Bute Energy

Aberedw Energy Park

Appendix 10.1:

Environmental Noise Assessment

HOARE LEA

Aberedw Energy Park.
Appendix 10.1 - Environmental noise assessment.

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Audit sheet.

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Contents.

Executive Summary

Hoare Lea (HL) have been commissioned by Land Use Consultants (LUC) on behalf of Aberedw Energy Park Ltd (the Applicant), to undertake a noise assessment for the construction and operation of the proposed Aberedw Energy Park (the Proposed Development). Noise will be emitted by equipment and vehicles used during construction of the wind farm and by the turbines during operation. The level of noise emitted by the sources and the distance from those sources to the receiver locations are the main factors determining levels of noise at receptor locations.

Construction Noise

Construction noise has been assessed by a desk-based study of a potential construction programme and by assuming the Proposed Development is constructed using standard and common methods. Noise levels have been calculated for receiver locations closest to the areas of work and compared with guideline and baseline values. Construction noise, by its very nature, tends to be temporary and highly variable and therefore much less likely to cause adverse effects. Factors including in particular the restrictions of hours of working have been taken into consideration. It is concluded that noise generated through construction activities will have a low impact.

Operational Noise

Operational turbines emit noise from the rotating blades as they pass through the air. This noise can sometimes be described as having a regular 'swish'. The amount of noise emitted tends to vary depending on the wind speed. When there is little wind the turbine rotors will turn slowly and produce lower noise levels than during high winds when the turbine reaches its maximum output and maximum rotational speed. Background noise levels at nearby properties will also change with wind speed, increasing in level as wind speeds rise due to wind in trees and around buildings, etc.

Noise levels from operation of the turbines have been predicted for those locations around the Site most likely to be affected by noise. Surveys have been performed to establish existing baseline noise levels at a number of these properties. Noise limits have been derived from data about the existing noise environment following the method stipulated in national planning guidance.

Predicted operational noise levels have been compared to the limit values to demonstrate that turbines of the type and size which will be installed can operate within the limits so derived. It is concluded therefore that operational noise levels from the wind farm will be within levels recommended in national guidance for wind energy schemes.

The impact of the proposed substation has been considered on a precautionary basis and determined to correspond to a low impact. The addition of this noise source to that of the wind turbines will not affect the outcome of the above assessment and operational noise will remain a low impact.

This Executive Summary contains an overview of the noise assessment and its conclusions. No reliance should be placed on the content of this Executive Summary until this report has been read in its entirety.

1. Introduction

1.1 This report presents an assessment of the potential construction and operational noise impacts of the Aberedw Energy Park (hereafter referred to as the 'Proposed Development') on the residents of nearby dwellings. The assessment considers both the construction and operation of the Proposed Development. Assessment of operational noise accounts for the cumulative total of the Proposed Development as well as a single small-scale wind turbine near Tremaen. Other, more distant wind farms were not considered as their potential noise contribution was considered negligible.

1.2 Noise and vibration which arises from the construction of a wind farm is a factor which should be taken into account when considering the Proposed Development. However, in assessing the impacts of construction noise, it is accepted that the associated works are of a temporary nature. The main work locations for construction of the turbines are distant from nearest noise sensitive residences and are unlikely to cause strong impacts. The construction and use of access tracks may, however, occur at lesser separation distances. Assessment of the temporary impacts of construction noise is primarily aimed at understanding the need for dedicated management measures and, if so, the types of measures that are required. Further details of relevant working practices, traffic routes, and proposed working hours are described in Chapter 4 (Development Description) and Chapter 11 (Transport and Access) of the Environmental Statement (ES).

1.3 Once constructed and operating, wind turbines may emit two types of noise. Firstly, aerodynamic noise is a 'broad band' noise, sometimes described as having a characteristic modulation, or 'swish', which is produced by the movement of the rotating blades through the air. Secondly, mechanical noise may emanate from components within the nacelle of a wind turbine. This is a less natural sounding noise which is generally characterised by its tonal content. Traditional sources of mechanical noise comprise gearboxes or generators. Due to the acknowledged lower acceptability of tonal noise in otherwise 'natural' noise settings such as rural areas, modern turbine designs have evolved to minimise mechanical noise radiation from wind turbines. Aerodynamic noise tends to be perceived when the wind speeds are low, although at very low wind speeds the blades do not rotate or rotate very slowly and so, at these wind speeds, negligible aerodynamic noise is generated. In higher winds, aerodynamic noise is generally masked by the normal sound of wind blowing through trees and around buildings. The level of this natural 'masking' noise relative to the level of wind turbine noise determines the subjective audibility of the wind farm. The relationship between wind turbine noise and the naturally occurring masking noise at residential dwellings lying around the Proposed Development will therefore generally form the basis of the assessment of the levels of noise against accepted standards.

1.4 The main noise sources associated with the substation are likely to be the power transformers and their cooling fans. The transformer noise is generally fairly constant, once energised, whereas the cooling fans operate as needed, depending on load and ambient temperature. The noise from the transformers is usually tonal in nature with most energy contained within discrete frequency components at 100 Hz and harmonics thereof. The cooling fans are likely to be broadband in nature but switch on and off.

1.5 Decommissioning noise effects have not been assessed, on the basis that construction noise effects will be more intensive and therefore represent the worst-case noise levels.

1.6 An overview of environmental noise assessment and a glossary of noise terms are provided in Annex A.

2. Policy and Guidance Documents

2.1 Planning Policy and Advice Relating to Noise

2.1.1 Current government planning advice to Local Authorities in Wales concerning noise takes several forms. General guidance is provided by 'Planning Policy Wales' (PPW)[1] and Future Wales[2] – The National Plan 2040. This guidance document is then supplemented by 'Technical Advice Note (Wales) 11: Noise'[3] (TAN11). The introduction to TAN11 sets out the importance of appropriately considering noise in planning applications and states how the planning system can be used to:

> *'minimise the adverse impact of noise without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens of business.'*

2.1.2 Annex B of TAN11 provides guidance on the assessment of environmental noise from different sources. Paragraph B19 of the Annex makes direct reference to noise from wind turbines and states:

> *'Detailed guidance on noise from wind turbines is contained in Planning Guidance (Wales), Technical Advice Note (Wales) 8 'Renewable Energy', 1996.'*

2.1.3 The 1996 version of TAN8 referenced in TAN11 and its subsequent update in 2005 have now been superseded by Future Wales: the National Plan 2040[4]. This sets out several Pre-Assessed Areas for Wind Energy which were assessed as "capable of accommodating development in an acceptable way" and explains that certain large-scale energy developments will be considered as Developments of National Significance and determined at the national level. Policy 18 of the National Plan includes several criteria for such large-scale developments, including the requirement that there should not be *"unacceptable adverse impacts by way of shadow flicker, noise […]."* It also notes that the "*cumulative impacts of existing and consented renewable energy schemes should also be considered.*" A more recent updated draft[5] of TAN11 for consultation does not consider wind turbines as part of its scope.

2.1.4 Planning Policy Wales explains that "impact on health and amenity" should be considered in relation to potentially polluting development. In relation to energy developments, it specifically notes that:

> *'Further guidance on wind turbine noise assessment can be found in ETSU-R-97 […] and further good practice guidance published by Institute of Acoustics'.*

2.1.5 The basic aim of ETSU-R-97[6] is to provide:

> *'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 local authorities'.*

2.1.6 ETSU-R-97 makes it clear from the outset that any noise restrictions placed on a wind farm must balance the environmental effects of the wind farm against the national and global benefits which would arise through the development of renewable energy sources, stating:

> *'The planning system must therefore seek to control the environmental impacts from a wind farm whilst at the same time recognising the national and global benefits that would arise through*

1 Planning Policy Wales, Edition 12, Welsh Government, 7 February 2024.
2 Future Wales: The National Plan 2040, Welsh Government, 2021.
3 Planning Guidance (Wales), Technical Advice Note (Wales) 11, Noise, 1997.
4 Future Wales: the National Plan 2040, February 2021.
5 Revised planning guidance in relation to air quality, noise and soundscape, "Technical Advice Note 11: Air Quality, Noise and Soundscape", draft for consultation (2022).
6 ETSU-R-97, The Assessment and Rating of Noise from Wind Farms, Final Report for the Department of Trade & Industry, September 1996. The Working Group on Noise From Wind Turbines.

the development of renewable energy sources and not be so severe that wind farm development is unduly stifled.'

2.1.7 The recommendations contained in ETSU-R-97 provide a robust basis for assessing the noise implications of a wind farm. ETSU-R-97 has become the accepted standard for such developments within the UK. This methodology has therefore been adopted for the present assessment and is described in greater detail below. The guidance on good practice on the application of ETSU-R-97, which is referenced in PPW, has been provided by the Institute of Acoustics[7] (IOA Good Practice Guide or GPG): this will therefore be referenced in the present assessment.

2.1.8 A recently published report commissioned by the UK Government (WSP BEIS Report)[8] presents a review of the advice in ETSU-R-97. The Designing for Renewable Energy in Wales guidance[9] and the Noise and Soundscape Plan for Wales[10] both reference the WSP BEIS review and note that it is being considered by the Welsh Government. The WSP BEIS report does not provide a replacement or update to ETSU-R-97 and until it is replaced or updated by the Welsh Government, the ETSU-R-97 methodology continues to be applicable, as confirmed the above-reference design guidance[9] and in PPW.

2.1.9 For assessing noise from non-wind turbines sources associated with the Proposed Development, such as fixed plant associated with the substation, Annex B of TAN 11 advises the use of the BS 4142 standard. Although TAN 11 references the 1997 version of the standard, the more recent 2019 version[11] is now applicable.

2.1.10 In Wales there are two legislative instruments which address the effects of environmental noise with regard to construction noise and vibration, and nuisance. The Environmental Protection Act 1990[12] (EPA) and the Control of Pollution Act 1974[13] (CoPA). The CoPA provides two means of controlling construction noise and vibration. Section 60 provides the Local Authority with the power to impose at any time operating conditions on the Proposed Development. Section 61 allows the developer to negotiate a set of operating procedures with the Local Authority prior to commencement of site works.

2.1.11 To assess construction noise and vibration, Annex B of TAN11 refers to BS 5228[14] 'Noise control on construction and open sites', Parts 1 to 4, as the appropriate source of guidance. This standard has been updated since TAN11 was published. The most recent update was published in January 2009 and consolidates all previous parts of the standard into BS 5228-1:2009 (amended 2014)[15] (BS 5228-1) for airborne noise and BS 5228-2:2009 (amended 2014)[16] (BS 5228-2) for ground borne vibration. These updated standards supersede all previous versions, and have therefore been adopted as the relevant versions upon which to base this assessment.

2.1.12 BS 5228-1 provides guidance on a range of considerations relating to construction noise including the legislative framework, general control measures, example methods for estimating construction noise levels and example criteria which may be considered when assessing the magnitude of the impacts.

7 A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.
8 WSP, A Review of Noise Guidance for Onshore Wind Turbines, report for the UK Department for Business, Energy & Industrial Strategy, October 2022 (published 10 February 2023).
9 The Design Commission for Wales, Designing for Renewable Energy in Wales, November 2023.
10 Welsh Government (2023), Noise and Soundscape Plan for Wales 2023 to 2028.
11 British Standard 4142: 2014+A1 2019 Method for rating and assessing industrial and commercial sound. British Standards Institution. 2019.
12 Environmental Protection Act, Part III, HMSO, 1990.
13 Control of Pollution Act, Part III, HMSO, 1974.
14 BS 5228 Noise and Vibration Control on Construction and Open Sites.
15 BS 5228-1:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 1: Noise'.
16 BS 5228-2:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration'.

Similarly, BS 5228-2 provides general guidance on legislation, prediction, control and assessment criteria for construction vibration.

2.1.13 TAN11 does not deal specifically with noise from stone extraction from borrow pits. However, Welsh planning guidance on surface mineral extraction provides guidance that is relevant to the types of mineral extraction activity associated with site construction works. Reference should be made to Minerals Technical Advice Note (Wales) 1: Aggregates (MTAN1)[17]. BS 5228-1 and BS 5228-2 also provide guidance relating to surface mineral extraction including the assessment of noise and vibration impacts associated with quarry blasting. BS 6472-2 2008[18] gives similar guidance on assessing vibration from blasting associated with mineral extraction.

3. Scope and Methodology

3.1 Methodology for Assessing Construction Noise

3.1.1 Construction works include both moving sources and static sources. The moving sources normally comprise mobile construction plant and Heavy Goods Vehicles (HGVs). The static sources include construction plant temporarily placed at fixed locations and in some instances noise arising from blasting activities where rock is to be worked through.

3.1.2 The analysis of construction noise has been undertaken in accordance with BS 5228-1 which provides methods for predicting construction noise levels on the basis of reference data for the emissions of typical construction plant and activities. These methods include for the calculation of construction traffic along access tracks and haul routes and also for construction activities at fixed locations such as the bases of turbines, construction compounds or substations.

3.1.3 The BS 5228 calculated levels are then compared with absolute noise limits for temporary construction activities which are commonly regarded as providing an acceptable level of protection from the short-term noise levels associated with construction activities.

3.1.4 Separate consideration is also given to the possible noise impacts of construction related traffic passing to and from the Site along local surrounding roads. In considering potential noise levels associated with construction traffic movement on public roads, reference is made to the accepted UK prediction methodology provided by 'Calculation of Road Traffic Noise'[19] (CRTN).

3.1.5 The nature of works and distances involved in the construction of a wind farm are such that the risk of non-negligible impacts relating to ground borne vibration are very low (excluding blasting). Occasional momentary vibration can arise when heavy vehicles pass dwellings at very short separation distances, but again this is not sufficient to constitute a risk of moderate/major impacts in this instance. Accordingly, vibration impacts do not warrant detailed assessment and are therefore not discussed further in this assessment.

3.1.6 It is anticipated that some rock extraction from borrow pits by means of blasting operations could be required in some instances. The analysis of the related potential impacts has been made in accordance with Minerals Planning Policy Wales Minerals Technical Advice Note 1: Aggregates (MTAN1), BS 6472-2 2008 and BS 5228.

17 Minerals Planning Policy (Wales), Minerals Technical Advice Note (Wales) 1: Aggregates, National Assembly for Wales, 2004

18 BS 6472-2:2008:Guide to evaluation of human exposure to vibration in buildings - Part 2: Blast-induced vibration.

19 Calculation of Road Traffic Noise, HMSO Department of Transport, 1988.

3.2 Methodology for Assessing Wind Turbine Operational Noise

3.2.1 The ETSU-R-97 assessment procedure specifies that noise limits should be set relative to existing background noise levels at the nearest properties and that these limits should reflect the variation in both turbine source noise and background noise with wind speed. The wind speed range which should be considered is between the cut-in speed (the speed at which the turbines begin to operate) for the turbines and 12 m/s (43.2 km/h), where all wind speeds are referenced to a ten metre measurement height (Annex F details how wind speeds are referenced to ten metre height).

3.2.2 Separate noise limits apply for the day-time and night-time. Day-time limits are chosen to protect a property's external amenity whilst outside their dwellings in garden areas and night-time limits are chosen to prevent sleep disturbance indoors. Absolute lower limits, different for day-time and night-time, are applied where the line of best-fit representation of the measured background noise levels equates to very low levels (< 30 dB(A) to 35 dB(A) for day-time, and < 38 dB(A) during the night).

3.2.3 The day-time noise limit is derived from background noise data measured during the 'quiet periods of the day' defined in ETSU-R97: these comprise- weekday evenings (18:00 to 23:00), Saturday afternoons and evenings (13:00 to 23:00) and all day and evening on Sundays (07:00 to 23:00). Multiple samples of ten-minute background noise levels using the $L_{A90,10min}$ measurement index are measured contiguously over a wide range of wind speed conditions (a definition of the $L_{A90,10min}$ index is given in Annex A). The measured noise levels are then plotted against the simultaneously measured wind speed data and a 'bestfit' curve is fitted to the data to establish- the background noise level as a function of wind speed. The ETSU-R-97 day-time noise limit is then set to the greater of either: a level 5 dB(A) above the bestfit curve to the background noise data over a 0---12 m/s wind speed range <u>or</u> a fixed level in the range 35 dB(A) to 40 dB(A). The precise choice of the fixed lower limit within the range 35 dB(A) to 40 dB(A) depends on a number of factors: the number of noise affected properties, the likely duration and level of exposure and the consequences of the choice on the potential power generating capability of the wind farm.

3.2.4 ETSU-R-97 clearly indicates that the day-time limit is intended to lie within the range from 35 dB(A) to 40 dB(A). Therefore, one can conclude that there must be projects where 35 dB(A) is appropriate and conversely, projects where 40 dB(A) is appropriate. Within ETSU-R-97 there is a specific example: *"A single wind turbine causing noise levels of 40 dB(A) at several nearby residences would have less planning merit (...) than 30 wind turbines also causing the same amount of noise at several nearby residences"*. Therefore, where a project offers relatively low power generating potential, the day-time limit should naturally tend towards the lower end of the range, unless the number of noise affected properties and the extent to which those properties would be affected by the higher noise levels is sufficiently low to justify noise limits tending towards the upper end of the range. Conversely, sites with relatively large power generating capacity should naturally justify limits towards the upper end of the range. The appropriate choice of value is considered in Section 5.7 in this Report.

3.2.5 The night-time noise limit is derived from background noise data measured during the night-time periods (23:00 to 07:00) with no differentiation being made between weekdays and weekends. The ten minute $L_{A90,10min}$ noise levels measured over these night-time periods are again plotted against the concurrent wind speed data and a 'best-fit' correlation is established. As with the day-time limit, the night-time noise limit is also set as the greater of: a level 5 dB(A) above the best-fit background curve <u>or</u> a fixed level of 43 dB(A). This fixed lower night-time limit of 43 dB(A) was set in ETSU-R-97 on the basis of World Health Organization (WHO) guidance[20] for the noise inside a bedroom and an assumed difference between outdoor and indoor noise levels with windows open. In the time since ETSU-R-97 was released, the WHO guidelines were revised to suggest a lower internal noise level, but conversely, a higher assumed difference between outdoor and indoor noise levels. Notwithstanding the WHO

20 Environmental Health Criteria 12 – Noise. World Health Organisation, 1980.

guideline revisions, the ETSU-R-97 limit remains consistent with current national planning policy guidance with respect to night-time noise levels. In addition, following revision of the night-time WHO criteria, ETSU-R-97 has been incorporated into planning guidance for Wales, England and Scotland and at no point during this process was it felt necessary to revise the guidance within ETSU-R-97 to reflect the change in the WHO guideline internal levels. The advice contained within ETSU-R-97 remains a valid reference on which to continue to base the fixed limit at night.

3.2.6 The exception to the setting of both the day-time and night-time lower fixed limits occurs in instances where a property occupier has a financial involvement in the wind farm development. Where this is the case then the lower fixed portion of the noise limit at that property may be increased to 45 dB(A) during both the day-time and the night-time periods alike.

3.2.7 ETSU-R-97 also offers an alternative simplified assessment methodology:

'For single turbines or wind farms with very large separation distances between the turbines and the nearest properties a simplified noise condition may be suitable. We are of the opinion that, if the noise is limited to an $L_{A90,10min}$ of 35dB(A) up to wind speeds of 10m/s at 10m height, then this condition alone would offer sufficient protection of amenity, and background noise surveys would be unnecessary.

3.2.8 The noise limits defined in ETSU-R-97 relate to the total noise occurring at a dwelling due to the combined noise of all operational wind turbines. The assessment will therefore need to consider the combined operational noise of the Proposed Development with other wind farms in the area to be satisfied that the combined cumulative noise levels are within the relevant ETSU-R-97 criteria. ETSU-R-97 also requires that the baseline levels on which the noise limits are based do not include a contribution from any existing turbine noise, to prevent unreasonable cumulative increases.

3.2.9 To undertake the assessment of operational noise in accordance with the foregoing methodology the following steps are required:

- specify the number and locations of the wind turbines on all wind farms;
- identify the locations of the nearest, or most noise sensitive, neighbours;
- measure the background noise levels as a function of site wind speed at the nearest neighbours, or at least at a representative sample of the nearest neighbours;
- determine the day-time and night-time noise limits from the measured background noise levels at the nearest neighbours;
- specify the type and noise emission characteristics of the wind turbines;
- calculate the noise immission levels due to the operation of the wind turbines as a function of site wind speed at the nearest neighbours; and
- compare the calculated wind farm noise immission levels with the derived noise limits and assess in the light of planning requirements.

3.2.10 The foregoing steps, as applied to the Proposed Development, are set out subsequently in this assessment.

3.2.11 Note that in the above, and subsequently in this assessment, the term 'noise emission' relates to the sound power level actually radiated from each wind turbine, whereas the term 'noise immission' relates to the sound pressure level (the perceived noise) at any receptor location due to the combined operation of all wind turbines on the Proposed Development.

3.3 Methodology for Assessing Operational Noise – non-turbine sources

3.3.1 Noise from non-wind turbines sources associated with the Proposed Development, such as fixed plant associated with the substation, will be assessed using the BS 4142 standard. This standard provides a method for rating the potential impact of noise from fixed plant installations based on the background noise levels that prevail on a site. This is compared to a "rated level" of noise which is based on the L_{Aeq} level with the potential addition of penalties to account for some characteristics of the sound, considering the context of the situation: this requires consideration of factors such as the nature of the area and, particularly at night-time, the absolute level of the specific noise considered. The impact magnitude is then determined on this basis from negligible through low to medium and high. The impact magnitude is then determined on the basis of the difference between rated level and background, with consideration of these contextual factors:

3.3.2 A difference of around +10 dB is likely to be an indication of a significant adverse impact, depending on context;

3.3.3 A difference of around +5 dB is likely to be an indication of an adverse impact, depending on context; and

3.3.4 A difference of +0 dB or less is an indication of the specific sound source having a low impact, depending on the context.

3.4 Criteria – Construction Noise

3.4.1 BS 5228-1 indicates a number of factors are likely to affect the acceptability of construction noise including site location, existing ambient noise levels, duration of site operations, hours of work, attitude of the site operator and noise characteristics of the work being undertaken.

3.4.2 BS 5228-1 informative Annex E provides example criteria that may be used to consider the magnitude of any construction noise impacts. The criteria do not represent mandatory limits but rather a set of example approaches intended to reflect the type of methods commonly applied to construction noise. The example methods are presented as a range of possible approaches (both facade and free field noise levels, hourly and day-time averaged noise levels) according to the ambient noise characteristics of the area in question, the type of development under consideration, and the expected hours of construction activity. In broad terms, the example criteria are based on a set of fixed limit values which, if exceeded, may result in a large impact unless ambient noise levels (i.e. regularly occurring levels without construction) are sufficiently high to provide a degree of masking of construction noise.

3.4.3 Based on the range of guidance values set out in BS 5228 Annex E, and other reference criteria provided by the World Health Organization (WHO) and Minerals Technical Advice Note 1: Aggregates (MTAN1), the following impact assessment scale has been derived. The values have been chosen in recognition of the relatively low ambient noise typically observed in rural environments. The presented criteria have been normalised to free-field day-time noise levels occurring over a time period, T, equal to the duration of a working day onsite. BS 5228-1 Annex E provides varied definitions for the range of day-time working hours which can be grouped for equal consideration. The values presented in Table 1 have been chosen to relate to day-time hours from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays.

Table 1 - Construction Noise Impact Assessment

Impact	Noise Level dB $L_{Aeq,T}$		Description
	4 weeks or more	up to 4 weeks	
Major	> 75	> 85	Trigger level for noise insulation works, or costs thereof, as set out in E.4 of BS 5228-1.
Moderate	> 65 ≤ 75	> 75 ≤ 85	Most stringent threshold values for potential significant effects given in Annex E of BS 5228-1 for example methods relevant to Proposed Development is exceeded.
Minor	> 55 ≤ 65	> 65 ≤ 75	Noise is likely to be audible, but unlikely to change behaviour. of BS 5228-1 thresholds not exceeded.
Negligible	≤ 55	≤ 65	At least 10 dB below the most stringent criteria provided in of BS 5228-1.
The values presented above relate to noise impacts that occur during working hours from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays. Alternate criteria would apply to noise impacts outside of these hours. For noise impacts 13:00 to 19:00 on Saturdays and 07:00 to 19:00 on Sundays the above thresholds would reduce by 10 dB(A) in each category. For noise impacts 19:00 to 07:00 on any day the above thresholds would reduce by 20 dB(A) in each category.			

3.4.4 When considering the impact of short-term changes in traffic, associated with the construction activities, on existing roads in the vicinity of the Proposed Development, reference can be made to the criteria set out in the Design Manual for Roads and Bridges (DMRB[21]). A classification of magnitudes of changes in the predicted traffic noise level calculated using the CRTN methodology is set out: for short-term changes such as those associated with construction activities, changes of less than 1 dB(A) are considered negligible, 1 to 3 dB(A) is minor, 3 to 5 dB(A) moderate and changes of more than 5 dB(A) constitute a major impact. This classification can be considered in addition to the criteria of Table 1.

3.4.5 Blasting operations can generate airborne pressure waves or “air overpressure”. This covers both those pressure waves generated which are in the frequency range of human audibility (approximately 20 Hz to 20 kHz) as well as infrasonic pressure waves (those with a frequency of below 20 Hz), which, although outside the range of human hearing, can sometimes be felt.

3.4.6 Noise from blasting (i.e. pressure waves in the human audible range) is not considered in the same way as noise from other construction activities due to the fact that a large proportion of the energy contained within pressure waves generated by a blast is at frequencies that are below the lower frequency threshold of human hearing, and that the portion of energy contained within the audible range is generally of low frequency and of smaller magnitude than the infrasonic pressure variations.

3.4.7 The relevant guidance documents advise controlling air overpressure (and hence noise from blasting) through the use of good practices during the setting and detonation of charges as opposed to absolute limits on the levels produced, therefore no absolute limits for air overpressure or noise from blasting will be presented in this assessment.

3.4.8 In accordance with the guidance in BS 6472-2: 2008 and MTAN1, ground vibration caused by blasting operations will be considered acceptable if peak particle velocity (PPV) levels, at the nearest sensitive locations, do not exceed 6 mm/s for 95% of all blasts measured over any 6-month period, and no individual blast exceeds a PPV of 10 mm/s. Because of the difficulties in predicting vibration from blasting operation, this is best controlled in practice where relevant using a testing process, with progressively increased charges, in consultation with the relevant local authority.

21 The Highways Agency, Transport Scotland, Transport Wales and The Department for Regional Development (Northern Ireland) (2020). ‘Design Manual for Roads and Bridges, LA 111 Noise and vibration’, revision 2.

3.5 Criteria - Operational Wind Turbine Noise

3.5.1 The acceptable limits for wind turbine operational noise are clearly defined in the ETSU-R-97 document and these limits should not be breached. Consequently, the test applied to operational noise is whether or not the calculated wind farm noise immission levels at nearby noise sensitive properties lie below the noise limits derived in accordance with ETSU-R-97. Depending on the levels of background noise the satisfaction of the ETSU-R-97 derived limits can lead to a situation whereby, at some locations under some wind conditions and for a certain proportion of the time, the wind farm noise may be audible. However, noise levels at the properties in the vicinity of the Proposed Development will still be within levels considered acceptable under the ETSU-R-97 assessment method.

3.6 Criteria - Operational Non-wind-Turbine Noise

3.6.1 The noise impact of non-turbine sources (substation) will be considered in line with the method of BS 4142 which considers the difference between the source considered and background noise levels, taking into account contextual factors. In particular, a noise level not exceeding 35 dB would be considered low in absolute terms[22]. Table 2 outlines the resulting impact magnitude criteria.

Table 2 – Operational Noise Impact Criteria – non-wind turbine sources

Impact	Description
Major	Rating level exceeds background by 10 dB or more, and is greater than 35 dB(A)
Moderate	Rating level exceeds background by 5 dB to 10 dB, and is greater than 35 dB(A)
Minor	Rating level exceeds background, by a maximum of 5 dB, or is less than 35 dB(A)
Negligible	Rating level equal to, or less than, background and less than 35 dB(A)

3.7 Consultation

3.7.1 Prior to undertaking the background surveys, a summary of the proposed monitoring locations was forwarded to the Environmental Health Department of Powys County Council's (PCC) appointed noise consultant, Dick Bowdler, for comment on 20th March 2024. This consultation was based on a preliminary project layout of 18 turbines which was of a similar shape to the layout now proposed. A response was received on 21st March 2024 from PCC's appointed noise consultant. The response was positive, broadly agreeing the proposed approach and caution was advised when allocating proxy locations, particularly if the survey is influenced by water noise.

3.7.2 A joint site visit took place on 30th April 2024 between Hoare Lea and Dick Bowdler to review the area surrounding the Proposed Development and the vicinity of the then installed measurement locations.

3.7.3 Further consultation on 4th September 2024 was undertaken to review the background noise survey findings and discuss noise limits and access difficulties. The data measured at Wern-heulog Farm was discussed as PCC had initial concerns that further exclusions may be appropriate; however, agreement was reached in the meeting that data for this, and all other survey locations, were appropriate. The final

22 Consideration of the levels set out in Table A1 in Annex A highlights that an external level of 35 dB(A) would be considered low in the context of World Health Organisation guidelines for community noise, as internal levels within habitable spaces would be at least 10 dB lower even with an opened window.

measurement locations were agreed to be representative for the purpose of an ETSU-R-97 assessment and in line with current good practice.

3.7.4 It was also agreed that 40 dB L_{A90} is an appropriate value for the lower fixed portion of the daytime noise limit for residential properties, in accordance with ETSU-R-97 guidance, as discussed below at 5.7.4, provided that the value is also applied as the lower fixed portion of the night-time noise limit to prevent the risk of any increase in noise in the night.

3.7.5 The agreed noise monitoring locations are shown on the plan in Annex B. Further information about the monitoring locations, the equipment used, and pictures of the survey positions are presented in Annex C.

4. Baseline

4.1 General Description

4.1.1 The Proposed Development is located in a rural area of relatively low population density. The noise environment in the surrounding area is generally characterised by 'natural' sources, such as wind disturbed vegetation, birds, farm animals and water course noise. Other sources of noise include distant road traffic from nearby A-roads, other vehicles using intermittent local roads and agricultural vehicle movements in the area.

4.2 Details of the Baseline Background Noise Survey

4.2.1 A total of four noise monitoring locations were agreed with the Local Authority as being representative of the background noise environment for the nearest residences to the Site. The four locations are shown on the plan in Annex B and listed in Table 3. Access was sought and refused at Ffynnonau, Fforest Field campsite, multiple properties in Cregrina including Pen Y Cae, Church House Farm Llanfaredd, Tyn Llwyn, Noyaddllwyd and Belli Bychan. Notwithstanding this, the resulting survey locations are considered to provide suitable coverage for all assessment locations and have been agreed with PCC to be representative.

Table 3 - Background Noise Monitoring Locations (approximate Easting / Northing)

No.	Property	Easting	Northing
1	Graig-yr-onen	311648	253369
2	Wern-heulog Farm	307987	253485
3	Pen y Banc	311852	251077
4	Lower Blaenmilo Farm	309203	249344

4.2.2 The assessment has considered operational noise from the Proposed Development at the monitoring locations noted above, as well as other residential properties: these assessment locations are listed in Table 4. The list of receptor locations is not intended to be exhaustive but sufficient to be representative of noise levels typical of those receptors closest to the Proposed Development. During the initial assessment process, three buildings were noted to be shown on OS mapping to the west of the Proposed Development, labelled Lower Goytre, Upper Goytre and Pen-y-waun. These have subsequently been confirmed to not be habitable dwellings and therefore are not included in this assessment as noise sensitive receptor locations.

4.2.3 The results obtained from the survey positions have been used to represent the background environment expected to occur at other nearby assessment locations. The use of the data in this way is justified by the relatively similar nature of the terrain and distances between the representative measurement properties to the proxy assessment properties, as well as the shared dominant influence of 'natural' sources (particularly at increased wind speeds) as well as location-specific sources (i.e. similar distances to the same road(s) for road traffic noise or watercourse noise) on background noise levels throughout the area. This approach is consistent with the guidance provided by ETSU-R-97 and current good practice as set out in the IOA GPG. For the case of Wern-heulog Farm, which was noted to be influenced by road traffic noise, it was agreed during consultation that its data will only be used as a proxy for properties along the same road (A481) that are typically situated closer to the road that this survey location.

4.2.4 Furthermore, the concerns expressed in the consultation response from the PCC appointed noise consultant on 21st March 2024 were taken into account regarding the potential influence of watercourse noise. This was minimised at the measurement properties where possible. Care was also taken when assigning measurement properties' background noise as proxy to assessment locations, avoiding the use of locations where watercourse noise was evident in the data as proxies unless clearly similar conditions were known at the assessment location. Locations where such representations have been made, and the source of the representations, are represented in Table 4. It is noted that where such representations have been made, the distance between the assessment location and nearest turbine is comparable to, if not greater than, the distance between the reference monitoring location and the nearest turbine.

Table 4 - Assessment properties in the vicinity of the Proposed Development

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Survey Location
Ffynnonau	309263	253036	858	T13	1 - Graig-yr-onen
Fforest Fields Yurts	309956	253107	805	T13	1 - Graig-yr-onen
Fforest Cottages	311006	253970	1175	T16	2 - Wern-heulog Farm
Woodbury	312368	252299	926	T18	1 - Graig-yr-onen
Pen Y Cae	312297	252148	816	T18	1 - Graig-yr-onen
Gwarallt	312184	251495	848	T18	1 - Graig-yr-onen
Pen-y-banc Cregrina	311853	251090	968	T18	3 - Pen-y-banc
Lower Llatho	311452	251021	970	T18	3 - Pen-y-banc
The Park	311832	250577	1453	T18	3 - Pen-y-banc
Penberth	310900	249232	1124	T7	3 - Pen-y-banc
Lower Blaenmilo	309216	249374	864	T1	4 - Lower Blaenmilo Farm
Tyn Llwyn	306935	251176	1345	T3	1 - Graig-yr-onen
Woodcroft	308336	253246	1325	T6	2 - Wern-heulog Farm
Graig-yr-onen*	311637	253342	810	T16	1 - Graig-yr-onen
Penarth	312075	252813	720	T17	1 - Graig-yr-onen
Church House Farm	306889	250746	1332	T3	1 - Graig-yr-onen
Upper Blaenmilo Farm*	309582	250478	681	T8	4 - Lower Blaenmilo Farm
Pen Y Bank Llanfaredd	306947	250359	1342	T3	1 - Graig-yr-onen
Treallt	307564	252659	1180	T6	1 - Graig-yr-onen
** Noise assessment properties that are financially involved with the Proposed Development*					

4.2.5 The background noise monitoring exercise was conducted over a period of just over four weeks between April and May 2024. The equipment used for the survey comprised four Rion NL-52 logging sound level meters, a Davis tipping-bucket rain gauges and an onsite LiDAR unit. All meters were enclosed in environmental cases and continuously logged at the required ten-minute averaging periods. Outdoor enhanced windshield systems were used to reduce wind induced noise on the microphones and provide protection from rain. These windshield systems were supplied by the sound level meter manufacturer and maintain the required performance of the whole measurement system when fitted. The environmental enclosures provided an installed microphone height of approximately 1.2 to 1.5 metres above ground level, consistent with the requirements of ETSU-R-97.

4.2.6 The sound level meters were located on the wind farm side of the property in question where possible, never closer than 3.5 metres from the façade of the property and as far away as was practical from obvious atypical, localised sources of noise such as running water, trees or boiler flues. Details and photographs of the measurement locations are presented in Annex C.

4.2.7 Measurement systems were calibrated on their deployment on 11th or 12th of April 2024 and upon collection of the equipment on the 8th or 9th of May 2024. In the case of measurement location 2, Wern-heulog Farm, the measurement system had to be restarted on 17th April 2024, when it was recalibrated and again on collection on the 24th May 2024. No acoustically important (>0.5 dB(A)) drifts in calibration were found to have occurred on any of the systems. This equates to a total ETSU-R-97 analysis period of at least 26 days for each location, which is in excess of the minimum of one week suggested by ETSU-R-97 and is compliant with the IOA GPG requirements.

4.2.8 All measurement systems were set to log the $L_{A90,10min}$ and $L_{Aeq,10min}$ noise levels continuously over the deployment period. The internal clocks on the sound level meters were all synchronized with Greenwich Mean Time (GMT) by the use of a Global Positioning System (GPS) receiver. The clock on the LiDAR from which wind data was subsequently collected for the analysis of the measured background noise as function of wind speed was also set to GMT.

4.3 Measured Background Noise Levels

4.3.1 The ETSU-R-97 assessment method requires noise data to be related to wind speed data at a standardised height of ten metres, with wind speeds either directly measured at a height of ten metres or by calculation from measurement at other heights, the appropriate choice being determined by practitioner judgement and the available data sources. Since the publication of ETSU-R-97, the change in wind speed with increasing height above ground level has been identified as a potential source of variability when carrying out wind farm noise assessments. The effect of site-specific wind shear can be appropriately addressed by implementing the ETSU-R-97 option of deriving ten metre height reference data from measurements made at taller heights. It is this method that has been used in the noise assessment for the Proposed Development to account for the potential effect of site-specific wind shear. This method is consistent with the preferred method described in the IOA GPG. Wind speeds were measured using the LiDAR at multiple heights, including 125m, located within the boundary of the development site. Values of wind speed at a standardised height of ten metres were calculated from those measured on the LiDAR ("standardised wind speed"). Full details of the calculation method are given in Annex F.

4.3.2 Figures D1 and D4 reproduced at Annex D show the range of wind conditions experienced during the noise survey period. During the quiet day-time and night-time periods wind speeds of up to 11 m/s were generally experienced. For measurement location 2, Wern-heulog Farm, where a slightly different measurement period was captured, wind speeds of up to 9 m/s were experienced. The wind was observed to be directed from the south-west for the majority of the survey period, consistent with the typical prevailing wind direction for the UK.

4.3.3 Figures E1 to E8 of Annex E show the results of the background noise measurements at each of the four locations. The background noise data are presented in terms of $L_{A90,10min}$ background noise levels plotted as a function of standardised ten metre height wind speed. Two plots are shown for each location, one for quiet day-time periods and the other for night-time periods, both derived in accordance with ETSU-R-97.

4.3.4 Data from all survey locations were inspected to identify periods which may have been influenced by extraneous noise sources, giving rise to atypical and elevated levels. ETSU-R-97 requires that any data affected by rainfall be excluded from the analysis. A rain gauge was installed at location 3, Pen y Banc; data from this gauge were therefore used to exclude those periods where rain was indicated. The rain gauge was moved on 9th May 2024 to location 2, Wern-heulog Farm, for the remainder of the measurement campaign.

4.3.5 In addition to the impact noise on surrounding vegetation and the sound level meter itself, in some environments, rainfall can result in appreciable changes in background sound levels, for example as a result of wet roads which increase tyre noise emissions or dissipating flow noise in water courses and drainage systems. Observations whilst on site indicated traffic noise to be an influence on background sound levels at Wern-heulog Farm, and thus the possible effect of increased tyre noise from wet roads was considered potentially relevant at that property, but did not appear to substantially affect the measurement data. In terms of water flow noise, the site and surrounding area consists of hills, valleys and uneven terrain, where water courses were considered likely to influence background noise levels. Careful selection of monitoring locations, and the positioning of the equipment at each location helped minimise watercourse noise through screening from buildings, terrain and increased separation distances.

4.3.6 The measured background noise data may also have been increased by other extraneous sources or atypical events. Time-histories of the noise levels at each survey location were therefore inspected to look for any atypical relationships when compared to the wind speeds present during that time. Any elevated levels found in this way were excluded. The trend of the data when plotted against wind speed was also inspected to look for atypical relationships or outliers within the data-set (particularly at low wind speeds) which were excluded. Data were also discarded if measured during the dawn chorus. Any data removed from the analysis in this way is indicated on the charts as red circles. The analysis and filtering of the data was therefore undertaken in accordance with current good practice as set out in the IOA GPG.

4.3.7 Following removal of those data points, best-fit lines were generated using a polynomial fit of a maximum of 4th order. These lines of best-fit define the ETSU-R-97 background noise levels (see Table 5 and Table 6) which were then used to derive the noise limits required by ETSU-R-97 that apply during the day-time and night-time periods up to 12 m/s. The corresponding ETSU-R-97 noise limits are summarised in Table 7 and Table 8. The noise limits have been set either at the prevailing measured background level plus 5 dB, or at the relevant fixed lower limit, whichever is the greater. The derivation of the relevant fixed lower limit value used for day-time and night-time periods (40 dB(A)), agreed in consultation with PCC (see Section 3.7) is described in a section 5.7. For involved properties the lower absolute limit becomes 45 dB(A) for day-time and night-time periods.

Table 5 - Day time L_{A90} (dB) background noise levels from the baseline noise survey according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
1 - Graig-yr-onen	26.3	27.0	27.7	28.4	29.2	30.0	30.8	31.7	32.5	33.4	34.3	-
2 - Wern-heulog Farm	35.4	35.3	35.3	35.3	35.4	35.6	35.9	36.2	-	-	-	-
3 - Pen-y-banc	26.7	26.9	27.5	28.5	29.9	31.7	33.8	36.4	39.3	42.6	-	-
4 - Lower Blaenmilo Farm	29.1	30.9	31.9	32.6	33.3	34.2	35.4	36.8	38.2	39.2	39.5	-

Table 6 - Night time L_{A90} (dB) background noise levels from the baseline noise survey according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
1 - Graig-yr-onen	21.0	20.0	19.6	19.7	20.3	21.5	23.2	25.5	28.3	31.6	35.5	39.9
2 - Wern-heulog Farm	22.4	22.0	22.0	22.5	23.5	25.0	26.9	29.3	32.2	-	-	-
3 - Pen-y-banc	22.1	20.9	20.8	21.7	23.4	25.9	29.0	32.5	36.4	40.6	44.9	49.2
4 - Lower Blaenmilo Farm	25.8	25.8	26.1	26.6	27.3	28.2	29.5	31.2	33.5	36.7	41.0	46.8

Table 7 - Day time L_{A90} (dB) noise limits derived from the baseline noise survey according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
1 - Graig-yr-onen	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
2 - Wern-heulog Farm	40.3	40.3	40.3	40.3	40.4	40.6	40.9	41.2	41.2	41.2	41.2	41.2
3 - Pen-y-banc	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.4	44.3	47.6	47.6	47.6
4 - Lower Blaenmilo Farm	40.0	40.0	40.0	40.0	40.0	40.0	40.4	41.8	43.2	44.2	44.5	44.5

Table 8 - Night time L_{A90} (dB) noise limits derived from the baseline noise survey according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
1 - Graig-yr-onen	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.5	44.9
2 - Wern-heulog Farm	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
3 - Pen-y-banc	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.4	45.6	49.9	49.9
4 - Lower Blaenmilo Farm	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.7	46.0	51.8

5. Noise Impact Assessment

5.1 Predicted Construction Noise Levels

5.1.1 The level of construction noise that occurs at the surrounding properties will be highly dependent on a number of factors such as the final construction programme, equipment types used for each process, and the operating conditions that prevail during construction. It is not practically feasible to specify each and every element of the factors that may affect noise levels, therefore it is necessary to make reasonable allowance for the level of noise emissions that may be associated with key phases of the construction.

5.1.2 In order to determine representative emission levels for this study, reference has been made to the scheduled sound power data provided by BS 5228. Based on experience of the types and number of equipment usually associated with the key phases of constructing a wind farm, the scheduled sound power data has been used to deduce the upper sound emission level over the course of a working day.

In determining the rating applicable to the working day, it has generally been assumed that the plant will operate for between 75% and 100% of the working day. In many instances, the plant will actually be expected to operate for a reduced percentage, thus resulting in noise levels lower than predicted in this assessment.

5.1.3 To relate the sound power emissions to predicted noise levels at surrounding properties, the prediction methodology outlined in BS 5228 has been adopted. The prediction method accounts for factors including screening and soft ground attenuation. The size of the site and resulting separation distances to surrounding properties allows the calculations to be reliably based on positioning all the equipment at a single point within a particular working area (for example, in the case of turbine erection, it is reasonable to assume all associated construction plant is positioned at the base of the turbine under consideration). In applying the BS 5228 methodology, it has been conservatively assumed that there are no screening effects, and that the ground cover is characterised as 50% hard / 50% soft.

5.1.4 Table 9 lists the key construction activities, the associated types of plant normally involved, the expected worst-case sound power level over a working day for each activity, the property which will be closest to the activity for a portion of construction, and the predicted noise level. It must be emphasised that these predictions only relate the noise level occurring during the time when the activity is closest to the referenced property. In many cases such as access track construction and turbine erection, the separating distances will be considerably greater for the majority of the construction period and the predictions are therefore the worst-case periods of the construction phase.

Table 9 - Predicted construction noise levels

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq}
Construct site entrance access	excavator / dump trucks / tippers / dozers / vibrating rollers	121	Craiglea (312015 / 253417)	25	85
Upgrade Access Track	excavator / dump trucks / tippers / dozers / vibrating rollers	121	Graig-yr-onen	120	70
Construct temporary site compounds (Non-financially involved (non-FI) property)	excavator / dump truck / tippers / rollers/ delivery trucks	118	Craiglea	330	57
Construct temporary site compounds (Nearest FI property)	excavator / dump truck / tippers / rollers/ delivery trucks	118	Graig-yr-onen	90	70
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	118	Fforest Field Yurts	670	50
Construct Sub-Station	excavator / concrete truck / delivery truck	112	Tynrheol (308629 / 253534) & Woodcroft	120	61
Construct crane hardstandings	excavators / dump trucks	116	Penarth	610	49
Construct turbine foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes /	121	Penarth	610	54

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq}
	water pumps / pneumatic hammers / compressors / vibratory pokers				
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	117	Upper Blaenmilo Farm	630	50
Reinstate crane bases	excavator / dump truck	115	Penarth	610	45
Reinstate road verges	excavator / dump truck	115	Graig-yr-onen	120	62
Lay cable to sub-stations	JCB / saws / hydraulic breaker / dump truck/ tipper / wacker plate / tandem roller / tractor & cable drum trailer / delivery truck	115	Woodcroft	140	61
Borrow Pit Quarrying	Primary and secondary stone Crushers / excavators / screening systems / pneumatic breakers / conveyors	127	Penarth	480	63
Concrete Batching	Batching Plant	110	Penarth	610	40

5.1.5 Comparing the above predicted noise levels to the range of background noise levels measured around the Proposed Development suggests that the noisier construction activities will be audible at various times throughout the construction phase. However, comparing the levels to the significance criteria presented previously indicates that the majority of construction activities will have impacts of negligible to minor magnitude.

5.1.6 For the site entrance works and the upgrade of access tracks which are closest to Craiglea and Graig-yr-onen respectively, predicted noise levels of 85 dB(A) are likely to represent those for a very short-term period when activity is closest to the receptor. Noise levels will quickly diminish as construction progresses, moving the activity further from the property. The short-term nature of this activity consequently categorises these impacts to be of minor magnitude, although there is a likelihood of moderate impacts at Craiglea based on the worst-case assumptions made. At Graig-yr-onen, the financially involved nature of the property will reduce the temporary impact of construction noise in practice such that a minor impact would result based on professional judgement. Additional measures should be taken to minimise the impact of the Site entrance construction works, such as liaison with the affected residents at Craiglea for works in proximity to the property and use of quieter construction techniques where reasonably practicable. These measures, and the relative short duration of the works, similar to road improvement works, will reduce these impacts to a minor magnitude.

5.1.7 Construction activity noise related to the temporary site compounds is predicted to reach levels of 70 dB L_{Aeq} at the Graig-yr-onen property. However, the short-term nature of the works involved, and the involved status of this receptor consequently categorises these impacts to be of minor magnitude.

5.1.8 In addition to on-site activities, construction traffic passing to and from the site will also represent a potential source of noise to surrounding properties. The traffic statement for the proposal presented in Technical Appendix 11.1: Transport Assessment has identified that the most intensive traffic would occur in months 8 and 9 of construction. Specifically the highest volume of traffic generated by construction is expected to occur in the modify month of construction in which an average of 244 total vehicle daily trips (two way) are predicted. Table 4 and Table 12 of Technical Appendix 11.1: Transport Assessment have been used to ascertain the projected traffic flows for scenarios without and with the Proposed Development, in 2028.

5.1.9 The predicted construction traffic flow values on two of the identified roads surrounding the Proposed Development are below the minimum flow volume of 1000 vehicles per day that is required by the CRTN methodology to enable reliable predictions. Assessment of construction traffic noise along these two routes are therefore based on the prediction methodology in BS 5288.

Table 10 - Projected traffic flows

Road	Without Development		With Development	
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles
C1336, near Site Access	159	3.8%	403	44.2%
A481, west of access to Fforest Fields	1046	7.7%	1164	13.5%
A481, west of A481 / A44 priority junction	785	27.8%	915	34.5%
A44, east of A481 / A44 priority junction	2603	26.5%	2727	28.9%
A44, southwest of New Radnor	2666	6.7%	2790	9.9%
A44, north of A481 / A44 priority junction	1967	23.8%	1973	23.7%
A44, east of Crossgates	4356	6.8%	4362	6.8%
A483, south of Crossgates	7427	3.4%	7433	3.4%
A483, Llandrindod Wells	6473	2.4%	6505	2.4%
A483, Ridgebourne	7064	3.0%	7096	3.0%
A483, east of A483 / A470 roundabout	6366	5.3%	6392	5.5%
A483, north of Wye Bridge	9644	5.7%	9670	5.8%
A470, Aberduhonw	5341	7.3%	5353	7.3%
A470, south of Erwood	6329	5.6%	6341	5.6%
A470, north of A470 / A438 priority junction	4183	6.0%	4195	6.0%

Table 11 - CRTN predicted increase in day time average traffic noise levels ($L_{A10,18hour}$)

Road/Link	Maximum Change in Traffic Noise Level, dB(A)	Magnitude of Impact
C1336, near Site Access	<1000 vehicles/day	See paragraph 5.1.10

Road/Link	Maximum Change in Traffic Noise Level, dB(A)	Magnitude of Impact
A481, west of access to Fforest Fields	1.9	Minor
A481, west of A481 / A44 priority junction	<1000 vehicles/day	See paragraph 5.1.10
A44, east of A481 / A44 priority junction	0.5	Negligible
A44, southwest of New Radnor	0.8	Negligible
A44, north of A481 / A44 priority junction	0.0	No Change
A44, east of Crossgates	0.0	No Change
A483, south of Crossgates	0.0	No Change
A483, Llandrindod Wells	0.0	No Change
A483, Ridgebourne	0.0	No Change
A483, east of A483 / A470 roundabout	0.1	No Change
A483, north of Wye Bridge	0.0	No Change
A470, Aberduhonw	0.0	No Change
A470, south of Erwood	0.0	No Change
A470, north of A470 / A438 priority junction	0.0	No Change

5.1.10 The nearest sensitive receiver locations in respect of vehicle movements along the C1336, near Site access route and the A481 road, west of access to Fforest Fields are Craiglea and Penfforest (309753 / 253845) respectively, which lie relatively close to the midsection of these routes, at a distance of 15 and 10 metres or more respectively. Large heavy goods vehicles can generate noise levels in the order of 108 dB (sound power level) when in motion. However, these types of plant usually pass a receiver location quite quickly. When stationary the same vehicles will be operating in idle which considerably lowers the noise output to the environment. Based on the prediction methodology in BS 5288 and accounting for 14 two way large vehicle trips on each route, moving at an estimated 70 km/h and 88 km/h on both routes respectively, the predicted noise level at those dwellings are 58 dB and 56 dB $L_{Aeq,T}$ respectively. Based on the assessment criteria of BS 5288, these noise levels correspond to a minor impact magnitude for both routes, at worst during the two peak construction months 8 and 9.

5.1.11 The review in Technical Appendix 11.1: Transport Assessment did not identify any cumulative onshore wind farm or energy related consented developments which should be included within the traffic assessment. Therefore no cumulative construction traffic noise impacts are expected.

5.1.12 In conclusion, noise from construction activities and associated construction traffic have been assessed and is predicted to result in a temporary minor impact at most.

5.1.13 This conclusion is based on construction activities generally being limited to the following working hours: from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays. However, activities that are unlikely to give rise to noise audible at the Site boundary may continue outside of the stated hours. Furthermore, turbine deliveries may take place outside these times with the prior consent of the relevant authorities. In addition, good practice measures recommended in BS 5228-1 will be implemented to minimise construction noise levels, as described in Chapter 10 of the ES.

5.2 Construction Noise and Vibration Levels – Blasting

5.2.1 Because of the difficulties in predicting noise and air overpressure resulting from blasting operations at onsite borrow pits, these activities are best controlled following the use of good practice during the setting and detonation of charges, as set out earlier in this report.

5.2.2 The transmission and magnitude of ground vibrations associated with blasting operations at borrow pits are subject to many complex influences including charge type and position, and importantly, the precise nature of the ground conditions (material composition, compaction, discontinuities) at the source, receiver, and at every point along all potential ground transmission paths. Clearly any estimation of such conditions is subject to considerable uncertainty, thus limiting the utility of predictive exercises. Mitigation of the impacts of these activities is best achieved through onsite testing processes carried out in consultation with the Local Authorities, as described in chapter 10 of the ES.

5.3 Operational Wind Turbine Emissions Data

5.3.1 The exact model of turbine to be used will be the result of a future tendering process and therefore a representative turbine model has been assumed for this noise assessment. This operational noise assessment is based upon the noise specification of the Nordex N163 wind turbine. 18 turbines have been modelled using the layout as indicated on the map at Annex B. The candidate turbine is a variable speed, pitch regulated machine with a rotor diameter of 163 metres and a hub height of 118.5 metres. Due to its variable speed operation the sound power output of the Nordex N163 turbine varies considerably with wind speed, being quieter at the lower wind speeds when the blades are rotating more slowly. The candidate turbine also incorporates the use of Serrated Trailing Edges (or STE), which reduce noise emissions, as standard. Data for the "6.X" variant of the turbine, with generation capacity of up to 7MW, was considered as the basis for the analysis. The data assumed for the Proposed Development is considered likely to represent the upper range of noise emissions for turbines typical for the Proposed Development.

5.3.2 The candidate turbine also incorporates noise control technology. This allows the sound power output of the turbine to be reduced across a range of operational wind speeds, albeit with some loss of electrical power generation, to enable the best compromise to be achieved in any given situation between emitted noise and electrical power generation. Noise control of the candidate turbine is provided in a number of noise control modes with various noise/power output combinations. Similar noise reduction management systems are also offered by other wind turbine manufacturers. These systems are generally similar in that they rely on the turbine's computer-based controller adjusting either the pitch of the blades or holding back the rotational speed of the blades to reduce emitted noise under selected wind conditions (direction, speed or some combination of the two). In this manner noise management only comes into play (and therefore potential power generation capacity is only lost) for those conditions under which it is required.

5.3.3 For the purposes of the assessment, the wind turbines on the Proposed Development have been modelled assuming that:

- T13 and T14 operate in noise reduced mode 5.a,
- T16 operates in noise reduced mode 3.a,
- T7 operates in reduced noise mode 2.a and
- All other turbines operate in their standard mode (mode 0.b).

5.3.4 Nordex have supplied specified noise emission data for the N163 turbine which has been derived from various manufacturers sound power tests. In the absence of specific information about uncertainty allowances in the data, a further correction factor of +2 dB was added to the specification data in line with advice in the IOA GPG. The sound power data has been made available for standardised reference wind speeds of 3 m/s to 12 m/s inclusive. In addition to the overall sound power data, reference has been made to specified sound spectrum data for the N163 Nordex turbine, based on an energetic average of the available third octave band information to calculate each octave band. The overall sound power and spectral data are presented in Table B3 and B4 in Annex B.

5.3.5 Assessment of the cumulative noise from operating the Proposed Development with other wind farms requires source information for the turbine types similar to that discussed above for the Proposed Development for each wind farm to be considered. Potential cumulative noise emissions from the single turbine at Tremaen is considered below in paragraph 5.6.1.

5.4 Choice of Wind Farm Operational Noise Propagation Model

5.4.1 The ISO 9613-2 model[23] has been used to calculate the noise immission levels at the selected nearest residential neighbours as advised in the IOA GPG. The model accounts for the attenuation due to geometric spreading, atmospheric absorption, and barrier and ground effects. All attenuation calculations have been made on an octave band basis and therefore account for the sound frequency characteristics of the turbines.

5.4.2 For the purposes of this assessment, all noise level predictions have been undertaken using a receiver height of four metres above local ground level, mixed ground (G=0.5) and an air absorption based on a temperature of 10°C and 70% relative humidity A receiver height of four metres will be typical of first floor windows and result in slightly higher predicted noise levels than if a 1.2 to 1.5 metre receiver height were chosen in the ISO 9613 algorithm. The attenuation due to terrain screening accounted for in the calculations has been limited to a maximum of 2 dB(A). In situations of propagation above concave ground, a correction of +3dB was added. These propagation factors are shown in Annex B.

5.4.3 This method is consistent with the recommendations of the above-referenced Institute of Acoustics Good Practice Guide which provides recommendations on the appropriate approach when predicting wind turbine noise levels. The IOA GPG also allows for directional effects to be taken into account within the noise modelling: under upwind propagation conditions between a given receiver and the wind farm the noise immission level at that receiver can be as much as 10 dB(A) to 15 dB(A) lower than the level predicted using the ISO 9613-2 model. However, predictions have been made assuming downwind propagation from every turbine to every receptor at the same time as a worst-case.

5.5 Predicted Wind Turbine Operational Noise Immission Levels

5.5.1 Table 12 shows predicted noise immission levels for the Proposed Development in isolation at each of the selected assessment locations for each wind speed over the range of wind speeds where source noise emission level data are available. All wind farm noise immission levels in this report are presented in terms of the L_{A90} noise indicator in accordance with the recommendations of the ETSU-R-97 report, obtained by subtracting 2 dB(A) from the calculated L_{Aeq} noise levels based on the turbine sound power levels presented in Annex B.

23 ISO 9613-2:1996 'Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation', International Standards Organisation, 1996.

Table 12 - Predicted L_{A90} (dB) wind farm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the Proposed Development alone.

Property	Standardised 10 m Wind Speed (m/s)										
	1	2	3	4	5	6	7	8	9	10	11	12
Ffynnonau	-	-	28.2	29.8	34.6	38.5	39.0	39.0	39.0	39.0	39.0	39.0
Fforest Fields Yurts	-	-	29.5	31.1	35.9	39.6	40.0	40.0	40.0	40.0	40.0	40.0
Fforest Cottages	-	-	24.9	26.5	31.3	35.4	35.9	35.9	35.9	35.9	35.9	35.9
Woodbury	-	-	26.7	28.3	33.1	37.4	38.2	38.2	38.2	38.2	38.2	38.2
Pen Y Cae	-	-	26.9	28.5	33.3	37.6	38.4	38.4	38.4	38.4	38.4	38.4
Gwarallt	-	-	26.7	28.3	33.1	37.4	38.1	38.1	38.1	38.1	38.1	38.1
Pen-y-banc Cregrina	-	-	28.2	29.8	34.6	38.9	39.6	39.6	39.6	39.6	39.6	39.6
Lower Llatho	-	-	28.4	30.0	34.8	39.1	39.8	39.8	39.8	39.8	39.8	39.8
The Park	-	-	25.3	26.9	31.7	36.0	36.7	36.7	36.7	36.7	36.7	36.7
Penberth	-	-	25.3	26.9	31.7	36.0	36.6	36.6	36.6	36.6	36.6	36.6
Lower Blaenmilo	-	-	28.7	30.3	35.1	39.4	40.0	40.0	40.0	40.0	40.0	40.0
Tyn Llwyn	-	-	24.2	25.8	30.6	35.0	35.8	35.8	35.8	35.8	35.8	35.8
Woodcroft	-	-	24.9	26.5	31.3	35.5	36.2	36.2	36.2	36.2	36.2	36.2
Graig-yr-onen*	-	-	28.4	30.0	34.8	39.0	39.5	39.5	39.5	39.5	39.5	39.5
Penarth	-	-	28.7	30.3	35.1	39.4	40.0	40.0	40.0	40.0	40.0	40.0
Church House Farm	-	-	24.1	25.7	30.5	34.8	35.6	35.6	35.6	35.6	35.6	35.6
Upper Blaenmilo Farm*	-	-	32.3	33.9	38.7	43.0	43.7	43.7	43.7	43.7	43.7	43.7
Pen Y Bank Llanfaredd	-	-	24.0	25.6	30.4	34.7	35.5	35.5	35.5	35.5	35.5	35.5
Treallt	-	-	24.2	25.8	30.6	34.9	35.6	35.6	35.6	35.6	35.6	35.6

5.6 Cumulative considerations

5.6.1 There is a smaller, operational wind turbine near to the Proposed Development. A single wind turbine with a hub height of 20.6 m and a tip height of 27 m is in operation near the Tremaen property (Planning Reference P/2013/0489). No information was found as to the make or model of the turbine or the likely noise levels it produces. The planning consent includes condition 9 which limits the operational noise from the turbine to 35 dB L_{A90} at any existing residential property. Noise impact from such small-scale turbines tend to be limited to the area immediately around them. One of the assessment locations, Treallt, is noted to be over 420 m away from this small turbine. Whilst it is noted that there are two other properties slightly closer to this turbine, they are also situated further from the Proposed Development. Whilst it is not anticipated that such a small turbine will be likely to generate 35 dB L_{A90} at this distance, it was assumed to do so for the purpose of presenting a precautionary cumulative noise assessment. The Proposed Development is calculated to produce a noise immission level just below 36 dB L_{A90} at this dwelling; therefore, the cumulative total with this existing small turbine (assuming it is operating at its limits) is below 39 dB L_{A90}. This is clearly below the derived noise limits of 40 dB L_{A90} which applies at Treallt. Lower noise levels will be experienced at other noise-sensitive locations located further away from this turbine and similar conclusions will be reached.

5.6.2 The Proposed Development is located approximately 7 km from Hendy Wind Farm and 9 km from Nant Mithil Wind Farm. At these separation distances, the cumulative noise contribution from each of these wind farms would be negligible at the assessment receptors considered for the Proposed Development.

5.6.3 The above demonstrates that existing wind turbine and the proposed wind farms currently in the planning system which are situated near to the Proposed Development will not cumulatively impact the noise impact assessment for the Proposed Development. Therefore, no further consideration has been given to potential cumulative effects.

5.7 ETSU-R-97 assessment

5.7.1 Figures E1 to E10 (Annex E) show the calculated wind farm noise immission levels at five representative noise assessment locations, which correspond to those already presented in Table 12 plotted as a function of standardised wind speed. For each noise measurement location, the corresponding noise assessment locations having the highest predicted noise levels are shown and so these charts represent assessment locations with the greatest impacts. For the case of measurement location 4, Lower Blaemilo Farm, predictions are also provided for Upper Blaemilo Farm which is financially involved. The calculated noise immission levels are shown overlaid on the day-time and night-time noise limit curves. These limits curves have been derived by calculating best-fit regression lines through the measured background noise data to give the prevailing background noise curve required by ETSU-R-97. The noise limits have then been set either at the prevailing measured background level plus 5 dB or at the relevant fixed lower limit whichever is the greater.

5.7.2 The ETSU-R-97 noise limits assume that the wind turbine noise contains no audible tones. Where tones are present a correction is added to the measured or predicted noise level before comparison with the recommended limits. The audibility of any tones can be assessed by comparing the narrow band level of such tones with the masking level contained in a band of frequencies around the tone called the critical band. The ETSU-R-97 recommendations suggest a tone correction which depends on the amount by which the tone exceeds the audibility threshold and should be included as part of the consent conditions. The turbines to be used for this site will be chosen to ensure that the noise emitted will comply with the requirements of ETSU-R-97 including any relevant tonality corrections.

5.7.3 The assessment (shown in tabular form in Table 13 and Table 14) shows that the predicted wind farm noise immission levels from the Proposed Development meet the ETSU-R-97 derived noise limits under all wind speeds and at all locations, based on a lower day-time limit of 40 dB(A). Graig-yr-onen and Upper Blaenmilo Farm are all considered as financially involved properties and the lower absolute limit is therefore 45 dB(A).

Table 13 - Difference between the ETSU-R-97 derived day time noise limits and the predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on 40 dB(A) lower day time limit and negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Ffynnonau	-	-	-11.9	-10.3	-5.5	-1.6	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Fforest Field Yurts	-	-	-10.5	-8.9	-4.1	-0.4	0.0	0.0	0.0	0.0	0.0	0.0
Fforest Cottages	-	-	-15.3	-13.8	-9.1	-5.2	-5.0	-5.3	-5.3	-5.3	-5.3	-5.3
Woodbury	-	-	-13.3	-11.7	-6.9	-2.6	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8
Pen Y Cae	-	-	-13.1	-11.5	-6.7	-2.4	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Gwarallt	-	-	-13.3	-11.7	-6.9	-2.6	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9
Pen-y-banc Cregrina	-	-	-11.8	-10.2	-5.4	-1.1	-0.4	-1.7	-4.7	-8.0	-8.0	-8.0
Lower Llatho	-	-	-11.6	-10.0	-5.2	-0.9	-0.2	-1.6	-4.5	-7.8	-7.8	-7.8
The Park	-	-	-14.7	-13.1	-8.3	-4.0	-3.3	-4.7	-7.6	-10.9	-10.9	-10.9
Penberth	-	-	-14.7	-13.1	-8.3	-4.0	-3.4	-4.8	-7.7	-11.0	-11.0	-11.0
Lower Blaenmilo	-	-	-11.4	-9.8	-5.0	-0.6	-0.4	-1.8	-3.2	-4.2	-4.5	-4.5
Tyn Llwyn	-	-	-15.8	-14.2	-9.4	-5.0	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2
Woodcroft	-	-	-15.4	-13.8	-9.1	-5.1	-4.7	-5.1	-5.1	-5.1	-5.1	-5.1
Graig-yr-onen*	-	-	-11.6	-10.0	-5.2	-1.1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Penarth	-	-	-11.3	-9.7	-4.9	-0.6	0.0	0.0	0.0	0.0	0.0	0.0
Church House Farm	-	-	-15.9	-14.3	-9.5	-5.2	-4.4	-4.4	-4.4	-4.4	-4.4	-4.4
Upper Blaenmilo Farm*	-	-	-12.7	-11.1	-6.3	-2.0	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
Pen Y Bank Llanfaredd	-	-	-16.1	-14.5	-9.7	-5.3	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5
Treallt	-	-	-15.8	-14.2	-9.4	-5.1	-4.4	-4.4	-4.4	-4.4	-4.4	-4.4

Table 14 - Difference between the ETSU-R-97 derived night time noise limits and the predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on 40 dB(A) lower night time limit and negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)										
	1	2	3	4	5	6	7	8	9	10	11	12
Ffynnonau	-	-	-11.9	-10.3	-5.5	-1.6	-1.0	-1.0	-1.0	-1.0	-1.5	-5.9
Fforest Field Yurts	-	-	-10.5	-8.9	-4.1	-0.4	0.0	0.0	0.0	0.0	-0.5	-4.9
Fforest Cottages	-	-	-15.1	-13.5	-8.7	-4.6	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1
Woodbury	-	-	-13.3	-11.7	-6.9	-2.6	-1.8	-1.8	-1.8	-1.8	-2.3	-6.7
Pen Y Cae	-	-	-13.1	-11.5	-6.7	-2.4	-1.7	-1.7	-1.7	-1.7	-2.1	-6.6
Gwarallt	-	-	-13.3	-11.7	-6.9	-2.6	-1.9	-1.9	-1.9	-1.9	-2.4	-6.8
Pen-y-banc Cregrina	-	-	-11.8	-10.2	-5.4	-1.1	-0.4	-0.4	-1.8	-6.0	-10.3	-10.3
Lower Llatho	-	-	-11.6	-10.0	-5.2	-0.9	-0.2	-0.2	-1.6	-5.8	-10.1	-10.1
The Park	-	-	-14.7	-13.1	-8.3	-4.0	-3.3	-3.3	-4.8	-8.9	-13.2	-13.2
Penberth	-	-	-14.7	-13.1	-8.3	-4.0	-3.4	-3.4	-4.8	-9.0	-13.3	-13.3
Lower Blaenmilo	-	-	-11.4	-9.8	-5.0	-0.6	0.0	0.0	0.0	-1.6	-6.0	-11.7
Tyn Llwyn	-	-	-15.8	-14.2	-9.4	-5.0	-4.2	-4.2	-4.2	-4.2	-4.7	-9.1
Woodcroft	-	-	-15.1	-13.5	-8.7	-4.5	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9
Graig-yr-onen*	-	-	-11.6	-10.0	-5.2	-1.1	-0.5	-0.5	-0.5	-0.5	-1.0	-5.4
Penarth	-	-	-11.3	-9.7	-4.9	-0.6	0.0	0.0	0.0	0.0	-0.5	-4.9
Church House Farm	-	-	-15.9	-14.3	-9.5	-5.2	-4.4	-4.4	-4.4	-4.4	-4.9	-9.3
Upper Blaenmilo Farm*	-	-	-12.7	-11.1	-6.3	-2.0	-1.3	-1.3	-1.3	-1.3	-2.3	-8.1
Pen Y Bank Llanfaredd	-	-	-16.1	-14.5	-9.7	-5.3	-4.5	-4.5	-4.5	-4.5	-5.0	-9.4
Treallt	-	-	-15.8	-14.2	-9.4	-5.1	-4.4	-4.4	-4.4	-4.4	-4.9	-9.3

5.7.4 The ETSU-R-97 fixed part of the limit during the day-time should lie within the range from 35 dB(A) to 40 dB(A). The factors to be used to determine where in this range have been discussed above. These are discussed in turn below:

- Number of properties: There is a moderate number of individual properties affected by noise from the Proposed Development, however its surroundings are generally of low population density, with a limited number of surrounding properties.
- Duration and level of exposure: The level of exposure in terms of comparing the turbine noise (from the Proposed Development) relative to background noise shows that predicted levels from the Proposed Development are sometimes comparable the range of measured baseline levels in quiet conditions during the day-time, and in other cases higher with different margins. The predictions are however based on downwind conditions (wind blowing from source to receiver), and the actual levels which occur in practice will be considerably lower (10 dB(A) to 15 dB(A)) under upwind conditions, particularly for properties located to the west or south of the project given the prevailing south-westerly wind direction in the UK.

- Generation capacity: The effect that having a limit at the lower end of this range would have on the number of turbines installed would be substantial. Furthermore, the relatively large generation capacity of the site (more than 90 MW) is a relevant consideration. The power generating capacity of modern wind turbines has dramatically increased over that which was typical at the time the ETSU-R-97 guidelines were produced. For example, at the time the guide was produced, a wind farm site comprising more than 150 turbines would have been required to achieve a similar generating capacity to that of the Proposed Development, thus highlighting the significance of the scheme.

5.7.5 The above factors are to be considered together in the context of the Proposed Development, other nearby wind energy schemes, as well as the local environment at receptor locations which may be affected by noise from the Proposed Development. By defining this range within ETSU-R-97, it is clear that there must be circumstances where accounting for the above factors would lead to a value of 40 dB(A) and conversely where such factors would lead to a value of 35 dB(A), or somewhere within this range. It is also clear that ETSU-R-97 does not propose there to be a default choice within this range.

5.7.6 Based on the above considerations, it is considered appropriate to set the limit toward the upper end of the range, at 40 dB(A). This was also agreed in discussions PCC's appointed noise consultant (see section 3.7). The Proposed Development has also been designed such that noise levels can also meet a night-time limit based on a lower fixed limit of 40 dB(A) at all non-financially involved noise assessment locations, instead of the value of 43 dB(A) recommended in ETSU-R-97, in accordance with the expressed preference of PCC's appointed noise consultant.

5.7.7 It is finally concluded that predicted noise immission levels from the Proposed Development are compliant with the appropriate noise limits derived at all locations and all wind speeds. This outcome has been achieved using the Nordex N163 wind turbine operating unconstrained, except T13, T14, T16 and T7 which were assumed to operate in noise-reduced modes, and by assuming worst-case downwind predictions. The selection of the final turbine to be installed at the Site will be made on the basis of enabling the relevant site specific noise limits of Table 15 to be achieved at surrounding properties. The noise limits of Table 15 were derived as the lowest of both the day and night noise limits determined in this assessment.

Table 15 – Site Specific Noise Limits L_{A90} (dB) derived for the Proposed Development alone.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Ffynnonau	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Fforest Fields Yurts	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Fforest Cottages	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Woodbury	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Pen Y Cae	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Gwarallt	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Pen-y-banc Cregrina	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.4	45.6	47.6	47.6
Lower Llatho	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.4	45.6	47.6	47.6
The Park	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.4	45.6	47.6	47.6
Penberth	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.4	45.6	47.6	47.6
Lower Blaenmilo	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.7	44.5	44.5
Tyn Llwyn	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Woodcroft	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Graig-yr-onen*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Penarth	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Church House Farm	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Upper Blaenmilo Farm*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Pen Y Bank Llanfaredd	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Treallt	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0

5.8 Low Frequency Noise, Vibration and Amplitude Modulation

5.8.1 Low frequency noise and vibration resulting from the operation of wind farms are issues that have been attracting a certain amount of attention over recent years. Consequently, Annex A includes a detailed discussion of these topics. In summary of the information provided therein, the current recommendation is that ETSU-R-97 should continue to be used for the assessment and rating of operational noise from wind farms.

5.8.2 Annex A also discusses the published research on the subject of wind turbine blade swish Amplitude Modulation (or AM). As a consequence of the combined results of this research, and in particular the development by the IOA of an objective technique for identifying and quantifying AM noise, as well as a review of the subjective response to AM noise by a Government-commissioned research group, a penalty-type approach to account for instances of increased AM outside what is expected from 'normal' blade swish has been proposed. Some uncertainty remains at this stage over the application of such a penalty and this will be subject to a period of testing and review over the next few years. However, the ETSU-R-97 method continues to be applicable in the absence of further guidance.

5.9 Substation operational noise

5.9.1 The main noise sources associated with the substation are likely to be the power transformers and their cooling fans. The transformer noise is generally fairly constant, once energised, whereas the cooling fans operate as needed, depending on load and ambient temperature. The noise from the transformers is usually tonal in nature with most energy contained within discrete frequency components at 100 Hz and harmonics thereof. The cooling fans are likely to be broad-band in nature but switch on and off.

5.9.2 The operational noise from the substation has been predicted at the nearest residential property following the methodology set out in ISO 9613-2. The substation operational noise level predictions have been undertaken using a receiver height of four metres above local ground level, soft ground (G=1) and an air absorption based on a temperature of 10°C and 70% relative humidity. No allowance has been included for screening provided by terrain, enclosures or intervening buildings, which is likely to be precautionary in this case given the enclosed nature of the substation and nearest properties.

5.9.3 The proposed substation is located approximately 130 m from the nearest residential property, Woodcroft. The specifications of the transformers likely to be used for the substation are not defined at this stage; however, based on experience of similar installations, it has been assumed that two transformers with each having a source sound power level of 85 dB(A), with forced air cooling (fans) operational, will be representative of the substation noise emissions. As a worst case, it has been assumed for the purpose of the noise assessment that the transformers will be located outside rather than enclosed in a building or other enclosure. The corresponding predicted noise levels from the substation at Woodcroft are of 35 dB L_{Aeq}.

5.9.4 The exact location of the substation could change through the micrositing allowance of 50 m. This was accounted for in the assessment by using the shortest distance between the area currently proposed and the residential property. This effectively assumes that the sources of noise described above would be located at the closest point to the property within the indicated area. A potential additional allowance of +3 dB increase due to micrositing was nevertheless considered to provide a robust assessment.

5.9.5 In accordance with the method described in BS 4142, a correction for the potential acoustic features, based on a subjective assessment and experience of similar sources, has also been included to provide the 'rating level'. Corrections can be applied for tonal, impulsive and / or intermittent characteristics that have the potential to lead to increased awareness of a sound. As a precaution, +4 dB has been included for a potential tone from the transformers that is clearly perceptible. The 'rating level' is compared against the typical background noise levels to estimate the likely impact. An essential part of the BS4142 assessment is to consider the context of the development in the surrounding area, which has been taken into account through the consideration of the absolute value of the 'rating level'.

5.9.6 With the addition of a penalty of +4 dB for tonal content from substation transformers noise, corrected or rated levels of L_{Ar} 39 dB(A) are expected. Background noise measurements at Wern-heulog Farm are representative of Woodcroft (which is closer to the road). It can be seen from Figures E3 and E4 in Annex E that the typical background noise at this location is around L_{A90} 24 dB at low wind speeds during the night-time and ranging between L_{A90} 25 dB to 36 dB (upper 36 dB due to road traffic noise) at low wind speeds during quiet daytime periods. Therefore, the predicted rated noise levels, assuming worst case assumptions as above, will lie above the existing background noise levels by a maximum margin of +15 dB at the nearest properties (or +18 dB allowing for micrositing).

5.9.7 Furthermore, BS 4142 requires consideration of several contextual factors including the nature of the source and the environment, but also the absolute levels of the noise (L_{Ar} 39 dB). Given these factors, when assessed against the criteria derived in Table 2, the predicted substation operational noise level is both clearly above typical background noise levels and will not be considered low in absolute terms. Therefore this corresponds to a Major adverse noise impact magnitude.

5.9.8 Potential mitigation of this source can be achieved through selection of suitable plant and layout arrangement, and the use of noise mitigation measures such as specialist enclosures around the equipment. Alternatively, location of the transformers inside a building, considering ventilation to minimise noise break-out, can also provide effective sound insulation of the transformer noise. These measures can be designed to achieve a reduction of at least 5 to 8 dB on the assumed emission levels, such that the total rated noise level following mitigation no more than L_{Ar} 35 dB at the nearest residential properties, resulting in a minor noise impact magnitude.

5.9.9 Because of the above conclusions, the nature of the sources and the different guidance documents applicable in each case, it is considered based on professional judgement that there will be negligible in-combination operational noise impacts from the wind turbine noise in addition to that from the substation (assuming mitigation to the substation noise as outlined above).

6. Summary of Key Findings and Conclusions

6.1.1 This report has presented an assessment of the impacts of construction and operational noise from the Proposed Development on the residents of nearby dwellings.

6.1.2 Several residential properties located around the wind farm have been selected as being representative of the closest located properties to the wind farm. Noise assessments have been undertaken at these properties by comparing predicted construction and operational noise levels with relevant assessment criteria. In the case of construction noise, relevant assessment criteria are in the form of absolute limit values derived from a range of environmental noise guidance. In relation to operational noise, the limits have been derived from the existing background noise levels at four surrounding properties, as derived from measurements made over approximately four weeks at each location.

6.1.3 The construction noise assessment has determined that associated levels are expected to be audible at various times throughout the construction programme, but remain with acceptable limits such that their temporary impacts are considered a minor impact magnitude.

6.1.4 Operational noise from the wind farm has been assessed in accordance with the methodology set out in ETSU-R-97, 'The Assessment and Rating of Noise from Wind farms'. This document provides a robust basis for assessing the operational noise of a wind farm as recommended by national planning policy.

6.1.5 It has been demonstrated that both the day-time and night-time noise limits can be satisfied at all assessment properties across all wind speeds. This assessment has been based on the use of the manufacturer's specified sound power data for the Nordex N163 wind turbine which is typical of the type and size of turbine which may be considered for this site, and assuming worst case downwind propagation.

6.1.6 The impact of the proposed substation operational noise has been considered on a precautionary basis and determined to correspond to a minor impact, assuming suitable noise mitigation is applied at the substation compound. The addition of this noise source to that of the wind turbines will not affect the outcome of the above assessment and operational noise will remain a minor impact.

6.1.7 In summary, the overall levels of construction noise are considered to represent a minor impact. At some locations under some wind conditions and for a certain proportion of the time, the wind farm noise may be audible; however, operational noise immission levels comply with the criteria of the guidance commended by planning policy for the assessment of wind farm noise.

Annex A - General Approach to Noise Assessment and Glossary

A.1. Some sound, such as speech or music, is desirable. However, desirable sound can turn into unwanted noise when it interferes with a desired activity or when it is perceived as inappropriate in a particular environment.

A.2. When assessing the effects of sound on humans there are two equally important components that must both be considered: the physical sound itself, and the psychological response of people to that sound. It is this psychological component which results in those exposed differentiating between desirable sound and unwanted noise. Any assessment of the effects of sound relies on a basic appreciation of both these components. This Annex provides an overview of these topics. A glossary of acoustic terminology is included at the end of this Annex.

A.3. The assessment of environmental noise can be best understood by considering physical sound levels separately from the likely effects that these physical sound levels have on people, and on the environment in general.

A.4. Physical sound is a vibration of air molecules that propagates away from the source. As acoustic energy (carried by the vibration back and forth of the air molecules) travels away from the source of the acoustic disturbance it creates fluctuating positive and negative acoustic pressures in the atmosphere above and below the standing atmospheric pressure. For most types of sound normally encountered in the environment these acoustic pressures are extremely small compared to the atmospheric pressure. When acoustic pressure acts on any solid object it causes microscopic deflections in the surface. For most types of sound normally encountered in the environment these deflections are so small they cannot physically damage the material. It is only for the very highest energy sounds, such as those experienced close to a jet engine for example, that any risk of physical damage exists. For these reasons, most sound is essentially neutral and has no cumulative damaging physical effect on the environment. The effects of environmental sound are therefore limited to its effects on people or animals.

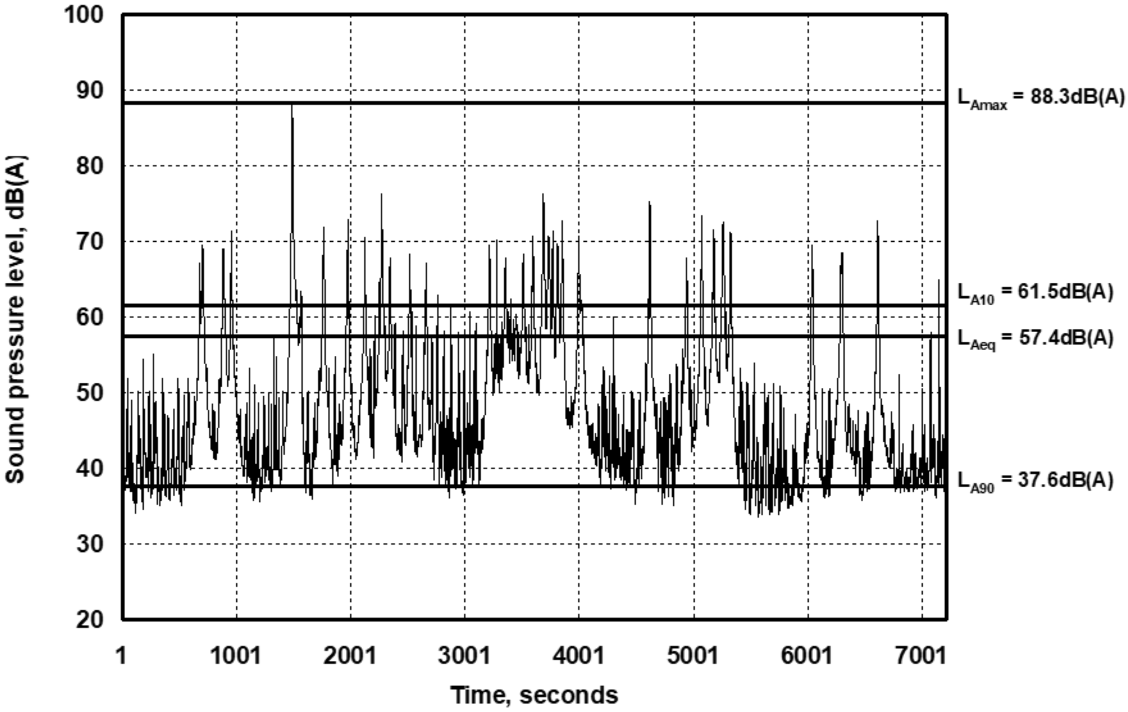
A.5. Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

Indicators of physical sound levels

A.6. Physical sound is measured using a sound level meter. A sound level meter comprises two basic elements: a microphone which responds in sympathy with the acoustic pressure fluctuations and produces an electrical signal that is directly related to the incident pressure fluctuations, and a meter which converts the electrical signal generated by the microphone into a decibel reading. Figure A1 shows an example of the time history of the decibel readout from a sound level meter located approximately 50 metres from a road. The plot covers a total time period of approximately 2 hours. The peaks in the sound pressure level trace correspond to the passage of individual vehicles past the measurement location.

A.7. Assigning a single value to the time varying sound pressure level presented in Figure A1 is clearly not straightforward, as the sound pressure level varies by over 50 dB with time. To overcome this, the measurement characteristics of sound level meters can be varied to emphasise different features of the sound that are thought to be most relevant to the effect under consideration.

Figure A1 Sample plot of the sound pressure level measured close to a road over a period of approximately two hours.



Objective measures of noise

A.8. The primary purpose of measuring environmental noise is to assess its effects on people. Consequently, any sound measuring device employed for the task should provide a simple readout that relates the objectively measured sound to human subjective response. To achieve this, the instrument must, as a minimum, be capable of measuring sound over the full range detectable by the human ear.

A.9. Perceived sound arises from the response of the ear to sound waves travelling through the air. Sound waves comprise air molecules oscillating in a regular and ordered manner about their equilibrium position. The speed of the oscillations determines the frequency, or pitch, of the sound, whilst the amplitude of oscillations governs the loudness of the sound. A healthy human ear is capable of detecting sounds at all frequencies from around 20 Hz to 20 kHz over an amplitude range of approximately 1,000,000 to 1. Even relatively modest sound level meters are capable of detecting sounds over this range of amplitudes and frequencies, although the accuracy limits of sound level meters vary depending on the quality of the unit. When undertaking measurements of wind turbine noise, as with all other noise measurements, it is important to select a measurement system that possesses the relevant accuracy tolerances and is calibrated to a matching standard.

A.10. Whilst measurement systems exist that are capable of detecting the range of sounds detected by the human ear, the complexities of human response to sound make the derivation of a likely subjective response from a simple objective measure a non-trivial problem. Not only does human response to sound vary from person to person, but it can also depend as much on the activity and state of mind of an individual at the time of the assessment, and on the 'character' of the sound, as it can on the actual level of the sound. In practice, a complete range of responses to any given sound may be observed. Thus, any objective measure of noise can, at best, be used to infer the average subjective response over a sample population.

Sound levels and decibels

A.11. Because of the broad amplitude range covered by the human ear, it is usual to quantify the magnitude of sound using the decibel scale. When the amplitude of sound pressure is expressed using decibels (dB) the resultant quantity is termed the sound pressure level. Sound pressure levels are denoted by a capital 'L', as in L dB. The conversion of sound pressure from the physical quantity of Newton per square metre, or Nm-2, to sound pressure level in dB reduces the range from 0 dB at the threshold of hearing to 120 dB at the onset of pain. Both of these values are derived with respect to the hearing of the average healthy young person.

A.12. Being represented on a logarithmic amplitude scale, the addition and subtraction of decibel quantities does not follow the normal rules of linear arithmetic. For example, two equal sources acting together produce a sound level 3 dB higher than either source acting individually, so 40 dB + 40 dB = 43 dB and 50 dB + 50 dB = 53 dB. Ten equal sound sources acting together will be 10 dB louder than each source operating in isolation. Also, if one of a pair of sources is at least 10 dB quieter than the other, then it will contribute negligibly to the combined noise level. So, for example, 40 dB + 50 dB = 50 dB.

A.13. An increase in sound pressure level of 3 dB is commonly accepted as the smallest change of any subjective significance. An increase of 10 dB is often claimed to result in a perceived doubling in loudness, although the basis for this claim is not well founded. An increase of 3 dB is equivalent to a doubling in sound energy, which is the same as doubling the number of similar sources. An increase of 10 dB is equivalent to increasing the number of similar sources tenfold, whilst an increase of 20 dB requires a hundredfold increase in the number of similar sources and an increase of 30 dB requires a thousand times increase in the number of sources.

Frequency selectivity of human hearing and A-weighting

A.14. Whilst the hearing of a healthy young individual may detect sounds over a frequency range extending from less than 20 Hz to greater than 20 kHz, the ear is not equally sensitive at all frequencies. Human hearing is most sensitive to sounds containing frequency components lying within the range of predominant speech frequencies from around 500 Hz to 4000 Hz. Therefore, when relating an objectively measured sound pressure level to subjective loudness, the frequency content of the sound must be accounted for.

A.15. When measuring sound with the aim of assessing subjective response, the frequency selectivity of human hearing is accounted for by down-weighting the contributions of lower and higher frequency sounds to reduce their influence on the overall reading. This is achieved by using an 'A'-weighting filter. Over the years, the A-weighting has become internationally standardised and is now incorporated into the majority of environmental noise standards and regulations in use around the world to best replicate the subjective response of the human ear. A-weighting filters are also implemented as standard on virtually all sound measurement systems.

A.16. Sound pressure levels measured with the A-weighting filter applied are referred to as 'A weighted' sound pressure levels. Results from such measurements are denoted with a subscripted capital A after the 'L' level designation, as in 45 dB LA, or alternatively using a bracketed 'A' after the 'dB' decibel designation, as in 45 dB(A).

Temporal variation of noise and noise indices

A.17. The simple A-weighted sound pressure level provides a snapshot of the sound environment at any given moment in time. However, as is adequately demonstrated by Figure A1, this instantaneous sound level can vary significantly over even short periods of time. A single number indicator is therefore required that best quantifies subjective response to time varying environmental noise, such as that shown in Figure A1. The question thus arises as to how temporal variations in level should be accounted for. This is most often achieved in practice by selecting a representative time period and calculating either the average noise level over that time period or, alternatively, the noise level exceeded for a stated proportion of that time period, as discussed below.

Equivalent continuous sound level, $L_{Aeq,T}$

A.18. The equivalent continuous sound level, or $L_{Aeq,T}$ averages out any fluctuations in level over time. It is formally defined as the level of a steady sound which, in a stated time period 'T' and at a given location, has the same sound energy as the time varying sound. The $L_{Aeq,T}$ is a useful 'general' noise index that has been found to correlate well with subjective response to most types of environmental noise.

A.19. The equivalent continuous sound level is expressed $L_{Aeq,T}$ in dB, where the A–weighting is denoted by the subscripted 'A', the use of the equivalent continuous index is denoted by the subscripted 'eq', and the subscripted 'T' refers to the time period over which the averaging is performed. So, for example, 45 dB $L_{Aeq,1hr}$ indicates that A-weighted equivalent continuous noise level measured over a one hour period was 45 dB.

A.20. The disadvantage of the equivalent continuous sound level is that it provides no information as to the temporal variation of the sound. For example, an $L_{Aeq,1hr}$ of 60 dB could result from a sound pressure level of 60 dB(A) continuously present over the whole hour's measurement period, or it could arise from a single event of 96 dB(A) lasting for just 1 second superimposed on a continuous level of 30 dB(A) which exists for the remaining 59 minutes and 59 seconds of the hour long period. Clearly, the subjective effect of these two apparently identical situations (if one were to rely solely on the L_{Aeq} index) could be quite different.

A.21. The aforementioned feature can produce problems where the general ambient noise level is relatively low. In such cases the $L_{Aeq,T}$ can be easily 'corrupted' by individual noisy events. Examples of noisy events that often corrupt $L_{Aeq,T}$ noise measurements in situations of low ambient noise levels include birdsong or a dog bark local to a noise monitoring point, or an occasional overflying aircraft or a sudden gust of wind. This potential downside to the use of $L_{Aeq,T}$ as a general measurement index is of particular relevance to the assessment of ambient noise in quiet environments, such as those typically found in rural areas where wind farms are developed.

A.22. Despite these shortcomings in low noise environments, the $L_{Aeq,T}$ index is increasingly becoming adopted as the unit of choice for both UK and European guidance and legislation, although this choice is often as much for reasons of commonality between standards as it is for overriding technical arguments. In the Government's current planning policy guidance notes the $L_{Aeq,T}$ noise level is the index of choice for the general assessment of environmental noise. This assessment is undertaken separately for day time ($L_{Aeq,16hr}$ 07:00 to 23:00) and night time ($L_{Aeq,8hr}$ 23:00 to 07:00) periods. However, it is often the case for quiet environments, or for non-steady noise environments, that more information than can be gleaned from the $L_{Aeq,T}$ index may be required to fully assess potential noise effects.

Maximum, L_{Amax}, and percentile exceeded sound level, $L_{An,T}$

A.23. Figure A1 shows, superimposed on the time varying sound pressure level trace and in addition to the $L_{Aeq,T}$ noise level, examples of three well established measurement indices that are commonly used in the assessment of environmental noise impacts. These are the maximum sound pressure level, L_{Amax}, the 90 percentile sound pressure level, $L_{A90,T}$ and the ten percentile sound pressure level, $L_{A10,T}$.

A.24. The $L_{Amax,F}$ readings is suited to indicating the physical magnitude of the single individual sound event that reaches the maximum level over the measurement period, but it gives no indication of the number of individual events of a similar level that may have occurred over the time period.

A.25. Unlike the $L_{Aeq,T}$ index and the $L_{Amax,F}$ indices, percentile exceeded sound levels, percentage exceeded sound levels provide some insight into the temporal distribution of sound level throughout the averaging period. Percentage exceeded sound levels are defined as the sound level exceeded by a fluctuating sound level for n% of the time over a specified time period, T. They are denoted by $L_{An,T}$ in dB, where 'n' can take any value between 0% and 100%.

A.26. The $L_{A10,T}$ and $L_{A90,T}$ indices are the most commonly encountered percentile noise indices used in the UK.

A.27. The 10%'ile index, or $L_{A10,T}$ provides a measure of the sound pressure level that is exceeded for 10% of the total measurement period. It therefore represents the typical upper level of sound associated with specific events, such as the passage of vehicles past the measurement point. It is the traditional index adopted for road traffic noise. This index is useful because traffic noise is not usually constant, but rather it fluctuates with time as vehicles drive past the receptor location. The $L_{A10,T}$ therefore characterises the typical level of peaks in the noise as vehicles drive past, rather than the lulls in noise between the vehicles.

A.28. The $L_{A90,T}$ noise index is the noise level exceeded for 90% of the time period, T. It provides an estimate of the level of continuous background noise, in effect performing the inverse task of the $L_{A10,T}$ index by detecting the lulls between peaks in the noise. It is for this reason that the $L_{A90,T}$ noise index is the favoured unit of measurement for wind farm noise where, for the reasons discussed above, the generally low $L_{Aeq,T}$ noise levels are easily corrupted by intermittent sounds such as those produced by livestock, agricultural vehicles or the occasional passing vehicle on local roads. The $L_{A90,T}$ noise level represents the typical lower level of sound that may be reasonably expected to be present for the majority (90%) of the time in any given environment. This is usually referred to as the 'background' noise level.

Temporal variations outside the noise index averaging periods, 'T'

A.29. Averaging noise levels over the time period 'T' of the $L_{Aeq,T}$ and $L_{An,T}$ noise indices can successfully account for variations in noise over the time period, T. Some variations, however, exhibit trends over longer periods. At larger distances from noise sources meteorological factors can significantly affect received noise levels. At a few hundred metres from a constant level source of noise the potential variation in noise levels may be greater than 15 dB(A). To account for this variability consideration must be taken of meteorological conditions, particularly wind direction, when measurements and predictions are undertaken. As a general rule, when compared with the received noise level under neutral wind conditions, wind blowing from the source to the receiver can slightly enhance the noise level at the receiver (typically by no more than 3 dB(A)), but wind blowing from the receiver to the source can very significantly reduce the noise level at the receiver (typically by 15 dB(A) or more).

A.30. A similar effect occurs under conditions of temperature inversion, such as may exist after sunset when radiative cooling from the ground lowers the temperature of the air lying at low level more quickly than the air at higher levels, by loss of temperature through convective effects. This results in the air temperature increasing with increasing height above the ground. Depending on the source to receiver distance relative to the heights of the source and receiver, this situation can lead to sound waves becoming 'trapped' in the layer of air lying closest to the ground. The consequence is that noise levels at receptor locations can increase relative to those experienced under conditions of a neutral temperature gradient or a temperature lapse. The maximum increases compared to neutral conditions are similar to those experienced under downwind conditions of no more than around 3 dB(A). It is also worth noting that temperature lapse conditions, which is the more usual situation where temperature decreases with increasing height, can result in reductions in noise level at receptor locations by 15 dB(A) or more compared with the neutral conditions. The similarity between the magnitude of potential variations in noise levels for wind induced and temperature induced effects is not surprising, as the physical mechanisms behind the variations in level are the same for both situations: both variations result from changes in the speed of sound as a function of height above local ground level.

A.31. Temperature inversions on very still days can also affect noise propagation over much larger distances of several kilometres. These effects can produce higher than expected noise levels even at these very large distances from the source. A classic example that many people have experienced is the distant, usually inaudible, railway train that suddenly sounds like it is passing within a few hundred metres of a dwelling. However, these situations must generally be considered as rare exceptions to the usually encountered range of noise propagation conditions, especially in the case of wind farm noise as they rely on calm wind conditions under which wind turbines do not operate.

Effects of sound on people

A.32. Except at very high peak acoustic pressures, the energy levels in most environmental sounds are too low to cause any physical disruption in any part of the body, just as they are too low to cause any direct physical damage to the environment. The main effects of environmental sound on people are therefore limited to possible interference with specific activities or to some kind of annoyance response. Some researchers have claimed statistical associations between environmental noise and various long term health effects such as clinical hypertension or mental health problems, although there is no consensus on possible causative mechanisms. Evidence in support of health effects other than annoyance and some indicators of sleep disturbance is weak. However, the theory that psychological stress caused by annoyance might contribute to adverse health effects in otherwise susceptible individuals seems plausible. Health effects in the 'more usual' definition of physiological health therefore remain as a theoretical possibility which has neither been proved nor disproved. However, the World Health Organisation (WHO) defines health in the wider context of:

> *'a state of complete physical, mental and social well-being and not merely the absence of infirmity'.*

And within this wider context potential health effects of environmental noise are summarised by the World Health Organisation as:

- interference with speech communications;
- sleep disturbance;
- disturbance of concentration;
- annoyance; and
- social and economic effects.

Speech interference

A.33. The instantaneous masking effects of unwanted noise on speech communication can be predicted with some accuracy by using specialist methods of calculation, but the overall effect of a small amount of speech interference on everyday life is harder to judge. The significance of speech masking depends on the context in which it occurs. For example, isolated noise events could interfere with telephone conversations by masking out particular words or parts of words but, because of the high redundancy in normal speech, the masking of individual words can often have no significant effect on the intelligibility of the overall message. Notwithstanding the above, noise levels from wind farms at even the closest located dwellings in otherwise quiet environments are usually no more than around 30 dB(A) indoors, even with windows open. This internal noise level is 5 dB(A) below the 35 dB(A) suggested by the World Health Organisation as the lowest potential cut-on level for issues relating to speech intelligibility.

Sleep disturbance

A.34. Although sleep seems to be a fundamental requirement for humans, the most significant effect of sleep loss seems to be increased sleepiness the next day. Sleep normally follows a regular cyclic pattern from awake through light sleep to deep sleep and back, this cycle repeating several times during the night at around 90 minute intervals. Most people wake for short periods several times every night as part of the normal sleep cycle without necessarily being aware of this the next day. REM, or rapid eye movement, sleep is associated with dreaming and occurs several times each night during the lighter sleep stages.

A.35. Electroencephalography (EEG) and similar techniques can be used to detect transient physiological responses to noise at night. Transient responses can be detected by short bursts of activity in the recorded waveforms which often settle back down to the same pattern as immediately before the event. Sometimes a transient response will be the precursor of a definite lightening of sleep, or even of an awakening, but often no discernible physical event happens at all.

A.36. These results suggest that at least parts of the auditory system remain fully operational even while the listener is asleep. The main purpose of this seems to be to arouse the listener in case of danger or in case some particular action is required which cannot easily be accomplished whilst remaining asleep. On the other hand, the system appears to be designed to filter out familiar sounds which experience suggests do not require any action. A very loud sound is likely to overcome the filtering mechanism and wake the listener, while intermediate and quieter sounds might only wake a listener who has a particular focus on those specific sounds. There is no evidence that the transient physiological responses to noise whilst asleep are anything other than normal. There is also considerable anecdotal evidence that people habituate to familiar noise at night, although some of the research evidence on this point is contradictory.

A.37. There is no consensus on how much sleep disturbance is significant. Some authorities take a precautionary approach, under which any kind of physiological response to noise is considered important, irrespective of whether there are any next day effects or not. Other studies suggest that transient physiological responses to unfamiliar stimuli at night are merely an indication of normal function and do not need to be considered as adverse effects unless they contribute to significant next-day effects. Recent World Health Organisation guidelines based mainly on laboratory studies suggest indoor limit values of 30 dB L_{Aeq} and 45 dB L_{Afmax} to avoid sleep disturbance, while other studies carried out in-situ, where habituation to the noise in question may have occurred, have found that much higher levels can be tolerated without any noticeable ill-effects.

Noise annoyance

A.38. Noise annoyance describes the degree of 'unwantedness' of a particular sound in a particular situation. People's subjective response to noise can vary from not being bothered at all, through a state of becoming aware of the noise, right through to the point of becoming annoyed by the noise when it reaches a sufficiently high level. There is no statutory definition of noise annoyance.

A.39. Numerous noise annoyance surveys carried out over the last three decades have attempted to establish engineering relationships between the amount of noise measured objectively using sound level meters and the amount of community annoyance determined from questionnaires. The chief outcome of 'reported annoyance' has been measured using a very large range of different ideas. Both the wording of any questionnaire used and the context in which the question is put, and the manner in which it is therefore interpreted by respondents, can be very important. Some researchers are developing standardised questionnaire formats to encourage greater comparability between different studies, but this does not address the possibility of different contextual effects.

A.40. Notwithstanding these problems, there is a general consensus that average reported annoyance increases with aggregate noise level in long term static situations. However, there has been comparatively little research and consequently no real agreement on the effects of change. Some studies have found that even small changes in noise level can have unexpectedly large consequences on reported annoyance, while others have found the opposite. The most likely explanation for these apparent discrepancies is that underlying or true annoyance depends on many non-acoustic factors in addition to noise level alone, and that the extent to which reported annoyance actually represents underlying annoyance can be highly dependent on context. As a consequence, attempts to find a common relationship across all noise sources and listening situations have generally floundered. This task has been complicated by the great range of individual sensitivities to noise observed in the surveys, often affected as much by attitude as by noise level.

A.41. Whether or not an exposed individual has a personal interest in a given sound often has a significant bearing on their acceptance of it. For example, if recipients gain benefit from an association with the sound producer, or if they accept that the sound is necessary and largely unavoidable, then they are likely to be more tolerant of it. This is often the case even if they don't necessarily consider it desirable. A good example of this is road traffic noise which is the dominant noise heard by over 90% of the population but results in relatively few complaints.

A.42. Notwithstanding the fact that attitudes may be as important as overall levels in determining the acceptance of a particular noise, there still remains a need to objectively quantify any changes in noise level. Whilst it may not be possible to attribute a particular degree of annoyance to a given noise level, an objective measure of noise that bears some relationship to annoyance is still useful. This objective measure enables an assessment of the effect of changes to be assessed on the basis that any reduction in overall noise level must be beneficial. Possible noise mitigation measures form a central consideration of any noise assessment, so an appropriate methodology must be adopted for assessing the effectiveness of any noise mitigation measures adopted.

A.43. When assessing the potential effects of any new source of noise, it is common practice to compare the A-weighted 'specific' noise level produced by the new source (usually measured using the $L_{Aeq,T}$ index) against the existing A-weighted 'background' noise level measured using the $L_{A90,T}$ index, as this is the typical level of noise that can be reasonably expected to be present the majority of the time to potentially 'mask' the new 'specific' noise. The assessment is therefore undertaken within the context of the existing noise environment. In some circumstances, it may prove equally instructive to compare the absolute level of a new specific noise against accepted absolute levels defined in standards or other relevant documents. The assessment is therefore undertaken against benchmark values, rather than against the context of the existing noise environment. Whatever approach is actually adopted for final assessment purposes, and often a combination of the two approaches is appropriate, it is important that the relevance of both contextual and benchmark assessments is at least considered in all cases.

A.44. Table 4.1 of the 2000 WHO Guidelines for Community Noise presents guideline benchmark values for environmental noise levels in specific environments. The noise levels relevant to residential dwellings are listed here in Table A1.

Table A1 Relevant extracts from 'Table 4.1 - Guideline Values for Community Noise in Specific Environments'

Specific Environment	Critical Health Effects	$L_{Aeq,T}$	Time base (hrs)	L_{Amax} (dB)
Outdoor living area	Serious annoyance, day time and evening	55	16	-
	Moderate annoyance, day time and evening	50	16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, day time and evening	35	16	-
	Sleep disturbance, night time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoors)	45	8	60
School class rooms (included for potential effects on concentration)	Speech intelligibility, disturbance of information extraction, message communication	35	-	-

A.45. The text accompanying the Table in the WHO Guidelines explains that the levels given in the Table are set at the lowest levels at which the onset of any adverse health due to exposure to noise has been identified. The text continues:

> *'These are essentially values for the onset of health effects from noise exposure. It would have been preferred to establish guidelines for exposure-response relationships. Such relationships would indicate the effects to be expected if standards were set above the WHO guideline values and would facilitate the setting of standards for sound pressure levels (noise immission standards)'.*

A.46. More recently, Environmental Noise Guidelines for the European Region (2018) were published and include general recommendations for wind turbine noise. However, they are designed to inform policy on noise, at the population and strategic level. They are based on the Lden noise indicator, which requires knowledge of the noise levels experienced over the course of a full year. This type of noise index is more suitable for general strategic studies and not appropriate for assessing the acceptability of noise produced by any specific development. Furthermore, these guidelines do not provide recommendations for indoor noise levels and the 2000 WHO Guidelines for Community Noise remain applicable in this regard. For these reasons, the 2018 guidelines will not be referenced any further.

A.47. In addition to consideration of the absolute A-weighted level of a new specific source of noise, other properties of the noise can heighten its potential effects when introduced into an existing background noise environment. Such properties of noise are commonly referred to as 'acoustic features' or the 'acoustic character'. These acoustic features can set apart the new source of noise from naturally occurring sounds. Commonly encountered acoustic features associated with transport and machinery sources, for example, can include whistles, whines, thumps, impulses, regular or irregular modulations, high levels of low frequency sound, rumbling, etc.

A.48. Due to the potential of acoustic features to increase the effects of a noise over and above the effects that would result from an otherwise 'bland' broad band noise of the same A-weighted noise level, it is common practice to add a 'character correction' to the specific noise level before assessing its potential effects. The resulting character corrected specific noise level is often referred to as the 'rated' noise level. Such character corrections usually take the form of adding a number of decibels to the physically measured or calculated noise level of the specific source. Typical character corrections are around +5 dB(A), although the actual correction depends on the subjective significance of the particular feature being accounted for.

A.49. The objective identification and rating of acoustic features can introduce a requirement to analyse sound in greater detail than has thus far been discussed. To this point all discussion has focussed on the use of the overall A-weighted noise level. This single figure value is derived by summing together all the acoustic energy present in the signal across the entire audible spectrum from around 20 Hz to 20,000 Hz, albeit with the lower and higher frequency contributions down-weighted in accordance with the A-weighting filter characteristics to account for the reduced sensitivity of the human ear at these frequencies.

A.50. However, in order to identify the presence of tones (which are concentrations of acoustic energy over relatively small bands of frequency), or in order to identify excessive levels of low frequency noise, it may be necessary to determine the acoustic energy present in the noise signal across much smaller frequency bands. This is where the concept of octave band analysis, fractional (e.g. 1/3, 1/12, 1/24) octave band analysis, or even narrow band Fast Fourier Transform (FFT) analysis is introduced. The latter enables signals to be resolved in frequency bandwidths of down to 1 Hz or even less, thereby enabling tonal content to be more easily identified and measured. As standard, noise emission data for wind turbines is supplied as octave band data, with narrow band tests also being undertaken to establish the presence of any tones in the radiated noise spectrum.

Low frequency noise and vibration – wind farms

A.51. One issue that has increasingly been raised concerning potential noise effects of operational wind farms relates not to the overall noise levels, but to the specific issue of low frequency sound. However, confusion sometimes arises from the use of the generalised term 'low frequency sound' to describe specific effects that may, or sometimes may not, actually relate the low frequency character of the sound itself.

A.52. In this respect, there are three distinct characteristics of sound that should be clearly differentiated between:

- Low frequency sound in the range from around 20 Hz to 200 Hz, which therefore lies within the commonly referenced range of human hearing of around 20 Hz to 20,000 Hz;
- Very low frequency sound, or infrasound, below 20 Hz, which therefore lies below the commonly referenced lower frequency limit of human hearing;
- Amplitude modulated sound that characterises the 'swish, swish' sound sometimes heard from rotating wind turbine blades.

A.53. Looking at the first two of the three types of sound referred to in the preceding bullet points, a distinction is usually made between low frequency sound and very low frequency sound, otherwise termed infrasound. This distinction is based on the fact that the frequency range of audible noise is generally taken to be from 20 Hz to 20,000 Hz. Therefore, the range of frequencies from about 20 Hz to 200 Hz is usually taken to cover audible low frequency sound, whereas frequencies below 20 Hz are usually described as infrasound. The implication here is that low frequency sound is audible and infrasound is inaudible. However, this relatively arbitrary distinction between low frequency sound and infrasound can introduce some confusion in that frequencies below 20 Hz can still be heard provided they produce a sound pressure level at the ear of the listener that lies above the threshold of audibility of that listener to sound at that particular frequency.

A.54. The fact that low frequency sound and infrasound from wind farms has been highlighted as a potential problem by some groups does not mean that that the wind energy industry had not previously considered the issue. In fact, the issue of low frequency sound was one of the predominant technical hurdles associated with the some of the earliest larger scale wind turbines installed in the USA. These turbines were of the 'downwind' type, 'downwind' referring here to the fact that the rotor blades were located downwind of the turbine tower rather than upwind of it, as is the case for current machines. It was found that the interruption of wind flow past the tower resulted in a region of lower than average wind speed immediately in the wake of the tower. The passage of the blades into this region of lower wind speed in the wake of the tower, then back into the higher wind speed as they emerged from the wake of the tower back into the main wind stream, resulted in the generation of low frequency sound, often in the subjective form of a distinctive impulse, often referred to as a 'thump' or 'tower thump'. It was for this reason that modern day turbine configurations now have the blades upwind of the tower, as research and measurements demonstrated that low frequency sound radiation is reduced to sub-audible levels once the interaction of downwind tower wake effects with the rotating blades are removed from the design.

A.55. One of the problems inherent in the assessment of both low frequency sound and infrasound is the variability of hearing sensitivity across human subjects with otherwise healthy hearing. This threshold for sound below 200 Hz varies significantly more between different subjects than does the hearing threshold at higher frequencies. However, what is always true is that the perception threshold to lower frequency noise is much higher than the perception threshold for speech frequencies between around 250 Hz to 4,000 Hz. For example, the average person with healthy hearing is some 70 dB less sensitive to sounds at 20 Hz than to sounds that fall within the range of speech frequencies. An additional factor relevant to the perception of infrasound is that, although audibility remains below 20 Hz, tonality is lost below 16 Hz to 18 Hz, thus losing a key element of perception.

A.56. Both low frequency sound and infrasound are generally present all around us in modern life. They may be generated by many natural sources, such as thunder, earthquakes, waves and wind. They may also be produced by machinery including household appliances such as washing machines and air conditioning units, all forms of transport and by turbulence. The presence of low frequency sound and infrasound in our everyday lives is heightened by the fact that the attenuation of sound in air is significantly lower at low frequencies than at the mid to high frequencies. As a result, noise which has travelled over long distances is normally biased towards the low frequencies. However, the fact that human hearing naturally down-weights, or filters out, sounds of such low frequencies means we are generally not aware of its presence. It is only under circumstances when it reaches a sufficiently high level, for example in the 'rumble' of distant thunder or the sound of large waves crashing on a shore, that we become aware of its presence.

A-weighting

A.57. It is because the human ear increasingly filters out sounds of lower frequencies that environmental noise measurements are undertaken as standard using sound level meters that apply the A-weighting curve, as it filters out lower frequency sounds to the same degree as the hearing of a healthy person with unimpaired hearing. The A-weighted sound level is used as a measure of subjective perception of sound unless there exists such a predominance of low frequency sound or infrasound relative to the level of sound at higher frequencies that the use of the A-weighting curve would down-weight the actual source of the problem to such a degree that the resultant objective noise levels do not truly reflect the potential subjective effects of the noise. It is for this reason that a number of alternative weighting curves have been developed, specifically aimed at better accounting for the assessment of low frequency sound and infrasound.

Alternative frequency weightings

A.58. One such curve is denoted C-weighting. Unlike the A weighting curve, which gradually reduces the significance of frequencies below 1000 Hz until at 10 Hz the attenuation is 70 dB, the C-weighting curve is flat to within 1 dB down to about 50 Hz and then drops by 3 dB at 31.5 Hz and 14 dB at 10 Hz. The C weighting curve was originally developed to reflect the fact that, at higher overall noise levels, low frequencies can have a greater subjective effect than at lower overall noise levels.

A.59. One relatively simple measure of undertaking a first-pass assessment as to whether low frequency sound is likely to be an issue is to determine the difference between the overall C weighted noise level and the overall A weighted noise level. The C weighted level includes contributions from low frequency sound, whereas the A weighted level filters it out. It has been suggested in that a level difference of more than 20 dB indicates that low frequency sound may be subjectively significant, but more detailed investigations are in practice required to determine whether or not this is actually the case.

A.60. Another curve, termed the G weighting curve, has been specifically derived to provide a measure of the audibility of infrasound when considered separately from higher frequency noise. The G weighting curve falls off rapidly above 20 Hz and below 20 Hz it follows assumed hearing contours with a slope of 12 dB per octave down to 2 Hz.

Wind-farm infrasound and vibration

A.61. Over the past few years there has been considerable attention paid to the possibility that operational wind farms may radiate sufficiently high levels of infrasound or vibration to cause health problems. Dedicated research investigations have however repeatedly shown this not to be the case.

A.62. As early as 1997 a report by Snow[24] gave details of a comprehensive study of infrasound and low frequency sound (up to around 100 Hz) and vibration measurements made in the vicinity of a wind farm. Measurements were made both on the wind farm site, and at distances of up to 1 kilometre. During the experiments a wide range of wind speeds and directions were recorded. It was found that the vibration levels at 100 metres from the nearest turbine itself were a factor of 10 lower than those recommended for human exposure in the most critical buildings (i.e. laboratories for precision measurements), and lower again than the limits specified for residential premises. A similar comparison with recognised limits for assessing structural damage showed that the measured vibrations were a factor of 100 below the recommended guidelines at 100 metres from the turbines.

A.63. Noise and vibration levels were found to comply with recommended residential criteria even on the wind turbine site itself. Although low level infrasonic (i.e. below 20 Hz) periodic noise from the wind farm was detected by instrumentation at distances up to 1 kilometre, the measuring instruments used were much more sensitive than human hearing. Based on his measurements Snow concluded that subjective detection of the wind turbines may be apparent at this distance, but if this is the case it will be due to higher frequency components (which are more readily masked by general ambient environmental noise) and not the low frequency components which lie below the threshold of audibility.

A.64. In 2003, findings on both low frequency sound and infrasound have been compiled into the previously referenced extensive review report commissioned by DEFRA and prepared by Dr G Leventhall[25]. Dr Leventhall notes that despite the numerous published studies there is little or no agreement about the

24 'Low frequency noise and vibration measurements at a modern wind farm', D. Snow, ETSU Report ETSU W/13/00392/REP, 1997
25 'A review of published research on low frequency noise and its effects', G. Leventhall, report for DEFRA, 2003

biological effects of infrasound or low frequency sound on human health. Leventhall notes that direct evidence of adverse effects of exposure to low-intensity levels of infrasound (less than 90 dB) is lacking. He goes on to describe the low frequency hearing threshold i.e. the lowest levels which are audible to an average person with normal hearing. He notes the threshold at 4 Hz is about 107 dB, at 10 Hz it is about 97 dB and at 20 Hz it is 79 dB. As such, high levels of infrasound are required to exceed the hearing thresholds at such low frequencies. Leventhall therefore concluded that most people can be reassured that there will be no serious consequences to peoples' health from infrasound exposure.

A.65. Indeed, specifically in relation to wind farms and infrasound, Leventhall went further still with his statement of reassurance. This additional reassurance followed the voicing of concerns by some interested parties that, because infrasound and very low frequency vibrations could be measured from wind farms, then it must follow that these were a potential hazard and source of annoyance. In fact what those concerned observers failed to account for is that highly sensitive electronic measuring equipment designed solely to detect such infrasonic sounds and vibrations is orders of magnitude more sensitive than even the most sensitive human. Thus, whilst such measurement systems may be able to detect such low-level phenomena, the same stimuli can have no effect on humans. Typical levels of infrasound produced by a wind turbine at representative separation distances would not exceed 70 dB, and clearly below the perception thresholds discussed above. In the light of this, Leventhall issued an open statement:

> *'I can state quite categorically that there is no significant infrasound from current designs of wind turbines. To say that there is an infrasound problem is one of the hares which objectors to wind farms like to run. There will not be any effects from infrasound from the turbines'.*

A.66. In 2004/2005 researchers from Keele University investigated the effects of the extremely low levels of vibration resulting from wind farms on the operation of a seismic array installed at Eskdalemuir in Scotland. This is one of the most sensitive ground-borne vibration detection stations in the world. The results of this study were initially misinterpreted, as just discussed for the DEFRA/Leventhall report, in that if infrasonic vibrations from wind farms can be measured, then they must consequentially have some potential effect on humans. In order to clarify their position, the authors subsequently explained[26] that:

> *'The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect'.*

A.67. They then continue:

> *'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 humans sensing the vibration and absolutely no risk to human health'.*

A.68. In relation to airborne infrasound as opposed to ground-borne vibrations, the researchers are equally robust in their conclusions, stating:

> *'The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect low frequency sound. There is no scientific evidence to suggest that infrasound [at such an extremely low level] has an impact on human health'.*

A.69. In 2006, the results of a study specifically commissioned by the UK Department of Trade and industry (DTI) to look at the effects of infrasound and low frequency noise (LFN) arising from the operation of wind farms have been published in what is commonly referred to as the DTI LFN Report[27]. This Report

26 'Wind farm noise', P. Styles, letter by Prof P Styles and S Toon printed in The Scotsman, August 2005.
27 'The measurement of low frequency noise at three UK wind farms', M. Hayes, DTI Report W/45/00656/00, 2006

is quite categorical in its findings: infrasound is not the perceived health threat suggested by some observers, nor should it even be considered a potential source of disturbance. Quoting from the Executive Summary to the DTI LFN Report:

> *'Infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion.*
>
> *The document "Community Noise" prepared for the World Health Organisation, states that "there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects". Other detection mechanisms of infrasound only occur at levels well above the threshold of audibility.*
>
> *It may therefore be concluded that infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour'.*

A.70. This has been subsequently confirmed by many international studies and reviews. For example, a study for the National Institute for Public Health and the Environment (RIVM) in the Netherlands[28] published in 2020 concluded in this regard that:

> *'Although low frequency sound and infrasound might have other effects than 'normal' sound has, these effects are highly unlikely at sound levels typical for wind turbines. Brain studies show that low frequency and infrasound are processed in the same parts of the brain as 'normal' sound and there is no evidence that infrasound elicits any reaction at sub-audible levels.'*

A.71. In conclusion, whilst is known that infrasound can have an adverse effect on people (potential adverse health impacts are listed by the World Health Organisation as stress, irritation, unease, fatigue, headache, possible nausea and disturbed sleep), these effects can only come into play when the infrasound reaches a sufficiently high level. This is a level above the threshold of audibility. However, all available information from measurements on current wind turbines reveals that the level of infrasound emitted by these wind turbines lies below the threshold of human perception.

Low frequency sound

A.72. A report prepared for DEFRA by Casella Stanger[29] lists wind farms as a possible source of audible low frequency sound (20 Hz to 200 Hz). However, this is one possible source in a list of many commonly encountered sources such as pumps, boilers, fans, road, sea and rail traffic, the wind, thunder, the sea, etc. The report only considers the general issues associated with low frequency sound and makes no attempt to quantify the potential problem associated with each of these sources. This is in contrast to other reports which have considered the specific situation associated with wind farms.

A.73. In respect of low frequency sound as opposed to infrasound, the DTI LFN Report identified that wind farm noise levels at the studied properties were, under certain conditions, measured at a level just above the threshold of audibility. The report therefore concluded that 'for a low frequency sensitive person, this may mean that low frequency sound associated with the operation of the three wind farms could be audible within a dwelling'. This conclusion was, however, placed into some context with the qualifying statement that 'at all measurement sites, low frequency sound associated with traffic movements along local roads has been found to be greater than that from the neighbouring wind farm'. In particular, it was concluded that, although measurable and under some conditions may be audible, levels of low frequency sound were below permitted night time low frequency sound criteria, including the latest UK criteria resulting from the 2003 DEFRA study into the effects of low frequency sound.

28 Health effects related to wind turbine sound: an update, I. van Kamp, G.P. van den Berg, National Institute for Public Health and the Environment (RIVM), RIVM report 2020-0150, October 2020.
29 'Low frequency noise', Report by Casella Stanger for DEFRA, 2001.

A.74. Based on the findings of the DTI LFN Report, low frequency sound in the greater than 20 Hz frequency range may, under some circumstances, be measured to be of a comparable or higher level than the threshold of audibility. On such occasions this low frequency sound may become audible to low frequency sensitive persons who may already be awake inside nearby properties, but not to the degree that it will cause awakenings. However, such noise should still be assessed for its potential subjective effects in the conventional manner in which environmental noise is generally assessed. In particular, the subjective effects of this audible low frequency sound should not be confused with the claimed adverse health effect arguments concerning infrasound which, in any event, have now been shown from the results of the DTI LFN Report to be wholly unsubstantiated.

A.75. In November 2006, the UK Government released a statement[30] concerning low frequency sound, reiterating the conclusion of the DTI LFN report that:

> *'there is no evidence of health effects arising from infrasound or low frequency sound generated by wind turbines'.*

A.76. The Government statement concluded the position regarding low frequency sound from wind farms with the definitive advice to all English Local Planning Authorities and the Planning Inspectorate that PPS22 and ETSU-R-97 should continue to be followed for the assessment of noise from wind farms.

Blade swish (amplitude modulation)

A.77. The noise assessment methodology presented in ETSU-R-97, sets out noise limits which already account for typically encountered levels of blade swish. Notwithstanding the conclusions and advice presented in the preceding paragraphs concerning both infrasound and low frequency sound, the DTI LFN Report went on to suggest that, where complaints of noise at night had occurred, these had most likely resulted from an increased amplitude modulation of the blade passing noise, making the 'swish, swish, swish' sound (often referred to as 'blade swish') more prominent than normal. Whilst it was therefore acknowledged that this effect of enhanced amplitude modulation of blade aerodynamic noise may occur, it was also concluded that there were a number of factors that should be borne in mind when considering the importance to be placed on the issue when considering present and proposed wind farm installations:

- it appeared that the effect had only been reported as a problem at a very limited number of sites (the DTI report looked at the 3 out of 5 U.K. sites where it has been reported to be an issue out of the 126 onshore wind farms reported to be operational at the time in 2006);
- the effect occurred only under certain conditions at these sites (the DTI LFN Report was significantly delayed while those involved in taking the measurements waited for the situation to occur at each location);
- at one of the sites concerned it had been demonstrated that the effect can be reduced to an acceptable level by the introduction of a Noise Reduction Management System (NRMS) which controls the operation of the necessary turbines under the relevant wind conditions (this NRMS had to be switched off in order to gain the data necessary to inform the DTI LFN Report);
- whilst still under review, it appeared that the most likely cause of the increased amplitude modulation was related to an increase in the stability of the atmosphere during evening and night time periods, hence the increased occurrence of such an effect at these times, but this effect had been shown by measurement of wind speed profiles to be extremely site specific;
- internal noise levels were below all accepted night time criteria limits and insufficient to wake residents, it was only when woken by other sources of a higher level (such as local road traffic) that there were self-reported difficulties in returning to sleep.

30 'Advice on Findings of the Hayes McKenzie Report on Noise Arising from Wind Farms', URN 06/2162 (November 2006).

A.78. The Government then commissioned an independent research project to further investigate the prevalence of the impact of enhanced levels of amplitude modulation across UK wind farms. This research work was awarded to the University of Salford who reported on their findings in July 2007[31]. The Salford study concluded that that the occurrence of increased levels of 'blade swish' was infrequent, but suggested it would be useful to undertake further work to understand and assess this feature of wind turbine noise.

A.79. As a consequence of the findings of the report by the University of Salford, the UK Department for Business, Enterprise and Regulatory Reform (BERR formerly the DTI) issued a statement in August 2007[32] which concluded:-

> *'A comprehensive study by Salford University has concluded that the noise phenomenon known as aerodynamic modulation (AM) is not an issue for the UK's wind farm fleet.*
>
> *AM indicates aerodynamic noise from wind turbines that is greater than the normal degree of regular fluctuation of blade swoosh. It is sometimes described as sounding like a distant train or distant piling operation.*
>
> *The Government commissioned work assessed 133 operational wind projects across Britain and found that although the occurrence of AM cannot be fully predicted, the incidence of it from operational turbines is low'.*

A.80. The statement then concludes with the advice:

> *'Government continues to support the approach set out in Planning Policy Statement (PPS) 22 – Renewable Energy. This approach is for local planning authorities to "ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels", through the use of the 1997 report by ETSU to assess and rate noise from wind energy development'.*

A.81. This represents an aspect of wind turbine noise which has become the subject of considerable research in the UK and abroad in the past years and the state of knowledge on the subject is rapidly evolving. An extensive research programme entitled 'Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect' was published in 2013[33]. This research, commissioned by RenewableUK (ReUK) was specifically aimed at identifying and explaining some of the key features of wind turbine AM noise.

A.82. Claims have emerged from different researchers that wind turbines were capable of generating noise with characteristics out with that expected of them. This characteristic was an enhanced level of modulated aerodynamic noise that resulted in the blade swish becoming more impulsive in character, such that those exposed to it would describe it more as a 'whoomp' or 'thump' than a 'swish'. It could also become audible at distances from the wind turbines that were considerably greater than the distances at which blade swish could ordinarily be perceived. It has since emerged that this may be similar to the character of the noise identified in the DTI LFN study. Hence for the purposes of the ReUK project, any such AM phenomena with characteristics falling outside those expected of this "normal" AM (NAM) were therefore termed 'Other AM' (OAM).

A.83. The research identified the most likely cause of OAM noise is transient stall on the wind turbine blade (i.e. stall which occurs over a small area of each turbine blade in one part of the blade's rotation only). The occurrence of transient stall will be dependent on a combination of factors, including the air inflow conditions onto the individual blades, how these inflow conditions may vary across the rotor disc, the design of the wind turbine blades and the manner in which the wind turbine is operated. Variable inflow

31 'Research into Aerodynamic Modulation of Wind Turbine Noise', Report by University of Salford, URN 07/1235 (July 2007)
32 'Government statement regarding the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise', BERR, Ref: 2007/033 (1st August 2007)
33 Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect, Renewable UK, December 2013.

conditions may arise, for example, from any combination of wind shear, wind veer, yaw errors, turbine wake effects, topographic effects, large scale turbulence, etc. However, the occurrence of OAM on any particular site cannot be predicted at this stage.

A.84. As a consequence of the combined results of the ReUK research, and most notably the development of objective techniques for identifying and quantifying AM noise and the ability to relate such an objective measure to the subjective response to AM noise, ReUK has proposed an AM test[34] for implementation as a planning condition, although this was subject to discussion.

A.85. The Institute of Acoustics (IOA) published in 2016 a standardised methodology[35] for the assessment and rating of AM magnitude. The method provides a decibel level each 10 minute which represents the magnitude of the modulation in the noise, and minimises the influence of sources not related to wind turbines. The proposed method, unlike other methods that have previously been proposed, utilises as the core of its detection capability the fact that AM noise from wind turbines, by definition, exhibits periodicity at a rate that is directly related to the rotational speed of the source wind turbine. The IOA document does not however provide any thresholds or criteria methodology for using the resulting AM values.

A.86. The UK Government (DECC or Department of Energy and Climate Change, now obsolete) commissioned a review focused on the subjective response to AM with a view to recommend how this feature may be controlled. The outcome of this research has been published[36] in October 2016 by the Department for Business, Energy & Industrial Strategy (DBEIS). This report recommends the use of a "character penalty" approach, in which a correction is applied to the overall A-weighted noise level to account for AM in the noise in a manner similar to that used to assess tonality in the noise according to ETSU-R-97. This penalty is based on the above IOA methodology for detecting AM. The researchers make a number of recommendations for local authorities to consider and qualifications for the use of such controls, and note that the current state of knowledge on the subject and the implications of their proposed control is limited and that a period of testing and review over the next few years would be beneficial. The authors were however unable to provide clarity on how exactly the recommendations would operate in practice for any particular wind farm. On publication of the report, DBEIS encouraged local authorities in England to consider the research but provided limited guidance on how the outcomes were to be accounted for within the planning system.

A.87. Subsequently, a report commissioned by the UK Department for Business, Energy & Industrial Strategy was published[37] in February 2023 and concludes that the noise limits in ETSU-R-97 should be reviewed and that updated guidance on amplitude modulation should be included but makes no firm recommendations with regards to any update. Therefore, until the UK or Welsh governments conclude such a review, the ETSU-R-97 methodology continues to be applicable. The UK Government has also confirmed[38] that ETSU-R-97 should continue to apply until the review recommendations are considered in further detail.

34 Template Planning Condition on Amplitude Modulation (guidance notes), RenewableUK, December 2013.

35 Institute of Acoustics (IOA) Amplitude Modulation Working Group, Final Report, A Method for Rating Amplitude Modulation in Wind Turbine Noise, June 2016.

36 Review of the evidence on the response to amplitude modulation from wind turbines, WSP for Department for Business, Energy & Industrial Strategy. https://www.gov.uk/government/publications/review-of-the-evidence-on-the-response-to-amplitude-modulation-from-wind-turbines

37 WSP, A Review of Noise Guidance for Onshore Wind Turbines, report for the UK Department for Business, Energy & Industrial Strategy, October 2022 (published 10 February 2023).

38 Government Response to the House of Lords Science and Technology Committee Report: The neglected pollutants: the effects of artificial light and noise on human health, December 2023. https://committees.parliament.uk/publications/42401/documents/210714/default/ [accessed September 2024]

Glossary of Acoustics Terminology

Terminology	Description
A-weighting	A filter that down-weights low frequency and high frequency sound to better represent the frequency response of the human ear when assessing the likely effects of noise on humans
Acoustic character	One or more distinctive features of a sound (e.g. Tones, whines, whistles, impulses) that set it apart from the background noise against which it is being judged, possibly leading to a greater subjective effect than the level of the sound alone might suggest
Acoustic screening	The presence of a solid barrier (natural landform or manmade) between a source of sound and a receiver that interrupts the direct line of sight between the two, thus reducing the sound level at the receiver compared to that in the absence of the barrier
Ambient noise	All-encompassing noise associated with a given environment, usually a composite of sounds from many sources both far and near, often with no particular sound being dominant
Annoyance	A feeling of displeasure in this case evoked by noise
Attenuation	The reduction in level of a sound between the source and a receiver due to any combination of effects including: distance, atmospheric absorption, acoustic screening, the presence of a building façade, etc.
Audio frequency	Any frequency of a sound wave that lies within the frequency limits of audibility of a healthy human ear, generally accepted as being from 20 Hz To 20,000 Hz
Background noise	The noise level rarely fallen below in any given location over any given time period, often classed according to day time, evening or night time periods (for the majority of the population of the UK the lower limiting noise level is usually controlled by noise emanating from distant road, rail or air traffic)
Db	Abbreviation for 'decibel'
Db(a)	Abbreviation for the decibel level of a sound that has been a-weighted
Decibel	The unit normally employed to measure the magnitude of sound
Directivity	The property of a sound source that causes more sound to be radiated in one direction than another
Equivalent continuous sound pressure level	The steady sound level which has the same energy as a time varying sound signal when averaged over the same time interval, t, denoted by $L_{Aeq,t}$
External noise level	The noise level, in decibels, measured outside a building
Filter	A device for separating components of an acoustic signal on the basis of their frequencies
Frequency	The number of acoustic pressure fluctuations per second occurring about the atmospheric mean pressure (also known as the 'pitch' of a sound)
Frequency analysis	The analysis of a sound into its frequency components
Ground effects	The modification of sound at a receiver location due to the interaction of the sound wave with the ground along its propagation path from source to receiver
Hertz	The unit normally employed to measure the frequency of a sound, equal to cycles per second of acoustic pressure fluctuations about the atmospheric mean pressure
Impulsive sound	A sound having all its energy concentrated in a very short time period
Instantaneous sound pressure	At a given point in space and at a given instant in time, the difference between the instantaneous pressure and the mean atmospheric pressure
Internal noise level	The noise level, in decibels, measured inside a building
L_{Aeq}	The abbreviation of the a-weighted equivalent continuous sound pressure level
L_{A10}	The abbreviation of the 10 percentile noise indicator, often used for the measurement of road traffic noise
L_{A90}	The abbreviation of the 90 percentile noise indicator, often used for the measurement of background noise
Level	The general term used to describe a sound once it has been converted into decibels
Loudness	The attribute of human auditory response in which sound may be ordered on a subjective scale that typically extends from barely audible to painfully loud
Noise	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure.

Terminology	Description
	Subjectively: sound that evokes a feeling of displeasure in the environment in which it is heard, and is therefore unwelcomed by the receiver
Noise emission	The noise emitted by a source of sound
Noise immission	The noise to which a receiver is exposed
Noise nuisance	An unlawful interference with a person's use or enjoyment of land, or of some right over, or in connection with it
Octave band frequency analysis	A frequency analysis using a filter that is an octave wide (the upper limit of the filter's frequency band is exactly twice that of its lower frequency limit)
Percentile exceeded sound level	The noise level exceeded for n% of the time over a given time period, t, denoted by $L_{An,t}$
Receiver	A person or property exposed to the noise being considered
Residual noise	The ambient noise that remains in the absence of the specific noise whose effects are being assessed
Sound	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure
	Subjectively: the sensation of hearing excited by the acoustic oscillations described above (see also 'noise')
Sound level meter	An instrument for measuring sound pressure level
Sound pressure amplitude	The root mean square of the amplitude of the acoustic pressure fluctuations in a sound wave around the atmospheric mean pressure, usually measured in pascals (Pa)
Sound pressure level	A measure of the sound pressure at a point, in decibels
Sound power level	The total sound power radiated by a source, in decibels
Spectrum	A description of the amplitude of a sound as a function of frequency
Standardised wind speed	Values of wind speed at hub height corrected to a standardised height of ten metres using the same procedure as used in wind turbine emission testing
Threshold of hearing	The lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa)
Tone	The concentration of acoustic energy into a very narrow frequency range

Annex B – Location Maps and Turbine Coordinates

Figure B1 Map showing the layout of the turbines (red dots), the noise assessment locations (black dots) and the background noise survey locations (blue dots). FI receptors are marked with *

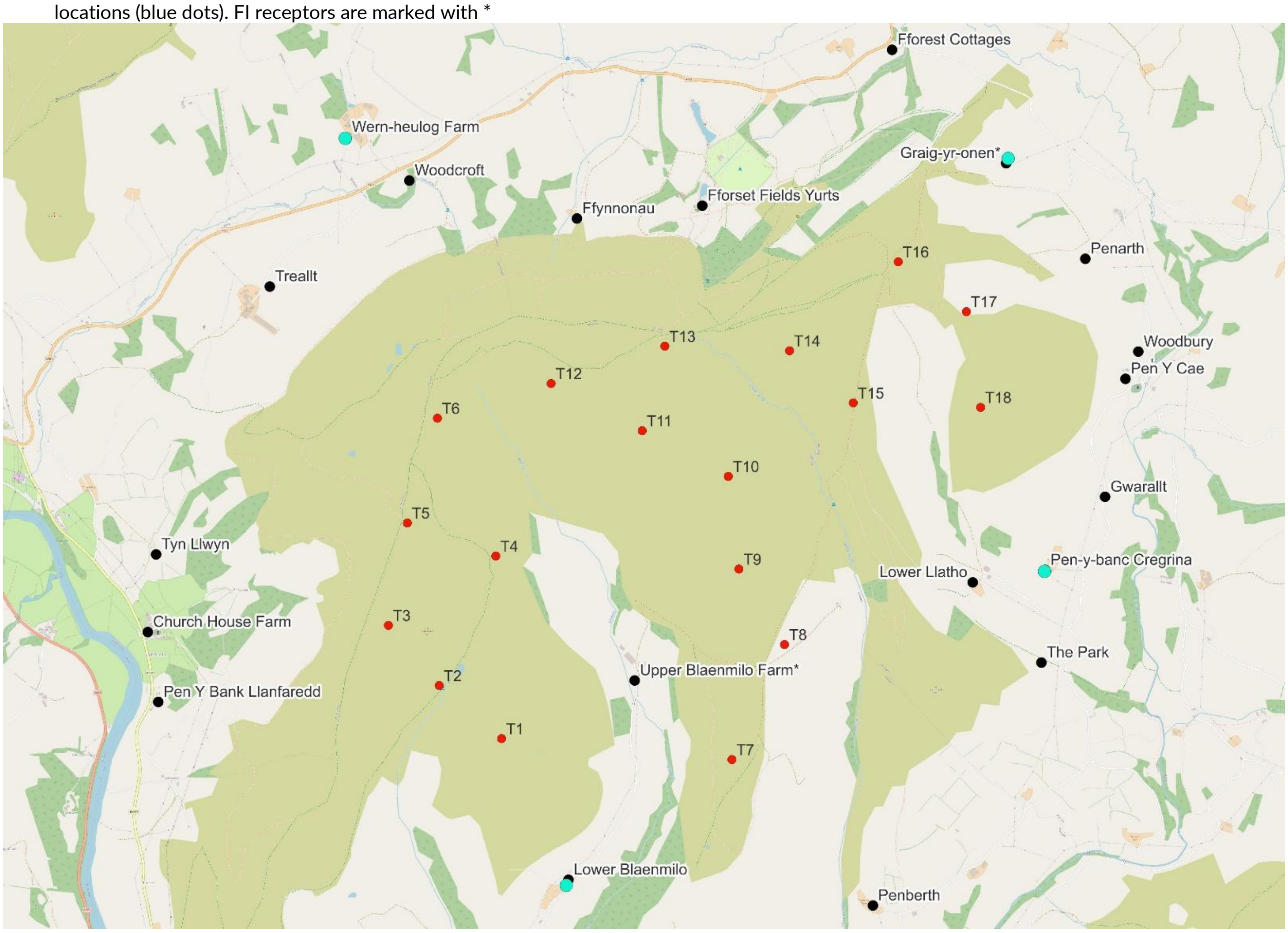


Table B1 – Turbine coordinates

Turbine	Easting	Northing
1	308846	250156
2	308501	250450
3	308220	250783
4	308814	251167
5	308325	251350
6	308491	251930
7	310120	250040
8	310411	250677
9	310159	251095
10	310100	251608
11	309624	251861
12	309120	252122
13	309749	252329
14	310439	252304
15	310791	252015
16	311040	252796
17	311417	252520
18	311496	251990

Table B2 - Propagation attenuation effects due to terrain (dB) – positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Turbine number	Property								
	Ffynnonau	Fforest Field Yurts	Fforest Cottages	Woodbury	Pen y Cae	Gwarallt	Pen-y-banc Cregrina	Lower Llatho	The Park
1	2	2	2	2	2	2	-3	2	2
2	2	2	0	2	2	2	0	2	2
3	2	2	0	2	2	2	0	2	2
4	2	2	0	2	2	2	0	2	2
5	2	2	0	2	2	2	0	2	2
6	2	2	0	2	2	2	0	2	2
7	2	2	2	2	2	2	-3	2	2
8	2	2	2	2	2	2	-3	2	2
9	2	2	2	2	2	2	-3	0	2
10	2	0	2	2	2	2	-3	0	0
11	2	2	0	2	2	2	0	2	0
12	2	2	0	2	2	2	0	2	2
13	0	0	0	2	2	2	0	0	0
14	2	0	0	2	2	2	0	0	0

Turbine number	Property								
	Ffynnonau	Fforest Field Yurts	Fforest Cottages	Woodbury	Pen y Cae	Gwarallt	Pen-y-banc Cregrina	Lower Llatho	The Park
15	2	0	2	2	2	2	0	0	-3
16	0	0	0	2	2	2	0	0	0
17	2	2	0	0	2	0	0	0	0
18	2	2	0	0	0	0	0	0	0

Turbine number	Property									
	Penberth	Lower Blaenmilo	Tyn Llwyn	Woodcroft	Graig-yr-onen	Penarth	Church House Farm	Upper Blaenmilo Farm	Pen y Bank Llanfaredd	Treallt
1	0	0	0	2	2	2	2	0	2	2
2	0	0	0	2	2	2	0	2	0	2
3	2	2	0	2	2	2	0	2	0	2
4	2	2	2	2	2	2	0	0	0	2
5	2	2	0	2	2	2	0	0	0	2
6	2	2	2	0	2	2	0	0	0	0
7	0	-3	2	2	2	2	2	0	2	2
8	0	0	2	2	2	2	2	0	2	2
9	0	-3	2	2	2	2	2	0	2	2
10	0	0	2	2	2	2	2	0	2	2
11	0	2	2	2	2	2	2	0	2	2
12	2	2	2	0	2	2	2	0	0	2
13	0	2	2	0	2	2	2	0	2	2
14	2	0	2	0	2	0	2	2	2	2
15	2	0	2	2	0	2	2	2	2	2
16	2	0	2	0	0	0	2	2	2	2
17	2	0	2	0	0	0	2	2	2	2
18	2	0	2	2	0	0	2	2	2	2

Table B3 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment - the Proposed Development

Turbine make / model	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Nordex N163 Mode 0.b (standard) 7MW	-	-	97.8	99.4	104.2	108.6	109.4	109.4	109.4	109.4	109.4	109.4
Mode 2.a	-	-	97.8	99.4	104.2	108.4	108.8	108.8	108.8	108.8	108.8	108.8
Mode 3.a	-	-	97.8	99.4	104.2	108.1	108.3	108.3	108.3	108.3	108.3	108.3
Mode 5.a	-	-	97.8	99.4	104.2	107.3	107.3	107.3	107.3	107.3	107.3	107.3
Derived from: Nordex N163 6.X VPC document 'Third octave sound power levels', reference F008_277a_A13_EN, Rev 05, 03/05/2024, Doc. 9007485. With an additional 2dB added for uncertainties in absence of uncertainty information, accounted for in the above values. Data for 118m hub height turbine model with Serrated Trailing Edges (STEs).												

Table B4 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - the Proposed Development

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Nordex N163	88.6	96.2	98.3	99.5	101.3	102.0	96.4	82.0	107.3
Derived from Nordex document 'Octave sound power levels', reference F008_277a_A19_IN, Rev 05, Doc 9007486 (data for *STE variant*). Data for a 118m hub height turbine model, with STEs.									

Annex C – Noise Monitoring Information Sheets

Table C1 - Information on the measurement location, equipment and noise data at Graig-yr-onen.

Measurement Location Name	Graig-yr-onen
Measurement Location Description	Graig-yr-onen was chosen as a representative proxy background measurement location following access refusal for background noise measurements at both the Fynnonau property and the Fforest Fields yurts campsite. The Graig-yr-onen property was determined to be a suitable proxy measurement location as it was similarly distanced from the main A481 road to minimise distant road traffic noise as the two locations and also located in a similar terrain and north/northeast orientation from the Proposed Development turbines. The logger was positioned in the garden adjacent to the residential farmhouse, avoiding exposure to potential localised sources of noise such as boiler flues and distanced at least 3.5 metres away from any solid walls and tall fences to minimise reflection effects. The location was chosen toward the rear of the property as the noise climate in main amenity space of the front garden was observed to be more influenced by mature vegetation. Observed local noise sources from the logger position were distant overhead passenger jet aircraft noise, occasional birdsong noise, occasional distant sheep livestock noise in the surrounding fields and occasional vegetation noise slightly present in calm winds. SLM Location: 311647 / 253369

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	00331820	23/05/2023
Microphone	Rion UC-59	04886	23/05/2023
Pre-amplifier	Rion NH-25	21771	23/05/2023
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Fri 12/04/24 09:10	Thu 25/04/24 11:50	94.0	93.9	-0.1	No significant drift
02	Thu 25/04/24 12:10	Wed 08/05/24 17:50	94.0	94.1	0.1	No significant drift

Data Exclusions
Quiet daytime measurement period data exclusions, due to atypically elevated short term noise events compared to the general background noise data trend: - Data between 0 <= WS <= 3 m/s, above L_{A90} levels of 35 dB - Data between 4 <= WS <= 5 m/s, above L_{A90} levels of 40 dB Nighttime measurement period data exclusions, due to atypically elevated short term noise events and morning dawn bird chorus resulting in sporadic elevated early morning noise levels compared to the general reduced background noise level data trend, over the remainder of the nighttime period: - Daily time of day exclusions of data between 04:15 GMT to 06:15 GMT - Data between 0 <= WS <= 7 m/s, above L_{A90} levels of 25 dB - Data between 7 <= WS <= 8 m/s, above L_{A90} levels of 30 dB All data for periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis.

Figure C1 - View of the monitoring location at Graig-yr-onen looking north-east

Figure C2 - View of the monitoring location at Graig-yr-onen looking north

Figure C3 - View of the monitoring location at Graig-yr-onen looking south east

Figure C4 - View of the monitoring location at Graig-yr-onen looking south west

Table C2 - Information on the measurement location, equipment and noise data at Pen y Banc.

Measurement Location Name	Pen y Banc
Measurement Location Description	Following visits to the Lower Llatho, the Park and Pen y Banc properties to determine a conservative and representative background noise measurement position for properties in the area, a logger was installed in the rear garden of the Pen y Banc property. This measurement property was chosen as there were no nearby audible watercourses present, unlike observations made at the Lower Llatho and the Park properties where distant continuous watercourse noise was observed. This measurement location also was determined to represent nearby residential properties to the southeast of the Proposed Development. The logger was positioned to minimise potential workshop/garage/local farm activity noise during the day (primarily occurring outside of quiet daytime periods, which were excluded from the analysis) at the front of the Pen y Banc property. The rear garden was also chosen as the logger could be distanced from large vegetation in the front garden and also avoided a boiler flue outlet in the front garden. Observed noise sources present were local intermittent birdsong. distant vegetation rustle from large trees and occasional distant quad bike activity from surrounding farms. No watercourse noise was observed at this property. SLM Location: 311864 / 251100

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	00331819	22/02/2024
Microphone	Rion UC-59	10813	22/02/2024
Pre-amplifier	Rion NH-25	21770	22/02/2024
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Thu 11/04/24 13:10	Thu 25/04/24 12:10	94.0	93.8	-0.2	No significant drift
02	Thu 25/04/24 12:40	Thu 09/05/24 12:20	94.0	94.2	0.2	No significant drift

Data Exclusions
Quiet daytime measurement period data exclusions, due to atypically elevated short term noise events compared to the general background noise data trend: - Data between 0 <= WS <= 6 m/s, above L_{A90} levels of 37 dB - Data between 6 <= WS <= 7 m/s, above L_{A90} levels of 40 dB - Data between 7 <= WS <= 9 m/s, above L_{A90} levels of 44 dB Nighttime measurement period data exclusions, due to atypically elevated short term noise events and morning dawn bird chorus resulting in sporadic elevated early morning noise levels compared to the general reduced background noise level data trend, over the remainder of the nighttime period: - Daily time of day exclusions of data between 04:00 GMT to 06:30 GMT - Data between 0 <= WS <= 6 m/s, above L_{A90} levels of 27.8 dB - Data between 6 <= WS <= 7 m/s, above L_{A90} levels of 35 dB - Data between 7 <= WS <= 9.5 m/s, above L_{A90} levels of 45 dB All data for periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis.

Figure C5 - View of the monitoring location at Pen y Banc looking west

Figure C6 - View of the monitoring location at Pen y Banc looking north

Figure C7 - View of the monitoring location at Pen y Banc looking east

Figure C8 - View of the monitoring location at Pen y Banc looking south

Table C3 - Information on the measurement location, equipment and noise data at Lower Blaenmilo Farm.

Measurement Location Name	Lower Blaenmilo Farm
Measurement Location Description	Observations were made at both the Upper Blaenmilo Farm and Lower Blaenmilo Farm properties to determine a conservative and representative background noise measurement position, for properties in the area to the south of the Proposed Development. A logger was installed in the outdoor patio area of the Lower Blaenmilo Farm property, adjacent to the house. This measurement property was chosen over Upper Blaenmilo Farm as continuous watercourse noise was dominant at Upper Blaenmilo Farm to the rear (west) of the house and garden, therefore likely to experience higher background noise levels. At Lower Blaenmilo Farm, the rear patio area was chosen to site the logger instead of in the garden area to the southeast. From the garden area, distant watercourse noise was observed at the bottom of the valley to the southeast of the property, however not observed from the patio area closer to the house. Additionally, the elevated patio area was protected from potential livestock in the main farmyard area, reducing the likelihood of damage/interference to equipment. Noise sources at the logger position included occasional localised wind disturbed vegetation noise, occasional distant livestock noise and localised intermittent birdsong noise. SLM Location: 309202 / 249343

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	00331833	23/05/2023
Microphone	Rion UC-59	04900	23/05/2023
Pre-amplifier	Rion NH-25	21784	23/05/2023
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Thu 11/04/24 14:30	Thu 25/04/24 12:50	94.0	93.7	-0.3	No significant drift
02	Thu 25/04/24 13:20	Thu 09/05/24 12:50	94.0	94.3	0.3	No significant drift

Data Exclusions
Quiet daytime measurement period data exclusions, due to atypically elevated short term noise events compared to the general background noise data trend: - Data between 0 <= WS <= 7 m/s, above L_{A90} levels of 41 dB - Data between 7 <= WS <= 10 m/s, above L_{A90} levels of 45 dB Nighttime measurement period data exclusions, due to atypically elevated short term noise events and morning dawn bird chorus resulting in sporadic elevated early morning noise levels compared to the general reduced background noise level data trend, over the remainder of the nighttime period: - Daily time of day exclusions of data between 04:00 GMT to 06:00 GMT - Data between 0 <= WS <= 4 m/s, above L_{A90} levels of 30 dB - Data between 4 <= WS <= 6 m/s, above L_{A90} levels of 31.5 dB - Data between 6 <= WS <= 9 m/s, above L_{A90} levels of 37.5 dB All data for periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis.

Figure C9 - View of the monitoring location at Lower Blaenmilo Farm looking north

Figure C10 - View of the monitoring location at Lower Blaenmilo Farm looking southeast

Figure C11 - View of the monitoring location at Lower Blaenmilo Farm looking south

Figure C12 - View of the monitoring location at Lower Blaenmilo Farm looking west

Table C4 - Information on the measurement location, equipment and noise data at Wern-heulog Farm.

Measurement Location Name	Wern-heulog Farm
Measurement Location Description	This measurement location was chosen to measure and represent the existing background noise at properties located along the A481 road to the west, north-west and north of the Proposed Development. This property was identified as a measurement location, following access refusals at properties to the west of the Proposed Development and others near the A481 road. Wern-heulog Farm was chosen as a measurement location, as it is set back from the A481 road. Although exposed to road traffic noise representative of the area's noise environment, the property is relatively distanced from the road (by approximately 300 m) and was therefore a conservative measurement location compared to the nearby properties located closer to the road. The logger was installed in a field to rear (southwest) of the property garden, upon request by the resident to not position it in the property garden. Temporary secured fencing (preventing rattle) was erected around the logger to protect the equipment from livestock damage/interference. The installed location in the field was considered representative of the garden amenity area. Noise sources included distant road traffic noise, occasional local livestock noise, occasional local birdsong noise and infrequent distant farm vehicle activity noise from a chicken farm along the A481 road, approximately 230 m to the southwest of the logger position. SLM Location: 307980 / 253485

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	00632045	22/05/2023
Microphone	Rion UC-59	11317	22/05/2023
Pre-amplifier	Rion NH-25	32073	22/05/2023
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Wed 17/04/24 10:40	Thu 25/04/24 11:20	94.0	93.9	-0.1	No significant drift
02	Thu 25/04/24 11:50	Sun 28/04/24 09:20	94.0	94.2	0.2	No significant drift
03	Thu 09/05/24 14:00	Fri 24/05/24 09:30	94.0	93.7	-0.3	No significant drift

Data Exclusions
Quiet Daytime measurement period exclusions of elevated noise levels, likely due to road traffic noise during busy traffic periods and potentially some periods of dawn chorus birdsong noise, where clusters of data showing background noise levels above 45 dB(A), were excluded from the analysis: - Daily time of day exclusions of data between 03:00 GMT to 06:15 GMT - Data between 0 <= WS <= 12 m/s, above L_{A90} levels of 45 dB All data for periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis.

Figure C13 - View of the monitoring location at Wern-heulog Farm looking north-west

Figure C14 - View of the monitoring location at Wern-heulog Farm looking north-east

Figure C15 - View of the monitoring location at Wern-heulog Farm looking southeast

Figure C16 - View of the monitoring location at Wern-heulog Farm looking west

Annex D – Wind Speeds and Directions

Figure D1 - Wind speed and direction range during all quiet day-time periods (Graig-yr-onen data shown; other data excluded at some of the other locations).

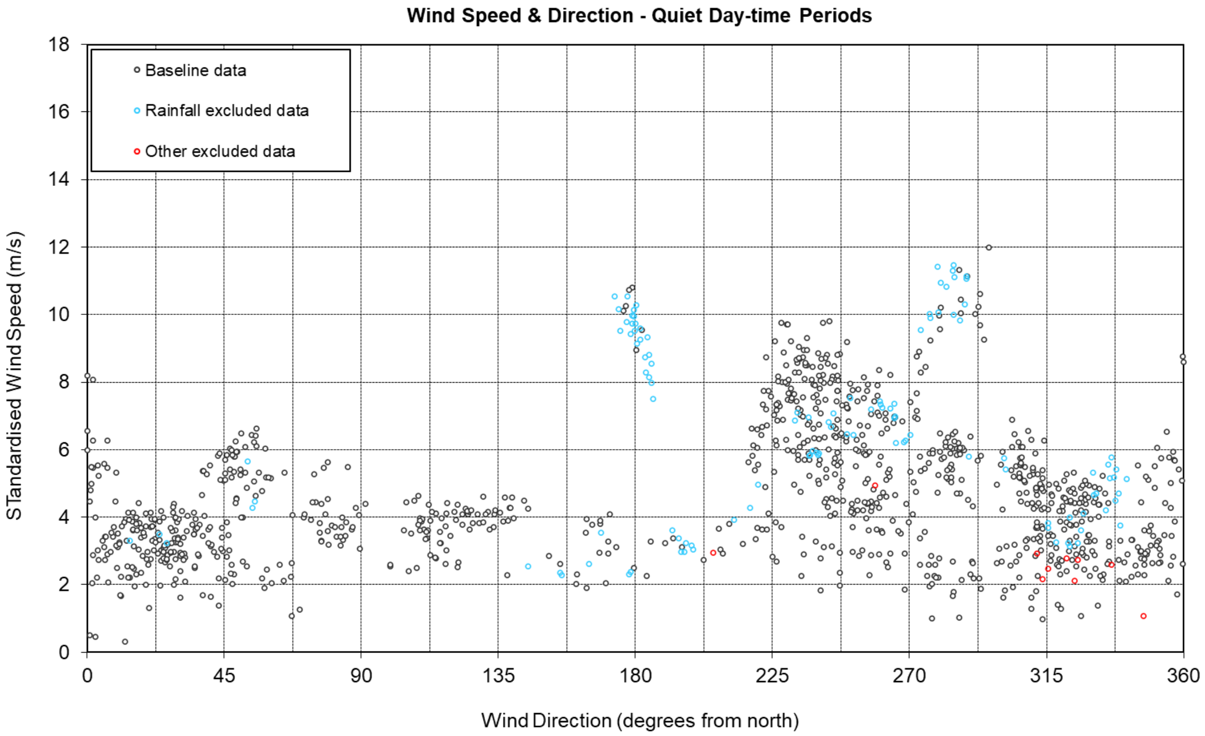


Figure D2 - Wind speed and direction range during all night-time periods (Graig-yr-onen data shown; other data excluded at some of the other locations).

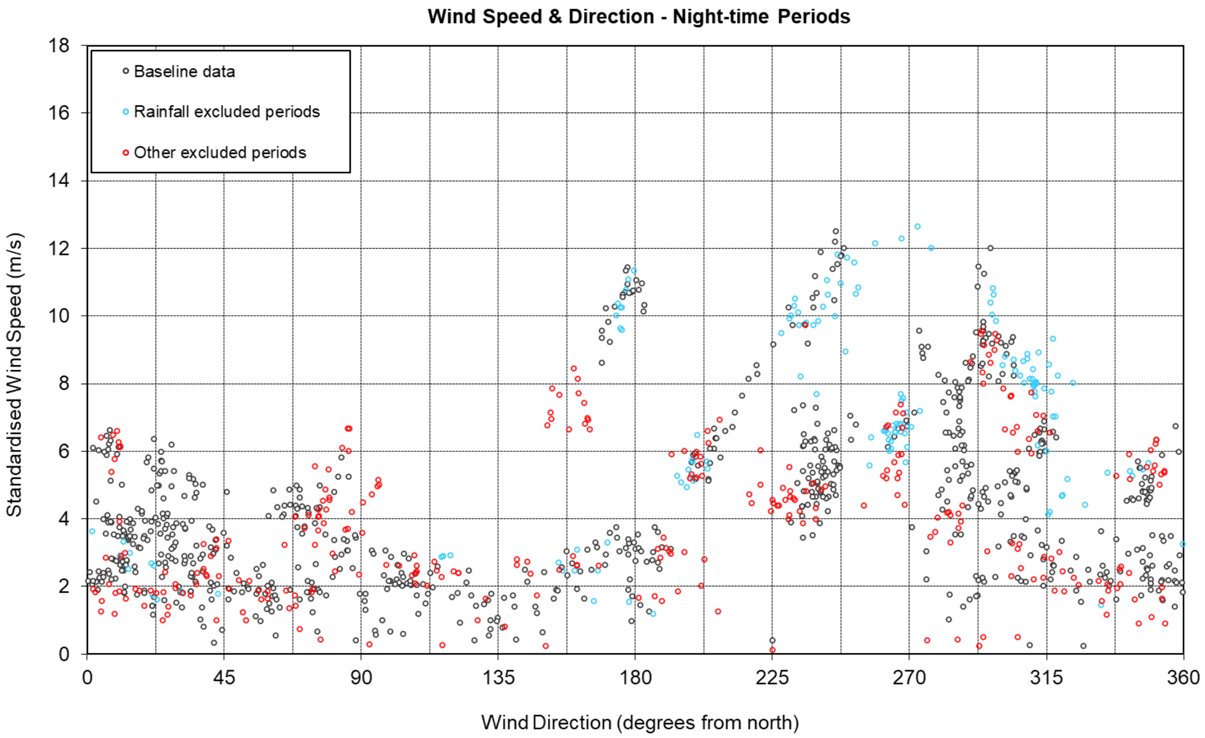


Figure D3 - Wind speed and direction range during all quiet day-time periods for Wern-heulog Farm

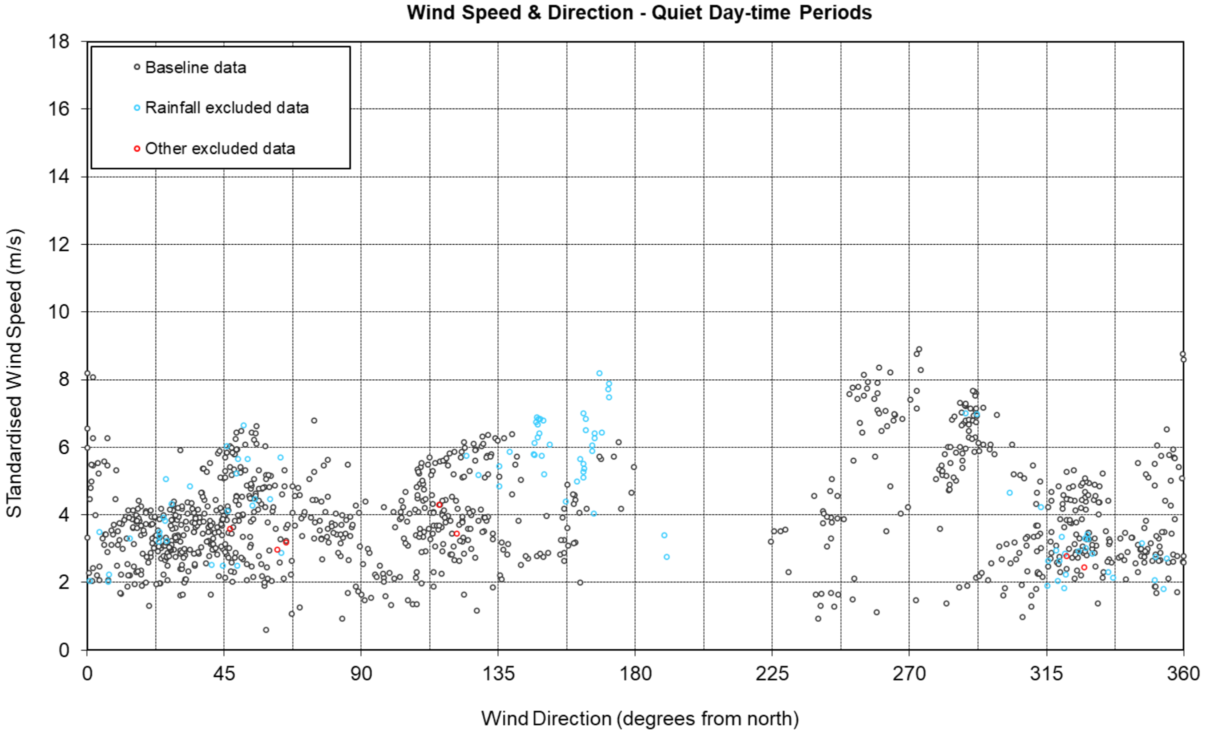
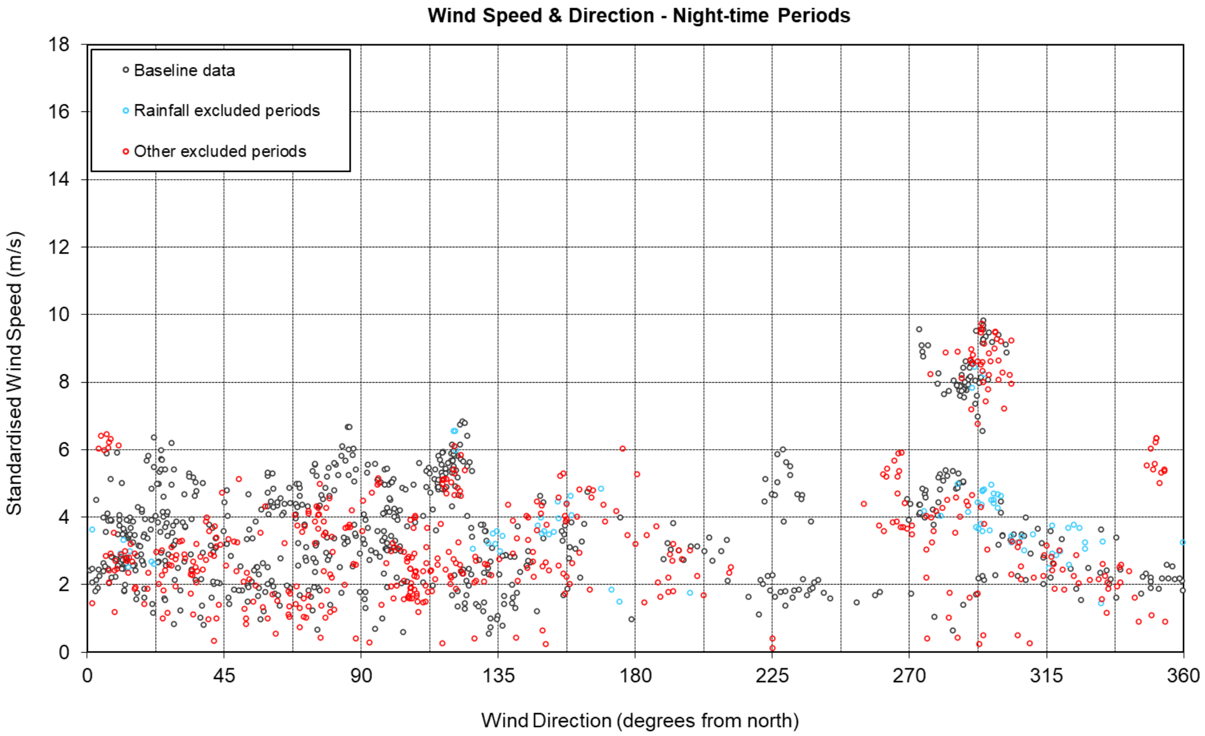


Figure D4 - Wind speed and direction range during all night-time periods for Wern-heulog Farm



Annex E – Background Noise and Noise Limits

Figure E1 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Fforest Field Yurts during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

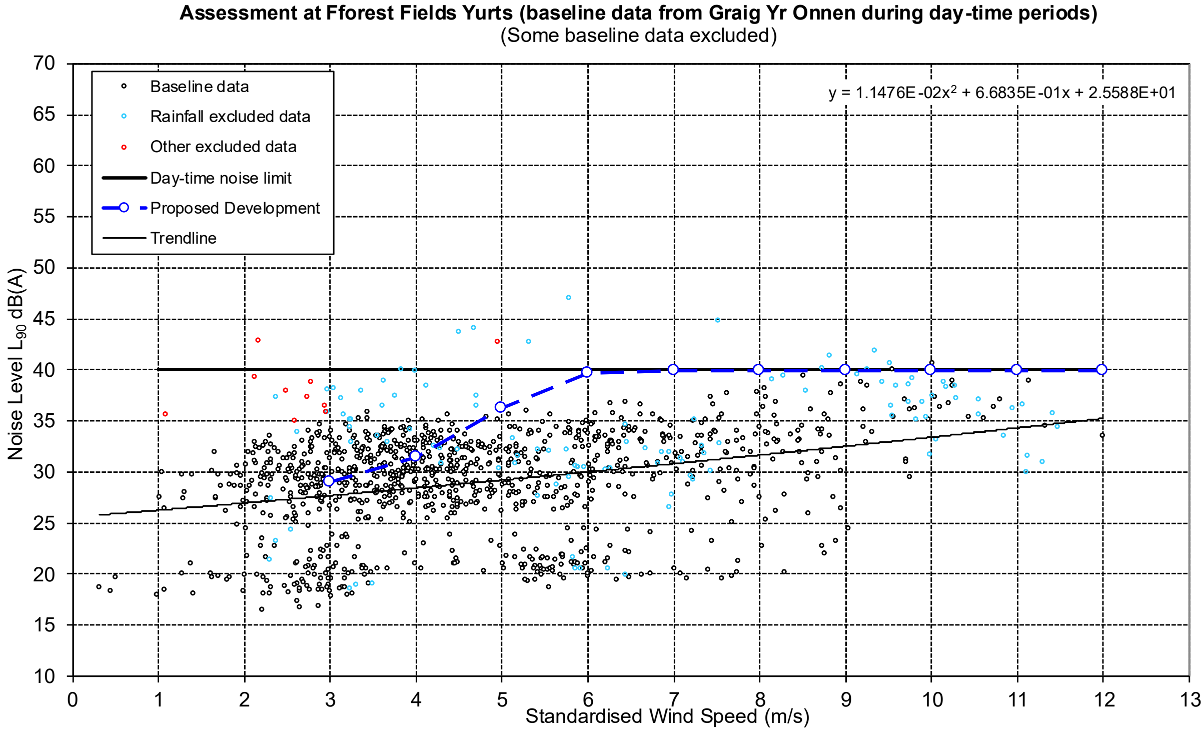


Figure E2 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Fforest Field Yurts during night time periods. Predicted immission noise levels are also shown for the Proposed Development.

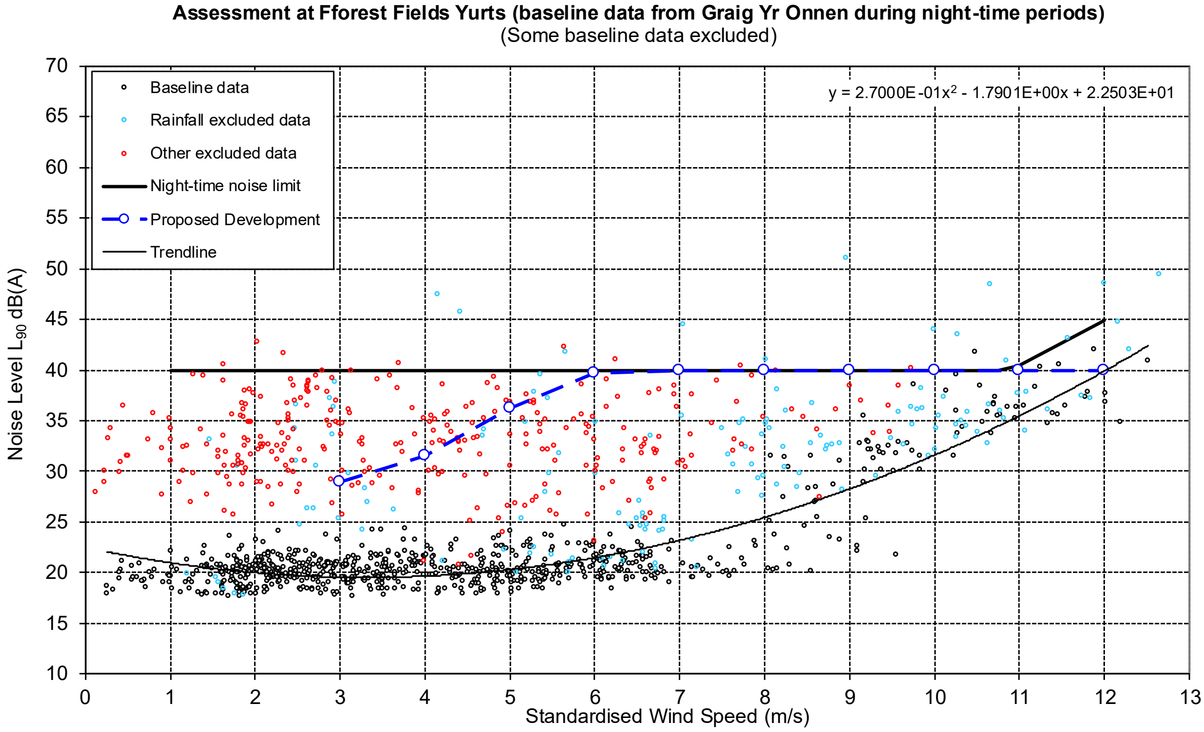


Figure E3 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Fforest Cottages during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

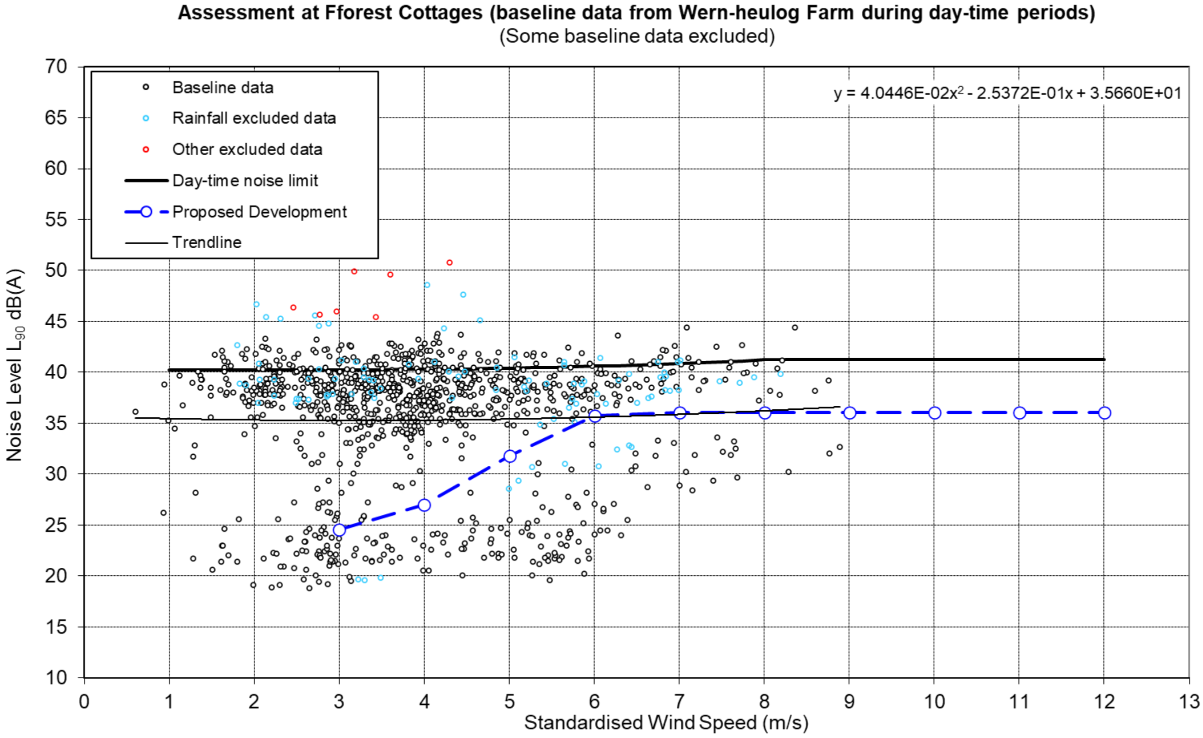


Figure E4 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Fforest Cottages during night time periods. Predicted immission noise levels are also shown for the Proposed Development.

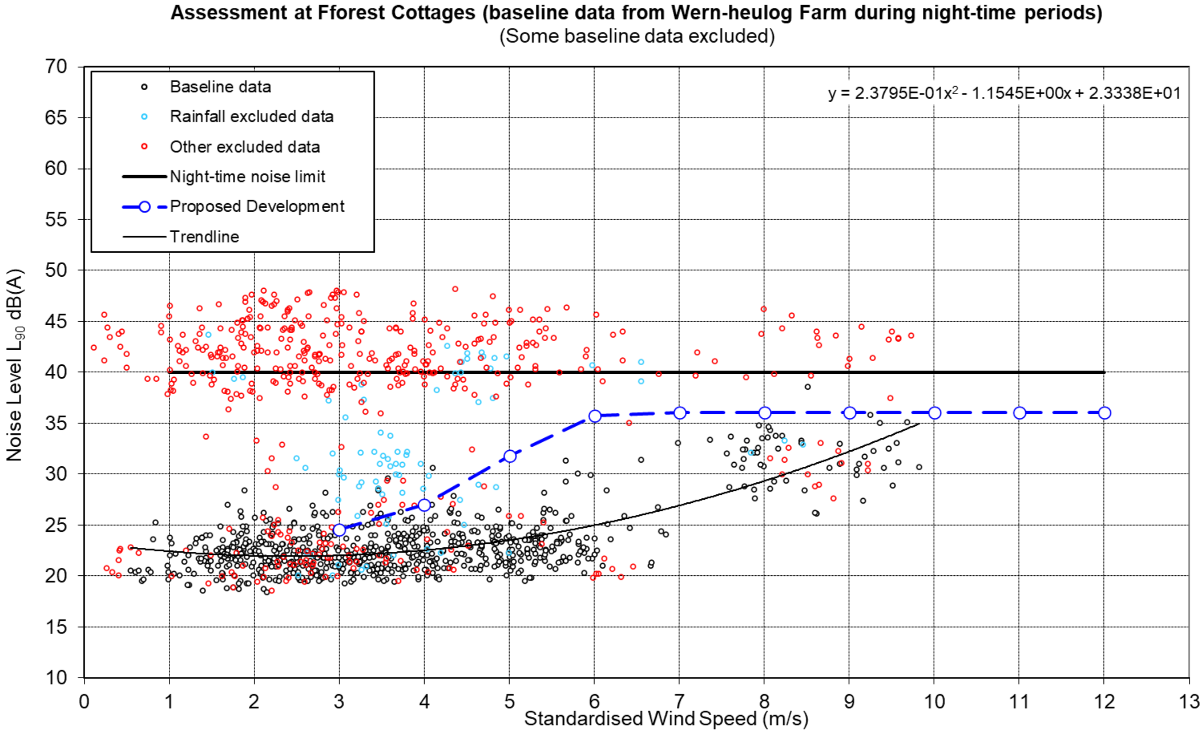


Figure E5 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Pen-y-banc Cregrina during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

Assessment at Pen-y-banc Cregrina (baseline data from Pen-y-banc during day-time periods)

(Some baseline data excluded)

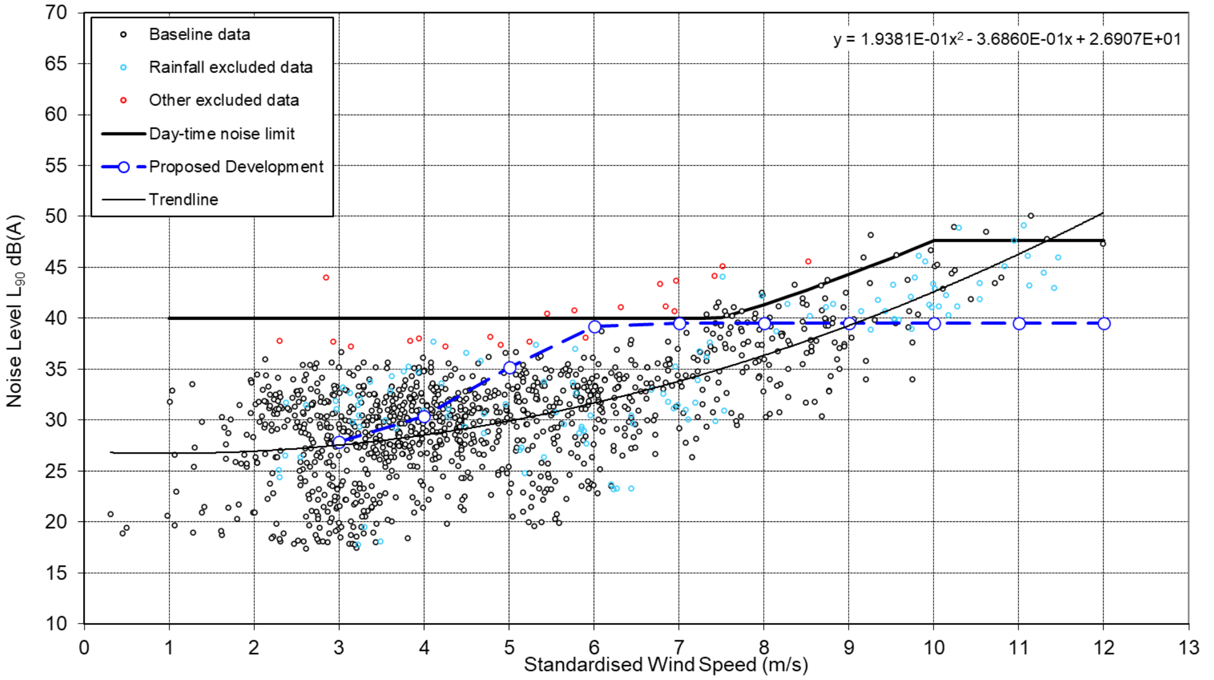


Figure E6 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Pen-y-banc Cregrina during night time periods. Predicted immission noise levels are also shown for the Proposed Development.

Assessment at Pen-y-banc Cregrina (baseline data from Pen-y-banc during night-time periods)

(Some baseline data excluded)

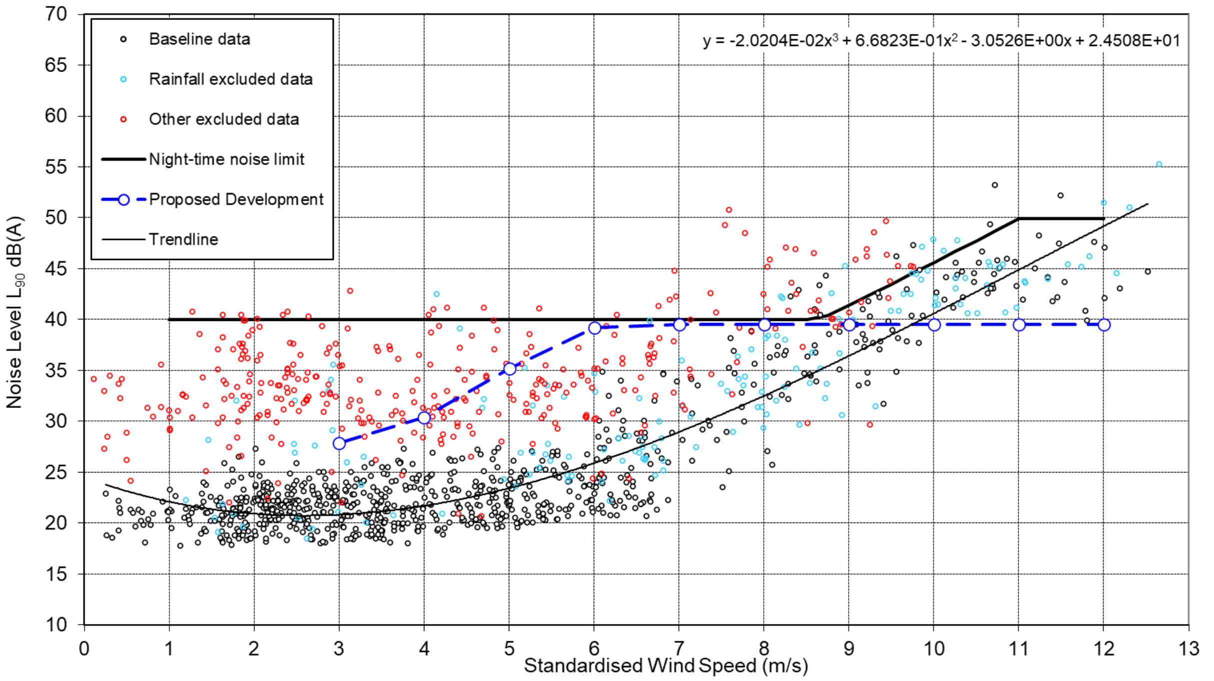


Figure E7 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Lower Blaemilo during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

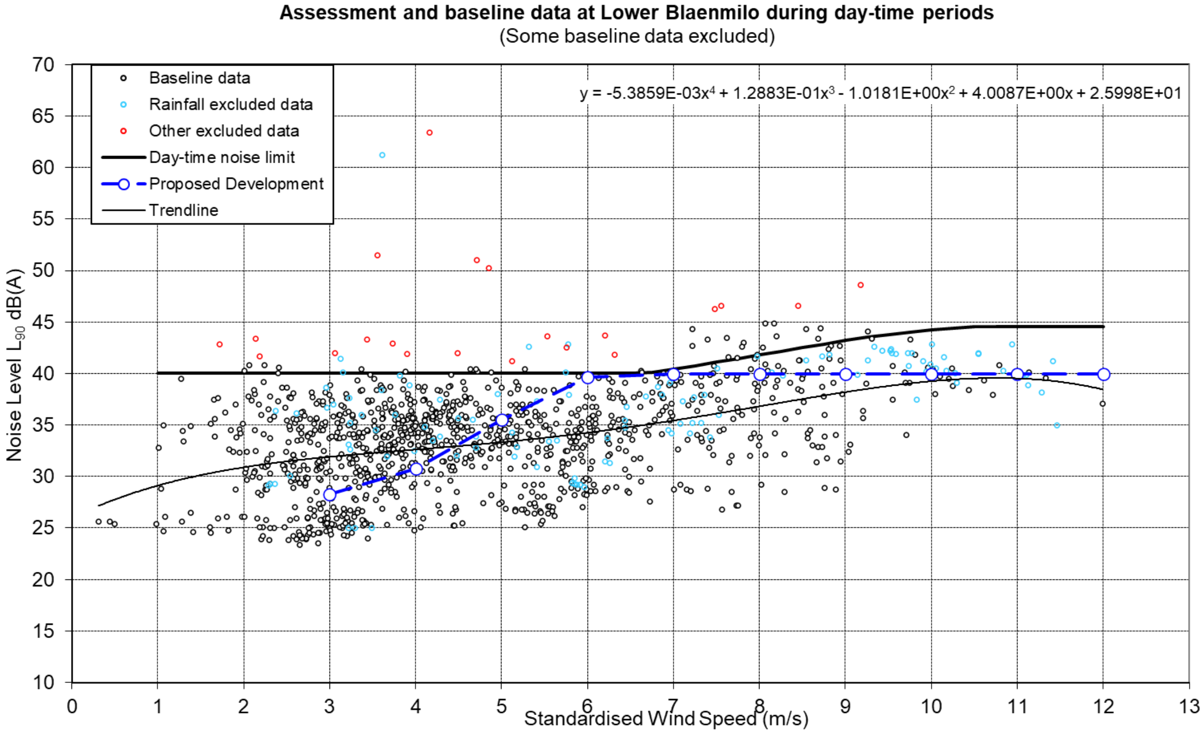


Figure E8 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Lower Blaemilo during night time periods. Predicted immission noise levels are also shown for the Proposed Development.

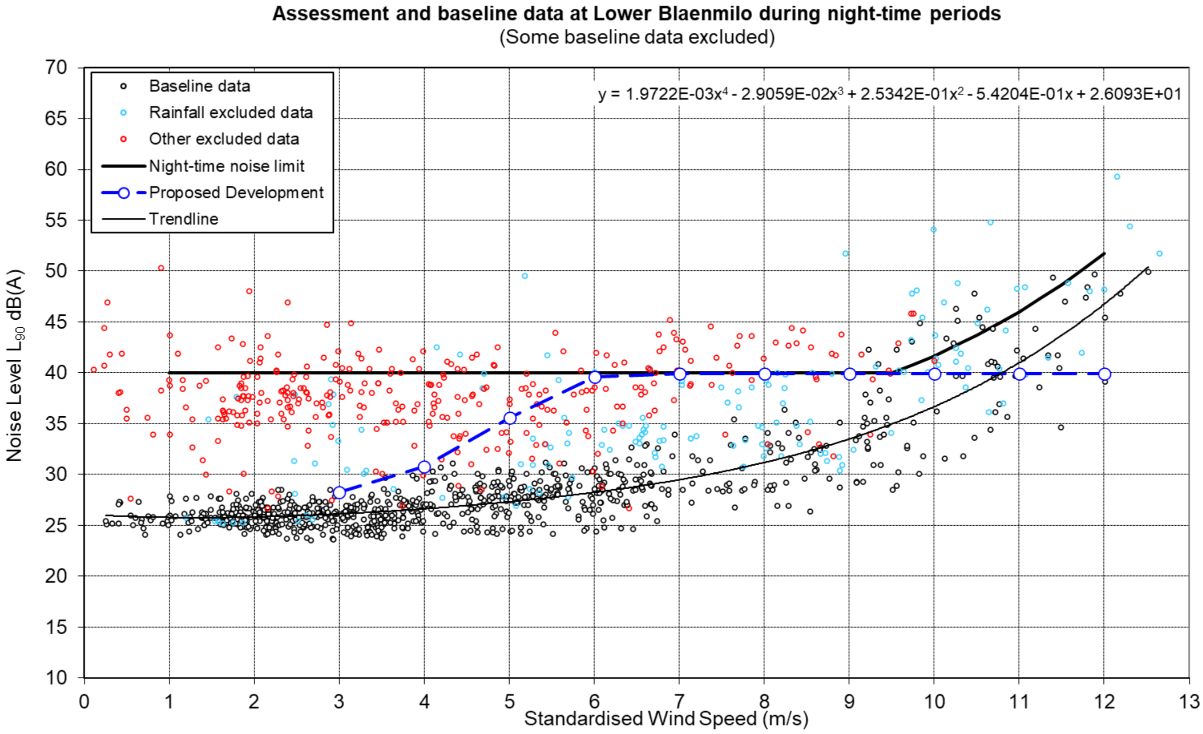


Figure E9 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Upper Blaemilo Farm during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

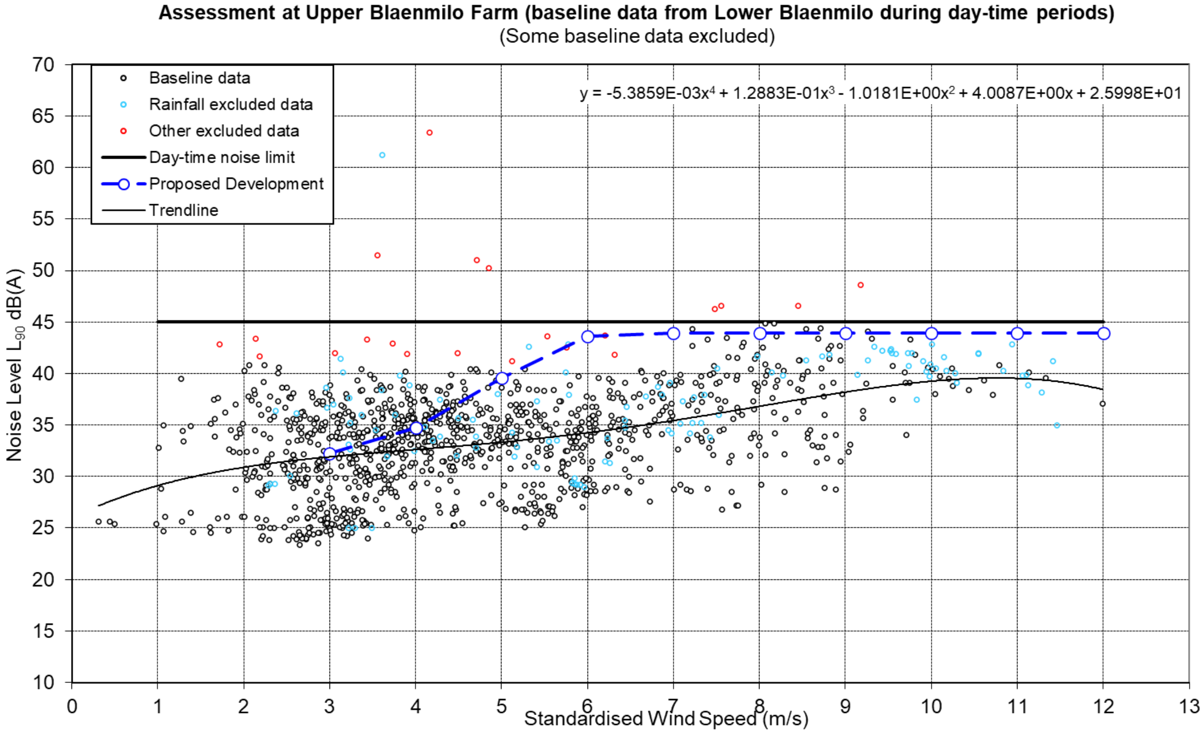
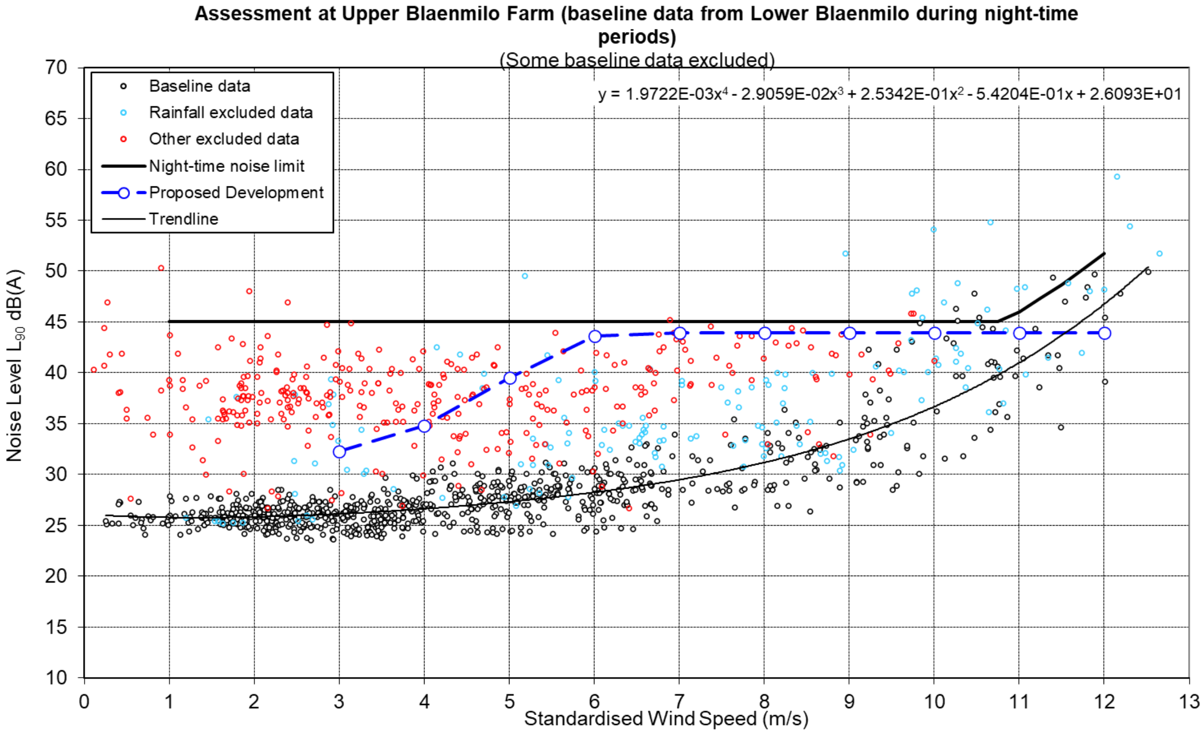


Figure E8 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Upper Blaemilo Farm during night time periods. Predicted immission noise levels are also shown for the Proposed Development.



Annex F – Wind Speed Calculations

F.1 The IOA GPG[39] requires that noise data recorded every 10 minutes are related to standardised ten metre wind speeds experienced at the hub height of the turbines, at a location on the wind farm representative of the wind farm. These wind speeds can be either measured directly at the turbine hub height or derived by calculation from measurements at two heights, with measurements at the upper height not less than 60% of the turbine hub height and measurements at least 15 metres below that. These are referred to as 'Method A' or 'Method B' in the IOA GPG which describes these as the preferred methods to use. IOA GPG SGN4[40] provides additional guidance on these methods.

F.2 The site of the Proposed Development has a temporary LIDAR remote sensing measuring system installed which measured wind conditions at a height of 125m. This LIDAR measurement height is considered representative on a precautionary basis of the proposed 118 m turbine hub height. The following data was therefore referenced:

- 125 metre wind speed
- 125 metre wind direction

F.3 The LIDAR used meets the accuracy and calibration requirements of the IOA GPG.

F.4 Wind speeds are standardised to a height of ten metres assuming a reference ground roughness length of 0.05 metres as described in the IOA GPG. This approach is of the same form as that given in BS EN 61400-11:2003[41] for calculating ten metre wind speeds related to hub height wind speeds when providing source noise emission data for wind turbines.

F.5 By using this method, measured background noise levels were correlated to ten metre wind speeds calculated from wind speeds at hub height. Any likely difference in the shear profile during the 24 hours of the day will be accounted for within the method and be reflected in the resulting standardised ten metre wind speed data. The method used to calculate ten metre wind speeds from those at hub height is the same as that used when deriving noise emission data for the turbines. Because the same method has been used, direct comparison of background noise levels, noise limits and predicted turbine noise immission levels may be undertaken. This method is consistent with guidance published in the IOA GPG.

39 A Good Practice Guide to the Application of ETSU R 97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.
40 A Good Practice Guide to the Application of ETSU R 97 for the Assessment and Rating of Wind Turbine Noise - Supplementary Guidance Note 4: Wind Shear, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, July 2014.
41 IEC 61400 11:2003 Wind turbine generator systems - Part 11: Acoustic noise measurement techniques.

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