

Appendix 8.7: Verification

APPENDIX 8.7 – 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.

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

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%.

For this assessment, six verification processes were undertaken to account for potential variability in dispersion in various areas modelled as part of the impact assessment. All six of these verification processes considered NO₂, while one considered PM as well.

NO₂ Verification

Verification 1: Ibstock

This verification process incorporated two diffusion tube monitoring locations in Ibstock. The modelled road network (including the modelled road speeds), and location of the verification diffusion tube monitoring locations are demonstrated in Figure 8.7.1.

Figure 8.7.1: Modelled Verification Road Network

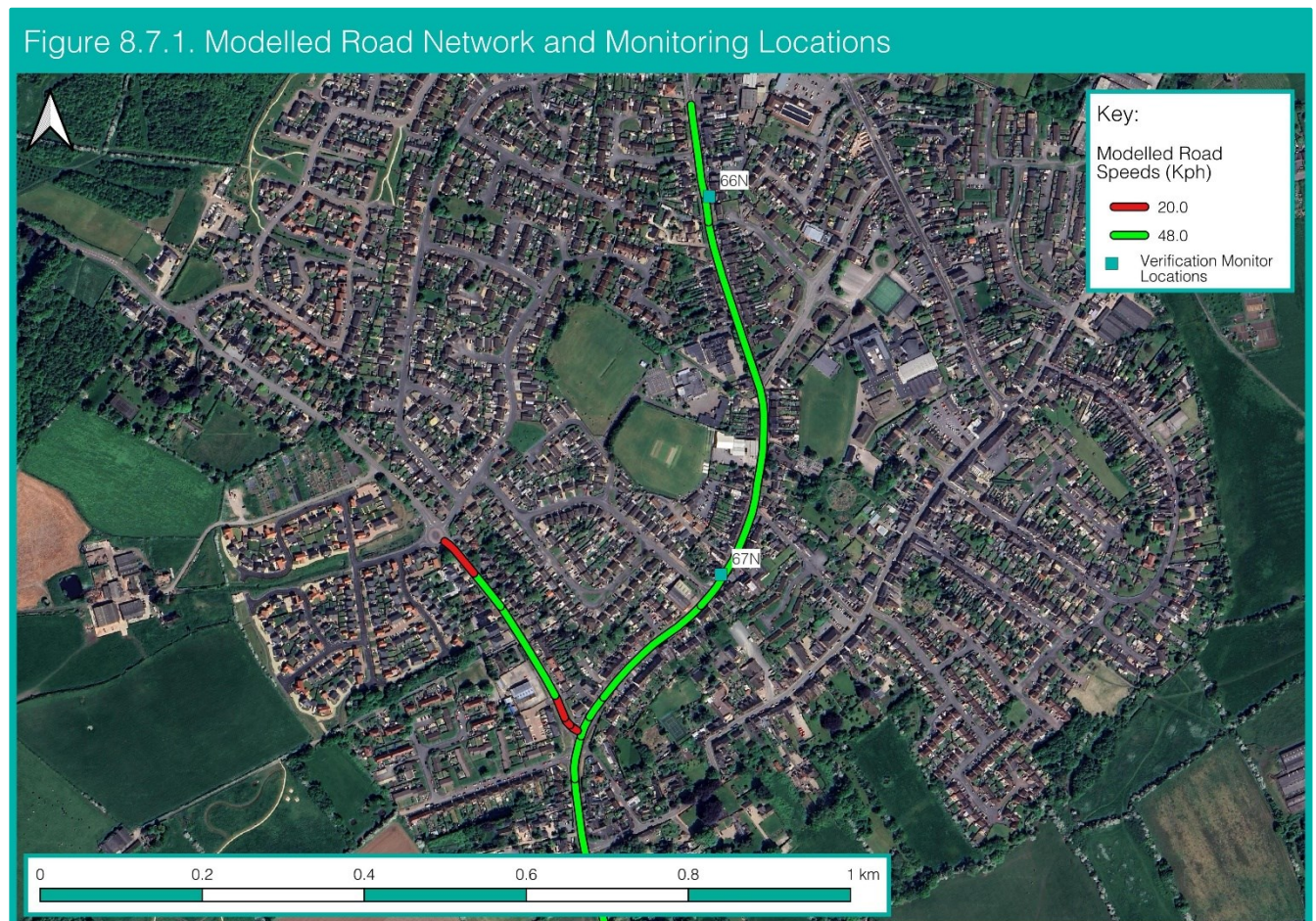


Table 8.7.1 compares the monitored and modelled NO₂ concentrations at the monitoring locations.

Table 8.7.1: Comparison of Monitored and Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
66N	Diffusion Tube	14.9	9.9	-33.8
67N	Diffusion Tube	16.3	10.1	-38.0

The data in Table 8.7.1 shows that the model is under-predicting NO₂ concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

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

As it is primary NO_x rather than secondary NO₂ 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 8.7.2.

Table 8.7.2: Deriving the Adjustment Factor

Site ID	Monitored Road NO _x (µg/m ³)	Modelled Road NO _x (µg/m ³)	Ratio
66N	14.4	3.6	4.151
67N	17.6	4.1	

Table 8.7.3 compares monitored and modelled NO₂ concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8.7.3: Comparison of Monitored and Adjusted Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
66N	Diffusion Tube	14.9	15.2	1.7
67N	Diffusion Tube	16.3	16.1	-1.3

The data in Table 8.7.3 shows that NO₂ concentrations in the model now all lie within 10% of monitored concentration, indicating that the model is performing acceptably.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in Table 8.7.4 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 8.7.4: Root Mean Squared Error

Site ID	Predictions	Observations	Difference
66N	15.2	14.9	0.3
67N	16.1	16.3	-0.2
RMSE:			0.2

The calculated RMSE is 0.2 µg/m³, which means that modelled results could be under or over predicting pollution concentrations between +/- 0.2 µg/m³. The RMSE means that modelled results are acceptable, as they are within the ideal 10% margin of error (as advised in TG22), and therefore no further adjustment factor is required.

Fractional Bias

The fractional bias, as set out in Table 8.7.5, 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 8.7.5: Fractional Bias

Average Observed Values (µg/m ³)	Average Predicted Values (µg/m ³)	Fractional Bias
15.6	15.6	-0.001

The calculated fractional bias is -0.001 which indicates that the model is slightly underpredicting. However, the fractional bias is close to the ideal value of 0, which suggests that the model is performing acceptably.

Verification 2: Flying Horse Roundabout

This verification process incorporated one diffusion tube monitoring location located near to the A511 Shaw Lane. The modelled road network (including the modelled road speeds), and location of the verification diffusion tube monitoring location is demonstrated in Figure 8.7.2.

Figure 8.7.2: Modelled Verification Road Network

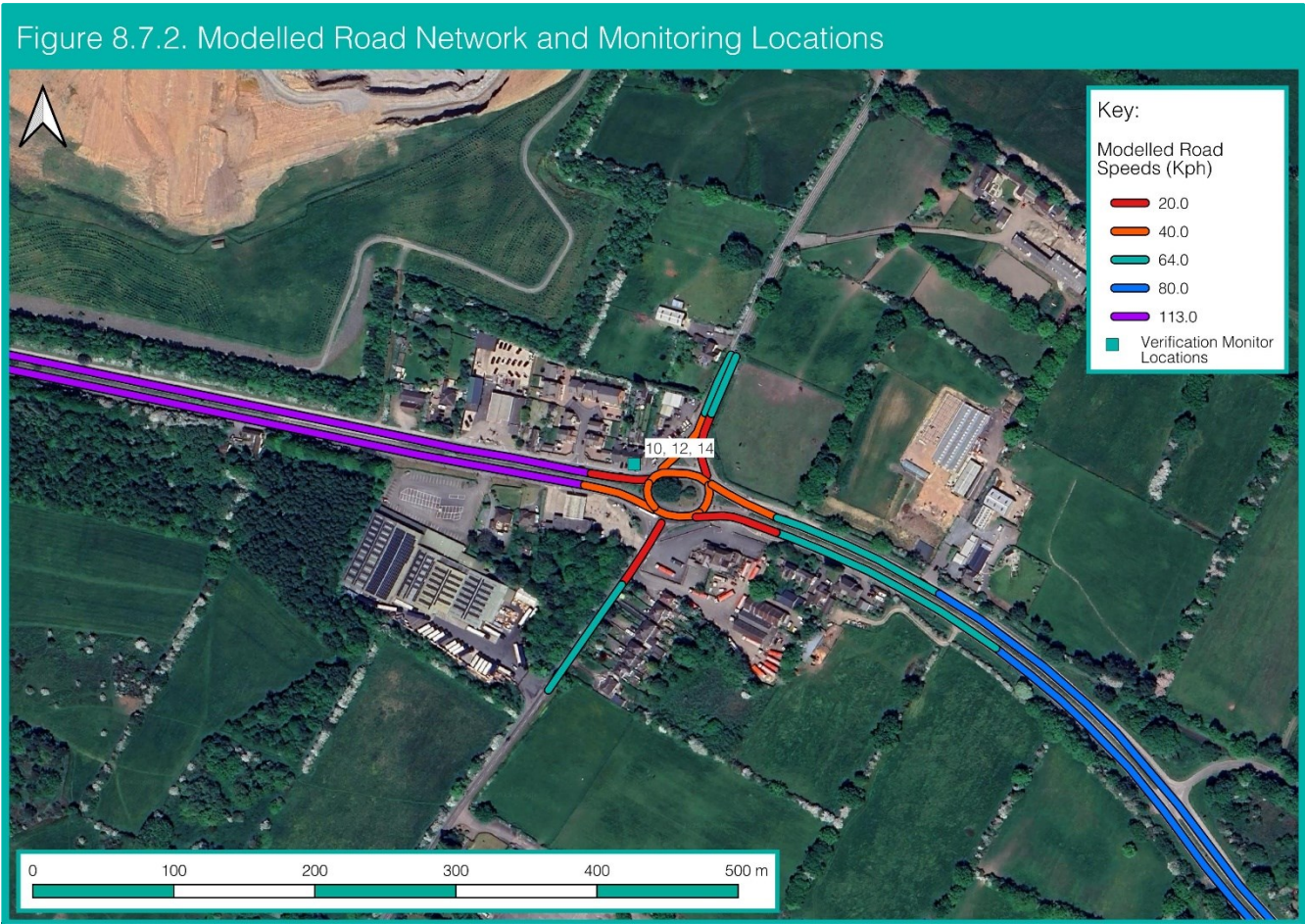


Table 8.7.6 compares the monitored and modelled NO₂ concentrations at this monitoring location.

Table 8.7.6: Comparison of Monitored and Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
10, 12, 14	Diffusion Tube	27.1	21.4	-21.1

The data in Table 8.7.6 shows that the model is under-predicting NO₂ 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 NO₂ 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 8.7.7.

Table 8.7.7: Deriving the Adjustment Factor

Site ID	Monitored Road NO _x (µg/m ³)	Modelled Road NO _x (µg/m ³)	Ratio
10, 11, 14	33.6	19.2	1.746

Table 8.7.8 compares monitored and modelled NO₂ concentrations at the monitoring location after the adjustment factor has been applied.

Table 8.7.8: Comparison of Monitored and Adjusted Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
10, 11, 14	Diffusion Tube	27.1	27.1	0.0

The data in Table 8.7.8 shows that NO₂ concentrations in the model now match the monitored concentration, indicating that the model is performing acceptably.

Verification 3: Sinope and Coalville

This verification process incorporated five diffusion tube monitoring locations and one automatic zephyr monitoring location located in Sinope and Coalville. The modelled road network (including the modelled road speeds), and location of the verification diffusion tube monitoring locations are demonstrated in [Figure 8.7.3](#) and [Figure 8.7.4](#).

Figure 8.7.3: Modelled Verification Road Network (Sinope)



Figure 8.7.4: Modelled Verification Road Network (Coalville)

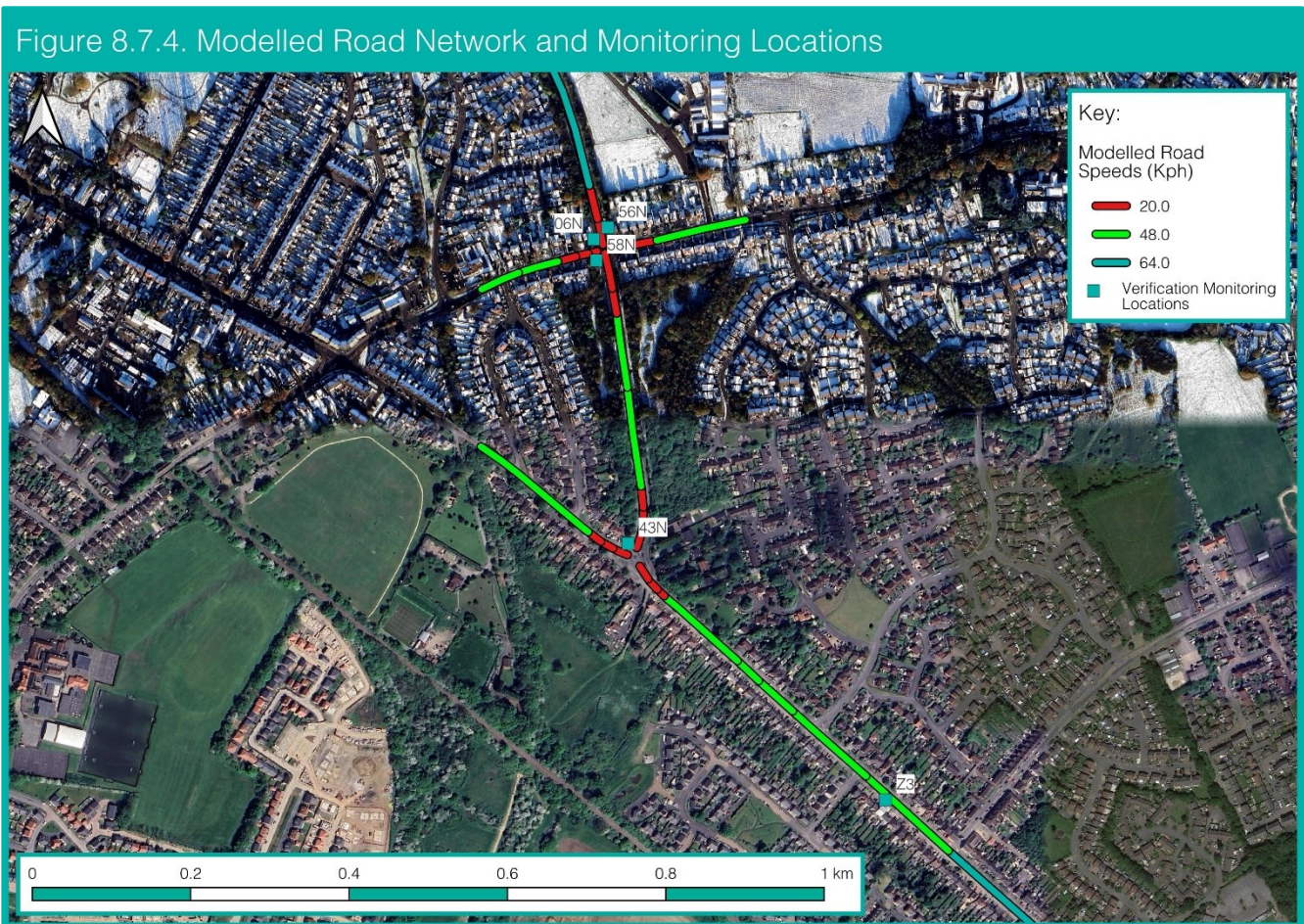


Table 8.7.9 compares the monitored and modelled NO₂ concentrations at the monitoring locations.

Table 8.7.9: Comparison of Monitored and Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
Z3	Zephyr	18.3	10.9	-40.3
06N	Diffusion Tube	23.4	12.5	-46.6
31N	Diffusion Tube	16.2	10.5	-35.5
43N	Diffusion Tube	19.9	12.3	-38.1
56N	Diffusion Tube	27.6	13.2	-52.1
58N	Diffusion Tube	15.6	12.2	-21.6

The data in Table 8.7.9 shows that the model is under-predicting NO₂ concentrations. This is not unusual and is likely to be the result of local dispersion conditions. Since the modelled results lie outside of the ideal 10% margin of error, an adjustment has been derived.

As it is primary NO_x rather than secondary NO₂ 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 8.7.10.

Table 8.7.10: Deriving the Adjustment Factor

Site ID	Monitored Road NO _x (µg/m ³)	Modelled Road NO _x (µg/m ³)	Ratio
Z3	18.27	2.17	4.330
06N	31.28	6.02	
31N	18.18	5.63	
43N	23.63	6.51	
56N	42.38	7.54	
58N	12.77	5.46	

Table 8.7.11 compares monitored and modelled NO₂ concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8.7.11: Comparison of Monitored and Adjusted Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
Z3	Diffusion Tube	18.3	14.3	-21.7
06N	Diffusion Tube	23.4	21.3	-9.0
31N	Diffusion Tube	16.2	18.9	16.4
43N	Diffusion Tube	19.9	21.8	9.4
56N	Diffusion Tube	27.6	23.9	-13.3
58N	Diffusion Tube	15.6	20.3	30.2

The data in Table 8.7.11 shows that a one of the concentrations of NO₂ produced by the model is not within 25% of the monitored concentration (58N). This result demonstrates that the model is not performing to the best possible standards. Nonetheless, it was considered the model was developed to its fullest potential. Therefore, a further statistical analysis should still be undertaken to understand the differences.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in Table 8.7.12 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 8.7.12: Root Mean Squared Error

Site ID	Predictions	Observations	Difference
Z3	14.3	18.3	-4.0
06N	21.3	23.4	-2.1
31N	18.9	16.2	2.7
43N	21.8	19.9	1.9
56N	23.9	27.6	-3.7
58N	20.3	15.6	4.7
RMSE:			3.3

The calculated RMSE is 3.3 µg/m³, which means that modelled results could be under or over predicting pollution concentrations between +/- 3.3 µg/m³. The RMSE means that modelled results are acceptable, as they are within a the ideal 10% margin of error (as advised in TG22), and therefore no further adjustment factor is required. It is noted that Diffusion Tube 58N sits outside of the ideal margin of error, however since the modelled results as a whole are deemed to be working within an acceptable margin of error, this is not considered cause for revisiting any modelling works.

Fractional Bias

The fractional bias, as set out in Table 8.7.13, 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 8.7.13: Fractional Bias

Average Observed Values (µg/m ³)	Average Predicted Values (µg/m ³)	Fractional Bias
20.2	20.1	0.004

The calculated fractional bias is 0.016 which indicates that the model is slightly overpredicting. However, the fractional bias is close to the ideal value of 0, which suggests that the model is performing acceptably.

Verification 4: Ratby

This verification process incorporated one diffusion tube monitoring location near to the M1 in Ratby. The modelled road network (including the modelled road speeds), and location of the verification diffusion tube monitoring location is demonstrated in Figure 8.7.5.

Figure 8.7.5: Modelled Verification Road Network

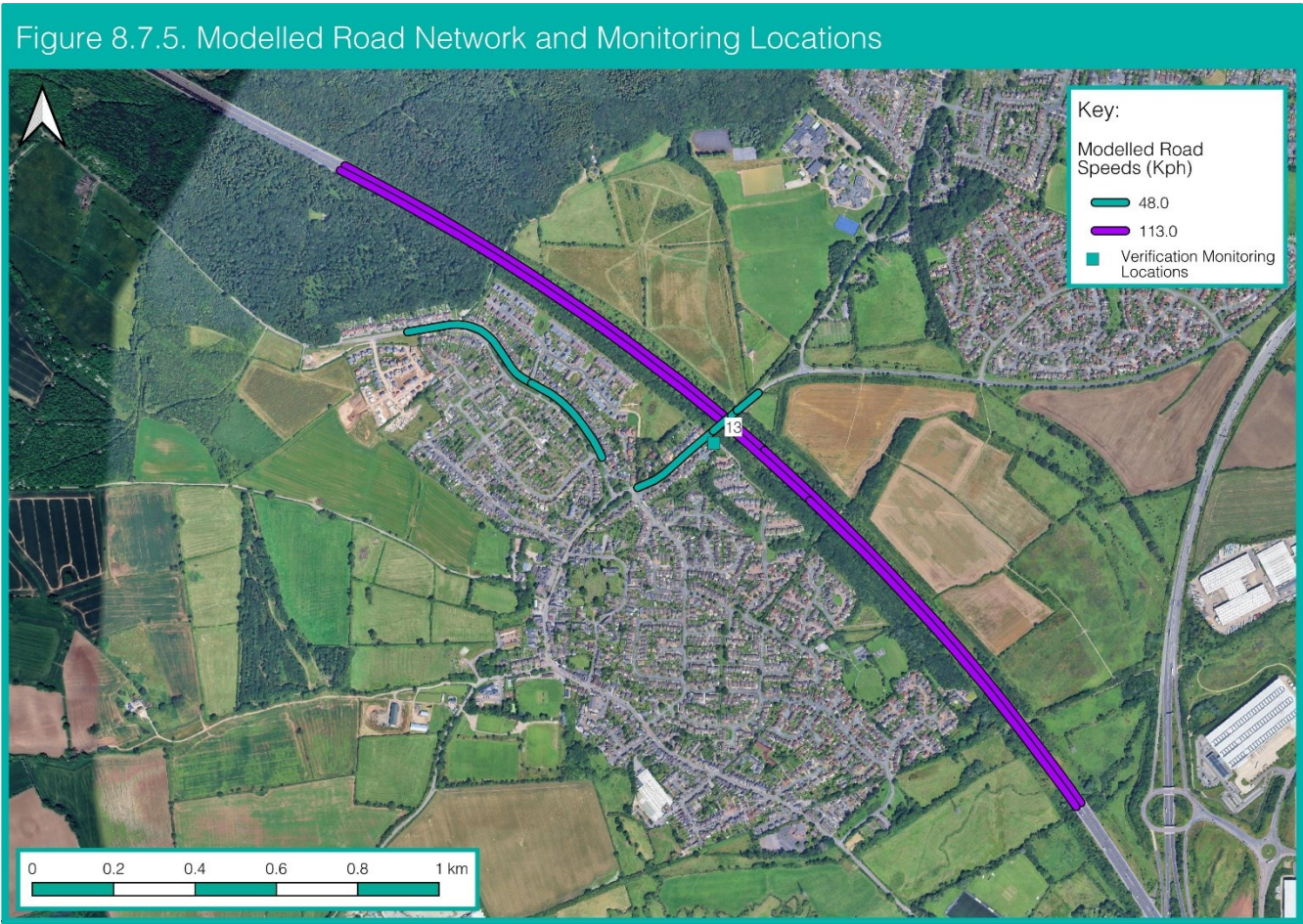


Table 8.7.14 compares the monitored and modelled NO₂ concentrations at the monitoring location.

Table 8.7.14: Comparison of Monitored and Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
13	Diffusion Tube	15.0	13.8	-8.1

The data in Table 8.7.14 shows that the model is under-predicting NO₂ concentrations. This is not unusual and is likely to be the result of local dispersion conditions.

While the difference for the site is not more than +/- 10% (and hence an adjustment factor does not need to be derived), to ensure a worst case assessment be undertaken, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO₂ 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 8.7.15.

Table 8.7.15: Deriving the Adjustment Factor

Site ID	Monitored Road NO _x (µg/m ³)	Modelled Road NO _x (µg/m ³)	Ratio
13	12.18	9.52	1.280

Table 8.7.16 compares monitored and modelled NO₂ concentrations at the monitoring location after the adjustment factor has been applied.

Table 8.7.16: Comparison of Monitored and Adjusted Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
13	Diffusion Tube	15.0	15.0	0.0

The data in Table 8.7.16 shows that NO₂ concentrations in the model now match the monitored concentration, indicating that the model is performing acceptably.

Verification 5: Kirby Muxloe and Narborough

This verification process incorporated two diffusion tube monitoring locations located near to the M1 in Kirby Muxloe and Narborough. The modelled road network (including the modelled road speeds), and location of the verification diffusion tube monitoring locations are demonstrated in Figure 8.7.6 and Figure 8.7.7.

Figure 8.7.6: Modelled Verification Road Network

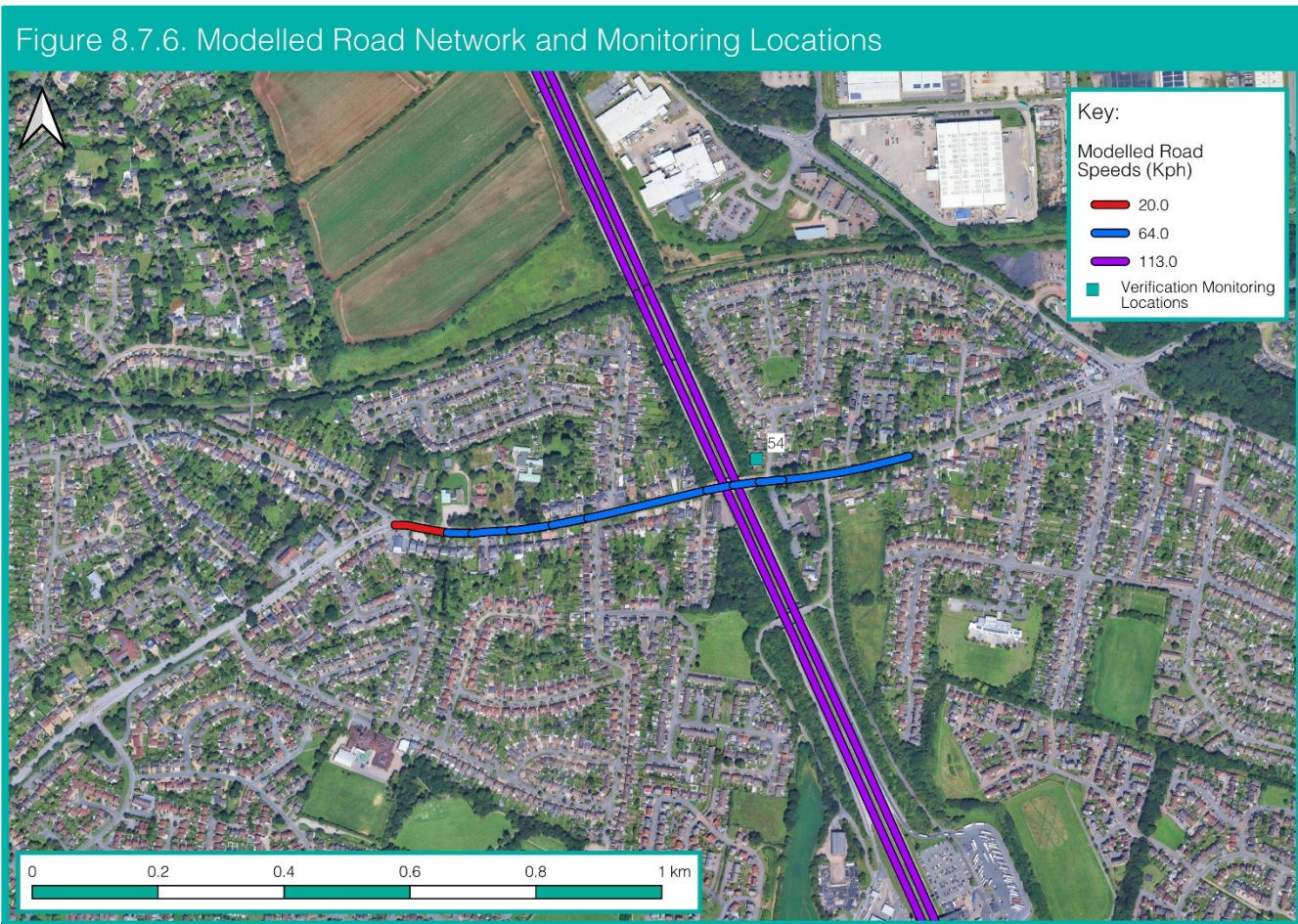


Figure 8.7.7: Modelled Verification Road Network

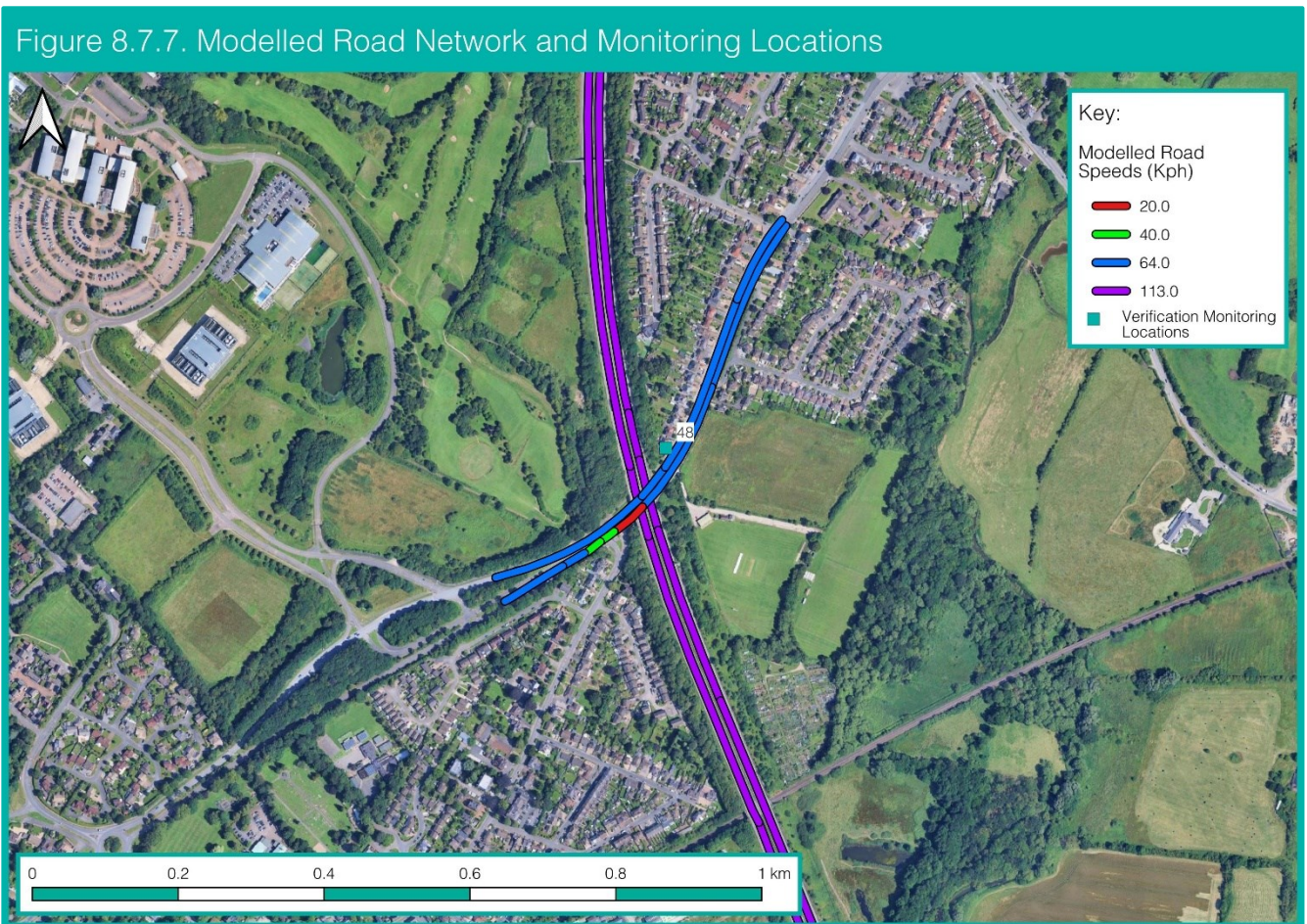


Table 8.7.17 compares the monitored and modelled NO₂ concentrations at the monitoring locations.

Table 8.7.17: Comparison of Monitored and Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
48	Diffusion Tube	20.7	17.4	-15.9
54	Diffusion Tube	23.6	17.3	-26.7

The data in Table 8.7.17 shows that the model is under-predicting NO₂ concentrations. This is not unusual and is likely to be the result of local dispersion conditions. Since all of the modelled results lie outside of the ideal 10% margin of error, an adjustment has been derived.

As it is primary NO_x rather than secondary NO₂ 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 8.7.18.

Table 8.7.18: Deriving the Adjustment Factor

Site ID	Monitored Road NO _x (µg/m ³)	Modelled Road NO _x (µg/m ³)	Ratio
48	22.52	14.80	1.823
54	25.00	10.14	

Table 8.7.19 compares monitored and modelled NO₂ concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8.7.19: Comparison of Monitored and Adjusted Modelled NO₂ Concentrations

Site ID	Type	Concentrations (µg/m ³)		
		Monitored	Modelled	% Difference
48	Diffusion Tube	20.7	22.5	8.8
54	Diffusion Tube	23.6	20.9	-11.4

The data in Table 8.7.19 shows that NO₂ concentrations in the model improved after the adjustment factor was applied, indicating that the model is performing acceptably within a 25% margin of error.

Root Mean Square Error

A Root Mean Square Error (RMSE) has been calculated in Table 8.7.20 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 8.7.20: Root Mean Squared Error

Site ID	Predictions	Observations	Difference
48	22.5	20.7	1.8
54	20.9	23.6	-2.7
RMSE:			1.8

The calculated RMSE is 1.8 µg/m³, which means that modelled results could be under or over predicting pollution concentrations between +/- 1.8 µg/m³. The RMSE means that modelled results are acceptable, as they are within the ideal 10% margin of error (as advised in TG22), and therefore no further adjustment factor is required.

Fractional Bias

The fractional bias, as set out in Table 8.7.21, 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 8.7.21: Fractional Bias

Average Observed Values ($\mu\text{g}/\text{m}^3$)	Average Predicted Values ($\mu\text{g}/\text{m}^3$)	Fractional Bias
22.2	21.7	0.019

The calculated fractional bias is 0.019 which indicates that the model is slightly overpredicting. However, the fractional bias is close to the ideal value of 0, which suggests that the model is performing acceptably.

Verification 6: Copt Oak

This verification process incorporated one diffusion tube monitoring location in Copt Oak. The modelled road network (including the modelled road speeds), and location of the verification diffusion tube monitoring location is demonstrated in Figure 8.7.8.

Figure 8.7.8: Modelled Verification Road Network

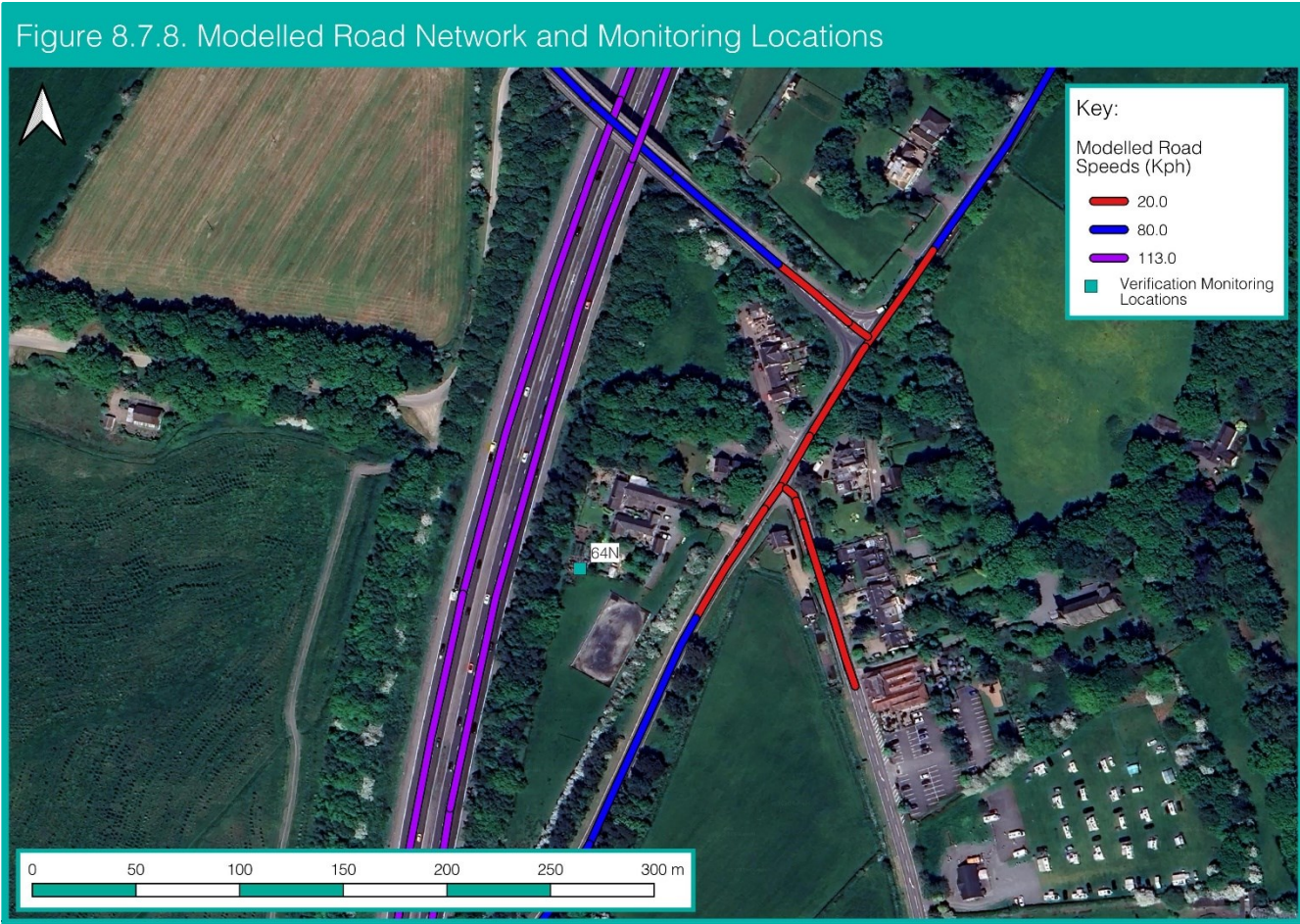


Table 8.7.22 compares the monitored and modelled NO_2 concentrations at the monitoring location.

Table 8.7.22: Comparison of Monitored and Modelled NO_2 Concentrations

Site ID	Type	Concentrations ($\mu\text{g}/\text{m}^3$)		
		Monitored	Modelled	% Difference
64N	Diffusion Tube	27.3	17.9	-34.6

The data in Table 8.7.22 shows that 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 is more than +/- 25%, an adjustment factor has been derived.

As it is primary NO_x rather than secondary NO₂ 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 8.7.23](#).

Table 8.7.23: Deriving the Adjustment Factor

Site ID	Monitored Road NO _x (µg/m ³)	Modelled Road NO _x (µg/m ³)	Ratio
64N	39.43	15.95	2.472

[Table 8.7.24](#) compares monitored and modelled NO₂ concentrations at the monitoring locations after the adjustment factor has been applied.

Table 8.7.24: Comparison of Monitored and Adjusted Modelled NO₂ Concentrations

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

The data in [Table 8.7.24](#) shows that NO₂ concentrations in the model now match the monitored concentration, indicating that the model is performing acceptably.

PM₁₀ and PM_{2.5} Verification

[Sinope & Coalville](#)

Monitor Z3 does have recorded concentrations of both PM₁₀ and PM_{2.5}, however, on analysis, the DEFRA background concentrations for PM₁₀ and PM_{2.5} at the grid square containing the monitoring location suggest lower PM₁₀ and PM_{2.5} concentrations than the roadside monitor records. Ultimately, this leads to the supposed modelled road PM₁₀ and modelled road PM_{2.5} being a negative number. Hence, the adjustment factor would be a negative number. Therefore, to provide a robust assessment, the modelled Road-PM₁₀ and Road-PM_{2.5} concentrations were adjusted by the relevant Road-NO_x adjustment factor throughout the modelled extent.

Receptor Application of Adjustment Factors

Due to the extent of the modelled highway network, 'pocket models' were generated which separated out relevant roads and receptors, simplifying the modelling process. On the whole, since the modelled highway network in each 'pocket model' was the same between the verification processes and scenarios modelled (with the exception of the addition of an area on the M1, north of junction 23), the verification factor calculated within each 'pocket model' was applied to receptors in the same pocket. Generally, the prefix given to each receptor ID identifies which adjustment factor was applied to the modelled concentration at each receptor.

However, there are some exceptions. Due to the nature of the local authority boundary between HBBC and NWLDC, the modelled road network relevant to each residential receptor regularly passed between the two local authorities, and hence the application of the relevant adjustment factor to each residential receptor in the area was considered. When in doubt over the most applicable adjustment factor, the worst case (highest) factor was applied.

[Table 8.7.25](#) summarises the process.

Table 8.7.25: Summary of Application of Adjustment Factors

Receptors	Relevant Verification	Adjustment Factor	RMSE
AB.R2a, AB.R2b & AB.R3 and AB.R11 – AB.R16	Verification 1: Ibstock	4.151	0.2
AB.R1 and AB.R4 - AB.R10 and CD.R1 – CD.R15	Verification 2: Flying Horse Roundabout	1.746	N/A
EF.R1 – EF.R10	Verification 3: Sinope and Coalville	4.330	3.3
GH.R1 – GH.R4	Verification 4: Ratby	1.280	N/A
KL.R1 – KL.R13	Verification 5: Kirkby Muxloe and Narborough	1.823	1.8
MN.R1 – MN.R2 and X.R1 – X.R3	Verification 6: Copt Oak	2.472	N/A