## APPENDIX 17.1 – NOISE PREDICTION METHODOLOGY

Operational noise predictions have been carried out using International Standard ISO 9613, *Acoustics - Attenuation of Sound during Propagation Outdoors* (International Organization for Standardization, 1996).) The propagation model described in Part 2 of this standard provides for the prediction of sound pressure levels based on either short-term downwind (i.e. worst case) conditions or long-term overall averages. When the wind is blowing in the opposite direction, noise levels may be significantly lower, especially if there is any shielding between the site and the houses. Only the 'worst case' downwind short-term predictions are carried out here, such that the long-term average predicted noise levels would be lower.

The Institute of Acoustics (IOA) document, *A Good Practice Guide* (GPG) *to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* suggests that ISO 9613-2 can be applied to obtain realistic predictions of noise from on-shore wind turbines during worst case propagation conditions, provided that the appropriate choice of input parameters are made.

The ISO 9613-2 standard is used for predicting sound pressure level by taking the source sound power level for each turbine in separate octave bands and subtracting a number of attenuation factors according to the following:

**Predicted Octave Band Noise Level = LW + D - Ageo - Aatm - Agr - Abar - Amisc**

These factors are discussed in detail below. 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

The sound power level of a noise source is normally expressed in dB re: 1pW. The assumed sound power levels and octave band spectra are presented within the main chapter.

The turbine coordinates used in the assessment are detailed at Table 17.1.1 below.

**Table 17.1.1 Wind Turbine Coordinates**

| Wind Farm | Easting | Northing |
|---|---|---|
| Proposed Development | 298458 | 961951 |
| | 298785 | 961581 |
| | 296988 | 961338 |
| | 297552 | 961453 |
| | 298118 | 961260 |
| | 299161 | 961256 |
| | 297093 | 960848 |
| | 297731 | 960965 |
| | 298265 | 960800 |
| | 298659 | 961115 |
| | 299273 | 960738 |
| | 297270 | 960386 |
| | 297751 | 960475 |
| | 298367 | 960322 |
| | 298779 | 960595 |
| | 297607 | 960006 |

| Wind Farm | Easting | Northing |
|---|---|---|
| | 298078 | 959956 |
| | 298809 | 960117 |
| | 299328 | 960196 |
| | 298510 | 959713 |
| | 299015 | 959669 |
| Proposed Limekiln Wind Farm Extension | 299998 | 960677 |
| | 299636 | 961633 |
| | 299842 | 961209 |
| | 299369 | 962017 |
| | 299937 | 960079 |

D – Directivity Factor

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. For wind turbines, 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

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:

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

where d = distance from the turbine

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

$A_{atm}$ - Atmospheric Absorption

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

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

where d = distance from the turbine

$\alpha$ = atmospheric absorption coefficient in dB/m

Values of '$\alpha$' from ISO 9613 Part 1 corresponding to a temperature of 10ºC and a relative humidity of 70% has been used. These are the values specified in the IOA GPG. These give relatively low levels of atmospheric attenuation and correspondingly conservative noise predictions, and the values were used are given below at Table 17.1.2.

**Table 17.1.2 Frequency Dependant Atmospheric Absorption Coefficients**

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

$A_{gr}$ Ground Effect

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 are inherently complex and depend 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 for 'hard' ground (including paving, water, ice, concrete & any sites with low porosity) and 1 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, as is the case here, a ground factor of G = 0.5 and a receptor height of 4 m should be used.

$A_{bar}$ - Barrier Attenuation

The effect of any barrier between the noise source and the receiver position is that noise would 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, however, been shown to be significantly greater than that measured in practice under downwind conditions. The IOA GPG states 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. There are no significant topographical features here that would significantly interrupt line of sight to the tip of the turbines and therefore no barrier corrections have been applied.

$A_{misc}$ – Miscellaneous Other Effects

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.

Concave Valley

The IOA GPG states that sound propagation across a concave ground profile, for example valleys or where the ground falls away significantly between the turbine and the receptor should incur an additional correction of +3 dB(A) to the overall A-weighted noise levels. This correction is implemented in order to take account of the reduced ground effects and, under some rare circumstances, the potential for multiple reflection paths caused by the concave profile.

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

$$h_m \geq 1.5 \times (\text{"abs"}\ (h_s - h_r)/2)$$

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 hr is the absolute receptor height above ground level.

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.

A computer program has been 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. In this case there are no significant concave ground profiles between any turbines and receptor locations that would require a correction.