Appendix A8.1: Air Quality Methodology

1.1 Introduction

1.1.1 This air quality technical appendix supports Chapter 8 (Air Quality) and includes the following:

- Background concentrations;
- air quality verification and adjustment;
- air quality monitoring annualisation and bias-adjustment;
- verification;
- adjustment for long-term trends in nitrogen dioxide (NO_2); and
- construction road traffic.

1.2 Background Concentrations

1.2.1 The background concentrations for nitrogen oxides (NO_x) (the collective term for nitric oxide (NO) and nitrogen dioxide (NO_2)), NO_2 and particulate matter with an average aerodynamic diameter of less than 10µm (PM_{10}) across the study area, including all major pollution sources, have been derived using the national pollution maps published on the Scottish Air Quality website (Scottish Air Quality, 2024). The maps are empirically derived estimations of a pollutant concentration for a given 1km grid square. These cover the whole country on a 1km x 1km grid and are published for each year from 2018 until 2030.

1.2.2 Scotland-specific maps for particulate matter with an average aerodynamic diameter of less than 2.5µm ($PM_{2.5}$) were not available from the Scottish Air Quality website, therefore, the ratio between the Department for Environment Food & Rural Affairs (Defra) $PM_{2.5}$ and Defra PM_{10} concentrations were calculated for each mapped data point across the study area (Defra, 2020a). These ratios were applied to the corresponding mapped data points for the Scotland-specific PM_{10} backgrounds to calculate the estimated Scottish Air Quality background $PM_{2.5}$ concentrations.

1.2.3 To assess if the mapped background pollutant concentrations for the base year were appropriate, a comparison was undertaken between 'monitored' NO_X concentrations at background Automatic Urban and Rural Network (AURN) sites and mapped NO_X background concentrations for the corresponding grid square and year.

1.2.4 The ratios between the background mapped and monitored concentrations were reviewed, with any outliers removed. The AURN monitoring sites selected for comparison against the mapped pollutant concentrations were, where possible, within 50 miles of the study area (in accordance with TG(22) guidance (Defra and devolved Administrations, 2022)), had data capture above 85%, were background sites and (for appropriateness to this assessment) were located on the eastern side of Scotland, to avoid significant variations in weather conditions, which could influence monitored pollutant concentrations. The comparison of monitored to mapped background NO_X and NO_2 concentrations identified that the Scottish Air Quality maps were overpredicting NO_X and NO_2 concentrations at all sites except Falkirk Grangemouth MC. An adjustment factor of 0.954 was applied to the mapped background NO_X concentrations for each grid square used in the assessment for the base year (2023) and the proposed year of opening (2036) backgrounds. The calculations to determine the adjustment factor are shown in Table A8.1-1.

1.2.5 There was only one AURN PM_{10} monitoring site which was considered appropriate for comparison against the mapped backgrounds. This site indicated a lowering of the background maps. As a conservative approach PM_{10} backgrounds were left unadjusted.

1.2.6 Sector removal was also undertaken as described in Chapter 8 (Air Quality), Section 3 (Methodology) of the EIA Report.

Table A8.1-1: Monitored (AURN) Versus Mapped Background NO_X and NO_2 Concentrations

Site Name	Location		Site Type	Monitored (µg/m³)		Mapped (µg/m³)		NO_X Monitored/ Mapped
	X	Y		NO_X	NO_2	NO_X	NO_2	
Dundee Mains Loan	340971	731892	Urban Background	9.08	7.30	15.4	10.6	0.591
Edinburgh Currie	317575	667874	Suburban Background	7.21	5.32	8.84	6.26	0.816
Edinburgh St Leonards	326264	673136	Urban Background	14.9	11.4	25.7	17.0	0.582
Falkirk Grangemouth MC	292818	682007	Urban Background	22.3	13.5	12.2	8.52	1.827
Average								**0.954**

1.3 Air Quality Verification and Adjustment

Introduction

1.3.1 The comparison of modelled concentrations with local monitored concentrations is a process termed 'verification'. Model verification investigates the discrepancies between modelled and measured concentrations, which can arise due to the presence of inaccuracies and/or uncertainties in model input data, modelling and monitoring data assumptions. The following are examples of potential causes of such discrepancy relevant to this assessment:

- estimates of background pollutant concentrations;
- traffic data uncertainties;
- vehicle emission factors uncertainties; and
- overall limitations of the dispersion model.

Model Precision

1.3.2 Residual uncertainty may remain after systematic error or 'model accuracy' has been accounted for in the final predictions. Residual uncertainty may be considered synonymous with the 'precision' 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 model precision provides an estimate of how the final predictions may deviate from true (monitored) values at the same location over the same period.

Model Performance

1.3.3 An evaluation of model performance has been undertaken to establish confidence in model results. Local Air Quality Management Technical Guidance (Defra, 2022) (hereafter referred to as LAQM TG(22)) identifies a number of statistical procedures that are appropriate to evaluate model performance and assess uncertainty. The statistical parameters used in this assessment are provided in Table A8.1-2, and further details can be found in LAQM TG(22) Box A7.17.

Table A8.1-2: Model Performance Statistics

Statistic	Comments	Ideal Value
Root Mean Square Error (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 Air Quality Objective (AQO) being assessed, it is recommended that the model inputs and verification should be revisited in order to make improvements.	<4.0

	For example, if the model predictions are for the annual mean NO_2 AQO of 40µg/m^3 and if an RMSE of 10µg/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 AQO would be derived, which equates to 4µg/m^3 for the annual mean NO_2 objective.	
Fractional Bias (FB)	FB is used to identify if the model shows a systematic tendency to over or under predict. FB values vary between +2 and -2 and has an ideal value of zero. Negative values suggest a model overprediction and positive values suggest a model underprediction.	0.0
Correlation Coefficient (CC)	CC 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.	1.0

1.3.4 These parameters estimate how the model results agree or diverge from the observations.

1.3.5 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.

1.3.6 The verification process involves a review of the modelled air 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.

1.3.7 Alternatively, the model may not perform well against the monitoring data, in which case there is a need to check all the input data to ensure that it is reasonable and accurately represented by 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 improve alignment with the monitoring data. This adjustment may be made either by using 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 in the study area.

1.4 Air Quality Monitoring Annualisation and Bias-Adjustment

1.4.1 Jacobs undertook a six-month air quality monitoring survey using diffusion tubes for NO_2, from 5 February 2024 to 6 August 2024 to provide an indication of existing air quality as there was no representative local authority monitoring in the vicinity of the proposed scheme.

1.4.2 Monitoring was undertaken at 13 selected locations representative of areas where a potential for changes in air quality was likely as a result of the proposed scheme or roadside locations representative of sensitive receptor locations. Monitoring locations were selected along the existing A9, Perth Road and at several sites within Dunkeld and Birnam. The locations of the scheme-specific monitoring sites considered in this assessment are shown on Figure 8.3 (Baseline Conditions) and details of the sites are provided in Table A8.1-3.

Table A8.1-3: Scheme-Specific NO_2 Monitoring Location Details

Site ID	Location Description	Location		Height (m)	Monitoring Type
		X	Y		
A9_01	On Lamp Post, Atholl Street	302649	742820	2.05	Roadside
A9_02	On Birnam Local Services sign, A923	302683	742201	2.11	Roadside
A9_03	On signpost Layby 19, A9	300328	743014	1.57	Roadside
A9_04	On signpost Layby 22, A9	300441	745767	1.36	Roadside
A9_05	on Lamp Post near Dunkeld train station, A9	303074	741709	2.20	Roadside
A9_06	On signpost Layby 16, A9	304478	740407	1.48	Roadside
A9_07	On Lamp Post, Perth Road	302946	742074	2.17	Roadside
A9_08	On Lamp Post, Perth Road	303558	741505	2.10	Roadside
A9_09	On signpost Layby 21, A9	300414	745245	1.49	Roadside
A9_10	On signpost Layby 13, A9	305909	739423	1.50	Roadside
A9_11	On signpost Layby 14, A9	305763	739459	1.47	Roadside
A9_12	On Parking directions sign, Bridge St	302661	742630	2.21	Roadside
A9_13	On Quad Trek sign, A923	302609	742907	1.80	Roadside

1.4.3 The six-month monitoring data were factored to 2023 using a ratio between 2023 and 2024 of the current Roadside NO_2 projection factors (for the rest of UK Heavy Duty Vehicle (HDV) =< 10% projection) of 1.057.

1.4.4 The data were annualised from the six-month period to a 2023 base year annual mean using annualisation factors derived from AURN monitoring data, in line with LAQM TG(22) guidance. AURN NO_2 monitoring data were compiled for Dundee Mains Loan, Edinburgh Currie, Edinburgh St Leonards and Falkirk Grangemouth MC for the 2023 base year and also 2024 for respective projected weighted period mean data.

1.4.5 The data for these sites were bias adjusted using a 2024 Defra national bias adjustment factor of 0.81. The final annualisation adjustment to the 2023 annual period is provided in Table A8.1-4. Site A9_07 was discounted from the verification process as data capture for the six-month monitoring period was less than 75%. All other locations were included.

Table A8.1-4: Adjusted and Annualised Jacobs Monitoring Data

Site ID	Location		Six-Month Monitoring Results 2024		2023 to 2024 Roadside Projection Factor	Annualisation Factor	2023 National Bias Adjustment Factor	Annualised and Adjusted 2023 NO_2 Annual Mean (µg/m³)
	X	Y	Data Capture (%)	NO_2 Weighted Period Mean (µg/m³)				
A9_01	300441	745767	84%	8.9	1.057	1.224	0.81	9.4
A9_02	303074	741709	100%	8.3	1.057	1.194	0.81	8.5
A9_03	304478	740407	100%	15.1	1.057	1.194	0.81	15.4
A9_04	302946	742074	100%	15.5	1.057	1.194	0.81	15.9
A9_05	303558	741505	100%	15.5	1.057	1.194	0.81	15.9
A9_06	300414	745245	100%	21.8	1.057	1.194	0.81	22.3
A9_07	305909	739423	50%	8.6	1.057	1.118	0.81	8.3
A9_08	305763	739459	100%	7.7	1.057	1.194	0.81	7.8
A9_09	302661	742630	84%	19.1	1.057	1.171	0.81	19.2
A9_10	302609	742907	84%	13.6	1.057	1.171	0.81	13.6
A9_11	300441	745767	100%	17.6	1.057	1.194	0.81	18.0
A9_12	303074	741709	100%	12.1	1.057	1.194	0.81	12.4
A9_13	304478	740407	100%	5.4	1.057	1.194	0.81	5.5

1.5 Verification

1.5.1 The verification method followed the process detailed in LAQM TG(22). The first stage of verification was undertaken by comparing the modelled versus monitored contribution from road traffic sources (Road NO_X). Road NO_X contributions at the diffusion tube sites were calculated using the latest Defra NO_X to NO_2 Calculator (Defra, 2020b), because diffusion tubes only measure total NO_2, from which Road NO_X needs to be estimated. Monitored NO_2 concentrations were first converted to total NO_X concentrations, the Road NO_X was then calculated by removing the sector-removed background concentration from the total NO_X monitored concentration and the Road NO_x adjustment verification factor estimated.

1.5.2 Once the modelled Road NO_X component had been adjusted with the relevant verification factor, this value was used, along with the sector-removed background in the Defra NO_X to NO_2 Calculator to obtain the updated modelled NO_2 concentration.

1.5.3 Table A8.1-5 provides the results of the monitored and modelled concentrations before and after adjustment.

Table A8.1-5: Monitored and Modelled NO_2 Concentrations (µg/m³)

Site ID	Monitored NO_2 (µg/m³)	Unadjusted Modelled Total NO_2 (µg/m³)	Percentage Difference (%)	Adjusted Modelled Total NO_2 (µg/m³)	Percentage Difference (%)
A9_01	9.4	4.5	-51.8	7.6	-18.4
A9_02	8.5	6.5	-23.8	12.7	48.3
A9_03	15.4	8.0	-47.9	17.1	10.6
A9_04	15.9	7.9	-50.0	17.0	7.0
A9_05	15.9	8.6	-46.1	17.9	12.6
A9_06	22.3	8.5	-62.0	18.0	-19.5
A9_08	7.8	4.6	-41.1	8.1	3.0
A9_09	19.2	7.8	-59.2	16.7	-12.8
A9_10	13.6	7.9	-41.8	16.3	20.0
A9_11	18.0	8.0	-55.8	16.5	-8.6
A9_12	12.4	5.7	-54.1	10.7	-14.1
A9_13	5.5	3.9	-30.4	5.9	7.2

1.5.4 Following adjustment there was slight underprediction of modelled NO_2 (when compared to the monitored NO_2) at some locations and overprediction at other locations.

Verification Summary

1.5.5 A review was undertaken of the monitored vs modelled performance across the study area. There was no clear pattern to indicate different zones, therefore a single verification adjustment factor was determined.

1.5.6 The summary results and model performance statistics defined in LAQM TG(22) are provided in Table A8.1-6.

Table A8.1-6: Verification Summary and Model Performance

Statistical Parameter	Verification Summary	
	No Adjustment	With Adjustment
No. of monitoring sites	12	12
NO_x road adjustment factor	N/A	2.614
NO_2 road adjustment factor	N/A	1.000
RMSE	7.70	2.34
FB	0.67	0.00
CC	0.87	0.88
No. within ±10%	0	4
No. within ±25%	1	11

1.5.7 The statistics support the methodology adopted. The statistics show that the RMSE and FB are improved when the adjustment is applied with the RMSE significantly under the required value of 10 and ideal value of 4.0. There is a very small difference in CC, but the linear relationship is good (i.e. closer to 1.0 than zero). Calculation, via a line of best fit, of the road NO_X adjustment factor from the modelled road NO_X and converted measured NO_X is shown in Diagram A8.1-1. The final Road NO_x adjustment factor was 2.6141.

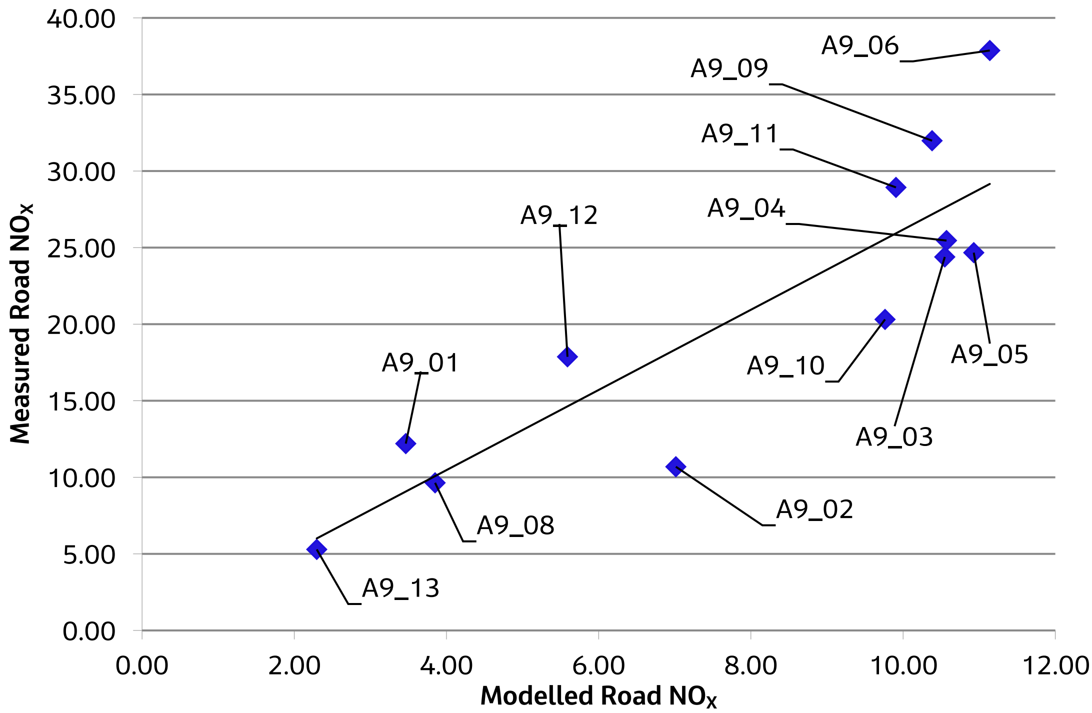

Diagram A8.1-1: Road NO_X Adjustment Factor Calculation from Modelled Vs Measured NO_X

Verification Methodology – PM_{10} and $PM_{2.5}$

1.5.8 There were no PM_{10} analysers within the study area. Therefore, the NO_X Road adjustment factor has been applied to the modelled PM_{10} and $PM_{2.5}$ road contributions, following guidance in LAQM TG(22).

1.6 Adjustment for Long-Term Trends in NO_2

1.6.1 In July 2011, Defra published a report (Trends in NO_X and NO_2 emissions and ambient measurements in the UK (Defra 2011)) examining the long-term air quality trends in NO_X and NO_2 concentrations. This identified that there has been a clear decrease in NO_2 concentrations between 1996 and 2002. Thereafter NO_2 concentrations stabilised with little to no reduction between 2004 and 2012. The consequence of the conclusions of Defra's advice on long-term trends was that there was a gap between projected vehicle emission reductions and projections on the annual rate of improvements in ambient air quality, which are built into the vehicle emission factors, the projected background maps and the NO_X to NO_2 calculator.

1.6.2 The trends in air quality at the time of the Defra study were based on measurements of emissions from the existing vehicle fleet. Newer vehicles would need to comply with the more stringent Euro 6/VI emissions standards from September 2014 onwards.

1.6.3 The Gap Analysis methodology, as set out in Design Manual for Roads and Bridges (DMRB) LA 105 Air Quality (National Highways et al., 2024), incorporates the Euro 6/VI improvements. Therefore, in line with DMRB LA 105, the LTTE6 factors have been applied to the future predictions for air quality modelling.

1.6.4 The LTTE6 factors assume that the measured trends from 2004 to 2012 continue to occur for all pre-Euro 6/VI fleet. They also take a precautionary approach to account for uncertainty associated with Euro 6/VI performance and fleet mix in the future, rather than assuming full reductions in emissions occur as predicted by Euro 6/VI, which has not been observed by air quality monitoring trends associated with recent Euro standards. This is implemented into LTTE6 by taking the mid-point between the measured trend predictions (which assume no improvement in emissions associated with Euro 6/VI) and predicted Euro 6/VI uptake and emission improvements.

1.6.5 The gap analysis method is not required to be applied to PM predictions, as there is less uncertainty in future year concentrations of these pollutants.

1.7 Construction Traffic

1.7.1 Indicative vehicle movement numbers for use in the assessment of construction traffic, in terms of online and offline heavy (HGV and plant) and other (staff and workers) traffic movements and sectional splits, are detailed in Table A8.1-7 Online traffic relates to traffic travelling along the A9, whereas offline traffic relates to haul route traffic (which generally is assumed to travel parallel to the A9 within the site boundary). Table A8.1-7 below shows the summarised one way and two-way movements over the whole construction period combined for online and offline (as a worst-case assumption) across all sections. To calculate the Annual Average Daily Traffic (AADT), the two-way movements were divided by the number of estimated construction years (3.44 years) and then divided again by 365 to get the annualised average daily number of vehicles, with the results shown in the last column of Table A8.1-7

Table A8.1-7: Summarised Construction Traffic

Element	Total Vehicle Movements	Total 2-Way Movements (AADT)
Earthworks one-way	82,742	-
Earthworks two-way (E/W)	165,484	132
Structures vehicle movements (30% of E/W total)	49,645	40
Temporary works vehicle movements (20% of E/W total)	33,097	26
Material deliveries (20% of E/W total)	33,097	26
20% of E/W allowance for other works	33,097	26

Element	Total Vehicle Movements	Total 2-Way Movements (AADT)
Total staff and workers/labour two-way (sum of below x 2)	426,400	340
Staff one way (assume on average 50 staff per day)	53,300	-
Labour/workers one way (assume 200 per day reduced to 75% due to car sharing))	159,900	-
Total two-way heavy (HGV and plant)	**314,420**	**250**
Total two-way all	**740,804**	**590**

1.7.2 Not all vehicles will be operating along the whole of the proposed scheme, in fact most vehicles will primarily only operate within one section for a period of time. There are four sections of the proposed scheme, and it is expected that, in terms of the vehicle movements, 35% will be in the South Zone, 10% in the Central Zone, 50% in the North Zone and 5% around the Dunkeld and Birnam (D&B) station Zone. Using these percentages, the AADTs for each section, shown in Table A8.1-8 below, have been derived from those in Table A8.1-7 above. The DMRB LA 105 (National Highways et al., 2024) methodology uses screening thresholds to identify road links where changes in traffic flow may result in air quality impacts, these are discussed in Chapter 8 Air Quality, sections 8.2.13 to 8.2.15. As can be seen in Table A8.1-8, the DMRB AADT thresholds of a change of 200 heavy vehicles and a change of 1000 all vehicles are not close to being exceeded in any Zone. However, even if there was some limited overlap of traffic operating in adjacent Zones, it is very unlikely that the DMRB thresholds would be exceeded. Therefore, based on DMRB LA 105, further assessment of construction traffic can be scoped out as it is unlikely that this level of change in traffic will result in a significant change in air quality concentrations. Construction traffic is therefore not discussed further.

Table A8.1-8: Total Construction Traffic 2-Way Movements (AADT) Per Zone

Construction Zone	Proportion of Traffic (%)	Total 2-Way Movements (LDV+HDV) (AADT)*	Total HDVs (AADT)*
Whole proposed scheme	100	590	250
South	35	207	88
Central	10	59	25
Dunkeld & Birnam (D&B)	5	30	13
North	50	295	125
*Rounded to nearest whole number			

1.8 References

Defra and the Devolved Administrations (2011). Trends in NO_X and NO_2 emissions and ambient measurements in the UK (prepared for defra by David Carslaw, Sean Beevers, Emily Westmoreland and Martin Williams (King's College London); James Tate (University of Leeds); Tim Murrells, John Stedman, Yvonne Li, Susannah Grice, Andrew Kent and Ioannis Tsagatakis (AEA). Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1103041401_110303_Draft_NOx_NO2_trends_report.pdf (Accessed October 2024).

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