NARROGIN WIND FARM
DETAILED ACOUSTIC ASSESSMENT

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SUMMARY

This report presents the results of an assessment of environmental noise associated with the Narrogin Wind Farm (Project) that is proposed to be developed by Neoen (Proponent).

The Project is proposed to comprise of up to twenty-five (25) wind turbines and related infrastructure. The proposed related infrastructure relevant to the environmental noise assessment comprises a Battery Energy Storage System (BESS) and one (1) substation.

The development application for the Project seeks permission to develop, construct and operate wind turbines with a maximum tip height of 291 m. The actual wind turbine which would be used at the Project site would be determined during the detailed design stage, following determination of the Project. The final selection would be based on a range of design requirements including achieving compliance with the development consent noise limits at surrounding receivers. In advance of a final selection, the assessment considers a candidate wind turbine model that is representative of the size and type of wind turbine that could be used at the site. For this purpose, the Vestas V172-7.2MW model has been nominated by the Proponent for this assessment.

Operational noise from the proposed wind turbines has been assessed with reference to the South Australian Environmental Protection Authority – *Wind Farms Environmental Noise Guidelines*, issued July 2009 and revised November 2021 (SA Guidelines 2021) and the *Environmental Protection (Noise) Regulations 1997* (WA Noise Regulations), using a practical approach developed following consultation with the Department of Water and Environmental Regulation (DWER).

A background noise monitoring survey was undertaken to obtain a representation of typical baseline conditions in the vicinity of the Project and derive applicable noise limits for receivers, as defined by the SA Guidelines 2021. The survey and results are detailed in Rp 001 20230131 *Narrogin Wind Farm - Background Noise Monitoring* dated 20 August 2024 (Background Noise Report).

Manufacturer specifications for the candidate wind turbine model have been used as the basis for the assessment. The specifications for each wind turbine include noise emission data in accordance with the international standard [1] referenced in the SA Guidelines 2021. The noise emission data used is consistent with the range of values expected for comparable types of multi-megawatt wind turbine models that may be considered for the site.

The noise emission data has been used with international standard ISO 9613-2[2] to predict wind turbine noise levels at neighbouring receivers. The ISO 9613-2 standard has been applied using well-established input choices and adjustments, based on research and international guidance, that are specific to wind farm noise assessment.

The results of the noise modelling for the Project demonstrate that the predicted noise levels for the proposed wind turbine layout achieve the base (minimum) noise limit determined in accordance with the SA Guidelines 2021 at all but one (1) non-associated receiver. At this receiver (169), wind turbine noise levels are predicted to be above the applicable noise limits by up to 0.3 dB. An example curtailment strategy has been developed to demonstrate compliance with the base (minimum) noise limit, using sound optimised modes for a limited range of wind conditions.

[1] IEC 61400-11:2012 *Wind turbines - Part 11: Acoustic noise measurement techniques*

[2] ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation*

Analysis of the noise emission frequency data for the candidate wind turbine model indicates the noise of the Project is not expected to be characterised by tonality. This is supported by evidence of operational wind farms in Australia which indicates that the occurrence of tonality at receivers is atypical. Accordingly, adjustments for tonality were not warranted and have therefore not been applied to the predicted noise levels.

The assessment has also considered operational noise from the proposed related infrastructure comprising a BESS and a substation. Predicted noise levels associated with the related infrastructure have been assessed in accordance with the WA Noise Regulations. The assessment demonstrates that the related infrastructure is predicted to be below the most stringent assigned level at all receivers. Noise from the related infrastructure is shown to have negligible impact on cumulative noise levels from the Project at receivers and would not affect the compliance outcomes of the wind turbine assessment.

The findings of the operational noise assessment therefore demonstrated support that the Project can be designed and operated to comply with WA requirements for both wind turbine noise and the related infrastructure. Prior to construction of the Project, the predicted noise levels are recommended to be updated for the final Project configuration and equipment selections in order to verify compliance with the limits.

Consistent with the SA Guidelines 2021, compliance is also recommended to be verified by post-construction noise compliance monitoring. The compliance testing procedures should be documented in an operational noise management plan. Given the size of the Project, the compliance testing regime to be documented in the operational noise management plan is recommended to include provisions for early onsite noise emission testing of selected wind turbines to verify consistency with the design validation modelling.

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1.0 INTRODUCTION

Neoen (Proponent), proposes to develop the Narrogin Wind Farm (Project) comprising up to twenty-five (25) wind turbines and related infrastructure. Throughout this report, the term Project refers to both the wind turbines and the related infrastructure.

This report presents the results of an assessment of operational noise for the proposed Project undertaken in accordance with the South Australia EPA *Wind farms environmental noise guidelines*, issued July 2009 and revised November 2021 (SA Guidelines 2021), consistent with the Western Australian Planning Commission *Position Statement: Renewable energy facilities*, dated March 2020 (Position Statement).

Noise associated with the operation of the proposed related infrastructure has been assessed in accordance with the Western Australia *Environmental Protection (Noise) Regulations 1997* (Noise Regulations).

The noise assessment presented in this report is based on:

- operational noise limits determined in accordance with applicable regulatory documentation
- predicted wind turbine noise levels, based on the proposed site layout and a candidate wind turbine model
- predicted noise levels from the related infrastructure, based on assumed noise emission data.

As required by the SA Guidelines 2021, background noise data has been acquired at representative receivers in the vicinity of the Project. The background noise monitoring was undertaken to obtain a representation of typical baseline conditions and derive applicable noise limits.

Acoustic terminology used in this report is presented in Appendix A. Throughout this report, the term *receiver* is used to identify any dwelling identified by the Proponent in the vicinity of the Project. Receivers are grouped as *associated receivers* i.e. host properties or receivers where a noise agreement is in place between the landowners and the Proponent, or *non-associated receivers* which comprise the remaining receivers, without an agreement with the Proponent.

General information about the definition of sound and the ways that different sound characteristics are described is presented in Appendix B. The effects of wind turbine noise on health and amenity are discussed in Appendix J.

2.0 PROJECT OVERVIEW

The Project is proposed to be located approximately 9 km southwest of the town of Narrogin in the Shire of Narrogin and Shire of Williams Local Government Areas of Western Australia.

The Project would involve the construction, operation and decommissioning of the following key components:

- up to twenty-five (25) wind turbines with a maximum tip height of 291 metres and a hardstand area at the base of each wind turbine
- electrical infrastructure, including underground cables from the wind turbine to the main transformer located in a substation
- one (1) high voltage (HV) collector substation
- Battery Energy Storage System (BESS), comprising battery enclosures and inverters, with capacity to deliver up to 100 megawatts (MW) of power for two hours
- other permanent on-site ancillary infrastructure:
  - permanent operation and maintenance facilities
  - at least one meteorological mast (location details to be determined)
- access track network:
  - access and egress points from public roads
  - operational access tracks on private property.

The coordinates of the wind turbines and ancillary infrastructure are presented in tabular format in Appendix C and the proposed candidate wind turbine model is shown in Section 6.2.

A site layout plan illustrating the wind turbine layout, related infrastructure and receivers is provided in Figure 1.

The topography of the site and surrounding area is depicted in the elevation map provided in Appendix D.

A total of seventeen (17) receivers have been identified by the Proponent within 3 km of the nearest wind turbine comprising:

- eight (8) associated receivers
- nine (9) non-associated receivers.

Receivers 132 and 210 are more than 3 km from the nearest wind turbine but were previously identified as background monitoring locations based on an earlier layout. The locations are included in Figure 1 for completeness as background noise monitoring has been carried out at these receivers. Further details are provided in the Background Noise Report.

The coordinates of the receivers identified within 3 km of the nearest wind turbine are tabulated in Appendix E.

Figure 1: Site layout

3.0 WESTERN AUSTRALIA LEGISLATION, POLICY & RELATED GUIDELINES

The environmental noise assessment requirements for the project are defined by the following publications:

- *Environmental Protection (Noise) Regulations 1997* (WA Noise Regulations)
- Western Australian Planning Commission *Position Statement: Renewable energy facilities*, dated March 2020 (Position Statement)
- South Australian Environmental Protection Authority publication *Wind Farms Environmental Noise Guidelines* issued July 2009 and revised November 2021 (SA Guidelines 2021)

This section summarises the requirements and guidance of the above publications.

3.1 Environmental Protection (Noise) Regulations

The WA Noise Regulations operate as a prescribed standard under the *Environment Protection Act 1986* and set limits on noise emissions.

The WA Noise Regulations refers to several Australian Standards on the subject of noise and defines assessment procedures for a range of different noise sources including noise generated on industrial, commercial and residential premises. However, the WA Noise Regulations does not define or refer to assessment requirements that are specific to wind turbine noise.

Section 7 of the WA Noise Regulations provides prescribed standards for general noise emissions:

> *7. Prescribed standard for noise emissions*
>
> *(1) Noise emitted from any premises or public place when received at other premises —*
>
> *(a) must not cause, or significantly contribute to, a level of noise which exceeds the assigned level in respect of noise received at premises of that kind; and*
>
> *(b) must be free of —*
>
> *(i) tonality; and*
>
> *(ii) impulsiveness; and*
>
> *(iii) modulation,*
>
> *when assessed under regulation 9.*
>
> *(2) For the purposes of subregulation (1)(a), a noise emission is taken to significantly contribute to a level of noise if the noise emission as determined under subregulation (3) exceeds a value which is 5 dB below the assigned level at the point of reception.*
>
> *(3) A level of a noise emission may be determined by —*
>
> *(a) measurement at its point of reception when, to the extent practicable, other noises that would contribute to the measured noise level are not present; or*
>
> *(b) calculation of the level at its point of reception based on measurement of the noise emission at a reference point determined by the inspector or authorised person to be a point where the relationship between the noise emission as measured at the reference point and at the point of reception can be established.*

Section 8 additionally provides ‘assigned levels’ which are noise levels that must not be exceeded from the use of a premises when received at other premises. The assigned levels are defined in terms of three descriptors:

- L_{A10} – the sound level exceeded for 10 % of the measurement period, calculated by statistical analysis
- L_{A1} – the sound level exceeded for 1 % of the measurement period, calculated by statistical analysis
- L_{Amax} - the maximum sound level, during a measurement period or a noise event.

Residential dwellings on premises located around the Project would be classed as ‘highly sensitive area’ as described in the regulations. The assigned levels applicable to highly noise sensitive areas have been extracted from the regulation and are reproduced in Table 1.

Table 1: WA Noise Regulations - Assigned levels, dB

Type of premises receiving noise	Time of day	L_{A10}	L_{A1}	L_{Amax}
Noise sensitive premises: highly sensitive area	0700 to 1900 hours Monday to Saturday	45 + IF	55 + IF	65 + IF
	0900 to 1900 hours Sunday and public holidays	40 + IF	50 + IF	65 + IF
	1900 to 2200 hours All days	40 + IF	50 + IF	55 + IF
	2200 hours on any day to 0700 hours Monday to Saturday and 0900 hours Sunday and public holidays	35 + IF	45 + IF	55 + IF

IF: influencing factor

The above levels include the application of an influencing factor (IF) as described in Schedule 3 of the WA Noise Regulations. The influencing factor is a modification to the assigned level that is developed through consideration of the planning zone for the noise sensitive area and its surrounds as well as traffic volumes on nearby road. Reference to the Local Planning Scheme indicates land surrounding the wind farm is zoned ‘Farming’ and would be classified as ‘Rural premises’ under Schedule 1. Road traffic counts provided by Main Roads Western Australia[3] show traffic volumes below the thresholds that affect the influencing factor. On this basis influencing factors are not applicable and have not been considered.

[3] World Health Organization publication *Guidelines for community noise* (1999) (WHO Guideline

3.2 Position Statement: Renewable energy facilities

The Position Statement is a policy outlining the Western Australian Planning Commission requirements to support the consistent consideration and provision of renewable energy facilities within Western Australia. The Position Statement provides guidance on a range of matters that are relevant to the development of renewable energy facilities in Western Australia, which are noted to principally include wind turbines and solar array systems. The Position Statement include guidance for the assessment of noise related to renewable energy projects and states:

> *Noise emissions from renewable energy facilities, including wind turbines, are required to meet the standards prescribed under the Environmental Protection (Noise) Regulations 1997. The South Australian Environmental Protection Authority – Wind Farms Environmental Noise Guidelines (2009) should also be referenced for assessment purposes. These guidelines acknowledge the potential for operation in the presence of higher wind-induced background noise levels.*

The Position Statement refers the 2009 version of the South Australian Environmental Protection Authority publication *Wind Farms Environmental Noise Guidelines*. In November 2021, after the Position Statement was published, this publication was revised with updated guidance and technical procedures.

Core procedures for both versions of the publication are broadly equivalent in terms of noise limits and assessment requirements. Changes primarily relate to technical procedures, such as the appropriate method of determining a relationship between noise levels and wind speeds. As the 2021 version of the publication is an update of the 2009 version of the publication referenced in the Position Statement, the 2021 version is referenced in this assessment.

3.3 SA Guidelines 2021

On the subject of noise limits applying to new wind farm developments the SA Guidelines 2021 state:

> *The predicted equivalent noise level ($L_{Aeq,10}$), adjusted for tonality in accordance with these guidelines, should not exceed:*
>
> - *35dB(A) at relevant receivers in localities which are primarily intended for rural living*
>
> *OR*
>
> - *40dB(A) at relevant receivers in localities in other zones*
>
> *OR*
>
> - *the background noise ($L_{A90,10}$) by more than 5dB(A).*
>
> *whichever is the greater, at all relevant receivers for wind speeds from cut-in to rated power of the WTG* [Wind Turbine Generator] *and each integer wind speed in between. These criteria apply for both day and night time hours, but have been based on conservative night time levels.*

In relation to rural living the following is included:

> *A rural living zone is for an area intended as rural-residential 'lifestyle' with high amenity requirements. This area should not be used for primary production purposes other than to produce food, crops or keep animals solely for the occupier's own use, consumption and/or enjoyment. It is expected that these zones have amenity that is quieter than urban residential and land uses that promote primary production.*

A review of planning data published on the Western Australia Department of Planning Lands and Heritage spatial register[4] shows that the wind farm site and surrounding land does not have an applicable Region Scheme or R-Code and is within a Farming zone. This indicates that the subject area is unlikely to correlate with a rural living zone under the SA Guidelines 2021.

Based on the above, the applicable base (minimum) noise limit in accordance with the SA Guidelines 2021 would be 40 dB L_{Aeq}. In the absence of measured background noise levels around the site, the base limit can be used for a conservative assessment in accordance with the SA Guidelines 2021 across the range of wind speeds the turbines would operate.

The SA Guidelines 2021 acknowledge that different noise limits can apply at the noise sensitive premises where the landowner has entered into an agreement with the proponent (associated receivers). The SA Guidelines 2021 refer to the WHO Guidelines[5] and recommends a 30 dBA indoor limit. On the basis that the noise reduction from outside to inside with a window open is 15 dB (as per the assumption in the WHO Guidelines referenced in the SA Guidelines 2021), the outdoor noise limit would be 45 dB L_{Aeq}. This is consistent with the 2009 version of the SA Guidelines and the limits for associated receivers used in other jurisdictions in Australia. Noise levels at these locations will ultimately need to be managed in accordance with the commercial agreements established between the proponent and the landowners.

3.4 Proposed noise limits for assessment

Overarching legislative requirement for the assessment of environmental noise is the WA Noise Regulations. While the WA Noise Regulations are not specific to renewable projects, they set general provisions in the form of assigned levels.

The assigned levels represent limits which are applicable to the project, including wind turbines and any ancillary infrastructure. This interpretation is reflected in the Position Statement which reiterates that renewable projects must comply with the requirements of the WA Noise Regulations.

However, operational wind turbine noise characteristics are complex and unique, exhibiting variations in noise levels with both wind speed and direction. Measurement and assessment of background and wind turbine noise across the range of conditions in which a wind farm operates is therefore complex, and normally involves the use of dedicated measurement and assessment methods which are specific to wind turbine noise. These complexities are recognised in the Position Statement through the reference to the SA Guidelines for wind turbine noise assessment procedures.

The SA Guidelines 2021 provide the benefit of being a publication which is specific to wind turbine noise and provides a comprehensive assessment method for addressing wind turbine noise at each stage of a project's development and operation. The core assessment methods of the SA 2021 Guidelines are consistent with procedures used throughout Australia and New Zealand for wind turbine noise.

However, while the Position Statement recognises the SA Guidelines 2021, there are important procedural differences which are problematic to reconcile directly with the technical requirement of the WA Noise Regulations.

During the course of the Project noise assessment, the Department of Water and Environmental Regulation (DWER) was consulted to determine the appropriate method of assessment for wind turbine noise. DWER advice is that there is not a definitive method of assessment in place to reconcile the application of the WA Noise Regulations with the SA Guidelines for the assessment of

4 https://espatial.dplh.wa.gov.au/planwa/Index.html?viewer=planwa

5 World Health Organization publication *Guidelines for community noise* (1999) (WHO Guidelines)

wind turbine noise. In recognition of this, it is understood that further WA government guidance that is specific to wind turbine assessment is in development but not yet available for review.

In advance of further guidance, DWER indicated that the SA Guidelines 2021 are typically adopted in conjunction with the WA Noise Regulations, and informed by background noise monitoring, using a pragmatic approach. This approach broadly involves:

- adoption of a lower base limit of 35 dB in lieu of the 40 dB specified in the SA Guidelines 2021, to reflect the night period assigned levels
- adoption of a base reference level of 45 dB L_{Aeq} applied to all associated receivers
- all-time noise limits applicable for both day and night period, consistent with the SA Guidelines 2021.
- use of the L_{A90} measurement metric detailed in the SA Guidelines 2021 as a proxy measurement parameter for assessing compliance with the assigned levels, based on wind turbine noise being a semi-steady state source, and the practical complications of attempting to measure wind turbine noise using statistical parameters in a fluctuating ambient noise environment

The above approach would not apply to the ancillary infrastructure associated with the Project. Noise from ancillary infrastructure would be assessed under the WA Noise Regulations.

4.0 NOISE PREDICTION METHOD

Operational Project noise levels are predicted using:

- noise emission data for the wind turbines and related infrastructure equipment
- a 3D digital model of the site and the surrounding environment
- international standards used for the calculation of environmental sound propagation.

The method selected to predict noise levels is International Standard ISO 9613-2: 1996 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation* (ISO 9613-2). The prediction method is consistent with the guidance provided by the SA Guidelines 2021 (referenced in the Position Statement) and has been shown to provide a reliable method of predicting the typical upper levels of the noise expected to occur in practice.

The method is generally applied in a comparable manner to both wind turbine and ancillary infrastructure. For example, for both types of sources, equivalent ground and atmospheric conditions are used for the calculations. However, when applied to wind turbine noise, additional and specific input choices apply, as detailed below.

Key elements of the noise prediction method are summarised in Table 2. Further discussion of the method and the calculation choices is provided in Appendix F.

Table 2: Noise prediction elements

Detail	Description
Software	Proprietary noise modelling software SoundPLANnoise version 9.0
Method	International Standard ISO 9613-2:1996 *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (ISO 9613-2). Adjustments to the ISO 9613-2 method are applied on the basis of the guidance contained in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (the UK Institute of Acoustics guidance). The adjustments are applied within the SoundPLANnoise modelling software and relate to the influence of terrain screening and ground effects on sound propagation. Specific details of adjustments are noted below
Source characterisation	Each wind turbine is modelled as a point source of sound. The total sound of the wind farm is then calculated on the basis of simultaneous operation of all wind turbines and summing the contribution of each. Calculations of wind turbine to receiver distances and average sound propagation heights are made on the basis of the point source being located at the position of the hub of the wind turbine. Calculations of terrain related screening are made on the basis of the point source being located at the maximum tip height of each wind turbine. Further discussion of terrain screening effects is provided below.
Terrain data	Elevation contours in 2 m vertical resolution provided by Umwelt.
Terrain effects (wind turbine-specific procedures)	Adjustments for the effect of terrain are determined and applied on the basis of the UK Institute of Acoustics guidance. *Valley effects*: +3 dB is applied to the calculated noise level of a wind turbine when a significant valley exists between the wind turbine and calculation point. A significant valley is determined to exist when the actual mean sound propagation height between the wind turbine and calculation point is 50 % greater than would occur if the ground was flat. *Terrain screening effects*: only calculated if the terrain blocks line of sight between the maximum tip height of the wind turbine and the calculation point. The value of the screening effect is limited to a maximum value of 2 dB. The Project is located in a hilly area characterised by significant variations in ground elevation between the wind turbines and surrounding receivers. Based on comparison of predicted noise levels with and without terrain elevation data included, calculated terrain effects range between -0.7 dB and +1.9 dB for receivers within 3 km of the proposed wind turbines. For reference purposes, the ground elevations at the wind turbine and receivers are tabled in Appendix C and Appendix E respectively. The topography of the Site is depicted in the elevation map provided in Appendix D.
Ground conditions	Ground factor of G = 0.5 on the basis of the UK Institute of Acoustics guidance and research outlined in Appendix F. The ground around the Project corresponds to acoustically soft conditions (G = 1) according to ISO 9613-2. The adopted value of G = 0.5 assumes that 50 % of the ground cover is acoustically hard (G = 0) to account for variations in ground porosity and provide a cautious representation of ground effects.

Detail	Description
Atmospheric conditions	Temperature 10 °C and relative humidity 80 % These represent conditions which result in relatively low levels of atmospheric sound absorption and are chosen on the basis of the UK Institute of Acoustics guidance and the SA Guidelines 2021. The calculations are based on sound speed profiles[6] which increase the propagation of sound from each wind turbine to each receiver location, whether as a result of thermal inversions or wind directed toward each calculation point. The primary consideration for wind farm noise assessment is wind speed and direction. The noise level at each calculation point is assessed on the basis of being simultaneously downwind of every wind turbine at the Project. Other wind directions in which part or the entire wind farm is upwind of the receiver will result in lower noise levels. In some cases, it is not physically possible for a receiver to be simultaneously downwind of each wind turbine and the approach is therefore conservative in these instances.
Receiver heights	1.5 m above ground level It is noted that the UK Institute of Acoustics guidance refers to predictions made at receiver heights of 4 m. Predictions in Australia are generally based on a lower prediction height of 1.5 m which results in lower noise levels. However, importantly, predictions in Australia do not generally subtract a margin recommended by the UK Institute of Acoustics guidance to account for differences between L_{Aeq} and L_{A90} noise levels. The magnitude of these differences is comparable and therefore balance each other out to provide similar predicted noise levels. This approach has been shown to be valid for predicting noise level of wind farms expected to be measured using the L_{A90} parameter (as per the SA Guidelines 2021).

[6] The sound speed profile defines the rate of change in the speed of sound with increasing height above ground

5.0 EXISTING NOISE ENVIRONMENT

Background noise level information is used to inform the setting of noise limits for the assessment of wind turbine noise under the SA Guidelines 2021. This is due to the need to consider the changes in background noise levels and wind turbine noise levels for different wind conditions.

The procedures for determining background noise levels for the assessment of wind turbines are defined in the SA Guidelines 2021, which is reference in the Position Statement. Background noise levels are considered in terms of $L_{A90,\ 10\ min}$.

The first step in assessing background noise levels involves determining whether background noise measurements are warranted. For this purpose, Section 3.1 of the SA Guidelines 2021 provides the following guidance:

> *Background noise measurements should be carried out at locations that are relevant for assessing the impact of WTG noise on nearby premises (relevant receivers).*
>
> *Relevant receiver locations are premises:*
>
> - *where someone resides or has development approval to build a residential dwelling;*
> - *where the predicted noise level exceeds the base noise level for the area [35 or 40 dB(A)] for wind speeds up to the speed of the rated power;*
> - *that are representative of the worst-case situation when considering the range of premises, e.g. a house located among a group of nearby houses within a residential zone.*

The initial stage of a background noise monitoring program in accordance with the SA Guidelines 2021 therefore comprises:

- preliminary wind turbine noise predictions to identify all receivers where predicted noise levels are higher than 35 dB L_{Aeq}
- identification of selected receivers where background noise monitoring should be undertaken prior to the development of the Project, if required.

If required, the surveys involve measurements of background noise levels at receivers and simultaneous measurement of wind speeds at the Project site. The survey typically extends over a period of several weeks to enable a range of wind speeds and directions to be measured. Data adversely affected by extraneous noise such as insect noise, rain and other considerations is filtered.

The results of the survey are then analysed to determine the trend between the background noise levels and the site wind speeds at the proposed hub height of the wind turbines. This trend defines the value of the background noise for the different wind speeds at which the wind turbines will operate. At the wind speeds when the value of the background noise is above 30 dB L_{A90}, the background noise levels are used to set the noise limits for the Project.

Preliminary noise modelling of an earlier Project layout indicated that background noise monitoring would be required to inform a detailed assessment. The background noise monitoring locations were proposed based on proximity to wind turbines, the location of receivers, and the predicted noise contours. Background noise monitoring was subsequently conducted at seven (7) locations in the vicinity of the proposed Project between 25 January 2024 to 15 March 2024, following approval from the landowners for background monitoring to be undertaken.

Analysis and results of the survey are detailed in MDA report Rp 001 20230131 *Narrogin Wind Farm - Background Noise Monitoring* dated 20 August 2024 (Background Noise Report).

A summary of background noise levels determined in accordance with the SA Guidelines 2021, as referenced in the Position Statement, are tabulated in Appendix G for the range of surveyed wind speeds. The results are illustrated in the graphical data provided for each receiver in the appendices of the Background Noise Report.

6.0 WIND TURBINE ASSESSMENT

6.1 Noise limits

6.1.1 Non-associated receivers

At non-associated receivers, the applicable noise limit in accordance with the SA Guidelines 2021 is 35 dB L_{A90} or background L_{A90} + 5 dB, whichever is higher.

Based on the background noise levels detailed in Appendix G, derived noise limits at the assessed non-associated receivers are summarised in Appendix H.

6.1.2 Associated receivers

As detailed in Section 3.4, a base reference level of 45 dB L_{Aeq} is applied to all associated receivers. Comparisons between the predicted noise levels and the 45 dB reference level are provided for informative purposes only. Noise levels at these locations will ultimately need to be managed in accordance with the commercial agreements established between the Proponent and the landowners.

6.2 Candidate wind turbine model

The wind turbine model ultimately selected for the Project would be determined based on a range of design requirements.

Accordingly, to assess the proposed Project at this stage, it is necessary to consider a candidate wind turbine model that is representative of the size and type of wind turbines being considered. The purpose of the candidate wind turbine model is to assess the viability of achieving compliance with the applicable noise limits, based on noise emission levels that are typical of the size of wind turbines being considered for the site.

For this assessment, the Proponent has considered the candidate wind turbine model detailed in Table 3.

The candidate model is a variable speed wind turbine, with the speed of rotation and the amount of power generated being regulated by control systems that vary the pitch of the blades (the angular orientation of the blade relative to its axis).

Table 3: Candidate wind turbine model specifications

Item	Details
Make	Vestas
Model	V172
Rated power, MW	7.2
Rotor diameter, m	172[1]
Hub height, m	200
Operating mode	PO7200 [2]
Blade serrations	Yes
Highest sound power[3], dB L_{WA}	107.9
Cut-in wind speed (hub height), m/s	3
Cut-out wind speed (hub height), m/s	25

1 See discussion below regarding 182 m rotor diameter being considered for the project.

2 'PO7200' is a manufacturer designation which indicates an unconstrained, Power Optimised mode of operation to achieve a rated power of 7.2 MW (i.e. without noise curtailment)

3 Specification sound power level, including a 1 dB margin to account for uncertainties.

The V172 has a rotor diameter of 172 m however a 182 m rotor diameter is being considered for the project to allow for future flexibility, as referenced in other submission documentation. A review of available sound power data for a range of wind turbine models has shown that there is no clear relationship between rotor diameter or power output and the noise emission characteristics of a given wind turbine model. In practice, the overall noise emissions of a wind turbine are dependent on a range of factors, including the rotor diameter and power output, and other important factors such as the blade design and rotational speed. Therefore, while rotor diameters and power ratings of contemporary wind turbines have increased, the noise emissions of the wind turbine are comparable to, or lower than, previous generations as a result of design improvements (notably, measures to reduce the speed of rotation, and enhanced blade design features such as serrations for noise control).

For this study noise modelling has been carried out based on the candidate turbine details outlined in Table 3, which is representative of the size and type of wind turbine being considered for the project. While the project seeks approval for a tip height of up to 291 m to accommodate a 182 m rotor, compared to the 286 m tip height associated with the candidate turbine, the 5 m difference in height typically has a negligible effect on the noise modelling results. This is specifically addressed through a sensitivity analysis discussed subsequently in the assessment sections of this report (Section 6.4).

Unless specified otherwise, this assessment has been based on all wind turbine models using unconstrained generation modes (i.e. no sound optimised operating modes) and with blade serrations. Blade serrations are now routinely used to reduce wind turbine noise emissions, and we understand that their use is now the market standard for wind turbines being offered in the Australian market.

A range of sound optimised modes are also available reducing the maximum power output and sound power levels.

6.3 Wind turbine noise emissions

6.3.1 Sound power levels

The noise emissions of a wind turbine are described in terms of the sound power level for different wind speeds. The sound *power* level is a measure of the total sound energy produced by each wind turbine and is distinct from the sound *pressure* level which depends on a range of factors such as the distance from the wind turbine.

Sound power level data for the candidate wind turbine model, including sound frequency characteristics, has been sourced from Vestas document 0128-4336_00 *Third octave noise emission EnVentus™ V172-7.2MW 50/60 Hz*, dated 30 June 2022

Based on the data sourced from the above specification, the noise modelling conducted for this assessment involved conversion of third octave band levels. to octave band levels and adjustment by addition of +1.0 dB at each wind speed to provide a margin for typical values of test uncertainty.

The overall A-weighted sound power levels (including the +1 dB addition) as a function of hub height wind speed are presented in Table 4. Data are presented for the normal operating mode (mode PO7200) and for selected sound optimised modes.

Table 4: Sound power levels versus hub height wind speed, dB L_{WA}

Operating mode	Hub height wind speed, m/s								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**≥12**
PO7200	95.6	96.2	99.6	103.2	106.6	107.9	107.9	107.9	107.9
SO2	95.0	95.9	98.8	102.3	104.7	105.0	105.0	105.0	105.0
SO6	95.0	95.9	98.8	101.0	101.0	101.0	101.0	101.0	101.0

Note: Other sound optimised modes are available

The reference octave band values used as the basis for this assessment are presented in Table 5 and were adjusted to the overall A-weighted noise levels detailed in Table 4.

Table 5: Octave band sound power levels, dB L_{WA}

	Octave band centre frequency, Hz									
Operating mode	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Total**
PO7200 [1]	79.5	91.6	99.1	102.3	102.5	100.8	96.3	88.7	78.0	107.9

1 Based on one-third octave band levels at 13 m/s, being the wind speed at which the maximum source sound power level occurs (taking into account energy in frequencies below 125 Hz)

The values presented above are considered typical of the range of noise emissions associated with comparable multi-megawatt wind turbines.

6.3.2 Tonality

Information concerning potential tonality is often limited at the planning stage of a project, and narrow band test data for tonality (in the form of IEC 61400-11 tonality data, as referenced in the SA Guidelines 2021) is presently unavailable for the candidate wind turbine model. However, the occurrence of tonality in the noise of contemporary multi-megawatt wind turbine designs is unusual. This is supported by evidence of operational wind farms in Australia which indicates that the occurrence of tonality at receivers is atypical.

On this basis, adjustments for tonality have not been applied to the predicted noise levels presented in this assessment. Notwithstanding this, the potential for tonality would be subject to further review and controls (i.e. contractual performance specifications) during the wind turbine procurement stage of the Project, following approval, and again following the construction.

6.4 Predicted noise levels

This section of the report presents the predicted A-weighted wind turbine noise levels at surrounding receivers, and an assessment of compliance with the applicable noise limits.

Wind turbine noise levels have been predicted using the selected candidate wind turbine model and sound power level data detailed in Section 6.3.1 for the wind speed which results in the highest predicted noise levels. As part of the noise modelling, a sensitivity analysis was conducted to consider the potential effect on the predicted noise levels with a slightly higher tip height than the candidate turbine. Specifically, the modelling was conducted using the candidate turbine noise emission data, but with the tip height set to 291 m corresponding to a 182 m rotor diameter. This demonstrated predicted noise levels differing by 0.1 dB or less at all locations and supports that the effect of the tip height change is negligible.

Predicted noise levels are presented in Table 6 for non-associated receivers and Table 8 for associated receivers and tabulated in Appendix K for each integer wind speed.

Sound levels in environmental assessment work are typically reported to the nearest integer to reflect the practical use of measurement and prediction data. However, in the case of Project layout design, significant layout modifications may only give rise to fractional changes in the predicted noise level. This is a result of the relatively large number of sources influencing the total predicted noise level, as well as the typical separating distances between the wind turbine locations and surrounding assessment positions. It is therefore necessary to consider the predicted noise levels at a finer resolution than can be perceived or measured in practice. It is for this reason that the levels presented in this section are reported to one decimal place.

Table 6: Highest predicted noise level at non-associated receivers (unconstrained operation), dB L_{Aeq}

Receiver	Highest predicted noise level (unconstrained operation)
98	33.6
106	31.5
151	30.3
169	35.3
170	32.4
173	32.4
177	32.2
180	29.7
183	32.0

Note: shaded value(s) are predicted above the base (minimum) criterion of 35 dB L_{Aeq}

It can be seen from Table 6 that the predicted wind turbine noise levels from the Project are below the base (minimum) criterion of 35 dB L_{Aeq} at all but one (1) non-associated receiver (169).

At receiver 169, an assessment of compliance considering the derived noise limits based on the measured background noise levels is presented in Table 8.

Table 7: Predicted noise levels and applicable noise limits - receiver 169, dB L_{Aeq}

	Hub-height wind speed, m/s							
	5	6	7	8	9	10	11	12
Predicted noise levels	23.6	27.0	30.6	34.0	35.3	35.3	35.3	35.3
Applicable noise limits	35.0	35.0	35.6	36.2	35.7	35.0	35.5	35.9
Excess	-11.4	-8.0	-5.0	-2.2	-0.4	+0.3	-0.2	-0.6

Note: Shaded value(s) are predicted above the corresponding background adjusted noise limit

It can be seen from Table 7 that wind turbine noise levels at receiver 169 are predicted above the base limit of 35 dB L_{Aeq} at hub height wind speed above 8 m/s, and above the applicable noise limits at the hub height wind speed of 10 m/s (excess of 0.3 dB).

To address this, an example curtailment strategy has been developed to demonstrate compliance with the noise limits, using sound optimised modes for a limited range of wind conditions. Details of the example curtailment strategy are presented in Section 6.5.

The above findings support that the Project can be designed and operated to comply with the nominated noise limits.

Predicted noise levels at associated receivers are provided in Table 8 for information.

Table 8: Highest predicted noise level at associated receivers, dB L_{Aeq}

Receiver	Predicted noise level
4	30.7
17	39.7
20	31.4
23	38.1
25	42.0
28	32.6
30	31.0
52	32.9

It can be seen from Table 8 that the predicted wind turbine noise levels from the proposed Project are below the reference level of 45 dB L_{Aeq} for all associated receivers by at least 3.0 dB.

6.5 Example curtailment strategy

Predicted noise levels at the one (1) non-associated receiver, 169, at which wind turbine noise levels were calculated to be above the minimum noise limit of 35 dB L_{Aeq} have been tabulated in Table 7 for the relevant range of wind speeds together with the applicable (all-time period) noise limits.

To reduce wind turbine noise levels below the base noise limit, wind turbine T22 would need to operate in SO2 mode with all other wind turbines operating in the normal PO7200 mode.

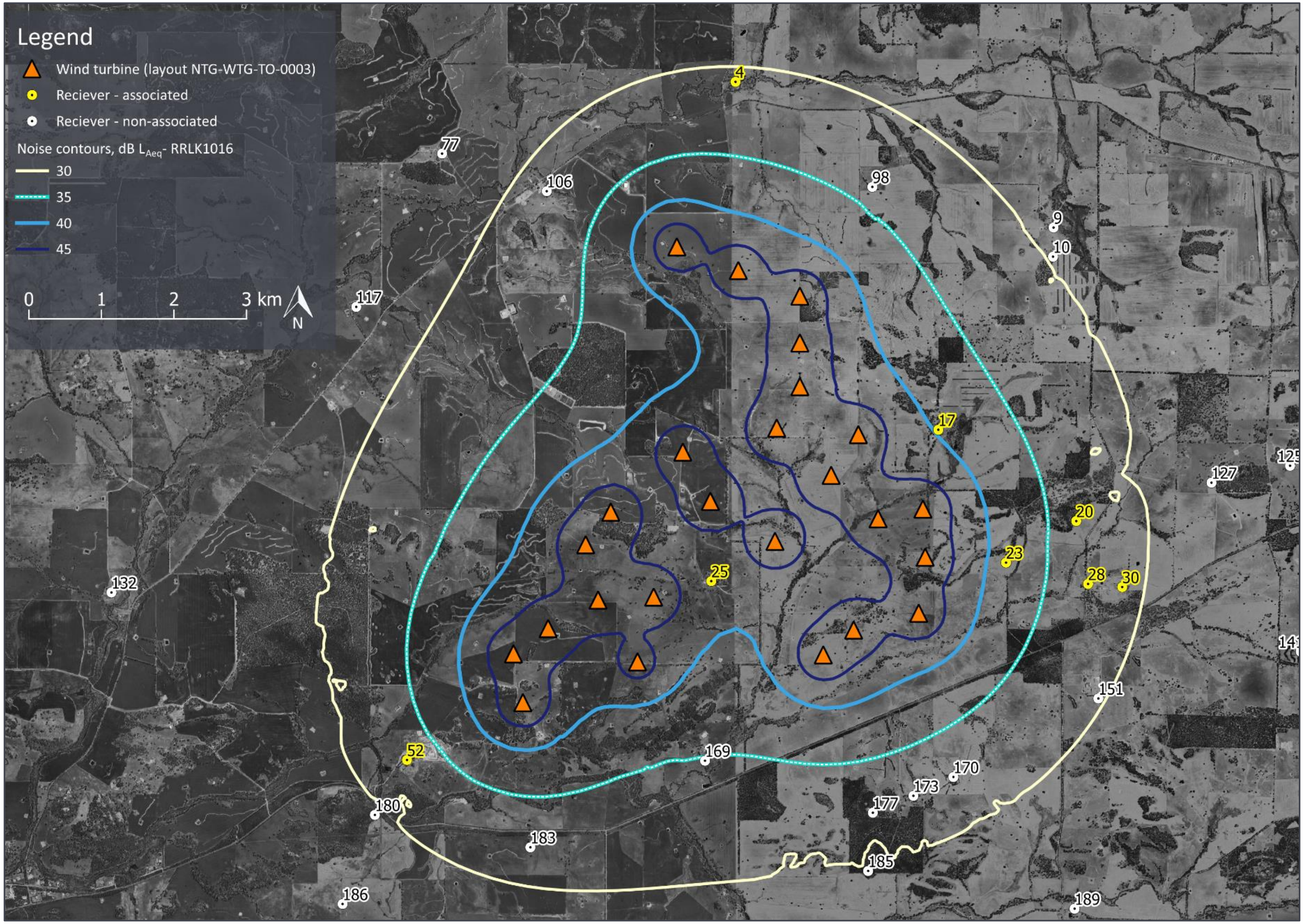
The location of the total predicted 30 dB, 35 dB, 40 dB, and 45 dB L_{Aeq} noise contours is illustrated in Figure 2, based on the curtailment strategy outlined above.

The example curtailment strategy presented above is only one of the many configurations possible to achieve the required noise reduction. If required, a detailed curtailment strategy accounting for both wind speeds and wind directions would be specified during detailed design once the Project has been approved, the layout finalised, and the wind turbine model selected.

6.6 Cumulative wind farm assessment

We are not aware of any nearby existing or proposed wind farms within 10 km of the Project. On this basis, cumulative wind farm noise is not a matter that requires further consideration or investigation.

Figure 2: Highest predicted noise level contours (accounting for the example curtailment)



7.0 RELATED INFRASTRUCTURE OPERATIONAL NOISE ASSESSMENT

The related infrastructure, including a BESS and a substation, are proposed to be located in the southern portion of the project area, as shown in the site layout plan in Figure 1.

A preliminary Project design has been supplied by the Proponent and is described as:

- one (1) high voltage (HV) transformer
- twenty-eight (28) medium voltage (MV) transformers
- fifty-six (56) battery units.

The assessment in this report has been based on equipment layouts, confirmed by the Proponent to be representative of the proposed size of the Project.

The coordinates of the related infrastructure are presented in tabular format in Appendix C2. The Project layout used for noise modelling purposes is also shown in Appendix C2.

7.1 Related infrastructure noise sources

The primary influence over the accuracy of a noise model is the accuracy of input noise data.

The preferred standard of noise data is third octave band sound power levels for each equipment item operating under the worst-case condition likely to occur during the operation of the Project, provided by the manufacturer and measured in accordance with a recognised standard.

The selection of an appropriate measurement standard will depend on various factors including the conditions under which the measurements occur, the measurement equipment available, and the character of the noise being measured, amongst others. Example standards include:

- ISO 3741 to ISO 3747 - determination using sound pressure level measurements
- ISO 9614-1 to ISO 9614-3 - determination using sound intensity measurements.

At this stage of the Project, equipment selections have not been conclusively determined and detailed third octave noise data is not available from the Proponent in all instances. Where this data is not available, MDA has established approximations or assumptions based on comparable data or existing acoustic literature.

Notwithstanding the above, responsibility for providing representative, accurate noise emissions data for proposed equipment items is that of the Proponent. Where inaccurate data is used, predicted noise levels may not accurately represent resultant noise levels in practice.

Sound power levels for individual Project equipment items, as used in the noise model, are detailed in Table 9. Data is provided as un-weighted (linear) octave band spectra and A-weighted overall sound power level.

Table 9: Related infrastructure equipment sound power levels, dB L_W

	Octave band centre frequency, Hz							
	63	125	250	500	1000	2000	4000	Overall
Combine inverter/battery units								
- Day/evening [1]	72	72	90	86	88	88	86	94
- Night	70	70	84	79	82	82	79	87
MV transformer (4.6 MVA)	74	82	79	74	66	59	53	75
HV transformer (200 MVA)	96	105	102	96	88	81	76	98

1 Between 0700 hrs and 2200 hrs – based on power electronic fans at 60% and battery fan at 60%. A lower overall sound power level (based on power electronic fans at 20% and battery fan at 50%) has been used for night operation when ambient temperatures are lower and battery is relatively inactive, as advised by the client and based on manufacturer data.

Additional information with respect to the source of the data is provided in Table 10.

Table 10: Noise data descriptions

Item	Description
Combined inverter/battery units	Manufacturer third octave band sound power levels have been provided by the Proponent for a combined inverter / battery unit of the size and type being considered for the project. Extensive specific operating conditions for the equipment were described in the supplied data sheet. The Proponent advised the expected operating duties during the ‘day/evening’ and ‘night’ periods as noted in Table 9, which the sound data is based on.
Transformers	At this stage of the project, specific details of the transformer makes and models are yet to be finalised. In lieu of measured sound power level data for specific transformer selections, reference has been made to Australian Standard AS 60076-10:2009 *Power transformers – Part 10: Determination of sound levels* (AS 60076-10:2009) which provides a method for estimating transformer sound power levels based on the power rating. Specifically, Figure ZA1 from AS 60076-10:2009 has been used to determine an estimated standard maximum sound power level of and for the MV and HV transformers respectively. Spectral data for each transformer was then estimated by applying Bies & Hansen[7] corrections from Table 11.27, (Location 1a for outdoor transformer noise) to the determined overall sound power level.

7.2 Assessable noise limits

The relevant limits for the assessment of noise from the related infrastructure are the assigned levels under the WA Noise Regulations as defined in Table 1.

Comparing the operational fan speeds for different time periods in Table 9 to the assessment periods in the WA Noise Regulations, it can be seen that the equipment may operate at the higher design duty (all fans at 60%) during the most stringent assessment period (between 0700 hours and 0900 hours on a Sunday or public holiday).

7 *Bies, D. H. & Hansen, C. H. (2009). Engineering noise control: theory and practice (Fourth edition.). p. 601*

The noise sources associated with the related infrastructure typically give rise to steady noise levels i.e. transformer and battery noise is not typically characterised by brief momentary increases in noise levels. Accordingly, the relevant assessment metric is the L_{AS10} assigned level.

7.3 Predicted noise levels

Noise levels associated with the operation of the related infrastructure have been predicted at the nearest non-associated and associated receivers based on the method detailed Section 4.0.

The predicted noise levels at the nearest non-associated and associated receivers are shown in Table 11 and Table 12, respectively.

Table 11: Predicted noise levels at the nearest non-associated receivers, dB L_{Aeq}

Nearest non-associated receiver	Distance from nearest equipment, m	Predicted noise level	
		Day/evening	Night
169	2,335	24	20
173	2,777	16	12
177	2,757	17	13

Table 12: Predicted noise levels at the nearest associated receivers, dB L_{Aeq}

Nearest associated receiver	Distance from nearest equipment, m	Predicted noise level	
		Day/evening	Night
17	3,710	15	11
23	2,817	16	12
25	1,295	32	27

It is noted that the sound power is provided as equivalent continuous noise levels (L_{eq}). Since noise from transformers and battery units can be characterised as being steady state, for assessment purposes, the L_{eq} noise level metric has been used for comparison with the L_{AS10} assigned levels.

While the specific equipment selections would not be finalised until the detailed design phase of the Project, noise levels from the related infrastructure are predicted to be below the assigned levels including the most stringent 35 dB L_{A10} 'night' limit at all nearby receivers.

Predicted noise level contours are shown in Appendix I.

Noise associated with battery units and transformers can often be tonal in nature, typically evidenced in associated third octave spectral noise data.

In accordance with the Noise Regulations, a +5 dB adjustment applies where noise levels at the receiver are found to have tonal characteristics. Noting the separation distances between the proposed related infrastructure and receivers, and the magnitude of the predicted noise levels, it is considered unlikely that tonality would present at receivers.

Notwithstanding the above, should tonality present at receivers and a +5 dB adjustment was applied, compliance would still be demonstrated at all non-associated receivers.

8.0 PROJECT CUMULATIVE NOISE ASSESSMENT

The calculated noise levels due to related infrastructure are more than 10 dB below the calculated noise levels from the wind turbines at all receivers. Cumulative noise from the Project is therefore predominantly due to the noise of wind turbines, and the impact from the related infrastructure on the total received noise levels would be negligible.

9.0 RECOMMENDED OPERATIONAL NOISE MANAGEMENT MEASURES

In order to appropriately manage operational noise from the Project during subsequent stages of development, the following is recommended:

- The predicted operational wind turbine noise levels should be updated with final layout and sound power levels of the final wind turbine selected for the Project to verify compliance with the nominated criteria, if they vary from what has been modelled in this assessment.
- Where the updated assessment indicates a continued requirement for curtailment, the curtailment strategy should be updated accordingly.
- The predicted operational related infrastructure noise levels should be updated with the final design and sound power levels of the final equipment selection to verify compliance with the limits in accordance with the WA Noise Regulations.
- An operational noise management plan should be prepared which identifies how compliance with the Project's operational noise limits will be demonstrated, including details of testing procedures and reporting time frames following commencing of operation of the Project.
- Following construction, compliance monitoring must be conducted in accordance with the procedure outlined in the operational noise management plan including sound power testing of selected wind turbines and evaluation of tonality.

In assessing operational wind turbine noise, it is expected that the Project will satisfy the applicable noise limits. Notwithstanding this, consideration has been given to available contingency strategies to reduce noise levels if required.

The following summarises the two key measures available to reduce the noise:

- Procurement contract: the procurement contract for the supply of wind turbines to the Project will typically include specifications concerning the allowable total noise emissions from the wind turbine, and the permissible characteristics of the wind turbine. In the event that wind turbine emissions are found to exceed the contracted values, the supplier will be required to implement measures to reduce the noise to the contracted value. This can include measures to rectify manufacturing defects or appropriate control settings.
- Noise reduction management strategy: modern wind farms include control systems which enable the operation of the wind turbines to be varied according to environmental constraints. Specifically, variable pitch wind turbines as proposed for the Project include control functions which enable the noise emissions to be selectively controlled; by adjusting the pitch of blade, the noise emissions can be reduced. In addition, where required, the wind turbines can be selectively shut down under relevant wind speeds and directions. These types of control measures can be used separately, or in combination, to achieve noise reductions for predetermined wind speed ranges and directions.

10.0 SUMMARY

An assessment of operational noise for the proposed Project has been carried out in accordance with the requirements of the SA Guidelines 2021, consistent with the Western Australian Planning Commission Position Statement and advice received following consultation with the Department of Water and Environmental Regulation (DWER).

The assessment is based on the proposed Project layout comprising twenty-five (25) wind turbines and related infrastructure, including a BESS and a substation.

Noise modelling was carried out based on a candidate wind turbine model (Vestas V172-7.2MW) which has been selected by the Proponent as being representative of the size and type of wind turbines that could be used for this Project. The results demonstrate that the proposed wind turbines are predicted to achieve compliance with the lower base limit of 35 dB L_{Aeq} specified in the SA Guidelines 2021 at all but one (1) assessed non-associated receiver, 169. For this receiver, wind turbine noise levels are predicted to be above the applicable noise limits by up to 0.3 dB at a limited range of wind speeds. An example curtailment strategy has been developed to demonstrate compliance with the lower base limit of 35 dB L_{Aeq}, using sound optimised modes for a limited range of wind conditions.

The assessment has also considered operational noise associated with the proposed related infrastructure. Predicted noise levels have been assessed in accordance with the WA Noise Regulations and demonstrated that the related infrastructure complied with the most stringent assigned levels at all receivers. Noise from the related infrastructure was shown to have negligible impact on the receiver cumulative noise levels from the Project and would not affect the compliance outcomes of the wind turbine assessment.

The findings of this noise assessment indicates that it is feasible for the proposed Project to be designed and operated to satisfy the requirements of the SA Guidelines 2021 and WA Noise Regulations. The proponent should verify the inputs and outcomes of this assessment prior to construction based on the final equipment selections and layout to confirm that compliance with the criteria set out in this assessment is demonstrated.

APPENDIX A GLOSSARY OF TERMINOLOGY

Term	Definition	Abbreviation
A-weighted 10th centile	The sound level exceeded for 10 % of the measurement period, calculated by statistical analysis	L_{A10}
A-weighted 1st centile	the sound level exceeded for 1 % of the measurement period, calculated by statistical analysis	L_{A1}
A-weighted 90th centile	The A-weighted pressure level that is exceeded for 90 % of a defined measurement period. It is used to describe the underlying background sound level in the absence of a source of sound that is being investigated, as well as the sound level of steady, or semi steady, sound sources.	L_{A90}
A-weighted average noise level	The equivalent continuous (time-averaged) A-weighted sound level. This is commonly referred to as the average noise level.	L_{Aeq}
A-weighted maximum noise level	The A-weighted maximum noise level. The highest noise level which occurs during the measurement period.	L_{Amax}
A-weighting	A method of adjusting sound levels to reflect the human ear's varied sensitivity to different frequencies of sound.	See discussion below this table.
Decibel	The unit of sound level.	dB
Hertz	The unit for describing the frequency of a sound in terms of the number of cycles per second.	Hz
Octave Band	A range of frequencies. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.	-
Sound power level	A measure of the total sound energy emitted by a source, expressed in decibels.	L_W
Sound pressure level	A measure of the level of sound expressed in decibels.	L_p
Annoying Characterises	Annoying characteristics that are not fundamental to a typical well-maintained wind farm. Such characteristics may include infrasound (low frequency noise below the audible frequency range) or adverse mechanical noise.	-
Tonality	A characteristic to describe sounds which are composed of distinct and narrow groups of audible sound frequencies (e.g. whistling or humming sounds).	-

The basic quantities used within this document to describe noise adopt the conventions outlined in ISO 1996-1:2016 *Acoustics - Description measurement and assessment of environmental noise – Basic quantities and assessment procedures*. Accordingly, all frequency weighted sound pressure levels are expressed as decibels (dB) in this report. For example, sound pressure levels measured using an "A" frequency weighting are expressed as dB L_A. Alternative ways of expressing A-weighted decibels such as dBA or dB(A) are therefore not used within this report, unless as part of direct quotes of external documents.

APPENDIX B DESCRIPTION OF SOUND

Sound is an important feature of the environment in which we live; it provides information about our surroundings and influences our overall perception of amenity and environmental quality.

While sound is a familiar concept, its description can be complex. A glossary of terms and abbreviations is provided in Appendix A.

This appendix provides general information about the definition of sound and the ways that different sound characteristics are described.

B1 Definition of sound

Sound is a term used to describe very small and rapid changes in the pressure of the atmosphere. Importantly, for pressure fluctuations to be considered sound, the rise and fall in pressure needs to be repeated at rates ranging from tens to thousands of times per second.

These small and repetitive fluctuations in pressure can be caused by many things such as a vibrating surface in contact with the air (e.g. the cone of a speaker) or turbulent air movement patterns. The common feature is a surface or region of disturbance that displaces the adjacent air, causing a very small and localised compression of the air, followed by a small expansion of the air.

These repeated compressions and expansions then spread into the surrounding air as waves of pressure changes. Upon reaching the ear of an observer, these waves of changing pressure cause structures within the ear to vibrate; these vibrations then generate signals which can be perceived as sounds.

The waves of pressure changes usually occur as complex patterns, comprising varied rates and magnitudes of pressure changes. The pattern of these changes will determine how a sound spreads through the air and how the sound is ultimately perceived when it reaches the ear of an observer.

B2 Physical description of sound

There are many situations where it can be useful to objectively describe sound, such as the writing or recording of music, hearing testing, measuring the sound environment in an area or evaluating new man-made sources of sound.

Sound is usually composed of complex and varied patterns of pressure changes. As a result, several attributes are used to describe sound. Two of the most fundamental sound attributes are:

- sound pressure
- sound frequency.

Each of these attributes is explained in the following sections, followed by a discussion about how each of these attributes varies.

B2.1 Sound pressure

The compression and expansion of the air that is associated with the passage of a sound wave results in changes in atmospheric pressure. The pressure changes associated with sound represent very small and repetitive variations that occur amidst much greater pressures associated with the atmosphere.

The magnitude of these pressure changes influences how quiet or loud a sound will be; the smaller the pressure change, the quieter the sound, and vice versa. The perception of loudness is complex though, and different sounds can seem quieter or louder for reasons other than differences in pressure changes.

To provide some context, Table 13 lists example values of pressure associated with the atmosphere and different sounds. The key point from these example values is that even an extremely loud sound equates to a change in pressure that is thousands of times smaller than the typical pressure of the atmosphere.

Table 13: Atmospheric pressure versus sound pressure – example values of pressure

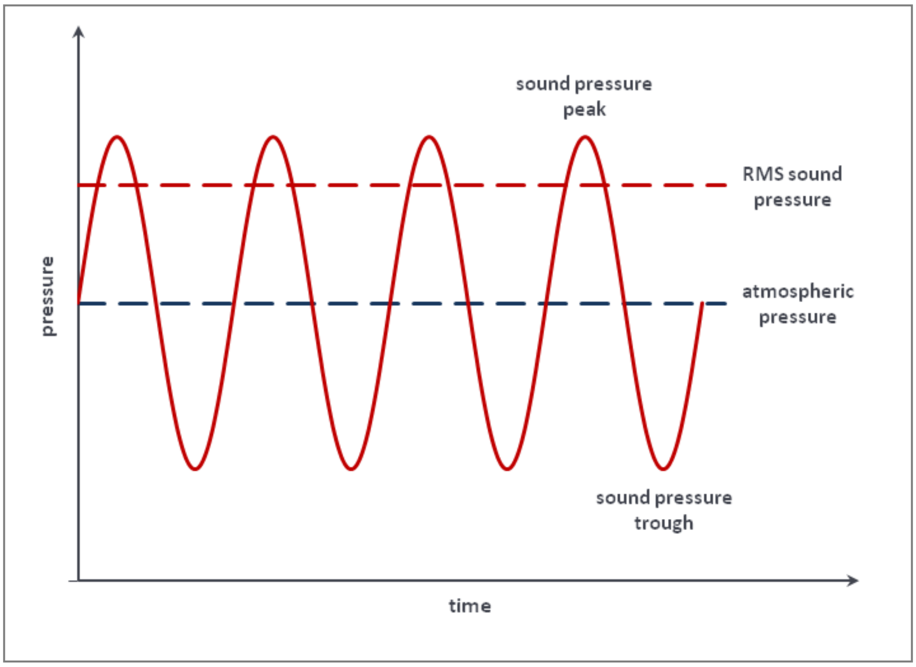
Example	Pascals	Bars	Pounds per Square Inch (PSI)
Atmospheric pressure	100,000	1	14.5
Pressure change due to weather front	10,000	0.1	1.5
Pressure change associated with sound at the threshold of pain	20	0.0002	0.003
Pressure change associated with sound at the threshold of hearing	0.00002	0.0000000002	0.000000003

The pressure values in Table 13 also show that the range of pressure changes associated with quiet and loud sounds span over a very large range, albeit still very small changes compared to atmospheric pressure. To make the description of pressure changes more practical, sound pressure is expressed in decibels or dB.

To illustrate the pressure variation associated with sound, Figure 3 shows the repetitive rise and fall in pressure of a very simple and steady sound. This figure illustrates the peaks and troughs of pressure changes relative to the underlying pressure of the atmosphere in the absence of sound. The magnitude of the change in pressure caused by the sound is then described as the sound pressure level. Since the magnitude of the change is constantly varying, the sound pressure may be defined in terms of:

- Peak sound pressure levels: the maximum change in pressure relative to atmospheric pressure i.e. the amplitude as defined by the maximum depth or height of the peaks and troughs respectively; or
- Root Mean Square (RMS) sound pressure levels: the average of the amplitude of pressure changes, accounting for positive changes above atmospheric pressure, and negative pressure changes below atmospheric pressure.

Figure 3: Pressure changes relative to atmospheric pressure associated with sound



B2.2 Frequency

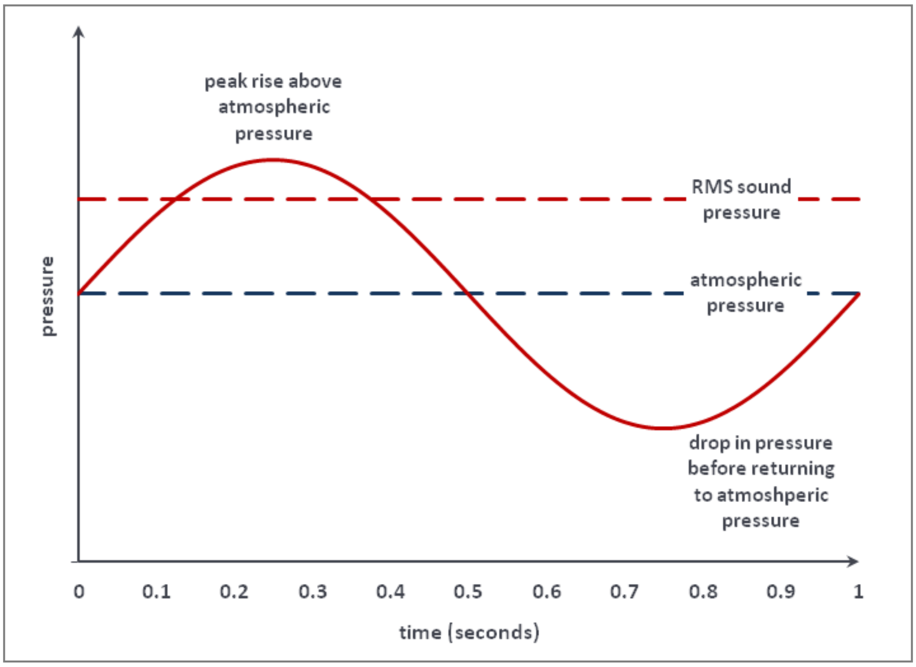
Frequency is a term used to describe the number of times a sound causes the pressure to rise and fall in a given period. The rate of change in pressure is an important feature that determines whether it can be perceived as a sound by the human ear.

Repetitive changes in pressure can occur as a result of a range of factors with widely varying rates of fluctuation. However, only a portion of these fluctuations can be perceived as sound. In many cases, the rate of fluctuation will either be too slow or too fast for the human ear to detect the pressure change as a sound. For example, local fluctuations in atmospheric pressure can be created by someone waving their hands back and forth through the air; the reason this cannot be perceived as a sound is the rate of fluctuation is too slow.

At the rates of fluctuation that can be detected as sound, the rate will influence the character of the sound that is perceived. For example, slow rates of pressure change correspond to rumbling sounds, while fast rates correspond to whistling sounds.

The rate of fluctuation is numerically described in terms of the number of pressure fluctuations that occur in a single second. Specifically, it is the number of cycles per second of the pressure rising above, falling below, and then returning to atmospheric pressure. The number of these cycles per second is expressed in Hertz (Hz). This concept of cycles per second is illustrated in Figure 4 which illustrates a 1 Hz pressure fluctuation. The figure provides a simple illustration of a single cycle of pressure rise and fall occurring in a period of a single second.

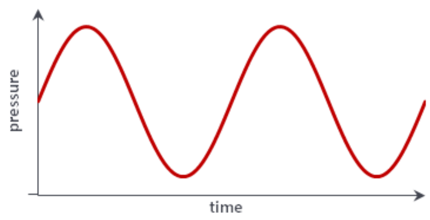
Figure 4: Illustration of a pressure fluctuation with a frequency of 1 Hz



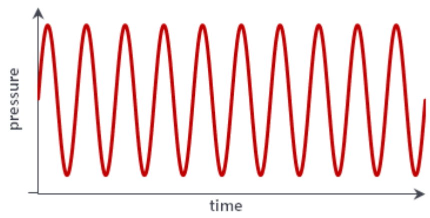
The rate that sound pressure rises and falls will vary depending on the source of the sound. For example, the surface of a tuning fork vibrates at a specific rate, in turn causing the pressure of the adjacent air to fluctuate at the same rate. Recalling the idea of pressure fluctuations from someone waving their hands, the pressure would fluctuate at the same rate as the hands move back and forth; a few times a second translating to a very low frequency below our hearing range (termed an infrasonic frequency). Examples of low and high frequency sound are easily recognisable, such as the low frequency sound of thunder, and the high frequency sound of crashing cymbals. To demonstrate the differences in the patterns of different frequencies of sound, Figure 5 illustrates the relative rates of pressure change for low, mid and high frequency sounds. Note that in each case the amplitude of the pressure changes remains the same; the only change is the number of fluctuations in pressure that occur over time.

Figure 5: Examples of the rate of change in pressure fluctuations for low, mid and high frequencies

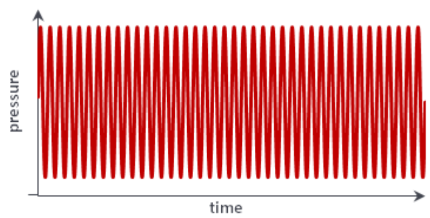
Low frequency sounds: 20 to 200 Hz



Mid-frequency sounds: 200 to 800 Hz



High frequency sounds: greater than 800 Hz



B2.3 Sound pressure and frequency variations

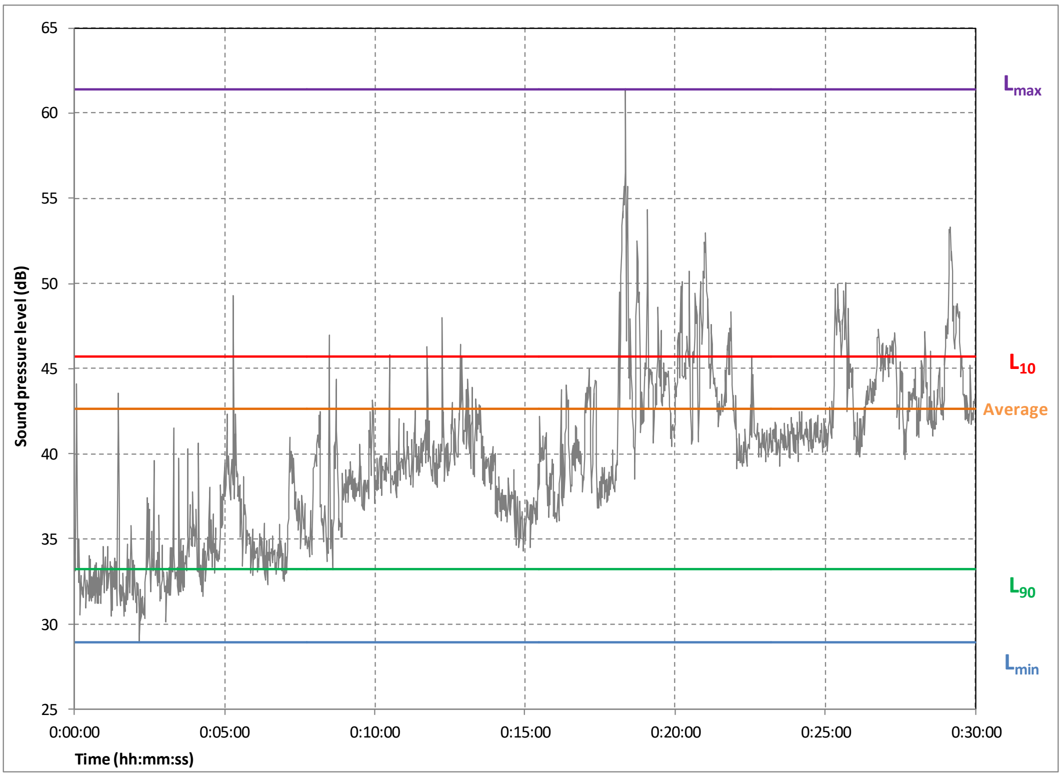
The preceding sections describe important aspects of the nature of sound, the changes in pressure and the changes in the rate of pressure fluctuations.

The simplest type of sound comprises a single constant sound pressure level and a single constant frequency. However, most sounds are made up of many frequencies, and may include low, mid and high frequencies. Sounds that are made up of a relatively even mix of frequencies across a broad range of frequencies are referred to as being 'broad band'. Common examples of broad band sounds include flowing water, the rustling of leaves, ventilation fans and traffic noise.

Further, sound quite often changes from moment to moment, in terms of both pressure levels and frequencies. The time varying characteristics of sound are important to how we perceive sound. For example, rapid changes in sound level produced by voices provide the component of sound that we interpret as intelligible speech. Variations in sound pressure levels and frequencies are also features which can draw our attention to a new source of sound in the environment.

To demonstrate this, Figure 6 illustrates an example time-trace of total sound pressure levels which varies with time. This variation presents challenges when attempting to describe sound pressure levels. As a result, multiple metrics are generally needed to describe sound pressure, such as the average, minimum or maximum noise levels. Other ways of describing sound include statistics for describing how often a defined sound pressure level is exceeded; for example, typical upper sound levels are often described as an L_{10} which refers to the sound pressure exceeded for 10 % of the time, or typical lower levels or lulls which are often described as an L_{90} which refers to the sound exceeded for 90 % of the time.

Figure 6: Example of noise metrics that may be used to measure a time-varying sound level



This example illustrates variations in terms of just total sound pressure levels, but the variations can also relate to the frequency of the sound, and frequently the number of sources affecting the sound.

These types of variations are an inherent feature of most sound fields and are an important point of context in any attempt to describe sound.

B3 Hearing and perception of sound

This section provides a discussion of:

- the use of the decibel to practically describe sound levels in a way that corresponds to the pressure levels the human ear can detect as sounds
- the relationship between sound frequency and human hearing.

The section concludes with a discussion of some of the complicating non-acoustic factors that influence our perception of sound.

B3.1 Sound pressure and the decibel

Previous sections discussed the wide range of small pressure fluctuations that the ear can detect as sound. Owing to the wide range of these fluctuations, the way we hear sound is more practically described using the decibel (dB). The decibel system serves two key purposes:

- Compressing the numerical range of the quietest and loudest sounds commonly experienced

  As an indication of this benefit, the pressure of the loudest sound that might be encountered is around a million times greater than the quietest sound that can be detected. In contrast, the decibel system reduces this to a range of approximately 0-120 dB.

- Consistently representing sound pressure level changes in a way that correlate more closely with how we perceive sound pressure level changes

  For example, a 10 dB change from 20-30 dB will generally be subjectively like a 10 dB change from 40-50 dB. However, expressed in units of pressure as Pascals, the 40-50 dB change is ten times greater than the 20-30 dB change. For this reason, sound pressure changes cannot be meaningfully communicated in terms of units of pressure such as Pascals.

Sound pressure levels in most environments are highly variable, so it can be misleading to describe what different ranges of sound pressure levels correspond to. However, as a broad indication, Table 14 provides some example ranges of sound pressure levels, expressed in both dB and units of pressure.

Table 14: Example sound pressure levels that might be experienced in different environments

Environment	Example sound pressure level	
Outside in an urban area with traffic noise	50-70 dB	0.006-0.06 Pa
Outside in a rural area with distant sounds or moderate wind rustling leaves	30-50 dB	0.0006-0.006 Pa
Outside in a quiet rural environment in calm conditions	20-30 dB	0.0002-0.0006 Pa
Inside a quiet bedroom at night	<20 dB	0.0002 Pa

The impression of how much louder or quieter a sound is, will be influenced by the magnitude of the change in sound pressure. Other important factors will also influence this, such as the frequency of the sound which is discussed in the following section. However, to provide a broad indication, Table 15 provides some examples of how changes in sound pressure levels, for a sound with the same character, can be perceived.

Table 15: Perceived changes in sound pressure levels

Sound pressure level change	Indicative change in perceived sound
1 dB	Unlikely to be noticeable
2-3 dB	Likely to be just noticeable
4-5 dB	Clearly noticeable change
10 dB	Distinct change - often subjectively described as halving or doubling the loudness

The example sound pressure level changes in Table 15 are based on side-by-side comparison of a steady sample of sound heard at different levels. In practice, changes in sound pressure levels may be more difficult to perceive for a range of reasons, including the presence of other sources of sound, or gradual changes which occur over a longer period.

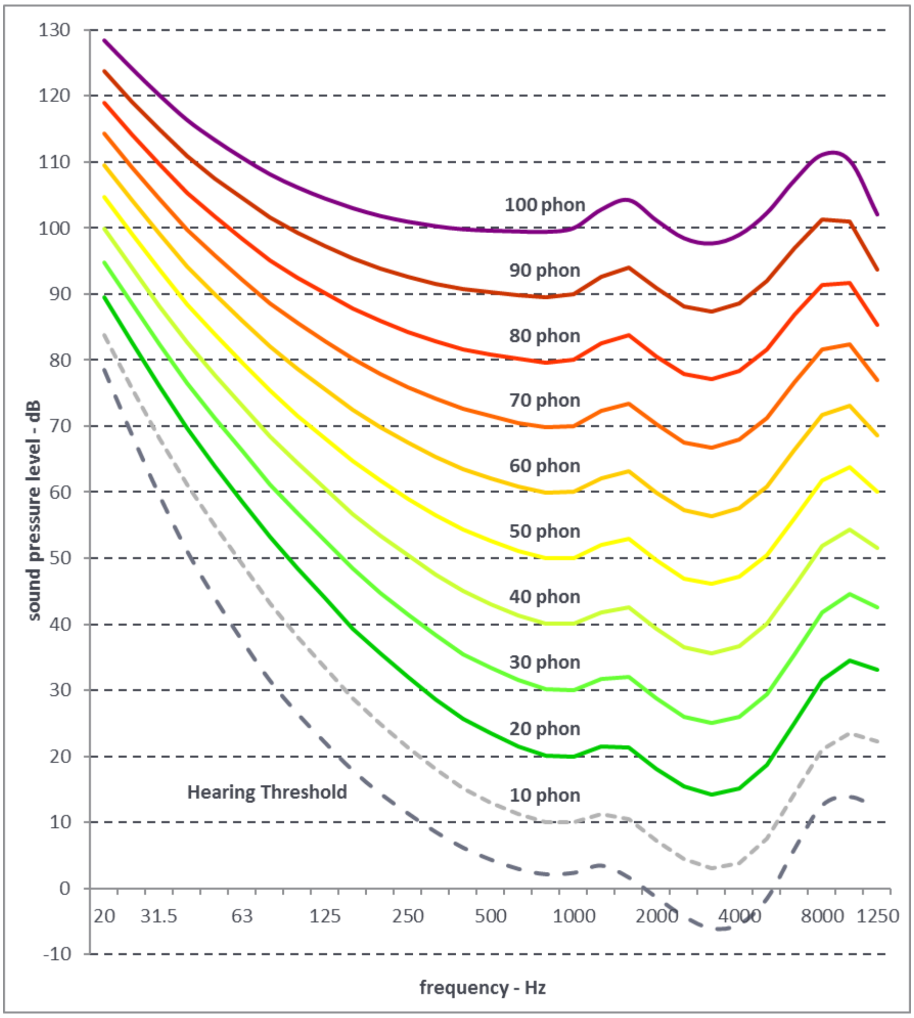
B3.2 Sound frequency and loudness

Although sound pressure level and the sensation of loudness are related, the sound pressure level is not a direct measure of how loud a sound appears to humans. Human perception of sound varies and depends on a number of physical attributes, including frequency, level and duration.

An example of the relationship between the sensation of loudness and frequency is demonstrated in Figure 7. The chart presents equal loudness curves for sounds of different frequencies expressed in 'phons'. Each point on the phon curves represents a sound of equal loudness. For example, the 40 phon curve shows that a sound level of 100 dB at 20 Hz (a very low frequency sound) would be of equal loudness to a level of 40 dB at 1,000 Hz (a whistling sound) or approximately 50 dB at just under 8,000 Hz (a very high pitch sound). The information presented is based on an international standard[8] that defines equal loudness levels for sounds comprising individual frequencies. In practice, sound is usually composed of many different frequencies, so this type of data can only be used as an indication of how different frequencies of sound may be perceived. An individual's perceptions of sound can also vary significantly. For example, the lower dashed line in Figure 7 shows the threshold of hearing, which represents the sounds an average listener could correctly identify at least 50 % of the time. However, these thresholds represent the average of the population. In practice, an individual's hearing threshold can vary significantly from these values, particularly at the low frequencies.

[8] ISO 226:2003 *Acoustics - Normal equal-loudness-level contours*

Figure 7: Equal loudness contours for pure tone sounds



The noise curves in Figure 7 demonstrate that human hearing is most sensitive at frequencies from 500 to 4,000 Hz, which usefully corresponds to the main frequencies of human speech. The contours also demonstrate that sounds at low frequencies must be at much higher sound pressure levels to be judged equally loud as sounds at mid to high frequencies.

To account for the sensitivity of the ear to different frequencies, a set of adjustments were developed to enable sound levels to be measured in a way that more closely aligns with human hearing. Sound levels adjusted in this way are referred to as A-weighted sound levels.

B3.3 Interpretation of sound and noise

Human interpretation of sound is influenced by many factors other than its physical characteristics, such as how often the sound occurs, the time of day it occurs and a person's attitude towards the source of the sound.

For example, the sound of music can cause very different reactions, from relaxation and pleasure through to annoyance and stress, depending on individual preferences, the type of music and the circumstances in which the music is heard. This example illustrates how sound can sometimes be considered noise; a term broadly used to describe unwanted sounds or sounds that have the potential to cause negative reactions.

The effects of excess environmental sound are varied and complicated and may be perceived in various ways including sensations of loudness, interference with speech communication, interference with working concentration or studying, disruption of resting/leisure periods, and disturbance of sleep. These effects can give rise to behavioural changes such as avoiding the use of exposed external spaces, keeping windows closed, or timing restful activities to avoid the most intense periods of disruption. Prolonged annoyance or interference with normal patterns can lead to possible effects on mental and physical health. In this respect, the World Health Organization (preamble to the *Constitution of the World Health Organization*, 1946) defines health in the following broad terms:

> *A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*

The World Health Organization Guidelines for Community Noise (Berglund, Lindvall, & Schwela, 1999) documents a relationship between the definition of health and the effects of community noise exposure by noting that:

> *This broad definition of health embraces the concept of well-being, and thereby, renders noise impacts such as population annoyance, interference with communication, and impaired task performance as 'health' issues.*

The reaction that a community has to sound is highly subjective and depends on a range of factors including:

- the hearing threshold of individuals across the audible frequency range

  These thresholds vary widely across the population, particularly at the lower and upper ends of the audible frequency range. For example, at low frequencies the distribution of hearing thresholds varies above and below the mean threshold by more than 10 dB.

- the attitudes and sensitivities of individuals to sound, and their expectations of what is considered an acceptable level of sound or intrusion

  This in turn depends on a range of factors such as general health and the perceived importance of sound amongst other factors relevant to overall amenity perception.

- the absolute sound pressure level of the sound in question

  The threshold for the onset of community annoyance varies according to the type of sound; above such thresholds, the percentage of the population annoyed generally increases with increasing sound pressure level.

- the sound pressure level of the noise relative to background noise conditions in the area, and the extent to which general background noise may offer beneficial masking effects

- the characteristics of the sound in question such as whether the sound is constant, continually varies, or contains distinctive audible features such as tones, low frequency components or impulsive sound which may draw attention to the noise

- the site location and the compatibility of the source in question with other surrounding land uses

  For example, whether the source is in an industrial or residential area.

- the attitudes of the community to the source of the sound

  This may be influenced by factors such as the extent to which those responsible for the sound are perceived to be adopting reasonable and practicable measures to reduce their emissions, whether the activity is of local or national significance and whether the noise producer actively consults and/or liaises with the community.

- the times when the sound is present, the duration of exposure to increased sound levels, and the extent of respite periods when the sound is reduced or absent (for example, whether the sound ceases at weekends).

The combined influence of the above considerations means that physical sound levels are only one factor influencing community reaction to sound. Importantly, this means that individual reactions and attitudes to the same type and level of sound will vary within a community.

APPENDIX C INFRASTRUCTURE COORDINATES

C1 Wind turbine coordinates

Table 16 sets out the coordinates of the proposed wind turbine layout (layout NGN-WTG-TO-0003)

Table 16: Wind turbine coordinates (Layout NGN-WTG-TO-0003) - CRS: GDA2020 MGA zone 50

Wind turbine	Easting, m	Northing, m	Terrain elevation, m
T1	499,789	6,355,685	530
T2	500,636	6,355,359	544
T3	501,484	6,355,006	550
T4	501,484	6,354,362	566
T5	501,484	6,353,760	559
T6	501,165	6,353,190	537
T7	502,290	6,353,099	538
T8	501,915	6,352,539	530
T9	502,562	6,351,940	516
T10	503,180	6,352,073	525
T11	503,212	6,351,411	564
T12	503,122	6,350,639	516
T13	502,225	6,350,407	531
T14	501,807	6,350,065	515
T15	501,141	6,351,629	513
T16	500,251	6,352,180	533
T17	499,871	6,352,858	548
T18	499,469	6,350,862	534
T19	498,704	6,350,821	531
T20	498,532	6,351,583	535
T21	498,878	6,352,032	556
T22	499,247	6,349,970	539
T23	498,015	6,350,428	512
T24	497,537	6,350,080	523
T25	497,667	6,349,408	531

C2 Related Infrastructure

Table 17 sets out the coordinates of the proposed related infrastructure (NGN-ESS-EQ-0001 / NGN-BOP-TX-0001).

Table 17: Related infrastructure equipment coordinates – CRS: GDA2020 MGA zone 50

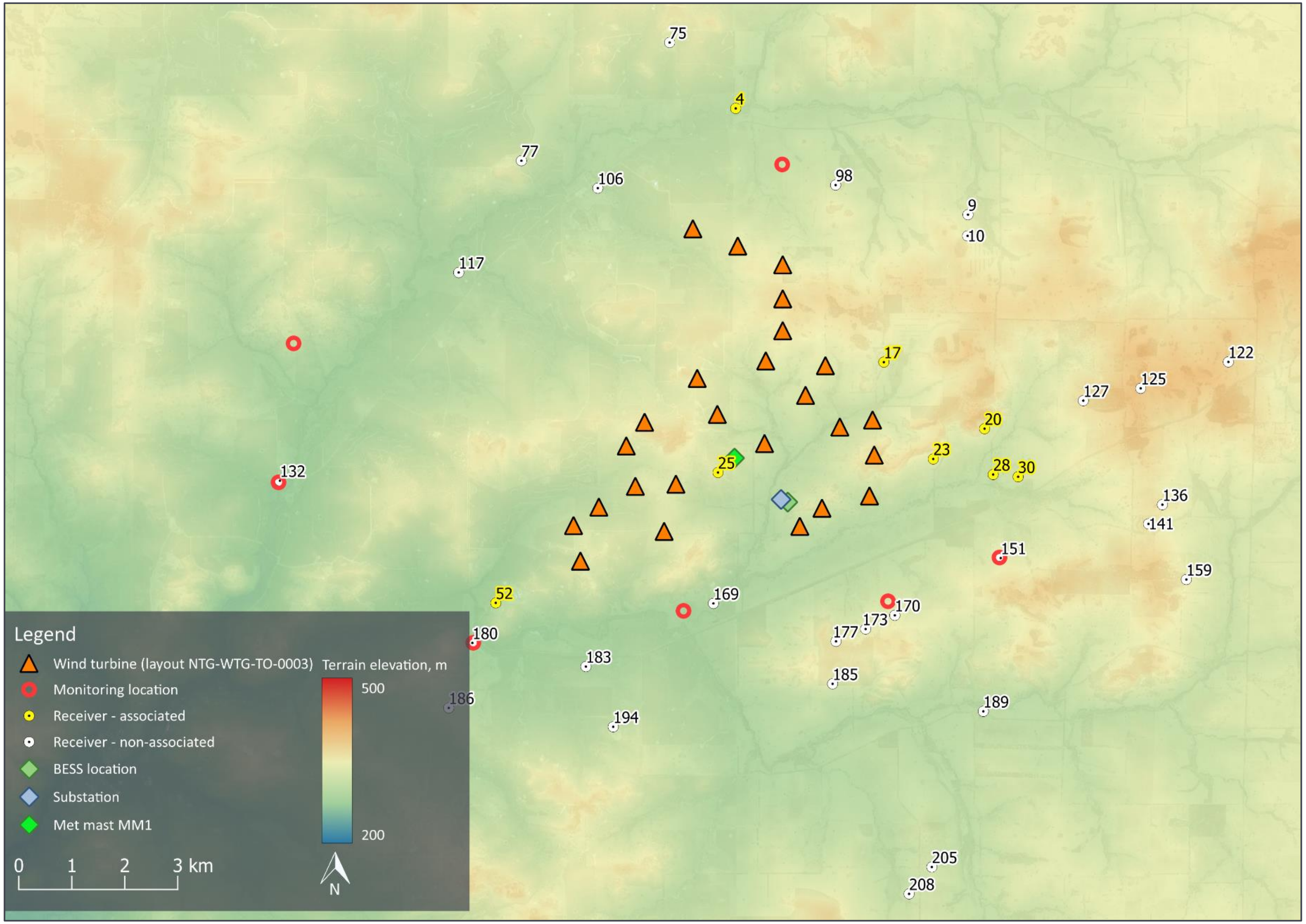
Reference	Description	Easting, m	Northing, m
TX1	HV Transformer	501,453	6,350,571
MV1	MV Transformer	501,533	6,350,534
MV2	MV Transformer	501,539	6,350,534
MV3	MV Transformer	501,545	6,350,534
MV4	MV Transformer	501,552	6,350,534
MV5	MV Transformer	501,558	6,350,534
MV6	MV Transformer	501,564	6,350,534
MV7	MV Transformer	501,571	6,350,534
MV8	MV Transformer	501,533	6,350,509
MV9	MV Transformer	501,539	6,350,509
MV10	MV Transformer	501,545	6,350,509
MV11	MV Transformer	501,552	6,350,509
MV12	MV Transformer	501,558	6,350,509
MV13	MV Transformer	501,564	6,350,509
MV14	MV Transformer	501,571	6,350,509
MV15	MV Transformer	501,588	6,350,534
MV16	MV Transformer	501,594	6,350,534
MV17	MV Transformer	501,601	6,350,534
MV18	MV Transformer	501,607	6,350,534
MV19	MV Transformer	501,613	6,350,534
MV20	MV Transformer	501,620	6,350,534
MV21	MV Transformer	501,626	6,350,534
MV22	MV Transformer	501,588	6,350,509
MV23	MV Transformer	501,594	6,350,509
MV24	MV Transformer	501,601	6,350,509
MV25	MV Transformer	501,607	6,350,509
MV26	MV Transformer	501,613	6,350,509
MV27	MV Transformer	501,620	6,350,509
MV28	MV Transformer	501,626	6,350,509
MP1	Battery unit	501,531	6,350,526

Reference	Description	Easting, m	Northing, m
MP2	Battery unit	501,533	6,350,526
MP3	Battery unit	501,538	6,350,526
MP4	Battery unit	501,540	6,350,526
MP5	Battery unit	501,544	6,350,526
MP6	Battery unit	501,546	6,350,526
MP7	Battery unit	501,550	6,350,526
MP8	Battery unit	501,552	6,350,526
MP9	Battery unit	501,557	6,350,526
MP10	Battery unit	501,559	6,350,526
MP11	Battery unit	501,563	6,350,526
MP12	Battery unit	501,565	6,350,526
MP13	Battery unit	501,570	6,350,526
MP14	Battery unit	501,571	6,350,526
MP15	Battery unit	501,531	6,350,517
MP16	Battery unit	501,533	6,350,517
MP17	Battery unit	501,538	6,350,517
MP18	Battery unit	501,540	6,350,517
MP19	Battery unit	501,544	6,350,517
MP20	Battery unit	501,546	6,350,517
MP21	Battery unit	501,550	6,350,517
MP22	Battery unit	501,552	6,350,517
MP23	Battery unit	501,557	6,350,517
MP24	Battery unit	501,559	6,350,517
MP25	Battery unit	501,563	6,350,517
MP26	Battery unit	501,565	6,350,517
MP27	Battery unit	501,570	6,350,517
MP28	Battery unit	501,571	6,350,517
MP29	Battery unit	501,587	6,350,526
MP30	Battery unit	501,589	6,350,526
MP31	Battery unit	501,593	6,350,526
MP32	Battery unit	501,595	6,350,526
MP33	Battery unit	501,599	6,350,526
MP34	Battery unit	501,601	6,350,526

Reference	Description	Easting, m	Northing, m
MP35	Battery unit	501,606	6,350,526
MP36	Battery unit	501,608	6,350,526
MP37	Battery unit	501,612	6,350,526
MP38	Battery unit	501,614	6,350,526
MP39	Battery unit	501,619	6,350,526
MP40	Battery unit	501,620	6,350,526
MP41	Battery unit	501,625	6,350,526
MP42	Battery unit	501,627	6,350,526
MP43	Battery unit	501,587	6,350,517
MP44	Battery unit	501,589	6,350,517
MP45	Battery unit	501,593	6,350,517
MP46	Battery unit	501,595	6,350,517
MP47	Battery unit	501,599	6,350,517
MP48	Battery unit	501,601	6,350,517
MP49	Battery unit	501,606	6,350,517
MP50	Battery unit	501,608	6,350,517
MP51	Battery unit	501,612	6,350,517
MP52	Battery unit	501,614	6,350,517
MP53	Battery unit	501,619	6,350,517
MP54	Battery unit	501,620	6,350,517
MP55	Battery unit	501,625	6,350,517
MP56	Battery unit	501,627	6,350,517

Figure 8: Related infrastructure layout

APPENDIX D SITE TOPOGRAPHY



APPENDIX E RECEIVER COORDINATES

Table 18 sets out the seventeen (17) receivers identified by the Proponent within 3 km of the proposed wind turbines considered in the environmental noise assessment, together with their respective distance to the nearest wind turbine.

This includes nine (9) associated receivers where a noise agreement has been formalised between the landowners and the Proponent.

Data supplied by the Proponent on 6 May 2024.

Table 18: Receivers within 3 km of the proposed wind turbines – GDA2020 MGA Zone 50

Receiver	Easting, m	Northing, m	Terrain elevation, m	Distance to the nearest wind turbine, m	Nearest wind turbine
Non-associated receiver					
98	502,483	6,356,510	329	1,888	T03
106	497,996	6,356,451	300	2,020	T01
151	505,598	6,349,465	345	2,788	T12
169	500,177	6,348,608	294	1,735	T22
170	503,600	6,348,384	344	2,362	T12
173	503,049	6,348,124	343	2,361	T14
177	502,490	6,347,892	354	2,336	T14
180	495,627	6,347,862	283	2,614	T25
183	497,770	6,347,415	287	2,065	T25
Associated receiver					
4	500,597	6,357,957	306	2,469	T01
17	503,393	6,353,166	343	1,228	T07
20	505,294	6,351,908	341	2,184	T10
23	504,326	6,351,336	338	1,250	T11
25	500,263	6,351,081	336	981	T18
28	505,456	6,351,043	316	2,343	T11
30	505,927	6,351,000	326	2,803	T11
52	496,070	6,348,618	294	1,859	T25

APPENDIX F NOISE PREDICTION MODEL

Environmental noise levels associated with wind farms are predicted using engineering methods.

The international standard ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (ISO 9613-2:1996) has been chosen as the most appropriate method to calculate the level of broadband A-weighted wind farm noise expected to occur at surrounding receptor locations. This method is considered the most robust and widely used international method for the prediction of wind farm noise.

A revised version of the standard, ISO 9613-2:2024[9], was published earlier in 2024 based on broadly equivalent procedures to ISO 9613-2:1996, subject to refinements, clarifications, and supplementary advice for different types of sources. Notably, ISO 9613-2:2024 introduces an informative annex on wind turbine noise modelling to reflect the recommendations of the UK Institute of Acoustics guidance.

At the date of preparing this report, the revised standard has not yet been implemented in commonly used proprietary noise modelling software options. However, the core elements of the two versions (particularly with respect to wind farm noise modelling), are similar, and proprietary software options already implement the UK Institute of Acoustics guidance with respect to ISO 9613-2:1996.

On this basis ISO 9613-2:1996 continues to be used and referenced in Australia and has been chosen as the most appropriate method to calculate the level of broadband A-weighted wind farm noise expected to occur at surrounding receptor locations. This method is considered the most robust and widely used international method for the prediction of wind farm noise.

The use of this standard is supported by international research publications, measurement studies conducted by Marshall Day Acoustics and direct reference to the standard in the South Australia EPA W*ind farms environmental noise guidelines*, NZS 6808:2010 *Acoustics – Wind farm noise.*

The standard specifies an engineering method for calculating noise at a known distance from a variety of sources under meteorological conditions favourable to sound propagation. The standard defines favourable conditions as downwind propagation where the source blows from the source to the receiver within an angle of ±45 degrees from a line connecting the source to the receiver, at wind speeds between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground. Equivalently, the method accounts for average propagation under a well-developed moderate ground based thermal inversion. In this respect, it is noted that at the wind speeds relevant to noise emissions from wind turbines, atmospheric conditions do not favour the development of thermal inversions throughout the propagation path from the source to the receiver.

To calculate far-field noise levels according to the ISO 9613-2:1996, the noise emissions of each wind turbine are firstly characterised in the form of octave band frequency levels. A series of octave band attenuation factors are then calculated for a range of effects including:

- geometric divergence
- air absorption
- reflecting obstacles
- screening
- vegetation
- ground reflections.

[9] ISO 9613-2:2024 *Acoustics — Attenuation of sound during propagation outdoors Part 2: Engineering method for the prediction of sound pressure levels outdoors*

The octave band attenuation factors are then applied to the noise emission data to determine the corresponding octave band and total calculated noise level at receivers.

Calculating the attenuation factors for each effect requires a relevant description of the environment into which the sound propagation such as the physical dimensions of the environment, atmospheric conditions and the characteristics of the ground between the source and the receiver.

Wind farm noise propagation has been the subject of considerable research in recent years. These studies have provided support for the reliability of engineering methods such as ISO 9613-2:1996 when a certain set of input parameters are chosen in combination. Specifically, the studies to date tend to support that the assignment of a ground absorption factor of G = 0.5 for the source, middle and receiver ground regions between a wind farm and a calculation point tends to provide a reliable representation of the upper noise levels expected in practice, when modelled in combination with other key assumptions; specifically all wind turbines operating at identical wind speeds, emitting sound levels equal to the test measured levels plus a margin for uncertainty (or guaranteed values), at a temperature of 10 ^{o}C and relative humidity of 70 % to 80 %, with specific adjustments for screening and ground effects as a result of the ground terrain profile.

In support of the use of ISO 9613-2:1996 and the choice of G = 0.5 as an appropriate ground characterisation, the following references are noted:

- A factor of G = 0.5 is frequently applied in Australia for general environmental noise modelling purposes as a way of accounting for the potential mix of ground porosity which may occur in regions of dry/compacted soils or in regions where persistent damp conditions may be relevant.
- NZS 6808:2010 refers to ISO 9613-2:1996 as an appropriate prediction method for wind farm noise, and notes that soft ground conditions should be characterised by a ground factor of G = 0.5.
- In 1998, a comprehensive study (commonly cited as the Joule Report), part funded by the European Commission found that the ISO 9613-2:1996 model provided a robust representation of upper noise levels which may occur in practice and provided a closer agreement between predicted and measured noise levels than alternative standards such as CONCAWE and ENM. Specifically, the report indicated the ISO 9613-2:1996 method generally tends to marginally over predict noise levels expected in practice.
- The UK Institute of Acoustics journal dated March/April 2009 published a joint agreement between practitioners in the field of wind farm noise assessment (the UK IOA 2009 joint agreement), including consultants routinely employed on behalf of both developers and community opposition groups, and indicated the ISO 9613-2:1996 method as the appropriate standard and specifically designated G = 0.5 as the appropriate ground characterisation. This agreement was subsequently reflected in the recommendations detailed in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (the UK Institute of Acoustics guidance). It is noted that these publications refer to predictions made at receiver heights of 4 m. Predictions in Australia are generally based on a lower prediction height of 1.5 m which tends to result in higher ground attenuation for a given ground factor, however conversely, predictions in Australia do not generally incorporate a -2 dB factor (as applied in the UK) to represent the relationship between L_{Aeq} and L_{A90} noise levels. The result is that these differences tend to balance out to a comparable approach and thus supports the use of G = 0.5 in the context of Australian prediction methods.

A range of measurement and prediction studies[10, 11, 12] for wind farms in which Marshall Day Acoustics' staff have been associated in have provided further support for the use of ISO 9613-2:1996 and G = 0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

The findings of these studies demonstrate the suitability of the ISO 9613-2:1996 method to predict the propagation of wind turbine noise for:

- the types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30 m maximum source heights considered in the original ISO 9613.
- the types of environments in which wind farms are typically developed, and the range of atmospheric conditions and wind speeds typically observed around wind farm sites.

  Importantly, this supports the extended scope of application to wind speeds in excess of 5 m/s.

In addition to the choice of ground factor referred to above, adjustments to the ISO 9613-2:1996 standard for screening and valleys effects are applied based on recommendations of the Joule Report, UK IOA 2009 joint agreement and the UK Institute of Acoustics guidance. The following adjustments are applied to the calculations:

- screening effects as a result of terrain are limited to -2 dB
- screening effects are assessed based on each wind turbine being represented by a single noise source located at the maximum tip height of the wind turbine rotor
- an adjustment of 3 dB is added to the predicted noise contribution of a wind turbine if the terrain between the wind turbine and receiver in question is characterised by a significant valley

  A significant valley is defined as a situation where the mean sound propagation height is at least 50 % greater than it would be otherwise over flat ground.

The adjustments detailed above are implemented in the wind turbine calculation procedure of the software used to conduct the noise modelling. The software uses these definitions in conjunction with the digital terrain model of the Site to evaluate the path between each wind turbine and receiver pairing, and then subsequently applies the adjustments to each wind turbine's predicted noise contribution where appropriate.

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[10] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions: The Risks of Conservatism*; Presented at the Second International Meeting on Wind Turbine Noise in Lyon, France September 2007.

[11] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions and Comparisons with Measurements*; Presented at the Third International Meeting on Wind Turbine Noise in Aalborg, Denmark June 2009.

[12] Delaire, Griffin, & Walsh – *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*; Presented at the Fourth International Meeting on Wind Turbine Noise in Rome, April 2011.

APPENDIX G TABULATED BACKGROUND NOISE LEVELS

Table 19: Background noise levels, dB L_{A90} – All-time period

Location	Hub height wind speed [1], m/s									
	3	4	5	6	7	8	9	10	11	12
98 proxy	18.8	19.4	20.2	20.7	22.0	22.9	23.1	22.7	23.5	25.0
180	27.1	29.2	31.5	32.4	34.2	35.0	34.4	33.7	34.8	35.8
169 proxy	24.0	25.6	27.3	28.5	30.6	31.2	30.7	29.4	30.5	30.9
170 proxy	21.3	22.0	23.0	24.0	26.0	26.9	27.1	26.9	28.0	29.1
151	25.7	26.8	27.9	28.8	31.0	31.4	31.9	31.7	32.9	33.6
132 [2]	26.2	26.3	27.0	27.7	28.6	29.3	29.1	27.6	28.4	29.3
210 [2]	23.6	24.2	25.2	26.3	28.5	30.0	30.1	29.4	30.3	31.7

1 MM1 met mast at 500,574 E / 6,351,351N (GDA2020 MGA Zone 50)

2 This receiver was selected for assessment purposes as part of a legacy wind turbine layout that has since been superseded. At that time 132 and 210 were within 3 km of a wind turbine. Following update of the wind turbine layout these receivers are now greater than 3 km from a wind turbine and is no longer considered within the assessment due to its distance from a wind turbine. Further information is provided in the Background Noise Report.

Table 20: Background noise levels, dB L_{A90} – Night period

Location	Hub height wind speed [1], m/s									
	3	4	5	6	7	8	9	10	11	12
98 proxy	19.9	18.9	18.9	19.1	19.8	20.0	20.3	20.4	21.1	23.1
180	26.1	25.3	27.8	27.5	29.3	29.9	29.1	30.4	31.5	33.5
169 proxy	23.3	23.0	23.1	23.3	25.0	24.8	24.5	25.0	26.3	27.8
170 proxy	23.3	21.6	22.2	21.2	22.6	22.3	23.2	24.4	25.2	27.0
151	28.7	28.3	28.0	25.4	27.5	26.8	27.9	28.7	30.1	31.7
132 [2]	25.4	23.1	23.0	21.9	23.0	22.8	23.3	23.4	24.4	26.3
210 [2]	23.6	21.8	21.5	21.0	22.1	22.7	24.0	25.0	25.8	28.5

1 MM1 met mast at 500,574 E / 6,351,351N (GDA2020 MGA Zone 50)

2 This receiver was selected for assessment purposes as part of a legacy wind turbine layout that has since been superseded. At that time 132 and 210 were within 3 km of a wind turbine. Following update of the wind turbine layout these receivers are now greater than 3 km from a wind turbine and is no longer considered within the assessment due to its distance from a wind turbine. Further information is provided in the Background Noise Report.

APPENDIX H TABULATED NOISE LIMITS

Table 21: Noise limits, dB L_{Aeq} – All-time period

Location	Hub height wind speed [1], m/s									
	3	4	5	6	7	8	9	10	11	12
98 proxy	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
180	35.0	35.0	36.5	37.4	39.2	40.0	39.4	38.7	39.8	40.8
169 proxy	35.0	35.0	35.0	35.0	35.6	36.2	35.7	35.0	35.5	35.9
170 proxy	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
151	35.0	35.0	35.0	35.0	36.0	36.4	36.9	36.7	37.9	38.6
132 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
210 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.1	35.0	35.3	36.7

1 MM1 met mast at 500,574 E /6,351,351N (GDA 2020 Zone 50)

2 This receiver was selected for assessment purposes as part of a legacy wind turbine layout that has since been superseded. At that time 132 and 210 were within 3 km of a wind turbine. Following update of the wind turbine layout these receivers are now greater than 3 km from a wind turbine and is no longer considered within the assessment due to its distance from a wind turbine. Further information is provided in the Background Noise Report.

While the assessment is based on the all-time period noise limits above, derived noise limits for the night period have been provided for reference in Table 22.

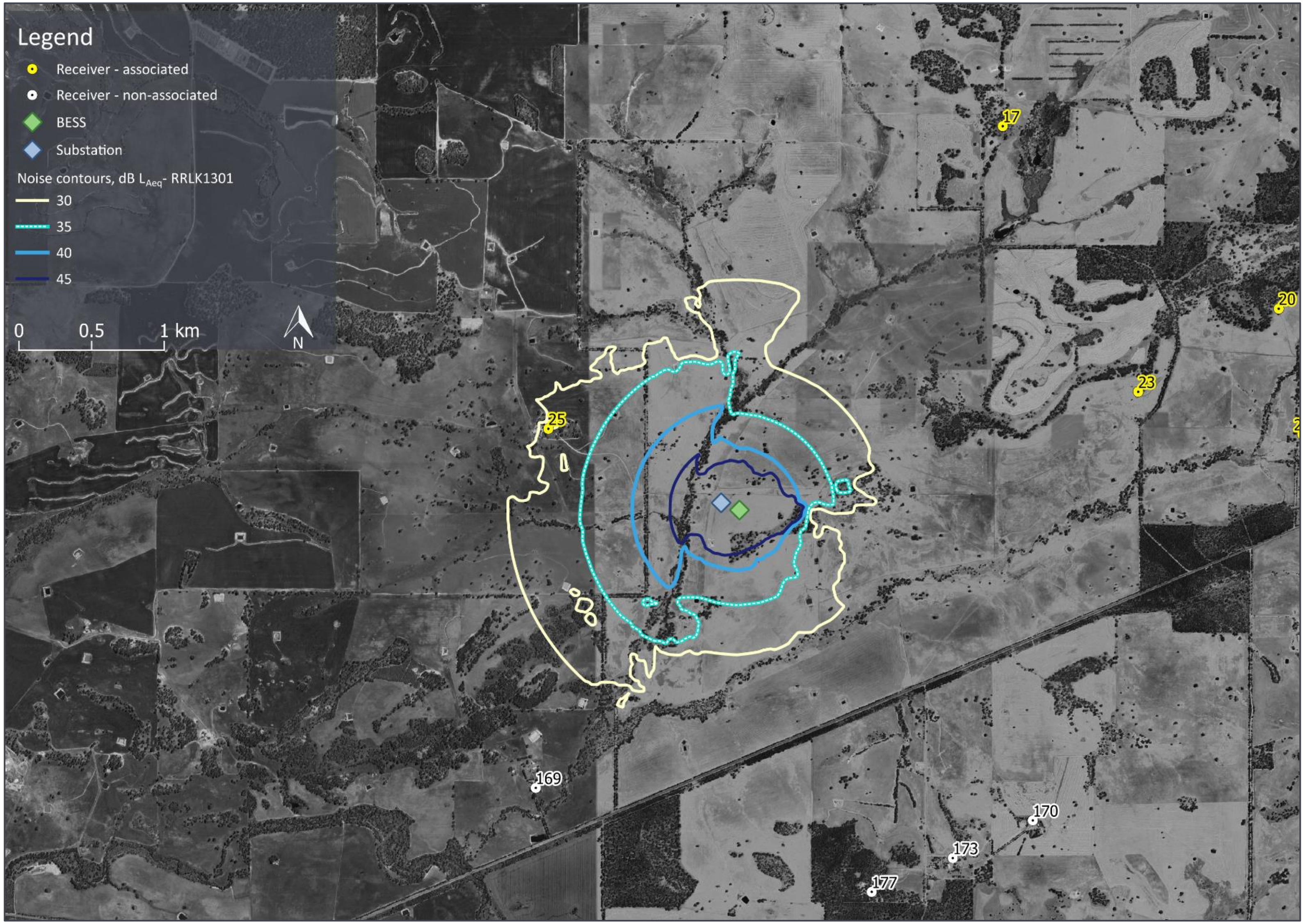
Table 22: Noise limits, dB L_{Aeq} –Night period

Location	Hub height wind speed [1], m/s									
	3	4	5	6	7	8	9	10	11	12
98 proxy	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
180	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.4	36.5	38.5
169 proxy	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
170 proxy	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
151	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.1	36.7
132 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
210 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0

1 MM1 met mast at 500,574 E /6,351,351N (GDA 2020 Zone 50)

2 This receiver was selected for assessment purposes as part of a legacy wind turbine layout that has since been superseded. At that time 132 and 210 were within 3 km of a wind turbine. Following update of the wind turbine layout these receivers are now greater than 3 km from a wind turbine and is no longer considered within the assessment due to its distance from a wind turbine. Further information is provided in the Background Noise Report.

APPENDIX I RELATED INFRASTRUCTURE PREDICTED NOISE LEVEL CONTOURS



APPENDIX J EFFECTS OF WIND TURBINE NOISE

In terms of the effect of wind turbine noise, one of the most important consideration is how the sound is perceived. However, judging whether or not a sound is noisy is highly subjective, and depends on many factors including the setting where the sound is heard, the character of the sound, and factors that influence how an individual perceives the sound.

In recognition of the rural settings where wind farms are usually built, wind farms are required to adhere to strict noise controls. Wind farm policies in Australia are among the most stringent international standards and set limits using a combination of a base (or fixed value) limit and an allowable margin above the background.

J1 Health and amenity

Sound is an important feature of the environment in which we live; it provides information about our surroundings and is a key influence on our overall perception of amenity and environmental quality. Sound is therefore an environmental quality that must be considered as part of any proposal to develop new infrastructure that could influence the sound environment of neighbouring communities.

Excessive or unwanted sound is commonly referred to as noise and can have a range of effects on people, depending on a range of physical and contextual factors. The *Guidelines for Community Noise* 1999 prepared by the World Health Organisation (WHO) provides a health-based framework of guideline limits and values to address the broad definition of health given as:

> *A state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity*

This broad definition means that effects ranging from community annoyance, sleep disturbance and speech interference, through to direct physiological impacts such as hearing damage, are all identified as potential health considerations. An important aspect of this range of considerations is that some effects will be highly dependent on the listener's perception and attitude to the noise in question, such as annoyance, while other effects are primarily related to the level of sound and the direct physiological risks these may represent, such as hearing damage.

Environmental noise policies, including those applied to wind farms, establish objective noise criteria to address these health considerations. In particular, environmental noise policies define criteria which are chosen to prevent direct physiological risks of sound and minimise as far as practically possible adverse health considerations such as annoyance and sleep disturbance.

Practically minimising the risks of noise effects related to annoyance and sleep disturbance requires the potential range of responses to sound to be considered. In this respect, it is important to note that individual attitudes and reactions to sound are highly variable and will depend on a complex set of acoustic and non-acoustic factors. These include the level and character of the sound in question, the time of day the sound occurs, the regularity of the sound, the environment in which the sound is heard, the individuals hearing acuity, and an individual's personal opinion and perception of the sound source or development in question. The latter will in turn depend on other complicating factors such as visual impressions of the source in question and the perceived community benefit, or otherwise, of the source in question.

Due to the complexity and range of potential responses to sound, it is not possible to define limits that will guarantee an audible sound will be acceptable to all individuals; this will always be a matter of personal judgement for each individual. Further, it is usually not feasible or practical to design new development or infrastructure to inaudible noise levels. As a result, minimising the risks of noise effects involves setting criteria which prevents the majority of people from being disturbed. This requires regulatory authorities to strike a balance between amenity and development, setting noise limits which are as stringent as can be practically achieved without preventing new development.

This type of approach to noise policy was outlined by the Victorian Department of Health in their 2013 publication on wind farm sound and health which states:

> *Noise standards are used not only for environmental noise (such as wind farms and traffic noise) but also for industry and even household appliances.*
>
> *Noise standards are set to protect the majority of people from annoyance. The wide individual variation in response to noise makes it unrealistic to set standards that will protect everyone from annoyance. A minority of people may still experience annoyance even at sound levels that meet the standard. This is the case not only for wind farms, but for all sources of noise.*

The subject of health effects related to operational wind farms in Australia has been extensively considered by the Commonwealth Government's National Health and Medical Research Council (NHMRC) and the Australian Medical Association; in particular, the NHMRC has undertaken and coordinated a systematic review of evidence related to wind farms and health. The research reviews[13] and public statements[14, 15] produced by these peak health bodies support that, as with any audible sound, wind farm noise can represent a potential source of annoyance or sleep disturbance for some individuals. Their findings did however indicate that there was no reliable evidence to support a relationship between wind farm noise and direct adverse effects on human health.

In July 2012, Health Canada undertook a large-scale epidemiology study in response to community health concerns expressed in relation to wind turbines. The following conclusions[16] were made from this research.

> *The following were not found to be associated with* [Wind Turbine Noise] *exposure:*
>
> - *self-reported sleep (e.g., general disturbance, use of sleep medication, diagnosed sleep disorders);*
> - *self-reported illnesses (e.g., dizziness, tinnitus, prevalence of frequent migraines and headaches) and chronic health conditions (e.g., heart disease, high blood pressure and diabetes); and*
> - *self-reported perceived stress and quality of life.*
>
> *While some individuals reported some of the health conditions above, the prevalence was not found to change in relation to* [Wind Turbine Noise] *levels.*
>
> [...]
>
> *The following was found to be statistically associated with increasing levels of* [Wind Turbine Noise]*:*
>
> - *annoyance towards several wind turbine features (i.e. noise, shadow flicker, blinking lights, vibrations, and visual impacts).*

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13 *Systematic review of the human health effects of wind* farms 2013, Adelaide University, commissioned by the NMRC

14 NHMRC Information Paper: *Evidence on Wind Farms and Human Health*, February 2015, National Health and Medical Research Council

15 AMA Position Statement – *Wind Farms and Health* 2014, Australian Medical Association

16 https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/wind-turbine-noise/wind-turbine-noise-health-study-summary-results.html

In 2018, the World Health Organization released the *Environmental Noise Guidelines for the European Region*[17] which concluded:

> *In accordance with the prioritization process, the GDG set a guideline exposure level of 45.0 dB L_{den} for average exposure, based on the relevant increase of the absolute %HA. The GDG stressed that there might be an increased risk for annoyance below this noise exposure level, but it could not state whether there was an increased risk for the other health outcomes below this level owing to a lack of evidence. As the evidence on the adverse effects of wind turbine noise was rated low quality, the GDG made the recommendation conditional.*
>
> [...]
>
> *Based on the low quantity and heterogeneous nature of the evidence, the GDG was not able to formulate a recommendation addressing sleep disturbance due to wind turbine noise at nighttime.*

As detailed in the MDA paper *WHO Environmental Noise Guidelines for the European Region: conditional recommendation for wind turbine noise in the context of Australian regulations*[18], achieving compliance with NZS 6808 corresponds to noise levels that are consistent with the recommendations of the 2018 WHO European Noise Guidelines.

These findings lend support to the suitability of the wind farm noise controls applied in SA Guidelines 2021, which are intended to provide reasonable protection of health and amenity at noise sensitive locations.

Further discussions of specific noise considerations related low-frequency sound and infrasound are provided in the following section.

J2 Low frequency noise, infrasound and ground vibration

The limits adopted for the assessment of operational noise from wind farms represent relatively low levels which have been specified in recognition of the quieter rural environments in which wind farms are normally located.

However, consistent with noise policies applied to other forms of development, the criteria are not intended to restrict wind farm noise to inaudible levels. Accordingly, a wind farm which achieves compliance with the criteria may still be audible at surrounding receivers on some occasions; this will depend on a range of factors such as the time of day, the speed and direction of the wind, the proximity to wind turbines, the extent of vegetation around the dwelling, and the degree to which the dwelling is sheltered from prevailing wind conditions. Irrespective of the relatively low levels which operational wind farm noise is restricted to, an individual's judgement of the audible noise from a wind farm is highly subjective and will be influenced by a range of contextual factors.

The subject of wind farm noise and its characteristics has attracted considerable attention. Specific attention has been directed to alleged matters relating to low frequency sound as well as infrasound and vibration. Low frequency sounds are generally regarded as sounds above 20 Hz and extending upwards into the range of 100-200 Hz. The definition of infrasound often varies in different jurisdictions but is generally accepted to refer to frequencies of sound which lie below 20 Hz. While 20 Hz is commonly cited as the lower bound of audibility, frequencies below 20 Hz can still be audible, provided that the level of the sound is sufficiently high to exceed the threshold of audibility at those frequencies.

17 https://www.euro.who.int/en/health-topics/environment-and-health/noise/environmental-noise-guidelines-for-the-european-region

18 http://tinyurl.com/WTN2019-Delaire

In common with many other sources of noise, wind turbines emit infrasound, low frequency sound and ground vibrations. However, what is often overlooked is that these types of sound and vibration are a feature of the everyday environment in which we live and arise from a wide range of natural sources such as the wind and the ocean to man-made sources such as domestic appliances, transportation and agricultural equipment. The important point in relation to wind turbines is that the levels of these types of emissions are low and therefore, in many cases, cannot generally be reliably measured amidst normal background levels.

The NSW Noise Assessment Bulletin states the following concerning infrasound:

> *there is currently no consistent evidence supporting a link between wind energy projects and adverse health outcomes in humans relating to infrasound.*

These types of emissions have been the subject of considerable misrepresentation in media commentary. Notably, the work of Dr Geoff Leventhall, a prominent UK consultant in the field of acoustics and vibration, and researcher in the field of low frequency noise is often cited in some documents which continue to claim concerns about infrasound and low frequency noise from wind turbines. However, Dr Leventhall has regularly made clear statements to assert that there is no significant infrasound from current designs of wind turbines and very little low frequency sound, neither of which are anywhere near the sorts of levels which would represent a direct health risk for neighbouring residents of modern wind farms. An example of such publication, co-authored by Dr Leventhall, was published in the UK Institute of Acoustics Bulletin in March 2009[19]. This publication was prepared as an agreement between acoustic consultants regularly employed on behalf of wind farm developers, and conversely acoustic consultants regularly employed by local councils and community groups campaigning against wind farm developments. The intent of the article was to promote consistent assessment practices, and to assist in restricting wind farm noise disputes to legitimate matters of concern.

On the subject of infrasound and low frequency noise, the article notes:

> *Infrasound is the term generally used to describe sound at frequencies below 20Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles. Sounds at frequencies from about 20Hz to 200Hz are conventionally referred to as low frequency sounds. A report for the DTI in 2006 by Hayes McKenzie concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view.*
>
> *A Portuguese group has been researching 'Vibro-acoustic Disease' (VAD) for about 25 years. Their research initially focussed on aircraft technicians who were exposed to very high overall noise levels, typically over 120dB. A range of health problems has been described for the technicians, which the researchers linked to high levels of low frequency noise exposure. However other research has not confirmed this. Wind farms expose people to sound pressure levels orders of magnitude less than the noise levels to which the aircraft technicians were exposed. The Portuguese VAD group has not produced evidence to support their new hypothesis that infrasound and low frequency noise from wind turbines causes similar health effects to those experienced by the aircraft technicians.*

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19 Institute of Acoustics Bulletin – Bowdler, Bullmore, Davis, Hayes, Jiggins, Leventhall, McKenzie - *Prediction and Assessment of Wind Turbine Noise* –March 2009

Another example of the misrepresentations made in relation to the environmental effects of wind turbines centred around work carried out by Keele University in the UK on ground vibration. Professor Peter Styles and his team at Keele University undertook a study of the effects of wind turbines on the seismic detection array at Eskdalemuir, Scotland. The results of this work were widely misinterpreted and resulted in a statement[20] from Professor Styles:

> *We are writing to clarify some misconceptions [...] about wind farm noise. Whilst it is technically correct that 'vibrations can be picked up as far away as 10km', to give the impression that they can be felt at this distance is highly misleading. 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. The Dunlaw study was designed to measure effects of extremely low level vibration on one of the quietest sites (Eskdalemuir) in the world, and one which houses one of the most sensitive seismic installations in the world. Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise – they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health. It is, however, an issue for the Eskdalemuir seismic array, as it can detect this level of vibration. It is designed to detect explosions and earthquakes of a low magnitude from all over the world. 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 the low frequency sound. There is no scientific evidence to suggest that infrasound has an impact on human health.*

More recent measurements[21, 22] have demonstrated that infrasound and low frequency sound produced by regularly encountered natural and man-made sources, such as the infrasound produced by the wind or distant traffic, is comparable to that of modern wind turbines, noting that:

> *Infrasound levels in the rural environment appear to be controlled by localised wind conditions. During low wind periods, levels as low as 40dB(G) were measured at locations both near to and away from wind turbines. At higher wind speeds, infrasound levels of 50 to 70dB(G) were common at both wind farm and non-wind farm sites.*
>
> *Organised shutdowns of the wind farms adjacent to [sic: measurement locations] indicate that there did not appear to be any noticeable contribution from the wind farm to the G-weighted infrasound level measured at either house. This suggests that wind turbines are not a significant source of infrasound at houses located approximately 1.5 kilometres away from wind farm sites*

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20 *Keele University Rejects Renewable Energy Foundation's Low Frequency Noise Research Claims*

21 Sonus report for Pacific Hydro - *Infrasound measurements from wind farms and other sources* – November 2010 See http://www.pacifichydro.com.au/media/192017/infrasound_report.pdf

22 Evans, T., Cooper, J. & Lenchine, V., *Infrasound levels near wind farms and in other environments*, South Australian Environment Protection Authority, Adelaide, 2013 - See https://www.epa.sa.gov.au/files/477912_infrasound.pdf

In 2010, the UK Health Protection Agency published a report[23] on the health effects of exposure to ultrasound and infrasound. The exposures considered in the report related to medical applications and general environmental exposure. The report notes:

> *Infrasound is widespread in modern society, being generated by cars, trains and aircraft, and by industrial machinery, pumps, compressors and low speed fans. Under these circumstances, infrasound is usually accompanied by the generation of audible, low frequency noise. Natural sources of infrasound include thunderstorms and fluctuations in atmospheric pressure, wind and waves, and volcanoes; running and swimming also generate changes in air pressure at infrasonic frequencies.*
>
> *[...]*
>
> *For infrasound, aural pain and damage can occur at exposures above about 140 dB, the threshold depending on the frequency. The best-established responses occur following acute exposures at intensities great enough to be heard and may possibly lead to a decrease in wakefulness. The available evidence is inadequate to draw firm conclusions about potential health effects associated with exposure at the levels normally experienced in the environment, especially the effects of long-term exposures. The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects.*

Also, a recent State Government of Victorian Department of Health document[24] concludes the following in relation to infrasound from wind farms:

> *Infrasound is audible when the sound levels are high enough. The hearing threshold for infrasound is much higher than other frequencies. Infrasound from wind farms is at levels well below the hearing threshold and is therefore inaudible to neighbouring residents.*

These studies all indicate that infrasound levels from the proposed Project are anticipated to be comparable with existing ambient levels.

In February 2015, the National Health and Medical Research Council (NHMRC) released an information paper[25] addressing human health effects of wind farms which includes consideration of noise.

From well over 4,000 articles which were identified during the NHMRC review, only thirteen (13) studies across Europe, North America and Australia satisfied a set of pre-specified eligibility criteria for detailed review and therefore form the basis of the report, which concludes:

> *Examining whether wind farm emissions may affect human health is complex, as both the character of the emissions and individual perceptions of them are highly variable. After careful consideration and deliberation of the body of evidence, NHMRC concludes that there is currently no consistent evidence that wind farms cause adverse health effects in humans. Given the poor quality of current direct evidence and the concern expressed by some members of the community, high quality research into possible health effects of wind farms, particularly within 1,500 metres (m), is warranted.*

These studies all indicate that infrasound levels are anticipated to be comparable with existing ambient levels and, as such, are not expected to represent an impact from the proposed wind farm. Similarly, vibration levels from wind turbines are well below perception thresholds, and low frequency levels are typically low.

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[23] Health Protection Agency UK – *Health Effects of Exposure to Ultrasound and Infrasound – Report of the independent Advisory Group on Non-ionising Radiation* - 2010

[24] Public Statement: Wind Turbines and Health - July 2010

[25] *Information Paper - Evidence on Wind Farms and Human Health*, February 2015

APPENDIX K TABULATED PREDICTED NOISE LEVELS

Table 23: Predicted noise levels at non-associated receivers, dB L_{Aeq}

Receiver	Hub-height wind speed, m/s								
	4	5	6	7	8	9	10	11	≥12
98	21.4	22.0	25.4	29.0	32.4	33.6	33.6	33.6	33.6
106	19.2	19.8	23.2	26.8	30.2	31.5	31.5	31.5	31.5
151	18.0	18.6	22.0	25.6	29.0	30.3	30.3	30.3	30.3
169	23.0	23.6	27.0	30.6	34.0	35.3	35.3	35.3	35.3
170	20.1	20.7	24.1	27.7	31.1	32.4	32.4	32.4	32.4
173	20.1	20.7	24.1	27.7	31.1	32.4	32.4	32.4	32.4
177	19.9	20.5	23.9	27.5	30.9	32.2	32.2	32.2	32.2
180	17.4	18.0	21.4	25.0	28.4	29.7	29.7	29.7	29.7
183	19.7	20.3	23.7	27.3	30.7	32.0	32.0	32.0	32.0

Table 24: Predicted noise levels at associated receivers, dB L_{Aeq}

Receiver	Hub-height wind speed, m/s								
	4	5	6	7	8	9	10	11	≥12
4	18.4	19.0	22.4	26.0	29.4	30.7	30.7	30.7	30.7
17	27.4	28.0	31.4	35.0	38.4	39.7	39.7	39.7	39.7
20	19.1	19.7	23.1	26.7	30.1	31.4	31.4	31.4	31.4
23	25.8	26.4	29.8	33.4	36.8	38.1	38.1	38.1	38.1
25	29.7	30.3	33.7	37.3	40.7	42.0	42.0	42.0	42.0
28	20.3	20.9	24.3	27.9	31.3	32.6	32.6	32.6	32.6
30	18.7	19.3	22.7	26.3	29.7	31.0	31.0	31.0	31.0
52	20.6	21.2	24.6	28.2	31.6	32.9	32.9	32.9	32.9