12. NOISE

12.1 INTRODUCTION

This chapter assesses the noise effects arising from the proposed Viking Wind Farm. The assessment has been undertaken by BMT Cordah Limited.

In the report, the following noise terms are used:

$L_{A90,t}$: the A-weighted noise level exceeded for 90% of the measurement period. This noise index is widely accepted as a descriptor of 'background' noise levels.

$L_{Aeq,\ t}$: the equivalent continuous sound level over a specified measurement period. This noise index is widely accepted as a descriptor of 'ambient' noise levels.

L_{WA}: sound power output level.

Quiet daytime: all evenings from 18:00 – 23:00 hours; plus
Saturday afternoon from 13:00 – 18:00 hours; plus
all day Sunday from 07:00 – 18:00 hours.

Night-time: 23:00 – 07:00 hours.

Noise considerations have influenced the design of the proposed development, and these are explained in Chapter 4 and Appendix 4.7.

The chapter considers the cumulative impact of all operational turbines; however the receptors and turbine locations are described according to the definitions provided for each of the quadrants of the site as described in Chapter 4 and in Figure 4.1.

12.2 SCOPE OF ASSESSMENT

12.2.1 Project interactions

The development will introduce new and additional noise sources, which may be audible at certain locations under suitable conditions:

- the construction phase will introduce temporary sources from construction plant; and
- wind turbines produce aerodynamic noise, due to the rotation of blades, and gearboxes and generators will introduce sources of mechanical noise.

Possible vibration effects have been scoped out of this assessment.

12.2.2 Study area

(a) Operational noise

Experience at existing wind farms suggests that operational noise is unlikely to be a significant issue at distances of greater than 1 km from turbines. However, the study area includes residential properties up to 1.5 km from the nearest turbine. The closest residential properties are identified in Table 12.1, and on Figures 12.1-12.3. Located within the study area are a number of villages or clusters of residential properties. In these case a representative receptor for the area has been selected, typically the closest property. The approximate number of properties represented by each receptor is also presented in Table 12.1.

Table 12.1 Noise sensitive receptors within 1.5km of wind turbines

Receptor	Grid Reference	Quadrant	Distance from Nearest Turbine (km)	Approximate number of properties represented
Hamars	HU 40856 64680	Collarfirth	1.23	2
Tagon	HU 40958 64013	Collarfirth	1.29	>10
Easterscord	HU 41327 66394	Collarfirth	1.06	2
Sursetter	HU 41110 65348	Collarfirth	1.09	3
Garven	HU 40686 73123	Delting	0.85	12
Moorfield	HU 42510 72681	Delting	0.94	1
Hill cottage	HU 38786 71947	Delting	1.37	4
Hardwall	HU 37431 70076	Delting	1.33	5
Grutin	HU 40469 68345	Delting	1.32	4
Laxobigging	HU 41360 73239	Delting	1.23	5
Upper Kergord	HU 40352 56468	Kergord	0.66	1
Springfield	HU 39820 55042	Kergord	1.32	5
Kergord	HU 39449 54187	Kergord	1.42	2
Stenswall	HU 39221 52638	Kergord	1.40	5
Catfirth	HU 43555 54049	Nesting	1.35	1
Lower House	HU 45846 59609	Nesting	0.99	1
Fern	HU 46139 59335	Nesting	1.0	1
Receptor (B9075)	HU 41732 55186	Nesting	1.04	1
North Tararet	HU 44751 63114	Nesting	1.23	1
Dury	HU 45818 60592	Nesting	1.23	3

The receptor at Upper Kergord is located within the development area and it is understood that the property will remain unoccupied for the duration of the development. This receptor has, therefore, been excluded from this study.

Due to the number of receptors located within the study area a number of proxy monitoring locations, to be representative of each of the receptor locations, were agreed in consultation with Shetland Islands Council. The proxy monitoring locations and background noise monitoring are discussed further in Section 12.5.

(b) **Construction noise**

The assessment of construction noise considered receptors located up to 1km from a borrow pit. The developers have identified up to sixty borrow pit locations, although it is understood that only fourteen will be required. The assessment considered receptors close to all sixty potential borrow pit locations.

Table 12.2 Noise sensitive receptors within 1km of borrow pits

Receptor	National grid reference	Distance to borrow pit (m)
Tigh-na-Binn	HU 37760 50326	203
Nethersound	HU 38052 50131	375
Oversound	HU 38278 50320	339
Uppersound	HU 38382 50424	390
Djuba	HU 38573 50722	572
Stranvaara	HU 38791 50248	829
Kallibrig	HU 38660 50078	798
Kurkigarth	HU 38744 51222	953
Cott R1	HU 37937 49801	680
Hellister R1	HU 38569 49774	946
Sandwater	HU 41741 55165	627
		980
Flammister	HU 44027 55862	655
		888
Whinnia lea	HU 46680 55855	120
		388
South Newing	HU 46850 55936	308
		425
Clymlsa	HU 47145 56233	500
		710
Burns	HU 46600 55064	591
Skellister	HU 46780 54961	735
Skellister W	HU 46207 54820	907
Susseter	HU 40900 65406	934
Garthsvale	HU 40969 65677	726
		872
Garth of Susetter	HU 40936 65736	738
		861
Souther house	HU 40864 69819	584

Receptor	National grid reference	Distance to borrow pit (m)
		955
Norther House	HU 40688 67021	717
Easterscord	HU 41362 66345	296
		671
		370
Southtown	HU 37092 69742	254
Voxter	HU 37113 69953	444
Hardwall	HU 37407 70072	721
Pund of Grutin	HU 40918 69015	778
Pund of Grutin R1	HU 40954 69175	634

12.2.3 Scoping and consultation

Scoping was undertaken to identify the key issues to be addressed in the ES. The scoping exercise included consultation with statutory and non-statutory bodies. The official scoping response requires that the assessment of noise effects should include predictions of noise during the construction, operational and decommissioning phases of the development.

The official scoping consultation response identifies guidance produced by ETSU on behalf of the DTI titled "The Assessment and Rating of Noise from Wind Farms" [1] as providing developers with best practice noise monitoring and reporting techniques.

Further to the official scoping consultation BMT Cordah consulted with Shetland Islands Council on the operational noise assessment and, in particular, the extent and locations of background noise monitoring.

The Royal Society for Protection of Birds (RSPB) included comment in their scoping response that the effect of noise on birds, particularly during breeding, should be assessed and appropriate mitigation considered. These effects are considered in Chapter 11: Ornithology and as such have not been included in this Chapter.

12.2.4 Effects to be assessed

Tables 12.3 and 12.4 present the potential significant construction and ongoing effects identified in scoping and form the basis of the effects to be assessed in this chapter. No potential significant secondary or cumulative[1] effects have been identified.

Table 12.3 Potential Construction Noise Effects

Construction Effects	Impact	Potential Effects on Receptors	Specific Receptors Identified in Scoping
Mobile plant operations	Mechanical noise	Noise effects at nearest receptors.	Residential properties within 1.5km
Borrow pit operations	Drilling and blasting noise	Noise effects at nearest receptors.	Residential properties within 1.5km

[1] Although noise sources are assessed on a cumulative basis

	Crusher plant noise	Noise effects at nearest receptors.	
Cable laying	Excavator noise	Noise effects at nearest receptors.	Residential properties within 1.5km

Table 12.4 Potential Ongoing Noise Effects

Ongoing Effects	Impact	Potential Effects on Receptors	Specific Receptor Identified in Scoping
Turbines	Audible mechanical and aerodynamic noise	Noise effects at nearest receptors.	Representative residential properties within 1.5km

12.2.5 Effects scoped out of assessment

Construction and ongoing effects which have been scoped out of the assessment are presented in Appendix 5.1, Tables 8 and 9.1.

Vibration effects from wind turbine operations are not generally considered to be a significant issue. Vibration effects have, therefore, been scoped out of the assessment.

Effects arising from the process of decommissioning (i.e. the removal of the wind farm) have been scoped out since they are of a similar nature to construction issues, but of a smaller scale and shorter duration.

12.3 POLICY CONTEXT

The assessment of effects on nearby receptors is considered in the context of relevant guidance, policies and legislation as follows:

12.3.1 Scottish Planning Policy Guidance SPP6 Renewable Energy

Paragraph 23 of SPP 6 [2] anticipates onshore wind as the most likely technology in providing Scotland’s renewable energy, and paragraph 26 identifies the factors, including noise, to be considered in determining the suitability of sites for wind farm developments. SPP 6 refers to PAN 45 for more detailed information.

12.3.2 Planning Advice Note 45: Renewable Energy Technologies

Planning advice note (PAN) 45 (2002) *Renewable Energy Technologies* [3] provides advice on noise from wind farms, as follows:

> *“Wind generated background noise increases with wind speed, and at a faster rate than wind turbine noise increases with wind speed. The difference between the noise of the wind farm and the background noise is therefore liable to be greatest at low wind speeds. Varying the speed of the turbines in such conditions can, if necessary, reduce the sound output from modern turbines.”*

> *“The report, ‘The Assessment and Rating of Noise from Wind Farms’, ETSU-R-97 describes a framework for the measurement of wind farm noise and gives indicative*

noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or planning authorities. The report represents a series of recommendations that can be regarded as relevant guidance on good practice."

12.3.3 ETSU-R-97: The Assessment and Rating of Noise from Wind Farms

Noise from the wind farm has been evaluated against the criteria set out in guidance document ETSU-R-97, as recommended in PAN 45. ETSU-R-97 advises that:

"The current practice on controlling wind farm noise by the application of noise limits at the nearest noise-sensitive properties is the most appropriate approach."

"Noise limits should be applied to external locations and should apply only to those areas frequently used for relaxation or activities for which a quiet environment is highly desirable."

"Generally, the noise limits should be set relative to the existing background noise at the nearest noise-sensitive properties and that the limits should reflect the variation in both turbine source noise and background noise with wind speed."

"Separate limits should apply for daytime and for night-time as during the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance."

"The LA90 10min, descriptor should be used for both the background noise and the wind farm noise, and when setting limits it should be borne in mind that the LA90 10min, of the wind farm is likely to be about 1.5 – 2.5 dB(A) less than the LAeq measured over the same period..."

"It is proposed to limit noise from a wind farm relative to the existing background noise but with special consideration given to the very low noise limits this would imply in particularly quiet areas. Noise from the wind farm will be limited to 5 dB(A) above background for both daytime and night-time periods…. It should be noted that this limit applies to the noise from the wind farm only and not to the total ambient noise with the wind farm operating. Noise limits would apply up to 12 m/s (10 m height)."

"The Noise Working Group recommends that an appropriate fixed limit for the night-time is 43 dB(A). This limit is derived from a 35 dB(A) sleep criterion…An allowance of 10 dB(A) has been made for attenuation through an open window (free-field to internal) and 2 dB subtracted to account for the use of LA90S rather than LAeqS (assuming the LA90 of turbine noise is 1.5 – 2.5 dB below the LAeq)."

"The Noise Working Group has therefore concluded that in low noise environments the daytime level of the LA90, 10min of the wind farm noise should be limited to an absolute level within the range of 35 – 40 dB(A). We believe that limits within this range offer a reasonable degree of protection to wind farm neighbours without placing unreasonable restriction on wind farm development. The levels are low compared to some of the advisory documents reviewed and this is because of our concern to properly protect the external environment."

"The Noise Working Group is …. of the opinion that one should only seek to place limits on noise over a range of wind speeds up to 12 m/s…. If a wind farm meets noise limits at wind speeds lower than 12 m/s it is most unlikely to cause any greater loss of amenity at

higher wind speeds. Whilst turbine noise levels will still be reasonably constant, even in sheltered areas the background is likely to contain much banging and rattling due to the force of the wind."

"The Working Group recommends that both day- and night-time lower fixed limits can be increased to 45dB(A)and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm."

12.3.4 PAN 56

PAN 56 (1999) [4] sets out a range of noise issues which planning authorities must be aware of when, amongst others, formulating development plans and making decisions on planning applications to preserve environmental quality. It is also of assistance to developers in the identification of noise issues relevant to proposed developments.

With respect to wind farms, PAN 56 identifies mechanical noise from turbines and aerodynamic noise from the blades. It advises that good acoustical design and siting of turbines is essential to ensure there is no significant increase in ambient noise levels at nearby noise sensitive properties.

PAN 56 identifies British Standard (BS) 5228 *Noise and vibration control on construction and open sites* [5] for guidance on construction site noise control, and as a method of prediction of noise from construction sites.

12.3.5 The Control of Noise (Codes of Practice for Construction and Open Sites) (Scotland) Order 2002

The order defines BS 5228: Part 1 1997 (incorporating Amendment no. 1) as suitable for the purpose of giving guidance on appropriate methods for minimising noise.

12.3.6 PAN 50

PAN 50 (1996-2000) *Controlling the environmental effects of surface mineral workings Annex A: The Control of Noise at Surface Mineral Workings* [6] provides advice on noise limits. A daytime noise limit of 55 dBLAeq, 1hr (free-field) is recommended. Daytime is defined as 0700-1900 hrs. A lower limit is advocated for night-time periods.

12.4 METHODOLOGY

12.4.1 Overview

Although sensitive receptors are identified, and the magnitude of noise impact is quantified, noise effects are not evaluated on the basis of a receptor sensitivity / magnitude of impact matrix. Instead, target noise limits are derived based on relevant standards, and an assessment is made as to whether or not these targets will be met.

Noise impacts are quantified using noise specifications for construction plant and suitable wind turbines as inputs to noise models.

12.4.2 Operational noise

Assessment of operational turbine noise was undertaken in accordance with guidance document ETSU-R-97 *The Assessment & Rating of Noise from Wind Farms*. In summary this method involves the following stages:

- identification of the nearest noise-sensitive properties;
- a screening exercise to identify any properties where expected levels of wind farm noise may exceed 35dB(A) for wind speeds up to 12m/s at 10m height, to determine if noise monitoring is necessary;
- if necessary, agreement of noise monitoring locations with the local authority[#];
- a background noise survey at residential properties in parallel with wind speed monitoring at the wind farm site[#];
- generation of a background noise curve from the measured data, characterising the noise levels as a function of wind speed[#];
- generation of agreed noise limits for each property;
- prediction of received noise levels at receptors, by means of a noise model, appropriately corrected for tonal emissions;
- comparison of predicted levels with agreed noise limits;
- assessment of any cumulative impacts; and
- identification of mitigation in terms of layout and attenuation if necessary.

The cumulative effect of multiple turbines on noise levels at a receptor is estimated by the logarithmic addition of the predicted noise levels attributable to each individual turbine. The study assumes identical turbines at each location.

(a) Predictions of operational noise

Predictions of operational noise levels were undertaken the proprietary noise propagation model CadnaA. The predictions were undertaken in accordance with International Standard ISO 9613-2, *Acoustics –Attenuation of Sound During Propagation Outdoors: Part 2 - General Method of Calculation* [7].

The propagation model described in this standard provides for the prediction of sound pressure levels based on down wind (i.e. worst-case) conditions. When the wind is blowing in the opposite direction noise levels will be significantly lower, therefore the propagation model is inherently conservative.

The ISO propagation model calculates the predicted 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 – Ageo - Aatm – Agr - Abar

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[#] If screening assessment indicates that >35dBA noise contribution is likely

The geometric divergence (Ageo) attenuation factor represents the reduction in noise levels with distance from the source. The attenuation factor is directly related to the distance from the source.

Atmospheric absorption (Aatm) is the attenuation of noise in the atmosphere as sound energy is converted to heat. The level of absorption varies depending on the distance from sources and atmospheric conditions (temperature and humidity). ISO 9613-1, *Acoustics Attenuation of Sound during Propagation Outdoors: Part 1 - Method of calculation of the attenuation of sound by atmospheric absorption* provides appropriate air attenuation factors for differing atmospheric conditions.

The ground attenuation factor (Agr) represents the reduction in noise levels due to the absorption and reflection of sound energy by ground cover. The ground attenuation will vary significantly depending on the absorbtive qualities of the ground cover. ISO9612-1 provides advice on appropriate ground attenuation factors based on ground cover ranging from hard ground (concrete) to soft absorbent ground.

The attenuation due to barriers (Abar) accounts for the screening and reflection effects provided by obstacles between the source and the receiver. The level of attenuation will vary depending on the degree by which the line of sight between source and receiver is affected and the frequency considered. In relation to wind farms, local topography will provide the largest influence on barrier effects.

The predicted octave band levels from each of the turbines are summed together to give the overall 'A' weighted predicted sound level from all the turbines acting together.

(b) **Other operation noise effects**

The assessment of other operation noise effects or phenomena i.e. infrasound, low frequency noise, amplitude or aerodynamic modulation (AM) is based upon a review of relevant literature.

12.4.3 Construction noise

The assessment of construction noise was undertaken in accordance with BS5228:1997. BS 5228 Part 1 (1997) in Annex D sets out a method for the estimation of noise from sites. The estimation procedure requires that the following factors are taken into account:

- the sound power output of processes and plant;
- the periods of operation of processes and plant;
- the distances between sources and receiver;
- the presence of screening and barriers;
- the reflection of sound; and
- soft ground attenuation.

Noise from smaller pieces of equipment such as generators or hand held tools have insignificant noise output in comparison to larger pieces of plant. The assessment of construction noise therefore includes large plant items only.

In order to assess worst case noise levels calculations of noise levels have been undertaken assuming all large items of plant are operating simultaneously. Predictions of noise have been undertaken for the closest sensitive receptors (see 12.5.2), again to assess the worst case scenario. Noise levels have been predicted using the standard equations for the attenuation of sound under hemispherical spreading:

attenuation for soft ground = 25 x log[(R/10)-2]

where R is the separation distance between noise source and receiver.

12.4.4 Limitations of assessment

(a) Construction noise

Details of the precise construction programme and methods of construction are unknown at this stage of the development, and will not be defined until a contractor has been appointed following planning approval. However, although the method of construction may vary slightly depending of the methods and type of plant chosen by individual contractors, the methods for constructing wind farms are broadly similar. The number of plant, timescales of use and sound power output level for each type of plant have therefore been scaled from more standard scale wind farm development projects.

The predictions of construction noise have been undertaken based upon estimated numbers and type of construction plant. Small variations on the number of plant or variations of the type of plant utilised are expected not to result in significant changes to noise levels.

(b) Operational noise

Monitoring of background noise levels was undertaken at sixteen representative properties, however a malfunction occurred in the monitoring equipment at two receptor locations, namely Gonfirth and Laxo, resulting in a low data capture rate. The data was therefore considered unsuitable for use in the assessment. Background noise levels for receptors around Gonfirth and Laxo was therefore obtained from the closest representative monitoring locations.

The predictions of operational noise levels include a number of assumptions with respect to local conditions and their effect on noise propagation.

The model assumed downwind propagation in calculating noise imission levels at receptor locations. Where a receptor is located close to turbines in differing directions the assessment assumes that the receptor is simultaneously downwind of all turbines which in reality is not possible. This method of assessment provides an over-estimate of the noise immission and as such can be considered a worst case.

Whilst a preferred turbine model has been identified by the developer it is not possible to guarantee the exact turbines which will be used in the development. Whilst there will be variations in turbine noise between different turbine models, the modelling is based upon a turbine of the appropriate size. The turbine model considered, Siemens 3.6MW, is not considered to be particularly quiet and as such is considered as a suitable assumed candidate turbine to assess the potential noise impact of the proposed development.

(c) **Wind shear**

Wind shear is the difference in wind speed with height. Wind shear depends on local atmospheric conditions and amongst other things the level of turbulence generated by the interaction between wind and ground cover, known as surface roughness.

In assessing wind farm noise it is necessary to account for the effects of wind shear when processing wind speed data at 10m height based on measured wind speeds at higher anemometer levels. As turbine noise is generated at hub height it is also necessary to relate the wind speed at the hub height to wind speeds at 10m for the purposes of predicted operational noise levels.

The wind speed data used in the assessment for deriving operational noise criteria were measured at 10m height, therefore no correction for wind shear effects is required.

The sound power data for the turbines is measured at a reference surface roughness of 0.05m, in accordance with international guidelines. This equates to a wind shear co-efficient of approximately 0.14. In evaluating wind speeds across the development site SSE typically consider wind shear co-efficients between 0.05 and 0.11 depending on which part of the site is being considered. Measured wind shear levels across the site are presented in Table 12.5 for reference.

Table 12.5 Measured wind shear exponents

Mast	Grid Reference	Measurement height [m]	Measurement period	Equivalent shear exponent
M1	443348, 1166820	40	04/03 – 04/07	0.07
M3	442663, 1164223	70	09/05 – 08/08	0.05
M4	444115, 1158602	40	04/03 – 04/08	0.09
M5	439094, 1158407	100	09/05 – 08/08	0.06
M6	437263, 1152515	70	09/05 – 02/07	0.11

The Viking site is, therefore, considered to have a low wind shear, which reflects the lack of vegetation on Shetland mainland.

As the wind shear levels are lower than those assumed by the turbine manufacturer in deriving sound power levels for the turbines, the assumed 10m sound power levels in this study are higher than will be observed in reality. Use of the manufacturer sound power data, based on a wind shear co-efficient of 0.14, in the assessment will therefore provide a conservative prediction of operational noise levels.

12.4.5 Evaluation criteria

(a) **Construction noise**

Predictions of construction noise have been undertaken assuming the following conditions as a worst case:

- all equipment operates simultaneously;
- no attenuation due to soft ground; and
- no attenuation due to screening.

Construction noise has been evaluated with respect to the PAN 50 daytime noise target level of 55 dB $L_{Aeq,\ 1hr}$.

(b) **Operational noise**

Consultation with Shetland Islands Council has resulted in agreement of target noise levels based on ETSU-R-97 advice taking into account any low background noise levels. Operational noise has therefore been evaluated with respect to the target levels identified in Table 12.5.

Table 12.5 Operational Noise Limits, ETSU-R-97 (dB(A))

Period	Time	ETSU Noise Limit dB(A)
Daytime	All evenings from 18:00-23:00 hours; Saturday afternoon 13:00-18:00 hours; Sunday, 07:00-18:00 hours.	35-40 dB(A) or 'background + 5 dB', whichever is higher
Night-time	23:00-07:00 hours	43 dB(A) minimum or 'background + 5 dB', whichever is higher

12.5 BASELINE ASSESSMENT

12.5.1 Desk surveys

A review of ordnance survey mapping was undertaken and Shetland Islands Council was consulted in order to identify any significant noise sources within or surrounding the study area.

Background noise on Shetland is predominantly influenced by the interaction of wind with vegetation and other obstacles. Furthermore, as receptors on Shetland tend to be located around the coast, noise from waves influence ambient noise levels.

Road traffic noise is not considered to be an important influence on background noise levels beyond short term peaks at receptors away from the main roads. Receptors in the settlements of Brae and Voe will be subject to noises typically expected in residential areas.

Receptors within the northern portion of the Delting Quadrant of the development will be subject to noise from the Sullom Voe oil terminal and other industrial activity around the harbour. Noise from these sources will be variable depending on ongoing activities e.g. flaring, and the impact will be dependent on wind direction.

12.5.2 Baseline noise measurements

(a) Preliminary assessment

A preliminary assessment of operational turbine noise was undertaken to determine whether or not noise limits would exceed 35dB(A) at the identified noise-sensitive properties.

The preliminary assessment considered a layout of two hundred and forty-six Vestas V80 turbines[1]. The preliminary assessment preceded the detailed design stage so the preliminary assessment considered a layout with turbines extending to the extremities of the site.

Predicted operational noise levels were greater than 35dB(A) at a number of receptors within the study area. It was therefore deemed necessary to undertake extensive monitoring in the area to determine background noise levels.

Following the preliminary assessment consultation discussions were held with Shetland Islands Council Environmental Health department to identify suitable monitoring locations. Shetland Islands Council identified sixteen representative properties, based on the preliminary assessment layout, at which monitoring was undertaken to provide representative background noise data for the study area.

The final scheme layout differs substantially from that considered in the preliminary assessment. Of the sixteen representative monitoring locations identified in consultation with Shetlands Islands Council ten are no longer within the study area, therefore these locations are no longer considered in the study.

(b) Monitoring locations

The representative receptors identified for the purposes of background noise monitoring are described below and are annotated in Figure 12.1.

Upper Kergord

An isolated property situated within the Kergord quadrant of the Viking site boundary. The property is unoccupied and will not be inhabited during the operation of the wind farm, however, background noise measurements at this location were also considered to be representative of levels at Springfield and other properties in Weisdale (Kergord and Stenswall). Measurements were undertaken in the field adjacent to the property.

Hillside

Measurements were undertaken within the grounds of a school in Hillside close to the boundary between the Delting and Collafirth quadrants. The readings are representative of background noise in and around Voe and Hillside. In particular, this location was considered representative of the properties at Hamars, Tagon, and Susetter.

No monitoring was undertaken in the vicinity of the properties at Graven, Moorfield, Hardwall or Laxobigging. In reviewing the monitoring data it was considered that the most

[1] This was undertaken prior to design finalisation; the final design has both fewer and larger turbines.

suitable proxy background site was that at Hillside, as the monitoring at Brae indicated elevated background noise levels which would be expected in villages but not at isolated properties. Furthermore the receptors are all located on the west of the central upland area similar to Hillside. The properties at Graven, Moorfield, Hardwall, Hill Cottage and Laxobigging may experience higher background noise levels at certain times due to noise from the Sullom Voe oil terminal, Scatsta airfield and industrial activity around Sullom Voe docks, however the monitored levels at Hillside are considered to provide a suitable conservative level in the absence of these noise sources.

Grutin

Measurements were undertaken in the grounds of the property situated close to the A968 close to the boundary between the Delting and Collafirth quadrants. Background noise measurements will be representative of noise levels at properties along the A968, including Easterscord.

Laxo

Measurements were undertaken at a property at North Tararet close to Laxo. Operational problems were experienced with the sound level meter resulting in a low data capture rate.

Dury

Measurements were undertaken in the garden of a property to the north-east of the Nesting Quadrant. Background noise measurements will be representative of properties situated along the B9075 and around the Dury Voe. In particular, the site is considered representative of the receptors at Lower House, Fern and North Tararet.

Catfirth

Measurements were undertaken close to the farmstead to the south of the Nesting quadrant. Measured background noise levels will be representative of noise levels in the South Nesting area.

Property at junction A970/B9075

Measurements were undertaken in a field adjacent to the isolated property at the junction of the A970/B9075 close to the boundary between the Kergord and Nesting quadrant.

12.5.3 Field survey

Norsonic NOR-118 or NOR-116 (Type 1) sound level meters were located at each of the receptors identified in Section 12.5.2 for a two week period from 5-17th August 2005. The meters were enclosed in environmental cases containing sufficient battery power for approximately 12-14 days. The microphones and environmental cases were equipped with appropriate wind and rain protection to ensure the accuracy of the monitoring. The sound level meters and microphones were calibrated prior to and after the monitoring exercise. Details of the sound level meters and microphones used are provided in Appendix 12.1.

The sound level meters logged L_{A90} and L_{Aeq} levels at 10-minute intervals over the two-week monitoring period. The background noise levels (L_{A90}) measured at each of the receptors was correlated with the corresponding wind speed measured at the site. The wind speed measurements were undertaken at a height of 10m.

In March 2009, an article in the Institute of Acoustic publication, Noise Bulletin [8] by a group of independent noise consultants, recommended that background noise levels be correlated with wind speeds at 10m derived from measured wind speeds at hub height, rather than those measured at 10m height. During the period of background noise monitoring the highest operational anemometer on the proposed wind farm site was 40m high, below that required to derive 10m high wind speeds using the method proposed in the article. Background noise levels were, therefore, correlated with measured 10m height wind speeds as this data was the best available data.

The correlated noise and wind speed data for Quiet Daytime and Night-time periods at each receptor are presented in Graphs 12.1-12.10 in Appendix 12.2. As wind speed measurements were undertaken at 10m height there was no requirement to undertake any 'correction' of wind speeds at differing heights to account for wind shear.

A 'line of best fit' was plotted on each of the graphs to determine the typical noise level at each site during each assessment period for the range of wind speeds. The typical quiet daytime noise levels at each monitoring site are summarised in Table 12.6.

Table 12.6 Measured Quiet Daytime Background Noise Levels, $L_{A90, 10\ min}$, dB

Receptor	Wind Speed (m/s)						
	4	5	6	7	8	9	10
Upper Kergord	22.3	23.6	25.4	27.8	30.7	33.9	37.4
Hillside	28	29.2	30.5	31.8	33.2	34.5	35.8
Dury	21	22.3	24.3	26.8	29.7	32.9	36.3
Grutin	34.3	34.3	34.4	34.9	35.4	36.2	37.1
Catfirth	26.2	28.2	30.3	32.4	34.7	37	39.4
B9075/A970	25.3	26.6	28.5	30.8	33.4	36.2	39
Range	**22-34**	**22-34**	**24-34**	**27-35**	**30-35**	**33-37**	**36-39**

The measured quiet daytime background noise levels vary from receptor to receptor with, excluding Grutin, measured levels varying by 5-6dB at any given wind speed. The lowest noise levels were typically measured at Dury, whilst the highest levels were measured at Gutin. The measured noise levels indicate a steady increase in measured background noise levels with wind speed at each of the receptor locations.

At higher wind speeds the measured background noise levels at some receptors are within 5dB of ETSU quiet daytime criteria. The secondary criterion of 'background + 5 dB' will therefore be applied to establish operational noise limits for assessing the effects of wind farm noise at each receptor.

Typical night-time noise levels at each monitoring site are summarised in Tables 12.7.

Table 12.7 Measured Night-time Background Noise Levels, $L_{A90, 10 min}$, dB

Receptor	Wind Speed (m/s)						
	4	5	6	7	8	9	10
Upper Kergord	20.6	21.7	23.4	25.6	28.5	31.9	36
Hillside	20	21	22.3	24.1	26.1	28.3	30.6
Dury	19.9	21.2	23.1	25.5	28.2	31.3	34.7
Grutin	34.3	34.3	34.6	35.0	35.5	36.1	36.6
Catfirth	20.7	22	23.3	24.8	26.7	29.1	32.2
B9075/A970	19.2	20.2	21.6	23.4	25.7	28.3	31.5
Range	**20-21**	**20-22**	**22-23**	**23-26**	**26-29**	**28-32**	**31-36**

With the exception of Grutin, the night-time background noise levels show closer correlation between monitoring locations than that observed during the quiet daytime period. Measured background noise levels during the night time period are low and are similar between monitoring locations at low wind speeds.

The measured background noise levels at each receptor are more than 5dB below the ETSU criterion of 43dB, therefore the fixed criterion only will therefore be applied to establish operational noise limits for assessing the effects of wind farm noise at each receptor.

12.5.4 Modifying influences

No planned developments have been identified in the vicinity of the proposed wind farm site that will have an effect on baseline noise conditions.

12.6 EFFECTS EVALUATION

12.6.1 Basis of assessment

(a) Development characteristics

Construction Noise

Construction activities with the highest potential to generate noise include track laying, excavating and the laying of foundations and aggregate excavation at the borrow pits.

By obtaining aggregate materials for site tracks from borrow pits on the site the number of delivery vehicles accessing the site will be minimised. Similarly, concrete will be mixed on-site, minimising the number of concrete deliveries.

It is proposed that fourteen borrow pits are used to source local stone during the construction phase, with twenty-three potential borrow pit sites having now been identified. It is understood that the final borrow pit locations will be selected following preliminary ground tests; therefore for the purposes of the noise assessment it is necessary to consider operations at each of the borrow pits.

It is proposed that borrow pit material will be removed using excavators of up to 40 tonne capacity. Where necessary, bulldozer drawn rippers will be used to pre-loosen rock. Dump trucks of 35 tonne capacity will be used to haul the material to the access tracks and constructions areas, and subsequently to haul surplus material to the pit during its restoration. For the purposes of assessment, it is assumed that blasting is required.

The anticipated duration of the workings on each borrow pits is 6 months in total. This will comprise an initial continuous period of activity of approximately 4 months, followed by a further two-month period of intermittent activity.

Noise generating construction work is assumed to occur at the working hours described in Section 4.4.3 of Chapter 4.

Noise predictions have been based upon the proposed list of equipment (or equivalent) and source noise terms listed in Table 12.8. The equipment list has been developed based on experience on other wind farm sites. Although the Viking wind farm site is substantially bigger than the average wind farm site the scale of the development site can be considered akin to a series of smaller wind farm developments. The type and numbers of construction plant required at each location and borrow pit will not, therefore, be different from that on an average wind farm. Source noise terms are based either on measured levels of actual plant, or have been estimated from BS 5228. These are identified as (m) and (e) respectively.

Table 12.8 Construction source noise terms

Plant Item	Number of plant	SPL dB LA_{eq} @ 10m	SWL dB L_{WA}	Haul route frequency (veh/hr)
Excavators CAT 375 (e)	8	78		
Dozers CAT D9 (m)	3	89		
Dump trucks Volvo A35 (e)	8		108	12
Drill Rig	1	86		
Crusher	1	90		
Concrete batcher	1	80		

Operational Noise

Noise predictions of operational noise were undertaken for the final layout of one hundred and fifty Siemens 3.6 MW turbines with a hub height of 90m. The noise predictions were undertaken based on the measured sound power level of the turbine, corrected for measurement un-certainty. The data for the wind turbine was taken from actual measurements conducted by the manufacturer. The method used to obtain sound power data conformed to International Energy Agency (IEA) recommended practice, the most commonly used procedure.

The assumed sound power levels, across the range 6-10m/s are presented in Table 12.9.

Table 12.9 Siemens 3.6 MW source noise terms, L_{WA} dB

Wind Speed (m/s)	6	7	8	9	10
Power output (kW)	1500	2325	3075	3470	3600
Measured Sound Power Level (L_{WA})	103.9	104.5	105.2	105.5	105.5
Measurement uncertainty	1.3	1.3	1.3	1.3	2.1
Assumed warranted sound power level (L_{WA})	105.2	105.8	106.5	106.8	107.6

The noise calculations were undertaken based on octave band sound power level data. The noise spectrum used for the predictions has been taken from the measurement report provided by the turbine manufacturers for the reference wind speed of 8 m/s, normalised to the sound power level at each integer wind speed. The assumed octave band spectra at 10 m/s wind speed are presented in Table 12.10.

Table 12.10 Siemens 3.6 MW octave band source noise terms, L_{WA} dB

Octave band centre frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Assumed octave band sound power level dB(A)	89.1	97.4	101.6	100.4	100.9	99.7	96.0	89.0

The ETSU-R-97 assessment method requires, where tones are present in noise immission levels at noise sensitive receptors, that a tonal penalty be added to predicted noise levels. The level of penalty is derived using a method known as the Joint Nordic method and depends on the amount by which the tone exceeds the audibility threshold. A warranty would be sought from the manufacturers of the turbines for the Viking site that the noise levels would not require a correction under the Joint Nordic method.

As discussed in Section 6.4.2 operational noise levels at receptors identified in the study area were predicted, using the turbine source noise terms, in accordance with the method described in ISO 9613-2. This method predicts noise levels under meteorological conditions favourable to downwind conditions. Predictions were undertaken using the proprietary software package CadnaA.

The noise predictions allow for the effects of geometric divergence (distance attenuation), atmospheric absorption and attenuation due to ground effects. The attenuation due to atmospheric absorption assumed atmospheric conditions of 10ºC and 70% humidity. Ground attenuation has been allowed for in the noise predictions, assuming mixed ground conditions (G=0.5) as described in ISO 9613-2.

The screening effects of barriers (terrain relief) on noise levels at receptor locations were allowed for in the model. Digital topographic data for the study area were obtained from Ordnance Survey and input to the model.

Predicted noise levels from the calculation method are LAeq values. The evaluation criteria defined by ETSU-R-97 are determined using measured background noise levels for which the index is LA90. ETSU-R-97 identified that LAeq levels may be expected to be about 1.5–2.5 dB higher than corresponding LA90 values. Therefore, 2 dB has been subtracted from the predicted noise levels to convert the results to LA90 values for comparison with ETSU-R-97 evaluation criteria.

(b) Assumed design, management and mitigation measures

Construction

Blasthole drilling can cause excessive noise at nearby properties, particularly when carried close to the site boundary and at or near ground level. The choice of appropriate drilling rigs such as down-the hole hammers or hydraulic drifters as opposed to compressed air drifters will reduce the impact of noise emissions. Blasts should be carefully designed to maximise its efficiency and to reduce the transmission of noise. Surface detonation may cause problems associated with air overpressure. This can be avoided by adopting the technique of down-the hole initiation, or by using a reasonable thickness of overburden to cover the charge.

In planning the construction works on the site, best practice measures for noise control will be adhered to. Consideration will be given to the noise effect of the proposed working methods and site layout on adjacent sensitive premises. Where appropriate, alternative methods or arrangements which avoid or reduce noise levels will be employed where practicable. Specific measures which will be considered are:

- *location of equipment*, taking account of local topography and natural screening,
- *working methods*, including the phasing of the works, location and gradient of access roads, equipment to be employed, working hours, and use and control of blasting;
- *selection of plant*, taking account of the characteristics of noise emissions from each item of plant and their collective effect;
- *deployment of plant*, in particular the timing of on- and off-site movement of plant and reducing the duration of noisier operations near occupied properties;
- *working hours*, where restrictions are applied to any operations where emissions of noise and vibration may have an adverse effect on the occupants of sensitive premises;
- *training and supervision* of operatives in proper techniques to reduce site noise, and self-monitoring of noise levels if appropriate; and
- *operation of plant*, including fitting and proper maintenance of silencers and/or enclosures, avoiding excessive and unnecessary revving of vehicle engines, and parking of equipment in locations which avoid possible effects on noise-sensitive properties.

Operation

It is assumed that the turbine specification will be sufficient to meet the modelled parameters.

12.6.2 Construction noise effects

(a) Mobile plant noise

Impact magnitude

This assessment considers noise from all construction plant operating at each borrow pit. The predicted construction noise levels at each receptor are detailed in Table 12.11. The predicted noise levels represent noise from the closest borrow pit to each receptor only.

Table 12.11 Predicted construction noise levels at closest receptors, dB(A)

Receptor	Grid Reference	Maximum Predicted Noise Level dB $L_{Aeq, 12hr}$
Tigh-na-Binn	437760 1150326	61.7
Nethersound	438052 1150131	55.0

Receptor	Grid Reference	Maximum Predicted Noise Level dB $L_{Aeq, 12hr}$
Oversound	438278 1150320	56.1
Uppersound	438382 1150424	54.6
Djuba	438573 1150722	50.4
Stranvara	438791 1150248	46.4
Kallibrig	438660 1150078	46.8
Kurkigrath	438744 1151222	44.9
Cott R1	437937 1149801	48.6
Hellister R1	438569 1149774	45.0
West Setter	439414 1154817	43.5
North House	440250 1156604	41.4
Sandwater	441741 1155165	49.4
Flammister	441741 1155165	49.0
Whinnia Lea	446680 1155855	67.4
South Newing	446850 1155936	57.2
Clymlsa	447145 1156233	51.9
Burns	446600 1155064	50.1
Skellister	446780 1154961	47.7
Skellister W	446207 1154820	45.4
Susetter	440900 1165406	45.1
Garthsvale	440969 1165677	47.8
Garth of Susseter	440936 1165736	47.7
Souther House	440864 1169819	50.2
Norther House	440688 1167021	48.0
Easterscord	441362 1166345	57.6
Southtown	437092 1169742	59.2
Voxter	437113 1169953	53.2
Hardwall	437407 1170072	47.9
Pund of Grutin	440918 1169015	47.1
Pund of Grutin R1	440954 1169175	49.3
PAN 50 Daytime noise Limit		**55**

Effects significance

The predicted construction noise levels at most receptors are below the derived PAN50 daytime noise limit; however construction noise levels above 55dB are predicted at Tigh-na-Binn, Oversound, Whinnia Lea, South Newing, Easterscord and Southtown. The closest borrow pits to each of these receptors are small borrow pits which will be used for a short time period to provide material for the initial stage of tracks onto the site. Activity at these borrow pits will therefore be restricted to a short time period to allow the initial tracks to be laid.

(b) **Borrow pit blasting**

Impact magnitude

Should blasting be required, methods of blasting will be employed which reduce air overpressure at the nearest sensitive receptors to levels which do not cause disturbance.

Effect significance

Adverse effects from air over pressure due to blasting are not predicted.

12.6.3 Operational noise effects

(a) **Turbine mechanical and aerodynamic noise**

Impact Magnitude

The predicted operational noise levels at a height of 10m over a range of wind speeds 6 m/s-10 m/s at each receptor are detailed in Tables 12.12 to 12.17 according to the proxy background monitoring location. The appropriate noise criteria for each receptor are also presented in the table for reference. The predicted worst-case noise levels at a wind speed of 10 m/s are presented as noise contours on Figure 12.3.

Table 12.12 Predicted operational noise levels at receptors represented by Hillside, dB L_{Aeq}

Receptor	Reference Wind Speed at 10m (m/s)				
	6	7	8	9	10
Graven	34.2	34.8	35.5	35.8	36.6
Moorfield	34.9	35.5	36.2	36.5	37.3
Hill Cottage	32.3	32.9	33.6	33.9	34.7
Hardwall	30.1	30.7	31.4	31.7	32.5
Laxobigging	34	34.6	35.3	35.6	36.4
Hamars	23.9	24.5	25.2	25.5	26.3
Tagon	22.6	23.2	23.9	24.2	25
Sursetter	27	27.6	28.3	28.6	29.4

Receptor	Reference Wind Speed at 10m (m/s)				
	6	7	8	9	10
Easterscord	28.1	28.7	29.4	29.7	30.5
ETSU Quiet Daytime limit	**36**	**37**	**38**	**40**	**41**
ETSU Night time limit	**43**	**43**	**43**	**43**	**43**

Table 12.13 Predicted operational noise levels at receptors represented by Grutin, dB L_{Aeq}

Receptor	Reference Wind Speed at 10m (m/s)				
	6	7	8	9	10
Grutin	20.9	21.5	22.2	22.5	23.3
ETSU Quiet Daytime limit	**39**	**40**	**40**	**41**	**42**
ETSU Night time limit	**43**	**43**	**43**	**43**	**43**

Table 12.14 Predicted operational noise levels at represented by Upper Kergord, dB L_{Aeq}

Receptor	Reference Wind Speed at 10m (m/s)				
	6	7	8	9	10
Springfield	33.5	34.1	34.8	35.1	35.9
Kergord	25.9	26.5	27.2	27.5	28.3
Stenswall	21.1	21.7	22.4	22.7	23.5
ETSU Quiet Daytime limit	**35**	**35**	**36**	**39**	**42**
ETSU Night time limit	**43**	**43**	**43**	**43**	**43**

Table 12.15 Predicted operational noise levels at represented by Dury, dB L_{Aeq}

Receptor	Reference Wind Speed at 10m (m/s)				
	6	7	8	9	10
Lower House	38	38.6	39.3	39.6	40.4
Fern	38	38.6	39.3	39.6	40.4
North Tararet	26.4	27	27.7	28	28.8
Dury	30.1	30.7	31.4	31.7	32.5
ETSU Quiet Daytime limit	**35**	**35**	**36**	**38**	**41**
ETSU Night time limit	**43**	**43**	**43**	**43**	**43**

Table 12.16 Predicted operational noise levels at receptors represented by Catfirth, dB L_{Aeq}

Receptor	Reference Wind Speed at 10m (m/s)				
	6	7	8	9	10
Catfirth	32.6	33.2	33.9	34.2	35

ETSU Quiet Daytime limit	**35**	**37**	**40**	**42**	**44**
ETSU Night time limit	**43**	**43**	**43**	**43**	**43**

Table 12.17 Predicted operational noise levels at receptors represented by the receptor at B9075 junction, dB L_{Aeq}

Receptor	**Reference Wind Speed at 10m (m/s)**				
	6	7	8	9	10
Receptor (B9075)	36.1	36.7	37.4	37.7	38.5
ETSU Quiet Daytime limit	**35**	**36**	**38**	**41**	**44**
ETSU Night time limit	**43**	**43**	**43**	**43**	**43**

Effects significance

The predicted operational noise levels for receptors represented by Hillside are tabulated against the derived ETSU evaluation criteria for the quiet daytime and night time periods in Table 12.12. The tabulated values demonstrate that the predicted noise levels at Hill Cottage, Hardwall, Hamars, Tagon, Easterscord and Sursetter are below the minimum ETSU quiet daytime level of 35dB at all wind speeds. The predicted noise levels at Graven, Moorfield and Laxobigging are below the ETSU criteria of 'background + 5dB'. The predicted noise levels at all receptors are below the ETSU night time noise limit of 43dB.

The predicted noise levels at Grutin, as presented in Table 12.13 are below both the minimum quiet daytime and night time ETSU limits at all wind speeds.

The predicted noise levels and derived ETSU criteria for receptors in the Kergord Quadrant are presented in Table 12.14. The tabulated results demonstrate that at both Kergord and Stenswall the predicted operational noise levels are below the minimum ETSU quiet daytime level of 35dB at all wind speeds. The predicted noise levels at Springfield receptors are below the ETSU criteria of 'background + 5dB' during the quiet daytime period. The predicted noise levels at all receptors in the Kergord Quadrant are below the ETSU night time noise limit of 43dB.

The predicted noise levels and derived ETSU criteria for receptors represented by Dury are presented in Table 12.15. The tabulated data demonstrate that predicted operational noise levels at North Tararet and Dury are below the minimum quiet daytime ETSU limit of 35dB at all wind speeds. At Lower House and Fern the predicted operational noise levels during the quiet daytime period are higher than the minimum ETSU quiet daytime criteria of 35dB . The predicted operational noise levels are also higher than the derived 'background+5dB' criteria for wind speeds between 6-9 m/s. However, the predicted levels are within the 35-40dB range specified for ETSU for the quiet daytime period. At the highest noise output, at 10m/s, the predicted noise levels are below the ETSU criteria of 'background + 5dB'. The predicted noise levels at all receptors are below the ETSU night time noise limit of 43dB.

The predicted noise levels and derived ETSU criteria for Catfirth are presented in Tables 12.16. The tabulated results demonstrate that the predicted operational noise levels are below the ETSU criteria of 'background + 5dB' during the quiet daytime period. The predicted noise levels are below the ETSU night time noise limit of 43dB.

The predicted operational noise levels at the receptor adjacent to the B9075 are below the derived ETSU criteria of 'background + 5dB' at all wind speeds with the exception of 6m/s, at which point the predicted noise level is 0.1dB above the derived limit. The predicted operational noise levels are, however, comfortably within the 35-40dB range proposed by ETSU for the quiet daytime period. The predicted noise levels are below the ETSU night time noise limit of 43dB.

Summary

The predicted operational noise levels at all receptors are therefore below the operational noise criteria set out by ETSU. Operational noise effects are therefore assessed as not being significant.

(b) **Low frequency noise and infrasound**

Impact magnitude

Low frequency noise was a feature of early wind turbine designs, where the blades were down-wind of the tower. Modern turbines, and the turbines that will be used in this development, have their blades upwind of the tower, thus reducing the low frequency noise to below the threshold of human perception.

Recent work by Leventhall (2004) [8] and Leventhall *et al* (2003)n [9] assessed the likely levels of low frequency noise at receptor locations 600 metres from a proposed site of five 1.3MW turbines. The 2004 study reported:

"It is concluded that noise from the proposed installation in the low frequency (10Hz to 200Hz) range is unlikely to be a problem."

Measurements of the emissions from larger turbines have shown levels of infrasound to be below audibility. Klug (2002) [10] reported the results of measurements of a Vestas V66-1750 turbine, comparing the measured levels with the German DIN45680 standard concluded:-

"Wind turbines are radiating sound at extremely low levels in the infrasound range (below 20 Hz).This sound is far below the detection threshold and thus far below levels which can cause any diseases. Measurements on a turbine in the megawatt class at the DEWI Test Site showed levels of 58 dB at a distance of 100 m to the turbine in the one-third octave band level at 10 Hz [2], which means more than 30 dB below the hearing threshold at this frequency."

Physic Gmbh (2003) [11] reports the results of 1/3 octave band and 'G' weighted measurements of a Nordex N80 2.5MW turbine at 200m. The measured values were also compared with the audibility thresholds from DIN45680 and were found to be below perceptible levels. In each case where measurements were made, low frequency noise was not considered to be of a level likely to be a cause for concern. At Viking, the turbines will be very much further from properties than was the case in these studies. It can be concluded therefore that low frequency noise will not result in perceptible impacts at the proposed site.

A study (Styles et al, 2005) [12] was undertaken into low frequency vibration with respect to the siting of wind farms and possible effects of the operation of the UK seismological array located at Eskdalemuir in southern Scotland. The study included vibration measurements arising from the existing Dunlaw wind farm in the Scottish Borders. Contrary to some perceptions, the study did not examine human response to either low frequency noise or vibration from wind turbines. To clarify any misconceptions, the authors of the report issued a subsequent press release which advised "…The Dunlaw study was designed to measure effects of extremely low level vibration on one of the quietest sites (Eskdalemuir) in the world, and one which houses one of the most sensitive seismic installations in the world. Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise – they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of human beings sensing the vibration and absolutely no risk to human health".

In 2006 the Department of Trade and Industry (DTI) [13] published a study that investigated claims that infrasound or low frequency noise emitted from wind turbines was causing adverse health effects. The study concluded that there is no evidence of health effects arising from infrasound or low frequency noise from wind turbines.

Effects significance

Based on published research no perceptible impacts are predicted, therefore no significant effects will result.

(c) Aerodynamic Modulation

Impact magnitude

The phenomenon of Aerodynamic Modulation (AM) of wind farm noise has been identified in isolated circumstances in ways not anticipated by ETSU-R-97. In response to this phenomenon the DTI commissioned Salford University to conduct a study to investigate historical complaints in relation to wind farm noise across the UK to determine where AM was a factor. The study also determined to develop an understanding of AM and to whether AM can be predicted.

The Salford University study [13] concluded that AM cannot be fully predicted, however, that the incidence of complaints relating to AM was low with less than four wind farms out of 133 operational wind farms studied experiencing problems. Of the wind farms experiencing problems remedial action has resolved the complaints in three cases with the other case still under investigation.

A Government Statement on AM [14], states that whilst the situation will remain under review, it does not consider there to be a 'compelling case for further work into AM'.

Effects significance

Based on published research it is considered that the likelihood of AM occurring at the Viking wind farm is low. No significant effects are therefore predicted.

12.7 MITIGATION

As detailed in Section 12.6 appropriate mitigation will be adopted during the construction phase of the development, including:

- appropriately locating equipment to minimise noise impacts, maximising natural screening where possible;
- appropriate phasing of the works, equipment to be employed, working hours, and use and control of blasting;
- utilising quietest plant where possible and deploying or moving plant at appropriate times to minimise noise impacts to occupied properties;
- restricting any operations where emissions of noise and vibration may have an adverse effect on the occupants of sensitive premises to appropriate times;
- training and supervision of operatives in proper techniques to reduce site noise, and self-monitoring of noise levels if appropriate; and
- efficient operation of plant, including fitting and proper maintenance of silencers and/or enclosures, avoiding excessive and unnecessary revving of vehicle engines, and parking of equipment in locations which avoid possible effects on noise-sensitive properties.

No significant impacts are predicted during the operational phase of the development as the wind farm layout was designed to minimise environmental impacts. A maintenance programme will be employed on the turbines to ensure efficient operation, thereby minimising mechanical noise.

12.8 RESIDUAL IMPACTS

Assessment of construction noise levels has determined that the adopted noise criteria may be exceeded at five receptor locations during operations at the closest borrow pits. The closest borrow pits to each of these receptors are small borrow pits which will be used for a short time period to provide material for the initial stage of tracks onto the site. Noise impacts will be minimised as much as possible by adopting the control measures outlined in Section 12.7 and all activities will be restricted to appropriate daytime hours to minimise the disturbance caused. It is considered that due to the temporary nature and the appropriate scheduling of the activities at the borrow pit that the impact can be considered to be of moderate significance.

The predicted noise levels at the closest sensitive receptors during the operational phase of the development are below the noise assessment criteria set out in ETSU. The predicted impact at the closest sensitive receptors is, therefore, deemed to be not significant.

12.9 SUMMARY

This chapter has assessed potential noise effects identified during the scoping of the environmental assessment, and the findings are summarised in Table 12.14 and 12.15.

12.10 MONITORING

Monitoring of operational noise levels may be required to determine compliance with planning conditions in the event of substantiated complaints regarding noise. It will be standard practice to require noise monitoring during turbine performance tests to verify compliance with the contract noise specification.

Table 12.18 Summary of construction effects

Construction Effects	Impact	Potential Effects on Receptors	Sensitivity	Impact magnitude	Duration	Effect significance
Mobile plant operations	Mechanical noise	Oversound, Whinnia Lea, South Newing, Easterscord, Southtown	High	Negligible - low	Temporary	Negligible - low
		All other receptors	High	Low	Temporary	Minor
Borrow pit operations	Drilling and blasting noise	Oversound, Whinnia Lea, South Newing, Easterscord, Southtown	High	Negligible - low	Temporary	Negligible - low
		All other receptors	High	Low	Temporary	Minor
	Crusher plant noise	Oversound, Whinnia Lea, South Newing, Easterscord, Southtown	High	Negligible - low	Temporary	Negligible - low
		All other receptors	High	Low	Temporary	Minor

Table 12.19 Summary of ongoing effects

Construction Effects	Impact	Potential Effects on Receptors	Sensitivity	Impact magnitude	Effect significance
Turbines	Audible mechanical and aerodynamic noise	Noise effects at nearest receptors.	High	Low	Negligible
Turbines	Low frequency noise and infrasound	Noise effects at nearest receptors.	High	Low	Negligible
Turbines	Amplitude modulation	Noise effects at nearest receptors.	High	Low	Negligible

12.11 REFERENCES

[1] Department of Trade and Industry (1996) The Assessment & Rating of Noise from Wind Farms (ETSU-R-97)

[2] Scottish Planning Policy Guidance SPP6 Renewable Energy, Scottish Executive (2007)

[3] Scottish Executive (2002) Planning Advice Note (PAN) 45 Renewable Energy Technologies

[4] Scottish Executive (1999) Planning Advice Note (PAN) 56 Planning and Noise

[5] British Standard (BS) 5228 *Noise and vibration control on construction and open sites (1997)*

[6] Scottish Executive (1996) Planning Advice Note PAN 50 *Controlling the Environmental Effects of Surface Mineral Workings*

[7] ISO 9613-2, Acoustics – Attenuation of Sound during Propagation Outdoors: Part 2 – General method of calculation. International Organisation for Standardisation 1996.

[8] Leventhall (2004) Assessment of Low Frequency Noise from the Proposed West Mill Wind Farm, Watchfield. A Report to Vale of the White Horse District Council.

[9] Leventhall et al (2003) A Review of Published Research on Low Frequency Noise and its Effects. Report for DEFRA by Dr Geoff Leventhall. Assisted by Dr Peter Pelmear and Dr Stephen Benton. www.defra.gov.uk.

[10] Klug (2002) Infraschall von Windenergieanlagen: Realität oder Mythos? Helmut Klug, DEWI, Extract from DEWI Magazin Nr. 20. Translated into English.

[11] Physic Gmbh (2003) Messung der Infraschall-Abstrahlung einer Windenergieanlage des Typs NORDEX N-80. 10th Juni 2003. Institut für technische und angewandte Physic Gmbh (in German only)

[12] Low Frequency Noise **&** Wind Turbines**,** Styles et al, Keele University (2006)

[13] DTI report W/45/00656/00/00, The measurement of low frequency noise at three UK wind farms. Deprtment of Trade and Industry 2006

[14] DEFRA Contract Report NANR233, Research into Aerodynamic Modulation of Wind Turbine Noise, University of Salford 2007