Appendix 11.2

Noise Modelling and Calculations

1. INTRODUCTION

1.1 This technical appendix sets out the details of the noise modelling predictions for the operational noise calculations, in line with relevant standards, methods, and guidance.

2. PREDICTED CHANGE IN ROAD TRAFFIC NOISE

2.1 Calculation of Road Traffic Noise (CRTN) provides a method for measuring and calculating both the absolute noise levels from road traffic and the relative change in road traffic noise from a change in traffic flows.

2.2 A simplified calculation can be derived to determine the change in road traffic noise based on changes to traffic flow volumes, average traffic speeds, and the percentage of heavy vehicles (which can include buses, goods delivery vehicles, construction vehicles, etc.). The method assumes that the road and receptor building layout remains the same, with traffic flows occurring at the same distances from receptors, with the same road surface, road gradient, and barrier effects.

2.3 In addition, for a change in road traffic noise to be meaningful, there is an assumption that at noise-sensitive receptor locations close to the road, the ambient noise environment is dominated by road traffic noise from a single road link for which calculations are undertaken. Uncertainties can arise where a receptor experiences contributions to its ambient noise from multiple road links, or other non-road noise sources, although there are methods provided for combining noise levels.

2.4 Calculations are typically undertaken using hourly traffic flows or 18-hourly (06:00-00:00) average annual weekday traffic (AAWT) flows, although estimated changes can be made (with relatively high uncertainty) using alternative traffic metrics.

2.5 A Basic Noise Level $L_{10,18h}$ (BNL) is calculated using the formula:

$$BNL = 29.1 + 10 \log_{10} Q \qquad dB(A)$$

where Q is the total traffic flow

2.6 A number of correction factors are then applied to the BNL to account for relevant parameters. The correction factor for mean traffic speed and the proportion of heavy vehicles is given by:

$$Correction = 33 \log_{10} (V + 40 + 500/V) + 10 \log_{10} (1 + 5p/V) - 68.8 \qquad dB(A)$$

where: V is the mean traffic speed in kilometres per hour
p is the percentage of heavy vehicles

2.7 In addition, the calculations method is stated to be valid for traffic flows down to a minimum of 1000 vehicles over an 18-hour day. Uncertainties are significantly increased for traffic flows notably lower than 1000 vehicles, while a low-flow correction is required for flows under 4000 vehicles. The low flow correction, K, is given by:

$$K = -16.6 \,(\log_{10} D)\,(\log_{10} C)^2 \qquad \text{dB(A)}$$

where: D = 30/d' and d' is the shortest slant distance between the source and receiver position
C = q/200 or Q/4000, and q and Q are the hourly and 18-hour traffic flows respectively.

3. OPERATIONAL NOISE PREDICTIONS

General Method of Calculation

3.1 The noise prediction methodology is based on guidance in *ESTU-R-97 The Assessment and Rating of Noise from Wind Farms* (ETSU) and incorporating guidance from the Institute of Acoustics document *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbines Noise* (IOA GPG), including consideration of wind shear.

Sound Power Levels

3.2 The sound power levels for each turbine hub height are shown in Table 11.6 and Table 11.7 of the EIAR Noise Chapter, including a +2 dB uncertainty factor, in line with the IOA GPG.

Wind Shear Correction

3.3 Wind turbine source sound power levels are typically specified in one of two ways. The first is in terms of 'standardised' 10 m height wind speeds, accounting for the specific hub-height to which the sound power levels relate. In some cases, the sound power levels are specified for a given hub height, but an alternative hub height is proposed or installed. In other cases the sound power levels are specified based on the hub height wind speeds, and the equivalent standardised 10 m height wind speed sound power levels for a given hub height can be calculated.

3.4 In order to allow like-for-like comparisons and appropriate usage in noise calculations, sound power levels are corrected, where applicable, to reflect the sound power level based on standardised 10 m height wind speeds, with reference to the specific hub height proposed or installed.

3.5 The following equation is used for the purpose of this correction:

$$V_{10} = V_h \left(\frac{\ln(\frac{10}{z_0})}{\ln(\frac{h}{z_0})} \right)$$

where: h is the hub height

V_{10} is the 10 m wind speed

V_h is the wind speed at hub height

Z_0 is the ground roughness length, standardised at 0.05 m

3.6 As the correction is based on the specific hub height of turbines, this accounts for the fact that different hub height turbines would experience different wind speeds at their hub heights for the same 10 m wind speed conditions. Each turbine model and hub height configuration therefore has a unique derived sound power level specification.

Noise Predictions Methodology

Overview

3.7 The noise prediction methodology is based on ETSU and the IOA GPG. These documents detail the assessment and calculation approach for wind farm noise, and advocate for the use of ISO 9613 *Acoustics – Attenuation of sound during propagation outdoors* as the basis for the noise predictions, with some specific assumptions and adjustments. The receptors included in the operational noise assessment are set out in Table 11.3 of the EIAR Noise Chapter, while the turbine co-ordinates and relevant hub heights are shown in Table 11.5 of the EIAR Noise Chapter.

ISO 9613

General Method of Calculation

3.8 The ISO 9613 standard is used for predicting sound pressure level for downwind propagation by taking the source sound power level for each turbine in separate octave bands and subtracting a number of attenuation factors. These are set out in ISO 9613-2 General method of calculation according to the following relevant parameters:

$$\textbf{Predicted Octave Band Noise Level} = L_w + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

3.9 These factors are discussed further, together with an additional term for taking wind direction into account where required. The predicted octave band levels from each turbine are summed together to give the overall 'A' weighted predicted sound level.

L_w – Source Sound Power Level

3.10 The sound power level of a noise source is normally expressed in dB re: 1 pW. Noise predictions are based on sound power levels detailed in the noise chapter.

3.11 The octave band noise spectra used for the predictions have been taken from the technical specifications of the turbine with the results shown in Table 11.6 and Table 11.7 of the EIAR Noise Chapter.

D – Directivity Factor

3.12 The directivity factor allows for an adjustment to be made where the sound radiated in the direction of interest is higher than that for which the sound power level is specified. In this case the sound power level is measured in a down wind direction, corresponding to the worst-case propagation conditions considered here and needs no further adjustment.

A_{geo} – Geometrical Divergence

3.13 The geometrical divergence accounts for spherical spreading in the free-field from a point sound source resulting in an attenuation depending on distance according to:

$$\mathbf{A_{geo} = 20 \times \log(d) + 11}$$

where d = distance from the turbine.

3.14 The wind turbine may be considered as a point source beyond distances corresponding to one rotor diameter.

A_{atm} – Atmospheric Absorption

3.15 Sound propagation through the atmosphere is attenuated by the conversion of the sound energy into heat. This attenuation depends on the temperature and relative humidity of the air through which the sound is travelling and is frequency dependent with greater attenuation at higher frequencies. The attenuation depends on distance according to:

$$\mathbf{A_{atm} = d \times \alpha}$$

where d = distance from the turbine, and
α = atmospheric absorption coefficient in dB/m.

3.16 Values of ‘α’ from ISO 9613 Part 1 *Calculation of the absorption of sound by the atmosphere*, as given in Table 1, correspond to a temperature of 10 ºC and a relative humidity of 70 %, the values specified in the IOA GPG. These values give relatively low levels of atmospheric attenuation and correspondingly worst-case noise predictions.

Table 1 – Frequency-dependent atmospheric absorption coefficients

Octave Band Centre Frequency (Hz) Atmospheric Absorption	**Octave Band Centre Frequency (Hz)**							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Coefficient (α, dB/m)	0.000122	0.000411	0.00104	0.00193	0.0037	0.00966	0.0328	0.117

A_{gr} – Ground Effect

3.17 Ground effect is the interference of sound reflected by the ground with the sound propagating directly from source to receiver. The prediction of ground effects is inherently complex and depends on the source height, receiver height, propagation height between the source and receiver and the ground conditions. The ground conditions are described according to a variable G which varies between 0.0 for ‘hard’ ground (includes paving, water, ice, concrete & any sites with low porosity) and 1.0 for ‘soft’ ground (includes ground covered by grass, trees or other vegetation). The IOA GPG states that where wind turbine source noise data includes a suitable allowance for uncertainty, a ground factor of G = 0.5 and a receptor height of 4 m should be used.

A_{bar} – Barrier Attenuation

3.18 The effect of any barrier between the noise source and the receiver position is that noise will be reduced according to the relative heights of the source, receiver and barrier and the frequency spectrum of the noise. The barrier attenuations predicted by the ISO 9613 model have been shown to be significantly greater than that measured in practice under downwind conditions. A study of propagation of noise from wind farm sites carried out for ETSU-R-97 concludes that an attenuation of just 2 dB(A) should be allowed where the direct line of sight between the source and receiver is just interrupted and that 10 dB(A) should be allowed where a barrier lies within 5 m of a receiver and provides a significant interruption to the line of sight. In this case a correction of 2 dB has been applied where there is no line of sight between the source and the receiver.

A_{misc} – Miscellaneous Other Effects

3.19 ISO 9613 includes effects of propagation through foliage, industrial plants and housing as additional attenuation effects. These have not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

Corrections for Ground Profile and Barriers

3.20 Sound propagation across a concave ground profile, for example valleys or where the ground falls away significantly between the turbine and the receptor, incurs an additional correction of +3 dB(A) to the overall A-weighted noise levels. This correction is calculated in order to take account of the reduced ground absorption effects and the potential for multiple reflection paths caused by the concave profile.

3.21 A computer programme is used to generate the ground profiles beneath each source-to-receptor path. From these plots it is possible to determine where a correction is appropriate, based upon guidance set out in the IOA GPG.

3.22 A mathematical condition is recommended in the IOA GPG for indicating where this correction should be applied:

$$h_m \geq 1.5 \times \left(\frac{abs(h_s - h_r)}{2}\right)$$

where h_m is the mean height above ground along the direct path between the source and the receptor,
h_s is the absolute source height above ground level, and
h_r is the absolute receptor height above ground level.

3.23 Whilst this condition is useful at highlighting where the ground profile beneath a source-to-receptor path may be concave, it is inherently non-robust and can produce false positives. It should therefore be used in conjunction with a visual assessment of the ground profile when determining whether a correction should be applied.

3.24 The ground profile correction factors used in the assessment are set out in Table 2 for each assessed receptor location.

Table 2 – Ground Profile and Barrier Corrections for the Proposed Development

Turbine	Correction Factor by Noise-Sensitive Receptor, dB(A)			
	R1	R2	R3	R4
T1	0	0	0	0
T2	-2	0	0	0
T3	0	0	0	0
T4	0	0	0	0
T5	-2	0	0	0
T6	-2	0	0	0
T7	-2	-2	-2	-2
T8	0	0	0	0

4. REFERENCES

Department of Transport and Welsh Office (1988), ‘Calculation of Road Traffic Noise’, Her Majesty’s Stationary Office (HMSO).

ETSU-R-97 (1996). The Assessment and Rating of Noise from Wind Farms. MM for the DTI.

Institute of Acoustics (May 2013). A Good Practice Guide to the Application of ETSU R 97 for the Assessment and Rating of Wind Turbine Noise. IOA.

International Organization for Standardization (1993). ISO 9613-1, Acoustics - Attenuation of sound during propagation outdoors, Part 1: Calculation of the absorption of sound by the atmosphere. ISO.

International Organization for Standardization (2024). ISO 9613-2, Acoustics - Attenuation of Sound During Propagation Outdoors, Part 2: Engineering method for the prediction of sound pressure levels outdoors. ISO.