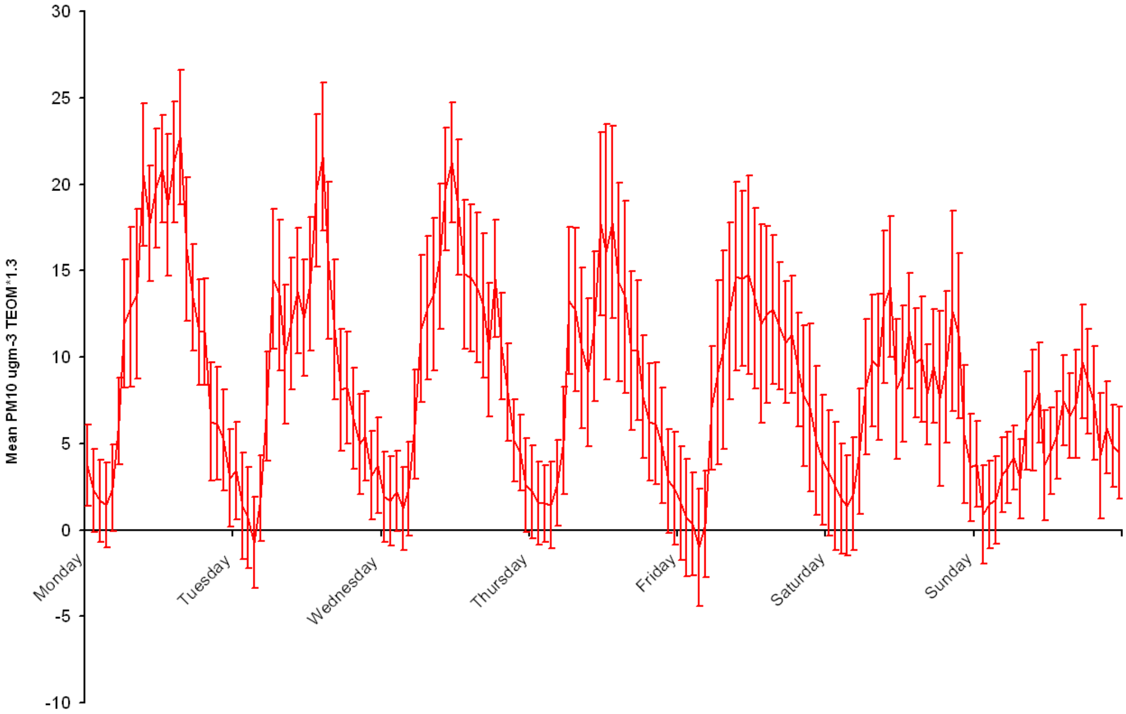

Figure 14 Concentrations of PM_{10} from local - other sources at Sutton 5 (2006) averaged by day of week and hour of day. Times are shown in GMT and uncertainty estimates are shown at 2 σ.

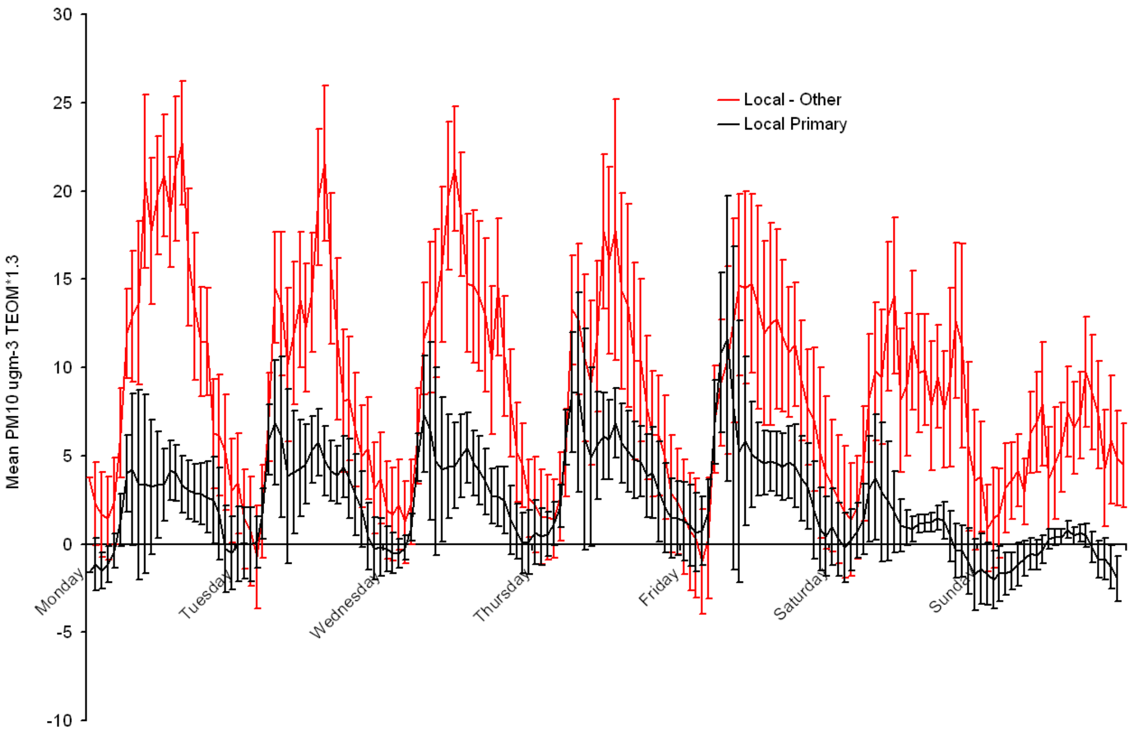

Figure 15 Concentrations of PM_{10} from the local sources at Sutton 5 (2006) averaged by day of week and hour of day. Times are shown in GMT and uncertainty estimates are shown at 2 σ.

Figure 15 shows the mean concentration from the local – other and local primary sources. The mean concentration of local primary PM_{10} showed a clear difference between weekdays and weekends with the mean concentration being greater on weekdays than on Saturday and Sunday, in line with behaviour of the mean concentration of local – other PM_{10}. Most notably the mean concentration of local primary and local other PM_{10} sources exhibited rapid concentration increases at the same time on weekday mornings, although the local primary PM_{10} peaks earlier each day. Both sources also showed similar rates of reduction during weekday afternoons and evenings. The similar diurnal pattern suggested a link between these sources. As discussed above the model experienced some problems in the partition between local and background primary PM_{10} sources due to the lack of background PM_{10} measurements in suburban south London. This may have caused the model to underestimate the local primary PM_{10} concentrations at certain times, for example on Sundays where negative concentrations were not always accounted for within the uncertainty estimates suggesting a possible slight source of bias that could not be explained by the information available in the model. The extent to which the local primary PM_{10} may explain the variance in the local – other PM_{10} concentration is explored in Figure 16 which shows a scatter plot of the mean concentration of the two sources averaged by hour of day and day of week. Figure 16 suggested a relationship between the two PM_{10} sources. The correlation coefficient (r^2) of 0.44 suggested that 44% of the averaged hour of day and day of week variance in the concentration in local – other PM_{10} may be explained by the variance in the local primary PM_{10} concentration.

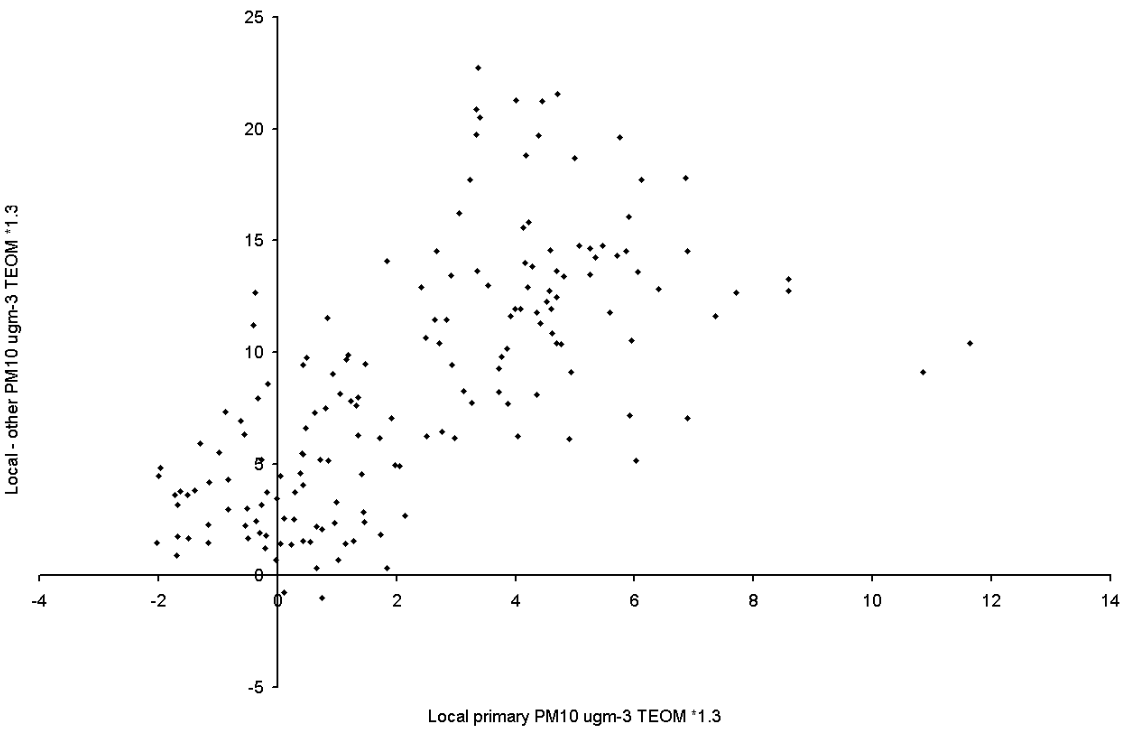

Figure 16 Scatter plot of local – other PM_{10} vs local primary PM_{10} at Sutton 5 during 2006. Both sources have been averaged by hour of day and day of week.

Mean PM_{10} by wind direction

Figure 17 shows the mean concentration of PM_{10} at Sutton 5, averaged by wind direction. This analysis provided important insight into the location of PM_{10} sources affecting a monitoring site.

The greatest overall mean concentration of PM_{10} arose during broadly southerly winds (150° to 210°). This mean concentration was caused by an elevation in the local – other PM_{10} from these wind directions. The concentration of PM_{10} from background secondary and natural sources was elevated during easterly winds (90°). This was indicative of long range transport of PM_{10} from continental sources and was consistent the expected behaviour of secondary PM_{10} sources as highlighted by APEG (1999) and Smith (1997).

The lowest mean PM_{10} concentrations from background sources were measured at the site during westerly winds. Winds from a westerly direction usually have a maritime origin and do not contain large concentrations of secondary PM_{10}.

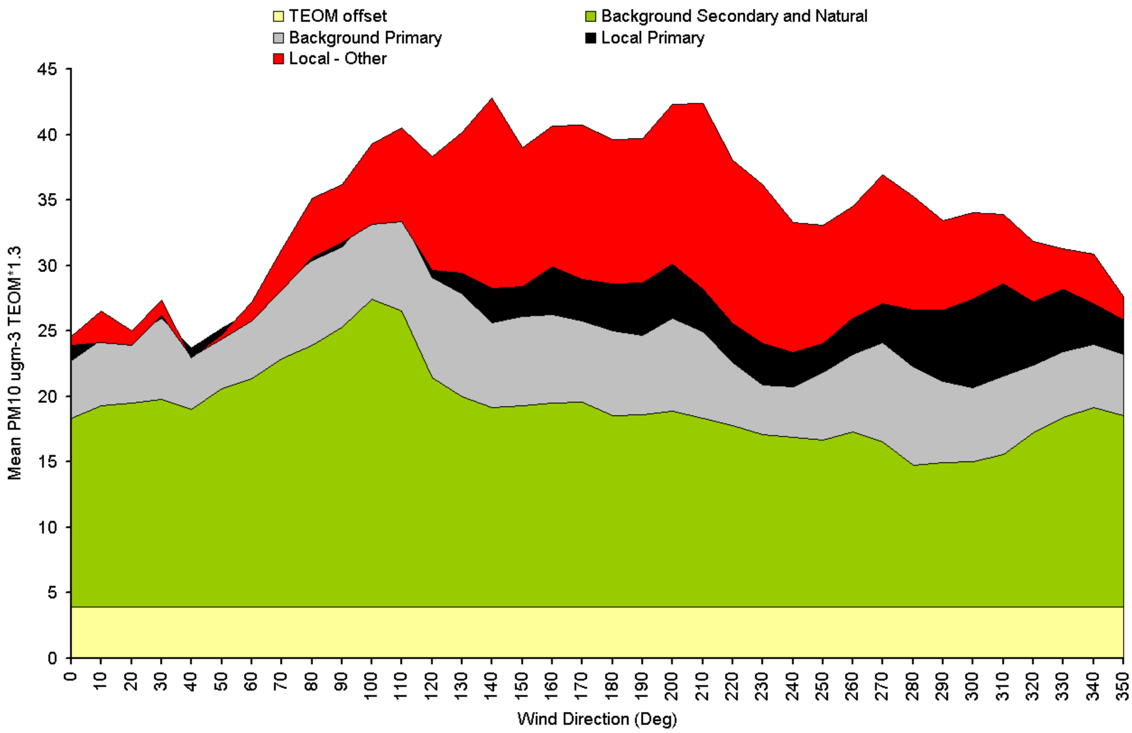

Figure 17 Source apportioned PM_{10} at Sutton 5 during 2006, averaged by wind 10^{o} direction sectors.

The contrasting background pollutant concentrations with respect to easterly and westerly winds is typical of sites in London and has been found in previous studies (e.g. Fuller and Hedley 2006). The behaviour of PM_{10} from local sources is also determined by wind direction but can be additionally affected by the location of local sources and buildings; the orientation of local roads with respect to wind direction and the geometry of street canyons are important determinants.

Figure 18 shows the mean concentration of local PM_{10} sources averaged by 10^{o} wind sectors. The mean concentration of the local – other PM_{10} was less than the uncertainty of the model for wind directions from the 330^{o} to 90^{o} sectors. Mean concentrations from all other directions were above the uncertainty estimate and therefore within the detection limit of the model.

Local – other PM_{10} exhibited greatest concentrations when wind originated from directions between 120^{o} and 280^{o}. This showed agreement with the orientation of Beddington Lane with respect to the monitoring site however it appeared that greater concentrations of local – other PM_{10} arose from Beddington Lane to the south of the monitoring site when compared to the concentration from Beddington Lane to the north of the site.

Figure 19 shows both local primary and the local – other PM_{10}. The local primary PM_{10} was determined from the local NO_X concentration and was therefore linked to vehicle exhaust sources local to the monitoring site; vehicles using Beddington Lane and other nearby roads. The mean concentration of local primary PM_{10} was clearly determined by the orientation of Beddington Lane relative to the monitoring site. The greatest mean concentration of primary PM_{10} originated from Beddington Lane to the north of the monitoring site with a lower mean concentration arising from

Beddington Lane to the south. The reason for this may have related to different speed or acceleration profiles on these two stretches of Beddington Lane; the road was more ‘open’ to the north. No primary PM_{10} emissions were detected from the housing to the east of the monitoring site.

Figure 20 shows the relative the annual mean concentration arising from each 10^{o} wind sector. The distribution of the local – other PM_{10} was close to that of the local primary PM_{10} for the section of Beddington Lane to the south of the monitoring site. The distribution of mean concentrations in Figure 20 emphasised the difference in the relative mean concentrations of the local sources arising from the sections of Beddington Lane to the north and south of the monitoring site.

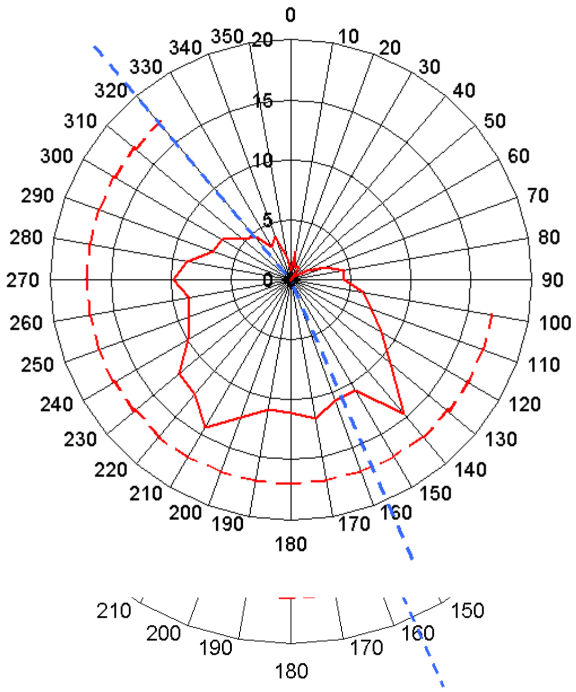

Figure 18 Source apportioned mean concentrations of local - other PM_{10} at Sutton 5 (2006) averaged by 10^{o} wind sector. The blue dotted line denotes the approximate orientation of Beddington Lane with respect to the monitoring site. The red dotted line shows the wind sectors where the modelled mean concentration of local – other PM_{10} exceeded the modelled uncertainty estimates. Mean concentrations are shown in µgm^{-3} TEOM*1.3.

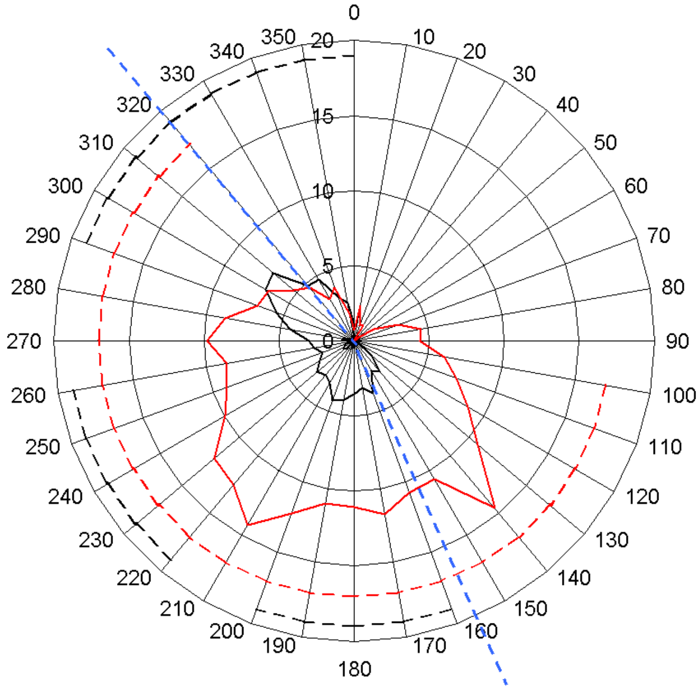

Figure 19 Source apportioned mean concentrations of PM_{10} from local sources at Sutton 5 (2006) averaged by 10° wind sector. The mean concentration of local – other PM_{10} is shown in red and local primary PM_{10} is shown in black. The blue dotted line denotes the approximate orientation of Beddington Lane with respect to the monitoring site. The red and black dotted lines shows the wind sectors where the modelled mean from the local PM_{10} sources exceeded their respective uncertainty estimates. Mean concentrations are shown in μgm^{-3} TEOM*1.3.

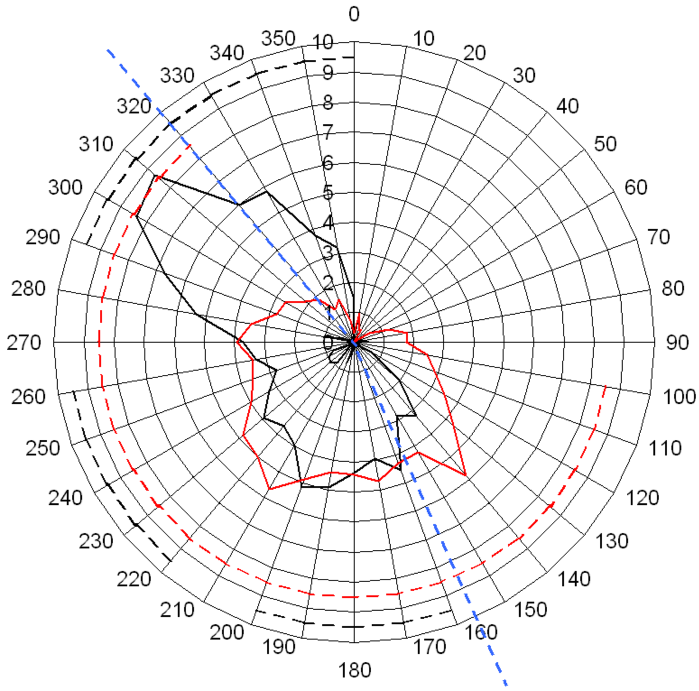

Figure 20 Source apportioned mean concentrations of PM_{10} from local sources at Sutton 5 (2006) averaged by 10° wind sector. Concentrations are expressed relative to the annual mean. Insignificant negative concentrations are not shown. The mean concentration of local – other PM_{10} is shown in red and local primary PM_{10} is shown in black. The blue dotted line denotes the approximate orientation of Beddington Lane with respect to the monitoring site. The red and black dotted lines shows the wind sectors where the modelled mean from the local PM_{10} sources exceeded their respective uncertainty estimates.

Reduction of Local – Other PM_{10} Required to Meet the Air Quality Strategy Objective

The measured concentration of PM_{10} at the Sutton 5 monitoring site exceeded the daily mean EU Limit Value during 2006. Source apportionment of daily mean concentrations allowed the assessment of PM_{10} reduction scenarios, for example the reduction in the concentration of the mean local – other PM_{10} required to achieve the daily mean AQS.

Figure 21 shows the number of days with mean concentrations of PM_{10} above 50 μgm^{-3} TEOM*1.3 for progressive reductions in the mean concentration of local – other PM_{10} based on measurements made during 2006. Pro-rata allowance was made for days lost due to incomplete measurement data. It is clear from Figure 21 that the annual number of days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3 was not linearly dependent on the concentration of the local – other PM_{10}. It was estimated that the mean concentration of local – other PM_{10} at Sutton 5 needed to be reduced by around 20 % (5 – 40%) for the site to have met the AQS Objective during 2006.

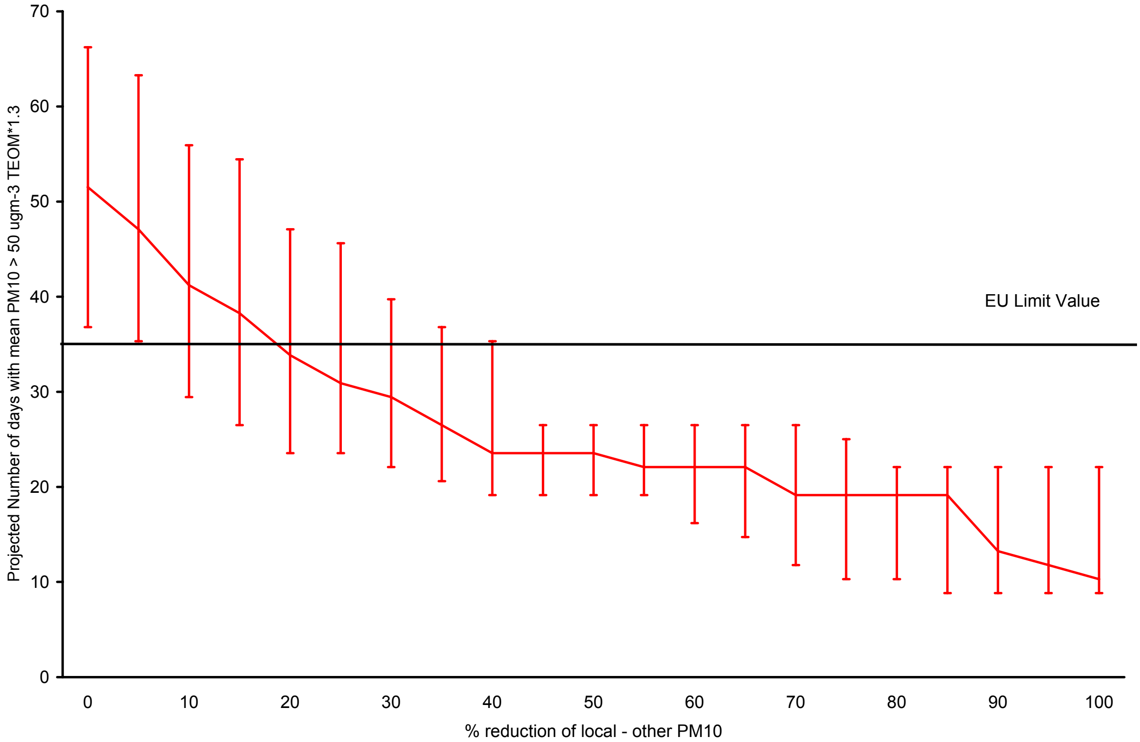

Figure 21 Reduction scenarios for the concentration of local - other PM_{10}, compared to the daily mean EU Limit Value. Analysis was based on 2006 measurements and pro-rata adjustment was made for measurement availability.

Further insight into the PM_{10} concentrations at Sutton 5 may be obtained from considering other studies of PM_{10} on haulage routes from waste facilities. Source apportionment studies at two sites close to entrances to waste facilites (Brent 5 and Bexley 4) found concentrations of local –other PM_{10} of up to 33 (+/- 3, 2σ) μgm^{-3} TEOM*1.3. Lower concentrations of local – other PM_{10} were found two other sites (Hammersmith & Fulham 3 and Hastings) that were several hundred metres from waste facilities. The concentration of local – other PM_{10} at Sutton 5 ((8 +/- 6, 2σ μgm^{-3} TEOM *1.3) was consistent with the monitoring site being several hundred metres from a waste facility.

Site	Distance from waste site along haul route	Mean local – other PM_{10} μgm^{-3} TEOM*1.3	Reference
Brent 5	~ 15m	33 (+/- 3, 2σ)	Fuller, Hedley and Baker 2007
Bexley 4	< 30 m	14(1) – 31(2)	(1) Fuller and Baker 1999 (2) Fuller and Hedley 2006
H'smith & Fulham 3	450 m	6 (10 – 4, 2σ)	Fuller and Hedley 2006
Hastings	1000 m	10	Fuller and Hedley 2004

Table 5 Concentrations of local - other PM_{10} from previous studies of PM_{10} near waste facilities.

7. Dispersion modelling method

Model Development

The dispersion modelling approach adopted in this report was refined from that used previously by KCL for the Council in its earlier Review and Assessment modelling reports and also those of other local authorities in the southeast of England; including the Mayor of London, London Boroughs, plus Unitary, Borough and District local authorities in Sussex, Surrey, Kent, Essex, Herts and Beds and Berkshire.

A receptor based approach has been developed by KCL through combining both modelling and measurement. Separate modelling was undertaken of two categories of sources: 1) the road network close to measurement sites and 2) all sources, including roads further away. These were combined with a constant representing emission sources. A multiple regression analysis was then undertaken with the monitoring results from the London Air Quality Network and other regional networks in the southeast to establish the modelling relationship used.

This approach describes the balance between the local road contribution and the background since it provides a good comprise between the most robust aspects of both modelling and measurements.

Further details on the methodology developed can be found on the GLA website (see http://www.london.gov.uk/mayor/environment/air_quality/docs/modelling.pdf).

A further refinement to the model for the purposes of this study, relates to the incorporation of an element for local - other primary PM_{10} and this is described further in sections below.

Modelling Detailed Road Networks

To improve the geographic accuracy of predictions all roads within the Beddington Lane area were split up into 10 m sections, as shown in Figure 22. This permitted each 10 m point to act as a source of emissions, thus allowing emissions to be varied along each link. This approach allowed roadside emissions, for example, near junctions where vehicle idling is important, to be increased. The roadside emission sources were also geographically accurate, enabling road junctions to be modelled thoroughly. This ensured that maps of pollutant concentrations were geographically accurate allowing more accurate assessments to be made of population exposure.

Treatment of Emissions

The model used the latest detailed emission factors released by DEFRA. These were applicable down to a speed of 5 km/hr, although the factors at such low speeds are highly uncertain.

Major Road Flows

The traffic data for Beddington Lane were obtained from the 2003 version of the London Atmospheric Emission Inventory (LAEI) and a 2005 estimate was used. The vehicle classification used for the roads was based on the vehicle split provided in the LAEI, as was the breakdown of vehicle ages. No details of vehicle flows were available for Coomber Way and the private access road to the Viridor Waste Management site; hence these roads were modelled as general London minor roads and therefore concentrations may be under predicted.

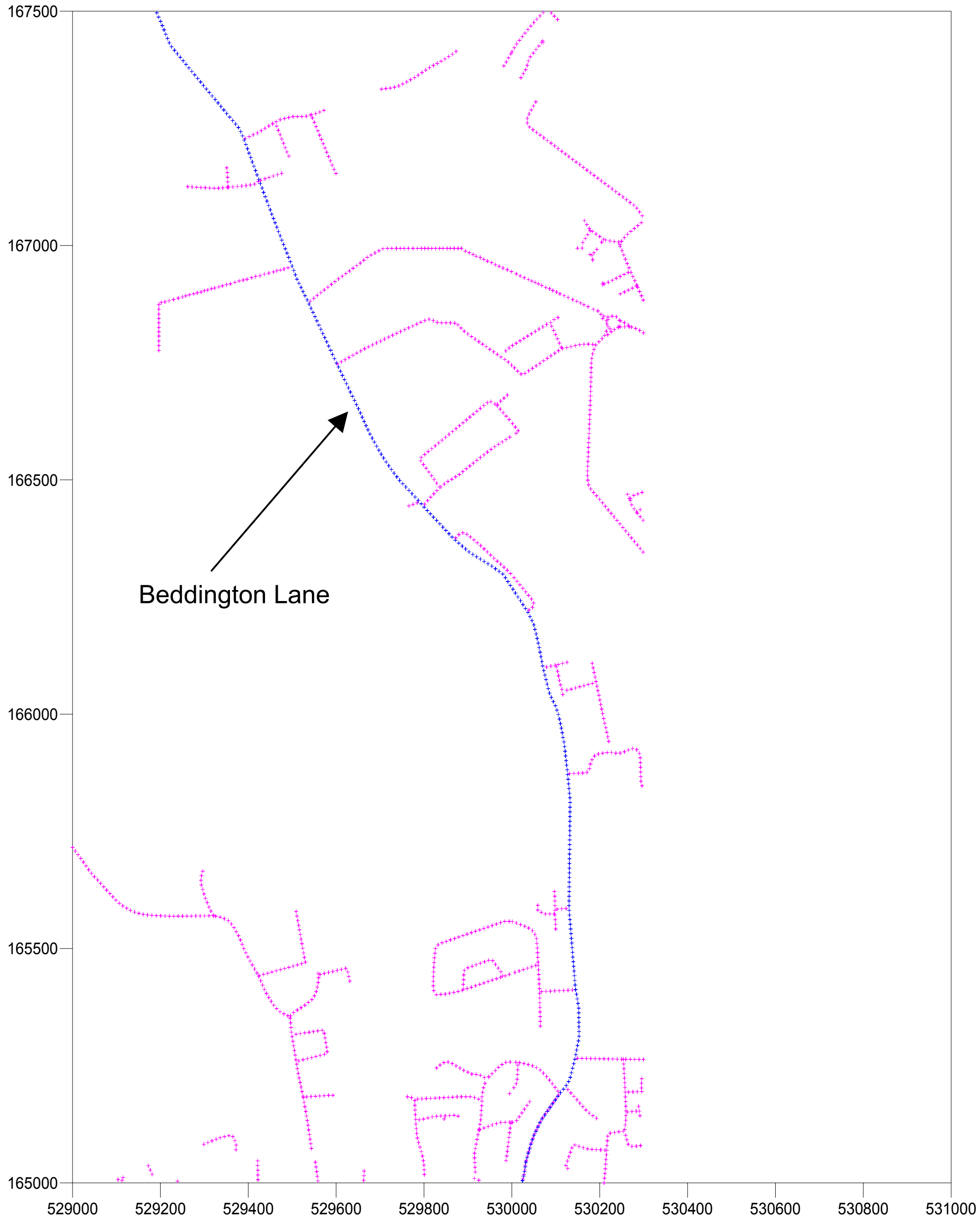

Figure 22 10m sections of road modelled, showing major roads (blue) and minor roads (pink)

Model Validation

A comprehensive validation exercise has been undertaken for the KCL models based on measurement sites in London and the southeast. This has been presented previously in earlier Council reports.

Incorporation of local - other PM_{10} into model

The KCL model incorporated vehicle related PM_{10} emissions arising from vehicle exhausts, tyre and brake wear and also typical roadside resuspension of particles. Locally produced PM_{10} emissions (i.e. the local - other PM_{10}), such as those that can arise from atypical resuspension of particles from road surfaces however were not specifically included within the model. A visual assessment from the site visit to Beddington Lane highlighted that silt was being deposited on road surfaces from vehicles using waste facilities in the area and findings from other KCL investigations in similar locations have indicated that atypical resuspension arose (Fuller and Baker; 2001, Fuller and Hedley 2006, Fuller et al 2007).

The level of emissions of such PM_{10} depends on many factors, including type of road surface, deposition of material onto the road, type of vehicles using the road and also their speed. In view of these variables there are no emission factors available that can be readily used for the purposes of modelling such emissions. Paragraph 8.93 of Technical Guidance 03 (DEFRA, 2003) highlights this lack of information. It further advises that resuspension is not likely not to be a problem in most instances. The source apportionment findings in this report however confirmed that for the Beddington Lane area that there was a large additional “local other” source of PM_{10} present.

To establish a local - other PM_{10} component within the KCL model, the model was run twice, once including the 2005 base case traffic and background and secondly for the 2005 background only (i.e. excluding all local traffic). The model was run using 2003 meteorology. The difference between the annual mean PM_{10} results was established at the Sutton 5 monitoring site in Beddington Lane. A factor was then derived from this difference. The factor was 3.47 and this was applied to the local road emissions only for the area. This factor compared favourably with the ratio of total local PM_{10} concentration : local primary PM_{10} from source apportionment (3.8).

Verification of model

The verification of this factor against monitored data is shown in Table 6.

PM_{10}	Annual mean (μgm^{-3})	Number of days > 50 μgm^{-3}
Modelled (based on 2005)	34.5	57.3
Monitored (2006)	35	55*

(*Estimated pro rata for 100% data capture)

Table 6 Modelled and monitored results for the Sutton 5 roadside site (see Figure 1)

The comparison between modelled and monitored results showed very good agreement for both the annual mean and daily mean objectives. As a result further adjustment of the model was not required.

Incorporation of changing resuspension emissions with distance

The model set up as outlined above did not include any change in local - other primary PM_{10} with distance along the road. It is recognised however that this component should decrease along Beddington Lane, with distance from the access point of the waste sites (which were considered the main sites of deposition onto roads and therefore also representative of the points of maximum source strength). It was assumed that the deposits were then smeared on the adjacent road surface away from these initial points.

To incorporate this change of emission source strength it is necessary to make a series of assumptions, this is due to both lacking emission factors and also the limited monitoring and activity data available for the area and in general.

KCL examined source apportionment studies associated with waste facilities elsewhere in London, where similar problems exist and monitoring is also undertaken. From this comparison, the Brent 5 site in Neasden was adjudged, from visits to both sites and observation of material on the roads, as a site with similar levels of activity (Fuller et al. 2007). The Brent 5 monitoring site was located much closer (approximately 15m from the access point to waste sites) than the Sutton 5 site and consequently pollution levels at Brent 5 were higher.

The local – other PM_{10} for the Brent 5 site was used to represent the level of pollution close to the two sites on Beddington Lane, Country Waste Management Ltd (CWM) and Viridor Waste Management (VWM). The access points identified for the sites were the site entrance on Beddington Lane (for CWM) and the site office for the VWM (near the western end of the private access road to the landfill site. Both of these points were approximately 800m from the Sutton 5 monitoring site. The sites are shown in Figure 23 as is the site operated by 777 Waste Management.

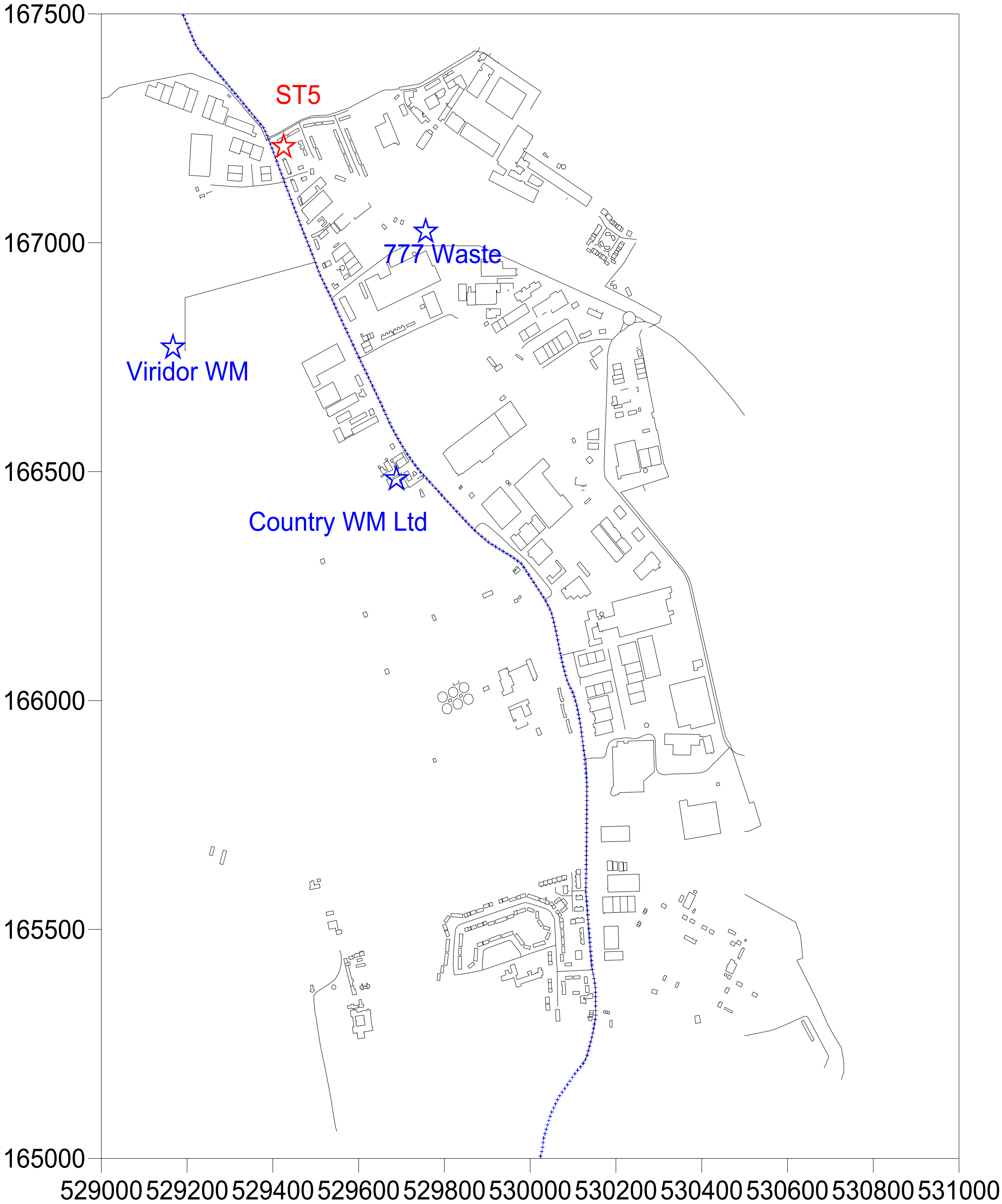

Figure 23 Location of waste sites close to the Sutton 5 monitoring site

Additional working assumptions were necessary to derive a factor for the fall off in source strength of local - other PM_{10} to be applied to the road emissions only. These were as follows:

1) The activity at the CWM and VWM sites was considered approximately equal and therefore the numbers of vehicles using each site and the associated deposition of material were considered equal too.

2) The local – other PM_{10} emission rate reduced with distance from the CWM and VWM sites.

3) The vehicles using the CWM and VWM sites travelled in both directions and these flows were considered approximately equal.

4) The distances from the CWM and VWM access points to the Sutton 5 monitoring site were similar and hence the factor at that location comprised an equal contribution from both operations.

5) A linear change in factor over distance (i.e. change in PM_{10} source strength) was assumed.

Important note - there was no traffic information available for Coomber Way where 777 Demolition and Haulage Co Ltd and Recycling Centre operate. It was assumed that the impact on local – other PM_{10} from vehicles using this site were equally distributed along Beddington Lane and incorporated within the assumptions used for Beddington Lane. Similarly there was no traffic information available for the private access road from VWM.

The change in relative emission rate was calculated from the difference in assumed local – other PM_{10} at Brent 5 and at Sutton 5. The relative individual emission rates derived, based on the working assumptions for the CWM and VWM sites are shown in Figure 24.

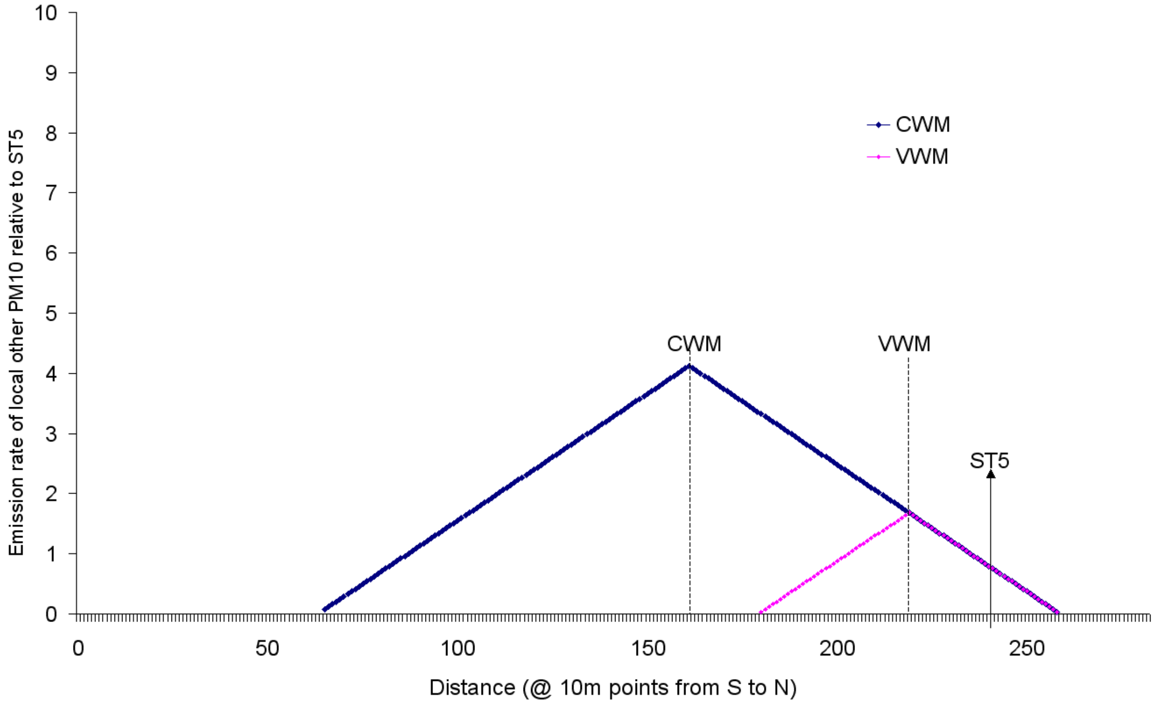

Figure 24 Relative emission rate of local other PM_{10} from each waste facility on Beddington Lane.

Figure 24 shows the individual emission rates for the two sites, it does not however indicate any combination of both. It also highlights that the factor for CWM was greater than that for VWM on Beddington Lane itself. The reduced level for VWM reflected the distance to Beddington Lane along the private access road. From the point where the VWM access road joined Beddington Lane the emission rates were assumed to be equal. The combined effect of VWM and CWM is shown in Figure 25 and discussed below.

The emission rates for the two sites combined, indicated an area of overlap between the sites where contributions were constant. This was because the assumed fall off in emission rate from vehicles heading south from VWM cancelled out the assumed fall off in emission rate from vehicles heading north from CWM.

Further north beyond the VWM there was a combined emission rate where both individual emission rates were reducing. It was however not clear whether the effect of the combined emission rate lead to an increased (i.e. doubled) fall off with distance. An alternative assumption was that the emission rate remained the same for both north and south directions. The overriding assumption used to determine the emission rate at points north of the VWM junction was that it must equal 1 at the Sutton 5 site. Further assumptions were necessary to derive a combined emission rate and to try to understand this better, four scenarios were considered (based on Figure 25):

Scenario 1) an equal reduction in emission rate to the north and south. This was based on the combined emission rates between the VWM access road junction with Beddington Lane and Sutton 5 (this is shown in pink).

Scenario 2) an unequal reduction in emission rate to the north and south. This was based on scenario 1 north beyond VWM and south of CWM the reduction in emission rate is represented as in Figure 24 (shown in dark blue).

Scenario 3) an equal reduction in emission rate to the north and south. This was based on the emission reduction rate from CWM alone to the south. To the north the relative emission rate had to be 1 at Sutton 5 (shown in yellow).

Scenario 4) a separate sensitivity check was carried out based on a reduced emission rate at the entrance to VWM and CWM, where the local - other PM_{10} was reduced by half to 16.5 μgm^{-3}. For this scenario an unequal distribution of emission rate reduction was used based on scenario 2 was used. Again the overriding issue used to determine the relative emission rate north of the VWM junction was that it equalled 1 at the Sutton 5 site (shown in light blue).

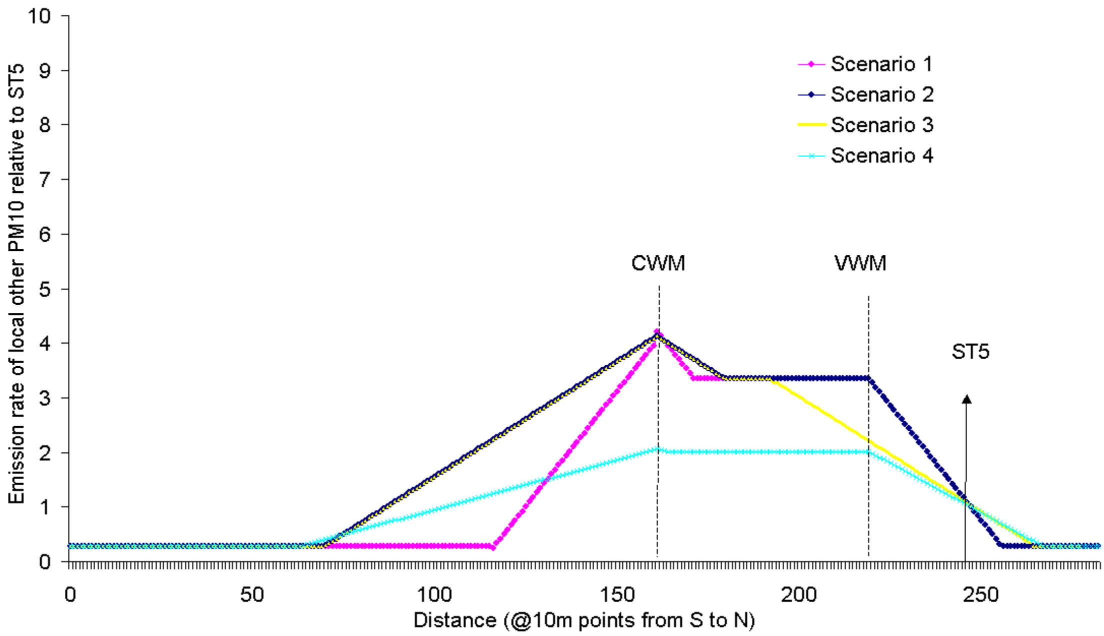

Figure 25 Combined relative emission rate of local other PM_{10} on Beddington Lane.

The emission rates (shown in Figure 25) were applied to the model. Figure 25 also shows the emission rate reducing to a "background" level (i.e. where the relative emission rate was $^{1}/_{3.47}$), which represented PM_{10} vehicle emissions only where there was no local - other PM_{10}.

8. Dispersion modelling results

The modelling was undertaken using the four emission scenarios to show the impact of different emission rates of local – other PM_{10} along Beddington Lane. Dispersion modelling was undertaken for both the annual mean and daily mean PM_{10} objectives.

Modelled annual mean PM_{10} (µgm^{-3}) in the Beddington Lane area

For all scenarios, concentrations exceeded the annual mean PM_{10} objective of 40 µgm^{-3} in the area close to the Beddington Lane road centre line and junctions. The area that exceeded this threshold however varied between scenarios. Scenarios 2 and 3 had the largest area of Beddington Lane (both north and south) predicted to exceed. The total length that exceeded was approximately 1.4km and this extended approximately 300m further than scenario 1, which was based on the greatest emission rate.

For scenarios 2 and 3 the impact reflected a shallower fall off in emission rate towards the south. In all instances the area that exceeded did not extend further north than the Sutton 5 site. The houses in Beddington Lane close to the Sutton 5 site were just outside the area that exceeded the AQS annual mean objective for all scenarios.

The predicted annual mean concentrations close to the Sutton 5 site for scenarios 3 and 4 had a shallower fall off in emission rate and consequently had lower concentrations than scenarios 1 and 2. The concentrations for scenario 4 used for sensitivity testing and based on a reduced local – other PM_{10} had lower maximum concentrations and therefore a slightly smaller area that was predicted to exceed.

All the modelled scenario predictions agreed well with the Sutton 5 measurements (see Table 7).

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Measured
34.7	34.7	34.4	34.5	35

Table 7 Annual mean concentrations (modelled and measured) at Sutton 5 (µgm^{-3})

The modelled annual mean results are shown in Figure 26 to Figure 29.

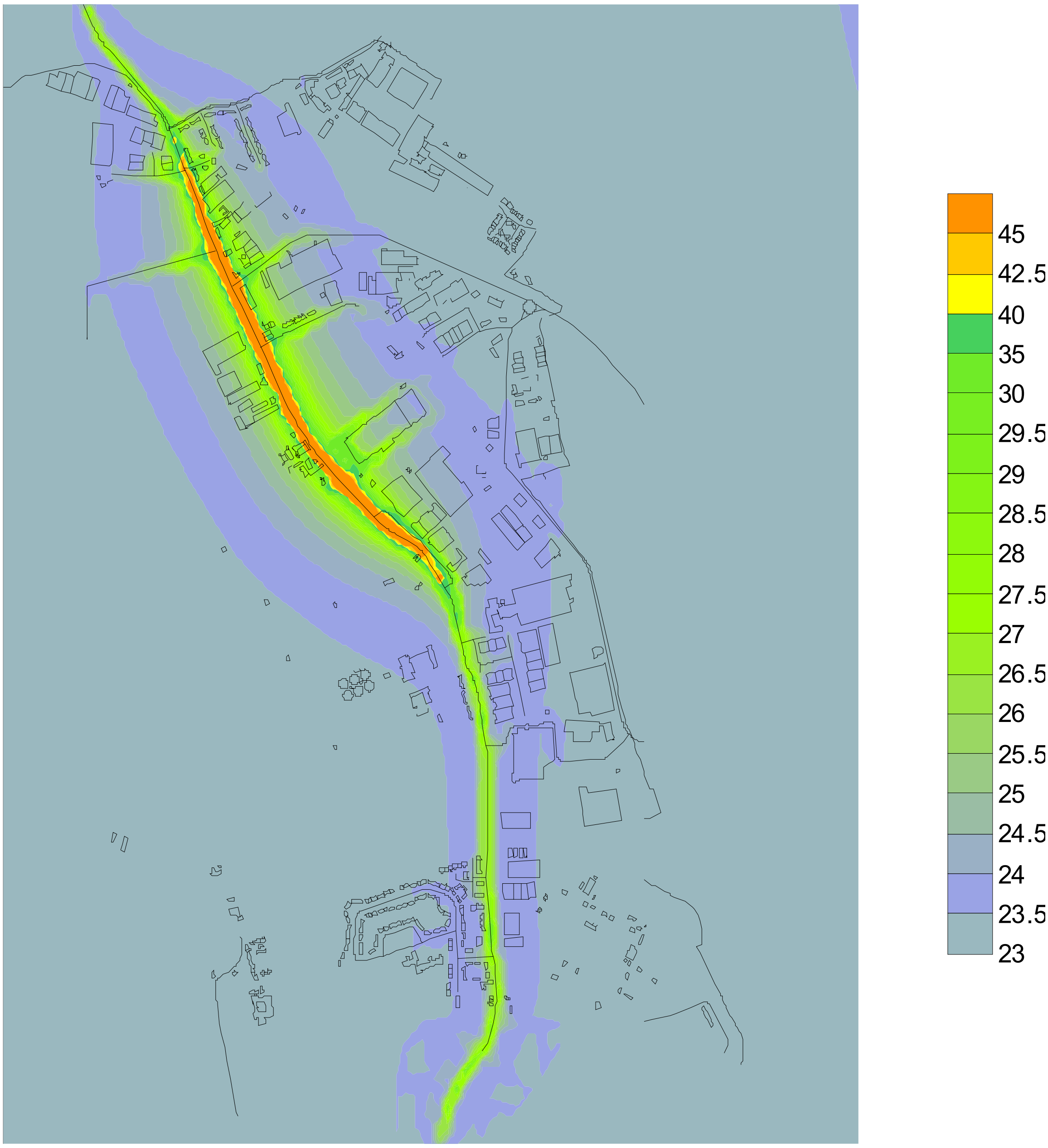

Figure 26 Predicted annual mean (Scenario 1) for the Beddington Lane area (μgm^{-3})

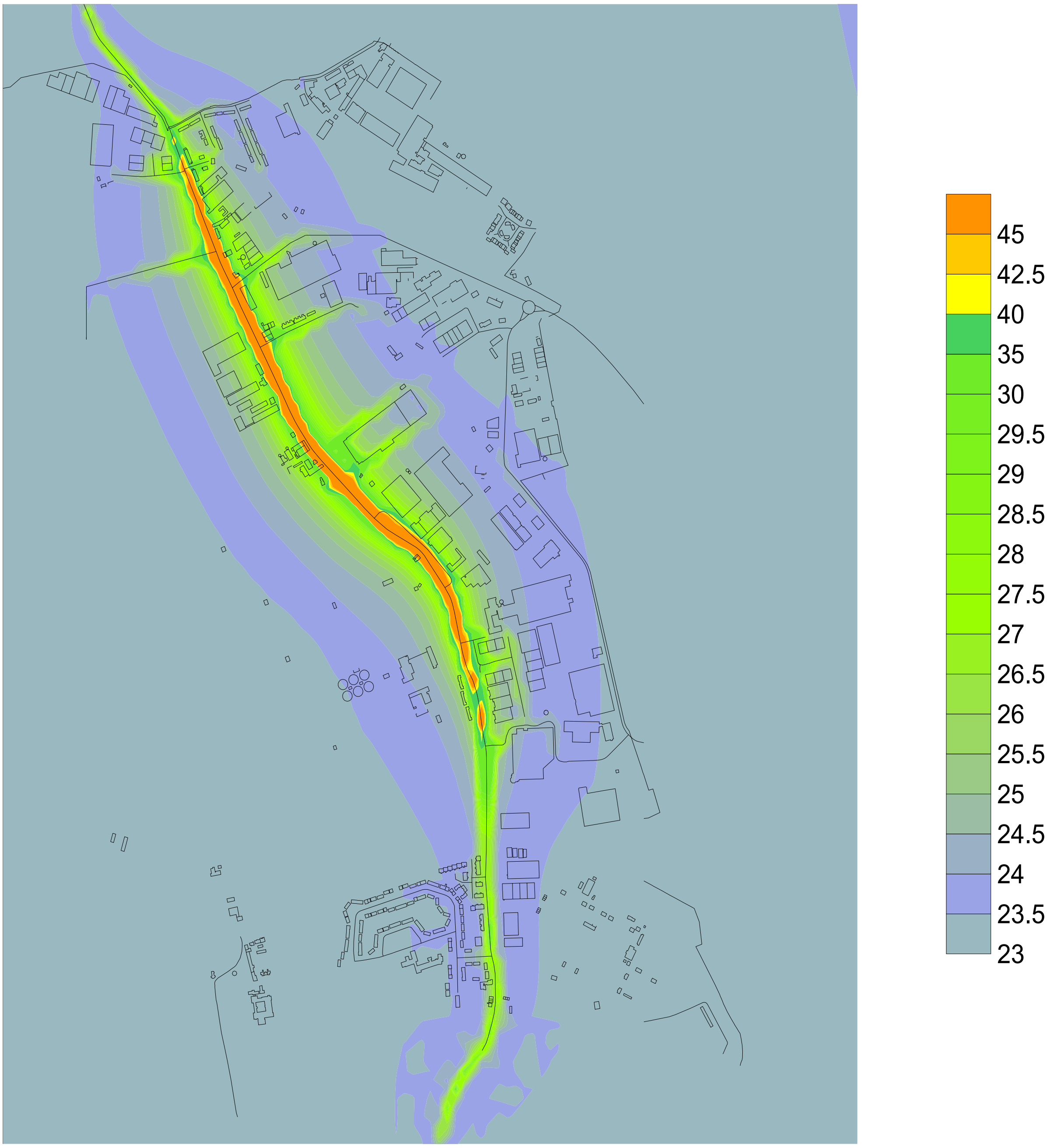

Figure 27 Predicted annual mean (Scenario 2) for the Beddington Lane area (μgm^{-3})

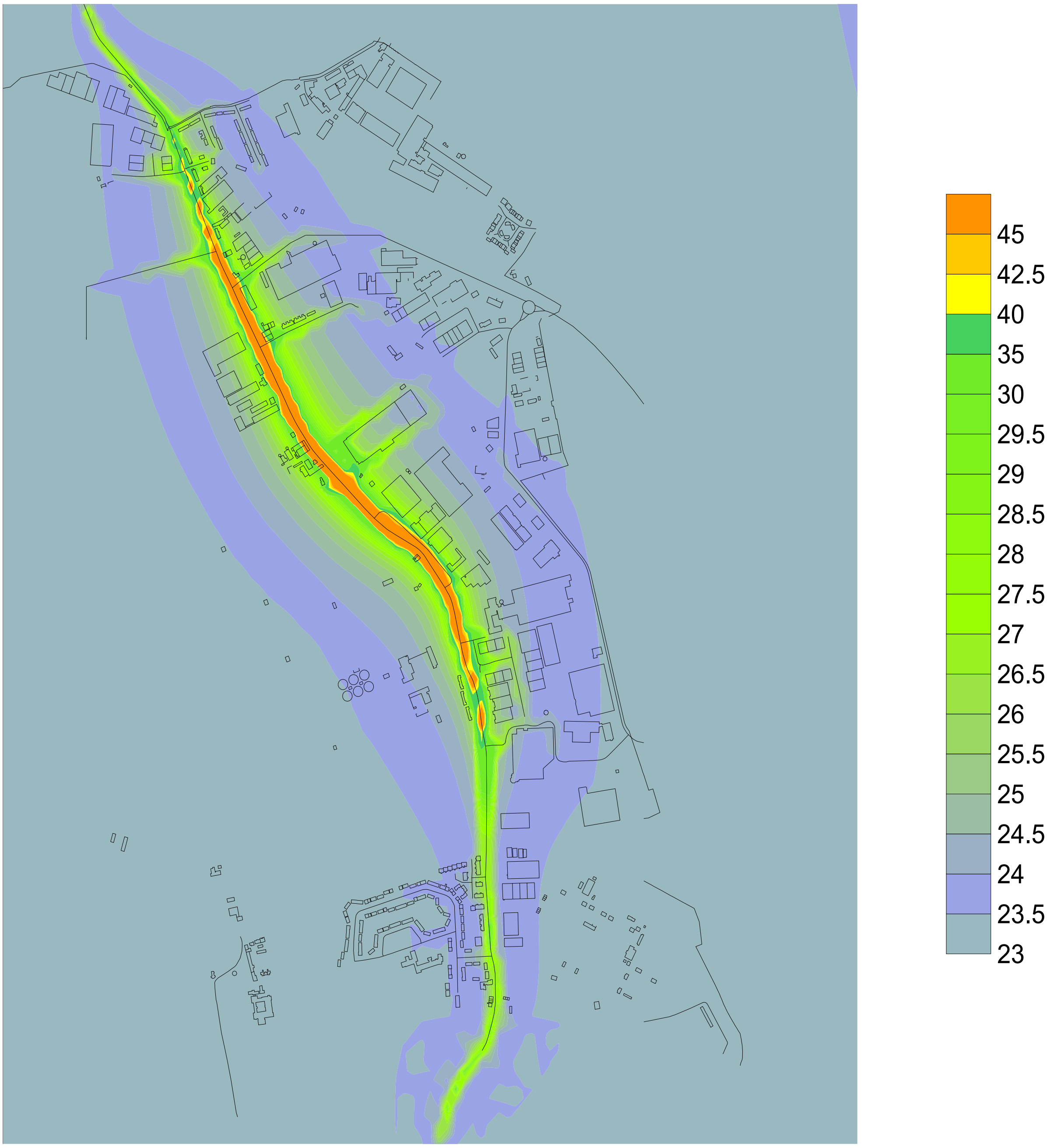

Figure 28 Predicted annual mean (Scenario 3) for the Beddington Lane area (μgm^{-3})

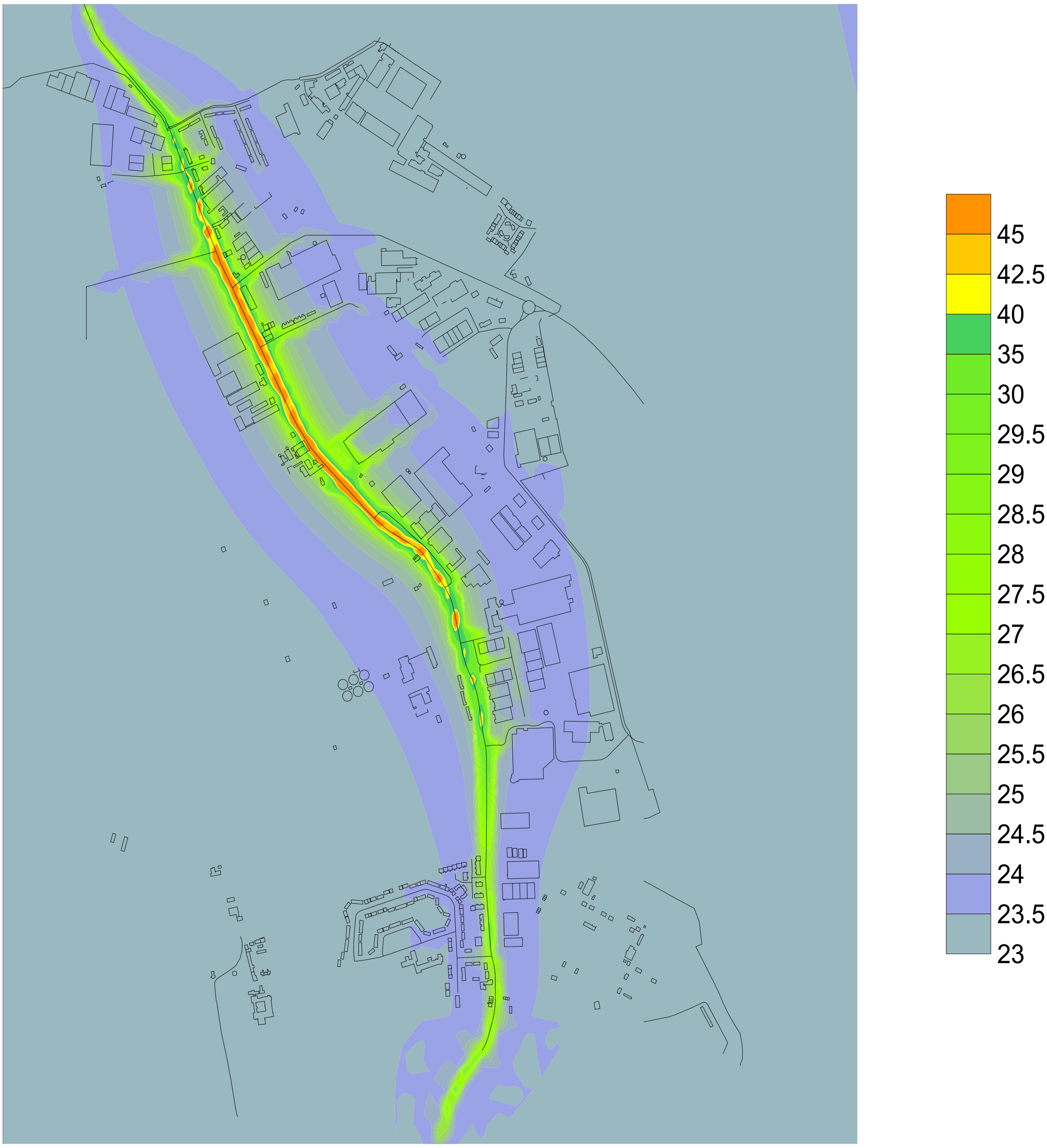

Figure 29 Predicted annual mean (Scenario 4) for the Beddington Lane area (μgm^{-3})

Modelled number of days PM_{10} > 50 µgm^{-3} in the Beddington Lane area

The predicted number of days with mean PM_{10} above 50 µgm^{-3} are shown in Figure 30 to Figure 33.

All scenarios showed areas that exceeded the daily mean objective of 35 days. These areas extended further along Beddington Lane to both the north and south than the area that exceeded for the annual mean. The extent of the area that exceeded the daily mean objective was also wider than that for the annual mean predictions. This was expected as the 2004 daily mean objective is generally harder to achieve than the 2004 annual mean objective. The extend of the area that exceeded for all scenarios included houses on Beddington Lane close to the Sutton 5 site. For scenarios 2, 3 and 4 the area that exceeds extended close to houses in the southern part of Beddington Lane.

The effect of the reduction in local – other PM_{10} of the initial sources (scenario 4) was mainly to reduce maximum concentrations close to the road centre line and consequently slightly decreased the width of the area that exceeded. The overall area that was predicted to exceed however was little changed from the other scenarios, indicating that the assumption made for the initial source strength was not crucial to determining the impact of local – other PM_{10} in this area.

All the modelled scenario predictions agreed well with the Sutton 5 measurements (see Table 8).

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Measured
58.8	58.8	56.9	57.4	55

Table 8 Number of days exceeding 50 µgm^{-3} (measured and modelled) at Sutton 5

The predicted number of days that exceeded the daily mean objective at the front façade of the houses on east side of Beddington Lane near the Sutton 5 site (based on the southern most house) was 83.6 (for scenario 1).

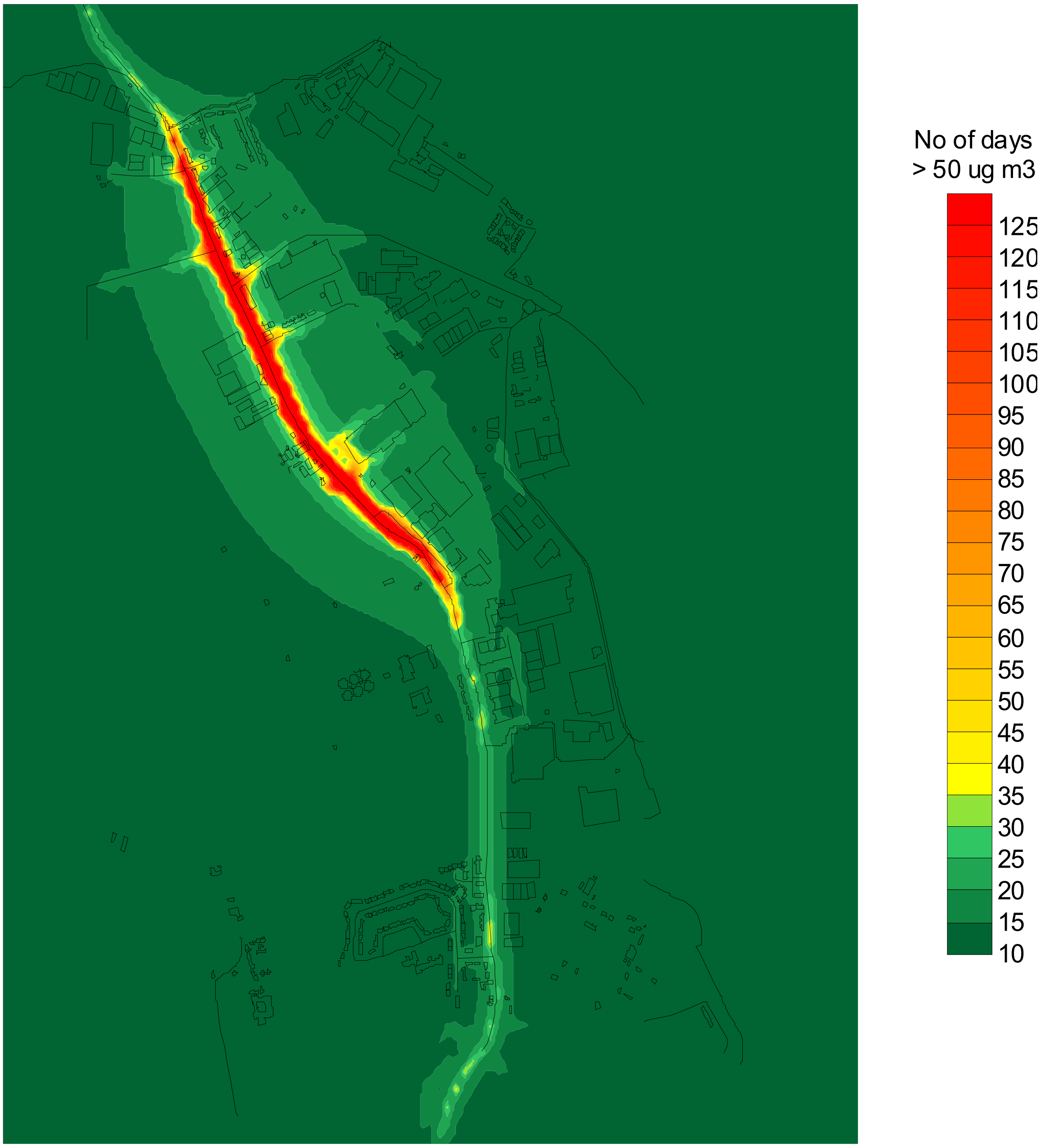

Figure 30 Predicted number of days > 50 μgm^{-3} for the Beddington Lane area (Scenario 1)

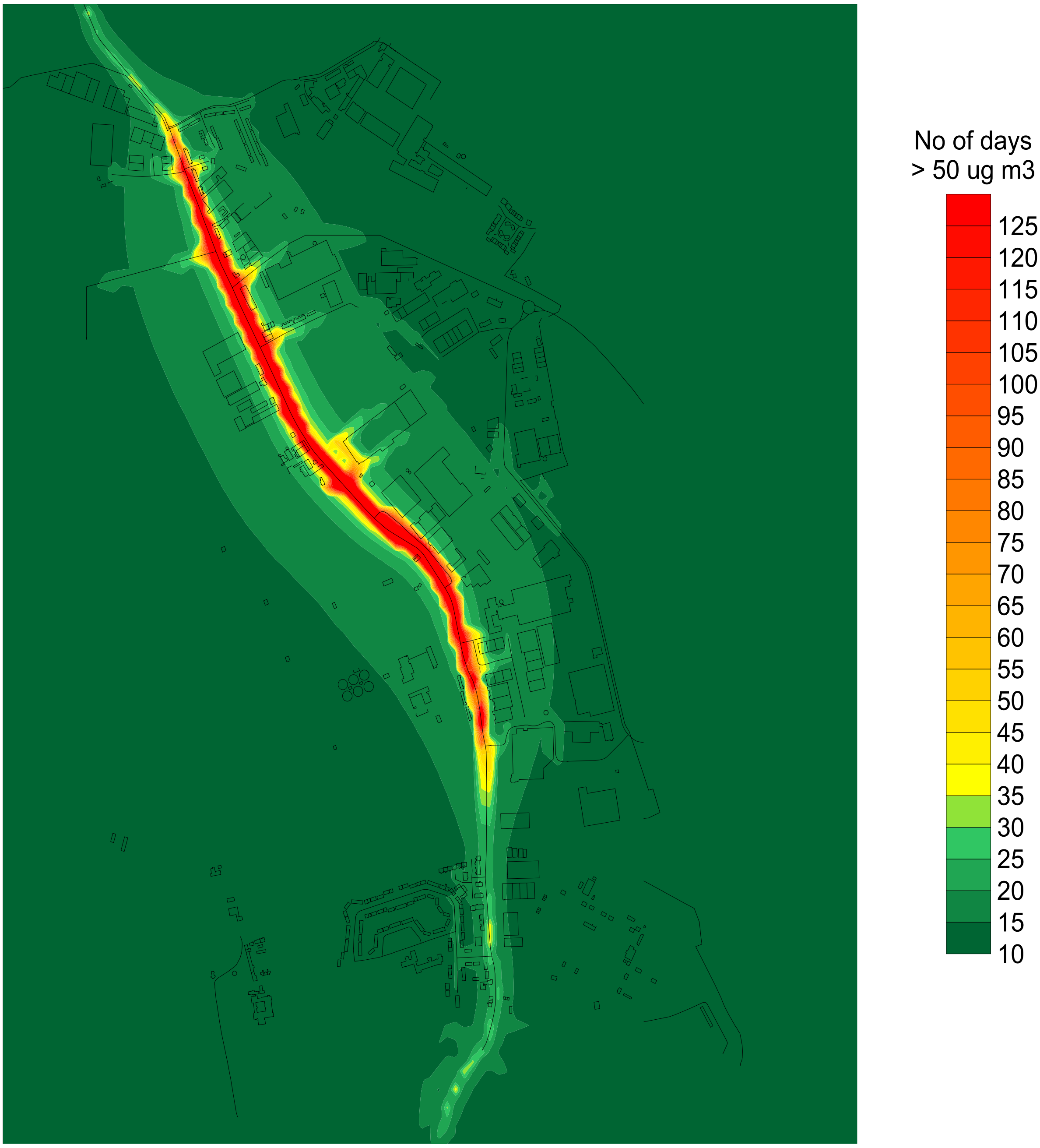

Figure 31 Predicted number of days > 50 μgm^{-3} for the Beddington Lane area (Scenario 2)

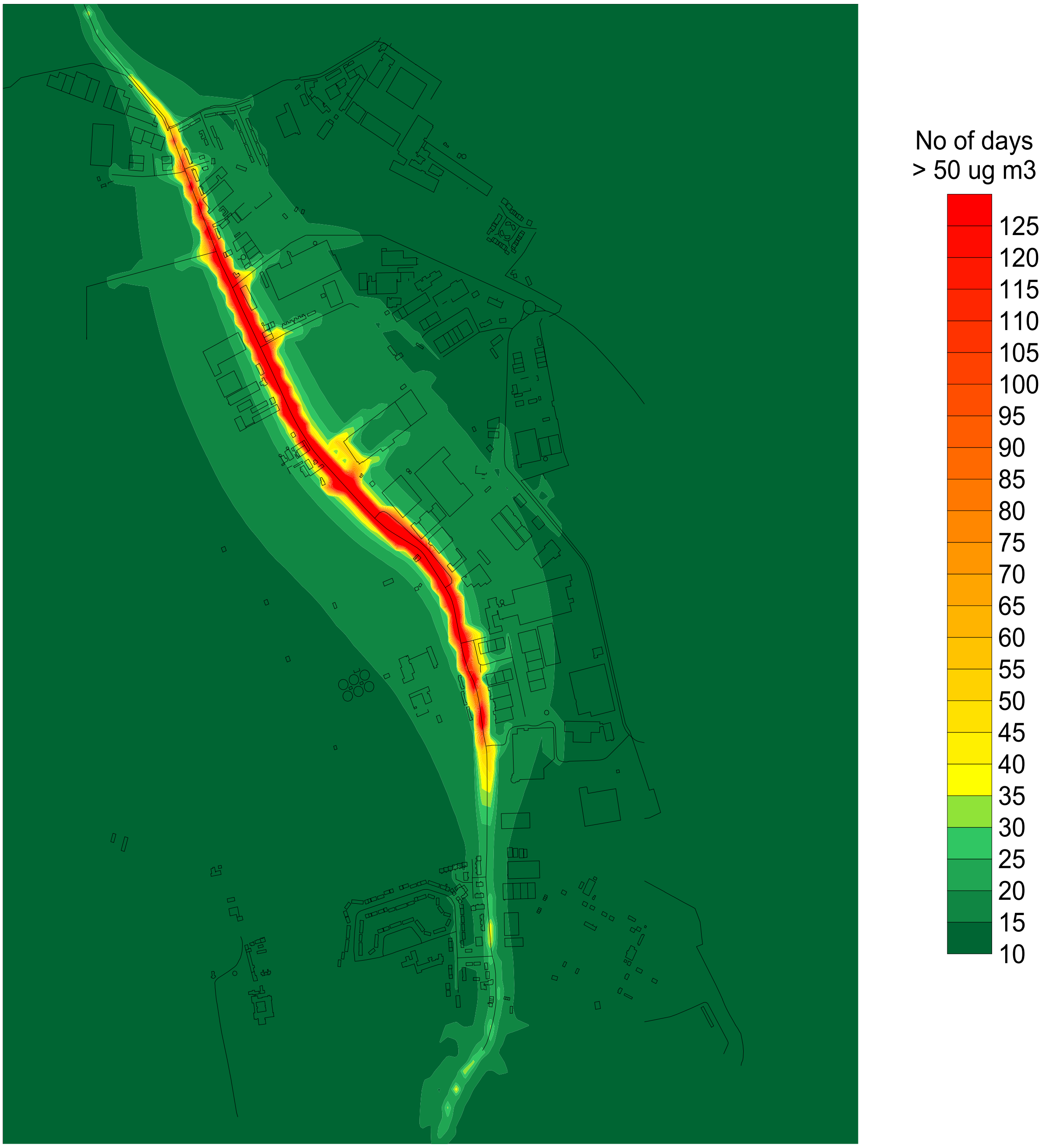

Figure 32 Predicted number of days > 50 μgm^{-3} for the Beddington Lane area (Scenario 3)

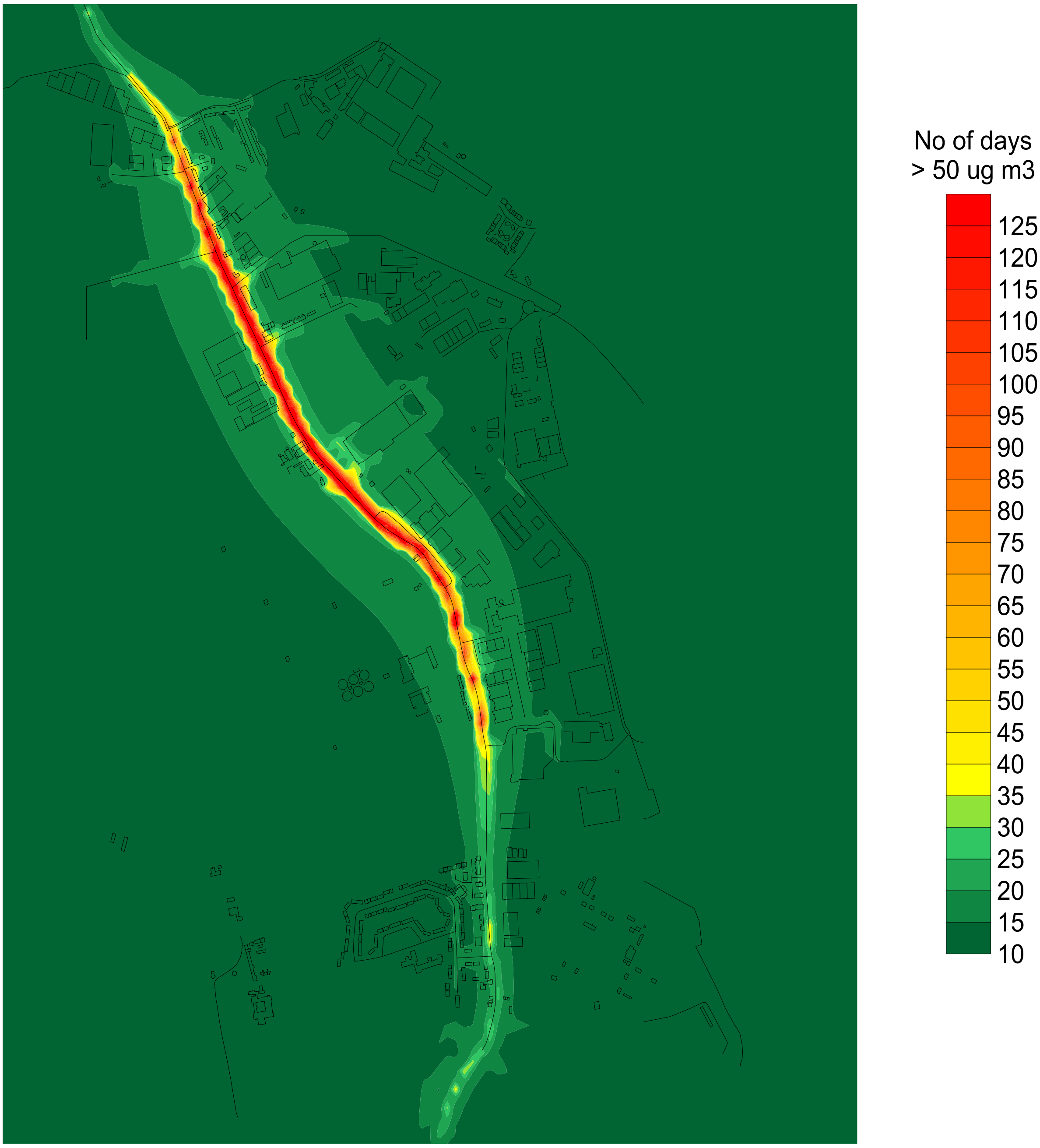

Figure 33 Predicted number of days > 50 μgm^{-3} for the Beddington Lane area (Scenario 4)

8. Conclusions

During 2006 the Sutton 5 monitoring site measured 50 days with mean PM_{10} concentration above 50 μgm^{-3} TEOM*1.3. This was substantially in excess of the EU Limit Value and AQS Objective of 35 days.

Source apportionment of the measured PM_{10} concentration was required to understand the sources of PM_{10} at the site. The source apportionment model performed well. When compared with PM_{10} concentrations at six nearby roadside sites, the model showed good agreement and confirmed that the uncertainty estimates were realistic. However at Sutton 5 the model did not agree with the measured concentrations indicating the presence of a further source of PM_{10} at the site. This source was termed local – other PM_{10}.

Source apportionment showed that 22 (+/- 17, 2σ) % or 8 (+/- 6, 2σ) μgm^{-3} TEOM *1.3 of the annual mean PM_{10} measured at the site came from local – other sources.

The daily mean concentration of PM_{10} at Sutton 5 showed considerable day to day fluctuation reaching a peak daily mean concentration of 96 μgm^{-3} TEOM*1.3. The vast majority of the days with mean PM_{10} concentration above 50 μgm^{-3} TEOM*1.3 were due to PM_{10} from the local – other source. If the local – other PM_{10} source was not present during 2006, the site would have experienced 10 (9 – 22, 2σ) days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3 and therefore would have achieved the AQS Objective / EU Limit Value for the year.

The local – other PM_{10} source exhibited greatest concentrations during working hours on weekdays and Saturdays. The mean concentration of both the local – other PM_{10} and local primary PM_{10} also increased sharply during the same hour each weekday. It is likely therefore that the local – other PM_{10} originated from sources that operated at these times and were linked to the local primary sources. It was found that 44 % of the changes in the mean local – other PM_{10}, when averaged by hour of day and day of week, could be explained by the changes in the local primary concentration.

The local – other PM_{10} had the largest concentrations when the wind originated from directions between 120° and 280°. These directions agreed broadly with the orientation of Beddington Lane with respect to the monitoring site. The mean concentration of local primary PM_{10} was analysed and this also showed very good agreement with the orientation of Beddington Lane relative to the monitoring site. Differences were evident between the distributions of the mean concentrations of local sources with respect to wind direction. The emissions of local – other PM_{10} appeared to be greater from Beddington Lane to the south of the monitoring site when compared with Beddington Lane to the north of the site. However, the relative mean concentration of local – other and local primary sources from Beddington Lane to the south of the site showed some similarities.

Within the source apportionment scheme the local primary PM_{10} was related to the NO_X concentration measured at the site and good agreement with this source and the orientation of the road would therefore be expected. Given that the local primary PM_{10} is a marker of road traffic emissions the similarities in the behaviour of the PM_{10} concentrations that arose from the local primary and local – other sources suggested that the local – other PM_{10} was linked to road traffic, however, it appeared that the local – other PM_{10} was not directly proportional to the emissions of local PM_{10} at all times and from all wind directions and therefore other factors were also affecting the emission of the local – other PM_{10}.

Comparing the results from the source apportionment study to that obtained in previous studies (Fuller and Baker 1999; Fuller and Hedley 2004; Fuller and Hedley 2006; Fuller, Hedley and Baker 2007), the concentration of local – other PM_{10} at Sutton 5 ((8 +/- 6, 2σ μgm^{-3} TEOM *1.3) was consistent with the monitoring site being several hundred metres from a waste facility. The Sutton 5 site was approximately 800 m from Country Waste Management Ltd, approximately 600 m from the gates to the Viridor land fill site and 560 m from 777. Each of these waste facilities lay to the south of the monitoring site. The greater concentrations of local – other PM_{10} from Beddington Lane to the south of the monitoring site when compared with Beddington Lane to the north of the monitoring site may be indicative of an emission gradient for local – other PM_{10} along Beddington Lane; greater emissions arising from the road to the south of the monitoring site which is closer to the waste facilities.

Although, the local – other PM_{10} was probably linked to vehicle sources it could not be completely accounted for by tailpipe emissions and expected mechanical tyre and brake wear. It was therefore likely that the local – other PM_{10} originated from the resuspension of silt from the road surface or direct suspension of material from 'dusty' vehicles. Silt may be carried from waste facilities onto Beddington Lane by vehicles leaving these sites. All traffic on Beddington Lane would have the potential to resuspend material deposited on the road which may have accounted for concentrations of local – other PM_{10} outside the times when the waste facilities were open; Sundays for example. These facts all suggested that the local – other PM_{10} was not linked to fugitive emissions from the waste facilities and other sites in the area.

In the absence of recommended emission factors for local – other PM_{10} sources, the above findings were used as the basis of assumptions to model the dispersion of PM_{10} in this area. Previously dispersion modelling was undertaken across the borough (e.g. LB of Sutton Stage 4 Review and Assessment report). The KCL model was further adapted to include the local – other PM_{10} component. An initial test run was undertaken without the local – other PM_{10} sources and this confirmed good agreement with the findings of the source apportionment for both annual mean PM_{10} concentrations and the number of days that exceed 50 μgm^{-3}.

To establish a local – other PM_{10} emission reduction along Beddington Lane a further assumption was made that the local – other PM_{10} emission source strength be based on findings from a comparable site elsewhere in London (i.e. the Brent 5 site). The Beddington Lane area was however complicated by the presence of more than one source. To assess the impact of how the emission gradient might vary, four different scenarios were adopted. Traffic data for Beddington Lane were obtained from the 2003 version of the London Atmospheric Emissions Inventory. The modelled scenarios were based on 2005 emissions using 2003 meteorology. In addition a separate scenario was tested for sensitivity purposes based on a 50% reduction in emission source strength (relative to Brent 5).

Modelling was undertaken for both AQS PM_{10} objectives along Beddington Lane only for all scenarios. The modelling predictions were also compared to the Sutton 5 monitoring results and found to provide a good agreement.

Predictions of the number of days exceeding 50 μgm^{-3} showed that the AQS objective was exceeded close to the road centre line and junctions only, for all scenarios. The extent along Beddington Lane that was found to exceed was approximately 1.8km (for scenario 3). For all scenarios (including 4) the that area exceeded included locations with relevant public exposure i.e. it included the façade of houses on Beddington Lane close to the Sutton 5 site. The number of days predicted to exceed was 83 at the front façade of house at the southern end of this terrace. The area that exceeded also approached the façade of houses on the southern part of Beddington Lane. The sensitivity testing indicated that changing the local – other PM_{10} source strength had little effect on the area that exceeded the AQS objective.

Predictions of annual mean concentrations showed that the AQS objective was exceeded close to the road centre line and junctions only for all scenarios. The maximum length of area that exceeded extended approximately 1.4km south of the Sutton 5 site and this distance varied by approximately 300m between scenarios dependent on assumed local – other PM10 emission reductions along Beddington Lane. The area that exceeded the annual mean objective did not encroach on the façades of houses on Beddington Lane.

9. Recommendations

- The findings of this report should be incorporated into the Council's Air Quality Action Plan.

- The Council should work together with the Environment Agency and waste businesses within the Beddington Lane area to reduce the silt deposited on Beddington Lane.

- The Council should continue to monitor concentrations of NO_X and PM_{10} to assess the concentration reductions achieved by any abatement measures installed at the waste facilities. It should however be recognised that the day to day variation in the concentration of local – other PM_{10} and the apparent seasonality exhibited in other studies (e.g. Fuller et al 2007) may confound this assessment in the short – term. This source apportionment study should be repeated annually to quantify changes in local – other PM_{10}.

- A further monitoring site should be installed in Beddington Lane to assess the reduction of local – other PM_{10} with distance from the waste facilities. This would enable better emission rates for the local – other PM_{10} to be determined and therefore better estimates of the area affected could be obtained using dispersion modelling.

- Specific traffic counts for Beddington Lane (both north and south of the Coomber Way roundabout) and Coomber Way would also further aid understanding and dispersion modelling of the area.

- Specific turning count information on the numbers of vehicles using the waste facilities along Beddington Lane and its side roads (including Coomber Way and private access roads) would assist in quantifying the activity of the individual sites.

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