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Appendix 12A
Noise

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The information within this appendix provides additional detail to **Chapter 12: Noise**.

12.1 Noise Terminology

The ratio between the quietest audible sound and the loudest tolerable sound is a million to one in terms of the change in sound pressure. Due to the wide range, a logarithmic scale is used in noise level measurement. The scale used is the decibel (dB) scale which extends from 0 to 140 dB corresponding to the intensity of the sound pressure level. It is widely accepted that a change of 3dB(A) is required for a person to perceive the change in a steady noise level and that an increase or decrease of 10dB(A) is perceived as being twice or half as loud respectively.

The ear has the ability to recognise a particular sound depending on the pitch or frequencies found at the source. Microphones cannot differentiate noise in the same way as the ear and to account for this, the noise measuring instrument applies a correction to correspond more closely to the frequency response of the human ear. The correction factor is called 'A Weighting' and the resulting measurements are written as dB(A). The dB(A) is internationally accepted and has been found to correspond well with people's subjective reaction to noise. Typical dB(A) noise levels for familiar noises are given in Table 12A.1.

Table 12A.1 Typical Noise Levels

Approximate Noise Level (dB)	Example
30	Rural area at night, no wind or adverse weather conditions
40	Library
50	Quiet office without noisy equipment such as photocopiers
60	Normal conversation
70	In car noise without radio
80	Household vacuum cleaner
100	Pneumatic drill
140	Threshold of pain

The following indices and descriptors are used when describing noise:

- L_W is the sound power level. It is a measure of the total noise energy radiated by a source of noise and is used to calculate noise levels at a distant location. The L_{WA} is the A-weighted sound power level;
- $L_{eq,\,T}$ is the equivalent continuous sound level, and is the sound level of a steady sound with the same energy as a fluctuating sound over a time period T. It is possible to consider this level as the ambient noise encompassing all noise at a given time. The L_{Aeq} is the A-weighted equivalent continuous sound level;
- $L_{90,\,T}$ index represents the noise level exceeded for 90 percent of the measurement period over a time-period T and is used to indicate quieter times during the measurement period. It is often used to measure the background noise level. The $L_{A90,\,T}$ is the A-weighted background noise level;
- L_{Amax} is the A-weighted maximum recorded noise level during the measurement period;

- Hard Ground – a ground cover which includes paving, water, ice, concrete and all other ground surfaces having a low porosity;
- Soft Ground (Porous) – ground cover which includes ground covered by grass, trees or other vegetation, and all other ground surface suitable for the growth of vegetation, such as farming land; and
- Mixed Ground – the surface consists of both hard and soft (porous) ground.

The ETSU Guidance includes a specific definition of tones in relation to wind farm noise. However, for the purposes of this assessment a tone may be considered a sound at a specific pitch or frequency which is audible above noise levels at other frequencies from the turbine at the receptor.

A final non-acoustic descriptor used in this assessment is wind shear. The level of wind shear for a particular site describes how wind speed varies with height and is assigned a coefficient which can be used to convert the wind speed measured at one height to the wind speed at another height.

12.2 Monitoring Methodology

The following details are taken from the 2011 ES to describe the noise monitoring completed at that time.

Measurements of background noise levels were undertaken between 17 March 2011 and 8 April 2011. During this period a maintenance issue with the wind monitoring mast after the 24 March 2011 meant that the total amount of useable survey was not sufficient in determining representative background noise levels at each of the receptors. Therefore, a further two weeks of noise monitoring was undertaken between 20 April 2011 and 5 May 2011. This ensured that approximately three weeks of useable data was available for each receptor (typically two weeks is considered the minimum requirement) to be considered within the noise assessment.

Background noise monitoring was undertaken at four locations surrounding the Stornoway Wind Farm site. Noise levels at these locations are deemed representative of the nearest sensitive receptors to the site. All monitoring locations were discussed and agreed on 16 March 2011 with the Consumer and Environmental Services Manager at the CnES Environmental Health Department prior to the noise surveys taking place. A member of the CnES Environmental Health Department was also present during the noise kit deployment in order for finalised monitoring locations to be decided.

The equipment used for the background noise monitoring comprised of Rion NL-31 Class 1 integrating logging sound level meters. These were enclosed in an environmental case with sufficient battery power to enable approximately 7 days continuous logging at the required 10 minute averaging periods, logging the L_{A90}, L_{Aeq} and a range of other parameters. The sound level meters were calibrated on deployment and recovery. The batteries were changed and the equipment calibrated approximately every seven days during the survey. No significant drifts in calibration were noted at any point.

The measurement systems were fitted with appropriate wind and rain protection for the microphone to maintain Class 1 measurement accuracy (the standard required for noise measurements in the UK). All microphones were located away from reflective façades in a location deemed to be representative of background noise at the property. The microphone was located away from any obvious local sources of noise, for example boiler flues. Details of the background noise, wind and rain measurements taken at each location are presented in Appendix 9B of the 2011 ES, and photographs of each measurement location are provided in Appendix 9C of the 2011 ES.

12.3 Baseline Analysis

The level of wind shear at a particular location defines the relationship between wind speeds at different heights. A low level of wind shear means that the wind speed at the hub height of the turbines is not much greater than that near the ground, whereas a high level of wind shear means that the wind speed at hub height is significantly greater than that near the ground.

Wind turbine manufacturers have in the past been referencing their turbine noise emissions to a 10 m height wind speed, assuming a standard level of wind shear in their calculations. The implication being that should the site experience a high level of wind shear, for a particular 10 m height wind speed, the wind speed at hub height might be greater than assumed within the noise modelling, and thus turbine noise levels would be greater for the same background noise level. For the most recent Vestas turbines including the V136 and V150, sound power levels have been given at hub height wind speeds. The relative 10 m wind speed for the sound power levels have been calculated using formula within the Institute of Acoustics '*A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*' (GPG, 2013). This has led to sound power levels at a specific hub height being related to wind speeds much lower at 10 m/s (using a roughness coefficient of 0.05, the difference is between 2 and 5 m/s less than at hub height depending on the hub height wind speed).

To reference baseline background noise data with wind speeds at 10 m height, the wind speeds against which the noise data were correlated in the 2011 ES were derived as follows:

- The wind speeds at 22 m and 50 m height were used to calculate the level of wind shear for each 10-minute period; this level of wind shear was then used to calculate the wind speed at any height;
- The wind speed at the 90 m hub height was then calculated from the measured 50 m height wind speed using the shear level obtained from Step 1;
- The hub height wind speed was then converted to a 10 m height wind speed using the standard level of shear assumed by turbine manufacturers in certifying turbine noise emissions, to maintain the requirement of the ETSU Guidance of deriving noise limits referenced to a 10 m height wind speed.

As the hub height for the Proposed Development has increased, the effect on the above calculations was reviewed, also considering the longer daytime period allowed for in the Outer Hebrides Supplementary Planning Guidance. The difference between the 2011 ES and revised criteria using the 105 m hub height are presented in Table 12A.2.

Table 12A.2 Review of Background Levels Calculated with 105 m Hub Height

Monitoring Location	Period	L_{A90} Sound Levels (dB) at Wind Speeds at 10 m Height (m/s)								
		4	5	6	7	8	9	10	11	12
					ES 2011					
M1	Daytime	32.8	33.7	34.8	36.1	37.6	39.3	41.2	43.3	45.7
	Night-time	27.6	27.9	28.4	29.4	30.7	32.3	34.4	36.7	39.5
M2	Daytime	29.2	30.3	31.5	32.8	34.1	35.4	36.8	38.3	39.8
	Night-time	23.1	24.0	25.0	26.3	27.7	29.3	31.1	33.1	35.3
M3	Daytime	33.4	34.2	35.0	36.1	37.3	38.6	40.0	41.7	43.4
	Night-time	26.8	27.9	29.0	30.3	31.7	33.3	34.9	36.7	38.6
M4	Daytime	28.1	30.4	32.7	35.1	37.4	39.4	42.2	44.7	47.1

Monitoring Location	Period	L_{A90} Sound Levels (dB) at Wind Speeds at 10 m Height (m/s)								
		4	5	6	7	8	9	10	11	12
	Night-time	20.4	22.7	25.1	27.6	30.2	32.9	35.8	38.7	41.8
2019 Review of Background Noise Levels Using a Hub Height of 105 m in Calculations										
M1	Daytime	33.7	34.7	35.8	37.1	38.7	40.3	42.2	44.3	46.5
	Night-time	27.6	27.8	28.4	29.3	30.6	32.2	34.3	36.7	39.4
M2	Daytime	31.0	32.0	33.1	34.3	35.6	36.9	38.3	39.8	41.4
	Night-time	23.1	23.9	24.9	26.2	27.6	29.2	31.0	33.0	35.2
M3	Daytime	38.0	38.9	40.0	41.2	42.7	44.4	46.3	48.4	50.7
	Night-time	26.7	27.8	28.9	30.2	31.6	33.2	34.9	36.7	38.6
M4	Daytime	31.0	33.2	35.4	37.6	39.7	41.7	43.8	45.8	47.7
	Night-time	21.0	23.3	25.6	28.0	30.6	33.3	36.0	38.9	41.9
Difference, 2019 – 2011 Levels (+=Higher Background Noise Levels in 2019)										
M1	Daytime	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.0	0.8
	Night-time	0.0	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	0.0	-0.1
M2	Daytime	1.8	1.7	1.6	1.5	1.5	1.5	1.5	1.5	1.6
	Night-time	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
M3	Daytime	4.6	4.7	5.0	5.1	5.4	5.8	6.3	6.7	7.3
	Night-time	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
M4	Daytime	2.9	2.8	2.7	2.5	2.3	2.3	1.6	1.1	0.6
	Night-time	0.6	0.6	0.5	0.4	0.4	0.4	0.2	0.2	0.1

The results show that there would be a slight lowering in background noise level during the night-time (except at M4, but this was corrected to remove existing wind farm influence, which wasn't undertaken in the 2019 review). However, this would not have a significant effect on noise criteria used within the assessment. The daytime background noise level increases with the new method due to the inclusion of the whole day within the noise criteria as per the Outer Hebrides SPG. It was decided to keep the 2011 ES criteria for consistency and as a precautionary measure for daytime levels.

12.4 Construction Methodology and Detailed Results

The following section is taken from the noise chapter within the 2011 ES. As discussed in the Noise Chapter within the EIA Report, the methods and assessment has remained the same as no changes are anticipated in the construction methods with the exception of the Borrow Pit blasting.

Overview of Construction and Decommissioning Noise Assessment Procedure

It is anticipated that the overall duration of the construction stage of the Stornoway Wind Farm would be approximately 30 months. During the construction period a range of different activities would take place within the development site, for example, there would be delivery of materials to the site, stone extraction within the site and turbine installation.

British standard (BS) 5228-1:2009+A1:2014 Noise and Vibration on Construction and Open Sites includes guidelines with regard to the acceptability of noise from construction sites. The appropriate noise limit for a project in an area such as the Stornoway Wind Farm would be 65dB $L_{Aeq, 12hours}$ (or $L_{Aeq, T}$).

The plant list given in Table 12A.3 is based upon the intended construction programme as provided by Lewis Wind Power Limited ("LWP") and upon experience of other wind farm construction projects. The noise emission data quoted is taken from BS5228-1:2009+A1:2014.

Table 12A.3 Construction Plant Source Data

Plant	L_{Aeq} at 10 m	Mobile / Fixed Plant	Number	Distance (m)	Total Sound Power Level, L_{wA} dB(A)
Turbine Foundation Construction					
30t tracked excavator	75	Mobile	1	10	103
ADT (tipping fill)	74	Fixed	2	10	105
ADT (moving)*	81	Mobile	2	10	112
Site dumper*	76	Mobile	2	10	107
Large rotary bored piling rig	83	Mobile	1	10	111
70t mobile crane	70	Mobile	1	10	98
Concrete mixer truck	80	Mobile	2	10	111
Diesel generator	74	Fixed	2	10	105
Vibrating poker	69	Fixed	2	10	100
Turbine Erection					
120t crane	67	Fixed	1	10	95
600t mobile crane	71	Mobile	1	10	99
Articulated HGV	81	Mobile	3	10	114
Diesel generator	65	Fixed	1	10	93
Site Track Construction					
30t tracked excavator	75	Mobile	1	10	103
23t ADT	74	Mobile	1	10	102
Site dumper	76	Mobile	2	10	107

Plant	L_{Aeq} at 10 m	Mobile / Fixed Plant	Number	Distance (m)	Total Sound Power Level, L_{wA} dB(A)
Bulldozer	75	Mobile	1	10	103
Vibrating roller	74	Mobile	1	10	102
		Haul Road Usage			
Heavy Good Vehicle	77	Mobile	10	10	105

*Drive by L_{Amax} level

Predictions of noise emissions have been carried out for the five phases listed in Table 12A.3, assuming 50% hard-ground between receptors and the plant, and that the plant is operating at the closest approach to each receptor. It is assumed that all mobile plant is operating 66% of the time, and all fixed plant 100% of the time. The borrow pit assessment differs in that it considers the distance from the borrow pit to the nearest sensitive receptors.

Predicted Impacts

Predictions of the noise levels from construction activities have been undertaken to each of the nearest properties using the plant list and source levels given in Table 12A.3. These construction noise levels across each assessed phase are summarised in Table 12A.4.

Table 12A.4 Noise Levels during Construction

Receptor	Predicted Construction Noise Level, $L_{Aeq,1hr}$ dB			
	Turbine Foundation Construction	Turbine Erection	Site Track Construction	Haulage Road Use
R1	38.7	35.0	35.2	19.8
R2	38.6	34.8	33.7	19.1
R3	38.5	34.8	33.9	19.1
R4	38.9	35.2	35.9	20.2
R5	38.9	35.2	39.4	22.1

The noise predictions confirm that noise effects may occur when work is at closest approach to the receptors. However, due to the high separation distances between the construction activity and the nearest receptors, the minimum noise guideline value of 65dB(A) quoted in BS5228-1:2009 would not be exceeded.

12.5 Noise Modelling Method

Computer noise modelling has been undertaken with CadnaA software (Version 4.0.135) which incorporates calculation methodology described in ISO 9613-2: '*Acoustics – Attenuation for sound during propagation outside*'. The predictions take account of the following:

- Geometric divergence (attenuation with distance);

- Air absorption;
- Barriers (including buildings or topography);
- Screening (including vegetation); and
- Ground absorption and reflection.

The computer noise modelling includes the inputs of turbine locations, heights and sound power level data, terrain and receptor locations and heights. For the purposes of the present assessment, all noise level predictions have been based upon the following assumed model parameters:

- A receiver height of 4.0m above local ground level - to represent the height of a typical bedroom window;
- Mixed ground (G = 0.5); and
- Air absorption based on a temperature of 10°C and 70% relative humidity.

Data has then been extracted from the computer noise modelling and corrected to include advice within the IOA GPG. The corrections consist of the following:

- A maximum reduction in noise level from screening obstacles (such as hills) of 2 dB;
- A valley correction of 3 dB, where appropriate; and
- $L_{A90,10min}$ is 2dB less than $L_{Aeq,10min}$ for turbine noise.

The data presented in Table 12A.5 to Table 12A.10 has been used within the computer noise modelling. Tonality and uncertainty corrections have been added to data taken from technical reports where required; otherwise a precautionary 2 dB uncertainty correction has been added. The Vestas turbines were presented in the technical specifications as sound power levels at hub height. In order to correct the data to wind speeds at 10 m height, the wind speed for a specific sound level has been reduced by 1 m/s (i.e. the hub wind speed relates to a 10 m height wind speed 1 m/s lower).

Table 12A.5 Sound Power Levels for the Vestas V136 (+2 dB Uncertainty Added)

Octave Band (Hz)	Sound Levels (dB) by Standardised 10m Height Wind Speed (V10) ms^{-1}								
	4	5	6	7	8	9	10	11	12
31.5	71.5	74.6	77.7	77.5	77.3	76.8	75.8	75.1	74.6
63	82.0	85.0	87.5	87.3	86.7	86.7	86.7	86.7	86.7
125	89.8	92.7	94.9	94.6	93.9	93.9	93.9	93.9	93.9
250	94.7	97.7	100.1	99.8	99.1	99.1	99.1	99.1	99.1
500	96.9	100.0	102.9	102.7	102.2	102.2	102.2	102.2	102.2
1000	96.3	99.6	103.4	103.4	103.3	103.3	103.3	103.3	103.3
2000	93.0	96.5	101.7	101.9	102.3	102.3	102.3	102.3	102.3
4000	86.9	90.8	97.6	98.1	99.2	99.2	99.2	99.2	99.2
8000	78.0	82.3	91.3	92.1	94.0	94.0	94.0	94.0	94.0

Octave Band (Hz)	Sound Levels (dB) by Standardised 10m Height Wind Speed (V10) ms^{-1}								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Total	**102.0**	**105.2**	**108.9**	**108.9**	**108.9**	**108.9**	**108.9**	**108.9**	**108.9**

Table 12A.6 Sound Power Levels for the Vestas V150 (+2 dB Uncertainty Added)

Octave Band (Hz)	Sound Levels (dB) by Standardised 10m Height Wind Speed (V10) ms^{-1}								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
31.5	71.9	74.9	78.5	78.2	77.0	77.0	77.0	77.0	77.0
63	82.1	84.8	88.1	87.6	85.7	85.7	85.7	85.7	85.7
125	89.6	92.2	95.5	94.9	92.8	92.8	92.8	92.8	92.8
250	94.6	97.3	100.7	100.1	98.1	98.1	98.1	98.1	98.1
500	97.1	100.0	103.7	103.3	101.7	101.7	101.7	101.7	101.7
1000	97.0	100.3	104.5	104.4	103.7	103.7	103.7	103.7	103.7
2000	94.3	98.3	103.2	103.5	103.9	103.9	103.9	103.9	103.9
4000	89.1	93.9	99.7	100.5	102.6	102.6	102.6	102.6	102.6
8000	81.2	87.0	94.0	95.4	99.5	99.5	99.5	99.5	99.5
Total	**102.5**	**105.8**	**110.0**	**110.0**	**109.9**	**109.9**	**109.9**	**109.9**	**109.9**

Table 12A.7 Sound Power Levels for the Enercon E82 E3 (1.5 dB Added for Tonality and 1 dB Added for Uncertainty as per Turbine's Technical Report)

Octave Band (Hz)	Sound Levels (dB) by Standardised 10m Height Wind Speed (V10) ms^{-1}								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
63	75.4	75.4	79.4	82.4	83.4	83.4	83.4	83.4	83.4
125	84.6	84.6	88.6	91.6	92.6	92.6	92.6	92.6	92.6
250	90.0	90.0	94.0	97.0	98.0	98.0	98.0	98.0	98.0
500	91.4	91.4	95.4	98.4	99.4	99.4	99.4	99.4	99.4
1000	87.9	87.9	91.9	94.9	95.9	95.9	95.9	95.9	95.9
2000	85.5	85.5	89.5	92.5	93.5	93.5	93.5	93.5	93.5
4000	80.7	80.7	84.7	87.7	88.7	88.7	88.7	88.7	88.7
8000	77.5	77.5	81.5	84.5	85.5	85.5	85.5	85.5	85.5
Total	**95.9**	**95.9**	**99.9**	**102.9**	**103.9**	**103.9**	**103.9**	**103.9**	**103.9**

Table 12A.8 Sound Power Levels for the Enercon E33 (5 dB Added for Tonality at 6 and 7 m/s and 1 dB Added for Uncertainty Across all Wind Speeds as per Turbine's Technical Report)

Octave Band (Hz)	**Sound Levels (dB) by Standardised 10m Height Wind Speed (V10) ms^{-1}**								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
63	55.5	55.5	66.5	69.4	65.3	65.5	65.5	65.5	65.5
125	77.5	77.5	88.5	91.4	87.3	87.5	87.5	87.5	87.5
250	75.7	75.7	86.7	89.6	85.5	85.7	85.7	85.7	85.7
500	77.9	77.9	88.9	91.8	87.7	87.9	87.9	87.9	87.9
1000	80.8	80.8	91.8	94.7	90.6	90.8	90.8	90.8	90.8
2000	79.0	79.0	90.0	92.9	88.8	89.0	89.0	89.0	89.0
4000	73.0	73.0	84.0	86.9	82.8	83.0	83.0	83.0	83.0
8000	66.5	66.5	77.5	80.4	76.3	76.5	76.5	76.5	76.5
Total	**85.8**	**85.8**	**96.8**	**99.7**	**95.6**	**95.8**	**95.8**	**95.8**	**95.8**

Table 12A.9 Sound Power Levels for the Nordex N60 (2 dB Added Uncertainty)

Octave Band (Hz)	**Sound Levels (dB) by Standardised 10m Height Wind Speed (V10) ms^{-1}**								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
63	88.6	89.6	90.6	91.6	92.8	94.1	95.6	97.1	98.6
125	92.9	93.9	94.9	95.9	97.1	98.4	99.9	101.4	102.9
250	94.2	95.2	96.2	97.2	98.4	99.7	101.2	102.7	104.2
500	94.8	95.8	96.8	97.8	99.0	100.3	101.8	103.3	104.8
1000	96.1	97.1	98.1	99.1	100.3	101.6	103.1	104.6	106.1
2000	95.9	96.9	97.9	98.9	100.1	101.4	102.9	104.4	105.9
4000	91.3	92.3	93.3	94.3	95.5	96.8	98.3	99.8	101.3
8000	80.6	81.6	82.6	83.6	84.8	86.1	87.6	89.1	90.6
Total	**102.5**	**103.5**	**104.5**	**105.5**	**106.7**	**108.0**	**109.5**	**111.0**	**112.5**

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Table 12A.10 Sound Power Levels for the WES 18/80 (1.5 dB Added Uncertainty as per Turbine's Technical Report)

Octave Band (Hz)	Sound Levels (dB) by Standardised 10m Height Wind Speed (V10) ms^{-1}								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
63	62.6	63.6	64.6	65.6	66.3	67.0	67.8	68.5	69.2
125	69.8	70.8	71.8	72.8	73.5	74.2	75.0	75.7	76.4
250	75.1	76.1	77.1	78.1	78.8	79.5	80.3	81.0	81.7
500	83.0	84.0	85.0	86.0	86.7	87.4	88.2	88.9	89.6
1000	85.4	86.4	87.4	88.4	89.1	89.8	90.6	91.3	92.0
2000	85.2	86.2	87.2	88.2	88.9	89.6	90.4	91.1	91.8
4000	78.9	79.9	80.9	81.9	82.6	83.3	84.1	84.8	85.5
8000	65.6	66.6	67.6	68.6	69.3	70.0	70.8	71.5	72.2
Total	**90.0**	**91.0**	**92.0**	**93.0**	**93.7**	**94.4**	**95.2**	**95.9**	**96.6**