11. NOISE & VIBRATION

11.1 Introduction

Amplitude Acoustics were engaged by Hibernian Wind Power Ltd. (Hibernian) to conduct an environmental noise impact assessment of the proposed 15-year extension of operation of Carnsore Wind Farm, Co. Wexford (Proposed Development). Carnsore Wind Farm is an existing 11.9 megawatt (MW), 14 no. turbine wind farm located at Carnsore Point, Co. Wexford and commenced operation in 2002.

This chapter documents the key acoustic and vibration issues that have been assessed including:

- The appropriate noise criteria for noise emissions from the turbines, the substation, and the decommissioning works.
- Modelling of noise emissions from the various noise sources.
- Assessing the noise impact with regard to the appropriate noise criteria.

11.1.1 Statement of Authority

This report was completed by Amplitude Acoustics, an acoustic consultancy that specialises in noise and vibration. Amplitude's team have successfully completed a large number of projects throughout Ireland, Europe, the Middle East, Australasia and North America. Our approach to the provision of services is based upon experience gained on many projects, underpinned by a deep understanding of the technical and social principles behind government noise policy.

This noise assessment was completed by Benny Cryan and Dr. Emmet English who have extensive experience in assessing wind farm developments.

Dr. Emmet English was the project director, who has a degree in Mechanical Engineering and a PhD in Acoustics. Emmet has over 17 years of professional experience in acoustics and is a member of Engineers Ireland (MIEI) and the Institute of Acoustics (IOA).

Benny Cryan was project manager, responsible for acoustic modelling and production of the report. Benny has a degree in Computer and Electronic Engineering, has completed the Institute of Acoustics (IOA) Diploma in Acoustics and Noise Control, and is a member of the Engineers Ireland (MIEI).

11.1.2 Fundamentals of Acoustics

Noise can fundamentally be described in terms of its magnitude or loudness and its frequency or character. Because the human ear perceives a vast range of sound pressures, measurements are expressed on a logarithmic scale, which makes the numbers less unwieldy. Changes in magnitude are normally expressed in decibels (dB). Noise in the environment is measured using the dB(A) scale which includes a correction for the response of the human ear to noises with different frequency content. The typical human reactions to changes in sound level are outlined in Table 11-1. It can be observed from Table 11-1 that a change of 1-2dB is generally considered imperceptible, whereas a 10dB change is generally considered as a halving or doubling of loudness of a sound.

Table 11-1 Subjective effect of changes to noise levels

Change in noise level, dB	Subjective change in apparent loudness
1	Not perceptible
2 – 3	Just perceptible
5	Clearly noticeable
10	Half or twice as loud
20	Much quieter or louder

The noise level in a particular location will depend on the type and number of noise sources in the vicinity, as well as the distance to each of the noise sources. Some examples of typical sound levels in dB(A) are shown in Figure 11-1 below.

Because dB(A) sound measurements are on a logarithmic scale, addition and subtraction of sound levels can be counter intuitive. For instance:

- When two sound levels of equal magnitude are added, the summed level is 3dB higher (a 3dB change indicates a doubling of power),
  - e.g. 40dB + 40dB = 43dB
- When the difference between two sound levels is greater than 10dB, the sum of the two levels is effectively equivalent to the higher of the two levels,
  - e.g. 30dB + 40dB = 40.4dB (a 1dB change is, in general, imperceptible)

The second example above is important in environmental noise as when there is a difference of 10dB or more between noise levels from two sources, the louder source dominates.

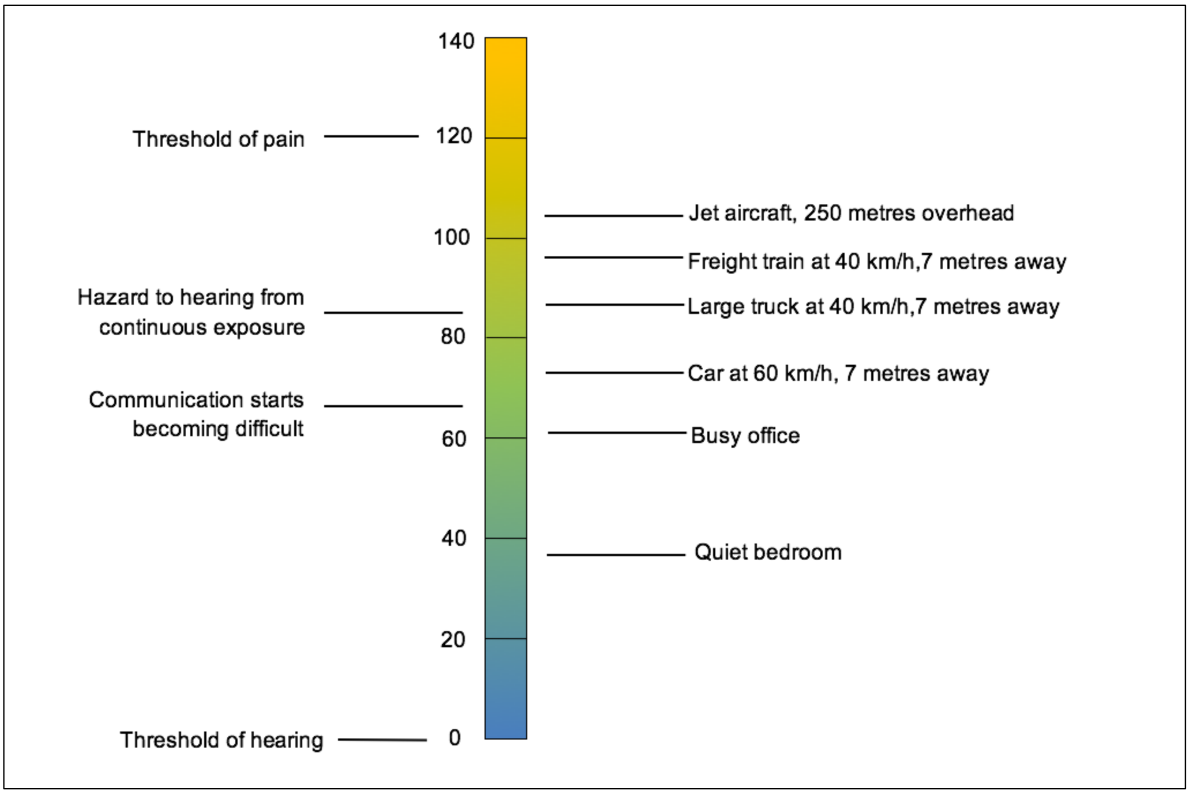

Figure 11-1 Typical sound pressure levels on the dB(A) scale

11.2 Guidance, Legislation and Assessment Criteria

The various phases of the development are covered by different sets of guidance and legislation as set out in the following sections.

11.2.1 Pre-Application Consultations

The scope for this chapter of the Environmental Impact Assessment Report (EIAR) has also been informed by consultation with statutory consultees, bodies with environmental responsibility and other interested parties. This consultation process is outlined in Section 2.6 of this EIAR. Issues and concerns highlighted with respect to noise and vibration are summarised in Table 2 below.

Table 11-2 Consultation Responses.

Consultee	Type and Date	Summary of Consultation Response	Response to Consultee
Wexford County Council (WCC) Sr. Executive Scientist	Pre-Application Consultation (specifically relating to noise) (11-11-20)	- WCC approval of proposed monitoring locations. - WCC requirement for assessment of Tonality, Amplitude Modulation (AM) and Low Frequency Noise (LFN). - WCC suggested requirement for attended measurements. - WCC requirement for assessment with consideration and guidance of the WCC commissioned RPS reports; Operational Assessments of Wexford Wind Farms.	All elements of assessment to be conducted in line with WCC's requirements.
Wexford County Council (WCC) Sr. Executive Scientist	Pre-Application Consultation (specifically relating to noise) (24-06-21)	- Monitoring and analysis described in D200405ME2_R0 is considered by WCC to be acceptable basis for assessment. - WCC approval of limitation of consideration of DRWEDG2019 to special audible characteristics only.	All elements of assessment to be conducted in line with WCC's requirements.

11.2.2 Decommissioning Phase

The wind turbine manufacturer has determined that the existing wind turbines at the Carnsore Wind Farm have a remaining lifespan of at least 15 years. Following the end of their useful life, the wind turbines may be replaced with a new set of turbines, subject to planning permission being obtained, or the Proposed Development will be decommissioned fully. Should this application be refused planning permission this will also lead to the decommissioning of the existing wind farm.

11.2.2.1 Decommissioning Noise Criteria

British Standard 5228:PT1 Code of practice for noise and vibration control on construction and open sites provides guidance on methods for predicting and measuring noise from construction sites and assessing the impact on those exposed to it.

The ABC method detailed in Annex E.3.2 of BS 5228 can be used for the control of decommissioning noise. Table E.1 summarises the ABC method and is reproduced in Figure 11-2 below.

Table E.1 **Example threshold of significant effect at dwellings**

Assessment category and threshold value period (L_{Aeq})	Threshold value, in decibels (dB)		
	Category A [A)]	Category B [B)]	Category C [C)]
Night-time (23.00–07.00)	45	50	55
Evenings and weekends [D)]	55	60	65
Daytime (07.00–19.00) and Saturdays (07.00–13.00)	65	70	75

NOTE 1 A significant effect has been deemed to occur if the total L_{Aeq} noise level, including construction, exceeds the threshold level for the Category appropriate to the ambient noise level.

NOTE 2 If the ambient noise level exceeds the threshold values given in the table (i.e. the ambient noise level is higher than the above values), then a significant effect is deemed to occur if the total L_{Aeq} noise level for the period increases by more than 3 dB due to construction activity.

NOTE 3 Applied to residential receptors only.

A) Category A: threshold values to use when ambient noise levels (when rounded to the nearest 5 dB) are less than these values.

B) Category B: threshold values to use when ambient noise levels (when rounded to the nearest 5 dB) are the same as category A values.

C) Category C: threshold values to use when ambient noise levels (when rounded to the nearest 5 dB) are higher than category A values.

D) 19.00–23.00 weekdays, 13.00–23.00 Saturdays and 07.00–23.00 Sundays.

Figure 11-2 Table E.1 from BS 5228 detailing ABC method

Using the ABC method, and existing ambient noise levels at the sites, the nearby noise sensitive locations are deemed to be Category A and the limits outlined in Table 11-3 apply.

Table 11-3 Decommissioning Noise limits

Noise Sensitive Locations	Threshold Value, $L_{Aeq, T}$ dB
Night-time(1)	45
Evenings and Weekends(2)	55
Daytime(3)	65

(1) *23:00hrs - 07:00hrs*
(2) *19:00hrs - 23:00hrs weekdays, 13:00hrs - 23:00hrs Saturdays and 07:00hrs - 23:00hrs Sundays*
(3) *07:00hrs – 19:00hrs weekdays and 07:00 -13:00hrs Saturdays.*

11.2.2.2 Decommissioning Vibration

Vibration criteria have been developed based on the guidance on construction vibration prediction, assessment and control contained within:

- BS 5228 British Standard Code of Practice for Noise and Vibration Control on Construction and Open Sites Pt 2: Vibration;
- BS 7385 – Evaluation and measurement for vibration in buildings – Part 2: Guide to damage levels from ground-borne vibration; and,
- Guidelines for the Treatment of Noise and Vibration in National Road Schemes (NRA, 2004).

People are very sensitive to vibration and can feel vibration long before it becomes an issue in terms of cosmetic damage or structural damage to buildings. Vibration causes nuisance as it is assumed that if vibration can be felt then damage is inevitable. However, it requires greater levels of vibration to cause damage to buildings and structures. Some people are more sensitive to vibration than others.

Table 11-44[1], below, describes likely effects of the listed vibration levels given in peak component particle velocity (ppv).

Table 11-4 Guidance of effects of Vibration Levels on residents

Vibration Level (ppv)	Description
0.14mm/s	Vibration might just be perceptible for frequencies normally associated with construction vibration. People are less sensitive to lower frequency vibration.
0.3mm/s	Vibration might just be perceptible in residential environments.
1.0mm/s	It is likely that vibration at this level in a residential environment will cause complaint. It is usually tolerated if prior warning and explanation is given to residents.
10.0mm/s	Vibration is likely to be intolerable for any more than a brief exposure to this level.

The response of a building to ground borne vibration is affected by the type of foundation, underlying ground conditions, the building construction and the state of repair of the building. Limits for transient vibration, above which cosmetic damage could occur, are provided in Table 11-5[2] below. Minor damage is possible at vibration magnitudes which are greater than twice those given in Table 11-5, and major damage to a building structure can occur at values greater than four times the tabulated values.

1 BS 5228-2 Table B.1

2 BS 7385-2 Table 1

Table 11-5 Transient vibration guide for cosmetic damage

Type of Building	Peak component particle velocity	
	4 Hz to 15 Hz	15 Hz and above
Reinforced or framed structures/ industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	50mm/s at 4Hz and above
Unreinforced or light framed structures. Residential or light commercial buildings[1]	15mm/s at 4 Hz increasing to 20mm/s at 15 Hz	20mm/s at 15 Hz increasing to 50mm/s at 40 Hz and above

1. At frequencies <4Hz a maximum displacement of 0.6mm is not to be exceeded.

11.2.3 Operational Noise

At the request of Wexford County Council (WCC), it has been agreed to assess operational noise from the existing Carnsore Wind Farm with consideration of the methodology employed in the WCC commissioned RPS Wind Farm Noise Report[3]. The RPS reports addressed compliance of existing wind farms under the following headings (text directly quoted):

1. *Compliance with Planning Conditions on the wind farms being tested and/or predicted sound levels at noise sensitive locations, as per the planning submitted Environmental Impact Statement (EIS);*
2. *Compliance with the Department of Environment, Community and Local Government (DECLG), Wind Energy Development Guidelines 2006, in so far as they relate to noise standards;*
3. *Comment on the sound levels with regard to noise standards in each of the following:*

   a) *UK and other countries with well-developed wind energy infrastructure and regulations.*
   b) *WHO noise guidelines for night-time noise.*
   c) *Presence of tones, low frequencies, amplitude modulation.*
   d) *On the likelihood of noise nuisance as per Section 108 of the EPA Act No. 7 of 1992.*

As this chapter assesses noise from the Proposed Development for planning under existing regulations, it is appropriate to limit assessment within the noise and vibration chapter to:

- Wind Energy Development Guidelines 2006, with consideration of:
  - Institute of Acoustics (IOA) Good Practice Guide (GPG) to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (2013);
  - The IWEA Best Practice Guidelines for the Irish Wind Energy Industry (2012);

[3] *Wexford County Council – Wind farms noise report – RPS – Assessments of Gibbet Hill, Knocknalour, Ballycadden, Ballynancoran.* https://www.wexfordcoco.ie/news/2017/07/14/wind-farms-noise-report

  - Content of Draft Revised Wind Energy Development Guidelines 2019 relating to Special Audible Characteristics; and,
  - Content of WCC commissioned RPS Wind Farm Noise Report relating to Special Audible Characteristics.

11.2.3.1 Assessment Methodology

The assessment methodology used to assess the operational noise impacts of the proposed wind farm has been developed with regard for the following:

- Wind Energy Development Guidelines 2006,
- ETSU-R-97 – The Assessment and Rating of Wind Farm Noise,
- Institute of Acoustics (IOA) Good Practice Guide (GPG) to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (2013),
- The IWEA Best Practice Guidelines for the Irish Wind Energy Industry (2012), and
- Draft Revised Wind Energy Development Guidelines 2019.

In addition, consideration has been given to the content and methodology of:

- WCC commissioned RPS Wind Farm Noise Reports for Gibbet Hill, Knocknalour, Balynancoran and Ballycadden wind farms.

The following methodology has been adopted for the assessment:

- Predictive noise modelling of the proposed wind farm is carried out in SoundPLAN version 8.2 environmental noise prediction software. SoundPLAN is ISO 17534 validated.
  - All predictive noise modelling is carried out as specified by the IOA GPG.
- Noise contour maps for the proposed turbines are produced.
- Identify all Noise Sensitive Locations (NSLs) within 2km of a turbine within the Proposed Development.
- Predict noise levels at each NSL within the study area due to:
  - Existing Carnsore turbines.
- Using the noise model and with consideration of the variety of coastal/inland locations within the study area, choose monitoring locations suitable for assessment of operational and baseline noise.
- Conduct operational and baseline noise monitoring at the chosen sites.
  - The monitoring should meet the requirements for baseline and post-completion measurements set out in the IOA GPG and IOA GPG Supplementary Guidance Note 5: Post Completion Measurements.
- Conduct attended night-time measurements under appropriate wind conditions with subjective observations and assessment of:
  - Subjectively observed tonality,
  - Subjectively observed Amplitude Modulation (AM), and
  - Subjectively observed Low Frequency Noise (LFN).
- Using the results of the baseline monitoring, set appropriate noise limits in accordance with the requirements of the WEDG06.
- Using the results of the operational noise monitoring, and correcting for background noise, determine the actual level of wind turbine noise (WTN) at sites where it is assessed to be measurable above background.
  - In addition, conduct assessment of special audible characteristics using subjective and objective methods.
- Compare the results of the operational noise monitoring with the results of noise modelling and, if necessary, determine an appropriate site factor to allow calibration of the noise model to real world measurements.
- At sites where WTN is directly measurable, compare measured WTN levels with noise criteria.

- At sites where WTN is not directly measurable, and all noise sensitive locations (NSLs) where monitoring has not been conducted, compare modelled WTN levels with noise criteria.

11.2.3.2 Wind Energy Development Guidelines (WEDG06)

The Wind Energy Development Guidelines 2006 contains recommended noise limits to control operational noise from wind turbines. The limits are stated in terms of L_{A90}, which represents the noise level exceeded for 90% of the time in any given time period. While L_{A90} is the index normally used to quantify the background noise level, it is also the parameter used to assess wind farm noise in Ireland and Internationally. Table 11-6 provides a succinct summary of the key operational noise requirements as defined in the Wind Energy Development Guidelines.

Table 11-6 Summary of operational noise requirements for the Proposed Development

Time of Day	Requirement
Day 18:00 -23:00 every day 13:00 - 18:00 Saturday 07:00 – 18:00 Sunday	- Where the prevailing background noise level is less than 30dB, the greater of 40dB or plus 5dB above background Or - Where the prevailing background noise level is greater than 30dB the noise limits are the greater of 45dB or plus 5dB above background.
Night 23:00 – 07:00 every day	- The greater of 43dB or plus 5dB above background

11.2.3.3 Special Audible Characteristics

Wind turbines have the potential to emit noise with special audible characteristics which generate greater nuisance to nearby residents than would otherwise be expected. The characteristics of concern for noise from wind turbines are tonal noise, amplitude modulation, and low frequency noise.

11.2.3.3.1 *Tonal Noise*

Tonal noise from wind turbines arises primarily from mechanical hub components such as bearings or gearing. Improvements in modern wind turbine designs have resulted in significant reductions of tonal noise emissions and tones would generally be expected to be audible only at shorter distances.

DRWEDG2019 states *"the methodology to be applied in relation to quantifying tonal emissions from wind energy developments is in accordance with ISO 1996-2 third Edition 2017 Acoustics - Description, measurement and assessment of environmental noise – Part 2: Determination of sound pressure levels Annex J and ISO/PAS 20065 on an objective method for assessing the audibility of tones in noise*". The method described in ISO 1996-2 Annex J is also recommended in BS4142 for the objective assessment of tonal noise.

Assessment Methodology

Assessment of tonality at each monitoring location is to be conducted as follows:

- Attended measurements will include subjective assessment of tonality at each monitoring location.
- Filtered operational measurement spectra will be analysed using the 1/3 octave method.
- Selected operational noise measurement audio at each site to be analysed using the ISO PAS 20065 method.

11.2.3.3.2 *Amplitude Modulation*

Amplitude modulation (AM) characteristics in noise from wind energy developments have generated sufficient complaints to justify several studies as well as the establishment of the Institute of Acoustics Amplitude Modulation Working Group (IoA AMWG), which has since determined a method for the assessment and rating of AM from wind turbines, the method adopted by DRWEDG2019.

"Blade swish" is observable at short distances from turbines and is termed "Normal amplitude modulation", rarely constituting an issue at typical separation distances from NSLs. "Other" or "Excessive" amplitude modulation (AM) may occur on certain sites and is thought to be due to transient stall conditions.

Other AM may be described as a "thumping" characteristic at the blade pass frequency of the wind turbines at relatively low frequencies, and may be heard at much greater distances, though often only intermittently under specific weather conditions.

The Defra NANR233 Report[4] (2007) surveyed 133 operational wind farm sites in the UK, finding that 27 of the sites had attracted complaints at some point. The report stated the following:

"AM was considered to be a factor in four of the sites, and a possible factor in another eight. Regarding the four sites, analysis of meteorological data suggests that the conditions for AM would prevail between about 7% and 15% of the time. AM would not therefore be present most days, although it could occur for several days running over some periods. Complaints have subsided for three out of these four sites, in one case as a result of remedial treatment in the form of a wind turbine control system. In the remaining case, which is a recent installation, investigations are ongoing."

The Defra report goes on to state that AM is not fully predictable due to the extremely complex nature of aerodynamic noise and is also a rare phenomenon.

Research into reduction of "Other" AM noise from wind turbines is ongoing. It remains a rare and unpredictable occurrence.

Assessment Methodology

Assessment of AM at each monitoring location is to be conducted as follows:

- Attended measurements will include subjective assessment of AM at each monitoring location.
- Selected operational noise measurement audio at each site to be analysed using the IOA AMWG method.

4 Research into Aerodynamic Modulation of Wind Turbine Noise - Dr. Andy Moorhouse, Malcolm Hayes, Dr. Sabine von Hünerbein, Ben Piper, Dr. Mags Adams, Salford University

- If there are detections of AM, the assessment method may also be applied to baseline measurements in order to determine if AM in measurements is a naturally occurring phenomenon, e.g. surf noise, rather than associated with WTN.

11.2.3.3.3 *Low Frequency Noise and Infrasound*

Low frequency noise has historically been associated with downwind rotor turbines and is less characteristic of modern upwind rotor designs. Extensive survey and analysis conducted by the South Australia Environment Protection Authority (SAEPA)5 compared low frequency noise at several rural and urban sites, with the rural locations including sites in the vicinity of wind farms (surveyed both with turbines operating and shut down) and also some with no wind turbines nearby. At typical separation distances, no association of low frequency noise with wind turbines was found. The study also measured infrasound levels at the rural sites close to windfarms, finding infrasound levels similar to those found in surveyed urban sites.

A study of wind turbine infrasound[6], and human responses to same, was commissioned by the Finnish Government's Analysis, Assessment and Research Activities. The study was conducted by VTT (the project lead, a Finnish state-owned research institution), the Finnish Institute for Health and Welfare, the Finnish Institute of Occupational Health, and the University of Helsinki. The project commenced on 16 August 2018 with publication of the report in June 2020.

The Finnish study included questionnaire surveys of residents in the vicinity of wind farm developments, long term noise measurements (total of 308 days full-spectrum indoor and outdoor measurements), and double-blind listening tests. Self-reported symptoms which questionnaire respondents intuitively associated with wind turbine infrasound were relatively common among residents within 2.5 km of a wind turbine. The indoor noise recordings obtained during the measurements which had the highest levels of infrasound and amplitude modulation were used in the double-blind listening tests, which included a control group and a group of participants who had self-reported symptoms which they intuitively attributed to wind turbine infrasound. Important findings of the study included the following:

- Participants who had previously reported wind turbine infrasound related symptoms were not able to perceive infrasound in the noise samples.
- Participants who had previously reported wind turbine infrasound related symptoms did not find samples with infrasound more annoying than those without previously reported wind turbine infrasound related symptoms.
- Wind turbine infrasound exposure did not cause physiological responses in either participant group.

Clearly, wind turbines do produce low frequency noise, as shown by the octave band data published by manufacturers. Modelling work conducted by Aagaard Madsen at the Technical University of Denmark[7] suggests that "*Important turbine design parameters with strong influence on LFN are the blade tip speed and the distance between rotor and tower*" but that "*For an upwind rotor the LFN levels are so low that it should not cause annoyance of neighbouring people".*

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5 Infrasound levels near windfarms and in other environments - T Evans, J Cooper & V Lenchine

6 Infrasound Does Not Explain Symptoms Related to Wind Turbines - Panu Maijala, Anu Turunen, Ilmari Kurki, Lari Vainio, Satu Pakarinen, Crista Kaukinen, Kristian Lukander, Pekka Tiittanen, Tarja Yli-Tuomi, Pekka Taimisto, Timo Lanki, Kaisa Tiippana, Jussi Virkkala, Emma Stickler, Markku Sainio.

7 *Aagaard* Madsen, H. (2010). Low frequency noise from wind turbines mechanisms of generation and its modelling. Journal of Low Frequency Noise, Vibration and Active Control, 29(4), 239-251. DOI: 10.1260/0263-0923.29.4.239

The DRWEDG2019 (not in force) prohibits low frequency noise levels from wind turbines at noise sensitive locations in excess of the unweighted 1/3 octave band levels shown in Table 11-7 below. The low frequency noise limits derive from DEFRA NANR45[8] which forms guidance for the assessment of low frequency noise complaints by local authorities in the UK.

Table 11-7 DRWEDG2019 Wind Turbine low frequency noise limits

Wind Turbine 1/3 octave LFN limits													
Centre frequency (Hz)	10	13	16	20	25	32	40	50	63	80	100	125	160
L_{Zeq} (dB)	92	87	83	74	64	56	49	43	42	40	38	36	34

Assessment Methodology

The WCC commissioned RPS Operational Assessments of Wexford Wind Farms, included assessment of LFN using a 1/3 octave assessment spectrum devised by RPS for the purpose. The assessment spectrum has been constructed using outside to inside adjustment factors for each 1/3 octave band to convert the NANR45 internal criteria to external criteria. For the purposes of this assessment, in line with the requirements of Wexford County Council, the RPS LFN spectrum, shown in Table 11-8 below, will be used for assessment of LFN in measurements at monitoring sites.

Table 11-8 RPS external LFN assessment spectrum.

Wind Turbine 1/3 octave LFN limits													
Centre frequency (Hz)	10	13	16	20	25	32	40	50	63	80	100	125	160
RPS limits (external) LZeq (dB)	92	87	83	74	64	57	52	48	49	49	49	49	49

Assessment of LFN at each monitoring location is to be conducted as follows:

- Attended measurements will include subjective assessment of LFN at each monitoring location.
- Filtered operational measurement 1/3 octave spectra will be analysed to detect any exceedance of the RPS limits shown in Table 11-8.
- If there are detections of LFN, the assessment method may also be applied to baseline measurements in order to determine if LFN in measurements is a naturally occurring phenomenon, e.g. surf noise, rather than associated with WTN.

8 DEFRA NANR45 Procedure for the assessment of low frequency noise disturbance Moorhouse, AT, Waddington, DC and Adams, MD

11.2.3.4 Substation Noise Limits

Noise limits for industrial and commercial developments in Ireland are typically based on the guidance and procedures of:

- EPA Guidance Note for Noise: Licence Applications, Surveys and Assessments in Relation to Scheduled Activities (NG4), and
- BS 4142:2014 Methods for rating and assessing industrial and commercial sound.

BS 4142: 2014 describes a method for assessing industrial, commercial and background noise levels in order to assess the likely effects on people who might be inside or outside a dwelling or premises used for residential purposes. BS4142 is referred to within *EPA NG4 Guidance Note for Noise* as the appropriate method to be adopted for complaints investigation. Notably, the standard outlines subjective and objective methods for assessing tonal and impulsive audibility. This involves applying a correction to the measured noise level of the source (L_{Aeq}) to give the rating level ($L_{Ar,T}$).

In addition, BS4142 states that the significance of sound of an industrial and/or commercial nature depends upon both the margin by which the rating level of the specific sound source exceeds the background sound level and the context in which the sound occurs. Put simply, if the rated source noise level exceeds the existing background level by +10 dB a significant adverse impact is likely. The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound source will have an adverse impact. Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact.

Typically, this is presented by local councils in the following form:

> *"Noise created due to the operation of a premises/facility shall not cause a noise nuisance to nearby noise sensitive location and should not exceed the background level by 10 dB(A) or more or exceed the typical NG4 limits outlined below - whichever is the lesser."*

- Daytime (07:00 to 19:00 hrs) – 55dB $L_{Ar,T}$
- Evening (19:00 to 23:00 hrs) – 50dB $L_{Ar,T}$
- Night-time (23:00 to 07:00 hrs) – 45dB $L_{Aeq,T}$

Where tonal noise is objectively assessed to be present, either using the method contained in (i) Section 5.1 of NG4 or (ii) BS 4142: 2014: Annex D (normative): Objective method for assessing the audibility of tones in sound, then a penalty is applied to the measured noise level. NG4 specifies penalties which should be applied during the daytime and evening, while also stating that tonal noise detectable by these objective methods should not be present during the night-time, at any NSL. Similarly, NG4 specifies penalties for impulsive noise during the daytime and evening, and states that clearly audible impulsive characteristics should not be present during the night-time, at any NSL.

As the substation will operate 24 hours per day, the Night-Time limit of 45dB $L_{Aeq,T}$ or 10dB above Background is adopted as the site specific noise limit for assessing the magnitude of the impact. As the background noise levels in the area are as low as 25dBA, a substation noise limit of L_{Aeq} 35dBA, with no objectively detectible night-time tonal characteristics at any NSL, has been adopted for the purposes of this assessment.

11.2.4 Attended Monitoring

Attended monitoring is to include subjective observations of WTN at each monitoring location. Subjective rating of Special Audible Characteristics is to be conducted using the rating scale shown in Table 11-9. This subjective rating scale has been adopted from the WCC commissioned RPS Operational Assessments of Wexford Wind Farms.

Table 11-9 Subjective rating of Special Audible Characteristics at monitoring sites.

1	2	3	4	5
Not significant	Noted	Evident	Clearly Audible	Dominant

11.3 Methodology

Guidance documents relating specifically to noise and vibration are set out in section 9.2. The general methodology for this assessment is as follows:

1. Characterise the receiving environment through baseline noise data obtained from baseline monitoring.
2. Review of the most applicable standards and guidelines to set acceptable noise and vibration criteria for the construction and operational phases of the Proposed Development.
3. Undertake predictive acoustic modelling to assess the potential impacts associated with the construction phase of the Proposed Development at NSL's.
4. Identify whether mitigation measures are required and, if so, specify options.
5. Describe the significance of the residual noise and vibration effects associated with the Proposed Development in accordance with the guidance provided in EPA Guidelines on the Information to be contained in Environmental Impact Assessment Reports Draft August 2017.

11.4 Study Area

The study area has been set to the area within 2km of any turbine within the Proposed Development.

11.4.1 Screening Area

The screening area is the area within a 20 km radius of the Proposed Development. All existing, permitted, and application-in-progress wind farm developments have been identified and considered for potential cumulative effects.

11.4.2 Noise Prediction Methodology

To predict wind turbine noise levels from Carnsore Wind Farm, an environmental noise model has been developed in SoundPLAN version 8.2 environmental noise prediction software. SoundPLAN is

ISO 17534[9] validated. The noise model implements the ISO 9613-2:1996[10] prediction algorithm. In accordance with standard prediction procedures for wind farm noise, predictions have been undertaken on the basis of the following parameters:

- Turbine and residence locations as per the coordinates provided herein,
- Topographical data sourced from the ASTER Global Digital Elevation Model (GDEM) Version 3,
- Ground absorption factor of 50% representing mixed reflective and absorptive ground as specified by the IOA GPG,
- Turbine hub heights and sound power levels as stated in in the following sections with the Turbine in standard operation:
  - Manufacturer stated uncertainty factors are added to the sound power levels used in the model in accordance with IOA Good Practice Guidelines
  - A correction of -2dB is applied to the Turbine sound power levels in order to predict the L_{A90} level at the NSLs in accordance with IOA Good Practice Guidelines
- Receiver height of 4 m above ground,
- Temperature of 10˚C and relative humidity of 70%,
- Topographical shielding limited to 2 dB, and
- Where a concave slope is detected using the method specified in the IoA GPG, a +3dB correction is applied.

The air absorption values from ISO 9613-2:1996 have been adopted for the purposes of predicting Turbine noise levels. Air absorption is dependent on the assumed temperature and humidity and therefore the relevant air absorption values for this assessment are shown in Table 11-10.

Table 11-10 Atmospheric attenuation values used in the model.

Conditions	Atmospheric attenuation in dB/km for octave band centre frequency in Hz							
	63	125	250	500	1000	2000	4000	8000
Temperature 10˚C Rel humidity 70%	0.1	0.4	1.0	1.9	3.7	9.7	32.8	117

This methodology is in accordance with that recommended by the UK Institute of Acoustics *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* (IoA GPG).

11.4.3 Proposed Turbine Model

As the Proposed Development is a life extension, the proposed turbine model is the one in place, i.e. the Vestas V52 850kW.

9 ISO/TR 17534-3:2015 Acoustics — Software for the calculation of sound outdoors — Part 3: Recommendations for quality assured implementation of ISO 9613-2 in software according to ISO 17534-1

10 International Standard ISO 9613-2, 1996, Acoustics – Attenuation of sound during propagation outdoors, Part 2: General method of calculation

11.4.3.1 Vestas V52-850 kW

The turbine assessed is the Vestas V52-850 kW turbine operating at 850 kW rated power with a hub height of 49m and a rotor diameter of 52m to give a tip height of 75m. The turbine model sound power data have been provided by Vestas in the Data Sheets *General Specifications V52- 850kW, Item No. 946506.V10.pdf* and are shown with standardised 10m wind speed in Table 11-11. Vestas do not specify the uncertainty of measurements, therefore 2dB has been assumed as per the guidance of the IOA GPG. As can be seen from Table 11-11, the turbine reaches maximum sound power at 9 m/s.

Table 11-11 Vestas V52-850 kW turbine sound power levels for standardised 10m wind speed.

Sound power level in dB(A) for standardised 10m wind speed (V10) in m/s						
V10 m/s	4	5	6	7	8	9
LwA	93	96	100	103.8	104.2	104.5

Octave band sound power levels were not available from Vestas. However, reference values were found in the Troston Loch Wind Farm EIAR[11] and are shown in Table 11-12.

Table 11-12 Assumed Vestas V52-850 kW turbine sound power level spectrum for standardised 10m wind speed.

Wind speed	Sound power level in dB(A) at octave band centre frequency in Hz								Overall
V10 m/s	63	125	250	500	1000	2000	4000	8000	dB(A)
9	84.7	91.1	96.8	98.9	98.8	97.1	91.6	77.9	104.5

Following operational noise monitoring of WTN from Carnsore Wind Farm, it has been determined that the sound power levels provided by Vestas result in a significant over-prediction of actual WTN levels at the monitoring sites. Consequently, a site correction factor has been used to calibrate the model to actual measured WTN levels.

11.4.3.2 Model Over-Prediction with Vestas Data Sheet Sound Power Levels

Noise data provided by Vestas relating to the V52 turbine is limited and, when inputted to the noise model, results in predicted wind turbine noise levels significantly in excess of the maximum total LA90 levels (including background) recorded during the survey.

Factors which may contribute to this overprediction include the following:

- The manufacturer test data includes uncertainty:
  - As no statement of uncertainty was included in data sheets, a +2dB correction for uncertainty was applied to test data in accordance with the guidance of the IOA GPG.
  - Uncertainty can have the effect of reported levels being higher than actual levels.
- Manufacturer stated levels are, generally, noise warranties:

[11] *https://www.edf-re.uk/our-sites/troston*

  - i.e. noise levels that turbines of said type should never exceed and exceedances of warrantied levels may result in financial penalties for the manufacturer.
  - The actual installed turbines may differ in component details from the turbine measured and may have lower noise levels in some cases.
- Site conditions may have effects on noise emissions.
  - The paper *Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms, Evans/Cooper*[12] shows significant overprediction of wind turbine noise levels at certain sites in South Australia.

Finally, it should be noted that noise modelling in accordance with the IOA GPG is intended to be sufficiently conservative to avoid under prediction of wind turbine noise levels at receivers during the planning process.

11.4.4 Carnsore Turbine Coordinates

Coordinates for the Carnsore turbines are shown in Table 11-13 below.

Table 11-13 Proposed Carnsore Wind Farm turbine locations, Irish Transverse Mercator

Turbine	ITM Co-ordinates	
	Easting	Northing
T01	711836	604272
T02	711756	604032
T03	711942	603713
T04	711992	604163
T05	711867	603876
T06	712058	603820
T07	712129	603956
T08	712239	604149
T09	712287	604373
T10	712032	604318
T11	711863	604464
T12	712122	604482
T13	712041	604594
T14	712231	604686

[12] *Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms, Tom Evans and Jonathan Cooper* https://www.acoustics.asn.au/conference_proceedings/AAS2011/papers/p30.pdf

11.4.5 Existing Operational WTN

11.4.5.1 Unattended Operational Monitoring

Operational noise monitoring has been completed concurrently with baseline monitoring, with monitoring locations, equipment and data sources as detailed in Sections 11.5.1 to 11.5.3. In addition to wind speed data, turbine data from the Carnsore SCADA has been provided by Hibernian Wind Power Ltd and this has been used to confirm operation of the turbines during monitoring. The data requirements of the IOA GPG have been met for all monitoring sites.

A comparison of measured operational noise levels with measured baseline noise levels is included in Appendix 5. To summarise key findings of this analysis:

- Site 1: WTN was not measurable as operational noise levels were within 2dB of baseline.
  - Site 1 separation distance from the nearest Carnsore turbine is approximately 1083m from T14.
- Site 2: WTN was not measurable as operational noise levels were within 2dB of baseline.
  - Site 2 separation distance from the nearest Carnsore turbine is approximately 1779m from T13.
- Site 3: WTN was not measurable as operational noise levels were within 3dB of baseline.
  - Site 3 separation distance from the nearest Carnsore turbine is approximately 469m from T01.
- Site 4: WTN is clearly measurable due to the small separation distance.
  - Site 4 separation distance from the nearest Carnsore turbine is approximately 242m from T13 (also approximately 312m from T11, 361m from T14 and 380m from T12).

Surf noise is discernible in both baseline and operational scatter plots for monitoring sites in the coastal zone. For periods where winds are relatively low (< 6m/s) but wave buoy data (M5 Weather Buoy) indicates larger swell (>2m), surf noise has a strong effect on measured ambient noise levels at Site 4. Review of selected measurements has been conducted with respect to wave buoy data in order to confirm the effect of ocean swell on both operational and baseline noise measurements. This has allowed appropriate exclusions to be made in scatterplots of operational and baseline measurements.

There is a similar divergence in baseline measurements between onshore and offshore wind conditions. It has been necessary to compare operational noise data with baseline data from the same wind sectors since downwind directions for all receivers are also onshore wind directions.

Figure 11-3 below shows a plot of night-time operational noise data recorded at Site 4 under downwind conditions (determined to be ±45° from direction of nearest turbines). Some exclusions have been made following inspection of weather buoy wave data.

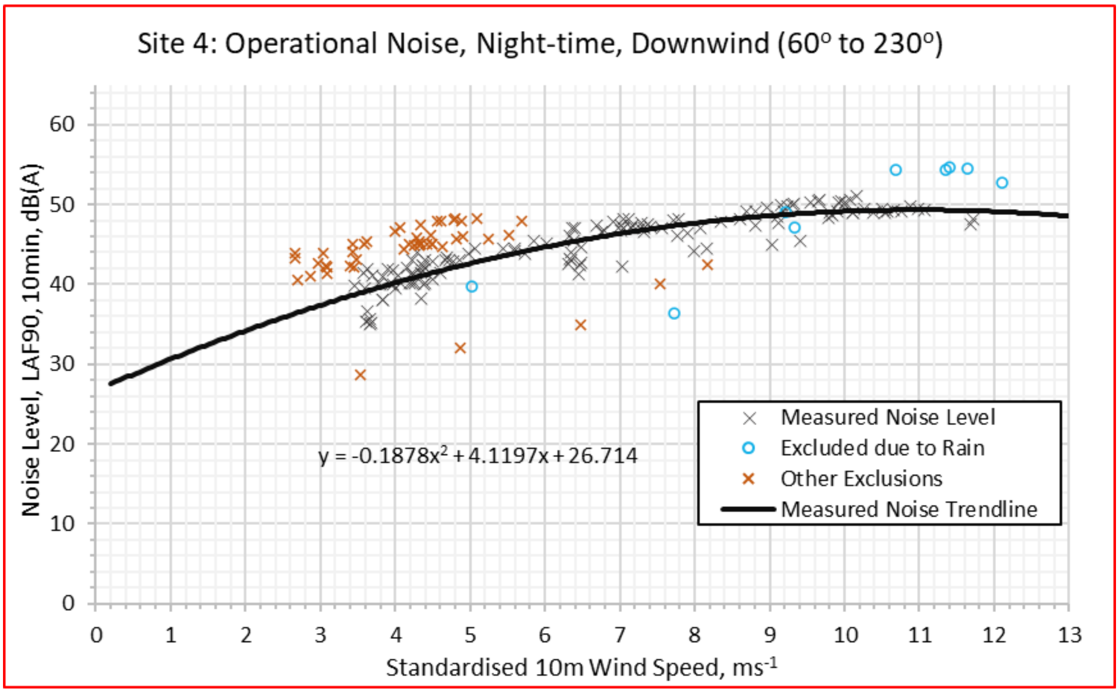

Figure 11-3 Night-time operational noise at Site 4 under downwind conditions, exclusions have been made with reference to M5 Weather Buoy wave data.

Figure 11-4 below shows a plot of night-time background noise data recorded at Site 4 under downwind conditions (determined to be ±45° from direction of nearest turbines). Some exclusions have been made following inspection of weather buoy wave data.

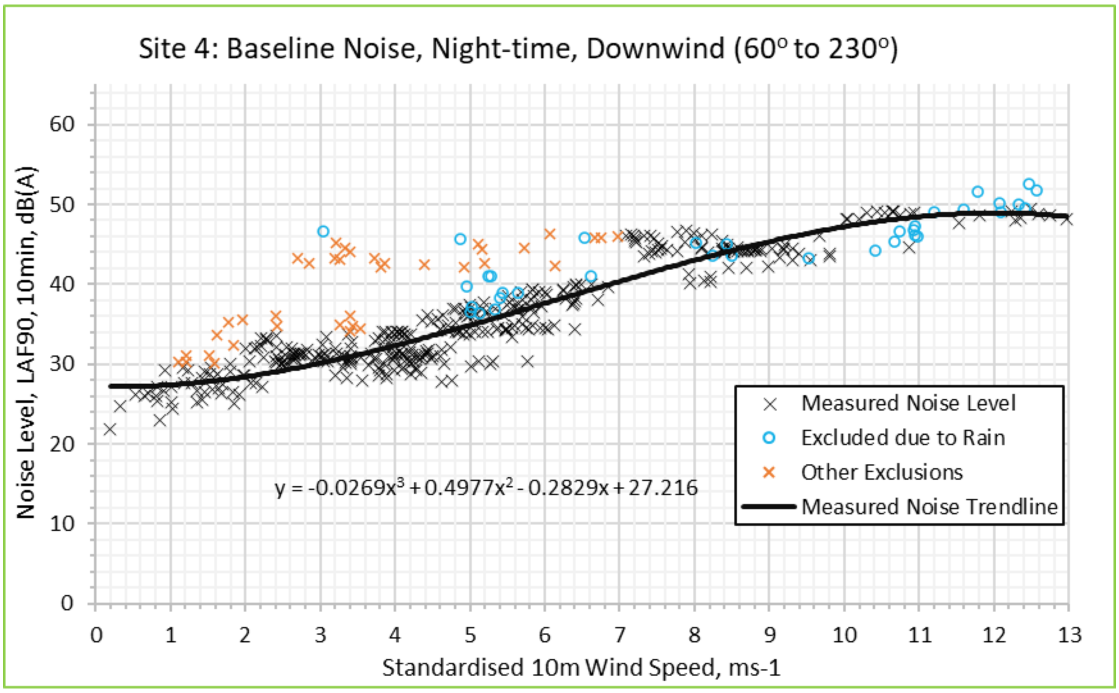

Figure 11-4 Night-time baseline noise at Site 4 under downwind conditions, exclusions have been made with reference to M5 Weather Buoy wave data.

Table 11-14 below shows trendline values at integer wind speeds for the scatter plots shown in Figure 11-4 and Figure 11-6.

Table 11-14 Scatterplot trendline values at integer wind speeds.

Trendline Values (dB LA90) at Integer Wind Speeds						
m/s	4	5	6	7	8	9
Total Operational	40.2	42.6	44.7	46.3	47.7	48.6
Baseline	32.3	34.9	37.6	40.4	43.0	45.4
Operational less Baseline	39.4	41.8	43.7	45.1	46.0	45.8

Analysis has been conducted of operational vs. baseline noise for a number of additional case comparisons to reduce uncertainty. It has been concluded that 45dB LA90 @ 7m/s should be adopted as the value for operational noise at Site 4. Values at other wind speeds have been determined using the following data and observations:

- The Vestas theoretical calculated noise curve,
- Operational less baseline under a variety of wind conditions,
- At higher windspeeds (≥8m/s), the contribution of surf noise is more difficult to control for,
- 7m/s has been determined to be the critical wind speed, in addition to:
- Professional judgement, and
- Attended measurement and observation.

11.4.5.2 Attended Monitoring

An experienced consultant attended each of the monitoring sites during the night-time on 4th June 2021 04:00 to 06:00 hrs and 5th June 2021 00:00 to 04:30 hrs. Observations were also made during daytime site visits on 30th April, 18th May, 4th June and 25th June 2021.

A SCADA communications fault meant that wind speed and direction were not recorded before 02:10 on 5th June 2021. Wind speeds recorded 02:10 to 04:30 on 5th June were V10 5 – 7m/s with downwind conditions for all sites with the exception of Site 3 for which wind conditions were on the boundary of downwind/crosswind. Crosswind conditions at Site 3 are expected to result in a moderate reduction of WTN of less than 3dB. Subjective rating of Special Audible Characteristics at each site are listed in Table 11-15 below.

Table 11-15 Attended site observations

Date	Time	Location	Subjective Observations		
			Tonality	"Other" AM	LFN
05/06/2021	01:10	Site 1	slight noted	not significant	not significant
05/06/2021	00:17	Site 2	not significant	not significant	not significant
05/06/2021	03:19	Site 3	not significant	not significant	not significant
05/06/2021	01:46	Site 4	noted	not significant	not significant

In addition, night-time observations were taken at the seashore east of Site 4 and south of Site 3:

- At a position on the road adjacent to the east seashore approximately 50m from T14:

- Surf noise was observed to be dominant with extremely small waves.
- WTN from T14 was clearly audible.

- At a position on the beach approximately 40m from the waterline and south of Site 3:
  - Surf noise dominated with WTN subjectively completely inaudible.
  - Natural surf noise form small waves (<1m) contained strong natural low frequency ("booming surf") and amplitude modulation components (periodic waves).

11.4.5.3 Objective Assessment of Special Audible Characteristics

It should be noted that while subjective and objective assessments of special audible characteristics has been undertaken, there have not been any noise complaints recorded for Carnsore Wind Farm.

11.4.5.3.1 *Tonality*

Tonal analysis, using the 1/3 octave band method, of operational measurements at all 4 monitoring sites has been conducted with the following result:

- No detections of tonal WTN at any monitoring sites.

In addition, the ISO PAS 20065 narrow band analysis method has been applied to selected measurements thought to have the highest probability of containing tonal WTN, with the following result:

- No detections of tonal WTN at any monitoring sites.

11.4.5.3.2 *"Other" AM*

The IOA AMWG analysis method has been applied to selected operational measurements at wind speeds thought most likely to contain "Other" AM, with the following results:

- The IOA method detected AM at Site 3.
- AM was also detected in baseline measurements at Site 3.

Detection of "Other" AM in baseline measurements at Site 3 is an interesting result which indicates care should be taken when assessing AM in coastal locations. There was a single detection of AM at Site 1 in one wind speed bin and, as Site 1 is of similar distance from a south facing shoreline to Site 3, it is believed that this detection is also related to surf noise. These results indicate that the IOA AMWG method will tend to detect AM in measurements containing marine surf noise. This is readily understood when one considers that both WTN "Other" AM and Surf Noise AM contain periodic low frequency "booming" or "thumping" sounds. This finding is also in agreement with attended observations where the consultant found WTN and surf noise to have similar audible features, the sources of which were sometimes difficult to differentiate.

11.4.5.3.3 *LFN*

1/3 octave band LFN analysis has been conducted for all monitoring sites, with the following results:

- LFN above thresholds was detected in some operational measurements at higher wind speeds.
- Similar patterns of LFN detections above threshold were seen in baseline measurements, indicating the source of LFN in measurements is not WTN-related.

The findings of the LFN analyses are similar to those for AM in the previous section. LFN present in measurements is believed to be a result of booming surf noise.

11.4.6 Calibration of Noise Model with Measurements

Results of noise modelling using manufacturer supplied sound power level data and standard IoA GPG noise model parameters have been compared with measurement and found to be an over-prediction of operational noise at the monitoring sites.

Consequently, a site correction factor has been determined through exhaustive analysis of operational and baseline noise measured at Site 4. The site correction factor has been applied to the turbine sound power levels in the noise model.

11.4.7 Cumulative Assessment

There are no other wind farm developments within 15km of the Proposed Development and consequently a cumulative assessment of WTN noise is not required.

11.4.8 Predicted Noise Contours

Noise contour maps of the study area are shown in Appendix 4 for:

1. Predicted existing noise levels due to existing Carnsore Wind Farm turbines only with all 14 turbines operating at their loudest condition.

2. Predicted existing noise levels due to existing Carnsore Wind Farm turbines only with all 14 turbines operating at the critical wind speed of 7m/s.

11.5 Receiving Environment

Carnsore Wind Farm is located within a coastal environment and topography inland and along the coast from the wind farm is relatively flat.

Noise sensitive locations (NSLs) within 2km of the Proposed Development have been identified using an Eircode database and include holiday homes. NSLs near to the coast have elevated baseline noise levels due to marine surf, with baseline levels expected to reduce for NSLs further inland. For all NSLs, wind directions placing receivers downwind of turbines also place them downwind of coastal noise.

Evening and night-time shutdowns of the existing Carnsore turbines were arranged for the duration of the baseline surveys, with shutdowns scheduled as follows:

- Daytime amenity: 18:00 – 20:00 hrs
- Night-time: 23:00 – 02:00 hrs

11.5.1 Noise Monitoring Locations

Baseline noise monitoring locations have been selected in order to characterise the two broad categorisations for NSLs within the study area, coastal and inland:

- Site 1 is located on the boundary of a garden in a quiet cul-de-sac NNE of the windfarm approximately 300 m from the Irish Sea coast.
- Site 2 is located inland, approximately 1600m from the coast, close to The Lobster Pot seafood restaurant.
    - It should be noted that Covid-19 restrictions were in place throughout the baseline surveys and consequently the road adjacent to Site 2 was not observed to be a significant source of noise during the evening and night-time.

- Site 3 is located close to a cluster of dwellings W of the wind farm on the Lane of Stones with the monitor location approximately 440 m from the Celtic Sea coast.
- Site 4 is located close to the wind farm gate and NSL1, approximately 390 m from the Irish Sea coast.

The location of the noise monitor at each location is presented in Table 11-16 alongside a description of the location. The location of the meteorological mast from which wind data was obtained is also presented.

Table 11-16 Baseline/Operational noise monitoring locations.

Location	ITM Coordinates		Description of location
	Easting	Northing	
Site 1	712617	605698	Approximately 50 m NNW of NSL70.
Site 2	711187	606155	Approximately 5 m E of NSL181.
Site 3	711373	604343	Approximately 30 m E of NSL5.
Site 4	711882	604776	Approximately 75 m ESE of NSL1.
Met Mast	711618	604102	Approximately 155 m WNW of T02.

In all cases the monitoring equipment was positioned at least 5 m away from the residence and any vertical reflecting surfaces, and as far away as practical from significant vegetation around the dwellings, as required by IOA GPG. Photographs of the monitoring equipment installed at each location are included in Appendix 2.

11.5.2 Noise Monitoring Equipment

Details of the noise monitoring equipment used during the baseline noise survey are provided in Table 11-17.

Table 11-17 Noise monitoring equipment used during surveys.

Location	Make	Serial number	Laboratory calibration valid until
Site 1	Svantek 971	87014	17th March 2022
Site 2	Svantek 971	77796	22nd April 2022
Site 3	Svantek 971	94098	9th April 2022
Site 4	Svantek 971	77789	23rd April 2022
Calibrator	Larson Davis CAL200	18194	17th September 2021

The Svantek 971 sound level meters are Class 1 instruments suitable for wind farm noise measurements in accordance with ESTU-97-R and the IOA GPG. A 130 mm diameter windshield was fitted to each microphone to remove influence of extraneous wind-induced noise on the measurements. The sound level meter calibration was field checked at the start and finish of the measurement periods, and no significant drift in calibration was observed for any periods used for analysis.

All items of equipment used carry a current calibration certificate from an accredited laboratory at the time of the monitoring. Copies of the calibration certificates are provided in Appendix 3.

11.5.3 Wind Data

Wind data has been obtained from an anemometer mounted at hub height on the permanent met mast installed on site in the wind farm at the coordinates detailed in Appendix 11-1.

11.5.4 Baseline Monitoring Results

Baseline monitoring results have been analysed in accordance with the IoA GPG. Baseline monitoring was conducted from 16 April 2021 to 9 May 2021.

11.5.4.1 Night-time Baseline Levels

The relationship between wind speed and the measured noise level was determined for the data across the night-time period by a least-squares regression formula. The night-time period is classified in ESTU-97-R and the IOA GPG as:

- 23:00 – 07:00 every day

Linear and polynomial trendlines were fitted to the data in accordance with ESTU-R-97 and with the coefficients of determination (R^2) for each order of polynomial fit line determined for valid 'night-time' data. The "best fit" polynomial was determined as the curve that provided both a higher regression coefficient and a sensible visual match to the data. The measured background noise levels for each location, including the trendline for the best fit polynomial, are shown in Figure 11-5 to Figure 11-8. In accordance with the IoA GPG measurements affected by rain have been excluded. Additional exclusions of measurements showing evidence of extraneous noise have also been made as shown.

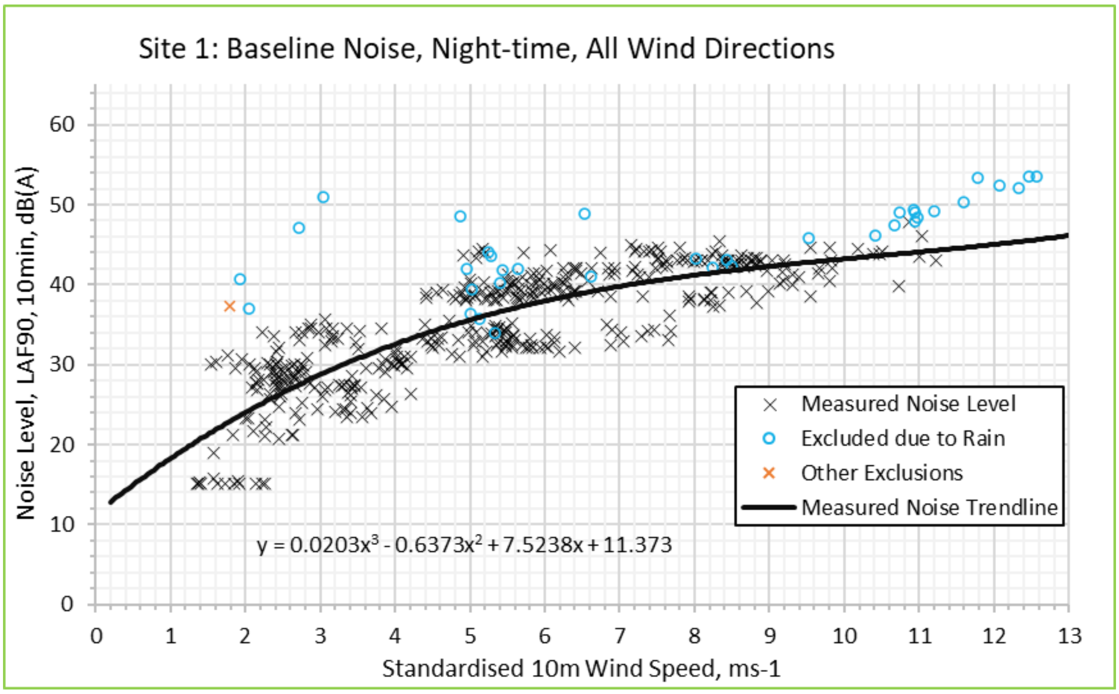

Figure 11-5 Background noise monitoring results at Site 1

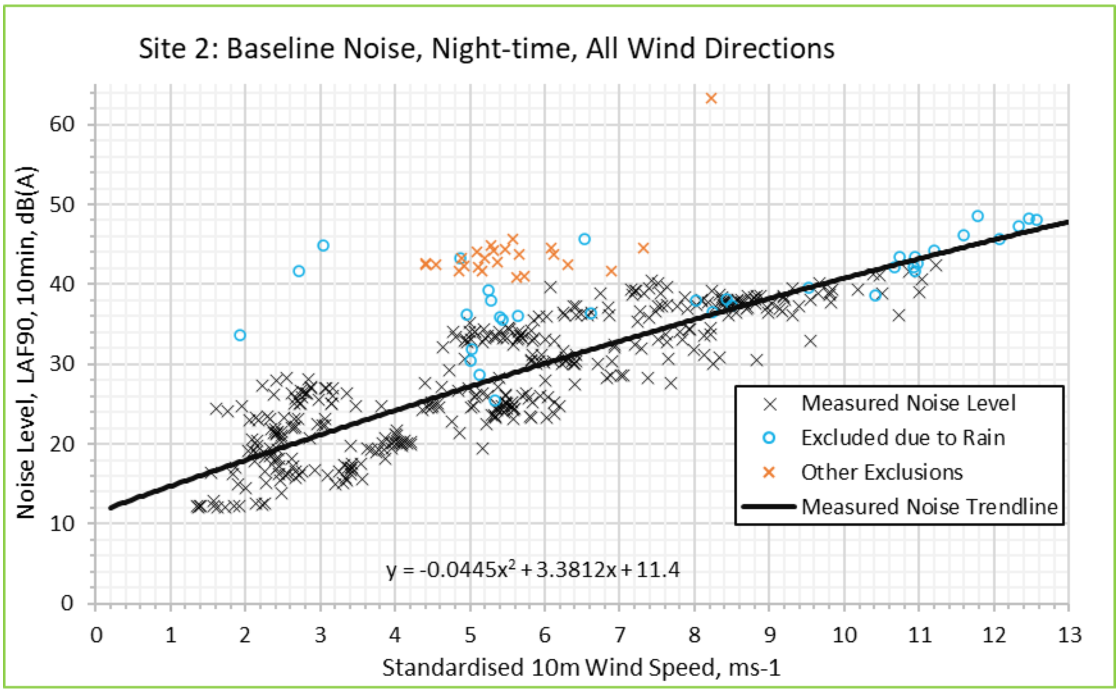

Figure 11-6 Background noise monitoring results at Site 2

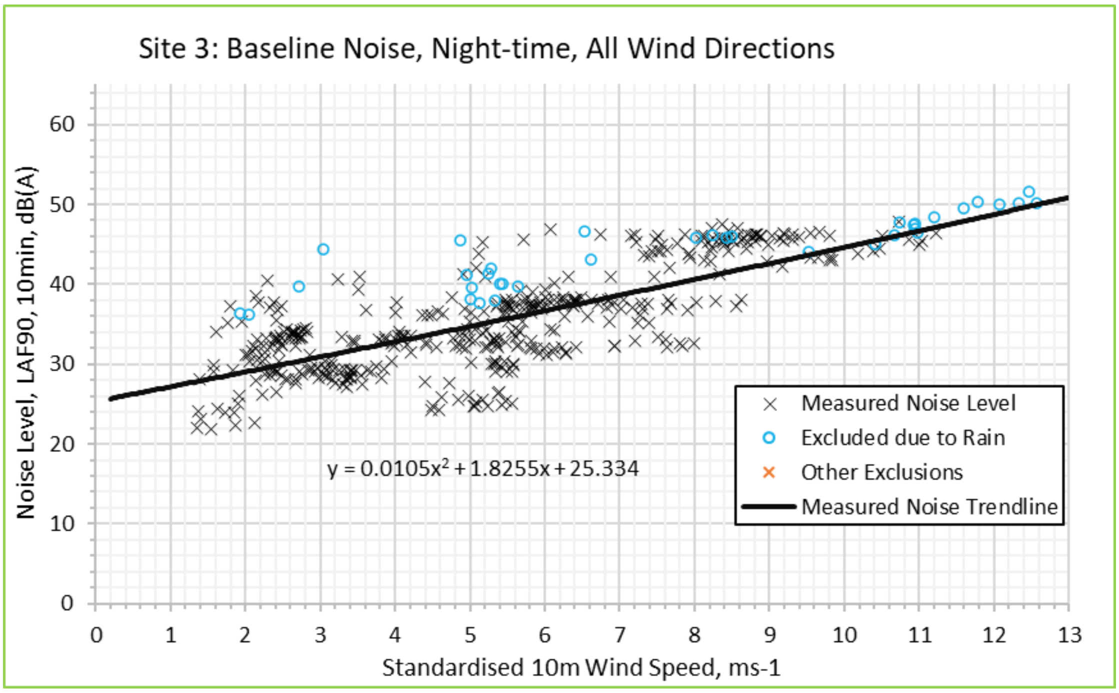

Figure 11-7 Background noise monitoring results at Site 3

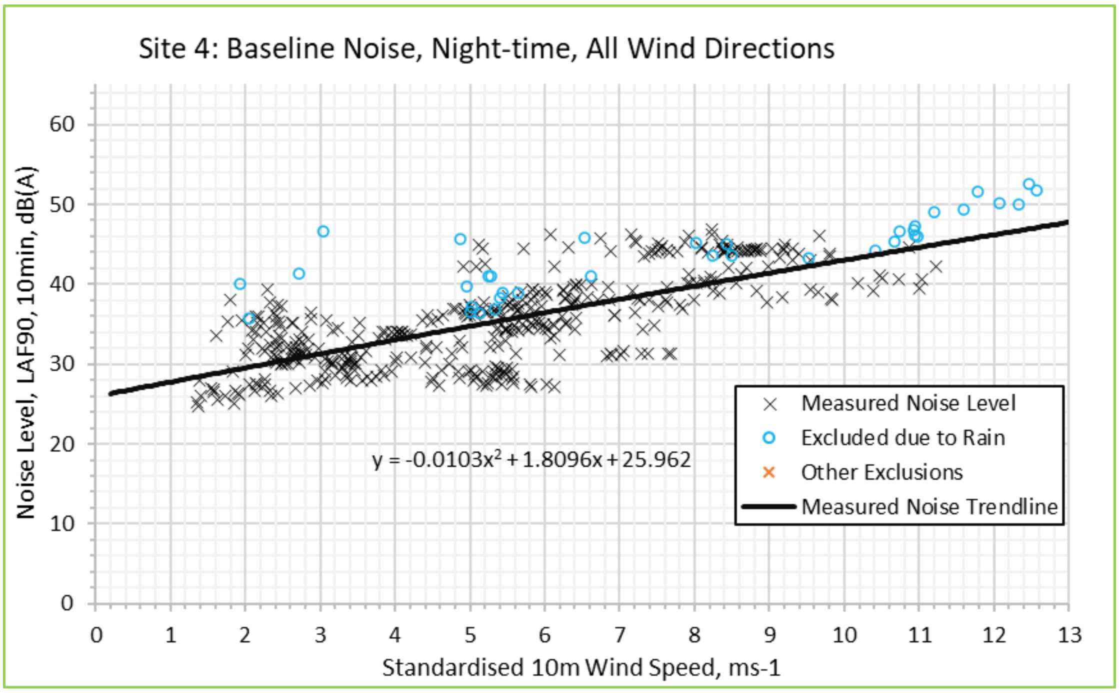

Figure 11-8 Background noise monitoring results at Site 4

11.5.4.2 Daytime Amenity Noise Levels

The relationship between wind speed and the measured noise level was determined for the data across the daytime period by a least-squares regression formula. The daytime 'amenity' period is classified in ESTU-97-R and the IOA GPG as:

- 18:00 – 23:00 every day
- 13:00 – 18:00 Saturday
- 07:00 – 18:00 Sunday

Linear and polynomial trendlines were fitted to the data in accordance with ESTU-R-97 and with the coefficients of determination (R^2) for each order of polynomial fit line determined for valid 'daytime amenity' data. The "best fit" polynomial was determined as the curve that provided both a higher regression coefficient and a sensible visual match to the data. The measured background noise levels for each location, including the trendline for the best fit polynomial, are shown in Figure 11-9 to Figure 11-12.

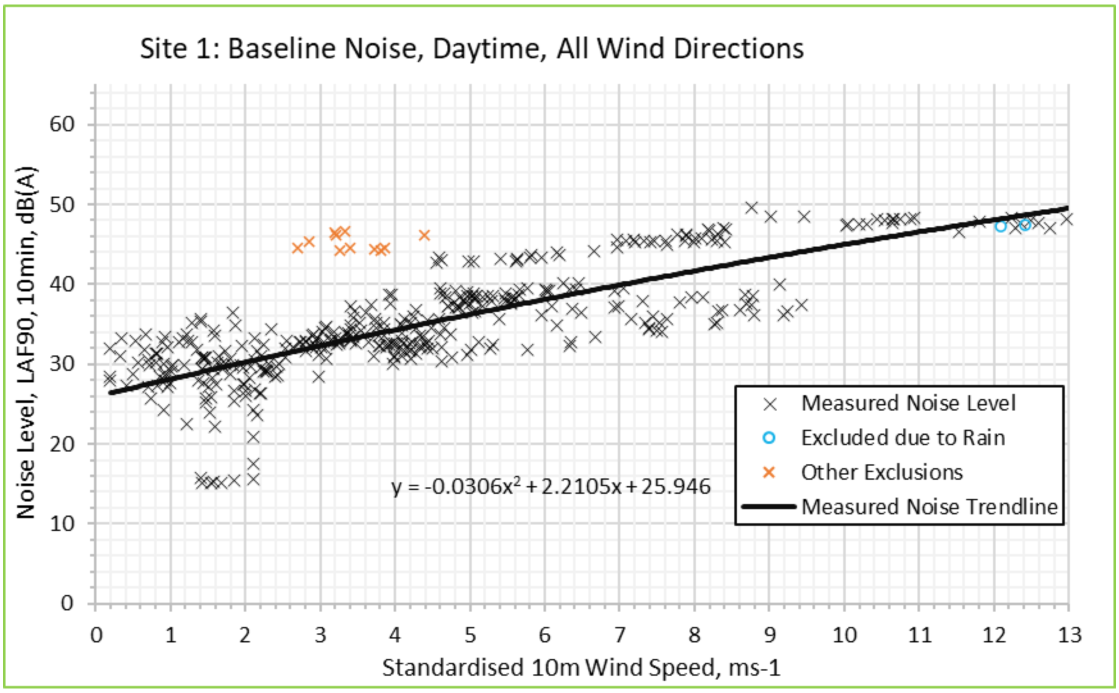

Figure 11-9 Background noise monitoring results at Site 1

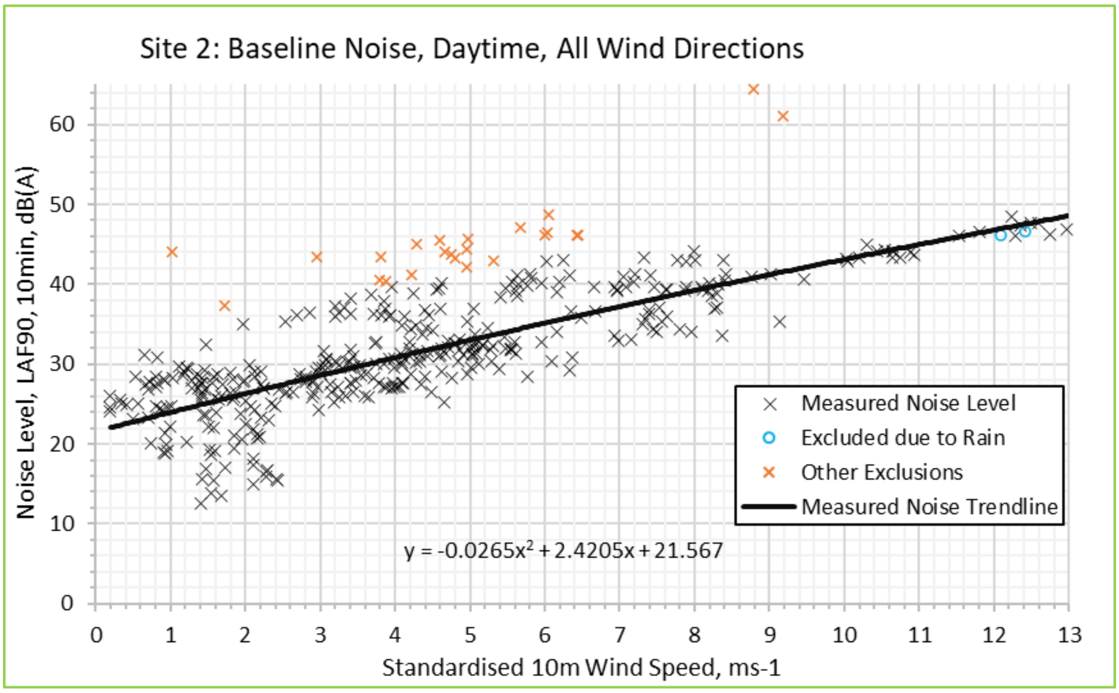

Figure 11-10 Background noise monitoring results at Site 2

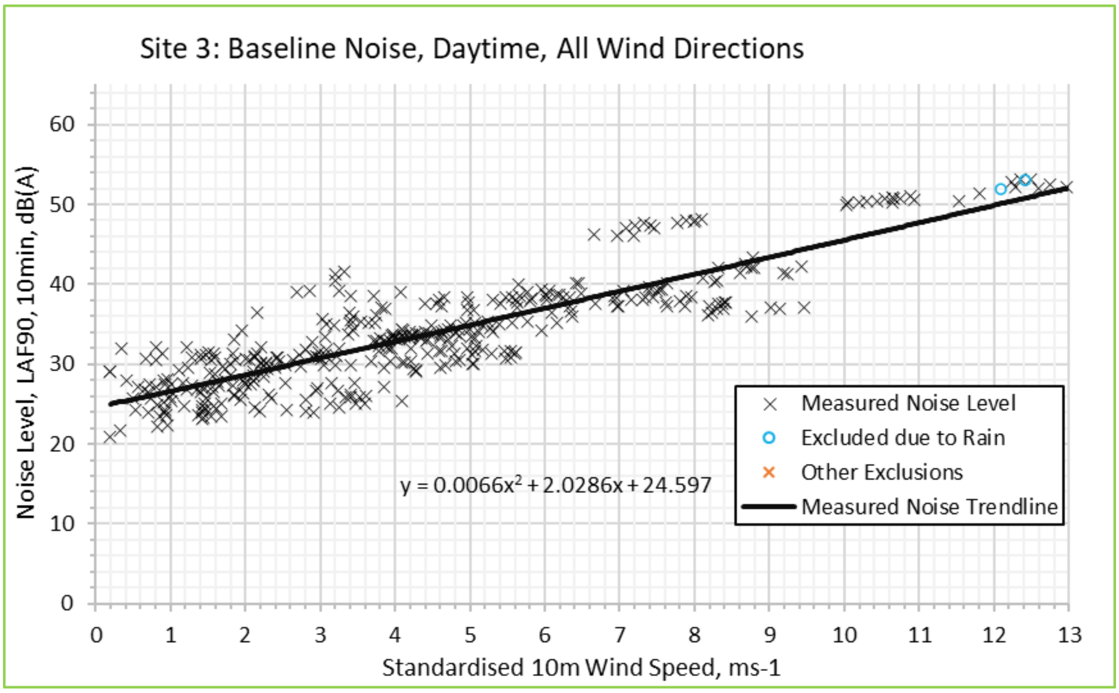

Figure 11-11 Background noise monitoring results at Site 3

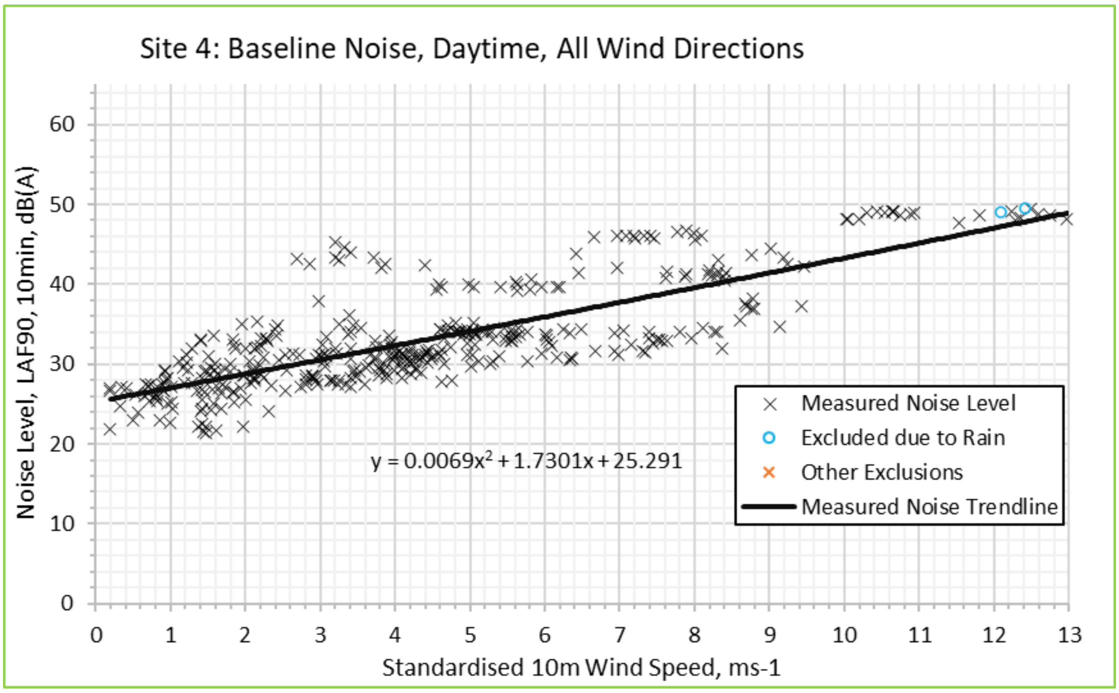

Figure 11-12 Background noise monitoring results at Site 4

11.5.5 WEDG06 Noise Limits

11.5.5.1 Night-time Limits

The applicable noise limits for the night-time period have been determined for each noise sensitive location from baseline background noise level data measured at the most relevant noise monitoring location. For all other residences, the minimum applicable limit of 43 dB(A) has been adopted for the purposes of this assessment.

Table 11-18 presents the night-time background noise levels and noise limits from 4m/s (turbine cut-in wind speed) up to a wind speed of 9 m/s (wind speed at which maximum turbine noise level is reached).

Table 11-18 Measured night-time background noise levels and WEDG06 noise limits in dB(A) L_{90} at noise sensitive locations.

V_{10} m/s	Site 1		Site 2		Site 3		Site 4	
	Back-ground	WEDG06 Limit	Back-ground	WEDG06 Limit	Back-ground	WEDG06 Limit	Back-ground	WEDG06 Limit
4	32.6	43.0	24.2	43.0	32.8	43.0	33.0	43.0
5	35.6	43.0	27.2	43.0	34.7	43.0	34.8	43.0
6	38.0	43.0	30.1	43.0	36.7	43.0	36.4	43.0
7	39.8	44.8	32.9	43.0	38.6	43.6	38.1	43.1
8	41.2	46.2	35.6	43.0	40.6	45.6	39.8	44.8
9	42.3	47.3	38.2	43.2	42.6	47.6	41.4	46.4

11.5.5.2 Daytime Limits

The applicable noise limits for the night-time period have been determined for each noise sensitive location from baseline background noise level data measured at the most relevant noise monitoring location. For all other residences, the minimum applicable limit of 45 dB(A) has been adopted for the purposes of this assessment.

Table 11-19 presents the daytime amenity background noise levels and noise limits from 4m/s (turbine cut-in wind speed) up to a wind speed of 9 m/s (wind speed at which maximum turbine noise level is reached).

Table 11-19 Measured daytime amenity background noise levels and WEDG06 noise limits in dB(A) L_{90} at noise sensitive locations.

V_{10} m/s	Site 1		Site 2		Site 3		Site 4	
	Back-ground	WEDG06 Limit	Back-ground	WEDG06 Limit	Back-ground	WEDG06 Limit	Back-ground	WEDG06 Limit
4	34.3	45.0	30.8	45.0	32.8	45.0	32.3	45.0
5	36.2	45.0	33.0	45.0	34.9	45.0	34.1	45.0
6	38.1	45.0	35.1	45.0	37.0	45.0	35.9	45.0
7	39.9	45.0	37.2	45.0	39.1	45.0	37.7	45.0
8	41.7	46.7	39.2	45.0	41.2	46.2	39.6	45.0
9	43.4	48.4	41.2	46.2	43.4	48.4	41.4	46.4

11.5.6 Sensitivity of Receptors

The existing Carnsore Wind Farm has operated since 2002 without noise complaints and should therefore be considered to be accepted by the local community with wind turbine noise an established part of the local soundscape.

Sources of background noise include coastal noise (marine surf), local roads, waterways, agriculture and wildlife. Based on levels measured during the baseline surveys, the locality would not be considered an area of low background noise.

Table 11-20 below shows the assessed sensitivity of receptors within the study area based on baseline monitoring, and the context detailed above.

Table 11-20 Assessed Sensitivity of Receptors

Type of Noise	Sensitivity of Receptors	Reasons
Construction	High	Medium background and ambient noise levels, character of construction noise would contrast with ambient.
Industrial	High	Medium background and ambient noise levels, character of industrial noise would contrast with ambient.
Road Traffic	Medium	Medium background and ambient noise levels, increased traffic would result in change in intensity but not character.
Wind Turbine	Medium	Medium background and ambient noise levels, increased wind turbine noise would result in change in intensity but not character.

11.6 Impacts of Proposed Development

11.6.1 Do Nothing Effects

An alternative 'do-nothing' land-use option to maintaining the existing wind energy development at the site would be to decommission the wind farm and restore the site to its original use as agricultural lands for pasture and crops. This scenario would involve the removal of the existing turbines and all associated wind farm infrastructure.

This "Do Nothing" scenario would effectively encompass the effects of decommissioning and site traffic as set out in later sections. There would be no noise impacts once the decommissioning was completed.

11.6.2 Construction & Decommissioning Phases

No construction activities or alterations to the existing wind farm are proposed beyond routine maintenance during the operational phase of the Proposed Development.

11.6.2.1 Decommissioning Noise

The applicant, Hibernian Wind Power (Hibernian) have determined that the existing wind turbines at the Carnsore site have a remaining lifespan of at least 15 years. Following the end of their useful life, the wind turbines may be replaced with a new set of turbines, subject to planning permission being obtained, or the Proposed Development will be decommissioned fully.

Upon decommissioning of the Proposed Development, the wind turbines will be disassembled in reverse order to how they were erected. All above ground turbine components will be separated and removed off-site for reuse or recycling. It is proposed to leave turbine foundations in place underground and to cover with earth and reseeded as appropriate. Leaving the turbine foundations in-situ is considered a more environmentally prudent option, as to remove that volume of reinforced concrete from the ground could result in significant environment nuisances such as noise, dust and/or vibration.

It is proposed that site roadways will be left in situ, as appropriate, to facilitate on-going agricultural use. If it were to be confirmed that the roads were not required in the future for any other useful purpose, they could be removed where required, however, this is not envisaged at this time. It is proposed to leave underground cables in place where they are below a level likely to be impacted by typical agricultural works. A decommissioning plan will be agreed with the local authorities at least three months prior to decommissioning of the Proposed Development.

To summarise Effects for Decommissioning Noise:

- **Magnitude:** Predicted decommissioning noise at receivers is low in level due to separation distances and benefits of topographical screening
- **Context:** Decommissioning noise is different in character to local ambient noise and receptors are assessed to be of high sensitivity
- **Extent:** Low population in locality within 1km from decommissioning activity
- **Probability:** While decommissioning noise is likely to be audible at nearby NSLs, there is low likelihood of high intensity
- **Duration:** Short-term
- **Frequency:** Daily decommissioning noise with occasional louder events

Table 11-21 - EPA description of effects: Decommissioning Noise

Quality	Significance	Duration/Frequency
Negative	Moderate	Short-term

11.6.2.2 Decommissioning Vibration

As ground-borne vibration attenuates quickly with distance, vibration levels due to decommissioning activities would be below the threshold of human perception.

To summarise Effects for Decommissioning Phase Vibration:

- **Magnitude:** Predicted decommissioning phase vibration at receptors is below the threshold of perception
- **Context:** Ground borne vibration may be experienced locally during period of high ocean swell, which may reduce the sensitivity of the local population
- **Extent:** Low population in locality within 1km from decommissioning activity
- **Probability:** Effects on receptors of decommissioning vibration are considered highly unlikely

- **Duration:** Short-term
- **Frequency:** Intermittent vibration due to heavy equipment

Table 11-22 - EPA description of effects: Decommissioning Vibration

Quality	Significance	Duration/Frequency
Negative	Imperceptible	Short-term

11.6.2.3 Site Traffic Noise and Vibration

Decommissioning works will result in increased HGV traffic on the approach road to the proposed Carnsore Wind Farm for the duration of the decommissioning phase. While this may result in a moderate increase in traffic noise and vibration levels along the approach route, the duration will be short-term.

To summarise Effects for Site Traffic Noise and Vibration:

- **Magnitude:** Traffic noise and vibration may be of moderate magnitude for some receptors
- **Context:** HGV traffic associated with the development represents a change in intensity but not in character
- **Extent:** Effects may occur along the access routes from Tagoat or Kilrane
- **Probability:** Effects on receptors of site traffic are likely but limited
- **Duration:** Short-term
- **Frequency:** Daily during works

Table 11-23 - EPA description of effects: Site Traffic Noise and Vibration

Quality	Significance	Duration/Frequency
Negative	Moderate	Short-term

11.6.3 Operational Phase Noise

The calibrated noise model has been used to predict WTN levels from the Proposed Development at all NSLs within 2km of turbines. The WTN levels at NSL001 are based upon measurements at Site 4 and a 0.5dB adjustment for distance which has been determined using the noise model. Results for the 30 nearest NSLs are shown in Table 11-24 below along with any excess over WEDG06 noise limits.

Table 11-24 Predicted/measured WTN levels at 30 nearest NSLs.

Location	Description	Predicted/measured WTN level in dB LA90 for V10 in m/s					
		4	5	6	7	8	9
WEDG06 Limit	**Day**	**45.0**	**45.0**	**45.0**	**45.0**	**45.0**	**46.4**
	Night	**43.0**	**43.0**	**43.0**	**43.1**	**44.8**	**46.4**
NSL001	Excess Day	–	–	–	–	0.2	–
		34.0	37.0	41.0	44.8	45.2	45.5
	Excess Night	–	–	–	1.7	0.4	–
NSL003	Excess Day	–	–	–	–	–	–
		29.7	32.7	36.7	40.5	40.9	41.2
	Excess Night	–	–	–	–	–	–
WEDG06 Limit	**Day**	**45.0**	**45.0**	**45.0**	**45.0**	**46.2**	**48.4**
	Night	**43.0**	**43.0**	**43.0**	**43.6**	**45.6**	**47.6**
NSL002	Excess Day	–	–	–	–	–	–
		31.3	34.3	38.3	42.1	42.5	42.8
	Excess Night	–	–	–	–	–	–
NSL004	Excess Day	–	–	–	–	–	–
		31.3	34.3	38.3	42.1	42.5	42.8
	Excess Night	–	–	–	–	–	–
NSL005	Excess Day	–	–	–	–	–	–
		31.3	34.3	38.3	42.1	42.5	42.8
	Excess Night	–	–	–	–	–	–
NSL006	Excess Day	–	–	–	–	–	–
		31.2	34.2	38.2	42.0	42.4	42.7
	Excess Night	–	–	–	–	–	–
NSL007	Excess Day	–	–	–	–	–	–
		31.1	34.1	38.1	41.9	42.3	42.6
	Excess Night	–	–	–	–	–	–
For all other residences, predicted maximum noise below 43dB LA90 implies compliance							
NSL008		30.2	33.2	37.2	41.0	41.4	41.7
NSL009		30.1	33.1	37.1	40.9	41.3	41.6
NSL010		30.2	33.2	37.2	41.0	41.4	41.7
NSL011		30.2	33.2	37.2	41.0	41.4	41.7
NSL012		29.8	32.8	36.8	40.6	41.0	41.3
NSL013		30.0	33.0	37.0	40.8	41.2	41.5
NSL014		29.8	32.8	36.8	40.6	41.0	41.3
NSL015		29.7	32.7	36.7	40.5	40.9	41.2
NSL016		29.5	32.5	36.5	40.3	40.7	41.0
NSL017		29.3	32.3	36.3	40.1	40.5	40.8
NSL018		29.4	32.4	36.4	40.2	40.6	40.9
NSL019		29.4	32.4	36.4	40.2	40.6	40.9
NSL020		29.3	32.3	36.3	40.1	40.5	40.8
NSL021		29.1	32.1	36.1	39.9	40.3	40.6
NSL022		29.3	32.3	36.3	40.1	40.5	40.8
NSL023		29.2	32.2	36.2	40.0	40.4	40.7

Location	Description	Predicted/measured WTN level in dB LA90 for V10 in m/s					
		4	5	6	7	8	9
NSL024		28.9	31.9	35.9	39.7	40.1	40.4
NSL025		29.0	32.0	36.0	39.8	40.2	40.5
NSL026		28.7	31.7	35.7	39.5	39.9	40.2
NSL027		28.2	31.2	35.2	39.0	39.4	39.7
NSL028		28.1	31.1	35.1	38.9	39.3	39.6
NSL029		27.9	30.9	34.9	38.7	39.1	39.4
NSL030		27.8	30.8	34.8	38.6	39.0	39.3

It can be seen from Table 11-24 that, based on monitoring and predictions of the calibrated noise model, compliance with WEDG06 noise limits is predicted for all NSLs with the exception of NSL001, for which there is a minor exceedance for 7m/s and 8m/s under downwind conditions:

- Minor exceedance of 7m/s night-time limit of 1.7dB
- Minor exceedance of 8m/s night-time limit of 0.4dB
- Minor exceedance of 8m/s daytime limit of 0.2dB

To summarise effects for proposed Carnsore turbines:

- **Magnitude:** Medium magnitude for NSL001 and moderate magnitude for all other receivers as predicted turbine noise levels are within WEDG06 limits, high background noise levels at nearest NSLs acts to mask WTN

- **Context:** WTN does not represent change in character of ambient noise

- **Extent:** Low population in locality

- **Probability:** Low population reduces likelihood of individuals with sensitivity to turbine noise, lack of existing complaints suggests adverse effects unlikely

- **Duration:** Lifespan of wind farm implies long-term duration

- **Frequency:** Intermittent depending on windspeed and direction

Table 11-25 - EPA description of effects: Operational phase Proposed Development noise for NSL001

Quality	Significance	Duration/Frequency
Negative	Medium	Long-term

Table 11-26 - EPA description of effects: Operational phase Proposed Development noise for all other receivers

Quality	Significance	Duration/Frequency
Negative	Moderate	Long-term

11.6.3.1 Intensity of Special Audible Characteristics

Special audible characteristics have been assessed in Sections 11.4.5.2 and 11.4.5.3 with no penalties indicated using either subjective or objective methods.

To summarise Effects for proposed Carnsore turbines:

- **Magnitude:** Negligible magnitude as neither subjective or objective methods have detected special audible characteristics specific to WTN
- **Context:** WTN does not represent change in character of ambient noise
- **Extent:** Low population in locality
- **Probability:** Presence of special audible characteristics above thresholds is unlikely, high background levels would act to mask any features that might occur
- **Duration:** Lifespan of windfarm implies long-term duration
- **Frequency:** Intermittent depending on windspeed and direction

Table 11-27 - EPA description of effects: Operational phase proposed turbine noise – Intensity of Special Audible Characteristics

Quality	Significance	Duration/Frequency
Negative	Negligible	Long-term

11.6.4 Operational Phase Vibration

As discussed in Section 11.6.2.2. ground borne vibration attenuates quickly with distance. At the separation distances of the NSLs (greater than 1.5 km for all uninvolved NSLs), there are no effects due to operational vibration of proposed Carnsore turbines predicted.

Table 11-28 - EPA description of effects: Operational phase turbine vibration

Quality	Significance	Duration/Frequency
Negative	Imperceptible	Long-term

11.6.5 Substation Operational Noise

The wind farm substation will remain in place as part of the Proposed Development. The site of the substation serving the existing Carnsore Wind Farm is located approximately 100m from NSL001, the nearest residence.

Electrical transformer noise was not audible close to NSL001 during site visits during either the daytime or the night-time.

Table 11-29 – Substation noise

Equipment	Sound Power Level, LwA (dB)	Predicted Noise Level at 100m
Electrical Substation	63	21

Note: Substation noise determined from Amplitude Acoustics internal database.

The calculated level of 21 dBA at the nearest NSL is very low and would be expected to be much less in reality due to screening and absorption effects.

To summarise Effects for Substation Noise:

- **Magnitude:** Substation sound power sufficiently low as to be expected to be imperceptible at receptor separation distances
- **Context:** Substation noise would represent a significant change in character and would therefore be prominent due to tonality
- **Extent:** Substation noise would not be expected to be measurable beyond site boundary
- **Probability:** Effects considered highly unlikely
- **Duration:** Long-term
- **Frequency:** Constant

Table 11-30 - EPA description of effects: Operation phase substation noise

Quality	Significance	Duration/Frequency
Negative	Not significant	Long-term

11.6.6 Uncertainty of Prediction Methods

ISO 9613-2:1996, the basis of the prediction methodology adopted in this noise assessment report, provides a discussion on uncertainty and advises a typical accuracy of overall A-weighted noise levels of ±3 dB at distances of up to 1 km from the source. It does not advise on the accuracy of predictions at distances further than this, however published studies[13] indicate that the correlation between predicted noise levels and measured operational data normally remains within this ±3 dB uncertainty at much greater distances.

Uncertainty in other inputs, such as the position of turbines and the location of residences, may also exist but are likely to have an insignificant impact on the prediction uncertainty as small changes in position do not result in any noticeable change in predicted noise levels when the distance between source and receiver is over 1 km.

13 Evans T & Cooper J, 2012, Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms, Acoustics Australia, vol. 40, no. 1, pp 28-36.

Uncertainty in sound power levels

Sound power levels of turbines are quantified in accordance with measurement standard IEC 61400-11 Edition 3.0 *Wind turbines – Part 11: Acoustic noise measurement techniques* (IEC 61400-11). The measurement process includes quantification of the uncertainty in the sound power level at each wind speed as documented in IEC 61400-11, this uncertainty is typically small and in the order of 1 dB or lower.

11.7 Mitigation Measures

The assessment of potential impacts has shown that no significant impacts due to noise from the proposed Carnsore Wind Farm Life Extension development are expected. However, a series of potential mitigation measures are laid out here to provide a template to demonstrate the potential to respond to such unlikely impacts.

11.7.1 Decommissioning Phase

11.7.1.1 Decommissioning Noise and Vibration

Various mitigation strategies may be employed to reduce construction noise, including the following:

- Limiting operation of noisiest activities to exclude periods identified as important to residential amenity.
- Selection of items of plant with lower noise levels.
- Engagement and dialogue between construction contractor and local community.
- Monitoring of site noise levels to ensure compliance with limits.
- Assign responsibility for issues relating to noise to a competent member of site staff.
- If necessary, install local noise barriers with absorptive linings near to specific sources, during construction works.
- Provide enclosures around generators.
- Switch off engines and equipment when not required.
- Warning reversing alarms should give adequate warning but have minimum impact on people outside site.
- Plant and activities should be reviewed so they are the quietest available (and therefore demonstrate use of best practicable means).

A key for minimising impact on neighbours is development of good community relations with local residents. It is good practice to:

- advise residents when works are due to start.
- provide site contact details if neighbours want to complain about the noise.
- establish a site point of contact for dealing with noise complaints.
- have an established procedure for dealing with complaints, recording time/details and responding within a certain time period.

Further guidance on construction noise reduction is available in BS5228. The guidance of BS5228 will be implemented as necessary for control of decommissioning noise from the Proposed Development.

11.7.1.2 Site Traffic Noise and Vibration

To limit impact of site traffic noise and vibration, traffic should be limited to times of day when vehicle pass-bys will cause minimum disruption, in particular to avoid sleep disturbance.

11.7.2 Operational Phase

11.7.2.1 Turbine Noise Emissions

The operational noise assessment of the Proposed Development has determined that mitigation of turbine noise emissions will be required under certain wind conditions for NSL001. The Vestas V52 has 4 operating modes, Level 0 to Level 4, with Level 0 being the default operating mode. The corresponding noise reductions with respect to Level 0 for Levels 14 are shown in Table 11-31.

Table 11-31 Manufacturer specified noise reduction in dBA for Vestas V52 at Standardised 10m wind speed (V10) in m/s for different operating modes relative to 'Level 0' operating mode.

Mode	Standardised 10m wind speed (V10) in m/s						
	5	6	7	8	9	10	11
Level 1	0	-0.2	-1.2	-1.2	-0.8	0	0
Level 2	0	-0.5	-2.1	-2.2	-1.7	-0.5	0
Level 3	0	-1.2	-3.3	-3.2	-2.7	-1.2	-0.3
Level 4	2.3	-1.5	-3.6	-7.3	-6.2	-4.4	-2.8

Predicted noise levels at NSL001 for each of the turbines have been analysed in combination with Table 11-31 and wind direction analysis to determine a suitable curtailment strategy to achieve compliance with the noise limits. Table 11-32 below details the resultant curtailment to achieve compliance with noise limits at NSL001.

Table 11-32 Mitigation strategy and required attenuation of turbine noise to achieve compliance under downwind conditions

Period	Required attenuation of turbine noise at NSL001 for V10 in m/s					
	4	5	6	7	8	≥9
Day	–	–	–	–	0.2	–
Night	–	–	–	1.7	0.4	–
Daytime Curtailment						
Curtailed Turbines	–	–	–	–	T13	–
Required Mode	–	–	–	–	Level 4	–
Predicted Reduction	–	–	–	–	0.5dB	–
Wind Direction Range (degrees)	–	–	–	–	140 to 170	–
Night-time Curtailment						
Curtailed Turbines	–	–	–	T11, T12, T13, T14	T13	–
Required Mode	–	–	–	Level 4	Level 4	–
Predicted Reduction	–	–	–	2dB	0.5dB	–
Wind Direction Range (degrees)	–	–	–	120 to 220	130 to 170	–

Mitigation will be implemented such as to ensure that the Proposed Development achieves compliance with the noise limits.

Special features such as Tonality, AM or LFN have not been identified in noise emissions from the turbines. If such were found, certain modifications to turbine operation could be employed to prevent the issue as observed in past such instances[14].

14 NANR233 Research into Aerodynamic Modulation of Wind Turbine Noise: Final report - Dr. Andy Moorhouse, Malcolm Hayes, Dr. Sabine von Hünerbein, Ben Piper, Dr. Mags Adams

11.7.2.2 Substation Noise Emissions

Substation noise levels at the NSLs have been assessed with no adverse effects anticipated and no mitigation required. In the unlikely event that adverse effects are identified, noise mitigation measures such as substation enclosures and barriers are available to reduce noise emissions.

11.8 Residual Impacts

This section summarises the likely residual noise and vibration impacts associated with the Proposed Development following the implementation of mitigation measures.

11.8.1 Operational Phase Noise

Following implementation of noise mitigation measures (turbine curtailment), some turbine noise emissions will remain. The Proposed Development is not predicted to result in any increase of turbine noise at any NSL.

Table 11-33 - EPA description of effects: Operational phase proposed turbine noise

Quality	Significance	Duration/Frequency
Negative	Moderate	Long-term

11.8.2 Operational Phase Vibration

There are no predicted effects due to operational vibration of the turbines at the Proposed Development.

Table 11-34 - EPA description of effects: Operational phase turbine vibration

Quality	Significance	Duration/Frequency
Negative	Imperceptible	Long-term

11.8.3 Decommissioning Phases

11.8.3.1 Decommissioning Noise

During decommissioning phases of the project there will be some effect on nearby noise sensitive properties. However, given the separation distances involved, and the temporary nature of the works, it is expected that the various noise sources will not be excessively intrusive. Furthermore, the application of binding noise limits and hours of operation, along with implementation of appropriate noise and vibration control measures, will ensure that noise and vibration effect is kept to a minimum.

Table 11-35 - EPA description of effects: Decommissioning Noise

Quality	Significance	Duration/Frequency
Negative	Slight	Short-term

11.8.3.2 Construction & Decommissioning Vibration

There are no predicted effects due to construction and decommissioning vibration of the turbines at the Proposed Development.

Table 11-36 - EPA description of effects: Decommissioning Vibration

Quality	Significance	Duration/Frequency
Negative	Imperceptible	Short-term

11.8.3.3 Site Traffic Noise and Vibration

Site traffic may result in a moderate increase in traffic noise and vibration levels along the approach route, the duration will be short-term.

Table 11-37 - EPA description of effects: Site Traffic Noise and Vibration

Quality	Significance	Duration/Frequency
Negative	Moderate	Short-term

11.8.4 Substation Noise Levels

There is no significant impact predicted by the assessment of noise emissions from the substation at the Proposed Development.

Table 11-38 - EPA description of effects: Operation phase substation noise

Quality	Significance	Duration/Frequency
Negative	Not significant	Long-term

11.9 Cumulative Effects

This assessment has considered the potential cumulative impacts of the Proposed Development in combination with other wind energy developments in the area.

Wind energy projects within 20km of the Proposed Development considered with regard to cumulative impacts include:

1. *Ardcavan Business Park, single turbine*
2. *Teagasc, Johnstown, single turbine*
3. *Richfield Wind Farm (SSE), 18 turbines.*

As stated in Section 11.4.7, as all of these wind energy projects are more than 15km distant from the Proposed Development, there are no cumulative effects of wind turbine noise and vibration.