Appendix 10.1: Air Quality Modelling Study

Introduction

10.1.1 This Appendix presents the technical information and data upon which the operational phase of the air quality assessment is based.

Model

10.1.2 In urban areas, pollutant concentrations are primarily determined by the balance between pollutant emissions that increase concentrations, and the ability of the atmosphere to reduce and remove pollutants by dispersion, advection, reaction and deposition. An atmospheric dispersion model is used as a practical way to simulate these complex processes; which requires a range of input data, which can include pollutant emissions rates, meteorological data and local topographical information.

10.1.3 The effect of the Development on local air quality was assessed using the advanced atmospheric dispersion model ADMS-Roads taking into account the contribution of emissions from forecast road-traffic on the local road network and from the heating plant by the completion year respectively.

ADMS-Roads

10.1.4 The ADMS-Roads model is a comprehensive tool for investigating air pollution in relation to road networks. On review of the Site, and its surroundings, ADMS-Roads was considered appropriate for the assessment of the long and short term effects from road traffic emissions associated with the proposals on air quality. The model uses advanced algorithms for the height-dependence of wind speed, turbulence and stability to produce improved predictions of air pollutant concentrations. It can predict long-term and short-term concentrations, including percentile concentrations.

10.1.5 ADMS-Roads model is a formally validated model, developed in the United Kingdom (UK) by CERC (Cambridge Environmental Research Consultants). This includes comparisons with data from the UK's air quality Automatic Urban and Rural Network (AURN) and specific verification exercises using standard field, laboratory and numerical data sets. CERC is also involved in European programmes on model harmonisation, and their models were compared favourably against other EU and U.S. EPA systems. Further information in relation to this is available from the CERC website at www.cerc.co.uk.

Model Scenarios

10.1.6 To assess the effect of the Development on local air quality, future ‘without Development’ and ‘with Development’ scenarios were assessed. The Development is anticipated to be complete in 2029 and therefore this is the year in which these future scenarios were modelled. The year 2019 was modelled to establish the existing baseline situation, because it is the year for which available monitoring data surrounding the Site is available against which the air quality model is verified (discussed further below). Base year traffic data for 2019 and meteorological data for 2019 were also used to be consistent with the verification year. Due to the COVID-19 pandemic, 2020 and 2021 monitoring data was not considered representative of baseline air quality conditions at and surrounding the Site and was not considered further.

Traffic Data

10.1.7 Traffic flow data comprising Annual Average Daily Traffic (AADT) flows, traffic composition (% HDVs – Heavy-Duty Vehicles) and speeds (in kph) were used in the model as provided by Stantec for the surrounding road network. **Table A1** presents the traffic data used within the air quality assessment. **Table A2** presents the trips associated with the Development for the air quality neutral assessment.

10.1.8 The methodology for calculating the expected change in vehicle trips because of the Development is set out in detail within the Transport Assessment and covers all of the proposed land uses. The assessment covers all traffic generated by the Site, including servicing and delivery trips.

Table A1: 24 hour AADT Data Used within the Assessment

Receptor Name	Speed (kph)	Direction	Base 2019		Without Construction 2028		With Construction 2028		Without Development 2029		With Development 2029	
			AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV
A316 Clifford Avenue	65	NB	16,486	11.0	17,864	11.0	17,908	11.2	18,005	11.0	18,158	10.9
	64	SB	14,431	9.5	15,637	9.5	15,681	9.8	15,761	9.5	16,055	9.4
A316 Lower Richmond road	48	WB	18,178	5.2	19,697	5.2	19,725	5.4	19,853	5.2	20,125	5.2
	48	EB	19,952	5.7	21,620	5.7	21,648	5.8	21,791	5.7	22,048	5.6
South Circular (north of A316)	48	NB	8,071	6.1	8,746	6.1	8,757	6.2	8,815	6.1	8,901	6.1
	48	SB	7,353	5.6	7,968	5.6	7,979	5.7	8,031	5.6	8,160	5.6
South Circular (south of A316)	48	NB	11,493	3.9	12,454	3.9	12,481	4.1	12,552	3.9	12,552	3.9
	48	SB	10,471	3.6	11,346	3.6	11,374	3.8	11,436	3.6	11,522	3.6
A3003 Lower Richmond Road (Watney's Sports Ground)	44	WB	8,484	8.6	9,194	8.6	9,303	9.6	9,266	8.6	9,863	8.2
	48	EB	9,096	8.9	9,857	8.9	9,966	9.9	9,935	8.9	10,615	8.5
A3003 Lower Richmond Road (Mortlake Green)	39	WB	8,477	8.3	9,186	8.3	9,186	8.3	9,258	8.3	9,902	8.0
	45	EB	9,268	11.2	10,043	11.2	10,043	11.2	10,122	11.2	10,791	10.7
Williams Lane	41	NB	283	6.7	307	6.7	307	6.7	309	6.7	647	4.8
	42	SB	349	7.4	378	7.4	378	7.4	381	7.4	678	5.6

Receptor Name	Speed (kph)	Direction	Base 2019		Without Construction 2028		With Construction 2028		Without Development 2029		With Development 2029	
			AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV
Mortlake High Street	51	WB	8,870	13.4	9,612	13.4	9,640	13.4	9,687	13.4	10,129	12.9
	33	EB	9,861	8.5	10,686	8.5	10,714	8.5	10,770	8.5	11,234	8.3
The Terrace (west of Barnes Bridge Station)	46	WB	8,607	8.7	9,326	8.7	9,355	8.6	9,400	8.7	9,749	8.5
	47	EB	9,267	8.7	10,042	8.7	10,071	8.7	10,121	8.7	10,552	8.5
White Hart Lane (south of Mortlake High Street)	39	NB	2,250	8.3	2,438	8.3	2,438	8.3	2,457	8.3	2,549	8.1
	41	SB	2,757	7.5	2,988	7.5	2,988	7.5	3,012	7.5	3,045	7.5
Sheen Lane (north of Level Crossing)	48	NB	3,223	4.4	3,493	4.4	3,493	4.4	3,520	4.4	3,736	4.3
	48	SB	2,832	2.5	3,068	2.5	3,068	2.5	3,093	2.5	3,298	2.6
Sheen Lane (south of Level Crossing)	48	NB	3,101	2.0	3,361	2.0	3,361	2.0	3,387	2.0	3,590	2.1
	48	SB	2,667	3.0	2,890	3.0	2,890	3.0	2,913	3.0	3,119	3.0
Sheen Lane (south of South Circular)	33	NB	2,394	3.3	2,594	3.3	2,594	3.3	2,615	3.3	2,743	3.3
	34	SB	2,605	5.1	2,823	5.1	2,823	5.1	2,845	5.1	2,965	5.0
South Circular Road (west of Sheen Lane)	43	WB	9,531	8.7	10,328	8.7	10,356	9.0	10,410	8.7	10,410	8.7
	44	EB	9,205	8.1	9,974	8.1	10,002	8.3	10,053	8.1	10,053	8.1

10.1.9 **Table A2** presents the trips associated with the development for the air quality neutral assessment.

Table A2: 24-hour AADT Data Used within the Air Quality Neutral Assessment

Land Use	Annual Trips
Residential	1,174
Office	395
Flexible Uses - Restaurant / bar / retail / community / leisure / Boathouse	314
Hotel	14
School	281
Cinema	164

Vehicle Speeds

10.1.10 To consider the presence of slow moving traffic near junctions, at roundabouts, the high level of congestion at the Chalkers Corner Junction; and vehicles idling at railway level crossings the following speeds have been used:

- 10kph at road links approaching junctions, Chalkers Corner Junction and the railway level crossings on Sheen Lane and White Hart Lane;
- 5kph at the Chalkers Corner Junction and the railway level crossings on Sheen Lane and White Hart Lane; and
- at all other junctions a reduction of 10kph from the free-flowing speed.

10.1.11 Queue lengths at Chalkers Corner have been provided by Stantec to replicate the existing levels of congestion on the road network and to determine when to apply the above speeds.

10.1.12 The approach to the speeds was agreed with LBRuT during a meeting on the 14^{th} November 2017.

Diurnal Profile

10.1.13 The ADMS-Roads model uses an hourly traffic flow based on the daily (AADT) flows. Traffic flows follow a diurnal variation throughout the day and week. Therefore, a diurnal profile was used in the model to replicate how the average hourly traffic flow would vary throughout the day and the week. This was based on traffic counts undertaken by Stantec on A316 Clifford Avenue; A3003 (at the Sports Ground and Mortlake Green); Williams Lane; Mortlake High Street; The Terrace; White Hart Lane; Sheen Lane; and the South Circular. **Figure A1** presents the diurnal variation in traffic flows which has been used within the model.

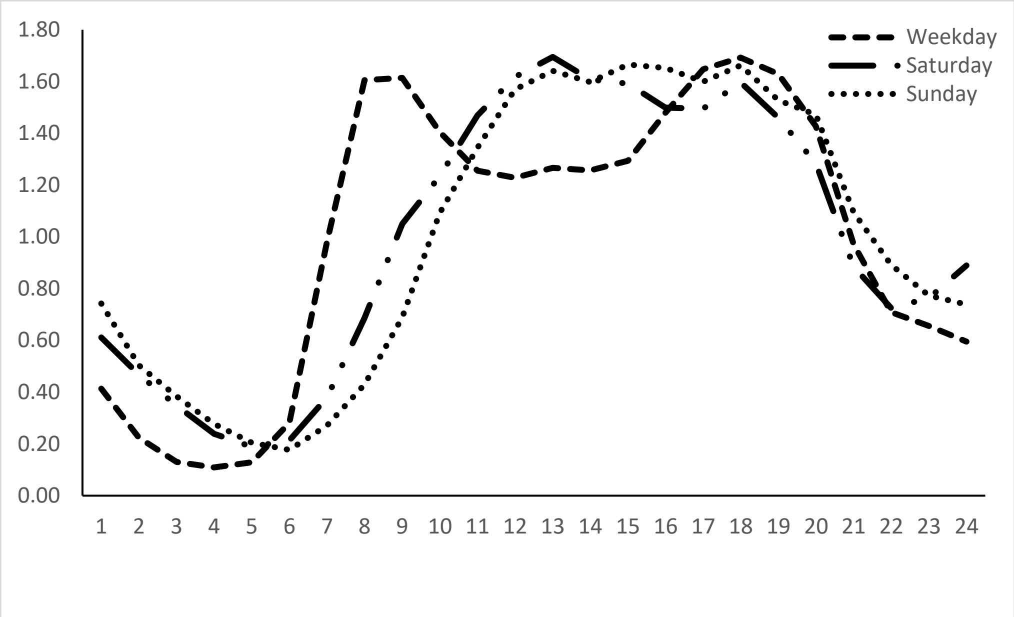

Figure A1: Local Road Network Diurnal Traffic Variation

Road Traffic Emission Factors

10.1.14 The latest version of the ADMS-Roads model (version 5.0.0.1) was used for the assessment. The model was input with the latest vehicle emission factors published by Defra in the Emission Factors Toolkit (v11.0 published in November 2021) and is based on the latest COPERT database published by the European Environment Agency.

10.1.15 The model uses several parameters (traffic flow, percentage of HDV, speed and road type) to calculate road traffic emissions for the selected pollutants.

Street Canyon Effect

10.1.16 Narrow streets with tall buildings on either side have the potential to create a confined space, which can interfere with the dispersion of traffic pollutants and may result in pollutant emissions accumulating in these streets. In an air quality model these narrow streets are described as street canyons.

10.1.17 ADMS-Roads includes a street canyon model to take account of the additional turbulent flow patterns occurring inside such a narrow street with relatively tall buildings on both sides. LAQM.TG(16) identifies a street canyon *"as narrow streets where the height of buildings on both sides of the road is greater than the road width."*

10.1.18 Following a review of the road network to be included within the model, it was considered that modelled roads are relatively wide and the existing buildings along these roads are not considered to be tall.

10.1.19 With the Development, it is considered that a street canyon, with residential exposure (contained within Buildings 13 and 17) would be created along Ship Lane. This street canyon would be created from the construction of Buildings 1, 2, 13 and 17 within the Development. A height of 27m was used in the 'with Development' scenarios to represent the proposed nine floors in Building 2.

10.1.20 Where receptors are located along these roads within the model domain, they have been positioned so as to be located within the street canyon (i.e. the distance from the receptor to the road centreline is less than half the canyon width).

Underground Car Parks

11.1. The Development includes two basement car parks with extraction systems – one located in Development Area 1 and one in Development Area 2. The technical specification of the ventilation strategy for Development Area 2 was indicative at the time of writing. As such the basement extraction system for Development Area 2 has not been considered in the air quality assessment. The final extraction system would be designed in accordance with best practice design and appropriate regulations and be secured by a suitably worded planning condition. As such, it is anticipated that the car park extraction system used for Development Area 1 would not give rise to significant environmental effects and has not been considered further at this stage.

11.2. The Development Area 1 basement car park would provide 408 car park spaces, 43 motorcycle spaces and 1,426 cycle spaces. The Development Area 1 basement car park would be ventilated by 11 louvres located across Development Area 1.

11.3. The dimensions of the Development Area 1 car park and the exhaust vents was obtained from plans provided by Hoare Lea, and Stantec provided the number of vehicle trips predicted to use the car parks. To account for at least 20% of the car park spaces having active electric charging point infrastructure, the vehicle trips for the Development Area 1 car park were reduced by 20% (from 1,856 to 1,485). The diurnal variation in traffic flows, as presented in **Figure A.1**, was used for the dispersion modelling of the car park emissions.

11.4. The characteristic petrol and diesel vehicle split for 2029, in addition to the indicative cold start emissions of NO_X and PM_{10} for 2029, were collated from the London Vehicle Fleet Composition Projections (Base 2013 revised in 2018) from the National Atmospheric Emission Inventory (NAEI) website[1].

11.5. The average distance travelled within the car park was calculated at 200m – a worst case assumption. The distance travelled was used to calculate the total 2028 car park emissions (in g/s) for both NO_X and PM_{10} as detailed in Row Q and Row U of **Table A3**. The emissions were then apportioned to the vent, and then divided by the volume of the source to get emissions in the $g/m^3/s$.

[1] Emission factors for transport - NAEI, UK (beis.gov.uk)

Table A3: Pollutant Emission for the Development Area 1 Car Park

ID	Input Parameter		Calculation	Development Area 1
A	2028 % Vehicle Split		Petrol	44.1
B			Diesel	32.7
C	Cold Start Emissions (g/trip)	NO_X	Petrol	0.049
D			Diesel	0.431
E		PM_{10}	Diesel	0.032
F	Car Park Trips (per day)			1,485
G	Car Park Trips (per hour)			61.9
H	Cold start trips (per day)		**F**/2	743
I	NO_X (petrol) Cold Start Trips (per second)		**A*****H**/86400	0.00379
J	NO_X (diesel) Cold Start Trips (per second)		**B*****H**/86400	0.00281
K	PM_{10} (diesel) Cold Start Trips (per second)			0.00281
L	NO_X Cold Start Emissions (g/s)		(**I*****C**)+(**J*****D**)	0.001397
M	PM_{10} Cold Start Emissions (g/s)		**K*****E**	0.00009
N	Average Distance Travelled (km)			0.2
P	NO_X Emission Rate (from ADMS Roads) (assuming 5kph) (g/km/s)			0.00006
Q	NO_X Emission Rate (g/s)		**N*****P**	0.0000128
R	NO_X Emission Rate with Cold Starts (g/s)		**Q**+**L**	0.00141
S	PM_{10} Emission Rate (from ADMS Roads) (assuming 5kph) (g/km/s)			0.00001
T	PM_{10} Emission Rate (g/s)		**N*****S**	0.0000010
U	PM_{10} Emission Rate with Cold Starts (g/s)		**T**+**M**	0.00009

11.6. The car park emissions were added as an industrial volume source in the ADMS-Roads model. The size of the louvres and emission rates from west to east across the Development Area 1 are presented in **Table A4**.

Table A4: Emission Rates for the Proposed Car Park Vent

Car Park Louvre	Dimensions (m^3)	Release Height (m)	Emission Rate ($g/m^3/s$)		
			NO_x	PM_{10}	$PM_{2.5}$
1	2	0	6.407E-05	4.135E-06	4.17E-06
2	7.1	0	1.805E-05	1.165E-06	1.175E-06
3	11.1	0	1.155E-05	7.45E-07	7.51E-07
4	6	0	2.136E-05	1.378E-06	1.39E-06
5	6.5	0	1.972E-05	1.272E-06	1.283E-06
6	6.5	0	1.972E-05	1.272E-06	1.283E-06
7	13	0	9.858E-06	6.36E-07	6.41E-07
8	5.2	0	2.464E-05	1.59E-06	1.604E-06
9	9.2	0	1.393E-05	8.99E-07	9.06E-07
10	5.4	0	2.373E-05	1.531E-06	1.544E-06
11	9.4	0	1.363E-05	8.8E-07	8.87E-07

Note: For accuracy, the changes arising from the Development have been calculated using the exact output from the ADMS models rather than the rounded numbers within Table A4.

Background Pollutant Concentrations

10.1.21 Background pollutant concentrations are pollution sources not directly considered in the dispersion modelling. Background pollutant concentrations have therefore been added to contributions from the modelled pollution sources, for each year of assessment.

10.1.22 The EHO at LBRuT requested background pollutant concentrations monitored at the Wetlands Centre, Barnes are used within the 2018 ES air quality assessment. The Wetlands Centre automatic monitor is located approximately 2.5km to the north-east from Site and is classified as a suburban monitor.

10.1.23 **Table A5** presents the most recent monitored concentrations measured at the Wetlands Centre automatic monitor.

Table A5: Measured Concentrations at the Wetlands Centre Suburban Background Automatic Monitor

Pollutant	Air Quality Strategy Objective	2015	2016	2017	2018	2019
NO_2	Annual Mean (40µg/m^3)	21	25	21	20	21
	200ug/m^3 as a 1 hour mean, not to be exceeded more than 18 times a year	0	0	0	0	0
PM_{10}	Annual Mean (40µg/m^3)	17	16	15	15	16
	50ug/m^3 as a 24 hour mean, not to be exceeded more than 35 times a year	1	3	3	0	3

Source: London Air Quality Network. Available at www.londonair.org.uk

10.1.24 **Table A5** shows all monitored pollutants at the Wetland Centre Suburban monitor were below their respective objectives in all years.

10.1.25 In addition to the monitoring data, forecast UK background concentrations of NOx, NO_2, PM_{10} and $PM_{2.5}$ are available from the Defra LAQM Support website1 for 1x1km grid squares for assessment years between 2018 and 2030 (published in August 2020). **Table A6** presents the Defra background concentrations for the years 2019, 2028 and 2029, for the grid squares the Site and local receptors considered in the air quality assessment are located within.

Table A6: Defra Background Maps in 2019, 2028 and 2029 for the Grid Squares at the Site and the Local Area

Pollutant	Annual Mean Concentration (µg/m^3)											
	520500, 175500(a)			519500, 175500(b)			518500, 175500(c)			519500, 176500(d)		
	2019	2028	2029	2019	2028	2029	2019	2028	2029	2019	2028	2029
NO_x	33.6	24.2	23.4	33.8	23.9	24.5	34.9	25.0	21.6	32.9	23.8	23.7
NO_2	22.6	17.0	16.6	22.8	16.9	17.2	23.4	17.5	15.4	22.3	16.8	16.7
PM_{10}	17.5	16.1	16.5	17.9	16.5	16.4	17.8	16.4	15.0	17.1	15.7	16.1
$PM_{2.5}$	11.8	10.9	11.1	12.1	11.1	11.1	12.0	11.1	10.1	11.5	10.5	10.9

Note: (a) Representative of Receptors: 1-15, 21, 23, 25, all Proposed Receptors and Diffusion Tubes 51, 70 and School 1 and 2
(b) Representative of Receptors: 16-20, 22 and 24 and Diffusion Tube 74, 52, and 1-7
(c) Representative of Diffusion Tube 18
(d) Representative of Diffusion Tube 55

10.1.26 As shown in **Table A5** and **Table A6**, the monitored background concentrations at the Wetlands Centre Suburban monitor in 2019 (as 21µg/m^3 for annual mean NO_2 and 16µg/m^3 for annual mean PM_{10}) are lower than the Defra background maps. The Defra background maps have therefore been used for a conservative assessment. Background concentrations used in the assessment are presented in **Table A7**.

Table A7: Background Concentrations used within the Assessment

Pollutant	Annual Mean Concentration (µg/m³)											
	2019				2028				2029			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
NO_x	33.6	33.8	34.9	32.9	24.2	24.2	24.2	24.2	23.4	24.5	21.6	23.7
NO_2	22.6	22.8	23.4	22.3	17.0	17.0	17.0	17.0	16.6	17.2	15.4	16.7
PM_{10}	17.5	17.9	17.8	17.1	16.1	16.1	16.1	16.1	16.5	16.4	15.0	16.1
$PM_{2.5}$	11.8	12.1	12.0	11.5	10.9	10.9	10.9	10.9	11.1	11.1	10.1	10.9

Note: (a) Representative of Receptors: 1-15, 21, 23, 25, all Proposed Receptors and Diffusion Tubes 51, 70 and School 1 and 2
(b) Representative of Receptors: 16-20, 22 and 24 and Diffusion Tube 74, 52, and 1-7
(c) Representative of Diffusion Tube 18
(d) Representative of Diffusion Tube 55

Meteorological Data

10.1.27 Local meteorological conditions strongly influence the dispersal of pollutants. Key meteorological data for dispersion modelling include hourly sequential data for wind direction, wind speed, temperature, precipitation and the extent of cloud cover for each hour of a given year. As a minimum ADMS-Roads and ADMS 5 requires wind speed, wind direction, and cloud cover.

10.1.28 Meteorological data to input into the model were obtained from the London Heathrow Airport Meteorological Station, which is the closest to the Site and considered to be the most representative. The 2019 data were used to be consistent with the base traffic year and model verification year. It was also used for the 2029 scenarios for the air quality assessment. **Figure A2** presents the wind-rose for the meteorological data.

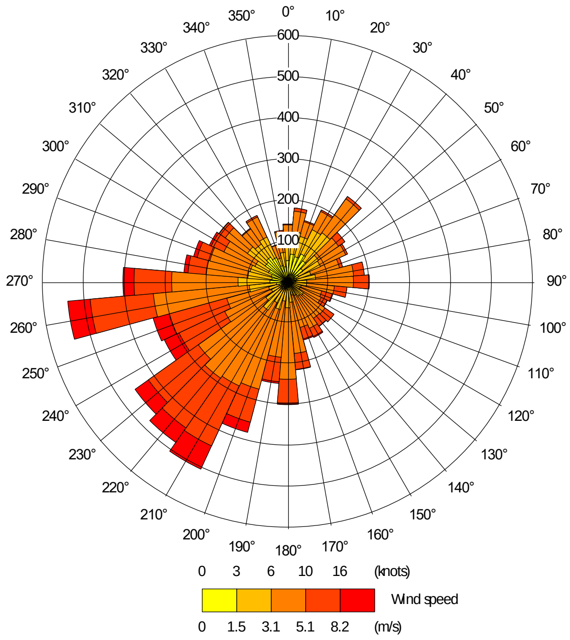

Figure A2: 2019 Wind Rose for the London Heathrow Airport Meteorological Site

10.1.29 Most dispersion models do not use meteorological data if they relate to calm winds conditions, as dispersion of air pollutants is more difficult to calculate in these circumstances. ADMS-Roads treats calm wind conditions by setting the minimum wind speed to 0.75 m/s. It is recommended in LAQM.TG(16) that the meteorological data file be tested within a dispersion model and the relevant output log file checked, to confirm the number of missing hours and calm hours that cannot be used by the dispersion model. This is important when considering predictions of high percentiles and the number of exceedances. LAQM.TG(16) recommends that meteorological data should only be used if the percentage of usable hours is greater than 85%. 2019 meteorological data from London Heathrow includes 8,427 lines of usable hourly data out of the total 8,760 for the year, i.e. 96.2% of usable data. This is above the 85% threshold and, therefore, is adequate for the dispersion modelling.

10.1.30 Within the air quality models, the surface roughness of 0.2 has been used for the meteorological site, which is representative of large open areas and is considered appropriate given the immediate open surrounding area at the meteorological site.

Model Data Processing

10.1.31 The modelling results were processed to calculate the averaging periods required for comparison with the AQS objectives.

10.1.32 NOx emissions from combustion sources (including vehicle exhausts) comprise principally nitric oxide (NO) and nitrogen dioxide (NO_2). The emitted nitric oxide reacts with oxidants in the air (mainly ozone (O_3)) to form more NO_2. Since only NO_2 is associated with effects on human health, the air quality standards for the protection of human health are based on NO_2 and not total NOx or NO.

10.1.33 ADMS-Roads was run without the Chemistry Reaction option to allow verification (see below). Therefore, a suitable NO_X:NO_2 conversion needed to be applied to the modelled NO_X concentrations. There are a variety of different approaches to dealing with NO_X:NO_2

relationships, a number of which are widely recognised as being acceptable. However, the current approach was developed for roadside sites, and is detailed within Technical Guidance LAQM.TG(16).

10.1.34 The LAQM Support website provides a spreadsheet calculator[2] to allow the calculation of NO_2 from NOx concentrations, accounting for the difference between primary emissions of NOx and background NOx, the concentration of O_3, and the different proportions of primary NO_2 emissions, in different years. This approach is only applicable to annual mean concentrations.

10.1.35 Research[3] undertaken in support of LAQM.TG(16) has indicated that the 1-hour mean AQS objective for NO_2 is unlikely to be exceeded at a roadside location where the annual-mean NO concentration is less than 60µg/m^3. The 1-hour mean objective is, therefore, not considered further within this assessment where the annual mean NO_2 concentration is predicted to be less than 60µg/m^3.

10.1.36 In order to calculate the number of PM_{10} 24-hour means exceeding 50µg/m^3 the relationship between the number of 24-hour mean exceedances and the annual mean PM_{10} concentration from LAQM.TG (09)1 was applied as follows:

$$\textbf{Number of Exceedances} = -18.5+0.00145 \times (\text{annual mean}^3) + \frac{206}{\text{annual mean.}}$$

10.1.37 With regards to the conversion factor for the Energy Centres, the screening approach suggested by the Environment Agency[4] for continuously operating plant is to assume that for the annual mean, 70% of the NOx is converted to NO_2 at ground level. This approach has been used for the NOx emissions prior to adding to the predicted annual mean NO_2 concentrations.

Other Model Parameters

10.1.38 There are a number of other parameters that are used within the ADMS-Roads which are described here for completeness and transparency:

- the model requires a surface roughness value to be inputted. A value of 1 was used at the Site (which is representative of cities and woodland) and a value of 0.2 was used at the location of the London Heathrow Airport Meteorological Station, which is representative of large open areas;
- the model requires the Monin-Obukhov length (a measure of the stability of the atmosphere) to be inputted. A value of 100m (representative of large conurbations >1,000,000) was used for the modelling; and
- the ADMS-Roads model requires the Road Type to be inputted. *'London [Outer]'* was selected and used for the modelling.

Model Verification

10.1.39 Model verification is the process of comparing monitored and modelled pollutant concentrations for the same year, at the same locations, and adjusting modelled concentrations, if necessary, to be consistent with monitoring data. This increases the robustness of modelling results.

10.1.40 Discrepancies between modelled and measured concentrations can arise for a number of reasons, for example:

- traffic data uncertainties;

- background concentration estimates;
- meteorological data uncertainties;
- sources not explicitly included within the model (e.g. car parks and bus stops);
- overall model limitations (e.g. treatment of roughness and meteorological data, treatment of speeds); and
- uncertainty in monitoring data, particularly diffusion tubes.

10.1.41 Verification is the process by which uncertainties such as those described above are investigated and minimised. Disparities between modelling and monitoring results are likely to arise as result of a combination of all of these aspects.

Nitrogen Dioxide

10.1.42 The dispersion model was run to predict annual mean NOx concentrations at the project specific kerbside and roadside diffusion tube monitoring locations (as presented in **Appendix 10.3 Air Quality Monitoring Report**.

10.1.43 The following roadside and kerbside diffusion tubes, monitored between July 2018 to January 2019, were modelled:

- Diffusion Tube 1: Lower Richmond Road;
- Diffusion Tube 2: Chertsey Court metal railings;
- Diffusion Tube 2: Chertsey Court, Lower Richmond Road
- Diffusion Tube 4: Chalkers Corner Junction;
- Diffusion Tube 6: Clifford Avenue;
- Diffusion Tube 6: Clifford Avenue;
- Diffusion Tube 7: Clifford Avenue metal railings;
- Diffusion Tube 8: Chertsey Court Clifford Avenue;
- School 1: Stag Brewery Sports Club; and
- School 2: Stag Brewery Sports Club.

10.1.44 **Table A8** compares the modelled and equivalent measured roadside NO_2 concentrations at the diffusion tube sites.

Table A8: Annual Mean NO_2 Modelled and Monitored Concentrations

Site ID	Monitored Annual Mean NO_2 (µg/m^3)	Modelled Total Annual Mean NO_2 (µg/m^3)	% Difference
DT74	52.0	42.6	-18.1
DT51	30.0	26.0	-13.4
DT52	55.0	50.4	-8.3
DT18	41.0	34.7	-15.4
DT55	40.0	33.3	-16.7
DT70	33.0	30.6	-7.3
Diffusion Tube 1	40.0	41.6	3.9
Diffusion Tube 2	34.3	36.7	6.9
Diffusion Tube 4	39.7	44.4	11.9
Diffusion Tube 6	45.7	43.5	-4.8
Diffusion Tube 7	39.2	39.9	1.8
School 1	28.1	27.0	-4.0
School 2	28.0	26.4	-5.6

10.1.45 LAQM.TG(16) suggests that where there is no systematic over or under prediction at the diffusion tube results and where the majority of modelled results are within 10% of the monitored concentrations that the model verification is appropriate and no further adjustment factor is required. Given the results in **Table A8** model adjustment was undertaken.

10.1.46 Box 7.15 in LAQM.TG(16) indicates a method based on comparison of the road NOx contributions and calculating an adjustment factor. This requires the roadside NO_x contribution to be calculated. In addition, monitored NO_x concentrations are required, which were calculated from the annual mean NO_2 concentration at the diffusion tube site using the NO_x to NO_2 spreadsheet calculator as described above. The steps involved in the adjustment process are presented in **Table A9**.

Table A9: Model Verification Result for Adjustment NO_x Emissions (µg/m³)

Site ID	Monitored NO_2	Monitored Road NO_x	Modelled Road NO_x	Ratio of Monitored Road Contribution NO_x/Modelled Road Contribution NO_x
DT21	52.0	70.6	44.9	1.6
DT51	30.0	15.5	6.9	2.3
DT52	55.0	79.4	66.0	1.2
DT18	41.0	39.6	24.4	1.6
DT55	40.0	39.6	23.6	1.7
DT70	33.0	22.2	16.7	1.3
Tube 1	40.0	38.4	42.3	0.9
Tube 2	34.3	24.8	30.3	0.8
Tube 4	39.7	37.6	49.7	0.8
Tube 6	45.7	53.1	47.3	1.1
Tube 7	39.2	36.4	38.1	1.0
School 1	28.1	11.4	9.0	1.3
School 2	28.0	11.1	7.8	1.4

10.1.47 **Figure A3** shows the mathematical relationship between modelled and monitored roadside NOx (i.e. total NOx minus background NOx) in a scatter graph (data taken from **Table A9**), with a trendline passing through zero and its derived equation.

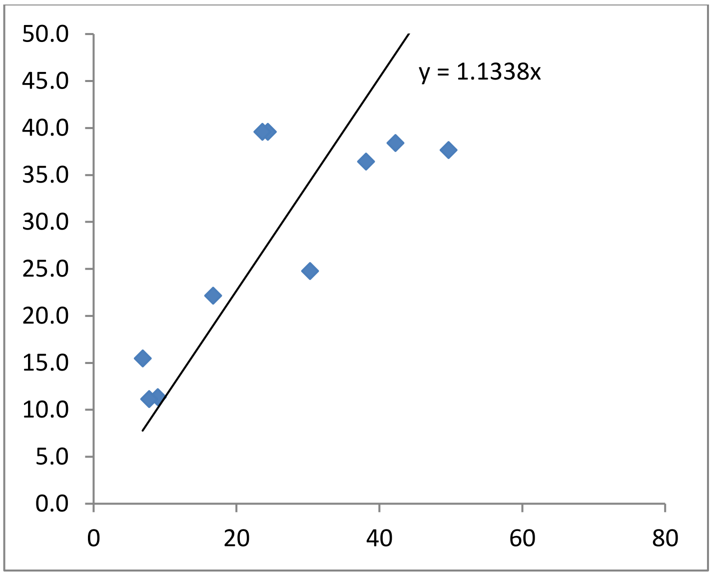

Figure A3: Unadjusted Modelled versus Monitored Annual Mean Roadside NO_x at the Monitoring Sites (µg/m³)

10.1.48 Consequently, in **Table A10** the adjustment factor (1.1338) obtained from **Figure A3** is applied to the modelled NOx Roadside concentrations to obtain improved agreement between monitored and modelled annual mean NOx. This has been converted to annual mean NO_2 using the NOx:NO_2 spreadsheet calculator.

Table A10: Adjusted Annual Average NO_2 Concentrations Compared to Monitored Annual Mean NO_2 Concentrations (µg/m^3)

Site ID	Adjusted Modelled Road NO_x	Adjusted Modelled Total NO_x	Modelled Total NO_2	Monitored Total NO_2	% Difference
DT21	50.9	84.7	44.9	52.0	-13.7
DT51	7.8	41.3	26.4	30.0	-11.9
DT52	74.9	108.7	53.5	55.0	-2.7
DT18	27.6	62.5	36.1	41.0	-12.0
DT55	26.8	59.7	34.7	40.0	-13.3
DT70	19.0	52.6	31.6	33.0	-4.2
Tube 1	47.9	81.7	43.7	40.0	9.4
Tube 2	34.4	68.2	38.4	34.3	11.9
Tube 4	56.3	90.1	46.9	39.7	18.1
Tube 6	53.7	87.5	45.9	45.7	0.5
Tube 7	43.2	77.0	41.9	39.2	6.9
School 1	10.2	43.8	27.6	28.1	-1.9
School 2	8.8	42.4	26.9	28.0	-3.9

Statistical Analysis

10.1.49 To determine if the model is performing well further statistical analysis of the performance of the modelled results has been undertaken using the methodology detailed in LAQM.TG(16) Box 7.17: Methods and Formulae for Description of Model Uncertainty. This statistical analysis checks the performance of the model used and the accuracy of the results (observed vs predicted).

10.1.50 The methodology for the calculations is presented in LAQM.TG(16) for the following:

- Correlation Coefficient: This is used to measure the linear relationship between the predicted and observed data. A value of zero means no relationship and a value of 1 means an absolute relationship. This statistic can be particularly useful when comparing a large number of model and observed data points.
- Fractional Bias: this is used to identify if the model shows a systematic tendency to over or under predict. Values very between +2 and -2 and has an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.
- Root Mean Square Error: This is used to define the average error or uncertainty of the model. The units of the Root Mean Square Error are the same as the quantities compared.

10.1.51 The results of the statistical calculation are presented in **Table A11**.

Table A11: Statistical Calculations of Error for the Modelled Results

Statistical Calculation	Perfect Value	Acceptable Variable Tolerance	Unadjusted Model Score	Unadjusted Model Score
Correlation Coefficient	1	N/A	0.88	0.88
Fractional Bias	0	+2 to -2	0.06	0.19
Root Mean Square Error	0	±10	4.4	4.0

10.1.52 Based on the results presented in **Table A11** it is considered that the model is performing well, there is no systematic over or under prediction of results and the root mean square error is within the acceptable tolerance levels, further adjustment is not necessary.

Particulate Matter (PM_{10} and $PM_{2.5}$)

10.1.53 PM_{10} and $PM_{2.5}$ monitoring data is not available for the Site area. Therefore, the roadside modelled NOx factor of 1.1338 factor has been applied to the roadside PM_{10} and $PM_{2.5}$ modelling results.

Verification Summary

10.1.54 Any atmospheric dispersion model study will always have a degree of inaccuracy due to a variety of factors. These include uncertainties in traffic emissions data, the differences between available meteorological data and the specific microclimate at each receptor location, and simplifications made in the model algorithms that describe the atmospheric dispersion and chemical processes. There will also be uncertainty in the comparison of predicted concentrations with monitored data, given the potential for errors and uncertainty in sampling methodology (technique, location, handling, and analysis) as well as processing of any monitoring data.

10.1.55 Whilst systematic under or over prediction can be taken into account through the model verification / adjustment process, random errors will inevitably occur and a level of uncertainty will still exist in corrected / adjusted data.

10.1.56 While every effort has been made to reduce the uncertainties within the model and thus reduce the verification factor as much as possible, the model verification has been unable to be reduced further and maybe a result of:

- local microclimate experienced at the monitoring locations which the model cannot replicate;
- limited ability to assess the uncertainty of model inputs, for example, the actual emission rates of vehicles on the local road network (particularly in proximity to the monitors used for the verification) compared to the emission rates used within the model;
- the inability to model all contributions in the local area (e.g. all heating plants) due to a lack of available information (including emissions and locations of flues);
- sampling and measurement error associated with the monitoring sites used for the verification. Such as the duration of monitoring (over saturated samples), accuracy of written monitoring duration, collection and transportation errors (if the sample cap has been replaced properly) and errors in analysis; and
- whether the model itself completely describes all the necessary atmospheric and built form processes, such as the local microclimate experienced at the monitoring locations and the real world impact of the street canyon.

10.1.57 Having consideration of the above uncertainty, overall, it is concluded that without the adjustment factor applied to the ADMS-Roads, the model is performing well and modelled results are considered to be suitable to determine the effects of the Development on local air quality.

Assessor Experience

Name: Eleri Paterson Hughes

Years of Experience: 1

Qualifications:

- BSc (Hons)
- Msc (Hons)
- Associate Member of IAQM
- Associate Member of IES

Eleri is a graduate air quality consultant with experience in preparing the technical delivery of a wide range of air quality projects for a variety of clients in both the public and private sector.

Name: Andy Fowler

Years of Experience: 11

Qualifications:

- CEnv
- BSc (Hons)
- Member of the IAQM
- Full Member of the Institution of Environmental Sciences (IES)

Andy has been responsible for the technical delivery of a wide range of air quality projects for a variety of clients in both the public and private sector. These projects include consideration of emissions from both transportation and industrial sources, through both monitoring and modelling, and therefore he has an in depth understanding of the regulatory requirements for these sources and the published technical guidance for their assessment.

References

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[4] Environment Agency. Air Quality Modelling and Assessment Unit. 'Conversion Ratios for NOx and NO2'.