SILVERTOWN TUNNEL

Environmental Statement Appendix 6.B (6.3.6.2)

Model Verification

~~April~~ September 2016

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Silvertown Tunnel

ES Appendix 6.B - Model Verification
6.3.6.2
TR010021
Model Verification

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Author: Transport for London

Rev.	Date	Approved By	Signature	Description

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0	29/04/2016	David Rowe (TfL Lead Sponsor)	[redacted]	For DCO Application
1.1	14/09/2016	David Rowe (TfL Lead Sponsor)	[redacted]	Figures 4-2 and 4-3 have been corrected to include full set of 77 monitoring points rather the erroneous 70 presented in v1. 2012 modelled concentrations and dependant data presented in the tables and figures of this appendix have been corrected updated to reflect new base year 2012 traffic data. A detailed note explaining the differences in traffic flows between the old and new base year 2012 datasets and the associated air quality impact is presented in ST150030-PLN-ZZZ-ZZ-TEN-ZZ-0826.

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List of Abbreviations

NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
$PM_{2.5}$	Particulate Matter <2.5 µm
PM_{10}	Particulate Matter <10 µm

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Glossary of Terms

Air Quality	The degree to which the air in a particular place is pollution-free.
Automatic Urban and Rural Network	The UK's largest automatic monitoring network. It is the main network used for compliance reporting against the Ambient Air Quality Directives.
Bias-adjusted results	Diffusion tubes can over or under estimate concentrations (often referred to as bias) compared to the chemiluminescent analyser (defined as the reference method). A co-location study can be undertaken with tubes exposed alongside an automatic analyser. The results can be used to calculate a bias adjustment factor which can then be applied to all diffusion tube results for that year to account for the bias.
Continuous (Automatic) Monitoring	Real-time analyser producing high-resolution measurements for a number of pollutants. Automatic analysers provide a concentration output every few seconds which is interrogated and stored by the data logger typically every 10 seconds.
Department for the Environment, Food and Rural Affairs	The UK government department responsible for safeguarding the natural environment, supporting the food and farming industry, and sustaining a thriving rural economy.
Development Consent Order	This is a statutory order which provides consent for the project and means that a range of other consents, such as planning permission and listed building consent, will not be required. A DCO can also include provisions authorising the compulsory acquisition of land or of interests in or rights over land which is the subject of an application. http://infrastructure.planninginspectorate.gov.uk/help/glossary-of-terms/

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Diffusion Tube	A simple, single-use sampling device that absorbs the pollutant directly from the ambient air with no requirement for a power source. Diffusion tubes are exposed at a monitoring location for a period of time (normally one month) and are then sent to a laboratory for analysis.
Environmental Statement	An Environmental Statement is the written material submitted to the local planning authority (the Planning Inspectorate in the case) in fulfilment of the EIA regulations.
Local Air Quality Management	The Local Air Quality Management (LAQM) process requires Local Authorities to periodically review and assess the current and future quality of air in their areas.
Nitrogen Dioxide	Combustion processes emit a mixture of nitrogen oxides (NO_x) and primarily nitric oxide (NO) which is quickly oxidised in the atmosphere to nitrogen dioxide (NO_2). Nitrogen dioxide has a variety of environmental and health impacts. It is a respiratory irritant which may exacerbate asthma and possible increase susceptibility to infections.
Nitrogen Oxides	Combustion processes emit a mixture of nitrogen oxides (NO_x), primarily nitric oxide (NO), which is quickly oxidised in the atmosphere to nitrogen dioxide (NO_2).
Particulate matter	Airborne PM includes a wide range of particle sizes and different chemical constituents. It consists of both primary components, which are emitted directly into the atmosphere, and secondary components, which are formed within the atmosphere as a result of chemical reactions. Of greatest concern to public health are the particles small enough to be inhaled into the deepest parts of the lung. Air Quality Objectives are in place for the protection of human health for PM_{10} and $PM_{2.5}$ – particles of less than 10 and 2.5 micrometres in diameter, respectively.

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Reference Case	An assumed 'future baseline' scenario, which represents the circumstances and conditions that TfL would anticipate in the future year 2021 without the implementation of the Scheme, taking account of trends (for example in population and employment growth) and relevant developments (such as other committed transport schemes). The Reference Case is used as a comparator for the Assessed Case, to show the significant effects of the Scheme against the appropriate reference scenario.
Roadside	An air quality monitoring site where sampling is undertaken typically within one to five metres of the kerb of a busy road (although distance can be up to 15m from the kerb in some cases).
Technical Guidance	The Local Air Quality Management Technical Guidance 2009 is designed by Defra to guide local authorities through the Review and Assessment process. It sets out the general approach to be used, together with detailed technical guidance.
Transport for London	A London government body responsible for most aspects of the transport system in Greater London. Its role is to implement transport strategy and to manage transport services across London. These services include: buses, the Underground network, Docklands Light Railway, Overground and Trams. TfL also runs Santander Cycles, London River Services, Victoria Coach Station and the Emirates Air Line. As well as controlling a 580km network of main roads and the city's 6,000 traffic lights, TfL regulates London's private hire vehicles and the Congestion Charge scheme.
Urban Background	An urban location distanced from sources and therefore broadly representative of city-wide background conditions; for example urban residential areas.

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1. INTRODUCTION

1.1.1 The comparison of modelled concentrations with local monitored concentrations is a process termed ‘verification’. Model verification identifies any discrepancies between modelled and measured concentrations, which can arise for a range of reasons. The following are examples of potential causes of such discrepancies:

- estimates of background pollutant concentrations;
- meteorological data uncertainties;
- traffic data uncertainties;
- emission factor uncertainties;
- model input parameters, such as ‘roughness length’; and
- overall limitations of the ability of the dispersion model to model dispersion in a complex urban environment.

1.1.2 The verification process involves a review of the modelled pollutant concentrations against corresponding monitoring data to determine how well the air quality model has performed. Depending on the outcome it may be considered that the model has performed adequately and that there is no need to adjust any of the modelled results.

1.1.3 Alternatively the model may perform poorly[1] against the monitoring data, as a result there is a need to check all the input data to ensure that it is reasonable and accurately represented in the air quality modelling process. Where all input data, such as traffic data, emissions rates and background concentrations have been checked and considered reasonable, then the modelled results may require adjustment to best align them with the monitoring data. This may be either be a single verification adjustment factor to be applied to the modelled concentrations across the study area or a range of different adjustment factors to account for different situations within the study area.

[1] The acceptable limits of model verification performance are set out in Defra’s Local Air Quality Management Technical Guidance (2009)

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2. RESIDUAL UNCERTAINTY

2.1.1 Residual uncertainty may remain after systematic error or ‘overall model accuracy’ has been accounted for in the final predictions. Residual uncertainty may be considered synonymous with the ‘residual inaccuracies’ of the model predictions, i.e. how wide the scatter or residual variability of the predicted values compare with the monitored ‘true value’, once systematic error has been allowed for. The quantification of final model accuracy provides an estimate of how the final predictions may deviate from the ‘true’ (monitored) values at the same location over the same period. It must though be recognised that some of the residual uncertainty will be down to uncertainties in the monitored values. This uncertainty is greater for monitoring using diffusion tubes than for automatic monitors.

2.1.2 Suitable local monitoring data for the purpose of verification is available for concentrations of NO_2 at the locations shown in Table 4-1. This monitoring data has been used to validate the dispersion model predictionpredictions and obtain adjustment factors which can be applied to predictions of pollutant concentrations in the base and future years.

Model Performance

2.1.3 An evaluation of model performance has been undertaken to establish confidence in model results. LAQM.TG(09) (Defra, 2009) identifies a number of statistical procedures that are appropriate to evaluate model performance and assess the uncertainty. The statistical parameters used in this assessment are:

- root mean square error (RMSE);
- fractional bias (FB); and
- correlation coefficient (CC).

2.1.4 A brief for explanation of each statistic is provided in

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~~2.1.6~~2.1.4 Table 2-1, and further details can be found in LAQM.TG(09) Box A3.7.

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Table 2-1 Statistical Parameters used to estimate model performance

Statistical Parameter	Comments	Ideal value
RMSE	RMSE is used to define the average error or uncertainty of the model. The units of RMSE are the same as the quantities compared. If the RMSE values are higher than 25% of the objective being assessed, it is recommended that the model inputs and verification should be revisited in order to make improvements. For example, if the model predictions are for the annual mean NO_2 objective of 40 µg/m^3, if an RMSE of 10 µg/m^3 or above is determined for a model it is advised to revisit the model parameters and model verification. Ideally an RMSE within 10% of the air quality objective would be derived, which equates to ±4 µg/m^3 for the annual mean NO_2 objective.	0.01
FB	It is used to identify if the model shows a systematic tendency to over or under predict. FB values vary between +2 and -2 and have an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.	0.00
CC	It is used to measure the linear relationship between predicted and observed data. A value of zero means no relationship and a value of 1 means absolute relationship. This statistic can be particularly useful when comparing a large number of model and observed data points.	1.00

~~2.1.7~~2.1.5 These parameters estimate how the model results agree or diverge from the observations. These calculations have been carried out prior to, and after, adjustment and provide information on the improvement of the model predictions as a result of the application of the verification adjustment factors.

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3. AIR QUALITY MONITORING DATA

3.1.1 The air quality monitoring data collected as part of this assessment and detailed in the baseline section was reviewed to determine the suitability of each of the monitoring locations for inclusion into the model verification process. The criteria used to determine the suitability of the monitoring for inclusion into the verification exercise is outlined below:

- within 50m of roads forming the air quality study area;
- monitoring from diffusion tubes for 2012 was used in preference to other years where there was greater than 75% data capture;
- where there was less than 75% data capture from the diffusion tubes in 2012 but a greater level of data capture (greater than 75%) in other years (2010, 2011, 2013) the result from one of these other years was in preference but only after adjustment based on the ratio of annual mean results in the year of measurement to the annual mean in 2012, at a number of automatic roadside monitoring sites;
- automatic monitoring data was used where there was greater than 90% data capture;
- monitoring sites were discounted where there was less than 75% data capture in 2012 and poor data capture in other years;
- monitoring was excluded from verification if major sources were missing from the traffic model that may influence monitored concentrations but could not be included in the air quality modelling (such as large car parks, industrial stacks in close proximity etc.); and
- sites where the location of the monitoring could not be confirmed to a satisfactory standard were omitted from the verification.

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4. VERIFICATION METHODOLOGY

4.1.1 The verification method following the process detailed in LAQM.TG(09). The initial verification was undertaken by comparing the modelled versus monitored Road NO_x. Road NO_x measured at the diffusion tubes was calculated using the latest Defra NOx to NO_2 calculator (v4.1), because diffusion tubes only measure NO_2 and do not directly measure NO_x.

4.1.2 Concentrations of road NO_x recorded at automatic monitors were calculated by subtracting background concentrations of NO_x (acquired from Defra background maps) from the total NO_x recorded at the automatic site.

4.1.3 Modelled PM_{10} and $PM_{2.5}$ concentrations were compared against monitoring data at the automatic sites to determine whether adjustment was required.

4.1.4 Following the removal of the monitoring locations with low data capture and those locations where road sources were not fully represented in the traffic data, a total of 77 diffusion tube and automatic monitoring sites were used in the verification. A description of the sites is presented in Table 4-1.

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Table 4-1 Monitoring Site Information

Site ID	X	Y	Data Owner	Monitoring Method	2012 Monitored NO_2 (µg/m³)	Annualised to 2012?	Year annualised from
ARC44	539532	178859	Transport for London	Diffusion Tube	49.6	Y	2014
ARC45	539831	179181	Transport for London	Diffusion Tube	39.3	Y	2014
ARC46	539568	178765	Transport for London	Diffusion Tube	44.4	Y	2014
ARC47	539732	178646	Transport for London	Diffusion Tube	37.6	Y	2014
ARC48	539732	178585	Transport for London	Diffusion Tube	37.9	Y	2014
ARC49	539775	178290	Transport for London	Diffusion Tube	42.8	Y	2014
ARC51	540025	178291	Transport for London	Diffusion Tube	53.4	Y	2014
ARC52	540337	178361	Transport for London	Diffusion Tube	71.2	Y	2014
ARC53	540278	178275	Transport for London	Diffusion Tube	53.4	Y	2014
GW36	539320	179234	Royal Borough of Greenwich	Diffusion Tube	53.6	N	
GW50	540203	178367	Royal Borough of Greenwich	Diffusion Tube	73	N	
GW51	539638	179024	Royal Borough of Greenwich	Diffusion Tube	47.4	N	
RBG10	540200	178367	Royal Borough of Greenwich	Automatic	71	N	
GW54	541915	175039	Royal Borough of Greenwich	Diffusion Tube	61.2	N	
RBG9	541885	175016	Royal Borough of Greenwich	Automatic	44	N	
ARC63	553158	172562	Transport for London	Diffusion Tube	39.5	Y	2014
ARC64	551201	173213	Transport for London	Diffusion Tube	27.9	Y	2014

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Site ID	X	Y	Data Owner	Monitoring Method	2012 Monitored NO_2 (μg/m³)	Annualised to 2012?	Year annualised from
ARC66	543371	175056	Transport for London	Diffusion Tube	35.6	Y	2014
ARC69	543530	175196	Transport for London	Diffusion Tube	37.4	Y	2014
ARC70	541474	175415	Transport for London	Diffusion Tube	35.2	Y	2014
ARC71	541718	175296	Transport for London	Diffusion Tube	38.3	Y	2014
BEX16	547676	174328	London Borough of Bexley	Diffusion Tube	40	N	
BEX24	547608	174344	London Borough of Bexley	Diffusion Tube	58.8	Y	2011
BEX413	546253	174774	London Borough of Bexley	Diffusion Tube	37	Y	2010
BEX414	546260	174730	London Borough of Bexley	Diffusion Tube	62.8	N	
BEX66	548905	174363	London Borough of Bexley	Diffusion Tube	48.6	Y	2011
DA50	553783	172319	Dartford Borough Council	Diffusion Tube	41	N	
DA89	553795	172259	Dartford Borough Council	Diffusion Tube	40	Y	2013
DA90	553957	172275	Dartford Borough Council	Diffusion Tube	39.7	Y	2013
GW103	540935	176575	Royal Borough of Greenwich	Diffusion Tube	51	N	
GW104	540743	177072	Royal Borough of Greenwich	Diffusion Tube	50.2	N	
GW23	540420	177706	Royal Borough of Greenwich	Diffusion Tube	40.6	N	
GW32	540661	177227	Royal Borough of Greenwich	Diffusion Tube	48.7	N	
RBG4	544997	175098	Royal Borough of Greenwich	Automatic	47	N	
DA14	555484	174441	Dartford Borough Council	Diffusion Tube	60	N	
DA20	555660	174863	Dartford Borough Council	Diffusion Tube	41	N	
DA21	555497	174025	Dartford Borough Council	Diffusion Tube	35	N	
DA22	555600	174030	Dartford Borough Council	Diffusion Tube	53	N	
DA24	555632	173558	Dartford Borough Council	Diffusion Tube	35	N	
DA25	555801	173194	Dartford Borough Council	Diffusion Tube	41.6	Y	2013

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Site ID	X	Y	Data Owner	Monitoring Method	2012 Monitored NO_2 (µg/m³)	Annualised to 2012?	Year annualised from
DA44	555656	174053	Dartford Borough Council	Diffusion Tube	44	N	
DA63	555612	173210	Dartford Borough Council	Diffusion Tube	31	N	
DA84	555574	174068	Dartford Borough Council	Diffusion Tube	58	N	
THR10	557570	177789	Thurrock Council	Diffusion Tube	52.9	N	
ARC15	541445	181866	Transport for London	Diffusion Tube	48.5	Y	2014
ARC16	542739	182119	Transport for London	Diffusion Tube	49.7	Y	2014
ARC1	540295	181768	Transport for London	Diffusion Tube	67.7	Y	2014
ARC26	545603	183461	Transport for London	Diffusion Tube	48.1	Y	2014
ARC2	540302	181791	Transport for London	Diffusion Tube	49.3	Y	2014
ARC30	547752	183529	Transport for London	Diffusion Tube	40	Y	2014
ARC31	547742	183479	Transport for London	Diffusion Tube	38	Y	2014
BD110	548097	183541	London Borough of Barking & Dagenham	Diffusion Tube	52.9	Y	2010
NEW19	539906	181702	London Borough of Newham	Diffusion Tube	68	N	
NEW20	539456	181499	London Borough of Newham	Diffusion Tube	64.5	N	
ARC13	543694	180899	Transport for London	Diffusion Tube	34.3	Y	2014
ARC20	543748	181309	Transport for London	Diffusion Tube	31.7	Y	2014
ARC11	541060	181491	Transport for London	Diffusion Tube	38	Y	2014
NEW12	543762	180784	London Borough of Newham	Diffusion Tube	34.1	N	
ARC5	539896	180842	Transport for London	Diffusion Tube	40.2	Y	2014
ARC6	540180	180371	Transport for London	Diffusion Tube	39.9	Y	2014
ARC7	540641	180148	Transport for London	Diffusion Tube	40.1	Y	2014
ARC27	540260	180329	Transport for London	Diffusion Tube	39.4	Y	2014
ARC19	541939	180194	Transport for London	Diffusion Tube	41.2	Y	2014

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Site ID	X	Y	Data Owner	Monitoring Method	2012 Monitored NO_2 (µg/m³)	Annualised to 2012?	Year annualised from
ARC39	543451	179951	Transport for London	Diffusion Tube	34.2	Y	2014
ARC40	542756	180020	Transport for London	Diffusion Tube	38.6	Y	2014
ARC42	543727	180071	Transport for London	Diffusion Tube	34.8	Y	2014
ARC36	539474	187856	Transport for London	Diffusion Tube	47.6	Y	2014
DT E	540828	188368	London Borough of Redbridge	Diffusion Tube	48.6	N	
RED3	540822	188371	London Borough of Redbridge	Automatic	48	N	
THA2	538290	181452	London Borough of Tower Hamlets	Automatic	62	Y	2010
THA73	538672	180739	London Borough of Tower Hamlets	Diffusion Tube	45.7	Y	2010
THA74	538271	180760	London Borough of Tower Hamlets	Diffusion Tube	67.6	Y	2010
THA76	537942	181027	London Borough of Tower Hamlets	Diffusion Tube	66.6	Y	2010
THA80	537581	183208	London Borough of Tower Hamlets	Diffusion Tube	59.6	Y	2010
THA81	537903	182994	London Borough of Tower Hamlets	Diffusion Tube	101.9	Y	2010
THA84	538366	181180	London Borough of Tower Hamlets	Diffusion Tube	52.2	Y	2010
WAF4	539025	186945	London Borough of Waltham Forest	Diffusion Tube	41.2	N	

4.1.5 For each monitoring site, the relevant 1x1km 2012 background concentrations for NO_x and NO_2 were acquired. The NO_2 to NO_x tool was used to calculate the total of road NO_x at each diffusion tube monitoring site. At those automatic sites which measured NO_x, the road NO_x component was calculated by subtracting the background NO_x from the total NO_x concentration. Table 4-2 summarises the background NO_x/NO_2 concentrations, raw (i.e. no adjustment) modelled and monitored road NO_x concentrations and raw modelled and monitored total NO_2 concentrations.

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Table 4-2 Unadjusted Modelled versus Monitoring Results 2012

Tube Id	BG NO_x (µg/m³)	BG NO_2 (µg/m³)	Monitored NO_2 (µg/m³)	Modelled Total NO_2 (µg/m³)	Monitored V Modelled Total NO_2 % Difference	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Monitored v Modelled Road NO_x % Difference
ARC44	45.5	29	49.6	36.8	-25.7	51.1	17.~~6~~5	-65
ARC45	42.6	27.6	39.3	31.7	-19.2	26.8	9	-66.4
ARC46	45.5	29	44.4	36.4	-18	36.8	16.6	-54.8
ARC47	45.5	29	37.6	35.~~8~~7	-~~4.9~~5.1	19.5	15~~.1~~	-~~22.5~~23.1
ARC48	45.5	29	37.9	33.2	-12.5	20.3	9.2	-54.~~5~~7
ARC49	45.5	29	42.8	36.~~3~~4	-15~~.1~~	32.3	16.~~3~~5	-49.~~6~~1
ARC51	45	28.8	53.4	38.~~6~~7	-27.~~8~~6	63.4	22.~~4~~6	-64.~~6~~3
ARC52	45	28.8	71.2	43	-39.~~6~~7	125.7	33.6	-73.3
ARC53	45	28.8	53.4	41.8	-21.7	63.1	30.4	-51.~~8~~9
GW36	42.6	27.6	53.6	39.~~8~~9	-25.~~7~~6	66.9	28.~~1~~2	-57.~~9~~8
GW50	45	28.8	73	50.4	-~~30.9~~31	132.7	54.~~3~~2	-59.~~1~~2
GW51	42.6	27.6	47.4	36	-24.1	48.4	18.~~9~~8	-61.~~1~~2
RBG10	45	28.8	71	50~~.1~~	-29.5	166	53.~~2~~1	-~~67.9~~68
GW54	38.7	25.5	61.2	36.~~2~~1	-~~40.8~~41.1	98.1	~~24.2~~23.8	-75.~~4~~8
RBG9	38.7	25.5	44	33.~~5~~4	-~~23.9~~24.2	58.3	17.~~6~~3	-~~69.8~~70.3
ARC63	27.4	19.1	39.5	31.~~5~~6	-20~~.2~~	45.2	26.3	-~~42.4~~41.9
ARC64	28	19.5	27.9	25.1	-10~~.1~~	17.2	11.~~2~~3	-34.~~8~~4
ARC66	36.1	24	35.6	35.1	-1.~~6~~3	25.8	24.~~4~~7	-4.5~~.4~~
ARC69	36.1	24	37.4	32	-14.~~4~~3	30.1	17.3	-42.~~7~~5
ARC70	38.7	25.5	35.2	32.~~6~~7	-7.~~4~~3	21.8	15.~~6~~7	-~~28.2~~
ARC71	38.7	25.5	38.3	31.3	-18.~~3~~2	29.2	12.~~6~~7	-56

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Tube Id	BG NO_x (µg/m³)	BG NO_2 (µg/m³)	Monitored NO_2 (µg/m³)	Modelled Total NO_2 (µg/m³)	Monitored V Modelled Total NO_2 % Difference	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Monitored v Modelled Road NO_x % Difference
BEX16	31	21.1	40	33.56	-16.2	43.6	27.35	-37.336.9
BEX24	31	21.1	58.8	36.937	-37.2	101.1	35.69	-64.85
BEX413	31.8	21.6	37	28.6	-22.7	34.7	14.9	-57.1
BEX414	31.8	21.6	62.8	31.6	-49.76	114.4	21.8	-80.9
BEX66	31.5	21.4	48.6	34.1	-3029.9	67.1	27.89	-58.64
DA50	27.4	19.1	41	38.6	-5.9	49.1	43.1	-12.63
DA89	27.4	19.1	40	30.931	-22.64	46.5	24.825	-46.62
DA90	27.4	19.1	39.7	27.8	-29.9	45.7	17.918	-60.97
GW103	39.9	26.1	51	39.6	-22.43	62.7	30.931.1	-50.75
GW104	45	28.9	50.2	42.76	-15.2	53.3	32.42	-39.16
GW23	45	28.9	40.6	36.7	-9.6	27.1	17.6	-35.2
GW32	45	28.9	48.7	42.43	-13.2	48.9	31.63	-35.39
RBG4	33.9	22.8	47	35.12	-25.31	68.1	27.68	-59.52
DA14	34.2	23.1	60	54.43	-9.45	94.8	77.1	-18.67
DA20	34.2	23.1	41	39	-4.8	40.2	35.3	-12.12
DA21	34.2	23.1	35	34.4	-1.78	25.7	24.3	-5.46
DA22	34.2	23.1	53	45.9	-13.45	73	52.98	-27
DA24	32.6	22.2	35	33.2	-5.23	27.6	23.43	-15.3
DA25	32.6	22.2	41.6	34.5	-17.1	43.7	26.54	-39.5
DA44	34.2	23.1	44	33.8	-23.1	47.9	23	-5
DA63	32.6	22.2	31	29.4	-5.3	18.5	14.9	-19
DA84	34.2	23.1	58	50.2	-13.5	88.4	64.87	-26

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Tube Id	BG NO_x (µg/m³)	BG NO_2 (µg/m³)	Monitored NO_2 (µg/m³)	Modelled Total NO_2 (µg/m³)	Monitored V Modelled Total NO_2 % Difference	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Monitored v Modelled Road NO_x % Difference
THR10	36	24	52.9	40.3	-23.~~8~~9	70.7	36.4	-48.~~4~~5
ARC15	45.4	29.2	48.5	42.~~2~~1	-13.~~1~~2	47.6	30.~~4~~2	-36.~~2~~5
ARC16	44.7	28.9	49.7	39.2	-21.1	51.8	23.~~7~~6	-54.~~2~~4
ARC1	47	30.1	67.7	48.~~5~~4	-28.4	108.5	45.~~3~~1	-58.~~3~~4
ARC26	42	27	48.1	38.5	-20	51.8	26.1	-49.7
ARC2	47	30.1	49.3	39.6	-19.~~7~~8	47.7	21.~~8~~7	-54.~~3~~5
ARC30	36.8	24.2	40	32	-20.1	36.6	16.9	-53.~~7~~8
ARC31	36.8	24.2	38	28.4	-25.3	31.5	8.9	-71.6
BD110	36.2	23.8	52.9	35.6	-32.8	74.8	26.2	-~~64.9~~65
NEW19	49.4	31.4	68	49.4	-27.4	105.9	44.~~7~~6	-57.~~8~~9
NEW20	49.4	31.4	64.5	48.1	-25.5	93.2	~~40~~38.9	-~~56.1~~58.2
ARC13	47.9	30.2	34.3	32.9	-4.1	9	5.~~8~~9	-~~35.3~~34.9
ARC20	44	28.4	31.7	30.4	-4.~~3~~2	7.3	4.~~3~~4	-40.~~8~~4
ARC11	45.4	29.2	38	33.3	-12.2	19.8	9	-54.~~6~~7
NEW12	47.9	30.2	34.1	34.7	1.7	8.6	~~9.9~~10	~~15.2~~16.3
ARC5	53.3	32.9	40.2	35.~~8~~7	-11.~~1~~2	16.9	6.~~4~~3	-~~61.8~~62.6
ARC6	45.5	29.2	39.9	33.2	-16.9	24.7	8.7	-64.~~8~~7
ARC7	45.5	29.2	40.1	32.3	-19.4	25.2	6.8	-72.~~9~~8
ARC27	45.5	29.2	39.4	32.3	-18	23.4	6.8	-~~71~~70.9
ARC19	48.9	30.8	41.2	33.2	-19.5	24.3	5.3	-78.2
ARC39	38.6	25.3	34.2	28.3	-17.2	19.6	6.~~3~~6	-~~67.7~~[illegible]
ARC40	54.9	33.6	38.6	35.1	-9.1	11.5	3.4	-70[illegible]

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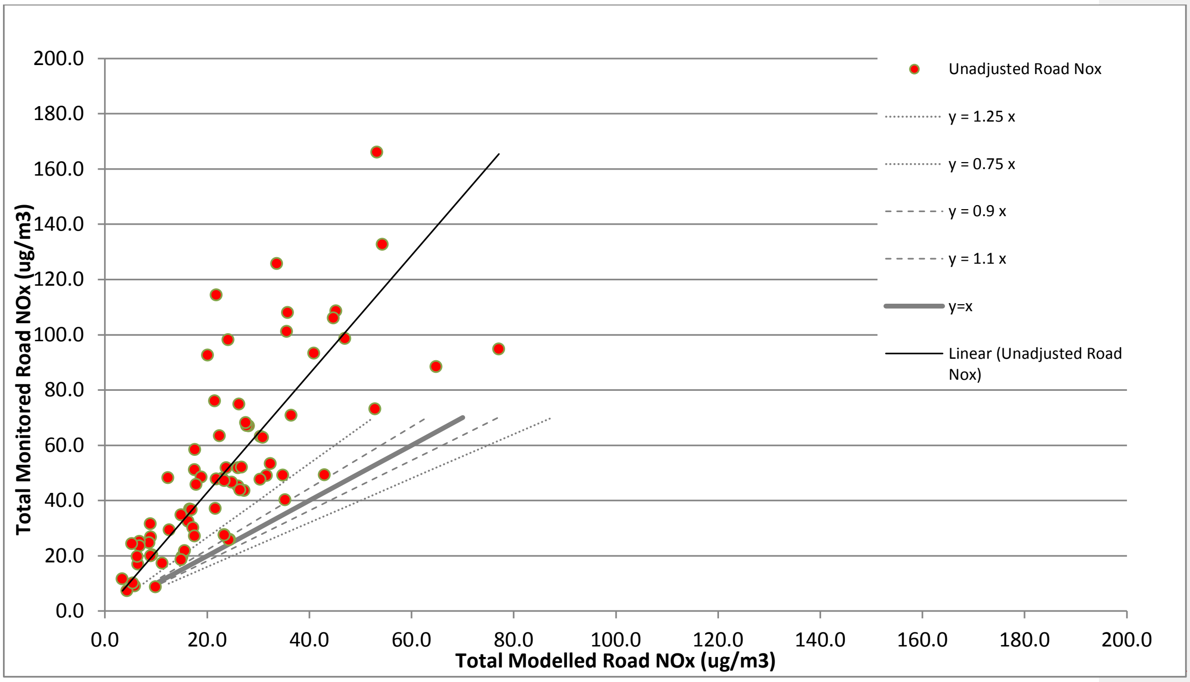
Tube Id	BG NO_x (µg/m³)	BG NO_2 (µg/m³)	Monitored NO_2 (µg/m³)	Modelled Total NO_2 (µg/m³)	Monitored V Modelled Total NO_2 % Difference	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Monitored v Modelled Road NO_x % Difference
ARC42	47.9	30.2	34.8	32.7	-5.9	10.1	5.~~5~~7	-~~45~~43.7
ARC36	43.9	28	47.6	33.6	-29.4	48.2	12.4	-74
DT E	42.9	27.6	48.6	39.~~2~~3	-19.3	52	26.~~7~~8	-48.~~6~~5
RED3	42.9	27.6	48	37.9	-21.1	47.1	23.4	-50.~~4~~3
THA2	52.4	32.9	62	51.~~5~~3	-17.3	98.6	~~47~~46.3	-~~52.3~~53
THA73	47.4	30.3	45.7	39.7	-13.1	37.1	21.~~6~~5	-41.~~6~~9
THA74	47.4	30.3	67.6	45.~~2~~4	-~~33.1~~32.9	107.9	~~35.8~~36.2	-66
THA76	55.4	34.4	66.6	43.1	-35.~~5~~3	92.5	20.~~1~~4	-~~78.2~~77.9
THA80	49.9	31.6	59.6	40.8	-31.5	76	21.~~5~~4	-71.~~7~~8
THA81	54.8	34.1	101.9	50.~~7~~6	-50.~~2~~3	239.8	41.~~7~~4	-82.~~6~~7
THA84	52.4	32.9	52.2	47.~~2~~1	-9.~~6~~8	49.1	34.~~8~~6	-29.~~1~~6
WAF4	46.7	29.4	41.2	39.6	-3.9	27.4	23.4	-14.~~7~~8

4.1.6 The modelled versus monitored road NO_x component concentrations were plotted on a scatter graph as presented on Figure 4-1.

Figure 4-1 Unadjusted Modelled vs Monitored Road NOx



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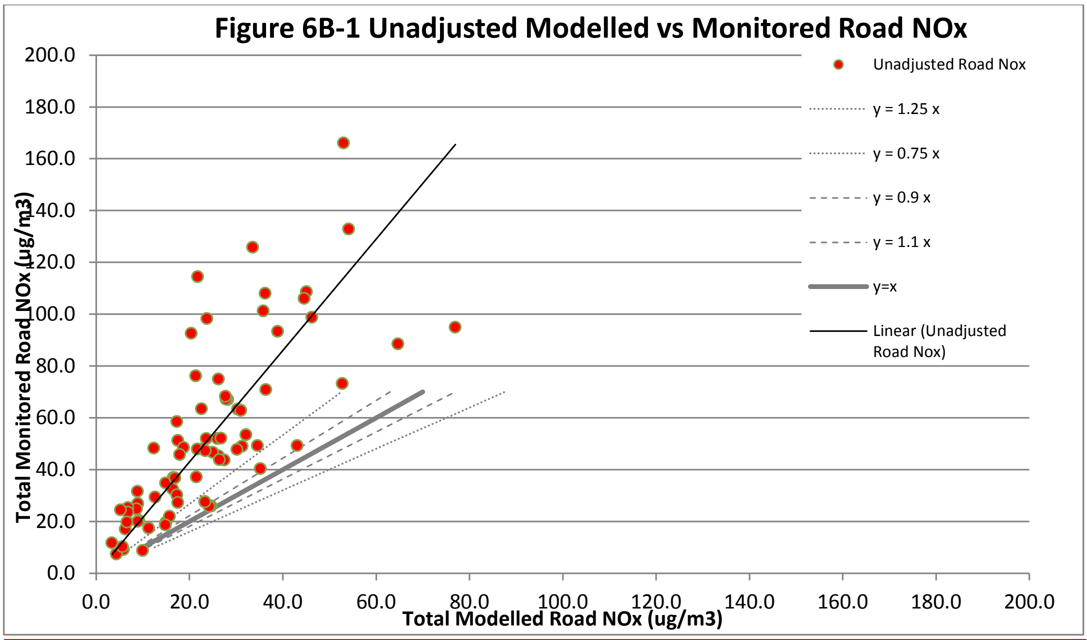

4.1.7 Figure 4-1 illustrates that the modelled concentrations systematically under predict the road component of NO_x in relation to the monitored concentrations. However, there is significant scatter in the data. To examine whether this scatter could be due to some systematic feature, such as the type of road or geographic area, a number of verification tests were carried out:

- Basic verification – Factor applied to all motorways and all A-roads separately.
- Overall Factor – one single verification factor for all receptors.
- Detailed Verification - Splitting the model into 8 verification zones following review of the modelled versus monitoring (including splitting specific Sections of the road network into different zones).

4.1.8 Following a review of the various verification options it was decided that a detailed split of geographically defined verification zones gave the best level of performance. The road NO_x verification factors for each of the modelled zones are presented in Table 4-3. The extent of each modelled zone is displayed in Drawing 6.6 – *Verification Zones* (PINS Document Reference Number: 6.2).

Table 4-3 Road NOx Verification Factors for Each Model Verification Zone.

	Verification	Number of Monitoring	RMSE	Number of Receptors

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	Factor	sites used		in zone
Greenwich Peninsular	2.72	13	4.6	1091
A205 South Circular	3.886	2	5.7	Not in study area
A102 and A2	1.97	19	7.1	1911
Dartford A282	1.3637	10	3.8	1331
A13	2.2730	10	3.3	4086
Canning Town and Beckton	1.549	4	1.9	2418
Silvertown	3.1411	8	1.8	429
A12 East Cross Route/Tower Hamlets	2.991	11	12.76	2006

4.1.9 When the eight verification factors in Table 4-3 were applied to the raw modelled results, total annual mean NO_2 concentrations at 94% of the modelled sites were within 25% of monitored NO_2 concentrations as summarised in Figure 4-3, as opposed to 71% of the sites when no adjustment was applied (Figure 4-2).

4.1.10 Figure 4-3 demonstrates that the once adjusted for road NO_x, total modelled NO_2 concentrations are closer to monitored total NO_2 concentrations, than the unadjusted total modelled NO_2 in Figure 4-2.

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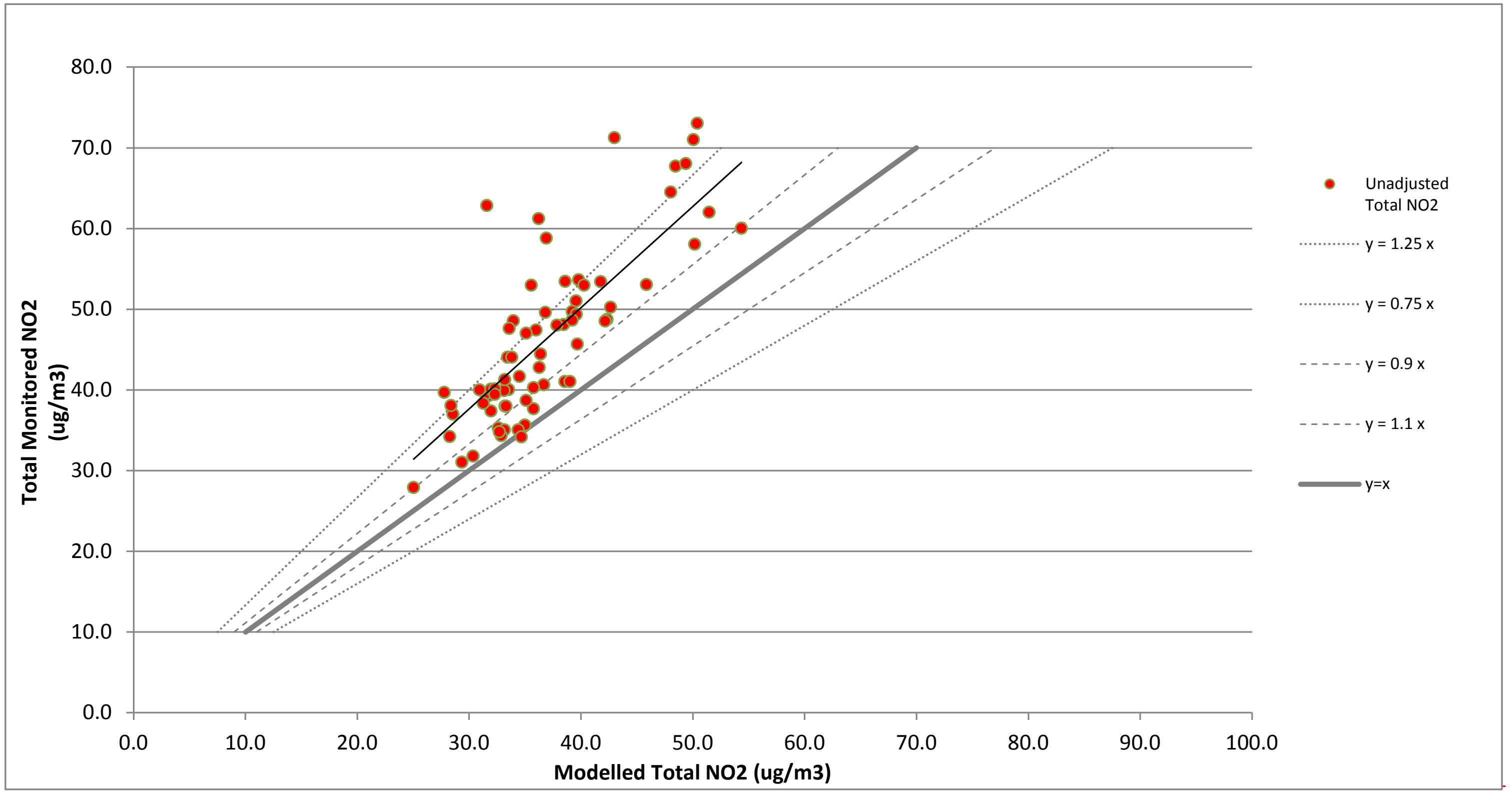
Figure 4-2 Unadjusted Total NO_2



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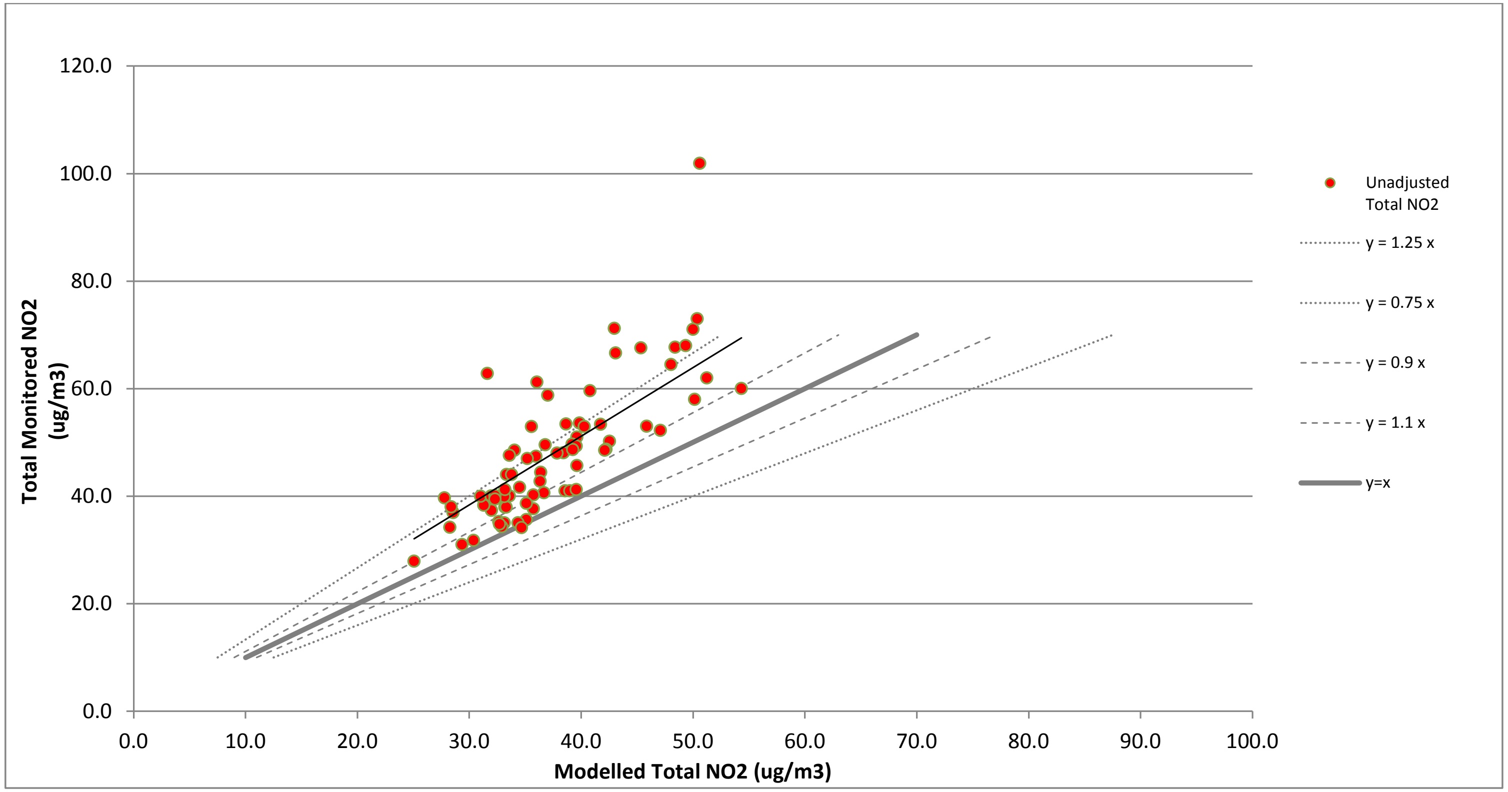

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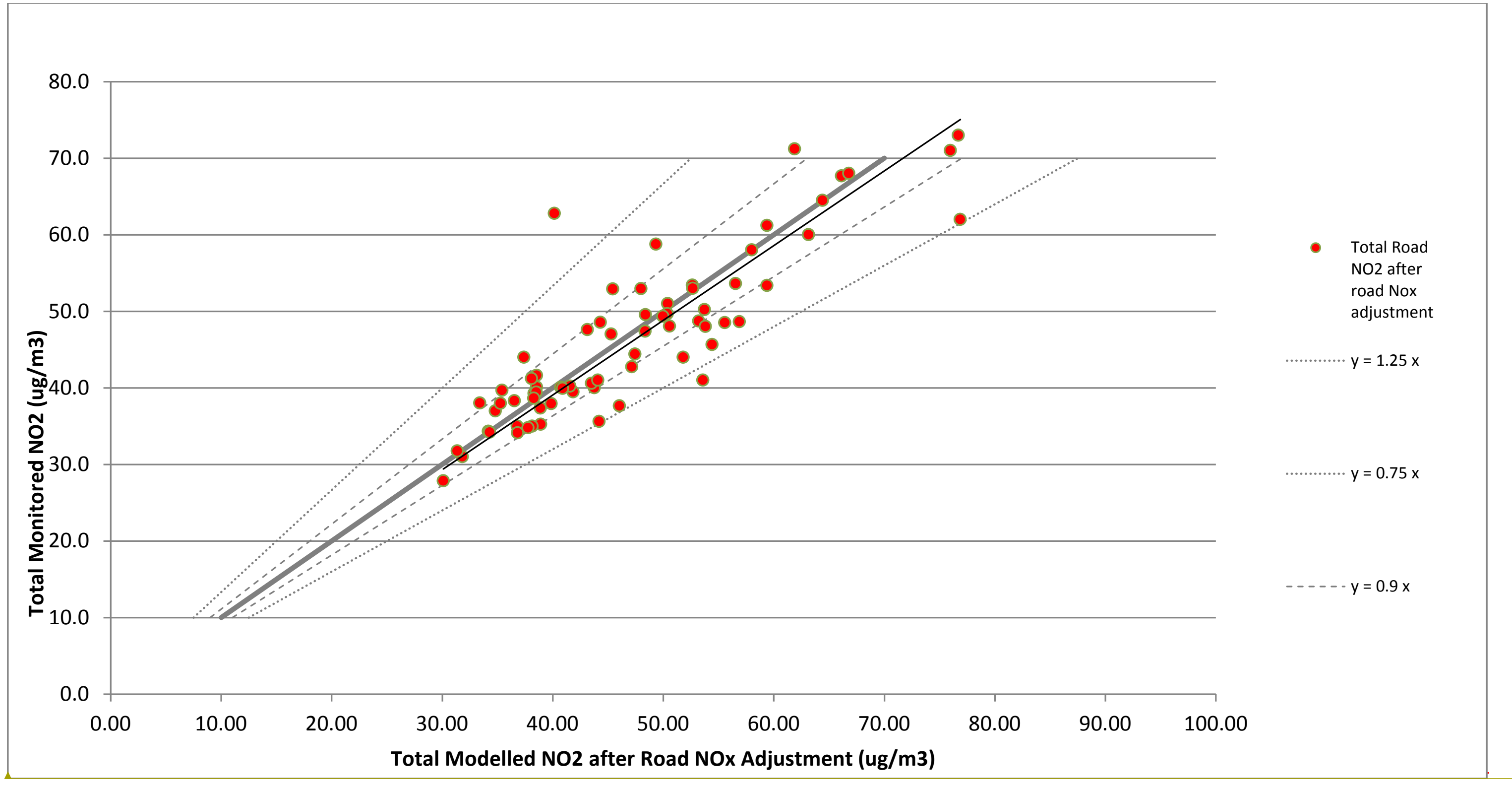
Figure 4-3 Adjusted Total NO_2



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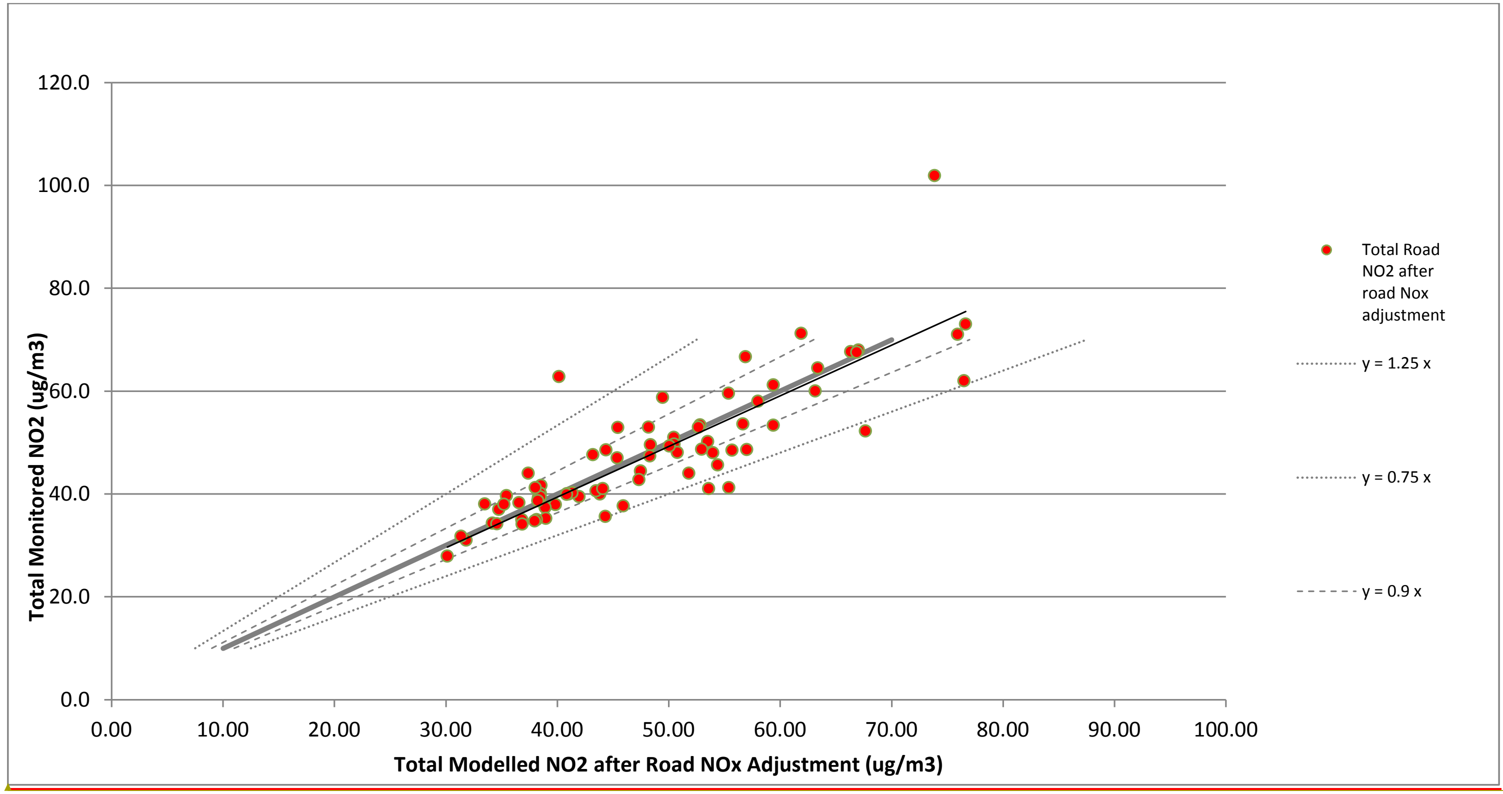

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Table 4-4 Model performance Statistics

Parameter	No Adjustment	NO_x Contribution Adjustment (8 zones)
Root Mean Square Error (RMSE)	13.1	6.6
Fractional Bias	0.2	0.0
Correlation Coefficient	0.80	0.9485

4.1.11 The model performance statistics show that the uncertainty in the predictions of the total NO_2 using the unadjusted model would have been large, as the RMSE is 136.10 µg/m^3. Additionally, the model had a tendency to under-predict actual concentrations because the fractional bias is greater than zero. When road NOx is adjusted by applying the eight geographical verification factors, the RMSE is reduced from 13.1 µg/m^3 to 6.6 µg/m^3. The model doesn't systematically under or over predict actual concentrations once adjusted because the fractional bias is zero. The adjusted model thus provides a much improved model performance.

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5. MODEL VERIFICATION OF $PM_{10}/PM_{2.5}$

5.1.1 The modelled versus monitored concentration for PM_{10} are presented in Table 5-1.

Table 5-1 Modelled versus Monitored PM_{10} 2012

Site	X	Y	Monitored total PM_{10} (µg/m³)	Modelled total PM_{10} (µg/m³)	Percentage Difference
Westhorne Avenue (GR9)	541885	175016	20.4	23.8	16.75%
RB4 Gardener Close, Wanstead	540822	188371	19.8	25.0	26.3%
Woolwich Flyover (RBG10)	540200	178367	32.5	26.4	-18.89%
Tower Hamlets Blackwall	538290	181452	26.4	28.4	7.65%
Falconwood (GB6)	544997	175098	26.0	23.01	-11.52%

5.1.2 The model both under and over predicts at the various monitoring sites. All the modelled concentrations are within 25% of the monitored concentrations with the exception of the Gardener Close site. The overall regression coefficient for the modelled versus monitored concentrations was 0.98 and as a result the modelled results were not adjusted.

Table 5-2 Modelled versus Monitored $PM_{2.5}$ 2012

Site	X	Y	Monitored $PM_{2.5}$ (µg/m³)	Modelled $PM_{2.5}$ (µg/m³)	Percentage Difference
Westhorne Avenue (GR9)	541885	175016	15.7	16.3	4%
RB4 Gardener Close, Wanstead	540822	188371	14.6	17.0	16%
Woolwich Flyover (RBG10)	540200	178367	15.4	18.0	17%
Tower Hamlets Blackwall	538290	181452	15.2	19.2	27%

5.1.3 The modelled versus monitored $PM_{2.5}$ concentrations were generally over predicted, the results of the modelling were therefore not adjusted.

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