East Midlands Gateway
Phase 2 (EMG2)

Document DCO 6.8A/MCO 6.8A

ENVIRONMENTAL STATEMENT

Volume 2 Technical Appendices

Appendix 8A

Model Verification

July 2025

08

The East Midlands Gateway Phase 2
and Highway Order 202X and The East Midlands Gateway
Rail Freight and Highway (Amendment) Order 202X

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Appendix 8a – Model Verification

Introduction

Model verification studies are undertaken in order to check the performance of dispersion models and, where modelled concentrations are significantly different to monitored concentrations, a factor can be established by which the modelled results can be adjusted in order to improve their reliability. The model verification process is detailed in TG22.

According to TG22, no adjustment factor is necessary where the results of the model all lie within 25% of the monitored concentrations, but ideally within 10%.

Model verification can only be undertaken where there is sufficient roadside monitoring data in the vicinity of the **EMG2 Project** being assessed. TG22 recommends that a combination of automatic and diffusion tube monitoring data is used; although this may be limited by data availability.

For this assessment, twelve verifications were undertaken, as set out below. However, for ease, a summary of these verifications is included below in **Table 8a.1**, which indicates the adjustment factor calculated, Root Mean Square Error (RMSE) and number of diffusion tube monitoring locations used for the verification. Furthermore, **Table 8a.1** identifies which receptor prefixes (as set out in full in **Appendix 8c Modelled Human Receptor Locations (DCO 6.8C / MCO 6.8C)** and **Appendix 8d Modelled Ecological Receptor Locations (DCO 6.8D / MCO 6.8D**) were adjusted by each adjustment factor.

Table 8a.1: Summary of Verification Processes

Area	Factor	RMSE	Tubes Used	Receptors Applied to
Human Receptors				
Area Immediately Surrounding the **EMG2 Project**	3.946	3.9	4	ABS, MN, TK
Kegworth	3.540	1.9	3	CD
Loughborough / Hathern	1.874	0.8	3	EF
Long Eaton / Sandiacre / Risley	1.017	1.2	5	GLN
South Derbyshire	2.458	N/A	1	H
Derby	1.282	3.2	6	OP
Castle Donnington (AQMA)	8.904	3.1	2	QR – within AQMA
Castle Donnington (Outside AQMA)	1.166	0.6	3	QR – outside of AQMA
Shepshed	1.541	5.5	3	U, VW
Copt Oak ('A' scenarios)	1.791	N/A	1	X
Copt Oak ('B' scenarios)	1.885	N/A	1	X
Whitwick	5.422	N/A	1	YZ
Ecological Receptors				
Oakley Wood SSSI	1.541	5.5	3	MN
Tonge Gorse Ancient & Semi Natural Woodland, Lount Meadows SSSI and Breedon Cloud Wood and Quarry, On-site Veteran Tree	3.946	3.9	4	AB, TU and Tree 20002
Off-Site Ancient Trees	1.166	0.6	3	All remaining trees

Verification 1: Area Immediately Surrounding the EMG2 Project

This verification process included four roadside diffusion tubes, located on roads near to the Site. These were considered most representative of roads near to the Site. These diffusion tubes were installed by Vanguardia as part of a diffusion tube survey aimed at ascertaining air pollutant concentrations in the vicinity of the **EMG2 Project** (as set out in in **Appendix 8e: Diffusion Tube Monitoring Programme (DCO 6.8E / MCO 6.8E)**. The modelled road network, and location of the verification monitoring locations are illustrated in **Figure 8a.1**.

Figure 8a.1: Location of Verification Monitoring locations (Verification 1)

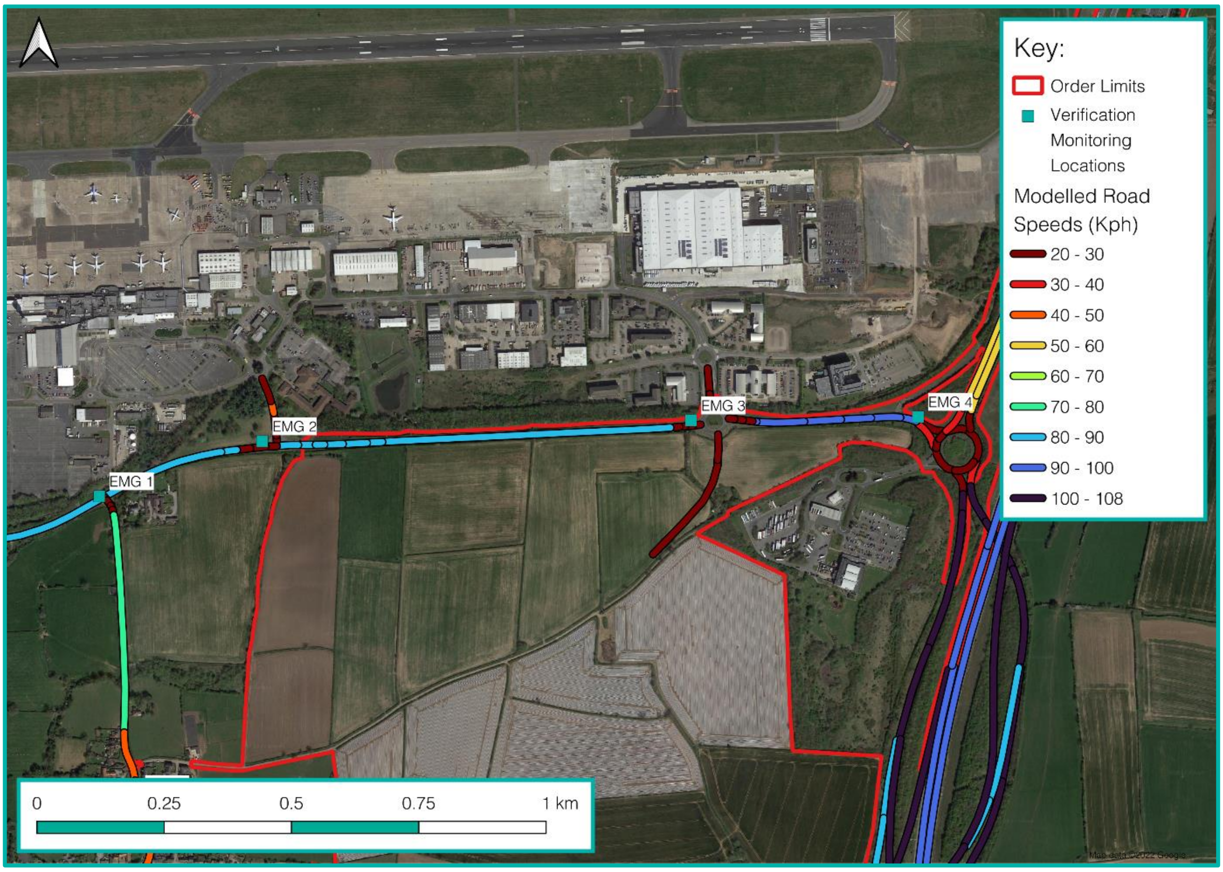

Table 8a.2 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.2: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 1)

Site ID	Type	Concentrations ($\mu g/m^3$)		
		Monitored	Modelled	% Difference
EMG1	Diffusion Tube	20.9	15.7	-24.8
EMG2	Diffusion Tube	19.3	16.3	-15.7
EMG3	Diffusion Tube	26.9	16.6	-38.4
EMG4	Diffusion Tube	37.4	18.4	-50.8

The data in **Table 8a.2** shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for all the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.3**.

Table 8a.3: Deriving the Adjustment Factor (Verification 1)

Site ID	Monitored Road NO_x ($\mu g/m^3$)	Modelled Road NO_x ($\mu g/m^3$)	Ratio
EMG1	17.75	6.04	3.946
EMG2	14.16	7.34	
EMG3	34.07	9.19	
EMG4	65.24	13.40	

Table 8a.4 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.4: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 1)

Site ID	Type	Concentrations ($\mu g/m^3$)		
		Monitored	Modelled	% Difference
EMG1	Diffusion Tube	20.9	23.4	12.2
EMG2	Diffusion Tube	19.3	25.4	31.6
EMG3	Diffusion Tube	26.9	27.7	3.1
EMG4	Diffusion Tube	37.4	33.5	-10.5

The data in **Table 8a.4** shows that all bar one concentrations in the model now lie within the acceptable 25% of the monitored concentrations. The adjusted modelled concentration at **EMG2 Project** sits outside the acceptable percentage difference, this is discussed further at the end of this section.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.5** to determine the error within the calculations after Road-NO_x adjustment, based upon the following calculation:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(obs_i - Pred_i)^2}$$

Table 8a.5: Root Mean Squared Error (RMSE) (Verification 1)

Site ID	Monitored	Modelled	Difference
EMG1	24.1	23.4	2.5
EMG2	25.3	25.4	6.1
EMG3	27.5	27.7	0.8
EMG4	33.3	33.5	-3.9
RMSE			3.9

The calculated RMSE is 3.9 µg/m^3, which means the modelled results could be over or under-predicting concentrations by 3.9 µg/m^3. The RMSE means modelled results are acceptable as they sit within the accepted 10% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.6** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$FB = \frac{(Avg.Obs - Avg.Pred)}{0.5\,(Avg.Obs + Avg.Pred)}$$

Table 8a.6: Fractional Bias (Verification 1)

Average Observed Value	Average Predicted Value	Fractional Bias
26.1	27.5	-0.052

The calculated fractional bias is -0.052, which is close to the ideal value of 0, which indicates the model performance is acceptable.

Verification 2: Kegworth

This verification process included three roadside diffusion tubes located along roads in Kegworth. These were considered most representative of roads in Kegworth, as well as Derby Southern Bypass (A50) near to Junction 24 of the M1. These diffusion tubes were installed by NWLDC. The modelled road network, and location of the verification monitoring locations are illustrated in **Figure 8a.2**.

Figure 8a.2: Location of Verification Monitoring Locations (Verification 2)

Table 8a.7 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.7: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 2)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
23N	Diffusion Tube	13.1	12.7	-3.2
47N	Diffusion Tube	16.8	12.6	-25.3
51N	Diffusion Tube	17.1	12.7	-26.0

The data in **Table 8a.7** shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for two of the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.8**.

Table 8a.8: Deriving the Adjustment Factor (Verification 2)

Site ID	Monitored Road NOx (µg/m³)	Modelled Road NO_x (µg/m³)	Ratio
23N	3.53	2.65	3.540
47N	11.58	2.38	
51N	12.25	2.59	

Table 8a.9 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.9: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 2)

Site ID	Type	Concentrations (µg/m³)		
		Monitored	Modelled	% Difference
23N	Diffusion Tube	13.1	15.8	20.6
47N	Diffusion Tube	16.8	15.4	-8.5
51N	Diffusion Tube	17.1	15.7	-8.1

The data in **Table 8a.9** shows that all concentrations in the model now lie within the acceptable 25% of the monitored concentrations, indicating the model performance is acceptable. Furthermore, two of the concentrations in the model now lie within the ideal 10% margin of error.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.10** to determine the error within the calculations after Road-NO_x adjustment, based upon the following calculation:

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\text{obs}_i - \text{Pred}_i)^2}$$

Table 8a.10: Root Mean Squared Error (RMSE) (Verification 2)

Site ID	Monitored	Modelled	Difference
23N	15.8	13.1	2.7
47N	15.4	16.8	-1.4
51N	15.7	17.1	-1.4
RMSE			1.9

The calculated RMSE is 1.9 µg/m³, which means the modelled results could be over or under-predicting concentrations by 1.9 µg/m³. The RMSE means modelled results are acceptable as they sit within the accepted 10% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.11** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$FB = \frac{(Avg.Obs - Avg.Pred)}{0.5\,(Avg.Obs + Avg.Pred)}$$

Table 8a.11: Fractional Bias (Verification 2)

Average Observed Value	Average Predicted Value	Fractional Bias
15.7	15.6	0.002

The calculated fractional bias is 0.002, which is close to the ideal value of 0, which indicates the model is performing acceptably.

Verification 3: Loughborough / Hathern

This verification process included three roadside diffusion tubes located beside the A6 and Shepshed Road in Hathern. These were considered most representative of roads in Loughborough and the nearby villages of Hathern and Sutton Bonnington. The diffusion tubes were utilised were installed by Charnwood Borough Council. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.3**.

Figure 8a.3: Location of Verification Monitoring Locations (Verification 3)

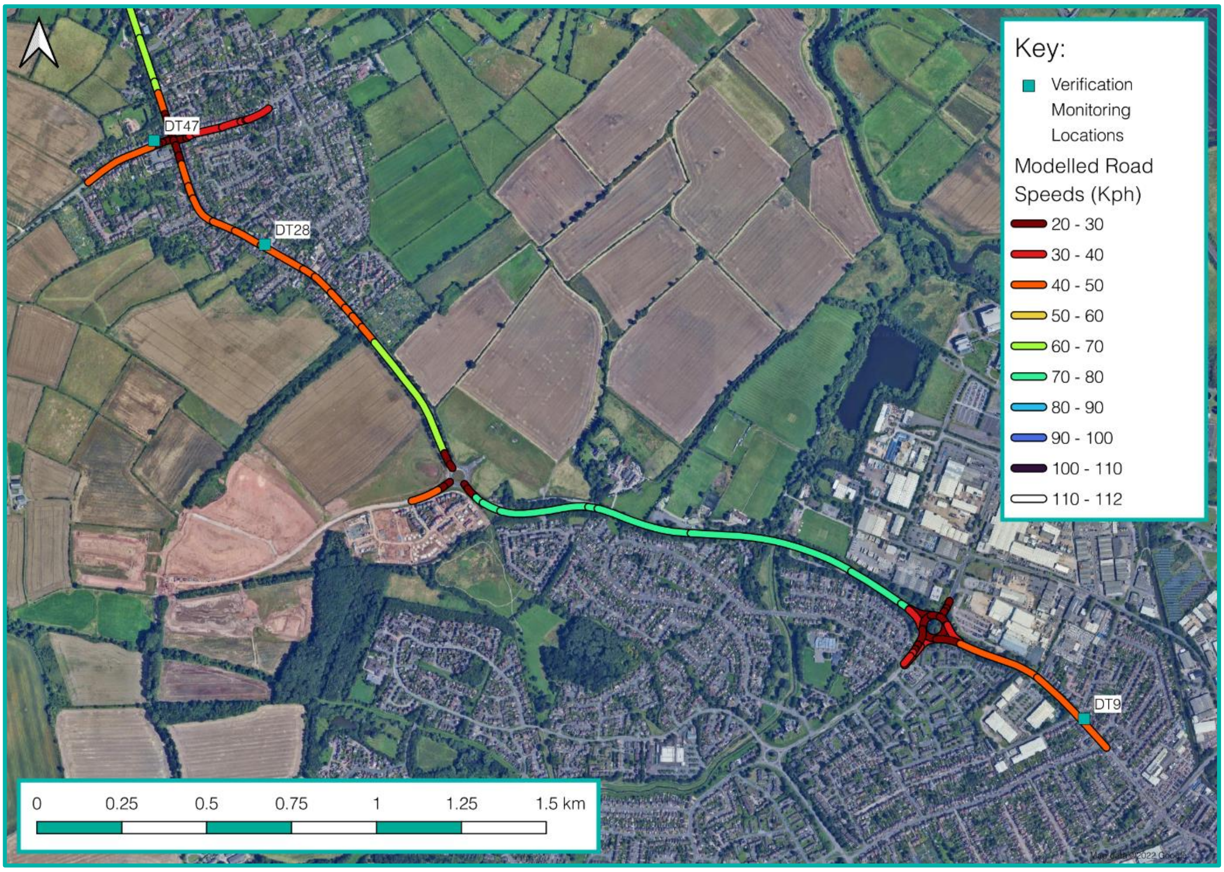

Table 8a.12 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.12: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 3)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
DT9	Diffusion Tube	17.3	14.8	-14.7
DT28	Diffusion Tube	17.3	14.8	-14.6
DT47	Diffusion Tube	16.3	13.0	-20.1

The data in **Table 8a.12** shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for all of the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.13**.

Table 8a.13: Deriving the Adjustment Factor (Verification 3)

Site ID	Monitored Road NO_x (µg/m^3)	Modelled Road NO_x (µg/m^3)	Ratio
DT9	7.39	4.13	1.874
DT28	13.75	8.14	
DT47	12.08	4.96	

Table 8a.14 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.14: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 3)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
DT9	Diffusion Tube	17.3	17.5	0.9
DT28	Diffusion Tube	17.3	17.9	3.6
DT47	Diffusion Tube	16.3	15.0	-7.9

The data in **Table 8a.14** shows that all concentrations in the model now lie within the ideal 10% margin of error, indicating the model performance is acceptable.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.15** to determine the error within the calculations after Road-NO_x adjustment, based upon the following calculation:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(obs_i - Pred_i)^2}$$

Table 8a.15: Root Mean Squared Error (RMSE) (Verification 3)

Site ID	Monitored	Modelled	Difference
DT9	17.5	17.3	0.2
DT28	17.9	17.3	0.6
DT47	15.0	16.3	-1.3
RMSE			0.8

The calculated RMSE is 0.8 µg/m^3, which means the modelled results could be over or under-predicting concentrations by 0.8 µg/m^3. The RMSE means modelled results are acceptable as they sit within the accepted 10% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.16** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$FB = \frac{(Avg.Obs - Avg.Pred)}{0.5\,(Avg.Obs + Avg.Pred)}$$

Table 8a.16: Fractional Bias (Verification 3)

Average Observed Value	Average Predicted Value	Fractional Bias
17.0	16.8	0.010

The calculated fractional bias is 0.010, which is close to the ideal value of 0, which indicates the model performance is acceptable.

Verification 4: Long Eaton / Sandiacre / Risley

This verification process included five roadside diffusion tubes located within the residential areas nearby to the M1 in Long Eaton, Sandiacre and the village of Risley. These were considered most representative of residential areas near the M1 within the EBC jurisdiction. The diffusion tubes utilised were installed by Erewash Borough Council. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.4**.

Figure 8a.4: Location of Verification Monitoring Locations (Verification 4)

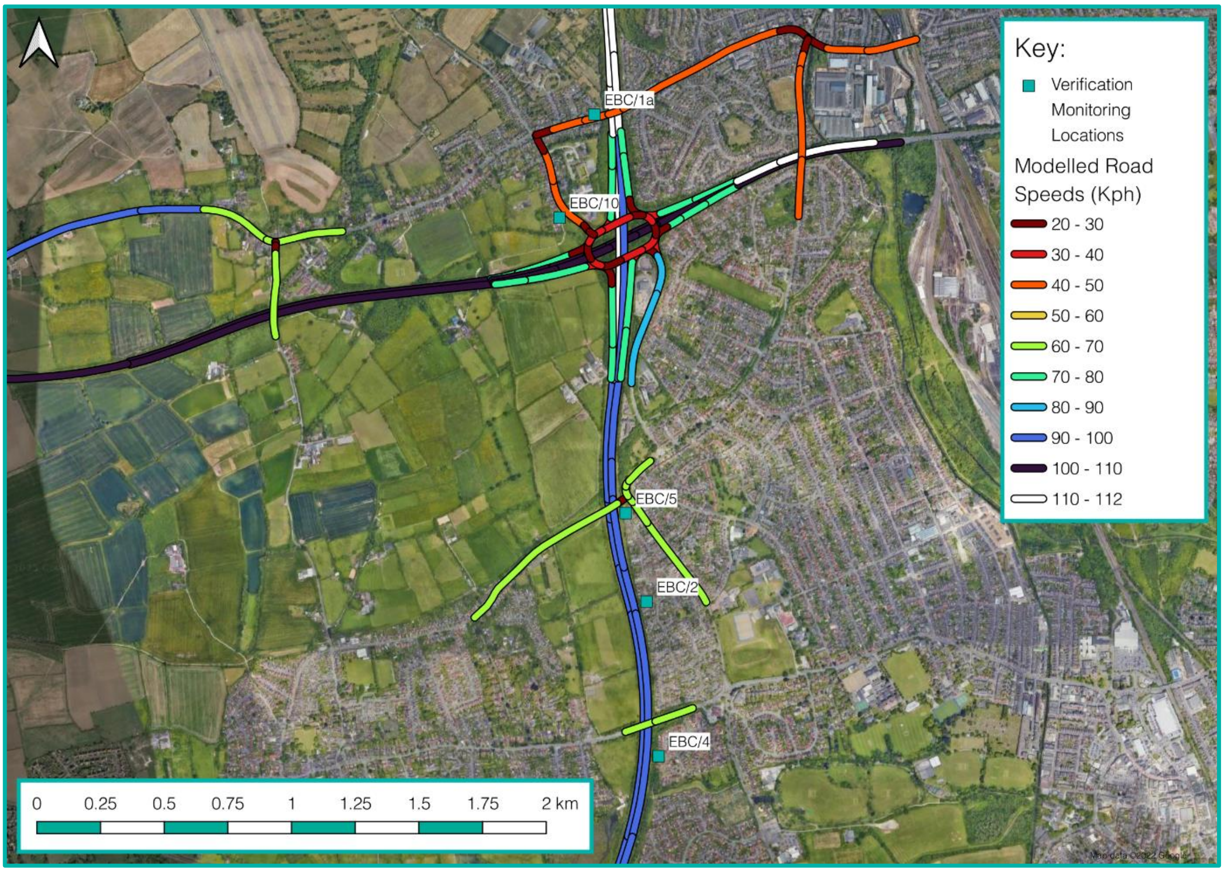

Table 8a.17 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.17: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 4)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
EBC/1a	Diffusion Tube	16.3	14.9	-8.6
EBC/2	Diffusion Tube	19.0	17.2	-9.5
EBC/4	Diffusion Tube	17.6	18.7	6.3
EBC/5	Diffusion Tube	17.8	17.7	-0.8
EBC/10	Diffusion Tube	11.9	14.1	18.7

The data in **Table 8a.17** shows the model is both under-predicting and over-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for one of the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.18**.

Table 8a.18: Deriving the Adjustment Factor (Verification 4)

Site ID	Monitored Road NO_x ($\mu g/m^3$)	Modelled Road NO_x ($\mu g/m^3$)	Ratio
EBC/1a	9.26	6.19	1.017
EBC/2	16.04	15.50	
EBC/4	12.96	12.96	
EBC/5	13.28	11.89	
EBC/10	2.20	6.97	

Table 8a.19 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.19: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification)

Site ID	Type	Concentrations ($\mu g/m^3$)		
		Monitored	Modelled	% Difference
EBC/1a	Diffusion Tube	16.3	15.0	-8.3
EBC/2	Diffusion Tube	19.0	18.8	-0.9
EBC/4	Diffusion Tube	17.6	17.8	0.9
EBC/5	Diffusion Tube	17.8	17.3	-2.9
EBC/10	Diffusion Tube	11.9	14.2	19.2

The data in **Table 8a.20** shows that all concentrations in the model now lie within the acceptable 25% margin with the majority within the ideal 10% margin of error, indicating the model performance is acceptable.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.20** to determine the error within the calculations before Road-NO_x adjustment, based upon the following calculation:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(obs_i - Pred_i)^2}$$

Table 8a.20: Root Mean Squared Error (RMSE) (Verification 4)

Site ID	Monitored	Modelled	Difference
EBC/1a	15.0	16.3	-1.4
EBC/2	18.8	19.0	-0.2
EBC/4	17.8	17.6	0.2
EBC/5	17.3	17.8	-0.5
EBC/10	14.2	11.9	2.3
RMSE			1.2

The calculated RMSE is 1.2 µg/m^3, which means the modelled results could be over or under-predicting concentrations by 1.2 µg/m^3. The RMSE means modelled results are acceptable as they sit within the accepted 10% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.21** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$FB = \frac{(Avg.Obs - Avg.Pred)}{0.5\,(Avg.Obs + Avg.Pred)}$$

Table 8a.21: Fractional Bias (Verification 4)

Average Observed Value	Average Predicted Value	Fractional Bias
16.5	16.6	-0.005

The calculated fractional bias is the ideal value of -0.005, which indicates the model performance is acceptable.

Verification 5: South Derbyshire

This verification process included one roadside diffusion tube located within the residential suburb of Alvaston in the south of Derby. This was considered most representative of the area of South West Derbyshire District Council (SWDDC) near the A6 (Derby Spur). The diffusion tube was installed by SDDC. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.5**.

Figure 8a.5: Location of Verification Monitoring Locations (Verification 5)

Table 8a.22 compares the monitored and modelled NO_2 concentrations at this monitoring location.

Table 8a.22: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 5)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
SDDC15	Diffusion Tube	15.8	14.7	-7.3

The data in Table 8a.22 shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

While the difference for the site is less than 10%, an adjustment factor has still been derived for robustness.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.23**.

Table 8a.23: Deriving the Adjustment Factor (Verification 5)

Site ID	Monitored Road NO_x ($\mu g/m^3$)	Modelled Road NO_x ($\mu g/m^3$)	Ratio
SDDC15	4.17	1.70	2.458

Table 8a.24 compares monitored and modelled NO_2 concentrations at the monitoring location after the adjustment factor has been applied.

Table 8a.24: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 3)

Site ID	Type	Concentrations ($\mu g/m^3$)		
		Monitored	Modelled	% Difference
SDDC15	Diffusion Tube	15.8	15.8	0.0

The data in **Table 8a.24** shows that the concentration in the model lies within the ideal 10% margin of error, indicating the model performance is acceptable.

Since only one monitoring location was used to inform this verification, it was not considered appropriate to undertake any further statistical analysis.

Verification 6: Derby

This verification process included six roadside diffusion tubes located beside the A6 the A42 (Brian Clough Way) in Derby. These were considered most representative of roads which head into and out of Derby City Centre. The diffusion tubes were installed by Derby City Council. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.6**.

Figure 8a.6: Location of Verification Monitoring Locations (Verification 6)

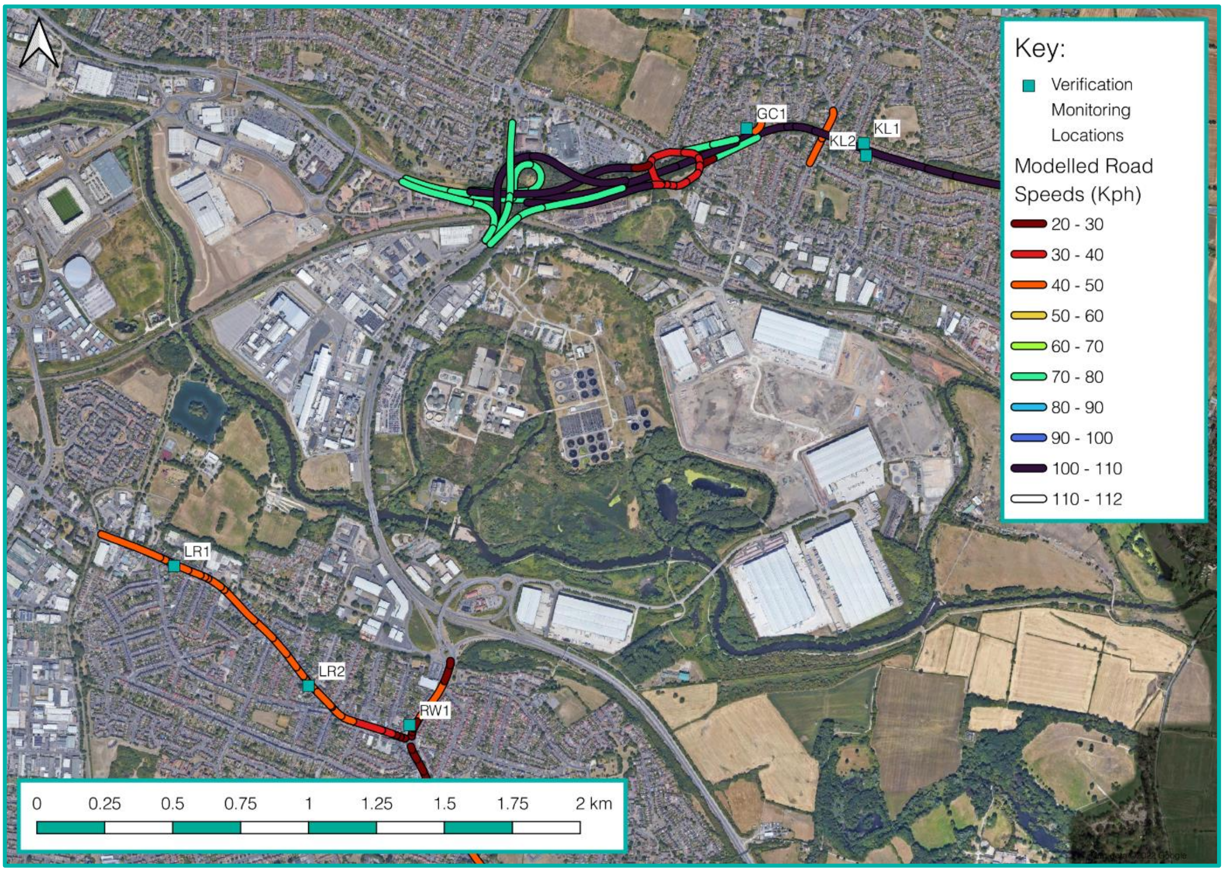

Table 8a.27 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.27: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 6)

Site ID	Type	Concentrations (μg/m^3)		
		Monitored	Modelled	% Difference
LR1	Diffusion Tube	38.2	35.4	-7.4
LR2	Diffusion Tube	28.1	22.1	-21.3
RW1	Diffusion Tube	23.9	20.1	-16.1
KL1	Diffusion Tube	18.7	18.7	0.0
KL2	Diffusion Tube	16.5	19.0	15.1
GC1	Diffusion Tube	18.1	21.6	-10.1

The data in **Table 8a.27** shows the model is both over- and under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for some of the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.28**.

Table 8a.28: Deriving the Adjustment Factor (Verification 6)

Site ID	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Ratio
LR1	38.38	30.08	1.282
LR2	29.13	14.15	
RW1	18.44	9.34	
KL1	8.68	8.68	
KL2	3.79	9.34	
GC1	2.62	10.44	

Table 8a.29 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.29: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 6)

Site ID	Type	Concentrations (µg/m³)		
		Monitored	Modelled	% Difference
LR1	Diffusion Tube	38.2	38.3	0.2
LR2	Diffusion Tube	28.1	23.8	-15.4
RW1	Diffusion Tube	23.9	21.2	-11.3
KL1	Diffusion Tube	18.7	19.8	5.7
KL2	Diffusion Tube	16.5	20.1	22.1
GC1	Diffusion Tube	18.1	22.8	26.0

The data in **Table 8a.29** shows that all concentrations in the model now generally lie within the acceptable 25% of the monitored concentrations, with one over predicting by 26%, which would represent a worst case. Therefore, the model is deemed to be performing acceptably.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.30** to determine the error within the calculations before Road-NO_x adjustment, based upon the following calculation:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(obs_i - Pred_i)^2}$$

Table 8a.30: Root Mean Squared Error (RMSE) (Verification 6)

Site ID	Monitored	Modelled	Difference
LR1	38.3	38.2	0.1
LR2	23.8	28.1	-4.3
RW1	21.2	23.9	-2.7
KL1	19.8	18.7	1.1
KL2	20.1	16.5	3.6
GC1	22.8	18.1	4.7
RMSE			3.2

The calculated RMSE is 3.2 µg/m^3, which means the modelled results could be over or under-predicting concentrations by 3.2 µg/m^3. The RMSE means modelled results are acceptable as they sit within the accepted 10% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.31** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$FB = \frac{(\text{Avg.Obs} - \text{Avg.Pred})}{0.5\,(\text{Avg.Obs} + \text{Avg.Pred})}$$

Table 8a.31: Fractional Bias (Verification 6)

Average Observed Value	Average Predicted Value	Fractional Bias
25.1	24.6	-0.018

The calculated fractional bias is -0.018, which is close to the ideal value of 0, which indicates the model performance is acceptable.

Verification 7: Castle Donnington (AQMA)

This verification process included two roadside diffusion tubes located within the Castle Donnington AQMA. These were considered most representative of residential dwellings located within the AQMA. The diffusion tubes were installed by NWLDC. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.7**.

Figure 8a.7: Location of Verification Monitoring Locations (Verification 7)

Table 8a.32 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.32: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 7)

Site ID	Type	Concentrations (µg/m³)		
		Monitored	Modelled	% Difference
17N	Diffusion Tube	24.1	11.6	-52.0
18N	Diffusion Tube	34.1	13.8	-59.6

The data in **Table 8a.32** shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for both of the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.33**.

Table 8a.33: Deriving the Adjustment Factor (Verification 7)

Site ID	Monitored Road NO_x (μg/m^3)	Modelled Road NO_x (μg/m^3)	Ratio
17N	31.15	2.32	8.904
18N	59.35	7.05	

Table 8a.34 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.34: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 7)

Site ID	Type	Concentrations (μg/m^3)		
		Monitored	Modelled	% Difference
17N	Diffusion Tube	24.1	19.8	-17.7
18N	Diffusion Tube	34.1	35.2	3.2

The data in **Table 8a.34** shows that all concentrations in the model now lie within the 25% margin of error, indicating the model is performing acceptably. However, due to the nature of the high adjustment factor (8.904), a further discussion of the performance of this verification is included at the end of this section.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.35** to determine the error within the calculations before Road-NO_x adjustment, based upon the following calculation:

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\text{obs}_i - \text{Pred}_i)^2}$$

Table 8a.35: Root Mean Squared Error (RMSE) (Verification 7)

Site ID	Monitored	Modelled	Difference
17N	19.8	24.1	-4.3
18N	35.2	34.1	1.1
RMSE			3.1

The calculated RMSE is 3.1 μg/m^3, which means the modelled results could be over or under-predicting concentrations by 3.1 μg/m^3. The RMSE means modelled results are acceptable as they sit within the accepted 10% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.36** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$FB = \frac{(Avg.Obs - Avg.Pred)}{0.5\,(Avg.Obs + Avg.Pred)}$$

Table 8a.36: Fractional Bias (Verification 7)

Average Observed Value	Average Predicted Value	Fractional Bias
29.1	27.5	0.056

The calculated fractional bias is 0.056, which is close to the ideal value of 0, which indicates the model performance is acceptable.

Discussion

Since the calculated adjustment factor of 8.904 suggests a substantial under-prediction of air pollutant concentrations in the un-adjusted model, a further discussion is required to better understand the model performance in this area. The two diffusion tube monitoring locations used for this verification monitored annual mean NO_2 concentrations which illustrated very notable impact from nearby sources, since background concentrations were relatively low, however the traffic data suggested the road passing these diffusion tubes (Bondgate) was unlikely to be a major source of pollution. It is therefore thought that the street canyon on Bondgate, which had been built into the model, was inhibiting dispersion of pollutants more than the model was able to pick up.

Nonetheless, after adjusting the model, it was deemed to be performing acceptably and therefore the modelled results are likely to be representative of real-life conditions in the area.

Verification 8: Castle Donnington (Outside of AQMA)

This verification process included three roadside diffusion tubes located within Castle Donnington but outside of the Castle Donnington AQMA. These were considered most representative of residential dwellings located outside the AQMA. The diffusion tubes were installed by NWLDC. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.8**.

Figure 8a.8: Location of Verification Monitoring Locations (Verification 8)

Table 8a.37 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.37: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 8)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
14N	Diffusion Tube	13.7	13.9	1.5
40N	Diffusion Tube	15.2	14.2	-6.8
41N	Diffusion Tube	19.9	16.7	-16.1

The data in **Table 8a.37** shows the model is both over- and under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for one of the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.38**.

Table 8a.38: Deriving the Adjustment Factor (Verification 8)

Site ID	Monitored Road NO_x (µg/m^3)	Modelled Road NO_x (µg/m^3)	Ratio
14N	4.68	5.11	1.166
40N	6.61	4.39	
41N	19.67	12.31	

Table 8a.39 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.39: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 8)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
14N	Diffusion Tube	13.7	14.3	4.4
40N	Diffusion Tube	15.2	14.5	-4.5
41N	Diffusion Tube	19.9	17.6	-11.6

The data in **Table 8a.39** shows that all concentrations in the model now lie within the ideal 25% margin of error, indicating the model is performing acceptably.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.40** to determine the error within the calculations before Road-NO_x adjustment, based upon the following calculation:

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\mathrm{obs}_i - \mathrm{Pred}_i)^2}$$

Table 8a.40: Root Mean Squared Error (RMSE) (Verification 8)

Site ID	Monitored	Modelled	Difference
14N	14.3	13.7	0.6
40N	14.5	15.2	-0.7
41N	17.6	19.9	-2.3
RMSE			0.6

The calculated RMSE is 0.6 µg/m^3, which means the modelled results could be over or under-predicting concentrations by 0.6 µg/m^3. The RMSE means modelled results are acceptable as they sit within the accepted 10% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.41** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$FB = \frac{(Avg.Obs - Avg.Pred)}{0.5\ (Avg.Obs + Avg.Pred)}$$

Table 8a.41: Fractional Bias (Verification 8)

Average Observed Value	Average Predicted Value	Fractional Bias
16.3	15.5	0.050

The calculated fractional bias is 0.031, which is close to the ideal value of 0, which indicates the model performance is acceptable.

Verification 9: Shepshed

This verification process included three roadside diffusion tubes located within Shepshed. These were considered most representative of residential dwellings located throughout Shepshed and the neighbouring villages of Finney Hill and Blackbrook. The diffusion tubes were installed by CBC. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.9**.

Figure 8a.9: Location of Verification Monitoring Locations (Verification 9)

Table 8a.42 compares the monitored and modelled NO_2 concentrations at these monitoring locations.

Table 8a.42: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 9)

Site ID	Type	Concentrations (µg/m³)		
		Monitored	Modelled	% Difference
DT17	Diffusion Tube	15.4	16.4	6.8
DT27	Diffusion Tube	23.3	13.3	-42.7
DT46	Diffusion Tube	14.3	13.0	-9.4

The data in **Table 8a.42** shows the model is both over- and under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for two of the sites is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.43**.

Table 8a.43: Deriving the Adjustment Factor (Verification 9)

Site ID	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Ratio
DT17	9.82	12.14	1.541
DT27	28.49	5.33	
DT46	8.41	5.49	

Table 8a.44 compares monitored and modelled NO_2 concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8a.44: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 9)

Site ID	Type	Concentrations (µg/m³)		
		Monitored	Modelled	% Difference
DT17	Diffusion Tube	15.4	19.3	25.3
DT27	Diffusion Tube	23.3	14.7	-37.0
DT46	Diffusion Tube	14.3	14.3	0.2

The data in **Table 8a.44** shows that one concentration sits within the ideal 10% margin of error. DT17 and DT27 sit outside the acceptable percentage difference of 25%, this is discussed further at the end of this section.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in **Table 8a.45** to determine the error within the calculations before Road-NO_x adjustment, based upon the following calculation:

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\text{obs}_i - \text{Pred}_i)^2}$$

Table 8a.45: Root Mean Squared Error (RMSE) (Verification 9)

Site ID	Monitored	Modelled	Difference
DT17	19.3	15.4	3.9
DT27	14.7	23.3	-8.6
DT46	14.3	14.3	0.0
RMSE			5.5

The calculated RMSE is 5.5 µg/m^3, which means the modelled results could be over or under-predicting concentrations by 5.5 µg/m^3. The RMSE means modelled results are acceptable as they sit within the accepted 25% margin of error (as advised in TG22) and therefore no further adjustment is required.

Fractional Bias

The fractional bias, as set out in **Table 8a.46** has been calculated to identify if the model shows a systematic tendency to over or under-predict. The following formula has been used to calculate the fractional bias.

$$\text{FB} = \frac{(\text{Avg.Obs} - \text{Avg.Pred})}{0.5\,(\text{Avg.Obs} + \text{Avg.Pred})}$$

Table 8a.46: Fractional Bias (Verification 9)

Average Observed Value	Average Predicted Value	Fractional Bias
17.7	16.0	0.093

The calculated fractional bias is 0.093, which is close to the ideal value of 0, which indicates the model performance is acceptable.

Discussion

Due to the nature of the variability in the results in this verification, a further investigation to understand this discrepancy was undertaken. It is thought much of the discrepancy can be attributed to the background concentrations used in the modelling works, which meant the same background concentrations were used for diffusion tubes DT17 and DT27. No motorway NOx removal process could be undertaken at DT17, due to the positioning of the grid squares in this area. It is likely that this caused the relative discrepancy in performance between DT17 and DT27, with DT46 unaffected by this since a different grid square's background concentration could be used.

Verification 10: Copt Oak ('A' Scenarios)

This verification process included one roadside diffusion tube located near the M1 as it passes through Copt Oak. This was considered most representative of residential dwellings located near to the M1 and along nearby roads.

The diffusion tubes were installed by NWLDC. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.10**.

It is pertinent to note that the adjustment factor derived from this verification has been applied to all 'A' modelling scenarios, with the adjustment factor derived for the same monitoring location from Verification 11, being applied to all 'B' modelling scenarios.

Figure 8a.10: Location of Verification Monitoring Location (Verification 10)

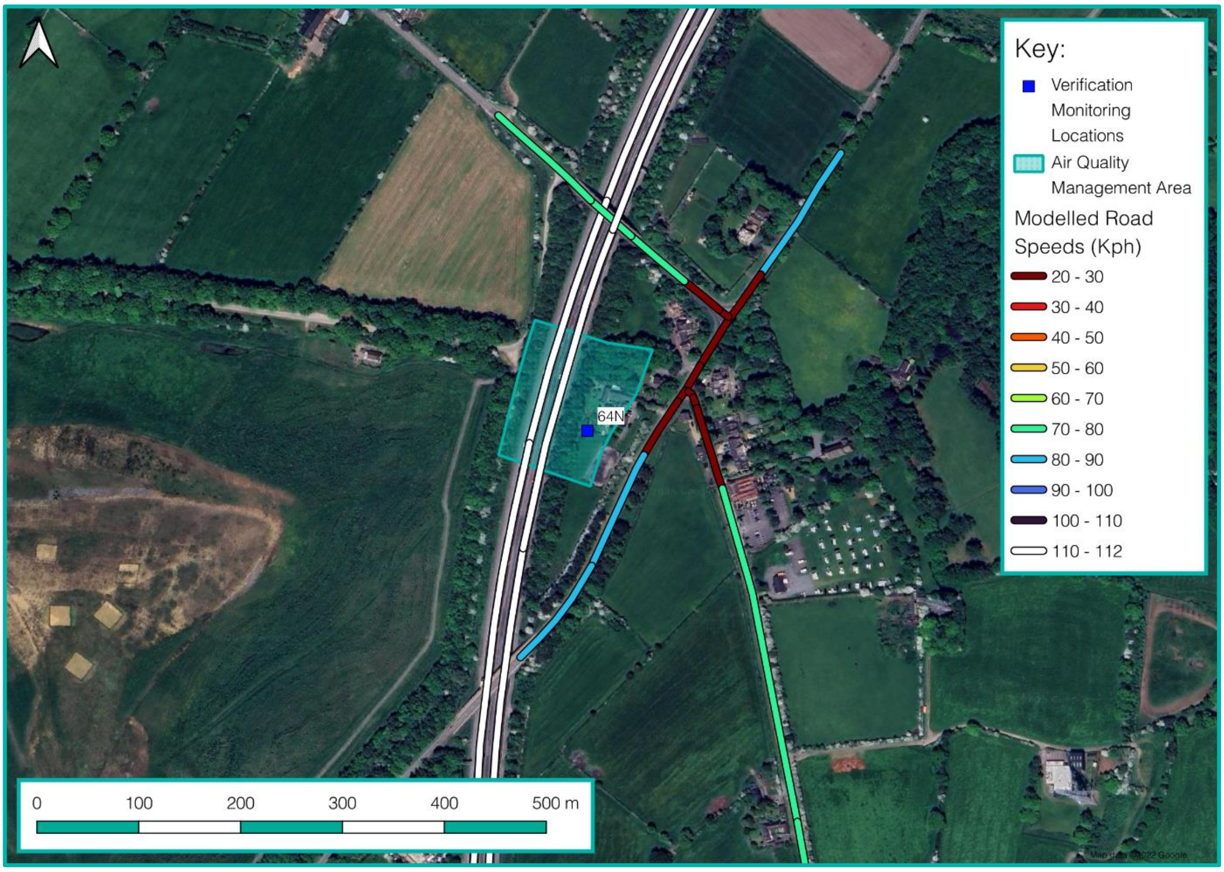

Table 8a.47 compares the monitored and modelled NO_2 concentrations at this monitoring location.

Table 8a.47: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 10)

Site ID	Type	Concentrations (µg/m³)		
		Monitored	Modelled	% Difference
64N	Diffusion Tube	27.3	20.7	-24.4

The data in **Table 8a.47** shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for this site is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.48**.

Table 8a.48: Deriving the Adjustment Factor (Verification 10)

Site ID	Monitored Road NO_x (µg/m^3)	Modelled Road NO_x (µg/m^3)	Ratio
64N	38.2	21.3	1.791

Table 8a.49 compares monitored and modelled NO_2 concentrations at the monitoring location after the adjustment factor has been applied.

Table 8a.49: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 10)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
64N	Diffusion Tube	27.3	27.3	0.0

The data in **Table 8a.49** shows that all concentrations in the model now lie within the ideal 10% margin of error, indicating the model performance is acceptable.

Since only one monitoring location was used to inform this verification, it was not considered appropriate to undertake any further statistical analysis.

Verification 11: Copt Oak ('B' Scenarios)

This verification process included one roadside diffusion tube located near the M1 as it passes through Copt Oak. This was considered most representative of residential dwellings located near to the M1 and along nearby roads. The diffusion tubes were installed by NWLDC. The modelled road network and location of the verification monitoring locations are illustrated in **8a.11**.

As discussed within verification 10, the adjustment factor derived from this verification has been applied to all 'B' modelling scenarios, with the adjustment factor derived for the same monitoring location from verification 10, being applied to all 'A' modelling scenarios.

Figure 8a.11: Location of Verification Monitoring Location (Verification 11)

Table 8a.52 compares the monitored and modelled NO_2 concentrations at the monitoring location.

Table 8a.52: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 11)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
64N	Diffusion Tube	27.3	20.2	-26.0

The data in **Table 8a.52** shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for this site is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.53**.

Table 8a.53: Deriving the Adjustment Factor (Verification 11)

Site ID	Monitored Road NO_x (µg/m^3)	Modelled Road NO_x (µg/m^3)	Ratio
64N	38.2	20.3	1.885

Table 8a.54 compares monitored and modelled NO_2 concentrations at the monitoring location after the adjustment factor has been applied.

Table 8a.54: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 11)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
64N	Diffusion Tube	27.3	27.3	0.0

The data in **Table 8a.54** shows that all concentrations in the model now lie within the ideal 10% margin of error, indicating the model performance is acceptable.

Since only one monitoring location was used to inform this verification, it was not considered appropriate to undertake any further statistical analysis.

Verification 12: Whitwick

This verification process included one roadside diffusion tube located along North Street, one of the main roads heading into the centre of Whitwick. This was considered most representative of the residential dwellings within Whitwick. The diffusion tubes were installed by NWLDC. The modelled road network and location of the verification monitoring locations are illustrated in **Figure 8a.12**.

Figure 8a.12: Location of Verification Monitoring Location (Verification 12)

Table 8a.57 compares the monitored and modelled NO_2 concentrations at the monitoring location.

Table 8a.57: Comparison of Monitored and Modelled NO_2 Concentrations (Verification 12)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
60N	Diffusion Tube	21.6	11.7	-45.9

The data in **Table 8a.57** shows the model is under-predicting NO_2 concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

As the difference for the site is more than +/- 10%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO_2 emissions that are modelled, an adjustment factor must be derived for the road contribution of NO_x. A ratio of the modelled versus monitored NO_x concentrations using the least squares statistical method has been undertaken to derive an adjustment factor, as set out in **Table 8a.58**.

Table 8a.58: Deriving the Adjustment Factor (Verification 12)

Site ID	Monitored Road NO_x (µg/m^3)	Modelled Road NO_x (µg/m^3)	Ratio
60N	27.63	5.10	5.422

Table 8a.59 compares monitored and modelled NO_2 concentrations at the monitoring location after the adjustment factor has been applied.

Table 8a.59: Comparison of Monitored and Adjusted Modelled NO_2 Concentrations (Verification 12)

Site ID	Type	Concentrations (µg/m^3)		
		Monitored	Modelled	% Difference
60N	Diffusion Tube	21.6	21.6	0.0

The data in **Table 8a.59** shows that all concentrations in the model now lie within the ideal 10% margin of error, indicating the model performance is acceptable.

Since only one monitoring location was used to inform this verification, it was not considered appropriate to undertake any further statistical analysis.