

# Stage 4 Review and Assessment for the London Borough of Richmond upon Thames



**University of London**

April 2002

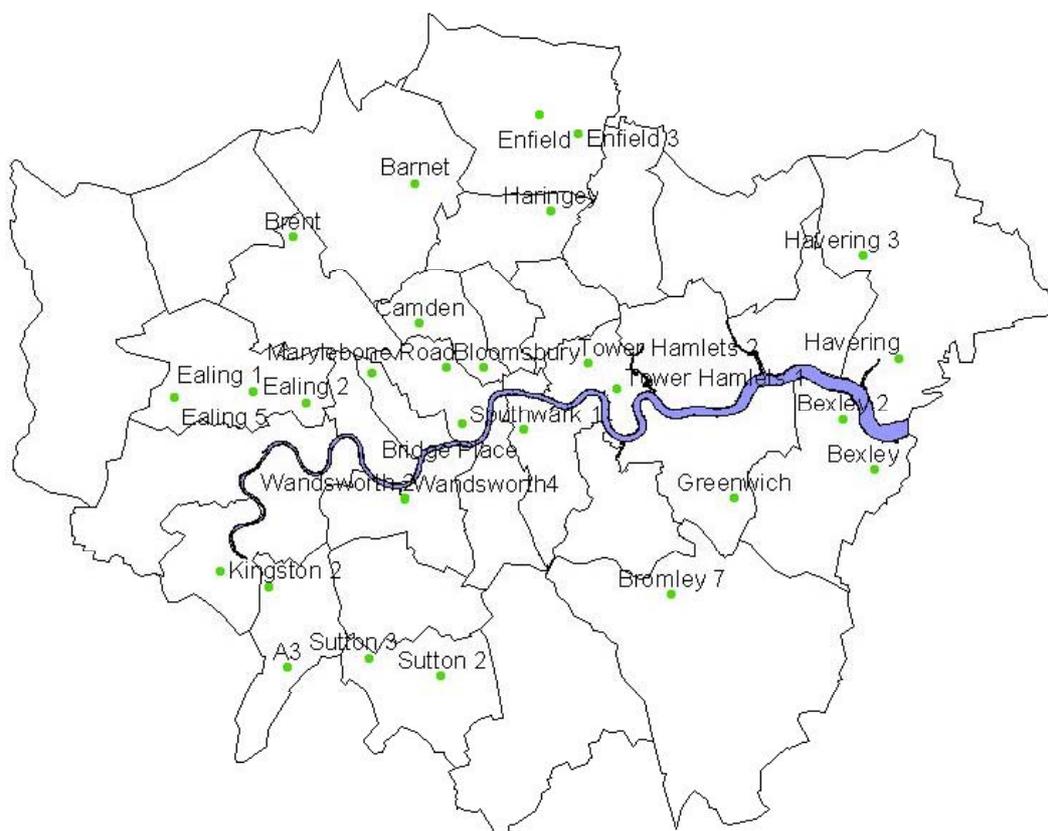
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## Appendix C

### 1 Model Validation

A comprehensive validation exercise has been undertaken for the NO<sub>x</sub>-NO<sub>2</sub> and PM<sub>10</sub> models at measurement sites in London. A very extensive data set exists for the years 1996, 1997, 1998 and 1999 and these were used in the exercise. Comparisons were made with sites located at roadside and kerbside in both open locations and street canyons, as well as in background locations. All sites were not available for every year and for NO<sub>x</sub>, NO<sub>2</sub> and PM<sub>10</sub>. However, Figure 10 below summarises those sites used during the validation exercise as a whole. The validation exercise goes beyond the sites available in the LBRuT's area. This is beneficial since it is only through a comparison with many sites types in different locations can the approaches used can be properly tested.

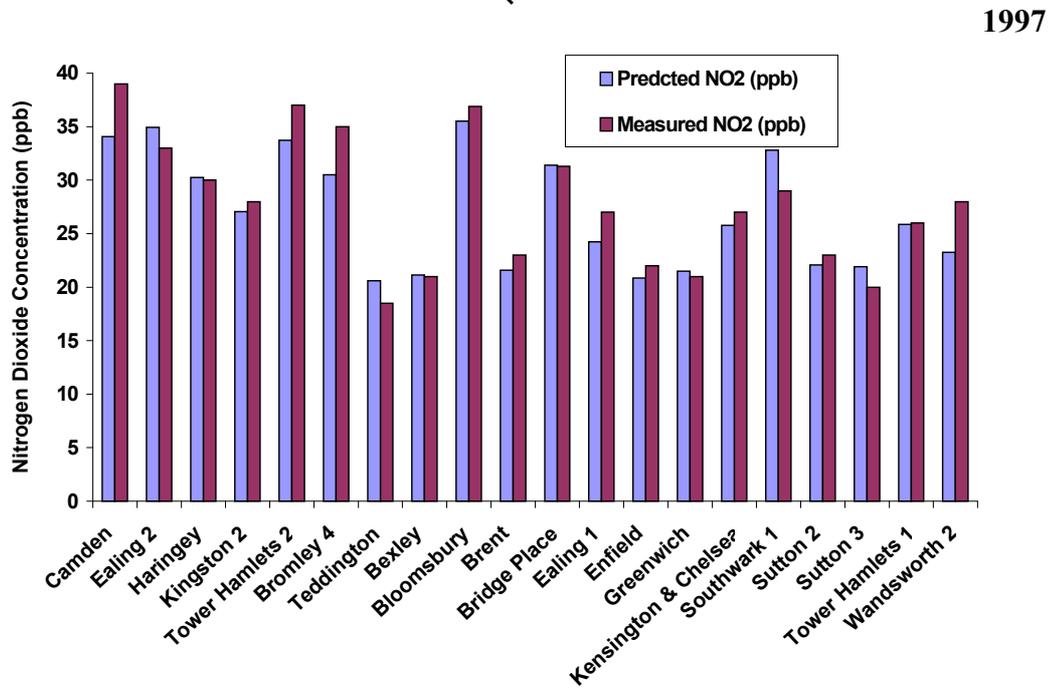
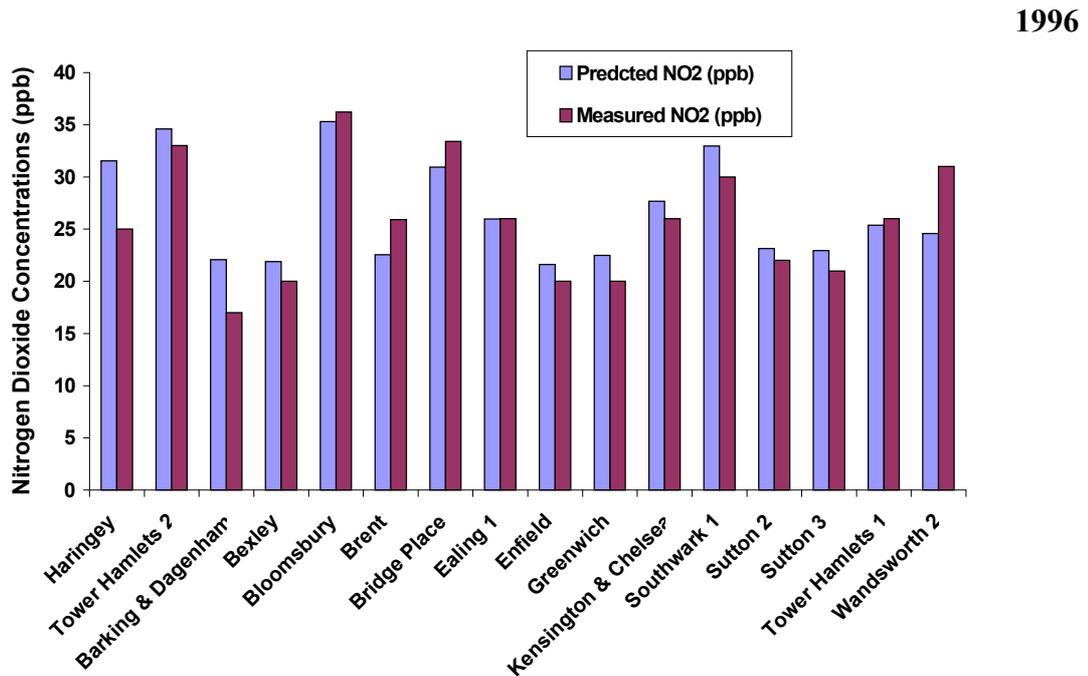


**Figure 10** Sites used to Validate Model Predictions

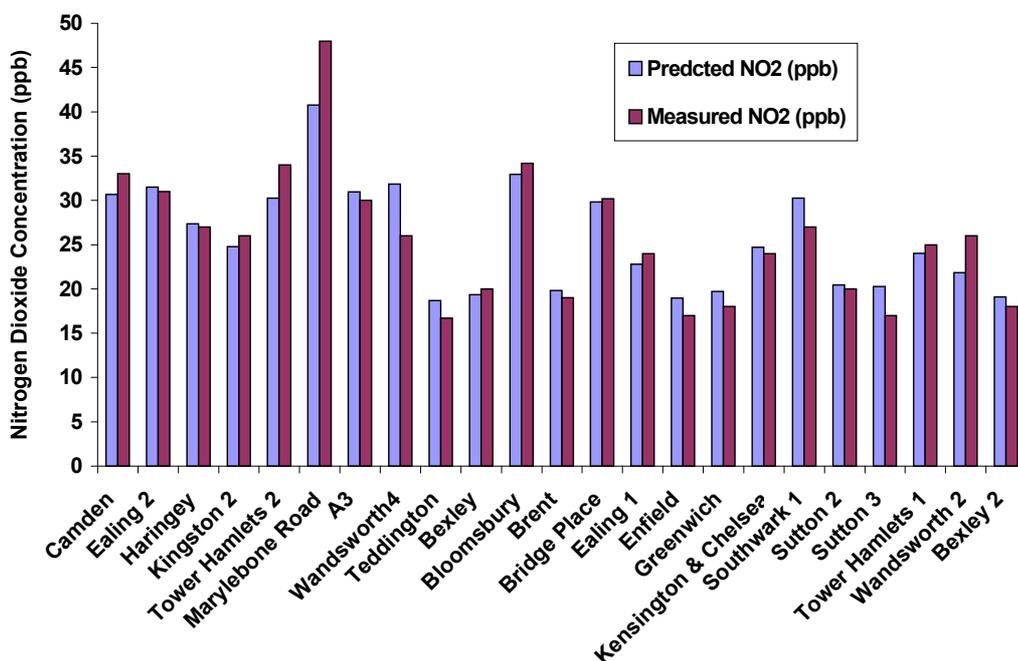
To ensure the validity of the exercise care was taken to locate the site locations as accurately as possible, particularly in relation to roadside sites, where a steep concentration gradient exists and poor site locations may lead to significant changes to the model performance.

### 1.1 Predictions of Annual Average NO<sub>2</sub> in London

The column plots in Figure 11 show predicted against measured concentrations of NO<sub>2</sub> for 1996 (first plot) to 1999 (last plot). Additionally Table 16 and Table 17 provide the actual results and a summary of the overall model performance. The average for all sites used was 94 % for 1999 and those sites with low data capture rates were not included.



1998



1999

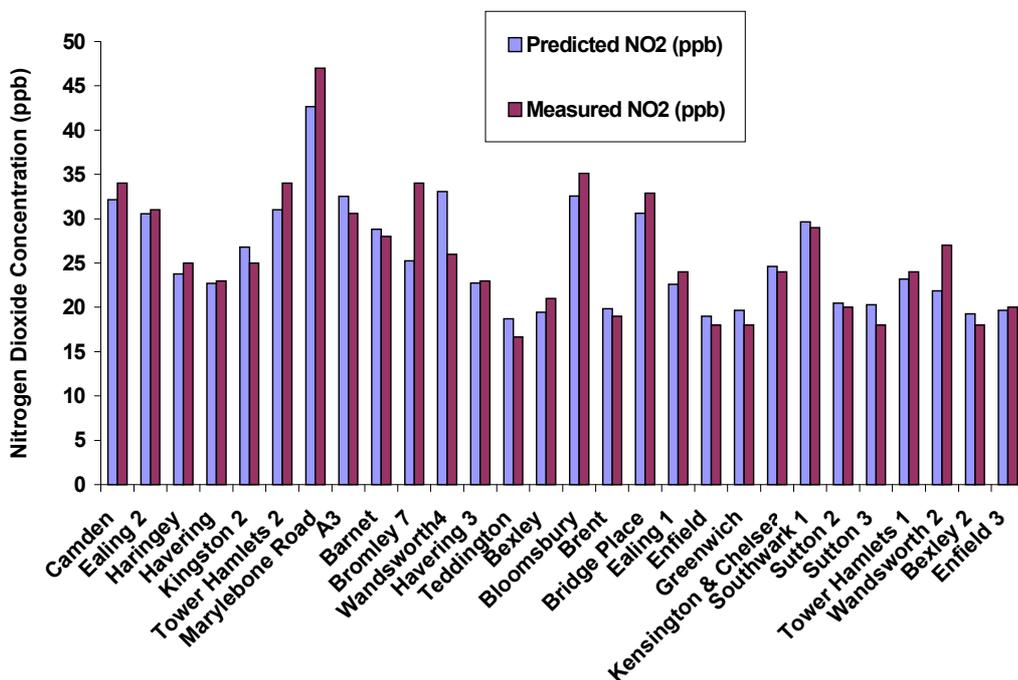


Figure 11 Predicted and Measured Annual Average NO<sub>2</sub> for 1996, 1997, 1998 and 1999

Overall the model performed very well with the average modelled and measured predictions showing close agreement. A summary of the overall performance of

the model is given in Table 17, which gives the standard deviation of the measured minus the predicted NO<sub>2</sub> concentrations as 12 % (1996), 9 % (1997), 11 % (1998), and 11 % (1999). The percentages were calculated by dividing the standard deviation by the all site average measured NO<sub>2</sub> concentration.

**Table 16** Annual Mean NO<sub>x</sub> and NO<sub>2</sub> (ppb) Validation Results for 1999

Site	Predicted NO <sub>x</sub>	Measured NO <sub>x</sub>	Predicted NO <sub>2</sub>	Measured NO <sub>2</sub>
A3	160.4	134	32	31
Barnet	78.7	95	27.8	27.6
Bexley 1	36.4	35	20.5	19.1
Bloomsbury	73.7	71	34	35
Brent 1	32	34	18.9	19.4
Bridge Place	60	55	30.3	31
Bromley 7	77.9	94	27.3	34
Camden 1	110.7	109	33.4	34.2
Cromwell Road	151	134	38.2	48
Croydon 2	107.6	91	29.7	20.3
Ealing 1	44.9	47	23.4	24.1
Ealing 2	82.4	91	28.9	31.1
Ealing 5	90.1	88	27.3	33.8
Enfield 1	32.4	32	19.2	17.6
Enfield 2	61.8	51.8	25.2	23.6
Enfield 3	35.2	37	20.3	19.7
Greenwich	36.4	33	21	18.5
Hackney 4	58.9	70	28.4	31.2
Haringey	53.6	70.2	25.8	26.6
Havering	50.6	70.6	25.8	22.9
Havering 3	53.7	66	24.4	23.2
Hillingdon	110.7	86.8	28.9	26.3
Islington	48.9	50	27.2	25.6
Kensington	46.9	42	25.1	23.8
Kingston 2	78.4	66	26.9	25.4
Marylebone Road	188.3	205	42.2	47.5
Southwark 1	64.9	62	32	29.1
Sutton 2	40.3	39	21.9	19.8
Teddington	31.1	26	18.6	16.7
Tower Hamlets 1	55.2	39	29	23.8
Tower Hamlets 2	88.2	124	31.6	36.4
Waltham Forest	42.9	41	23.9	22.8
West London	62.7	52	29.7	28.6

This level of accuracy does not apply to all sites and certain roadside sites are not as well predicted. The most obvious example of this is the Croydon 2, which is poorly predicted for all years and has not been included in the summary above. This site exhibits a very low NO<sub>2</sub> to NO<sub>x</sub> ratio, which is more typical of a rural motorway site, as thus the model over predicts by a large margin, typically 10 ppb. Other sites, included in the summary above, that also identify poor model performance are Bromley 7, which is under predicted by 9 ppb and Wandsworth 4,

which is over predicted by 7 ppb. The first full year of operation of Bromley 7 was during 1999 and so it is difficult to draw firm conclusions from this result alone. Over prediction at Wandsworth 4 occurred in both 1998 and 1999, which might be a result of the very low vehicle speeds at this site (approximately 10 km/hr throughout the day) and the uncertainty in emission factors at this speed, as described in Appendix E.

**Table 17** All Site Average NO<sub>2</sub> (ppb)

Year	Predicted Average (ppb)	Measured Average (ppb)	Average difference (measured - predicted) (ppb)	Standard Deviation (measured - predicted) (ppb)
1996	26.6	25.8	-0.8	3.2
1997	27.0	27.8	0.8	2.4
1998	25.7	25.7	0.0	2.7
1999	25.5	25.9	0.4	2.9

## 1.2 Predictions of the 24 hour mean AQS PM10 Objective

The map in Figure 12 shows the sites used to validate the model, these include sites both in London and the other surrounding areas.

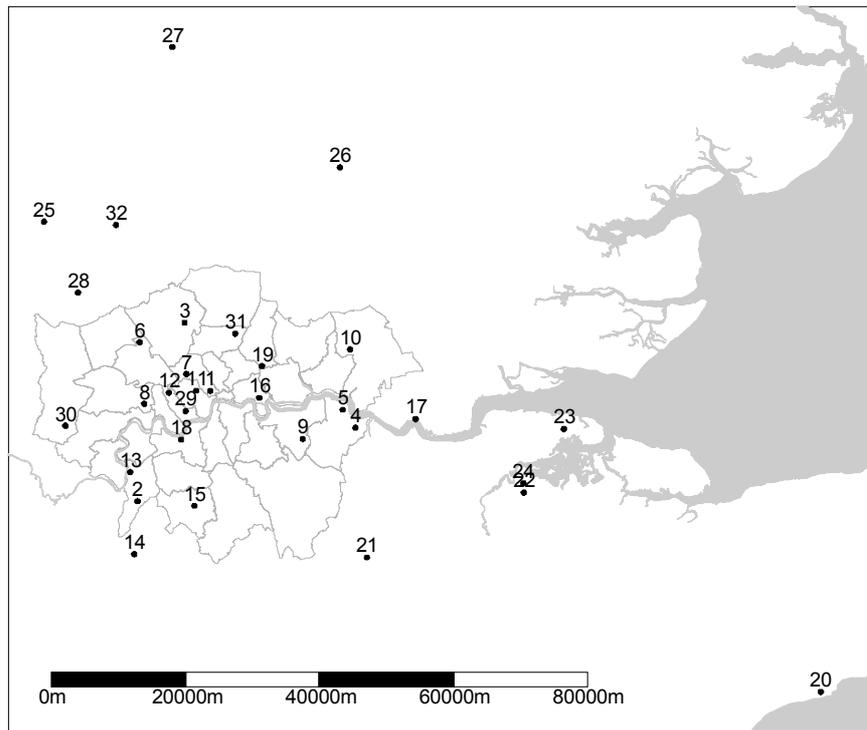
Table 18 and Table 19 provide the results and a summary of the overall model performance. Those sites with low data capture rates were not included and by way of example, the all site 1999 data capture rates averaged 96 %. The insistence of a very high data capture rate for measurements is essential in this case, as the PM10 pollution is episodic in nature and therefore loss of data can lead to a bias in the measured results. In addition, sites with instruments other than the TEOM were not included in the analysis as the relationship between the measurements and European gravimetric standards are not well understood at present.

Furthermore, care should be taken to avoid very localised particle effects, which are not covered in the inventory or the model calculations. One such example is Marylebone Road. This site was removed from the comparison in 1999 due to localised building works, which increased the days greater than 50 µg/m<sup>3</sup> significantly and invalidated any model comparison made.

Overall the model performed well with the average modelled and measured predictions showing close agreement. A summary of the overall performance of the model is given in Table 20, which gives the standard deviation of the measured minus the predicted PM10 days greater than 50 µg/m<sup>3</sup> as 16 % (1996), 21 % (1997), 24 % (1998), and 22 % (1999). The percentages were calculated by dividing the standard deviation by the all site average measured PM10 days greater than 50 µg/m<sup>3</sup>.

Much of the inaccuracy of the PM10 predictions is associated with the error in predicting annual average NO<sub>x</sub> correctly, and highlights the difficulty in dispersion

calculations in urban areas as well as the error in estimating emissions of NO<sub>x</sub> themselves. With this in mind only those sites, which have a complete dataset of NO<sub>x</sub> measurements for the year, were chosen for prediction of PM10. The results given above indicate that overall the predictions for 1996 represent the best model performance and those for 1998, the worst. Care should be taken interpreting the results in this way as there are relatively few site predictions in 1996, although it is reasonable to assume that the existence of a large source of secondary particles during many of the PM10 episodes in 1996 would reduce the model sensitivity to NO<sub>x</sub> predictions, thereby improving the overall performance.



**Figure 12** Monitoring sites in used to derive the model.

Several sites in the PM10 validation are not well predicted. First is the Wandsworth 4 site, which the model over predicts by 24 days (i.e. those extra days greater than 50  $\mu\text{g}/\text{m}^3$ ). This is consistent with the difficulty in predicting for NO<sub>x</sub> at this location, which is assumed to be due to the effect of low vehicle speeds. Second is the A3 site, which is predicted well for NO<sub>x</sub> and should show good performance for PM10. However, the PM10 model relationships calculated from the London sites do not perform well at the A3 site and here too the PM10 model over predicts the days greater than 50  $\mu\text{g}/\text{m}^3$  by approximately 27.

**Table 18** Predicted and measured number of days where PM10 > 50 µg/m<sup>3</sup> (TEOM\*1.3)

Site code	Site name	Site type	Annual Mean NO <sub>x</sub> (ppb)	Annual mean PM <sub>10</sub> µg m <sup>-3</sup> TEOM *1.3			Daily means >50 µg m <sup>-3</sup> TEOM *1.3		
				Measured	Modelled	Difference	Measured	Modelled	Difference
1996									
9	Greenwich 4	U	41	23	24	1	38	46	8
31	Haringey 1	R	89	29	28	-1	67	63	-4
12	Kens & Chelsea 1	U	53	25	25	0	46	54	8
15	Sutton 1	R	79	27	28	1	50	60	10
16	Tower Hams 1	U	50	27	25	-2	61	51	-10
1	Bloomsbury	U	80	30	28	-2	65	63	-2
1997									
6	Brent	U	46	22	22	0	26	30	4
4	Bexley 1	S	48	23	23	0	32	30	-2
7	Camden 1	K	153	32	31	-1	86	78	-8
9	Greenwich 4	U	43	21	22	1	24	29	5
31	Haringey 1	R	96	26	26	0	50	46	-4
12	Kens & Chelsea 1	U	57	24	23	-1	33	32	-1
13	Kingston 2	R	90	27	26	-1	48	44	-4
15	Sutton 1	R	77	24	25	1	34	37	3
16	Tower Hams 1	U	54	25	25	0	36	31	-5
17	Thurrock	U	40	23	22	-1	31	29	-2
24	Medway Chatham	R	53	22	23	1	23	22	-1
22	Medway Luton	U	30	18	21	3	16	22	6
23	Medway Stoke	RU	19	19	20	1	19	18	-1
1998									
2	A3	R	153	24	28	4	38	62	24
31	Haringey 1	R	75	22	22	0	22	24	2
12	Kens & Chelsea 1	U	42	20	20	0	16	13	-3
11	Marylebone Road	K	197	32	32	0	83	89	6
15	Sutton 3	S	62	21	21	0	13	19	6
6	Brent	U	32	18	19	1	8	10	2
4	Bexley 1	S	36	19	19	0	18	12	-6
5	Bexley 2	S	31	19	19	0	19	10	-9
8	Ealing 2	R	96	23	24	1	22	33	11
13	Kingston 2	R	71	23	22	-1	28	22	-6
14	Mole Valley 2	S	26	17	18	1	8	8	0
32	St Albans	S	36	18	19	1	4	10	6
16	Tower Hams 1	U	43	21	20	-1	23	14	-9
17	Thurrock	U	37	19	19	0	14	11	-3
18	Wandsworth 4	R	56	19	21	2	12	18	6
24	Medway Chatham	R	51	21	20	-1	15	15	0
22	Medway Luton	U	25	14	18	4	2	8	6
23	Medway Stoke	RU	16	17	17	0	3	7	4
21	Sevenoaks 2	U	23	19	18	-1	10	8	-2

Key to Site Types: K= Kerbside, R = Roadside, U = Urban Background, S = Suburban, RU = Rural.

**Table 19** Comparison of measurements and modelled results for 1999 to EU Limit Values

Site code	Site name	Site type	Annual Mean NO <sub>x</sub> (ppb)	Annual mean PM <sub>10</sub> µg m <sup>-3</sup> TEOM *1.3			Daily means >50 µg m <sup>-3</sup> TEOM *1.3		
				Measured	Modelled	Difference	Measured	Modelled	Difference
<b>1999</b>									
2	A3	R	134	23	27	4	22	45	23
7	Camden 1	K	110	26	25	-1	33	33	0
9	Greenwich 4	U	33	17	19	2	5	10	5
31	Haringey 1	R	71	22	22	0	17	16	-1
12	Kens & Chelsea 1	U	42	20	20	0	16	12	-4
11	Marylebone Road	K	206	35	33	-2	111	88	-23
15	Sutton 3	S	61	19	21	2	4	15	11
1	Bloomsbury	U	71	22	22	0	21	25	4
3	Brent	S	96	22	24	2	16	26	10
6	Barnet 1	K	32	18	19	1	6	6	0
4	Bexley 1	S	38	19	19	0	17	11	-6
5	Bexley 2	S	31	18	19	1	17	8	-9
25	Dacorum	U	30	16	19	3	2	6	4
8	Ealing 2	R	92	23	23	0	25	26	1
26	East Herts 2	U	22	16	18	2	6	6	0
10	Havering 3	R	67	22	21	-1	22	16	-6
29	Kens & Chelsea 2	R	134	30	27	-3	51	45	-6
13	Kingston 2	R	66	22	21	-1	15	16	1
30	Heathrow	U	71	22	22	0	27	25	-2
14	Mole Valley 2	S	26	17	18	1	1	6	5
27	North Herts	R	61	22	21	-1	8	15	7
16	Tower Hams 1	U	39	21	19	-2	21	7	-14
17	Thurrock	U	37	19	19	0	3	11	8
18	Wandsworth 4	R	63	20	21	1	17	15	-2
28	Watford	R	54	20	20	0	7	13	6
19	Waltham Forest	U	41	19	20	1	12	12	0
24	Medway Chatham	R	51	19	20	1	7	12	5
20	Folkestone	S	19	21	18	-3	15	6	-9
22	Medway Luton	U	27	14	18	4	1	6	5
23	Medway Stoke	RU	16	18	17	-1	6	6	0
21	Sevenoaks 2	U	24	17	18	1	2	6	4

Key to Site Types: K= Kerbside, R = Roadside, U = Urban Background, S = Suburban, RU = Rural.

**Table 20** All Site Average Number of Days where PM10 > 50 µg/m<sup>3</sup> (TEOM\*1.3)

Year	Predicted Average (days)	Measured Average (days)	Average difference (measured - predicted) (days)	Standard Deviation (measured - predicted) (days)
1996	61.6	55.4	6.2	8.7
1997	39.2	42.2	-3.0	8.8
1998	24.6	24.2	0.4	5.7
1999	15.5	17.8	2.6	3.9

