Transport Research Laboratory

The Highways Agency roadside air pollution monitoring network report - 2008 Volume I

by J S Price, J Pittman and D Gardiner

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Impact of reduced emissions on air quality - 2008

Client: **Highways Agency**

(Andrew Bean)

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Executive summary

This report is the eighth in a series summarising air pollutant concentrations, meteorological data and traffic flows measured at sites across the Highways Agency long term roadside monitoring network. The network comprises four monitoring sites located on the M4, M25 and M60 motorways and in the Bell Common Tunnel on the M25 motorway. Concentrations of carbon monoxide (CO), oxides of nitrogen (NO_X), nitric oxide (NO), nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$) and ozone (O_3) were measured at all sites. In addition, concentrations of total hydrocarbons (methane (CH_4) and non-methane hydrocarbons (HC)) and ammonia (NH_3) were measured at the M4, M25 and M60 motorway sites and concentrations of sulphur dioxide (SO_2), hydrogen sulphide (H_2S), aromatic hydrocarbons, polycyclic aromatic hydrocarbons (PAH), aldehydes and metals were measured at the M25 and M60 motorway sites. Meteorological data (including wind speed, wind direction, temperature and relative humidity) were collected at the M4, M25 and M60 motorway sites and solar radiation was measured at the M25 site. Traffic flows were recorded at all four monitoring sites. The air pollution monitoring equipment used at each site is comparable with equipment used in similar monitoring stations within the UK National Air Quality Monitoring Network.

Table 1 provides a summary of statistics generated from data collected during 2008 at each of the monitoring sites and compares this with objectives set out by the Air Quality (England) Regulations 2000 (SI 2000 No. 928) and updated by the Air Quality (England) (Amendment) Regulations 2002 (SI 2002 No. 3043). Exceedance of the NO_2 annual mean objective concentration occurred at all four monitoring sites in the Highways Agency network in 2008. Exceedance of the NO_2 1-hour mean objective and both the PM_{10} annual mean and 24-hour mean objectives occurred at the Bell Common Tunnel site in 2008. Exceedance of the running 8-hour mean objective for O_3 occurred at the M60 site in 2008. There were no exceedances of the relevant objectives for SO_2, $PM_{2.5}$, PAH, benzene, CO or lead at any of the monitoring sites in 2008.

Table 1: Annual summary of monitoring data recorded at sites in the Highways Agency network, 01/01/2008 to 31/12/2008

Pollutant	Objective	Unit	M25	M4	M60	Bell Common
CO	Max. daily running 8-hr mean of 10 mg/m^3	mg/m^3	1.3	1.6	2.0	2.1
NO_2	Max. of 18 exceedances of 1-hr mean of 200 μg/m^3	No. of exceedances	12	0	0	**1976**
	Annual mean of 40 μg/m^3	μg/m^3	**52.4**	**42.8**	**44.6**	**158.6**
O_3	Max. of 10 exceedances of running 8-hr mean of 100 μg/m^3	μg/m^3	7	9	**17**	0
TEOM adjusted PM_{10}	Max. of 35 exceedances of 24-hr mean of 50 μg/m^3	No. of exceedances	18	11	7	-
	Annual mean of 40 μg/m^3	40 μg/m^3	26.3	27.7	22.9	-
Osiris PM_{10}	Max. of 35 exceedances of 24-hr mean of 50 μg/m^3	No. of exceedances	-	-	**-**	**50**
	Annual mean of 40 μg/m^3	μg/m^3	-	-	-	**45.0**
TEOM $PM_{2.5}$	Annual mean of 25 μg/m^3	μg/m^3	14.9	13.6	13.6	-
Osiris $PM_{2.5}$	Annual mean of 25 μg/m^3	μg/m^3	-	-	-	16.4
SO_2	Max. 3 exceedances of 24-hr mean of 125 μg/m^3	No. of exceedances	0	-	0	-
	Max. 24 exceedances of 1-hr mean of 350 μg/m^3	No. of exceedances	0	-	0	-
	Max. 35 exceedances of 15-min mean of 266 μg/m^3	No. of exceedances	0	-	0	-

In addition to comparison with UK Air Quality Regulations, the monitoring data are also presented as average hourly data to enable direct comparison with the full time series data measured at each site and dating back to 1992 (*i.e.* the date of installation of the first monitoring site on the M4 motorway).

Contents

List of Tables **ii**

1 Introduction **3**

2 Data collection **4**

2.1 M4 (Theale 2), Pinglewood 4

2.2 M25, Bell Common Tunnel 5

2.3 M25 (M25B), Staines 5

2.4 M60, Kirkhams 7

2.5 Quality assurance and quality control 8
2.5.1 Site visits 8
2.5.2 Data checking 8
2.5.3 Data calibration and ratification 8
2.5.4 Data analysis 9

3 Compliance with UK Air Quality objectives and permitted exceedances **10**

3.1 Nitrogen dioxide 10

3.2 Sulphur dioxide 12

3.3 Ozone 13

3.4 Particulate Matter 14
3.4.1 PM_{10} 14
3.4.2 $PM_{2.5}$ 16

3.5 Aromatic hydrocarbons (BTEX) 17

3.6 Carbon monoxide 17

3.7 Lead 18

3.8 Pollutants not covered by the UK Air Quality Regulations 18
3.8.1 Polycyclic aromatic hydrocarbons 18
3.8.2 Aldehydes 19
3.8.3 Total hydrocarbons 20
3.8.4 Ammonia 20
3.8.5 Heavy metals 21
3.8.6 Hydrogen sulphide 22

3.9 Traffic data 22

4 Summary **24**

References **25**

Appendix A Photographs and locations of monitoring sites **26**

Appendix B Calibration and maintenance records **34**

Appendix C Meteorological data **39**

Appendix D Air Quality Strategy objectives **40**

Appendix E Conversion factors **41**

List of Tables

Table 1: Annual summary of monitoring data recorded at sites in the Highways Agency network, 01/01/2008 to 31/12/2008 vi
Table 2.1: Site information: M4 (Theale 2), Pinglewood 4
Table 2.2: Site information: M25, Bell Common Tunnel 5
Table 2.3: Site information: M25B, Staines 6
Table 2.4: Site information: M60, Kirkhams 7
Table 3.1: Compliance with UK Air Quality objectives, nitrogen dioxide (NO_2) 10
Table 3.2: Annual mean nitric oxide (NO) concentration 11
Table 3.3: Annual mean total oxides of nitrogen (NO_X) concentration 11
Table 3.4: Instrument comparison –average concentrations, nitric oxide (NO) and total oxides of nitrogen (NO_X) (Horiba and APIs) 12
Table 3.5: Compliance with UK Air Quality objectives, sulphur dioxide (SO_2) 13
Table 3.6: Compliance with UK Air Quality objectives, ozone (O_3) 13
Table 3.7: Compliance with UK Air Quality objectives, particulate matter (PM_{10}) 15
Table 3.8: Annual mean PM_{10} concentrations, 2008 16
Table 3.9: Number of exceedences of PM_{10} 24 hourly objective, 2008. 16
Table 3.10: Compliance with Provisional UK Air Quality objectives, particulate matter ($PM_{2.5}$) 17
Table 3.11: Compliance with UK Air Quality objectives, benzene 17
Table 3.12: Compliance with UK Air Quality objectives, carbon monoxide (CO) 18
Table 3.13: Compliance with UK Air Quality objectives, lead 18
Table 3.14: Compliance with UK Air Quality provisional objective, benzo[a]pyrene (B[a]P) 19
Table 3.15: Annual mean concentration, acetaldehyde and formaldehyde 20
Table 3.16: Annual mean concentration, methane (CH_4) 20
Table 3.17: Annual mean concentration, ammonia (NH_3) 21
Table 3.18: Annual mean concentration, heavy metals 22
Table 3.19: Annual mean concentration, hydrogen sulphide (H_2S) 22
Table 3.20: Annual average daily and hourly traffic flow 23

1 Introduction

Transport Research Laboratory (TRL) Ltd has operated an air pollution monitoring network on behalf of the Highways Agency since the early 1990s. The first site was installed on the M4 motorway site in August 1992. In 2008, there were 4 monitoring sites in operation:

- M4 (Theale 2), Pinglewood;
- M25, Bell Common Tunnel;
- M25 (M25B), Staines; and
- M60, Kirkhams.

These sites were installed in August 1992, January 2007, June 1995 and May 1999 respectively.

This report is the eighth in a series summarising air pollutant concentrations, meteorological data and traffic flows measured at sites across the Highways Agency network. Monitoring data collected at previous and current sites in the network and reports previously published as part of this series are available on the TRL website[1].

This report has been structured to provide a clear overview of data collected in 2008. The report has been split into two volumes, this Volume I contains:

Section 2: Data collection – provides details of the location of each automatic monitoring site, the period of operation, the equipment installed and the method used to collect data at each site.

Section 3: Compliance with UK Air Quality Objective Concentrations and Allowed Exceedances – examines compliance with objectives at each monitoring site in 2008. Pollutants not covered under the UK Air Quality Regulations are also discussed.

Section 4: Summary – provides a summary and draws conclusions from the reported data.

Volume II of the report presents time series plots for pollutant concentrations recorded at the four monitoring sites in 2008. It also contains a summary of historical data including comparison with air quality standards and objectives, hourly data summary statistics and traffic flows.

[1] http://www.trl.co.uk/research_development/sustainability/environmental_assessment_/air_quality/air_quality_archive.htm

2 Data collection

2.1 M4 (Theale 2), Pinglewood

The first site installed as part of the Highways Agency network was located on the M4 motorway. This site (Theale 1) was installed in August 1992 and was situated at the edge of the eastbound carriageway of the M4 motorway between junctions 11 and 12. The Theale 1 site was operational until July 1994, after which the site was relocated to make way for the construction of the M4 Reading motorway service area. The Theale 2 site was installed in April 1995 and is located at the edge of the hard shoulder on the eastbound carriageway of the M4 motorway approximately 2 km east of the Theale 1 site. Monitoring equipment from the Theale 1 site was relocated to the Theale 2 site and supplemented by a Rupprecht and Patashnick tapered element oscillating microbalance (TEOM) (model 1400a) configured to measure particulate matter with an aerodynamic diameter of less than 10 microns (PM_{10}). Table 2.1 provides details of the monitoring system and pollutants measured at the Theale 2 site. Photographs and a map showing the location of the M4 site are provided in Appendix A.1.

Table 2.1: Site information: M4 (Theale 2), Pinglewood

Site	M4, Theale 2, Pinglewood
Location	Eastbound carriageway, between junction 11 and 12
Grid reference	SU 69945 69435
Road type	Rural motorway
Commencement date	April 1995
Particulate inlet height above ground level	2.7 m
Particulate inlet height above enclosure roof	0.75 m
Particulate inlet distance from hard shoulder	4.1 m
Gaseous inlet height above ground level	1.5 m
Gaseous inlet distance from hard shoulder	0.5 m
Gaseous manifold flow rate	6.3 m/sec
Gaseous residence time	0.7 sec
Wind vane & anemometer height above ground level	4.25 m
Wind vane & anemometer height above enclosure roof	2.25 m
Relative humidity & temperature sensor height above ground level	2.0 m
Meteorological equipment distance from hard shoulder	6.0 m
Carbon monoxide (CO)	Infra red (IR) absorption
Total oxides of nitrogen (NO_X), nitrogen dioxide (NO_2), nitric oxide (NO)	Chemiluminescence
Ozone (O_3)	Ultra violet (UV) absorption
Particulate matter (PM_{10} and $PM_{2.5}$)	Heated gravimetric - TEOM
Total hydrocarbons (HC) and methane (CH_4)	Flame ionisation detector
Ammonia (NH_3)	Passive diffusion tubes
Meteorological conditions	Wind speed, wind direction, temperature, relative humidity
Traffic flow	Automatic Traffic Counter (ATC)

During 2008, the M4 motorway site operated continuously with the following minor disruptions to data collection:

- A power failure between 01/01/2008 and 02/01/2008.
- A CO instrument fault occurred between 25/02/2008 and 28/02/2008.
- An O_3 instrument fault on 25/02/2008.

- A fault with the FID occurred between 26/06/2008 and 08/07/2008. The instrument was removed from site between these dates to be repaired.

Records of visits to the M4 monitoring site in 2008, including the reason for each visit and actions performed are presented in Appendix B.1.

2.2 M25, Bell Common Tunnel

The monitoring site on the M25 motorway at the Bell Common Tunnel was installed in January 2007. This site is situated on the eastbound (clockwise) carriageway of the M25 motorway to the west of junction 27. The site was installed with the aim of obtaining a better understanding of the long term trend in emissions. Air quality data collected at this site will not be affected by meteorological conditions because it is located in a tunnel. Table 2.2 provides details of the monitoring system and pollutants measured at the Bell Common Tunnel site. Photographs and a map showing the location of the Bell Common Tunnel site are provided in Appendix A.2.

Table 2.2: Site information: M25, Bell Common Tunnel

Site	M25, Bell Common Tunnel
Location	Clockwise direction, west of M25 Junction 27
Grid reference	TL 544500, 201500
Road type	Suburban motorway
Commencement date	January 2007
Carbon monoxide (CO)	Infra red (IR) absorption
Total oxides of nitrogen (NO_X), nitrogen dioxide (NO_2), nitric oxide (NO)	Chemiluminescence
Ozone (O_3)	Ultra violet (UV) absorption
Particulate matter (PM_{10} and $PM_{2.5}$)	Heated gravimetric - Osiris
Traffic flow	Automatic Traffic Counter (ATC)

Monitoring at the Bell Common Tunnel site in 2008 was influenced by a major construction and refurbishment project to replace mechanical and electrical equipment. This work started in October 2008 and is due to be completed in March 2010. This work resulted in night time lane closures and disruptions to traffic flow within the tunnel. Concentrations recorded at the Bell Common Tunnel site during 2008 would have been influenced by reduced traffic speeds during the road works, the presence of construction traffic and night time working. The lack of space for equipment in the tunnel resulting from the works meant that the Osiris monitor (used to measure concentrations of particulate matter) was removed from this site before the works started on 24 July 2008. Other monitoring equipment remained in place for the duration of the works and operated continuously in 2008 with minor disruptions to data collection resulting from a NO_X instrument fault between 05/06/2008 and 10/06/2008 and a CO instrument fault between 15/05/2008 and 20/05/2008 and between 30/09/2008 and 11/12/2008. Records of visits to the Bell Common Tunnel monitoring site in 2008, including the reason for each visit and actions performed are presented in Appendix B.2.

2.3 M25 (M25B), Staines

In June 1995, a monitoring site (M25A) was installed on the M25 motorway between Junctions 13 and 14. Due to road widening, this site was closed in 2003 and relocated in February 2004 (to site M25B) approximately 100 m to the north of site M25A. Major road works on the M25 motorway during 2004 resulted in periods of data loss and variations in vehicle emissions resulting from increased queuing and the traffic being diverted further away from the monitoring station at various times throughout the road works. The sample inlet was placed in its final position in November 2005. Table 2.3 provides details of the monitoring system and pollutants measured at the M25 site. Photographs and a map showing the location of the M25 site are provided in Appendix A.3.

Table 2.3: Site information: M25B, Staines

Site	M25B, Staines
Location	Clockwise carriageway, between junction 13 and 14
Grid reference	TQ 025725
Road type	Rural motorway
Commencement date	February 2004
PM_{10} inlet height above ground level	2.7 m
PM_{10} inlet height above enclosure roof	0.7 m
$PM_{2.5}$ inlet height above ground level	2.4 m
$PM_{2.5}$ inlet height above enclosure roof	0.4 m
Particulate inlet distance from hard shoulder	4.05 m
Gaseous inlet height above ground level	1.9 m
Gaseous inlet distance from hard shoulder	1 m
Gaseous manifold inlet gas flow rate	6.1m/sec
Gaseous residence time	0.8 sec
Wind vane and anemometer distance from hard shoulder	5.05 m
Wind vane and anemometer height above ground level	3.75 m
Wind vane and anemometer height above enclosure roof	1.75 m
Temperature & relative humidity sensor height above ground level	2.1 m
Temperature & relative humidity sensor distance from hard shoulder	5.05 m
Pyranometer sensor height above ground level	3.45 m
Pyranometer sensor height above enclosure roof	1.45 m
Pyranometer sensor distance from hard shoulder	4.5 m
Carbon monoxide (CO)	Infra red (IR) absorption
Total oxides of nitrogen (NO_X), nitrogen dioxide (NO_2), nitric oxide (NO)	Chemiluminescence
Ozone (O_3)	Ultra violet (UV) absorption
Total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons (NMHC)	Flame ionisation detector (FID)
Sulphur dioxide (SO_2), hydrogen sulphide (H_2S)	Ultra violet (UV) fluorescence
Particulate matter (PM_{10} and $PM_{2.5}$)	Heated gravimetric - TEOM
Ammonia (NH_3)	Passive diffusion tubes
Aromatic hydrocarbons - BTEX	Pumped samples (gas chromatography)
Polycyclic aromatic hydrocarbons (PAH)	Particle phase by Partisol (gas chromatography)
Aldehydes	Pumped samples (high pressure liquid chromatography)
Metals	Particle phase - ICP
Meteorological conditions	Wind speed, wind direction, temperature, relative humidity, solar radiation
Traffic flows	Automatic Traffic Counter (ATC)

During 2008, the M25 motorway site operated continuously with the following minor disruptions to data collection:

- Power failures between 29/04/2008 and 01/05/2008, 26/05/2008 and 29/05/2008, 03/06/2008 and 04/06/2008 and between 06/06/2008 and 07/06/2008.
- NO_X instrument faults between 01/01/2008 and 04/01/2008, on 11/01/2008 and between 16/01/2008 and 17/01/2008, which resulted in some data loss.

Records of visits to the M25 monitoring site in 2008, including the reason for each visit and actions performed are presented in Appendix B.3.

2.4 M60, Kirkhams

Monitoring began on the M60 motorway in May 1999. This site is located on the westbound hard shoulder (Manchester Orbital Road) on a shallow motorway embankment approximately 300 m north east of junction 17. Table 2.4 provides details of the monitoring system and pollutants measured at the M60 site. Photographs and a map showing the location of the M60 site are provided in Appendix A.4.

Table 2.4: Site information: M60, Kirkhams

Site	M60, Kirkhams
Location	Eastbound carriageway, east of junction 17
Grid reference	SD 81305 04995
Road type	Suburban motorway
Commencement date	May 1999
Enclosure level above road surface	2.0 m
Particulate inlet above ground level	3.2 m
Particulate inlet above enclosure roof level	0.6 m
Particulate inlet distance from hard shoulder	18 m
Gaseous inlet above ground level	3.5 m
Gaseous inlet above enclosure roof level	0.9 m
Gaseous inlet distance from hard shoulder	18 m
Gaseous manifold inlet flow rate	3.2 m/s
Gaseous residence time	0.8 sec
Meteorological equipment above ground level	6.8 m
Meteorological equipment above enclosure roof level	4.2 m
Meteorological equipment distance from hard shoulder	18 m
Carbon monoxide (CO)	Infra red (IR) absorption
Total oxides of nitrogen (NO_X), nitrogen dioxide (NO_2), nitric oxide (NO)	Chemiluminescence
Ozone (O_3)	Ultra violet (UV) absorption
Particulate matter (PM_{10})	Heated gravimetric – TEOM and Partisol
Total hydrocarbons (HC) and methane (CH_4)	Flame ionisation detector
Sulphur dioxide (SO_2), hydrogen sulphide (H_2S)	Ultra violet (UV) fluorescence
Ammonia (NH_3)	Passive diffusion tubes
Aromatic hydrocarbons - BTEX	Pumped samples (gas chromatography)
Polycyclic aromatic hydrocarbons (PAH)	Particle phase by Partisol (gas chromatography)
Aldehydes	Pumped samples (high pressure liquid chromatography)
Meteorological conditions	Wind speed, wind direction, temperature, relative humidity
Traffic flow	Automatic Traffic Counter (ATC)

During 2008, the M60 motorway site operated continuously with the following disruptions to data collection:

- Power failures between 21/02/2008 and 23/02/2008, 22/03/2008 and 23/03/2008, 09/08/2008 and 11/08/2008, 03/09/2008 and 05/09/2008 and from 30/12/2008 to 31/12/2008.
- A NO_X instrument fault resulted in a loss of data on 22/03/2008.
- An SO_2/H_2S instrument fault occurred on 22/07/2008. The instrument was removed for repair and re-installed on 28/07/2008, resulting in a loss of data over these 7 days. SO_2/H_2S instrument faults also occurred between 07/02/2008 and 08/02/2008, between 24/05/2008 and 25/05/2008 and on 26/05/2008,

between 09/10/2008 and 12/10/2008 and between 25/12/2008 and 26/12/2008, resulting in intermittent data loss over these time periods.

- A CO instrument fault occurred between 06/06/2008 and 07/06/2008.
- An O_3 instrument fault occurred between 05/02/2008 and 18/02/2008, resulting in a loss of the majority of data over these 14 days.
- Partisol data was lost due to no filters being deployed from 01/1/2008 and 17/1/2008. A fault with the Partisol resulted in data loss between 30/10/2008 and 10/12/2008. The Partisol was exchanged with another instrument whilst the fault was being repaired but unfortunately the replacement instrument also failed. Intermittent filter jams with both instruments resulted in a period of data loss.

Records of visits to the M60 monitoring site in 2008, including the reason for each visit and actions performed are presented in Appendix B.4.

2.5 Quality assurance and quality control

TRL Ltd quality assurance and quality control procedures require all data to be backed up on a secure server and all documentation associated with each monitoring site to be uniquely identified and securely stored. Quality assurance and quality control procedures follow those used in the Automatic Urban and Rural Network (AURN)[2] and are outlined below.

2.5.1 Site visits

TRL Ltd undertakes regular site visits to calibrate the equipment at each monitoring site. Procedures follow those outlined in the Site Operators Manual for the AURN[3]. Zero and span checking of the equipment is completed on a fortnightly basis. Equipment is routinely serviced by TRL Ltd and external contractors as required in line with manufacturer's recommendations. Records of site visits at each monitoring site, including the reason for each visit and actions performed are presented in Appendix B.

2.5.2 Data checking

TRL Ltd central data communication and logging facility (Enview 2000) has been externally audited by the Environment Agency. This system is used to undertake daily data inspections during office hours. Three-day plots of data recorded at each monitoring site are inspected for accurate date and time readings, continuous power supply, continuity and validity of measurements and maximum and minimum data values. Any anomalies or queries arising from the daily inspections are brought to the attention of the Project Manager, who will initiate any necessary action (*e.g.* a site visit).

On a weekly basis, data collected by the management system are examined using summary statistics and outlier analysis. Any unusual episodes are recorded and examined over longer data periods to determine the impact on long term trends. Pollution episodes are also cross-referenced with peaks and troughs recorded at other national monitoring sites.

2.5.3 Data calibration and ratification

Air pollutant data are ratified as per AURN recommended procedures[3]. The calibration and ratification process for automatic gas analysers corrects the raw dataset for 'drift' in the zero baseline and the upper range of the instrument. The zero reading recorded during the calibration exercise is used to adjust any offset of the baseline. The difference between the span values obtained at two subsequent calibration visits is used

[2] http://www.airquality.co.uk/reports/cat13/0910081142_AURN_QA_QC_Manual_Sep_09_FINAL.pdf
[3] http://www.airquality.co.uk/reports/empire/lsoman/lsoman.html

to calculate a linear scaling factor, which is applied to data collected between these two visits. Following application of the scaling factor and adjustment of the baseline, data are validated by visual inspection.

2.5.4 Data analysis

Statistical analysis has also been carried out to allow for comparison with UK Air Quality objective values set out by the Air Quality (England) Regulations 2000 (SI 2000 No. 928) and updated by the Air Quality (England) (Amendment) Regulations 2002 (SI 2002 No. 3043). Compliance with the relevant objective has been assessed for each pollutant covered by the Regulations (see Section 3). A number of pollutants monitored at sites within the Highways Agency network are not covered by the UK Air Quality Regulations. Monitored concentrations of these pollutants have been compared with Environment Agency Guidelines[4]. Although the pollutants are not covered by UK legislation, guidance values for safe levels of human exposure exist and it is therefore considered useful to monitor concentrations.

At the M60, M4 and M25 sites meteorological data was collected. This has been ratified and can be found in Appendix C.

Statistical analysis of hourly data collected at each monitoring site has also been undertaken. Minimum, maximum, mean and standard deviation values have been calculated for each pollutant at each monitoring site for the year 2008. This allows for comparison with data collected in previous years and the analysis of long term trends in pollutant concentrations. Data for 2008 are presented together with historical datasets in Volume II.

[4] http://www.environment-agency.gov.uk/business/topics/pollution/35761.aspx

3 Compliance with UK Air Quality objectives and permitted exceedances

This section compares data collected at the four Highways Agency monitoring sites in 2008 with the UK Air Quality objectives. A summary of UK Air Quality objectives and permitted numbers of exceedances is provided in Appendix D. It is important to note that these objectives do not apply at the monitoring sites in the Highways Agency network because they are classified as areas not accessible to the public and therefore no relevant exposure exists. It is, however, still considered useful to compare the monitored data with these criteria. Each pollutant covered by the UK Air Quality Regulations is discussed in turn. Percentage capture rates for calibrated data are provided. Concentrations of non-regulated pollutants are also presented and discussed in comparison with guidance values recommended by the Environment Agency[5].

3.1 Nitrogen dioxide

Nitrogen dioxide (NO_2) concentrations are recorded by the continuous analysers as 15-minute means. 1-hour means have been calculated from the 15-minute data for each hour of the year to allow for comparison with UK Air Quality objectives. Time-series plots of hourly NO_2 concentrations for all sites are presented in Volume II of this report. Table 3.1 provides a comparison between the UK Air Quality objectives and the hourly NO_2 data recorded at all four monitoring sites.

Table 3.1: Compliance with UK Air Quality objectives, nitrogen dioxide (NO_2)

Statistic	Objective concentration	Permitted number of exceedances	M25	M4	M60	Bell Common
1 hour mean	200 μg/m^3	18	12	0	0	**1976**
Annual mean	40 μg/m^3	n/a	**52.4**	**42.8**	**44.6**	**158.6**
Calibrated 1-hour data capture (% of calendar year)	n/a	n/a	96	99	97	98

Bold type indicates exceedance of UK Air Quality objective

The one-hour mean data for NO_2 at the M4 and M60 sites were typically in the range 20-120μg/m^3 and there were no exceedances of the UK Air Quality objectives at these sites. For short periods of time, concentrations of NO_2 were below the typical range observed at these sites and have in most cases been correlated with higher levels of measured ozone *e.g.* at the M4 site during March, May, September and December 2008. These periods are annotated on the data plots in Volume II.

The one-hour mean measurements at the M25 site were typically in the range 20-160μg/m^3, higher than those at the M4 and M60, and are thought to relate to the higher volumes of traffic using this motorway (see Table 3.20). Concentrations of NO_2 at the Bell Common site were higher than the other sites, ranging from 100-300μg/m^3, reflecting the tunnel location of the site. There were a large number of exceedances of the Air Quality objective (see Table 3.1), with a number of substantial peaks reading up to 600-700μg/m^3. These occurred during peak hours (7-9am and 4-7.30pm) and are thought to be valid measurements due to the increased traffic build up in the tunnel during these times. High ratified data capture rates (*i.e.* above 90%) for NO_2 were

[5] http://www.environment-agency.gov.uk/business/topics/pollution/35761.aspx

achieved at all four monitoring sites in 2008. Disruptions caused by power failures (noted in Section 2) were minimised by timely site visits.

During 2008, the annual mean NO_2 objective value was exceeded at all 4 monitoring sites. A similar trend was observed to that described above for the one-hour mean, with annual means recorded at the M4 and M60 sites of 40.8 and 44.6 µg/m^3 respectively, a higher annual mean at the M25 site at 52.4µg/m^3 and the annual mean at the Bell Common Tunnel site the highest of all 4 sites at 158.6µg/m^3. The high annual mean concentration recorded at the Bell Common Tunnel site is not unexpected as there is limited dispersion and dilution in a tunnel environment and pollutant concentrations tend to be higher than in normal ambient air. The monitoring station is located near the midpoint of the tunnel and has recorded very low levels of ozone (see Section 3.3). This indicates that within the tunnel, reactions between NO and ozone to form NO_2 are largely complete at this point. The levels of NO_2 recorded at the monitoring station are likely, therefore, to be mainly due to primary NO_2. The one-hour mean concentration recorded during 2008 is slightly lower than that found in a previous study investigating primary NO_2 emissions from vehicles in Hatfield and Bell Common tunnels (Boulter *et al*, 2007). The study involved two separate months of monitoring in June and December 2006 and the average NO_2 concentration during each monitoring period was 189µg/m^3 and 178µg/m^3 respectively. For information, annual mean concentrations of NO and NO_X recorded at each monitoring site in 2008 are provided in Table 3.2 and Table 3.3.

Table 3.2: Annual mean nitric oxide (NO) concentration

Statistic	M25	M4	M60	Bell Common
Annual mean (µg/m^3)	102.6	83.0	80.0	814.3
Calibrated data capture (% of calendar year)	96	99	97	98

Table 3.3: Annual mean total oxides of nitrogen (NO_X) concentration

Statistic	M25	M4	M60	Bell Common
Annual mean (µg/m^3)	155.1	125.8	115.8	972.9
Calibrated data capture (% of calendar year)	96	99	97	98

At the M4 site, oxides of nitrogen were measured using a Horiba instrument in 2008. It was found that concentrations of NO_X recorded at this site during 2008 were consistently higher than other comparable sites (data compared to that collected at Harwell, Oxford Centre Roadside and Reading New Town: data available on the UK Air Quality Archive[6]). The Horiba instrument was serviced in January 2009. To investigate this issue, two additional instruments (an API 200A and an API 200E) were installed at the M4 motorway site between 30/04/2009 and 26/06/2009. The comparison of average concentrations from the Horiba instrument and the two APIs during this period is shown in Table 3.4.

[6] http://www.airquality.co.uk/

Table 3.4: Instrument comparison –average concentrations, nitric oxide (NO) and total oxides of nitrogen (NO_X) (Horiba and APIs)

Statistic	Horiba	API1	API2	Average API	Scaling factor (API Average / Horiba)
NO	50.1	36.8	38.2	37.5	0.75
NO_X	90.5	62.4	64.5	63.5	0.70
NO_2	40.4	25.6	25.3	25.9	-

It was found that concentrations recorded by the Horiba instrument were incompatible with data collected by the two APIs during this period. The two APIs produced readings consistent with each other: the mean NO_2 concentrations for the two-month period recorded by the two APIs were within 0.5µg/m^3 of each other. The Horiba instrument was found to be reading data 25% higher than the mean of the two API instruments for NO and 30% higher for NO_x. Therefore data collected by the Horiba instrument in 2008 were adjusted to account for systematic 'over-reading'. Scaling factors were calculated from the mean NO and NO_X readings recorded by the three instruments during the co-location period (30/04/2009 to 26/06/2009) (see Table 3.4). The scaling factors were applied to NO and NO_X data collected by the Horiba instrument at the M4 site over the entire calendar year (2008). NO_2 concentrations were recalculated using the scaled NO and NO_X data (NO_2 = NO_X minus NO). After this comparison study the Horiba instrument was removed on 27th June 2009 and the API 200E was left at site to continue monitoring at the M4. The figures provided in Table 3.1, Table 3.2 and Table 3.3 are the results following adjustment to take account of the over-reading by the Horiba instrument.

3.2 Sulphur dioxide

Sulphur dioxide (SO_2) concentrations have been recorded by the continuous analysers as 15-minute means at two of the four monitoring sites (the M25 and M60 motorways). High data capture rates for SO_2 were achieved at both the M25 and M60 sites in 2008. Minor disruptions to data collection caused by power failures or instrument faults are discussed in Section 4. The UK Air Quality Regulations provide three objective concentrations for SO_2 (measured as 15-minute, 1-hour and 24-hour means). Table 3.5 shows that there were no exceedances of the SO_2 objective concentrations at either monitoring site in 2008.

The 15-minute and 1-hour mean data for SO_2 at the M25 and M60 sites were typically in the range 1 to 30µg/m^3. At the M25 site there were minor peaks in the data on 3rd January, 12th February, 29th December and between 17th and 19th February (up to 91µg/m^3 as a 15-minute mean). The peaks in the 24-hour mean data corresponded with the higher 15-minute and 1 hour mean concentrations; the highest concentration was observed on the 19th February. It should be noted that these peaks are at very low concentrations and are well below the UK Air Quality objectives. The reason for the occasional elevated concentrations at the M25 site is unknown. There are no other local continuous SO_2 monitors to compare the results with and no other known local sources of SO_2 emissions. At the M60 site no peaks in the data were observed.

The low levels of SO_2 recorded at these sites are to be expected due to the reduction in sulphur content of diesel fuel for road vehicles which has resulted in reduced SO_2 emissions. There has been a 99% reduction in SO_2 emissions from diesel fuels between 1994 and 2008 (AEA, 2010).

The 1-hour mean time-series plots of 15-minute, 1-hour and 24-hour mean SO_2 concentrations recorded at the M25 and M60 sites are presented in Volume II of this report.

Table 3.5: Compliance with UK Air Quality objectives, sulphur dioxide (SO_2)

Statistic	Objective concentration	Permitted number of exceedances	M25	M4	M60	Bell Common
15-minute mean	266 µg/m^3	35	0	-	0	-
1-hour mean	350 µg/m^3	24	0	-	0	-
24-hour mean	125 µg/m^3	3	0	-	0	-
Calibrated data capture (% of calendar year)	n/a	n/a	98	-	96	-

3.3 Ozone

Ozone (O_3) concentrations have been recorded by the continuous analysers as 15-minute means at all four sites. 1-hour means have been calculated from the 15-minute data and the running 8-hour mean has been calculated for comparison with the UK Air Quality objective at all four monitoring sites. Time-series plots of the running 8-hour mean concentration of O_3 are presented in Volume II of this report.

Table 3.6: Compliance with UK Air Quality objectives, ozone (O_3)

Statistic	Objective concentration	Permitted number of exceedances	M25	M4	M60	Bell Common
8-hour running mean	100 µg/m^3	10	7	9	**17**	0
Calibrated 1-hour data capture (% of calendar year)	n/a	n/a	97	99	94	100

Bold type indicates exceedance of UK Air Quality objective

Table 3.6 illustrates exceedance of the 8-hour running mean at three of the monitoring sites: the M25, M4 and M60 motorway. The running 8-hour mean concentration of ozone for the M4, M25 and M60 sites was typically between 5 and 90µg/m^3 and there were exceedances of the UK Air Quality objective concentration at each of these sites. There were 17 exceedances of the 8-hour running mean at the M60 site which is greater than the number permitted under the UK Air Quality Regulations. All of the exceedences of the 8-hour running mean objective concentration at the M60 and M4 occurred in May and at the M25 they occurred in June. The reason for these exceedances is unknown, however, higher concentrations of O_3 are typically observed during the summer months, as described below.

The running 8-hour mean concentration at Bell Common Tunnel was less than 8µg/m^3 for the whole year. This low level of O_3 in the tunnel was to be expected (as discussed in Section 3.1) because the available O_3 has been converted to NO_2.

High data capture rates for O_3 were achieved at the M25, M4 and Bell Common Tunnel sites in 2008. At the Bell Common Tunnel site, a data capture rate of 99.7% was

achieved and this has been rounded to 100% in Table 3.6. Minor disruptions to data collection are discussed in Section 4.

O_3 is a secondary pollutant (*i.e.* it is not emitted directly from any source *e.g.* road traffic). O_3 forms in the lower atmosphere by reactions between volatile organic compounds (VOCs), CO and NO_X in the presence of sunlight. O_3 reacts with NO emitted directly from vehicle exhausts to form secondary NO_2. At a roadside location, there is routinely an excess of NO and thus the limit to the formation of NO_2 is usually determined by the availability of O_3. During the summer months, higher concentrations of O_3 are typically observed due to an increase in the availability of sunlight. This is the rationale behind the investigation into the levels of NO_2 and O_3 as described below.

Concentrations of NO_2 and O_3 measured at the Highways Agency roadside sites have been analysed in conjunction with each other in order to explain episodes of high and low concentrations of these pollutants. Time-series plots presented in Volume II of this report have been annotated accordingly. For example, at the M25 site, an increase in NO_2 concentrations was observed between 6th and 21st February 2008, at the same time as O_3 concentrations were noticeably lower than in previous days. This indicates that more O_3 was involved in conversion to NO_2, although the reason for greater conversion is not clear.

3.4 Particulate Matter

Concentrations of particulate matter (PM_{10} and $PM_{2.5}$) are recorded as 15-minute means at each monitoring site. 1-hour and 24-hour means have been calculated from the 15-minute data to allow for comparison with the UK Air Quality objective for PM_{10} and the provisional UK Air Quality Objective for $PM_{2.5}$.

The calibrated data capture rates for PM_{10} and $PM_{2.5}$ reported in Table 3.7 and Table 3.10 are for the entire calendar year. High data capture rates for PM_{10} and $PM_{2.5}$ were achieved at the M25 and M4 motorway sites and by the TEOM at the M60 motorway. The Partisol at the M60 motorway achieved a data capture rate of 73%. Data loss was caused by sample losses (noted in Section 2.4). At the Bell Common Tunnel site, the data capture rate up to the removal of the Osiris monitor (see Section 2.2) was 99%. The data capture rate achieved at the Bell Common Tunnel site was not for the entire calendar year and therefore the period means reported in Table 3.7 and Table 3.10 must be treated with caution. The Osiris instrument was chosen to measure particulates in Bell Common tunnel due to the high concentrations expected, which meant the TEOM was deemed unsuitable because the filter would require changing more frequently than the planned site visits. However, it should be noted that the Osiris has not been equivalence tested against the standards set out in the EC Guidance for the Demonstration of Equivalence of Ambient Air Monitoring Methods (Bureau Veritas, 2006).

3.4.1 PM_{10}

Table 3.7 shows exceedances of the 24-hour mean objective concentration for PM_{10}. There were 50 exceedances of the 24-hour mean, greater than the number permitted under the UK Air Quality Regulations.

Time-series plots of the 24-hour mean concentration of PM_{10} are presented in Volume II of this report. The 24-hour mean concentration of PM_{10} was typically in the range of 15-40 µg/m^3 at the M25, M4 and M60 site. The exceedances of the 24-hour mean objective occurred on the 23rd January at both the M25 and M4 site and at the M4, M25 and M60 sites during mid-February. High PM_{10} concentrations were observed at other monitoring sites during these times and so it is believed there was a national pollution episode. The other exceedances were observed at the M25 site in May and June, at the M60 site in May and at the M25 site on the 29th and 30th December and the 30th December at the M4. High concentrations of PM_{10} were observed at other UK monitoring sites on the 30th

December, implying that this could have been a national pollution episode. The remaining exceedances were believed to be localised pollution episodes and were not observed at other sites at the same times. The 24-hour mean concentration for PM_{10} at Bell Common Tunnel site was typically in the range 30 to 70 µg/m^3 and there was at least one exceedance each month prior to the Osiris being removed in July.

Table 3.7 shows that the annual mean PM_{10} objective was exceeded at the Bell Common Tunnel site in 2008. As noted above, statistics for this site must be treated with caution due to the low data capture rate achieved for the entire calendar year. Given that the number of exceedances of the 24-hour mean objective concentration for PM_{10} exceeded the number permitted in one year by the UK Air Quality Regulations in the months for which the equipment was in place at the Bell Common Tunnel site (see Table 3.7), it can be assumed that the annual mean PM_{10} objective was also exceeded at this site in 2008.

Table 3.7: Compliance with UK Air Quality objectives, particulate matter (PM_{10})

Statistic	Objective concentration	Permitted number of exceedances	Measurement method	M25	M4	M60	Bell Common
24-hour mean	50 µg/m^3	35	TEOM adjusted (*1.3)	18	11	7	-
Annual mean	40 µg/m^3	n/a	TEOM adjusted (*1.3)	26.3	27.7	22.9	-
24-hour mean	50 µg/m^3	35	Osiris	-	-	**-**	**50**
Annual mean	40 µg/m^3	n/a	Osiris	-	-	-	**45.0**
Calibrated data capture (% of calendar year)	n/a	n/a	-	97	99	97	99*

Bold type indicates exceedance of UK Air Quality objective
* Bell Common Tunnel site equipment in place between 01/01/2008 and 11/07/2008

PM_{10} concentrations recorded by TEOM analysers at the M4, M25 and M60 sites have been adjusted by a correction factor of *1.3 in this series of reports to allow for comparison with the UK Air Quality objectives. The TEOM results historically have been corrected by multiplying by 1.3 in order to generate a nominal gravimetric-equivalent result (DEFRA, 2007). To inform analysis of the differences between various measurement and correction methods, the section below reports the PM_{10} concentrations recorded at sites in the Highways Agency network.

3.4.1.1 PM_{10} comparison

This section provides a comparison between TEOM data (including raw data, data adjusted by the *1.3 correction factor and data obtained using the VCM). Data has also been compared with that recorded by a co-located Partisol (EU equivalence method) at the M60 and M25 sites. The TEOM analyser is known to fail the PM_{10} equivalence test when compared to the gravimetric EU reference sampler (Harrison, 2006). Use of the volatile correction model (VCM) (ERG, 2009) has therefore been investigated (see Section 3.4.1.1). Note that to maintain the long term comparison, TEOM data presented in Table 3.7 and throughout this report has been corrected by an adjustment factor of *1.3.

Table 3.8 provides a summary of annual mean concentrations obtained using each method. Data obtained using the TEOM VCM method results in a lower annual mean

than that obtained from the TEOM*1.3 correction factor and from the Partisol. At both the M25 and M60 sites, the number of exceedances is higher using data collected by the Partisol method compared to that obtained from the TEOM*1.3 correction factor or the TEOM VCM (see Table 3.9). However there was no difference in the number of exceedances between the TEOM*1.3 and VCM correction methods at the M25 and only one additional exceedance using the VCM method compared to the TEOM*1.3 method for the M4 and M60. Since this work was completed there has been further investigation into TEOM correction methods and it is now accepted that the VCM is the preferred method[7]. Future reports in this series will therefore include PM_{10} concentrations measured by TEOMs corrected using the VCM method as standard.

Table 3.8: Annual mean PM_{10} concentrations, 2008

Site	PM_{10} concentration ($\mu g/m^3$)			
	TEOM (raw)	TEOM x1.3	$TEOM_{vcm}$	Partisol
M25	20.2	26.3	23.2	24.5
M4	21.3	27.7	25.6	-
M60	17.7	23.0	20.0	23.9

Table 3.9: Number of exceedences of PM_{10} 24 hourly objective, 2008.

Site	Number of exceedences			
	TEOM (raw)	TEOM x1.3	$TEOM_{vcm}$	Partisol
M25	4	18	18	19
M4	3	11	12	-
M60	4	7	9	11

3.4.2 $PM_{2.5}$

Table 3.10 shows that there were no exceedances of the proposed UK Air Quality objective concentration for annual mean $PM_{2.5}$ at any of the monitoring sites in 2008. High data capture rates (*i.e.* above 90%) for $PM_{2.5}$ were achieved at the M25 and M4 motorway sites and by the TEOM at the M60 motorway. As mentioned in Section 2.4, the Partisol at the M60 motorway achieved a data capture rate of 73% due to data loss caused by laboratory and field issues. As noted above, the data capture rate reported in Table 3.10 is for the entire calendar year. The data capture rate for $PM_{2.5}$ up to the removal of the Osiris monitor at the Bell Common Tunnel site was 99%.

[7] http://www.airquality.co.uk/reports/cat13/0902231025_VCM_Application_to_Hourly_and_AURN_FDMS_Purge_Measurements.pdf

Table 3.10: Compliance with Provisional UK Air Quality objectives, particulate matter ($PM_{2.5}$)

Statistic	Objective concentration	Permitted number of exceedances	Measurement method	M25	M4	M60	Bell Common
Annual mean	25 μg/m^3	n/a	TEOM	14.9	13.6	13.6	-
Annual mean	25 μg/m^3	n/a	Partisol	-	-	13.5	-
Annual mean	25 μg/m^3	n/a	Osiris	-	-	-	16.4
Calibrated data capture (% of calendar year)	n/a	n/a	-	96	99	TEOM adjusted: 98 Partisol: 73	99*

* Bell Common Tunnel site equipment in place between 01/01/2008 and 11/07/2008

3.5 Aromatic hydrocarbons (BTEX)

Aromatic hydrocarbons, including benzene, toluene, ethylbenzene, meta-, para- and ortho-xylene (collectively known as BTEX), are measured at the M25 and M60 sites using passive diffusion tubes that provide a data set of daily mean concentrations for each pollutant. Table 3.11 shows that the UK Air Quality objective value for benzene (annual mean of 5μg/m^3 in England and Wales) was achieved at both the M25 site and the M60 sites in 2008.

Table 3.11: Compliance with UK Air Quality objectives, benzene

Statistic	Objective concentration	Permitted number of exceedances	M25	M4	M60	Bell Common
Annual mean	5 μg/m^3	n/a	0.45	-	0.48	-
Data capture (% of calendar year)	n/a	n/a	98	-	90	-

The data capture rate for aromatic hydrocarbons improved in 2008 compared to 2007 when technical issues with the analyser resulted in data corruption for the first seven months of the year at the M25 site and the first six months of the year at the M60 site (Highways Agency, 2008). The technical issues were resolved in 2008 and hence the data capture rate improved.

3.6 Carbon monoxide

Concentrations of carbon monoxide (CO) are recorded as 15-minute means by the continuous analysers. 1-hour mean concentrations were calculated from the 15-minute mean data for comparison with the UK Air Quality objective concentration. Time-series plots of the running 8-hour mean concentration of CO are presented in Volume II of this report. The running 8-hour mean concentrations for carbon monoxide were typically less than 1 mg/m^3 for the M25, M4 and M60 sites and less than 2 mg/m^3 for Bell Common. There were no peaks observed at any of the sites.

Table 3.12 shows that there were no exceedances of the running 8-hour mean objective for CO at any of the monitoring sites in 2008. High data capture rates were achieved for

CO at the M25, M4 and M60 motorway sites. Minor disruptions to data collection caused by power failures or instrument faults are discussed in Section 4. At the Bell Common Tunnel site, an instrument fault resulted in a loss of data throughout October and November (see Section 2.2).

Table 3.12: Compliance with UK Air Quality objectives, carbon monoxide (CO)

Statistic	Objective concentration	Permitted number of exceedances	M25	M4	M60	Bell Common
Maximum running 8-hour mean	10 mg/m^3	n/a	1.3	1.6	2.0	2.1
Calibrated data capture (% of calendar year)	n/a	n/a	98	99	98	79

3.7 Lead

Concentrations of selected heavy metals are monitored at the M25 motorway site. The measurement method follows that employed on the UK Heavy Metals Monitoring Network in line with Directive 2004/107/EC (EC, 2004). The UK Air Quality Regulations set an objective annual mean concentration for lead equal to or less than 0.25µg/m^3. Concentrations of other heavy metals which are not covered by the UK Air Quality Regulations are discussed in Section 3.8.5.

The annual mean concentration of lead recorded at the M25 site in 2008 was well below the UK Air Quality objective. A high (*i.e.* greater than 90%) data capture rate was achieved for lead monitoring in 2008.

Table 3.13: Compliance with UK Air Quality objectives, lead

Statistic	Objective concentration	Permitted number of exceedances	M25	M4	M60	Bell Common
Annual mean	0.25 µg/m^3	n/a	0.0092	-	-	-
Data capture (% of calendar year)	n/a	n/a	96	-	-	-

3.8 Pollutants not covered by the UK Air Quality Regulations

Concentrations of a number of pollutants not covered by the UK Air Quality Regulations are recorded at sites within the Highways Agency long term roadside monitoring network. Whilst these pollutants are not covered by UK legislation, guidance values for safe levels of human exposure exist and it is therefore considered useful to monitor concentrations. In addition, monitoring over an extended time period can provide a useful indication of emissions trends at roadside sites.

3.8.1 Polycyclic aromatic hydrocarbons

PAH monitoring in the Highways Agency network began in 2003 at the M25 site and in 2004 at the M60 site. Benzo[a]pyrene (B[a]P) is the compound that is considered to be representative for the cancer risk associated with the whole PAH mixture (EPAQS, 1999). An annual mean concentration for B[a]P of 0.25ng/m^3 is the value listed in the UK Air Quality Strategy (Defra, 2007) as an objective for PAH. This pollutant is not, however,

covered by EU Daughter Directives on Air Quality and is not therefore transposed into UK law through the UK Air Quality Regulations.

Table 3.14 presents the annual mean concentrations of B[a]P measured at the M25 and M60 sites during 2008. The UK Air Quality Strategy provisional objective was achieved at the M25 monitoring site and the annual mean recorded at the M60 site was the same as the objective value (0.25 ng/m^3).

Table 3.14: Compliance with UK Air Quality provisional objective, benzo[a]pyrene (B[a]P)

Statistic	Objective concentration	Permitted number of exceedances	M25	M4	M60	Bell Common
Annual mean	0.25 ng/m^3	n/a	0.24	-	0.25	-
Data capture (% of calendar year)	n/a	n/a	86	-	61	-

In 2008, data capture rates of 86% and 61% were achieved at the M25 and M60 sites respectively in 2008. The data capture rate achieved at the M60 site means that the statistics for this site must be treated with caution. The Partisol at the M60 had multiple breakdowns relating to filters jamming and this resulted in data losses between the 10th July and 9th August, 24th September and 25th October and 8th and 31st December. There were also two periods of data loss due to the filters running out, these were 17th June to 9th July and 24th August and 7th September. The Partisol at the M25 was removed for repair on 3rd February and was re-installed on 28th March, so there were no results recorded for this period. A filter exchange problem between 10th and 14th August and 29th August and 2nd September resulted in filters being exposed twice so therefore the results were not valid. The filters from the period between 7th and 31st December were lost by the local service engineer.

3.8.2 Aldehydes

Aldehydes are not included in the UK Air Quality Regulations. Human health effects (including eye, skin and respiratory irritation and neurophysical and behavioural changes (at particularly high levels)) resulting from exposure to aldehydes (particularly formaldehyde) provide the reasons for measuring this group of pollutants. A report prepared for the Committee on the Medical Effects of Air Pollution (COMEAP) records threshold levels of exposure to formaldehyde being associated with sensory irritation in the general population of approximately 0.6-1.2mg/m^3 for formaldehyde and less than 90mg/m^3 for acetaldehyde[8].

Annual mean concentrations of formaldehyde and acetaldehyde recorded at the M25 and M60 motorway sites in 2008 are presented in Table 3.15. Concentrations were well below the recommended guidelines at both sites during 2008.

Following the loss of some data in 2007 due to technical issues at the laboratory, the data capture rate at the M25 site recovered in 2008, with a mean capture rate for all aldehydes of 96% compared to 67% in 2007. Data loss occurred at the M60 site in March 2008 due to invalid flow readings resulting in a slightly low data capture rate.

[8] http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/aldehydes-imperialcollreview.pdf

Table 3.15: Annual mean concentration, acetaldehyde and formaldehyde

Pollutant	Statistic	Guideline Values	M25	M4	M60	Bell Common
Acetaldehyde	Annual mean (mg/m^3)	90	0.00069	-	0.00002	-
Formaldehyde	Annual mean (mg/m^3)	0.6-1.2	0.00138	-	0.00003	-
Aldehydes	Data capture (% of calendar year)	-	96	-	87	-

3.8.3 Total hydrocarbons

Total hydrocarbons and methane are not included in the UK Air Quality Regulations and the Environment Agency[9] has not recommended a long term Environmental Assessment Level. However, the UK government is committed to reducing emissions of methane under the United Nations Framework Convention on Climate Change (Kyoto Protocol). The target for the UK is to achieve a reduction of the global warming potential of six greenhouse gases including methane of 12.5% by 2008-2012 (based on 1990 emissions estimates). Concentrations of total hydrocarbons (THC) and methane (CH_4) are measured at the M4, M25 and M60 motorway sites. At the beginning of 2008, the supplier and service company for the Horiba 350 hydrocarbons analysers advised TRL that the analysers were no longer supported for spares or servicing. No other service companies could support the analysers. The HA were advised of this issue and the replacement costs. It was agreed to continue operating the analysers for as long as practicable using existing calibration procedures for CH_4 under the caveat that the instruments would be removed when calibration and operation were no longer acceptable. The results for non-methane hydrocarbons (NMHC) could not be validated and have not been presented in this report. At the time of writing, reliable and cost effective replacements for continuous ambient hydrocarbon measurements have yet to be identified. High data capture rates (*i.e.* above 90%) for concentrations of CH_4 were achieved at the M25 and M60 sites in 2008. Data loss occurred at the M4 site due to problems with the FID as noted in Section 2.1.

Table 3.16: Annual mean concentration, methane (CH_4)

Statistic	M25	M4	M60	Bell Common
Annual mean (µg/m^3)	1.18	1.51	1.57	-
Calibrated data capture (% of calendar year)	91	88	94	-

3.8.4 Ammonia

Ammonia (NH_3) concentrations are recorded at the M4, M25 and M60 motorway sites using passive diffusion tubes exposed at approximately 2-weekly intervals. This pollutant is not included in the UK Air Quality Regulations. The Environment Agency recommends comparison against an annual average Environmental Assessment Level[10]

[9] http://www.environment-agency.gov.uk/business/topics/pollution/185.aspx
[10] Personal communication between TRL Ltd and Environment Agency, July 2010

of 180µg/m^3. The annual averages recorded at the Highways Agency roadside monitoring sites in 2008 were well below this level.

At the M25 and M60 sites, triplicate tubes were deployed at two locations. At the M25 site, one set of tubes was deployed close to the inlet at the roadside and one set was deployed in the field at the rear of the monitoring station approximately 50m from the roadside. At the M60 site, one set of tubes was deployed at the roadside and a second set was deployed at the inlet approximately 18m from the roadside. At the M4 site, triplicate tubes were located at the roadside only, because there was no suitable background site.

High data capture rates (*i.e.* above 90%) for ammonia were achieved at the M25 sites and the M4 site in 2008. Data loss occurred at the M60 site between March 2008 and June 2008 due to the laboratory losing the exposed ammonia tubes.

Table 3.17 shows the levels of ammonia found at the M60 roadside site are more than double the roadside (inlet) levels found at the M4 and M25 sites. The annual mean concentration of ammonia at the inlet at the M60 site is similar to those found at the M4 and M25 inlets; however the M60 inlet is 15m further from the roadside. The reason for the elevated levels of ammonia at the M60 roadside site is unknown; there are no other known local sources.

Table 3.17: Annual mean concentration, ammonia (NH_3)

Statistic	M25		M4	M60		Bell Common
	Roadside (4.3m from traffic)	Background (50m from roadside)	Inlet (3.8m from traffic)	Roadside (3.3m from traffic)	Inlet (18m from roadside)	
Annual mean (µg/m^3)	6.69	8.53	8.04	20.34	6.72	-
Data capture (% of calendar year)	100	97	100	71	71	-

3.8.5 Heavy metals

Concentrations of selected heavy metals are recorded at the M25 motorway site. Lead is included in the UK Air Quality Regulations and results obtained for this pollutant at the M25 site in 2008 are discussed in Section 3.7. Annual mean concentrations of arsenic, cadmium and nickel are also subject to target values under the 4th Daughter Directive (2004/107/EC)[11]. Target values set under this Directive require member states to take all cost effective abatement measures but do not require them to undertake any measures entailing disproportionate costs. Target values are 6ng/m^3, 5ng/m^3 and 20ng/m^3 for arsenic, cadmium and nickel respectively. Annual mean concentrations of arsenic, cadmium and nickel recorded at the M25 site remained well below these target values in 2008 (see Table 3.18).

[11] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0107:EN:NOT

Table 3.18: Annual mean concentration, heavy metals

Pollutant	Target Value	Statistic	M25	M4	M60	Bell Common
Arsenic	6 ng/m^3	Annual mean (ng/m^3)	0.42	-	-	-
Cadmium	5 ng/m^3	Annual mean (ng/m^3)	0.14	-	-	-
Nickel	20 ng/m^3	Annual mean (ng/m^3)	2.25	-	-	-
Arsenic, cadmium and nickel	n/a	Data capture (% of calendar year)	98	-	-	-

3.8.6 Hydrogen sulphide

Concentrations of hydrogen sulphide (H_2S) are measured at the M25 and M60 motorway sites. The Environment Agency[12] recommends comparison against the long term Environmental Assessment Level of 140µg/m^3. Annual average concentrations of H_2S recorded at the Highways Agency roadside monitoring sites in 2008 were well below this value. High data capture rates (*i.e.* above 90%) for H_2S were achieved at both the M25 and M60 sites in 2008.

Table 3.19: Annual mean concentration, hydrogen sulphide (H_2S)

Statistic	EAL	M25	M4	M60	Bell Common
Annual mean (µg/m^3)	140	3.21	-	5.71	-
Calibrated data capture (% of calendar year)	-	98	-	95	-

3.9 Traffic data

In addition to measurement of pollutant concentrations, information on total traffic flow is collected by Automatic Traffic Counters (ATCs) at all four monitoring sites (see Table 3.20). Traffic flows recorded in 2008 at each monitoring site are presented together with historical datasets in Volume II. The traffic flow reported for Bell Common Tunnel is the total traffic through both bores. At the time of writing, separate clockwise and anticlockwise traffic flows were not available. The road works that started in October involved contra-flow traffic management.

[12] http://publications.environment-agency.gov.uk/pdf/GEHO1105BJXV-e-e.pdf

Table 3.20: Annual average daily and hourly traffic flow

Statistic	M25	M4	M60	Bell Common
Annual average daily traffic flow	CW* 99742 ACW* 101258	EB* 57629 WB* 57444	CW 80433 ACW 72845	124218
Annual average vehicles per hour	CW 4156 ACW 4219	EB 2402 WB 2394	CW 3404 ACW 3056	5289
Data capture (% of calendar year)	CW 54 ACW 99	EB 82 WB 69	CW 95 ACW 97	100

* CW: clockwise; ACW: anti-clockwise; EB: Eastbound; WB: Westbound

4 Summary

This report provides a summary of air pollutant concentrations, meteorological data and traffic flows measured at four motorway sites during the calendar year 2008 as part of the Highways Agency long term roadside monitoring network.

The report compares concentrations of pollutants with objectives set out by the UK Air Quality Regulations. The following exceedances have been recorded during 2008:

- The annual mean NO_2 objective concentration of 40µg/m^3 was exceeded at all four monitoring sites.
- The 1-hour mean NO_2 objective concentration of 200µg/m^3 was exceeded at the Bell Common Tunnel site.
- Exceedances of the annual mean and 24-hour PM_{10} objectives of 40µg/m^3 and 50µg/m^3 respectively were assumed to occur at the Bell Common Tunnel site.
- Exceedance of the running 8-hour mean O_3 objective of 100µg/m^3 occurred at the M60 site in 2008.

There were no exceedances of:

- UK Air Quality Regulations for SO_2, benzene, CO or lead at any of the monitoring sites during 2008.
- The provisional UK Air Quality objective for $PM_{2.5}$ at any site.
- The provisional UK Air Quality objective for benzo[a]pyrene at the M25 site (the annual mean was the same as the objective mean at the M60 site).
- The Environment Agency recommended Environmental Assessment Level (EAL) for exposure to non-regulated air pollutants (PAH, ammonia and hydrogen sulphide).
- The target values under the 4th Daughter Directive (2004/107/EC) for Arsenic, Cadmium and Nickel at the M25 site.

The annual average daily traffic flow has increased from 2007 levels at the M4, M25 and Bell Common sites by 0.7, 0.8 and 4.5 percent respectively and reduced by 1.8 percent at the M60 site.

Monitoring at the Bell Common Tunnel site was influenced by a major construction and refurbishment project to replace mechanical and electrical equipment. This work started in October 2008 and the Osiris (particulate monitor) was removed from the hard shoulder walkway in July due to a lack of space in the Tunnel. The exceedance of the particulate objective is based on only seven months of data.

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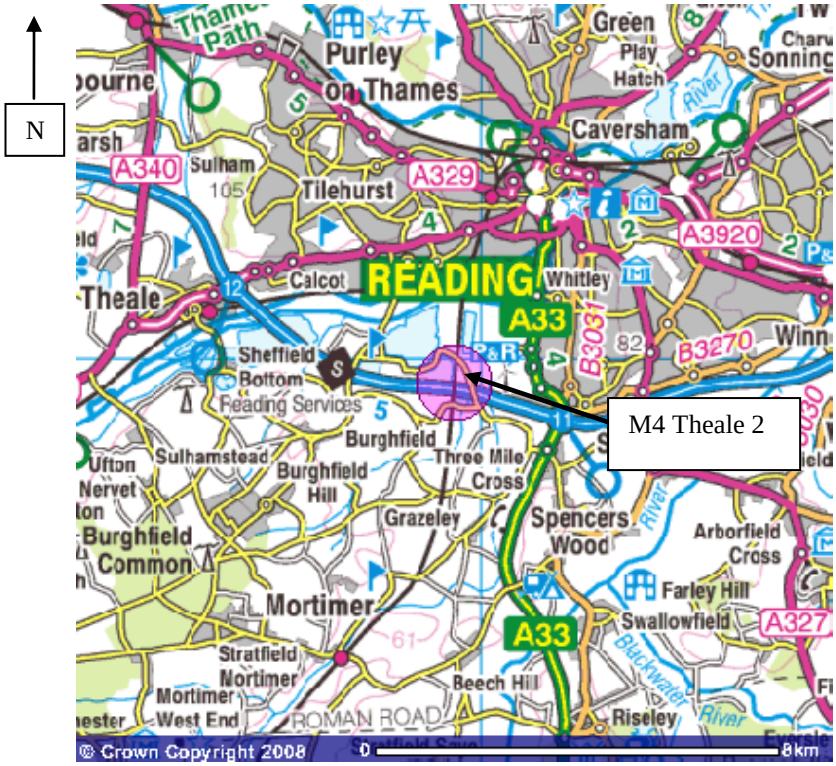
Appendix A Photographs and locations of monitoring sites

A.1 M4 (Theale 2), Pinglewood

A.1.1 Ordnance Survey map



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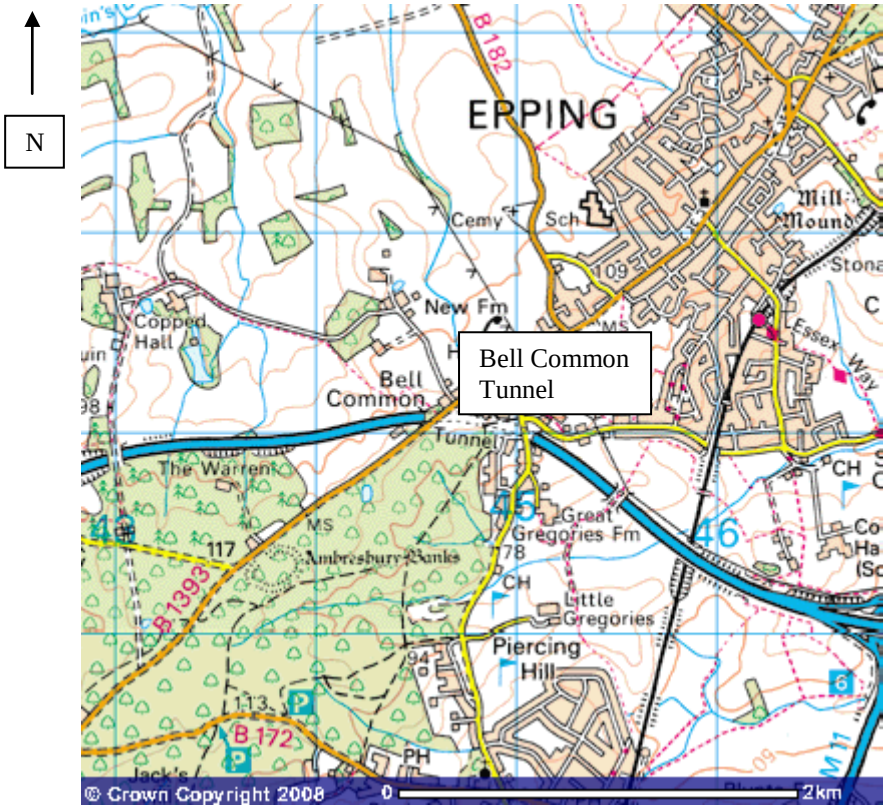
A.1.2 Site photos

A.1.2.1 M4 monitoring station

A.1.2.2 Selection of instruments inside the M4 monitoring station

A.2 M25, Bell Common Tunnel

A.2.1 Ordnance Survey map



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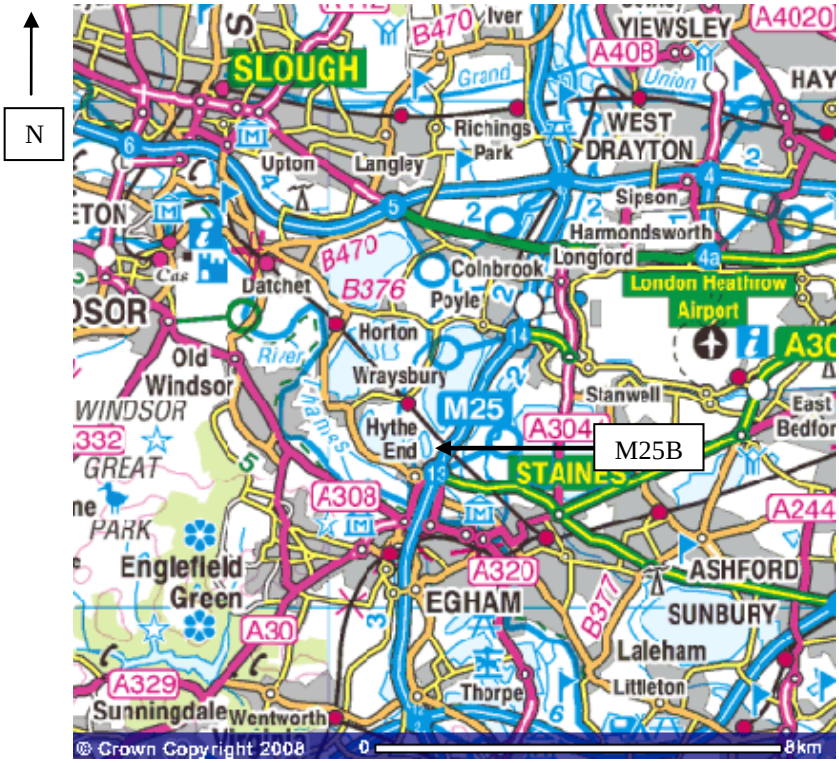
A.2.2 Site photos

A.2.2.1 View of Western end of Bell Common Tunnel (monitoring station located in the Clockwise bore on the left of picture)

A.2.2.2 Selection of instruments inside the Bell Common Tunnel monitoring station

A.3 M25 (M25B), Staines

A.3.1 Ordnance Survey map



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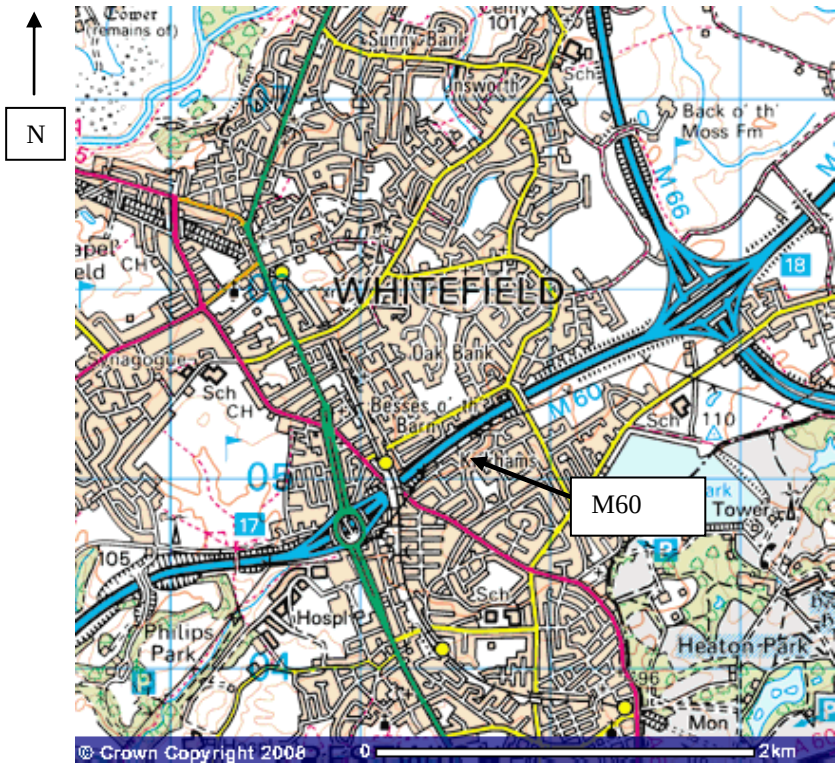
A.3.2 Site photos

A.3.2.1 M25 monitoring station

A.3.2.2 Selection of instruments inside the M25 monitoring station

A.4 M60, Kirkhams

A.4.1 Ordnance Survey map



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A.4.2 Site photos

A.4.2.1 M60 monitoring station

A.4.2.2 Selection of instruments inside the M60 monitoring station

Appendix B Calibration and maintenance records

B.1 M4 (Theale 2), Pinglewood

Date	Reason for visit	Notes/Actions taken
03/01/08	NH_3 tube change.	NH_3 tubes swapped out.
11/01/08	Span/Zero check.	-
17/01/08	NH_3 tube change.	NH_3 tubes swapped out.
24/01/08	Span/Zero check.	-
30/01/08	Span/Zero check.	By-pass DFUs on both TEOMs replaced. NH_3 tubes swapped out.
14/02/08	Interim visit.	Diffusion tubes & filters changed.
15/02/08	Span/Zero check.	Met kit installed.
28/02/08	Span/Zero check.	PM_{10} & $PM_{2.5}$ sharp cut off heads replaced. By-pass DFUs on both TEOMs replaced. NH_3 tubes swapped out.
13/03/08	Span/Zero check.	-
27/03/08	Span/Zero check.	Swapped out Hydrogen bottle. NH_3 tubes swapped out.
10/04/08	Span/Zero check.	By-pass DFUs on both TEOMs replaced.
14/04/08	NH_3 tube change.	NH_3 tubes swapped out.
24/04/08	Span/Zero check.	A/C now ok.
01/05/08	Interim visit.	Diffusion tubes & filters changed.
08/05/08	Span/Zero check.	NH_3 tubes swapped out.
21/05/08	Span/Zero check.	NH_3 tubes swapped out. O_3 calibration carried out.
05/06/08	Span/Zero check.	PM_{10} head & $PM_{2.5}$ cut off swapped out. NH_3 tubes swapped out.
19/06/08	Span/Zero check.	NH_3 tubes swapped out.
02/07/08	Span/Zero check.	Hydrogen bottle changed.
17/07/08	Span/Zero check.	By-pass DFUs on both TEOMs replaced. NH_3 tubes swapped out.
31/07/08	Span/Zero check.	NH_3 tubes swapped out.
20/08/08	Span/Zero check	PM_{10} & $PM_{2.5}$ heads swapped out.
28/08/08	Span/Zero check.	NH_3 tubes swapped out.
04/09/08	Span/Zero check.	-
11/09/08	Span/Zero check.	NH_3 tubes swapped out.
26/09/08	Span/Zero check.	By-pass DFUs on both TEOMs replaced.
01/10/08	Span/Zero check & NOx analyser installation.	Second NOx analyser installed for comparison check.
02/10/08	NH_3 tube change.	NH_3 tubes swapped out.
09/10/08	Span/Zero check & O_3 cals.	O_3 calibration carried out. NH_3 tubes swapped out.
23/10/08	Span/Zero check.	Hydrogen bottle changed.
06/11/08	Span/Zero check.	NH_3 tubes swapped out.
20/11/08	Span/Zero check.	By-pass DFUs on both TEOMs replaced. NH_3 tubes swapped out.
04/12/08	Span/Zero check.	NH_3 tubes swapped out.
18/12/08	Span/Zero check.	NH_3 tubes swapped out.

B.2 M25, Bell Common Tunnel

Date	Reason for visit	Notes/Actions taken
08/01/08	Span/Zero check.	-
25/01/08	Span/Zero check.	Changed CO gas cylinder
08/02/08	Span/Zero check.	-
26/02/08	Span/Zero check.	Installed 3 x 55m sample filters holders. Osiris filter changed.
12/03/08	Span/Zero check.	-
04/04/08	Span/Zero check.	Osiris filter changed.
25/04/08	Span/Zero check.	Osiris filter changed. O_3 cals carried out.
20/05/08	Span/Zero check.	CO analyser (TRL number 1341) removed for repair. CO analyser (TRL number 1373) installed.
06/06/08	Span/Zero check.	Osiris filter changed. NOx showing chopper warning – repaired on site.
19/06/08	Span/Zero check.	Osiris filter changed.
08/07/08	Span/Zero check.	-
24/07/08	Span/Zero check.	Osiris removed for service not to be re-installed due to start of tunnel works.
08/08/08	Span/Zero check.	-
26/08/08	Span/Zero check.	-
12/09/08	Span/Zero check.	-
30/09/08	Span/Zero check.	CO and NOx units reset due to power failure yesterday.
21/10/08	Span/Zero check.	-
11/11/08	Span/Zero check.	-
19/11/08	Span/Zero check.	-
11/12/08	Span/Zero check.	O_3 zero/span re-set. CO swapped out - (TRL number 1373) removed, CO analyser (TRL number 1341) installed.

B.3 M25 (M25B), Staines

Date	Reason for visit	Notes/Actions taken
03/01/08	Span/Zero check.	NOx showing chopper warning; NOx TRL number 1606 swapped out with number 1102. By-pass DFUs replaced on TEOMs. NH_3 tubes swapped out.
11/01/08	Interim visit.	Diffusion tubes and filters changed.
17/01/08	Span/Zero check.	NH_3 tubes swapped out.
24/01/08	Interim visit.	Diffusion tubes and filters changed.
30/01/08	Interim visit.	Replaced partisol filters. NH_3 tubes swapped out. Swapped out partisol 2025 & 2000 PM_{10} heads.
08/02/08	Span/Zero check.	System reset warning showing on NOx, SO_2/H_2S & NH_3. Instruments reset. STS25 pump swapped out.
14/02/08	Interim visit.	Diffusion tubes and filters changed. TEOM heads swapped out.
21/02/08	Span/Zero check.	TEOMs showing flow alarm warning; cleared upon filter change. By-pass DFUs replaced on TEOMs.
28/02/08	-	DNPH gas flow meter swapped out. NH_3 tubes swapped out.
29/02/08	-	Swapped out NOx pump & drier pipe work. DNPH pump swapped out & reset.
07/03/08	Span/Zero check.	-
13/03/08	Interim visit.	Partisol changed. Diffusion tubes and filters changed.
21/03/08	Span/Zero check.	Calibration checks good. Started pump running on P2000 for metals.
27/03/08	Interim visit.	Diffusion tubes and filters changed.
03/04/08	Span/Zero check.	Calibration checks ok. PM_{10} heads on both partisol units swapped out.
10/04/08	Interim visit.	Diffusion tubes and filters changed.
14/04/08	NH3 tubes change.	NH_3 tubes swapped out.
17/04/08	Span/Zero check.	-
24/04/08	Interim visit.	Diffusion tubes and filters changed.
25/04/08	BTEX tube change	-
01/05/08	-	Power to site tripped out, reset power & ran up instruments. Power lead to O_3 unit faulty, replaced.
08/05/08	Interim visit.	Diffusion tubes and filters changed.
14/05/08	TEOM filter change	-
15/05/08	Span/Zero check.	-
21/05/08	Interim visit.	Diffusion tubes and filters changed.
29/05/08	Span/Zero check.	Power tripped out, fault with ozone analyser, removed. Fuse blown on H_2S/SO_2 pump, replaced. PM_{10} heads swapped out on partisol 200& 2025.
05/06/08	Interim visit.	Diffusion tubes and filters changed.
09/06/08	Pump swaps & wind speed.	PM_{10} TEOM pump swapped out. H_2S/SO_2 pump swapped out too. Wind speed sensor installed.
12/06/08	Span/Zero check.	-
13/06/08	TEOM $PM_{2.5}$ issues	Flow alarm on $PM_{2.5}$ TEOM. Stripped block and cleaned orifices in ultrasonic bath. Re-installed TEOM control box but main flow still reading 0.02. Control box returned to TRL for investigation.
19/06/08	Interim visit.	Diffusion tubes and filters changed.
26/06/08	Span/Zero check.	-
03/07/08	Interim visit.	Diffusion tubes and filters changed.
10/07/08	Span/Zero check.	Fitted O_3 scrubber to DNPH and checked/adjusted flow through system. Partisol filters ok. FID silica gel replaced. All sample filters replaced.
17/07/08	Interim visit.	Diffusion tubes and filters changed.
24/07/08	Span/Zero check.	-
31/07/08	Interim visit.	Diffusion tubes and filters changed.
07/08/08	Span/Zero check.	Replaced DFUs on both TEOMs.
21/08/08	Span/Zero check.	-
28/08/08	Interim visit.	Swapped out STS25 meter. Diffusion tubes and filters changed.

Date	Reason for visit	Notes/Actions taken
04/09/08	Span/Zero check.	-
11/09/08	Interim visit.	DNPH ozone scrubber installed. Diffusion tubes and filters changed.
26/09/08	Interim visit.	Diffusion tubes and filters changed.
02/10/08	Span/Zero check.	Wind speed instrument returned to TRL for inspection. NH_3 tubes swapped out.
09/10/08	Interim visit & O_3 checks.	Diffusion tubes and filters changed. O_3 calibrations carried out.
16/10/08	Span/Zero check.	-
30/10/08	Span/Zero check.	-
06/11/08	Interim visit.	Diffusion tubes and filters changed.
13/11/08	Span/Zero check.	-
20/11/08	Interim visit.	Diffusion tubes and filters changed. Swapped out pyranometer.
27/11/08	Span/Zero check.	R/H sensor and pyranometer checked. R/H working ok now. Solar responds ok. Reset wind direction to North at 13:20hr.
04/12/08	Interim visit.	Partisol filter exchange failed on first filter, swapped out whole magazine. Diffusion tubes and filters changed.
11/12/08	Span/Zero check.	Large in-line DFUs replaced on By-pass lines on both TEOMs. Filter exchange failed on partisol 2025, removed Burr from cassette & set to start at 00:01hr.
18/12/08	Interim visit.	Wind speed sensor installed. Diffusion tubes and filters changed.
23/12/08	-	Full partisol magazine deployed.

B.4 M60, Kirkhams

Date	Reason for visit	Notes/Actions taken
07/01/08	Span/Zero check.	-
18/01/08	Span/Zero check.	Changed mass flow controller & pump on PM_{10} TEOM.
05/02/08	Span/Zero check.	New BTEX tubes deployed.
18/02/08	Span/Zero check.	-
03/03/08	Span/Zero check.	-
17/03/08	Span/Zero check.	-
31/03/08	Span/Zero check.	-
11/04/08	Span/Zero check.	BTEX, NH3, and DNPH tubes changed. New partisol filters deployed.
06/05/08	Span/Zero check.	Repaired STS25 pump.
20/05/08	Span/Zero check.	NH_3 tubes swapped out.
02/06/08	Span/Zero check.	Changed DFU on $PM_{2.5}$ TEOM.
06/06/08	O_3 calibration carried out.	-
16/06/08	Span/Zero check.	HC flames will not relight, returned to TRL for repair. BTEX tube pump u/s, returned to TRL.
30/06/08	Span/Zero check.	HC unit was re-installed.
18/07/08	Span/Zero check.	-
22/07/08	Interim visit.	H_2S/SO_2 swapped out broken internal filter glass with replacement analysers. Removed H_2S/SO_2 for repair.
28/07/08	Interim visit.	H_2S/SO_2 re-installed.
01/08/08	Span/Zero check.	Tubes deployed. Partisol returned to workshop for repair.
11/08/08	Span/Zero check.	Changed DFU on TEOMs.
10/09/08	Span/Zero check.	-
19/09/08	Span/Zero check.	-
03/10/08	Span/Zero check.	Reset partisol as filter exchange had failed. NH_3 tubes deployed.
24/10/08	Span/Zero check.	Re-installed the repaired Partisol.
07/11/08	Span/Zero check.	NH_3 tubes swapped out.
21/11/08	Span/Zero check.	-
08/12/08	Span/Zero check.	-
22/12/08	Span/Zero check.	-

Appendix C Meteorological data

Meteorological data are collected at three of the four current monitoring sites (see Table C.1). Historically, these data were recorded to enable the analysis of long term trends in emissions and pollutant concentrations at each monitoring site. This analysis is not, however, included in this report.

The wind speed and wind direction sensors located at the M25 and M4 sites are located 5.05m and 6m respectively from the hard shoulder and at a height of 3.75m and 6m respectively. The annual average prevailing wind direction in the UK is expected to be from the south west at approximately 225 degrees. The annual average wind direction data obtained at the M25 and M4 sites, and the position of the carriageways relative to north, would suggest that the resulting annual average wind directions at these two sites may be influenced by turbulence from vehicle movements on the adjacent carriageways. The traffic flow on the M25 is from 200 degrees to north and at the M4 at 280 degrees from north. The wind sensors at the M60 site are located a distance of 18m from the carriageway and at a height of 6.8m above ground level. It is unlikely that the wind direction data at this location would be influenced by any turbulence effects from vehicle movements on the adjacent M60 carriageway.

C.1 Meteorological data

Statistic	M25	M4	M60	Bell Common
Annual average wind speed (m/s)	2.4	2.4	1.2	-
Annual maximum wind speed (m/s)	14.3	22.4	7.4	-
Annual minimum wind speed (m/s)	0.1	0.0	0.0	-
Wind speed data capture (% of calendar year)	49*	99	58*	-
Annual average wind direction (degrees from north)	269.9	200.1	98.3	-
Wind direction data capture (% of calendar year)	98	100	98	-
Annual average temperature (ºC)	11.9	12.2	10.0	-
Annual maximum temperature (ºC)	31.7	30.2	26.8	-
Annual minimum temperature (ºC)	-2.4	-3.6	-4.8	-
Temperature data capture (% of calendar year)	98	87	96	-
Annual average relative humidity (%)	68.4	70.6	80.5	-
Annual maximum relative humidity (%)	97.2	98.9	98.9	-
Annual minimum relative humidity (%)	19.0	15.0	15.5	-
Relative humidity data capture (% of calendar year)	92	85	96	-
Annual average solar radiation (W/m^2)	171.0	-	-	-
Annual maximum solar radiation (W/m^2)	1980.7	-	-	-
Annual minimum solar radiation (W/m^2)	0.0	-	-	-
Solar radiation data capture (% of calendar year)	78	-	-	-

*Wind data capture at the M60 and M25 were low due to technical faults with the anemometer sensors.

Appendix D Air Quality Strategy objectives

D.1 UK Air Quality Strategy objectives

Pollutant	Objective	Compliance date
Nitrogen dioxide (NO_2)	Hourly mean concentration should not exceed 200 µg/m^3 more than 18 times a year Annual mean concentration should not exceed 40 µg/m^3	31 December 2005
Particulate matter, expressed as PM_{10}	24-hour mean concentration should not exceed 50 µg/m^3 more than 35 times a year Annual mean concentration should not exceed 40 µg/m^3	31 December 2004
Particulate matter, expressed as $PM_{2.5}$	Annual mean concentration should not exceed 25 µg/m^3 in UK	2020
Benzene	Running annual mean concentration should not exceed 16.25 µg/m^3 Annual mean concentration should not exceed 5 µg/m^3	31 December 2003 31 December 2010
1,3-butadiene	Running annual mean concentration should not exceed 2.25 µg/m^3	31 December 2003
Carbon monoxide (CO)	Maximum running 8-hour mean concentration should not exceed 10 mg/m^3	31 December 2003
Polycyclic aromatic hydrocarbons (PAH)	Annual mean concentration should not exceed 0.25 ng/m^3	31 December 2010
Lead (Pb)	Annual mean concentration should not exceed 0.5 µg/m^3 Annual mean concentration should not exceed 0.25 µg/m^3	31 December 2004 31 December 2008
Sulphur dioxide (SO_2)	Hourly mean concentration of 350 µg/m^3 not to be exceeded more than 24 times a year 24-hour mean of 125 µg/m^3 not to be exceeded more than 3 times a year 15-minute mean of 266 µg/m^3 not to be exceeded more than 35 times a year	31 December 2004 31 December 2004 31 December 2005
Ozone (O_3)	8-hour mean of 100 µg/m^3 not to be exceeded more than 10 times a year	31 December 2005

Appendix E Conversion factors

E.1 Conversion factors

Pollutant	Conversion factor
Ozone	1 ppb = 2.00 µg/m^3
Nitrogen oxide (as NO_2 equivalent)	1 ppb = 1.91 µg/m^3
Nitrogen dioxide	1 ppb = 1.91 µg/m^3
Sulphur dioxide	1 ppb = 2.66 µg/m^3
Methane	1 ppm = 0.67 mg/m^3
Non-methane hydrocarbons	1 ppm = 0.58 mg/m^3
Carbon monoxide	1 ppm = 1.16 mg/m^3
Ammonia	1 ppb = 0.71 µg/m^3
Hydrogen sulphide	1 ppb = 1.42 µg/m^3