LONDON CITY AIRPORT

2015 SECTION 106 ANNUAL PERFORMANCE REPORT

APPENDIX 13
DATA FROM AIR QUALITY MEASUREMENT PROGRAMME

01 July 2016

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London City Airport Air Quality Measurement Programme:

Annual Report 2015

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Executive Summary

This document represents the 2015 Annual Report for the Air Quality Measurement Programme (AQMP) that is operated by Air Quality Consultants Ltd. on behalf of London City Airport. This programme measures concentrations of nitrogen dioxide (NO_2) and fine particles (the so called PM_{10} fraction, i.e. particles that are less than 10 micrometres in diameter).

Monitoring is carried out at two automatic monitoring stations. One is situated on the roof of City Aviation House (LCA-CAH) whilst the other is to the north of Royal Albert Dock, adjacent to the Newham Dockside building (LCA-ND). These automatic sites are supplemented by a network of passive monitoring devices (nitrogen dioxide diffusion tubes) located at a further 18 sites in and around the Airport boundary.

The Government has set a number of air quality objectives to protect human health. These are based on monitoring carried out over the period of a calendar year.

In some cases, these objectives refer to average concentrations of pollutants measured over the calendar year (the "annual mean"); in other cases they refer to the number of hours or days on which a specified pollutant concentration should not be exceeded (for example, no more than 35 days in each calendar year on which PM_{10} concentrations exceed 50 µg/m^3, and no more than 18 hours in each calendar year on which nitrogen dioxide concentrations exceed 200 µg/m^3).

In addition to the objectives, the Government has established a set of descriptors for the 1-hour mean concentrations of nitrogen dioxide and 24-hour mean concentrations of PM_{10}. Air quality is defined by these descriptors as being Low, Moderate, High and Very High.

Pollution concentrations measured in and around the Airport are associated with a wide range of sources at the local, regional, national and international scales. On occasions when pollution levels rise, these higher levels are often observed across the whole of London as a "regional pollution episode". To assist with the interpretation of the results, pollution levels measured at other London monitoring sites are included in this report.

Nitrogen Dioxide

The 2015 annual mean nitrogen dioxide concentration measured at the automatic station on the roof of City Aviation House was 29.6 µg/m^3 (microgrammes per cubic metre); a slightly lower concentration, 25.8 µg/m^3, was measured at the Newham Dockside site. The annual mean objective (40 µg/m^3) was not exceeded at either site in 2015.

There were no exceedences of the 1-hour mean objective value (200 µg/m^3) at either site, the objective was therefore achieved. At both sites, all of the 1-hour mean concentrations fell into the "Low" pollution band.

Annual mean concentrations of nitrogen dioxide at other background and roadside sites elsewhere in London over this period ranged from 19.6 to 45.1 µg/m^3. The 1-hour mean concentrations over the monitoring period show similar patterns at all seven monitoring sites. There was a good correlation between observed peaks at the Airport sites and other London sites, suggesting that these occurrences were principally due to regional sources and changing weather conditions that affect the dispersion and dilution of pollutant emissions.

The annual mean nitrogen dioxide concentrations measured at the diffusion tube sites ranged from 21 to 34 µg/m^3 compared with the objective value of 40 µg/m^3. There were no measured exceedences of the air quality objective. As measured concentrations are well below 60 µg/m^3, it is highly unlikely that the 1-hour mean objective was exceeded.

Fine Particles (PM_{10})

The annual mean PM_{10} concentration measured at the automatic station on the roof of City Aviation House was 20.3 µg/m^3. This compares with the objective value of 40 µg/m^3. There were three recorded exceedences of the 24-hour mean objective (compared with the 35 exceedences allowed in a calendar year). The majority of the 24-hour mean concentrations were classified as “Low” (99.2%), with 24-hour mean concentrations classified as “Moderate” for the remaining 0.8% of the time. There were no 24-hour mean concentrations within the ‘High and ‘Very High’ pollution bands.

24-hour mean concentrations of PM_{10} at other background sites in London over this period showed a similar pattern to those seen at the Airport site. There was a good correlation between observed peaks at the Airport site and other London sites, suggesting that these occurrences were principally due to regional sources and changing weather conditions that affect the dispersion and dilution of pollutant emissions.

1 Introduction

1.1 This document represents the 2015 Annual Report for the Air Quality Measurement Programme, operated on behalf of London City Airport (LCA).

1.2 Approval to expand Airport operations to 120,000 noise-factored aircraft movements per annum was granted in July 2009. A legal agreement between London City Airport and the London Borough of Newham associated with this planning approval sets out a number of obligations, one of which relates to an Air Quality Measurement Programme (AQMP).

1.3 The AQMP, as defined within the legal agreement, comprises an automatic air quality monitoring station situated on the roof of City Aviation House, and a network of nitrogen dioxide diffusion tubes, situated in and around the Airport site. In addition, London City Airport commissioned a second automatic air quality monitoring station at a site adjacent to the Newham Dockside building in September 2008. The operation of this additional site falls outside the AQMP, but the data are included in this Annual Report for the sake of completeness.

1.4 The monitoring programme is managed by Air Quality Consultants Ltd. (AQC) on behalf of London City Airport. Service support for the automatic monitoring stations is provided by Enviro Technology Services plc, with Ricardo Energy & Environment providing independent audit checks.

1.5 Chapter 2 of this Report sets out the various standards and guidelines against which air pollution concentrations should be compared. Chapter 3 describes the monitoring methodology and provides a summary of the measured concentrations in 2015 with respect to these criteria, and compares the measured concentrations with other local monitoring sites. Chapter 4 then provides some analysis of the monitoring data with respect to trends and source contributions.

2 Assessment Criteria

2.1 The Government has established a set of air quality standards and objectives to protect human health. The 'standards' are set as concentrations below which effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of an individual pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of economic efficiency, practicability, technical feasibility and timescale. The objectives for use by local authorities are prescribed within the Air Quality Regulations, 2000 (Stationery Office, 2000) and the Air Quality (England) (Amendment) Regulations 2002 (Stationery Office, 2002). The relevant objectives for this report are provided in Table 1.

Table 1: Relevant Air Quality Objectives

Pollutant	Time Period	Objective / Value
Nitrogen Dioxide	1-hour mean	200 μg/m^3 not to be exceeded more than 18 times a year
	Annual mean	40 μg/m^3
Fine Particles (PM_{10})[a]	24-hour mean	50 μg/m^3 not to be exceeded more than 35 times a year [b]
	Annual mean	40 μg/m^3

[a] Measured by the gravimetric method.

[b] Equivalent to a 90th percentile of 24-hour mean concentrations of 50 μg/m^3.

2.2 The objectives for nitrogen dioxide and PM_{10} were to have been achieved by 2005 and 2004 respectively, and continue to apply in all future years thereafter.

2.3 The European Union has also set limit values for both nitrogen dioxide and PM_{10}. Achievement of these values is a national obligation rather than a local one, and compliance can only be determined by the national monitoring network operated by Defra. The limit values for nitrogen dioxide are the same levels as the UK objectives, and were to be achieved by 2010 (Stationery Office, 2007). The limit values for PM_{10} are also the same level as the UK statutory objectives, and were to be achieved by 2005.

2.4 In addition to the objectives, Defra has established a set of descriptors for the 1-hour mean values for nitrogen dioxide, classifying the concentrations in an index from 1 to 10 and thus labelling the levels as Low, Moderate, High and Very High (Defra, 2011). The banding is referred to as the Daily Air Quality Index (DAQI). The DAQI criteria are set out in Table 2.

Table 2: DAQI Bandings (µg/m^3)

Band	Index	Nitrogen Dioxide 1-hour Mean (µg/m^3)	PM_{10} 24-hour mean (µg/m^3) [a]
Very High	**10**	601 or more	101 or more
High	**9**	535 – 600	92 – 100
	8	468 – 534	84 – 91
	7	401 – 467	76 – 83
Moderate	**6**	335 – 400	67 – 75
	5	268 – 334	59 – 66
	4	201– 267	51 – 58
Low	**3**	135 – 200	34 – 50
	2	68 – 134	17 – 33
	1	0 – 67	0 – 16

[a] Reference equivalent. 24-hour values are midnight to midnight.

3 Monitoring Methodology and Results

Automatic Monitoring Stations

3.1 Monitoring was carried out at two automatic stations as follows:

- City Aviation House (LCA-CAH): nitrogen dioxide and PM_{10}
- Newham Dockside (LCA-ND): nitrogen dioxide

3.2 The locations of the two automatic sites are shown in Figure 1.

3.3 The LCA-CAH automatic monitoring station measures PM_{10} using a Rupprecht and Patashnick TEOM 1400 Particulate Monitor, whilst both automatic stations measure nitrogen dioxide using M200E TAPI chemiluminescence analysers. The data are stored as 15-minute mean concentrations. Before further processing and ratification the raw PM_{10} concentrations have been adjusted to a "reference-equivalent" concentration using the Volatile Correction Model (VCM) as recommended by Defra (2009). This adjusts the TEOM data using the "purge" concentration measured by an FDMS analyser, assuming this represents the volatile component that has been lost. A "VCM web portal" has been established that allows this correction to be derived from the mean of up to three nearby FDMS analysers in the national network.

3.4 Independent site audits, conducted by Ricardo Energy & Environment, confirmed that both automatic monitoring stations were operating above the minimum standards set for the national networks operated by Government. Audits were carried out on 2nd March 2015, 27th August 2015 and 29th February 2016 and have been taken into account in producing the fully ratified dataset.

3.5 Ratification of the data has been based on calibration factors determined from the calibration reports, along with visual examination of the data and comparison with monitoring data from nearby national network background sites (Bexley, Bloomsbury and Eltham) (Defra, 2015). Any erroneous data have been flagged and removed from subsequent analysis. 1-hour, 24-hour, and annual mean concentrations have then been calculated.

3.6 Pollution concentrations measured at both automatic Airport monitoring stations are associated with a wide range of sources at the local, regional, national and international scales. On occasions when pollution levels rise, these higher levels are often observed across the whole of London as a "regional pollution episode". To assist with the interpretation of the results, comparable data have been obtained from the national Air Quality Archive (Defra, 2015) for three background sites, Bexley, Bloomsbury and Eltham, and from the Air Quality England website (AQE, 2015) for two sites within the London Borough of Newham at Wren Close, Canning Town (background) and Cam Road, Stratford (roadside).

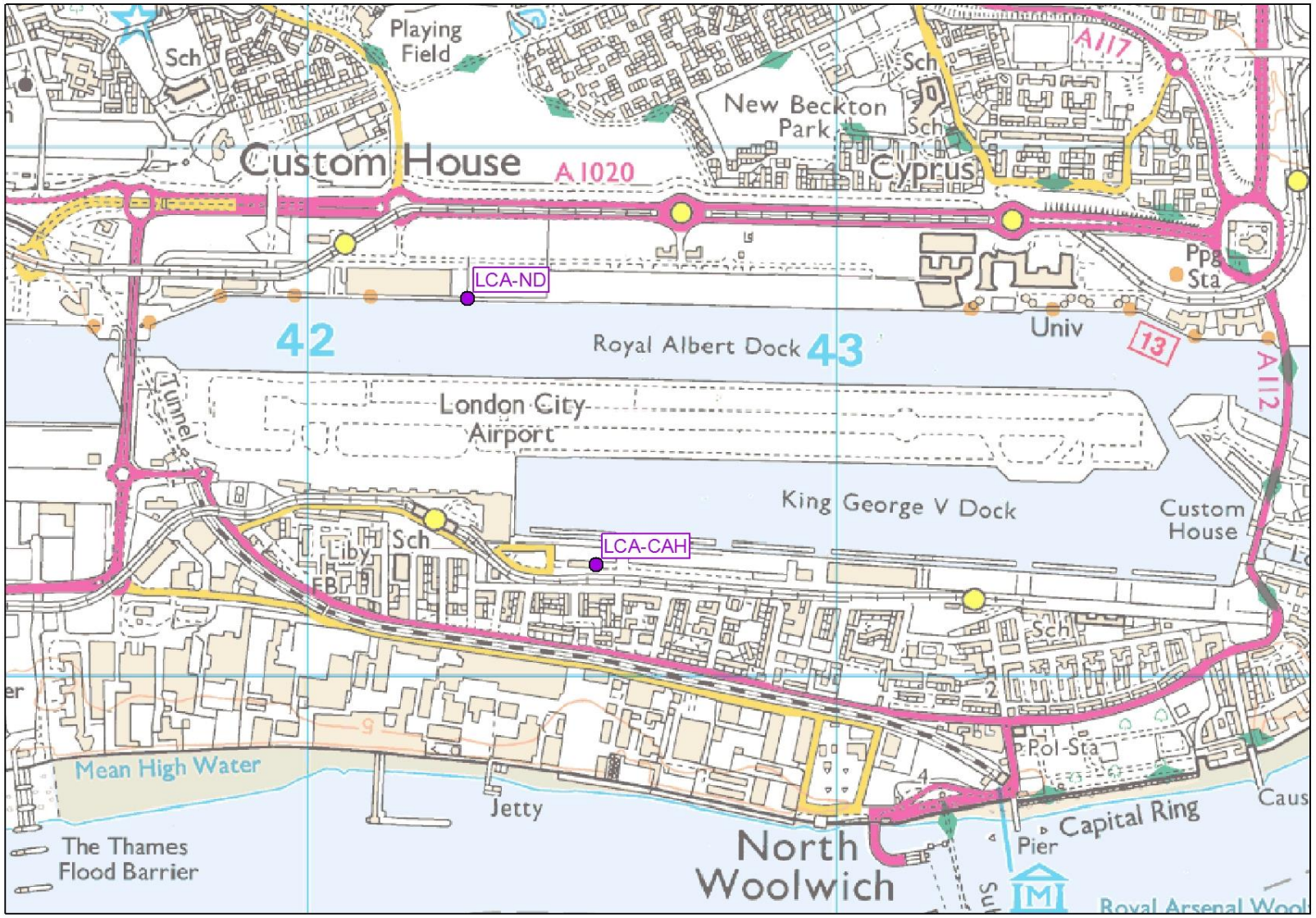

Figure 1: Automatic Monitoring Locations (red dots).

Nitrogen Dioxide

3.7 The 2015 nitrogen dioxide results for the LCA-CAH and LCA-ND automatic monitoring stations are summarised in Table 3. Data capture[1] for LCA-CAH and LCA-ND was 93.5% and 87.4%, respectively. The annual mean concentration did not exceed the objective of 40 µg/m^3 at either site. The 1-hour mean objective was also not exceeded and there were no 1-hour mean concentrations above the objective value (200 µg/m^3) recorded at either site.

Table 3: Nitrogen Dioxide (NO_2) Data Summary for LCA-CAH and LCA-ND, 2015[a]

Metric	LCA-CAH	LCA-ND	Objectives
	NO_2	NO_2	
Maximum 1- Hour Mean	196 µg/m^3	149 µg/m^3	-
No. 1-Hour Mean > 200 µg/m^3	0	0	200 µg/m^3; no more than 18 exceedences
Annual Mean	29.6 µg/m^3	25.8 µg/m^3	40 µg/m^3
Data Capture	93.5%	87.4%	-

[a] Nitrogen oxides concentrations are provided in Appendix 1.

3.8 Table 4 shows the distribution of the 1-hour mean values into the different pollution bands (DAQI). At both sites, all measured 1-hour mean nitrogen dioxide concentrations fell into the 'Low' pollution band during 2015.

Table 4: DAQI Bandings for Nitrogen Dioxide, 2015

Band	Index	LCA-CAH	LCA-ND
Very High [a]	**10**		
High [a]	**9**		
	8		
	7		
Moderate [a]	**6**		
	5		
	4		
Low [a]	**3**	5	1
	2	450	280
	1	7732	7379

[a] Number of 1-hour values

3.9 Nitrogen dioxide concentrations for five monitoring sites across London in 2015 are summarised in Table 5. These sites range from central London (Bloomsbury) to outer London (Bexley). The

[1] It is inevitable that a small amount of data will be "lost" in each year due to routine downtime for calibrations and site servicing.

measured annual mean concentrations at London City Airport (29.6 µg/m^3 at LCA-CAH and 25.8 µg/m^3 at LCA-ND) were lower than those at Canning Town, Bloomsbury and Stratford (30.6 µg/m^3, 45.1 µg/m^3 and 36.9 µg/m^3 respectively), and higher than those measured at Eltham and Bexley (19.6 µg/m^3 and 20.9 µg/m^3, respectively). This is broadly consistent with the location of London City Airport between the areas of high concentrations in central London and lower concentrations towards the outskirts. The maximum 1-hour mean concentrations recorded at both sites at London City Airport were the same as those recorded at all of the monitoring sites, in that there were no exceedences of the 1-hour mean objective.

Table 5: Nitrogen Dioxide (NO_2) Data Summary for London Monitoring Sites, 2015[a]

Metric	Background Site				Roadside Site
	Bexley	Bloomsbury	Eltham	Canning Town	Stratford
Max. 1-hr Mean (µg/m^3)	91.2	135.0	97.9	158.7	133.9
No. 1-hr >200 µg/m^3	0	0	0	0	0
Annual Mean (µg/m^3)	20.9	45.1	19.6	30.6	36.9
Data Capture (%)	79.3	92.8	99.0	94.1	99.0

[a] Includes provisional data. Nitrogen oxides concentrations are provided in Appendix 1.

Particulate Matter PM_{10}

3.10 The 2015 PM_{10} results for the LCA-CAH automatic monitoring station are summarised in Table 6. Data capture was 99.9%. The recorded annual mean concentration (20.3 µg/m^3) was well below the objective of 40 µg/m^3. There were three measured exceedences of the 24-hour mean objective value of 50 µg/m^3 compared with the 35 exceedences that are allowed. In addition, the 90th percentile of 24-hour mean concentrations (30.9 µg/m^3) was well below 50 µg/m^3.

Table 6: PM_{10} Data Summary for LCA-CAH, 2015

Metric	TEOM, VCM-corrected	PM_{10} Objectives
	PM_{10}	
Maximum 24-hour Mean	65.8 µg/m^3	-
No. 24-Hour Means >50 µg/m^3	3	50 µg/m^3; no more than 35 exceedences
90th Percentile	30.9 µg/m^3	50 µg/m^3
Annual Mean	20.3 µg/m^3	40 µg/m^3
Data Capture	99.9%	-

3.11 Table 7 shows the distribution of the 24-hour mean values into the different pollution bands (DAQI). The majority of 24-hour measured PM_{10} concentrations fell into the 'Low' pollution band (99.2%) during 2015; there were three, 24-hour mean concentrations within the 'Moderate' pollution band (0.8%). There were no 'High' or 'Very High' events.

Table 7: DAQI Bandings for PM_{10}, 2015

Band	Index	LCA-CAH
Very High [a]	10	
High [a]	9	
	8	
	7	
Moderate [a]	6	
	5	3
	4	
Low [a]	3	25
	2	213
	1	123

[a] Number of 24-hour mean values.

3.12 PM_{10} concentrations for six sites across London in 2015 are summarised in Table 8. These sites range from central London (Bloomsbury and Eltham) to outer London (Bexley), with two in east London (Stratford). The measured annual mean concentration at London City Airport (20.3 µg/m^3) was lower than that at the sites in east London (Stratford 24.6 µg/m^3 and Canning Town 21.5 µg/m^3) and higher than that measured at Bexley (17.8 µg/m^3 using VCM-corrected TEOM, 15.0 µg/m^3 using FDMS), Bloomsbury (19.7 µg/m^3) and Eltham (16.1 µg/m^3). The number of 24-hour mean exceedences of 50 µg/m^3 was the same as that measured at Eltham and Bexley (TEOM), lower than that measured at Stratford, Canning Town and Bloomsbury, and higher than that measured at Bexley (FDMS).

Table 8: PM_{10} Data Summary of Background London Monitoring Sites, 2015[a]

	Background Sites					Roadside Site
	Bexley (TEOM)	Bexley (FDMS)	Bloomsbury (FDMS)	Eltham (FDMS)	Canning Town (FDMS)	Stratford (FDMS)
Maximum 24-hr mean (µg/m^3)	66.9	67.5	72.8	68.1	69.9	77.3
Annual Mean (µg/m^3)	17.8	15.0	19.7	16.1	21.5	24.6
No. 24-hr mean >50 µg/m^3	3	2	6	3	5	13
90th Percentile	30.1	27.9	33.6	26.4	32.6	36.5
Data Capture (%)	94.1	90.1	72.1	97.2	71.7	99.1

[a] All values are reference equivalent. All data, except where stated, are reported as VCM-corrected TEOM concentrations.

Nitrogen Dioxide Diffusion Tube Network

3.13 London City Airport also operates a network of passive diffusion tube samplers for nitrogen dioxide. The intent of this network is to establish the wider spatial pattern of nitrogen dioxide concentrations in the area surrounding the Airport. The locations of the monitoring sites are shown in Figure 2, and are described in Table 9; grid references and the monthly mean data are provided in Appendix 3. The diffusion tubes are exposed for approximately 4-week intervals. They are supplied and analysed by Gradko International Ltd., and are prepared using the 20% TEA in water method.

3.14 The diffusion tubes record monthly mean concentrations, which have been averaged to give the annual mean. The results cannot therefore be directly compared with the 1-hour mean objective. However, measurements across the UK have shown that the 1-hour mean nitrogen dioxide objective is unlikely to be exceeded where the annual mean concentration is below 60 $\mu g/m^3$ (Defra, 2009).

Table 9: Description of Diffusion Tube Monitoring Sites [a]

Location	Site ID
Lamp post at top of Parker Street, adjacent to housing	LCA 01
Lamp post on Camel Road, adjacent to nearest property on Hartmann Street	LCA 02
Lamp post on access road in Silvertown Quay. Approx. 36 metres from kerbside of main road	LCA 03
Lamp post at waterfront to east end of Newham Dockside	LCA 04
Lamp post on Straight Road, at kerbside	LCA 05
Lamp post on pedestrian walkway adjacent to nearest housing at Gallions Way	LCA 06
Landing Lights	LCA 07
Lamp post on Brixham Street	LCA 08
City Aviation House (triplicate tubes)	LCA 09
Jet Centre – airside	LCA 10
Lamp post at waterfront, eastern end of the University of East London	LCA 11
ILS, to north of runway and south of Royal Albert Dock	LCA 12
Lamp post at north west corner of Newham Dockside	LCA 13
Lamp post on waterfront at western end of Newham Dockside	LCA 14
Lamp post at kerbside (approx 1 m) of Royal Albert Way	LCA 15
Waterfront, approx 180 m east of Newham Dockside	LCA 16
Newham Dockside analyser (duplicate – as of August 2015)	LCA 18
Waterfront, approximately 460m east of Newham Dockside	LCA 19

[a] LCA-17 was discontinued in January 2012 as the lamppost on which diffusion tubes were deployed was removed.

3.15 It is important to note that not all of these monitoring sites represent relevant public exposure for annual mean concentrations of nitrogen dioxide; thus the objectives are not strictly applicable at all of these sites. For instance, the sites at Landing Lights (LCA 07), the Jet Centre (LCA 10) and the ILS (LCA 12) are located on land that is not generally accessible by the public, or is owned by the Airport. The sites at LCA 04 (at the waterfront of Newham Dockside), LCA 11 (at the waterfront of the University of East London) and LCA 13, 14, 15 and 16 (in the vicinity of Newham Dockside and Royal Albert Way) would also not represent relevant exposure for annual mean concentrations according to the criteria defined in LAQM.TG(09)[2], but are relevant for the 1-hour mean objective. Site LCA 03 is located within an area of land allocated for redevelopment at Silvertown Quay, but public access is currently prohibited. These sites have been included in the study to better understand the spatial pattern of nitrogen dioxide concentrations around the Airport.

3.16 Diffusion tubes are known to show systematic bias in relation to automatic (reference) monitors. For this reason, a co-location study has been carried out, with triplicate tubes exposed alongside the inlet to the automatic monitor at LCA-CAH, and duplicate tubes exposed in close proximity to the inlet of the LCA-ND automatic monitor (from August 2015). Comparison of the matched period results shows that the diffusion tubes were over-reading by an average of 16.6%. An adjustment factor of 0.858 has therefore been applied to all diffusion tube results to ensure that they give the best representation of true concentrations (see Appendix 3). The results from the triplicate tubes at LCA-CAH and the duplicate tubes at LCA-ND indicate overall "good" precision (±5.4% and ±10.1%) in 2015, see Appendix 4 (Defra, 2009).

3.17 The bias-adjusted results are summarised in Table 10, and are also shown in Figure 3. The results show that the annual mean objective of 40 µg/m^3 was achieved at all diffusion tube monitoring locations during 2015. All measured annual mean nitrogen dioxide concentrations were well below 60 µg/m^3, and it is thus unlikely that the 1-hour mean objective was exceeded at any location.

[2] Defra Technical Guidance Note LAQM.TG(09) suggests that in the case of the annual mean objective, a relevant location might be where a member of the public would be exposed for a cumulative period of 6 months in a year.

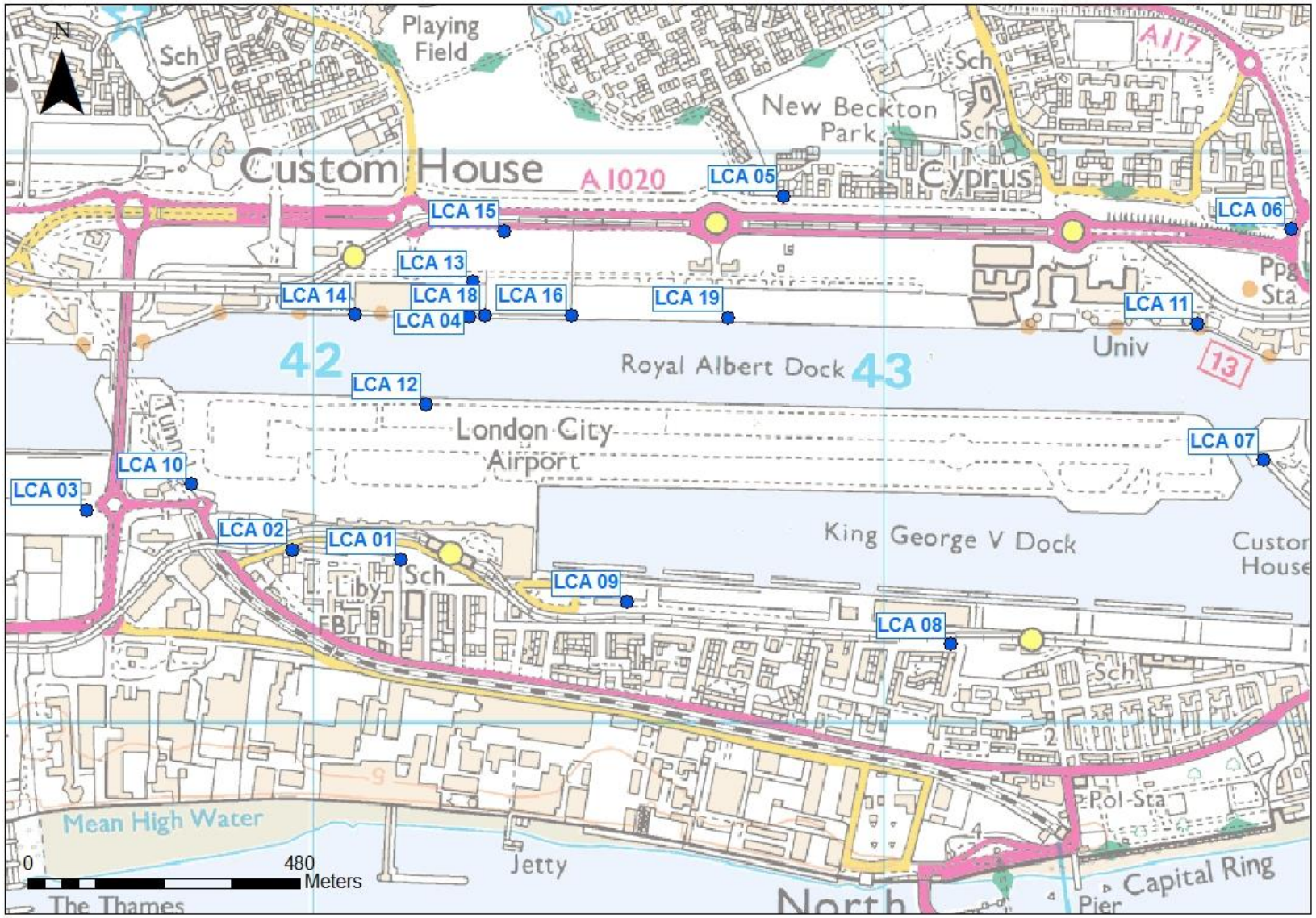

Figure 2: Diffusion Tube Monitoring Locations (blue dots)

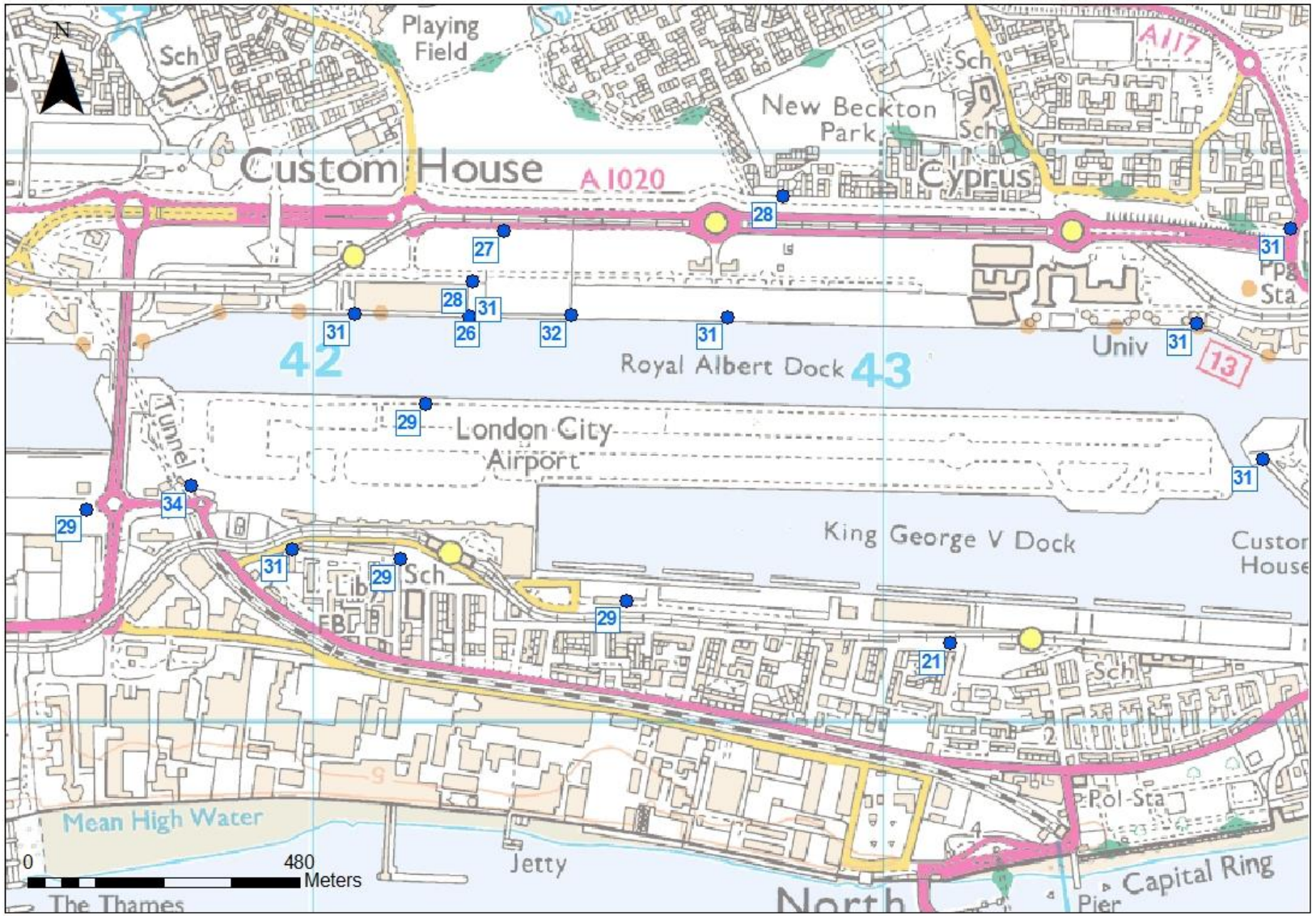

Figure 3: Nitrogen Dioxide Diffusion Tube Results, 2015 (µg/m^3)

Table 10: Diffusion Tube Data Summary for London City Airport, 2015 (Adjusted for Bias)

Site ID	Adjusted Value (µg/m^3) [a b]
LCA 01	29.1
LCA 02	31.3
LCA 03	29.3
LCA 04	30.6
LCA 05	27.8
LCA 06	31.2
LCA 07	31.4
LCA 08	21.1
LCA 09	28.8
LCA 10	34.0
LCA 11	31.3
LCA 12	28.5
LCA 13	28.4
LCA 14	31.1
LCA 15	26.5
LCA 16	32.4
LCA 18	26.4
LCA 19	30.5

[a] Data have been adjusted using a local bias adjustment factor for 2015 of 0.858. The co-location studies are carried out at LCA-CAH using triplicate tubes and at LCA-ND with a single tube located at the automatic monitors. Diffusion tubes were exposed for the period between 9th January 2015 to 13th January 2016.

4 Data Analyses

4.1 This chapter provides analyses of the data, including time series, trends and source contributions.

Time Series

4.2 The measured 1-hour mean nitrogen dioxide concentrations at LCA-CAH and LCA-ND, and at Bexley, Bloomsbury, Eltham, Canning Town (Wren Close) and Stratford (Cam Road), are shown as a time series in Figures 4 and 5 respectively.

4.3 The concentrations over the monitoring period show similar patterns at all seven monitoring sites. The concurrence of periods with elevated concentrations at all sites suggests that these episodes were due to regional changes in concentrations. Figure 4 shows two brief, elevated pollution periods (on 27th February and 1st July) at LCA-CAH and one brief, elevated pollution period at LCA-ND (on 29th April); these are likely to be local pollution sources at the individual sites, as there is no concurrent periods at the other monitoring sites across London or at the other LCA site.

4.4 The measured daily mean PM_{10} concentrations at LCA-CAH and at the two Bexley monitors, Bloomsbury, Eltham, Canning Town (Wren Close) and Stratford (Cam Road), are shown in Figures 6 and 7 respectively. Once again, the analysis suggests that periods of high pollution were principally due to regional changes in concentrations.

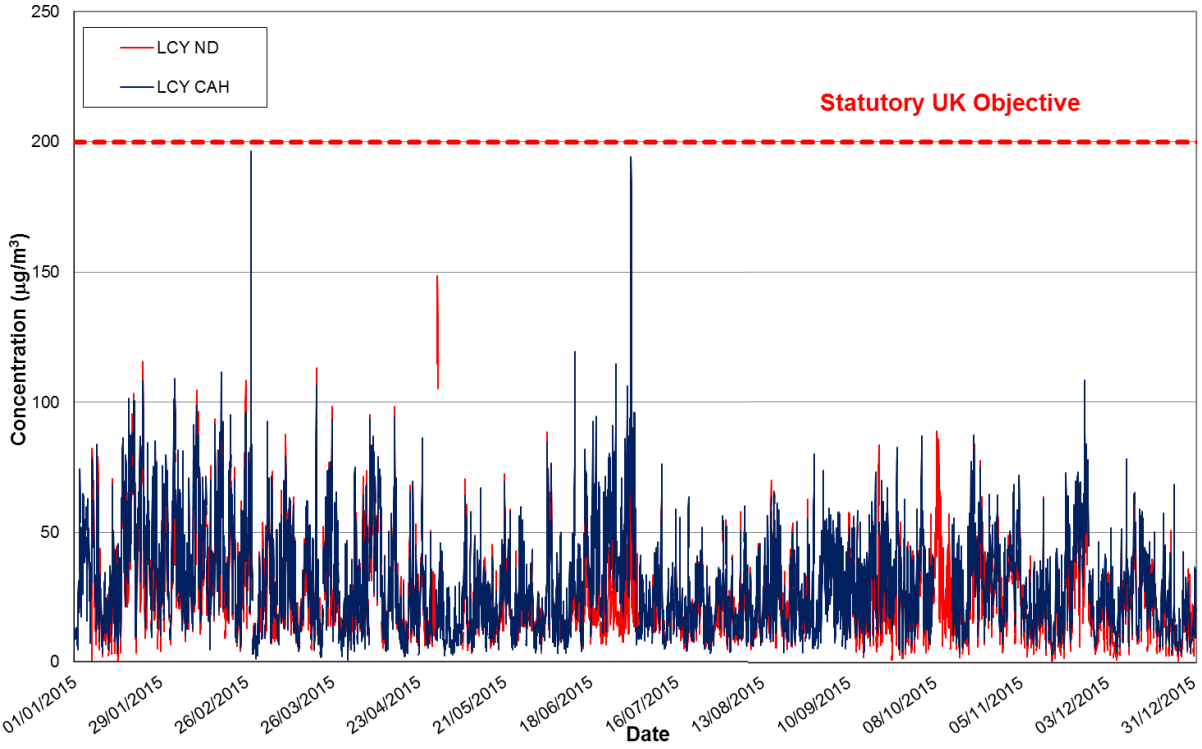

Figure 4: 1-Hour Mean Nitrogen Dioxide Concentrations at London City Airport, 2015

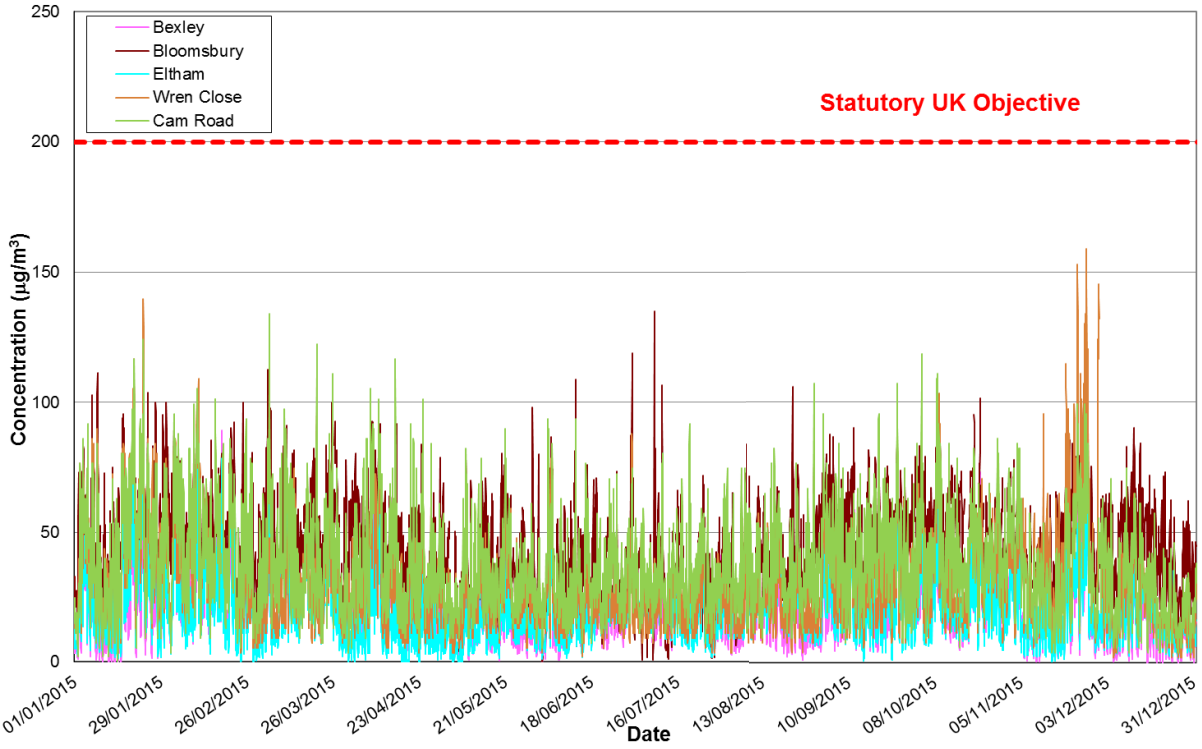

Figure 5: 1-Hour Mean Nitrogen Dioxide Concentrations at London Monitoring Sites, 2015

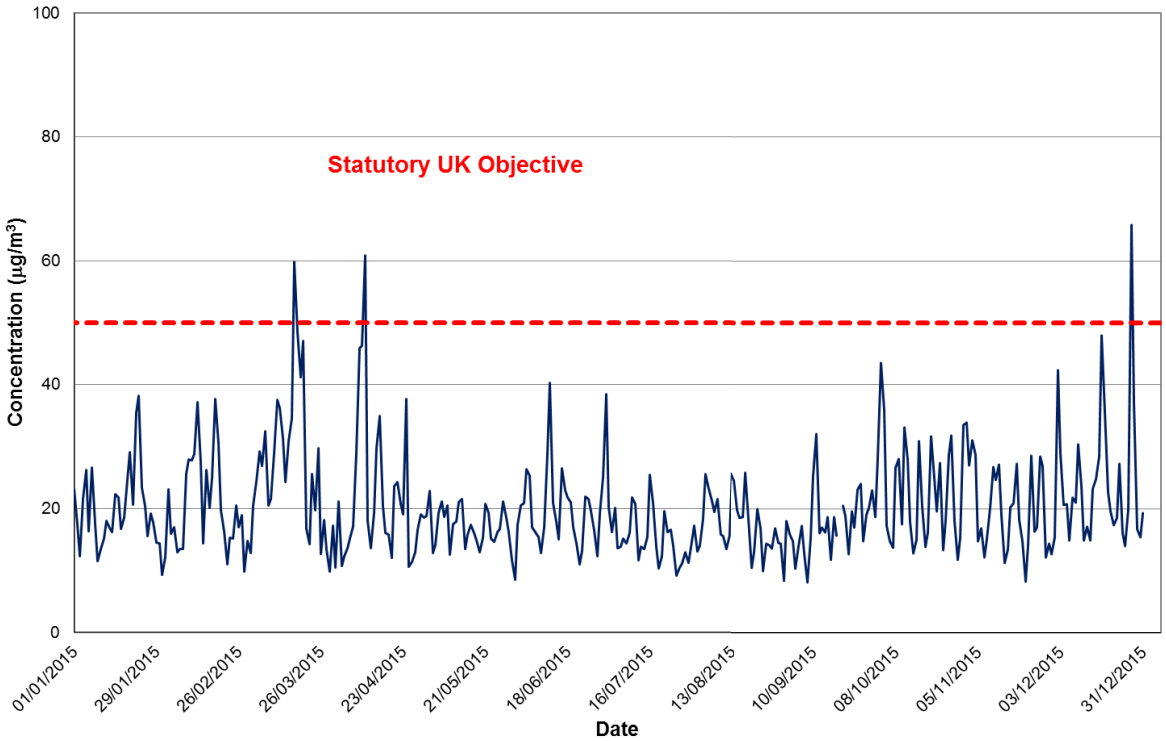

Figure 6: Daily Mean PM_{10} Concentrations at London City Airport (LCA-CAH), 2015

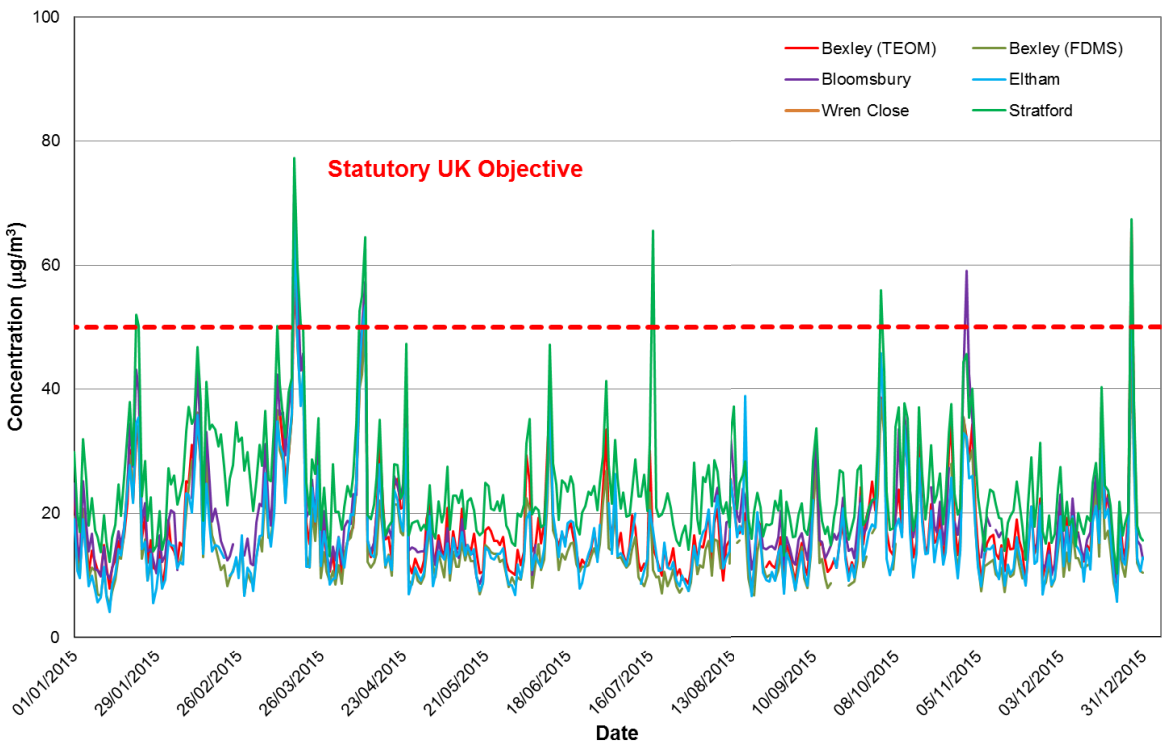

Figure 7: Daily Mean PM_0 Concentrations at London Monitoring Sites, 2015

Trends in Pollutant Concentrations

4.5 The automatic station at the LCA-CAH site has been in operation since September 2006 and that at LCA-ND since September 2008. It is therefore appropriate to examine whether there are any trends in the measured pollutant concentrations over time.

4.6 Figure 8 shows the trends in measured annual mean nitrogen dioxide concentrations at LCA-CAH and LCA-ND (NO_2 only[3]) and at the five other monitoring locations identified for the regional evaluation of pollution episodes (Bexley, Bloomsbury, Eltham, Canning Town and Stratford). From a visual examination of Figure 8, there appears to be a downward trend at all sites, but to varying degrees and less so at some monitoring sites than others.

4.7 Because of the interest in trends, a more detailed analysis has been carried out, focusing on monitoring sites in the east London area. The results of the detailed analysis are provided in Appendix 5. In summary, there is a statistically significant downward trend at most east-London monitoring sites for both nitrogen dioxide and nitrogen oxides (NOx), including LCA-CAH and LCA-ND.

4.8 The trends in annual mean PM_{10} concentrations are shown in Figure 9, for the LCA-CAH site and two other monitoring locations, for which nine years data are available. There is no clear trend between 2007 and 2015, with concentrations remaining largely unchanged over this period.

[3] For the period 2009 to 2015 only.

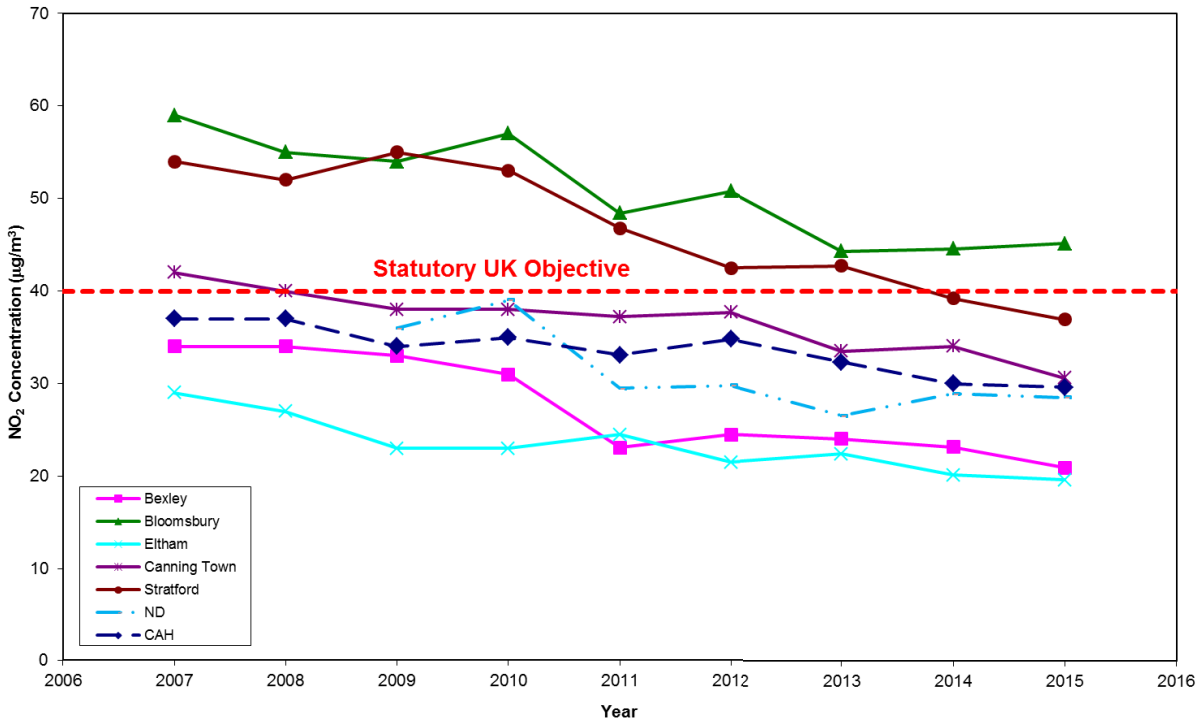

Figure 8: Annual Mean Nitrogen Dioxide Concentrations, 2007 – 2015 ($\mu g/m^3$)

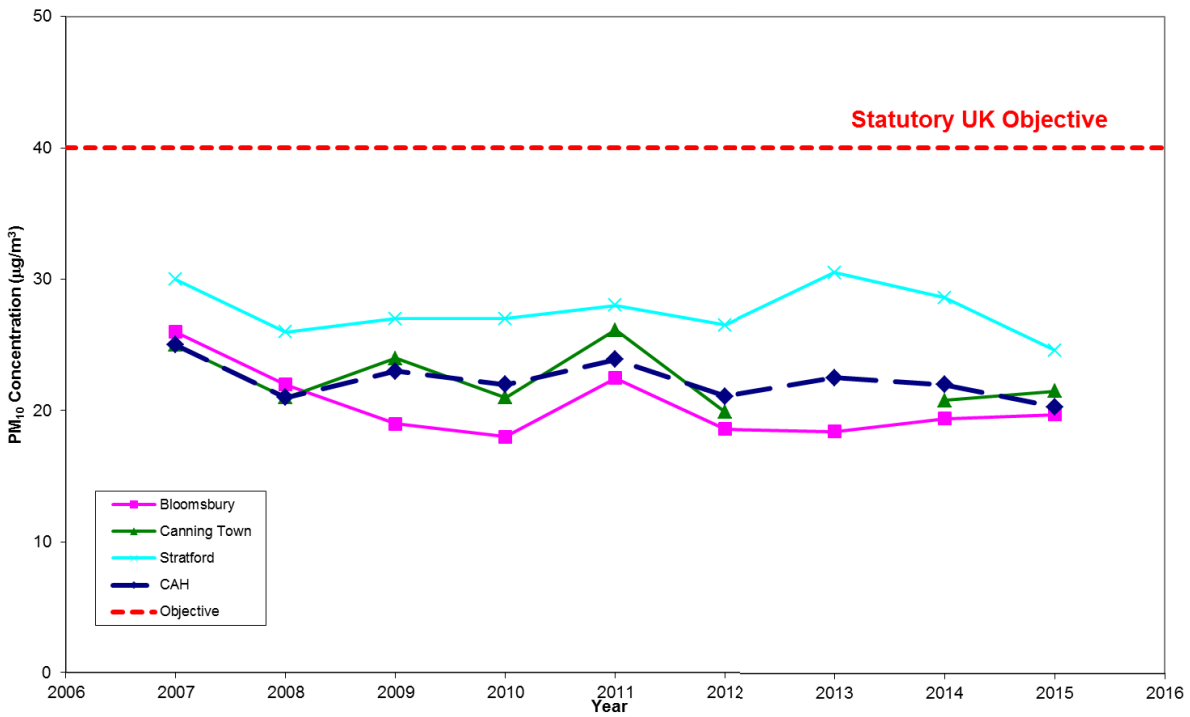

Figure 9: Annual Mean PM_{10} Concentrations, 2007 – 2015 ($\mu g/m3$) [a]

[a] The Canning Town TEOM was decommissioned in 2013, and re-commissioned again in 2014.

Bivariate Pollution Roses

4.9 Pollution roses are a useful technique for exploring the influence of different sources of air pollution at a monitoring site. Bivariate pollution roses have been prepared using the "Openair" software[4]. These bivariate roses process average pollution concentration data by both wind direction and wind speed. They provide a powerful tool in identifying source contributions to measured concentrations at monitoring sites. The concentrations are shown by colour shading, with the distance from the centre point representing increasing wind speed.

4.10 It is known from both modelling studies and the analysis of empirical data that emissions from different source types behave differently in low and high wind speed conditions. For emissions from ground-level sources (such as road traffic), concentrations are highest during low wind speeds, and decrease rapidly with increasing wind speed (due to greater dilution and dispersion). In contrast, emissions released from elevated (e.g. chimney) sources, give rise to higher concentrations at higher wind speeds, as the plume is more likely to come down to ground close to the source. Emissions from the buoyant plumes of jet aircraft engines tend to behave in a similar manner to elevated sources. Carslaw *et al* (2006) showed how these bivariate plots could be used to identify the contribution of aircraft emissions to measured concentrations at Heathrow Airport.

4.11 Figure 10 shows bivariate pollution roses for NOx concentrations in 2015 at the LCA-CAH and LCA-ND sites, using wind data from the meteorological station at London City Airport. During low wind speeds, dispersion is reduced and concentrations from ground-level sources are higher. The pattern at both monitoring sites is that the highest NOx concentrations occur during low wind speeds (i.e. towards the centre of the rose), indicating that the highest concentrations are associated with ground-level source releases (the wind-speed scale runs from 0 to 20 m/s, with the concentration scale running from 0 to around 100 µg/m^3). These higher concentrations are not associated with any particular wind direction. There is also some indication that emissions from the apron area are making a small contribution at both sites, with these contributions being associated with moderate wind speeds (especially to the northwest for LCA-CAH and less so to the south and west for LCA-ND). The association with higher wind speeds is suggestive of emissions from an elevated buoyant source reflecting emissions from aircraft engines.

[4] www.openair-project.org/about_us.php

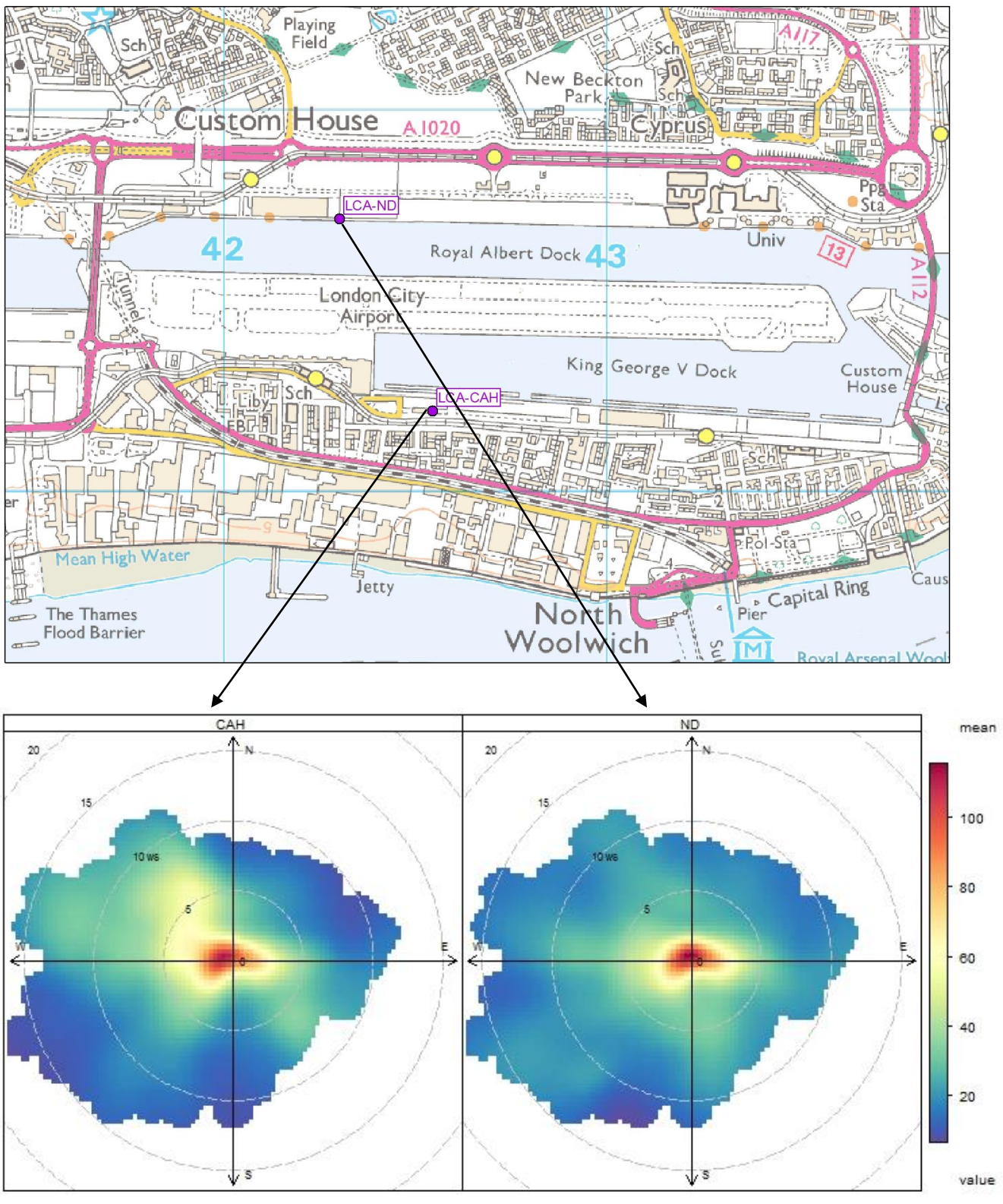

Figure 10: Bivariate Pollution Roses at LCA-CAH and LCA-ND Sites, 2015 (NO_x, µg/m^3)

5 References

Carslaw, D.C., Beevers, S.D., Ropkins, K and Bell, M.C. (2006). Detecting and quantifying aircraft and other on-airport contributions to ambient nitrogen oxides in the vicinity of a large international airport. *Atmos Environ*, 40/28 pp 5424-5434.

Carslaw, D., Beevers, S., Westmoreland, E. and Williams, M. (2011) Trends in NOx and NO_2 emissions and ambient measurements in the UK.

Defra, 2009. Review & Assessment: Technical Guidance LAQM.TG(09).

Defra (2011a) *Notification of changes to the Air Quality Index (Letter 1st December 2011)*, Defra.

Defra, 2011b. Precision and Accuracy Spreadsheet Tool Available at http:// http://laqm.defra.gov.uk/bias-adjustment-factors/local-bias/AEA_DifTPAB_v04.xls

Defra, 2016, Defra Air Quality website. Available at: http://uk-air.defra.gov.uk/

KCL, 2016. London Air Quality Network. www.londonair.org.uk

Stationery Office, 2000. Air Quality Regulations, 2000, Statutory Instrument 928.

Stationery Office, 2002. The Air Quality (England) (Amendment) Regulations 2002. Statutory Instrument 3043.

Stationery Office, 2007. The Air Quality Standards Regulations, 2007 (No. 64).

6 Glossary

Exceedence	A period of time where the concentration of a pollutant is greater than the appropriate air quality objective.
FDMS	Filter Dynamics Monitoring System.
LAQN	London Air Quality Network.
LCA-CAH	London City Airport – City Aviation House monitoring site.
LCA-ND	London City Airport – Newham Dockside monitoring site
$\mu g/m^3$	Microgrammes per cubic metre.
NO_2	Nitrogen dioxide.
NO_x	Nitrogen oxides (taken to be NO_2 + NO).
NO	Nitric oxide.
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date, taking into account costs, benefits, feasibility and practicality. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides.
PM_{10}	Small airborne particles, more specifically particulate matter less than 10 micrometers in aerodynamic diameter.
Standards	A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal.
TEA	Triethanolamine – absorbent for nitrogen dioxide used in diffusion tubes.
TEOM	Tapered Element Oscillating Microbalance.
VCM	Volatile Correction Model.

A1 Appendix 1 – Nitrogen Oxides Results

A1.1 Nitrogen oxides (NO_x) concentrations, which are essentially the sum of nitrogen dioxide and nitric oxide, are presented in Table A1.1 for the automatic monitoring stations at London City Airport and for five sites across London in Table A1.2.

Table A1.1: Nitrogen Oxides (NO_x) Data Summary for LCA-CAH and LCA-ND, 2015

Site	LCA-CAH	LCA-ND
Maximum 1-Hour Mean	517 µg/m^3	678 µg/m^3
Annual Mean	43.6 µg/m^3	42.6 µg/m^3
Data Capture	93.5%	87.5%

Table A1.2: Nitrogen Oxides (NO_x) Data Summary for London Monitoring Sites, 2015

Site	Bexley	Bloomsbury	Eltham	Canning Town	Stratford
Maximum 1-Hour Mean (µg/m^3)	446	480.4	584	738	692
Annual Mean (µg/m^3)	30.3	74.8	27.3	43.7	64.1
Data Capture %	79.3	98.5	99.0	95.9	99.0

A2 Appendix 2 – Diffusion Tube Data

A2.1 Raw monthly average diffusion tube data, along with the location details and monitoring periods, are presented in Table A2.1.

Table A2.1: Raw Monthly Diffusion Tube Data for 2015, Not Bias Adjusted (µg/m^3)

Site ID	Grid ref	09/01/15 to 30/01/15	30/01/15 to 27/02/15	27/02/15 to 08/04/15	08/04/15 to 07/05/15	07/05/15 to 04/06/15	04/06/15 to 07/07/15	07/07/15 to 07/08/15	07/08/15 to 08/09/15	08/09/15 to 01/10/15	01/10/15 to 06/11/15	06/11/15 to 10/12/15	10/12/15 to 13/01/16	Unadjusted Annual Mean	Data Capture (%)
LCA 01	542154, 180288	38.3	40.9	31.1	34.4	25.4	29.7	26.4	36.3	40.6	39.2	30.5	-	33.9	92%
LCA 02	541965, 180299	41.3	39.9	34.4		35.9	35.7	34.9	37.5	43.5	35.6	29.9	32.3	36.4	92%
LCA 03	541589, 180373	39.6	47.5	33.4	37.0	24.5	30.8	29.0	31.9	44.0	31.8	27.4	33.6	34.2	100%
LCA 04	542271, 180708	36.9	43.8	31.1	33.3	28.8	29.5	32.6	33.3	43.2	40.6	31.4	43.4	35.7	100%
LCA 05	542847, 180914	37.2	35.5	30.9	28.9	23.9	27.5	28.4	44.2	35.3	33.3	27.9	36.2	32.4	100%
LCA 06	543712, 180868	44.3	41.2	32.0	37.9	-	-	-	33.8	40.7	36.1	27.8	34.0	36.4	75%
LCA 07	543662, 180460	44.0	42.6	34.3	35.3	33.7	30.3	-	34.4	40.4	25.0	41.3	41.9	36.7	92%
LCA 08	543120, 180133	-	36.3	31.0	26.1	22.8	16.7	-	7.7	27.6	22.7	27.8	27.6	24.6	83%
LCA 09	542532, 180196	40.7	41.8	38.6	-	28.4	28.7	27.7	33.9	39.5	36.8	25.4	34.9	34.2	92%
		37.2	39.6	32.8	31.2	26.7	30.6	30.2	31.3	40.3	35.9	27.4	34.7	33.2	100%
		43.3	44.1	36.1	29.3	23.8	28.6	30.3	35.1	40.1	34.2	28.4	31.2	33.7	100%
LCA 10	541758, 180428	49.5	43.6	41.0	38.5	35.8	34.4	38.7	42.3	45.4	42.6	29.7	34.5	39.7	100%
LCA 11	543549, 180693	49.0	39.5	36.0	34.2	28.0	28.3	32.4	37.3	34.5	37.2	43.2	38.5	36.5	100%
LCA 12	542192, 180561	39.9	37.1	27.6	30.5	23.7	27.3	32.4	29.9	33.5	40.9	36.1	39.4	33.2	100%
LCA 13	542280, 180769	46.6	46.6	29.2	26.9	27.6	29.2	-	33.9	34.9	26.9	30.3	32.4	33.1	92%
LCA 14	542070, 180712	42.3	47.5	45.4	27.8	26.3	28.8	32.1	31.2	43.4	37.8	30.6	41.8	36.2	100%
LCA 15	542316, 180862	35.8	45.8	33.8	30.2	28.4	29.7	30.5	36.7	39.1	13.2	20.4	27.1	30.9	100%
LCA 16	542451, 180712	53.3	40.1	35.4	36.2	26.7	30.3	34.4	34.9	39.4	33.0	38.7	51.3	37.8	100%
LCA 18	542303, 180707	-	-	-	-	-	-	-	30.3	32.6	33.8	31.6	28.7	31.4	42%[a]
		39.2	35.4	29.9	30.7	26.4	26.4	26.3	29.4	28.8	25.5	30.7	36.9	30.5	100%
LCA 19	542728, 180705	38.1	37.7	32.2	31.2	26.7	28.2	30.0	36.9	41.8	35.6	40.5	47.8	35.6	100%

– not available [a] Duplicate tube added on 7th August 2015

A3 Appendix 3 – Bias Adjustment Factor for Diffusion Tubes

A3.1 Diffusion tubes are known to exhibit bias when compared to results from automatic analysers. Therefore diffusion tube results need to be adjusted to account for this bias. One of the main factors influencing diffusion tube performance is thought to be the laboratory that supplies and analyses the tubes. The diffusion tubes exposed at London City Airport are supplied and analysed by Gradko International Ltd. (20% TEA in water).

A3.2 In order to determine the bias exhibited by these tubes, studies are carried out using triplicate tubes co-located at LCA-CAH and a single tube at LCA-ND. All diffusion tube data presented in this report have been adjusted using the overall factor calculated from the data presented in Table A3.1, with the optimum relationship defined using orthogonal regression.

Table A3.1: Results of Diffusion Tube and Continuous Monitor Co-location Studies in 2015 [a]

	Diffusion Tube	Automatic	Adjustment Factor
LCA-CAH	30.8	29.5	0.878
LCA-ND	33.6	25.6	0.837
Overall Factor [b]			**0.858**

[a] Diffusion tubes were exposed for the period between 9th January 2015 to 13th January 2016. The automatic monitoring data correspond to this period.

[b] The overall factor has been determined using orthogonal regression.

A3.3 Table A3.2 presents the bias adjustment factors applied to the data for the last nine years.

Table A3.2: Previous Bias Adjustment Factors

Year	Factor
2007	0.764
2008	0.786
2009	0.717
2010	0.801
2011	0.738
2012	0.744
2013	0.771
2014	0.832
2015	0.858

A4 Appendix 4 – Diffusion Tube Precision

A4.1 Diffusion tube precision describes the ability of a measurement to be consistently reproduced, i.e. how similar the results of duplicate or triplicate tubes are to each other. It is an indication of how carefully the tubes have been handled in either the laboratory and/or the field. Tube precision is separated into two categories 'Good' or 'Poor' as follows: tubes are considered to have **'Good'** precision where the coefficient of variation (CV) of duplicate or triplicate diffusion tubes for eight or more periods during the year is less than 20%, and the average CV of all monitoring periods is less than 10%. Tubes are considered to have **'Poor'** precision where the CV of four or more periods is greater than 20% and/or the average CV is greater than 10%.

A4.2 Table A4.1 shows that for each of the twelve periods of monitoring at LCA-CAH there was 'Good' precision, with the average precision of <10% and none of the periods having a CV >20%. Overall, therefore, the precision of the diffusion tubes is 'Good', which is consistent with the performance of 20% TEA in water tubes supplied by Gradko International in other co-location studies (Defra, 2015).

Table A4.1: Precision of Triplicate Diffusion Tubes, LCA-CAH

Period	Start Date	End Date	Tube 1	Tube 2	Tube 3	Mean	Standard Deviation	CV	Tube Precision
1	09/01/15	30/01/15	40.7	37.2	43.3	40	3.1	8	Good
2	30/01/15	27/02/15	41.8	39.6	44.1	42	2.2	5	Good
3	27/02/15	08/04/15	38.6	32.8	36.1	36	2.9	8	Good
4	08/04/15	07/05/15	-	31.2	29.3	30	1.3	4	Good
5	07/05/15	04/06/15	28.4	26.7	23.8	26	2.4	9	Good
6	04/06/15	07/07/15	28.7	30.6	28.6	29	1.1	4	Good
7	07/07/15	07/08/15	27.7	30.2	30.3	29	1.5	5	Good
8	07/08/15	08/09/15	33.9	31.3	35.1	33	1.9	6	Good
9	08/09/15	01/10/15	39.5	40.3	40.1	40	0.4	1	Good
10	01/10/15	06/11/15	36.8	35.9	34.2	36	1.3	4	Good
11	06/11/15	10/12/15	25.4	27.4	28.4	27	1.5	6	Good
12	10/12/15	13/01/16	34.9	34.7	31.2	34	2.1	6	Good
Average CV								**5**	**-**

A4.3 Table A4.2 shows that for four of the five periods[5] of monitoring at LCA-ND there was 'Good' precision; one of the periods having a CV 20%. The average precision across the five months was 10%. Overall, the precision of the diffusion tubes is 'Good', which is consistent with the performance of 20% TEA in water tubes supplied by Gradko International in other co-location studies (Defra, 2015).

Table A4.2: Precision of Duplicate Diffusion Tubes, LCA-ND

Period	Start Date	End Date	Tube 1	Tube 2	Mean	Standard Deviation	CV	Tube Precision
1	09/01/15	30/01/15						
2	30/01/15	27/02/15						
3	27/02/15	08/04/15						
4	08/04/15	07/05/15						
5	07/05/15	04/06/15						
6	04/06/15	07/07/15						
7	07/07/15	07/08/15						
8	07/08/15	08/09/15	30.3	29.4	30	0.6	2	Good
9	08/09/15	01/10/15	32.6	28.8	31	2.7	9	Good
10	01/10/15	06/11/15	33.8	25.5	30	5.9	**20**	**Poor Precision**
11	06/11/15	10/12/15	31.6	30.7	31	0.7	2	Good
12	10/12/15	13/01/16	28.7	36.9	33	5.8	18	Good
Average CV							**10**	**-**

[5] A second diffusion tube monitoring site was co-located with the LCA-ND analyser in August 2015.

A5 Appendix 5 – Detailed Trend Analysis

Nitrogen Dioxide

A5.1 Figure A.5.1 shows the smooth-trend analyses of 1-hour mean nitrogen dioxide concentrations for LCA-CAH, LCA-ND and seven other, nearby monitoring sites (Greenwich Burrage Grove, Greenwich Millennium Village, Greenwich Eltham, Greenwich Woolwich Flyover, Newham Cam Road, Newham Wren Close and Tower Hamlets Blackwall)[6], over the period 2007 to 2015.

A5.2 A Theil-Sen analysis has been applied to the data to identify statistically significant trends and slopes, and the results are described in Table A.5.1. There is a statistically significant downward trend in nitrogen dioxide concentrations at LCA-CAH, LCA-ND and five monitoring sites (Greenwich Burrage Grove, Greenwich Eltham, Newham Cam Road, Newham Wren Close and Tower Hamlets Blackwall). There is no statistically significant trend at two of the other monitoring sites presented.

Table A5.1: Theil-Sen Analysis, Nitrogen Dioxide Concentrations at City Aviation House, Newham Dockside and Other Monitoring Sites, 2007 to 2015

Monitoring Site	Theil-Sen Analysis [a]	Statistically Significant Trend?
City Aviation House (LCA-CAH)	-0.88 [-1.49, -0.37]	**Yes**
Newham Dockside (LCA-ND) [b]	-2.16 [-3.03, -1.2]	**Yes**
Greenwich Burrage Grove	-2.47 [-3.1, -1.83]	**Yes**
Greenwich Millennium Village	-0.38 [-1.1, 0.43]	No
Greenwich Eltham	-0.91 [-1.42, -0.38]	**Yes**
Greenwich Woolwich Flyover	-0.94 [-1.61, 0.01]	No
Newham Cam Road	-2.36 [-3.19, -1.63]	**Yes**
Newham Wren Close	-1.31 [-2.12, -0.6]	**Yes**
Tower Hamlets Blackwall	-1.6 [-2.34, -0.9]	**Yes**

[a] The first value is the slope. The number in brackets is the upper and lower 95th percentile confidence interval.

[b] Analysis carried out for 2009 to 2015.

[6] The Poplar site at Tower Hamlets was decommissioned in July 2013 data. As the data for the period 2007 to 2013 was statistically not significant, it has been removed from this analysis.

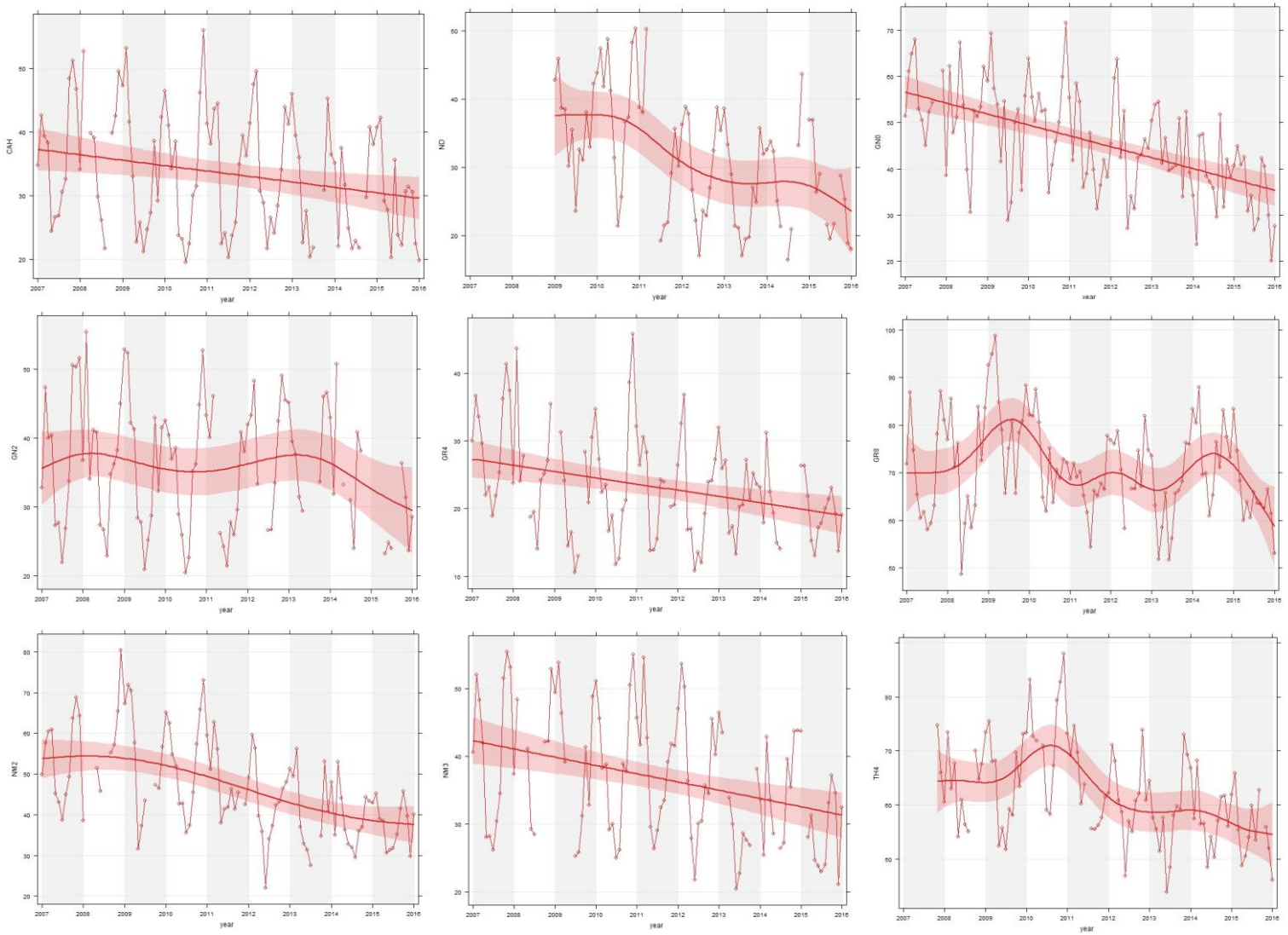

Figure A.5.1: Smooth Trend Analysis, Hourly Nitrogen Dioxide Concentrations at City Aviation House, Newham Dockside and Other Monitoring Sites, 2007 – 2015 (Left to Right: City Aviation House, Newham Dockside, Greenwich Burrage Grove, Greenwich Millennium Village, Greenwich Eltham, Greenwich Woolwich Flyover, Newham Cam Road, Newham Wren Close, Tower Hamlets Blackwall)

Nitrogen Oxides (NO_x)

A5.3 Figure A.5.2 shows the smooth trend analysis of 1-hour mean NO_x concentrations for LCA-CAH, LCA-ND and other monitoring sites (Greenwich Burrage Grove, Greenwich Millennium Village, Greenwich Eltham, Greenwich Woolwich Flyover, Newham Cam Road, Newham Wren Close, Tower Hamlets Blackwall) for the period 2007 to 2015.

A5.4 The Theil-Sen analysis, shown in Table A.5.2, indicates a statistically significant downward trend in NOx concentrations at six monitoring sites (Greenwich Burrage Grove, Greenwich Eltham, Greenwich Woolwich Flyover, Newham Cam Road, Newham Wren Close and Tower Hamlets Blackwall).

Table A5.2: Theil-Sen Analysis, NO_x Concentrations at City Aviation House and Other London Monitoring Sites, 2007 to 2015.

Monitoring Site	Theil-Sen Analysis [a]	Statistically Significant Trend?
City Aviation House (LCA-CAH)	-1.97 [-3.66, -0.69]	**Yes**
Newham Dockside (LCA-ND) [b]	-7.58 [-9.7, -5.01]	**Yes**
Greenwich Burrage Grove	-6.24 [-8.17, -4.2]	**Yes**
Greenwich Millennium Village	-1.32 [-3.61, 0.78]	No
Greenwich Eltham	-1.35 [-2.39, -0.44]	**Yes**
Greenwich Woolwich Flyover	-5.16 [-8.54, -1.48]	**Yes**
Newham Cam Road	-5.78 [-8.26, -3.81]	**Yes**
Newham Wren Close	-2.39 [-4.33, -0.67]	**Yes**
Tower Hamlets Blackwall	-5.39 [-8.84, -2.66]	**Yes**

[a] The first value is the slope. The value in brackets is the upper and lower 95th percentile confidence interval.

[b] Analysis carried out for 2009 to 2015

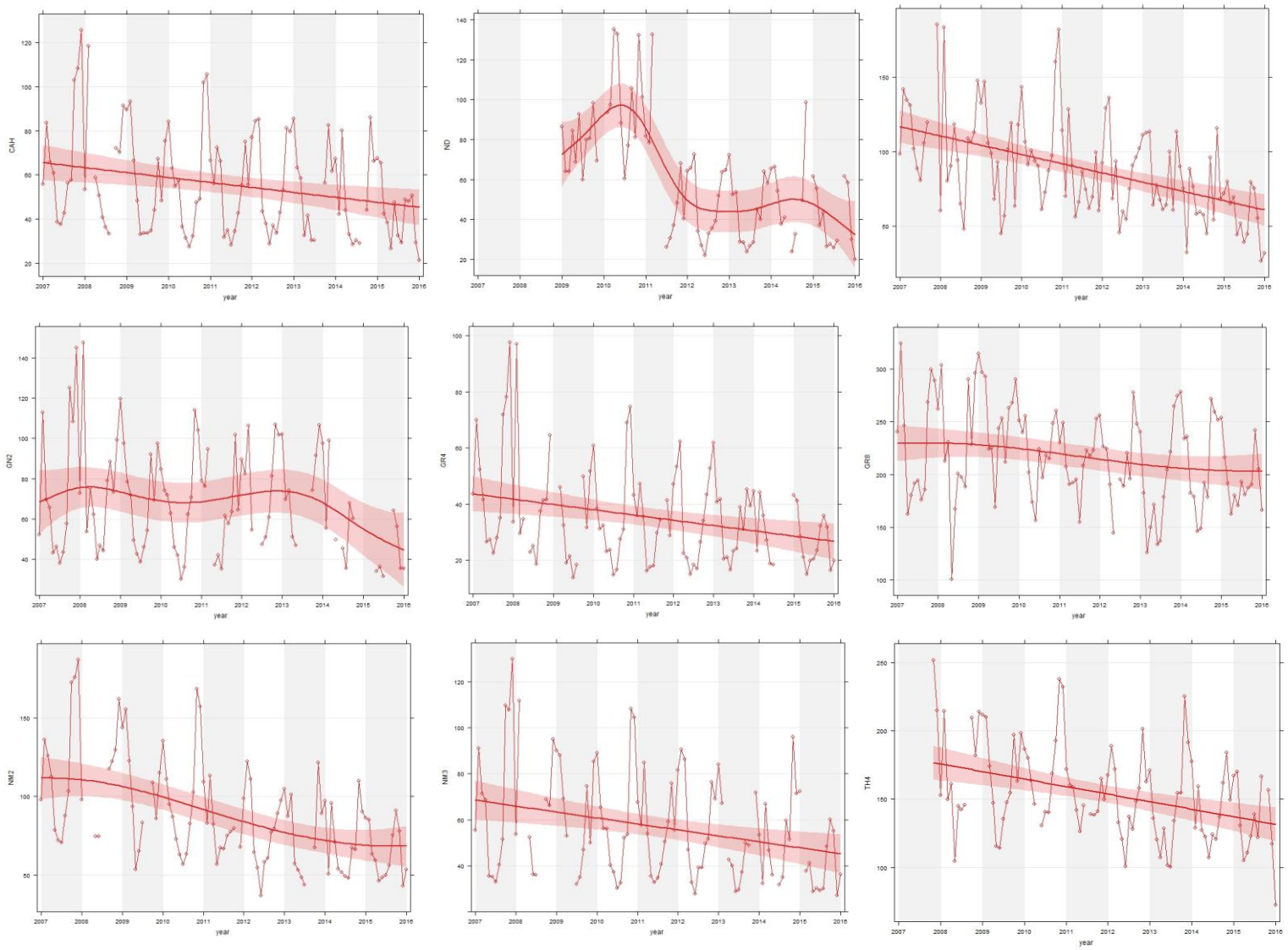

Figure A.5.3 Smooth Trend Analysis, Hourly NO_x Concentrations at City Aviation House, Newham Dockside and Other London Monitoring Sites, 2007 – 2015 (Left to Right: Aviation House, Newham Dockside, Greenwich Burrage Grove, Greenwich Millennium Village, Greenwich Eltham, Greenwich Woolwich Flyover, Newham Cam Road, Newham Wren Close, Tower Hamlets Blackwall)