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PALING YARDS WIND FARM

APPENDIX 7

NOISE IMPACT ASSESSMENT

global environmental solutions

Paling Yards Wind Farm

Noise Impact Assessment

Report Number 640.10127-R1

20 November 2012

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Suite 403, 68 York Street
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Paling Yards Wind Farm

Noise Impact Assessment

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EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR Consulting) has completed a noise impact assessment of Paling Yards Wind Farm. The methodology and criteria used in the assessment are supported by the South Australian Environmental Protection Authority (SA EPA) *Environment Noise Guidelines for Wind Farms (February 2003)*, World Health Organization (WHO) limits, construction noise guidelines (DECC Interim Construction Noise Guideline 2009) and blasting impact.

Simultaneous noise monitoring and wind monitoring was conducted at 8 locations during the period 7th June 2011 through to 24th June 2011 to determine baseline conditions and establish criteria for surrounding residential receivers.

Noise predictions were made for receptors within a 6 km of a proposed WTG. WTG noise has been predicted using an indicative layout of 59 WTG's and an assumed mix of 3 turbine types and assessed against relevant criteria prescribed by the SA EPA Guideline and World Health Organisation (WHO) goals where appropriate.

All non-project involved receptors were found to be below the relevant noise criteria. Some project involved receptors are predicted to slightly exceed the WHO noise criteria, however, these locations are used for a very limited part of the year only and it is proposed to enter into a noise agreement regulating their use and that these will not be used should post construction noise testing definitively show an exceedance of the criteria.

The project is yet to select and finalise the WTG layout and WTG makes/models. Upon finalising the layout and WTG models a revised noise prediction and assessment will be completed in which the noise impact mitigation techniques listed in **Section 9.3** will be investigated thoroughly to produce a fully compliant layout.

WTG vibration levels have been evaluated and based upon overseas research available were found to be acceptable.

Construction noise and vibration impacts have been assessed and the 'worst case' scenarios modelled were found to be generally acceptable.

Blasting impact has been assessed and found to be acceptable. With a maximum instantaneous charge (MIC) of up to 20 kg, the airblast overpressure is anticipated to be below the acceptable level of 115 dB Linear for all existing residences. Similarly, vibration levels are anticipated to be well below the acceptable criteria.

Construction traffic noise impact has been assessed and the 'worst case' maximum construction traffic generated scenario would increase existing traffic noise levels along local roads by up to 4-7 dBA but due to the typically large setback of dwellings from the road network would result in noise level that would be considered acceptable under the ECRTN and RNP.

Subsequent to a request by the Department of Planning, due consideration has been paid to a number of the additional requirements of the proposed *Draft NSW Planning Guidelines Wind Farms – Appendix B: NSW Wind Farm Noise Guidelines* released in December 2011. These include consideration to separate daytime and night-time periods and alternative methods of evaluation for Special Audible Character.

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1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR Consulting), has been engaged by Union Fenosa Wind Australia Pty Ltd (Union Fenosa) as the acoustical consultants for the proposed Paling Yards Wind Farm.

This report describes the methodology and findings of the Noise Impact Study (NIS) for the proposed Paling Yards Wind Farm forming part of the Environmental Impact Assessment for the proposed project.

Detailed in this report are the main aspects of the proposed wind farm project, the acoustic criteria, the background noise measurements and the predicted noise levels at all potentially impacted receivers from the operation of the proposed wind farm. It also addresses the acoustic impact of the wind farm during the construction phase, including blasting and transportation noise.

2 THE PROJECT

The proposed Paling Yards Wind Farm will comprise a number of elements, including:

- → Up to 59 individual wind turbines;
- → Internal unsealed tracks for turbine access;
- → Upgrades to local road infrastructure;
- → An underground electrical and communication cable network linking turbines to each other and the proposed substation;
- → A temporary concrete batching plant to supply concrete for the foundations of the turbines and other associated structures;
- → Potential for obstacle lighting to selected turbines;
- → Removal of small portions of native vegetation within the site and en route to the substation;
- → A wind farm and substation control room and facilities building;
- → An electrical substation and overland connection to the transmission line; and
- → A connection to the Mt Piper to Bannaby 500 kV transmission line which bypasses the north and east of the site.

A full description of the Wind Farm layout, including all turbine and receptor locations, can be found in **Section 5.**

3 WIND FARM ASSESSMENT METHODOLOGY

3.1 Acceptability Limit Criteria

The methodology and acceptability limit criteria that have been applied to this study are based upon the *South Australia Environment Protection Authority (SA EPA) Noise Guidelines for Wind Farms (February 2003)* (SA EPA Guidelines). The principal acceptability limit criteria is that the wind farm $L_{A90(10\ min)}$ noise should not exceed the greater of an amenity limit of 35 dBA or the pre-existing background noise by more than 5 dBA (for any given wind speed).

The project requirements and wind farm acceptability limit criteria are discussed in more detail in **Section 7.3**.

3.2 Wind Farm Noise Level Prediction

The noise emission model used in this study to predict wind farm noise levels at sensitive receptors is based on ISO 9613-2:1996 as implemented in the SoundPLAN computer noise model. The model predicts noise levels through spherical spreading and includes the effect of air absorption (as per ISO 9613), ground attenuation and shielding.

Predicted L_{Aeq} noise levels were calculated based upon sound power levels determined in accordance to the recognised standard IEC-61400-11:2002 *(Wind Turbine Generator Systems - Part 11: Acoustic Noise Measurement Techniques)*, where available, for the wind range 6 to 10 m/s.

The noise character of Wind Turbine Generator (WTG) noise emissions is also assessed for any special audible characteristics, such as tonality or low frequency content, which would be deemed more annoying or offensive. If characteristics such as tonality are identified then the predicted noise level would be penalised by the addition of 5 dBA. It should be noted that the characteristic noise level modulation of WTGs, commonly referred to as 'swish', is considered to be a fundamental part of wind farm noise and is taken into account by the SA EPA Guideline assessment procedure.

3.3 Ambient Noise Monitoring

In order to establish the intrusive noise limit, background noise monitoring is required to establish the pre-existing ambient noise environment as a function of wind speed. As wind speed increases the ambient noise level at most receivers generally also increases as natural sources such as wind in trees begin to dominate. The variation of background noise with wind speed is usually quite site specific and related to various physical characteristics such as topographic shielding and the extent and height of exposed vegetation.

Noise monitoring is completed for a period of approximately 2 weeks and correlated to synchronous wind speed and direction data at the wind farm monitoring mast. The captured data is screened for validity, with data monitored during periods of rain or where the average wind speed at the microphone position likely exceeded 5 m/s being discarded from the data set. Other data that was obviously affected by external noise sources (eg. pond pumps, grass mowing, birds at dawn, frogs etc) was also removed from the data set. A regression analysis of all valid data is used to determine a line of 'best fit' from which the noise limit is established.

3.4 Assessment Procedure

In general, the assessment procedure contains the following steps:

1 Predict and plot the L_{Aeq} 35 dBA noise level contour from the wind farm under reference conditions. Receivers outside the contour are considered to be within acceptable wind farm noise levels.

2 Establish the pre-existing background noise level at each of the relevant assessment receivers within the L_{Aeq} 35 dBA noise level contour through background noise monitoring.

3 Predict wind farm noise levels at all relevant assessment receivers for the wind range from cut-in of the WTG to approximately 10 m/s.

4 Assess the acceptability of wind farm noise at each relevant assessment receiver to the established limits.

In addition, where the assessment of a receiver has predicted unacceptable wind farm noise levels, a process of noise mitigation and alternative wind farm layouts is considered and Steps 3 and 4 are repeated until an acceptable arrangement is developed.

A brief explanation and description of the acoustic terminology used in this report is included in **Appendix D.**

4 ENVIRONMENTAL NOISE CRITERIA

4.1 Introduction

The New South Wales (NSW) Government Department of Planning and Infrastructure (DPI) has issued information on the required inputs into the Environmental Assessment (EA). The environmental assessment requirements issued by the Director-General (**DGRs**) in relation to the noise impacts of the proposed Paling Yard Wind Farm are as follows:

→ Include a comprehensive noise assessment of all phases and components of the project including, but not limited to turbine operation, the operation of the electrical substation, corona and/or Aeolian noise from the transmission line, construction noise (focusing on high noise-generating activities and any works proposed outside of standard construction hours), traffic noise during construction and operation, and vibration generating activities (including blasting) during construction and/or operation. The assessment must identify noise/vibration sensitive locations (including approved but not yet developed dwellings), baseline conditions based on monitoring results, the levels and character of noise (eg tonality, impulsiveness etc) generated by noise sources, noise/vibration criteria, modelling assumptions and worst case and representative noise/vibration impacts;

→ In relation to wind turbine operation, determine the noise impacts under operating meteorological conditions (ie wind speeds from cut in to rated power), including impacts under meteorological conditions that exacerbate impacts (including varying atmospheric stability classes and the Van den Berg effect for wind turbines). The probability of such occurrences must be quantified;

→ Include monitoring to ensure that there is adequate wind speed/profile data and ambient background noise data that is representative for all sensitive receptors;

→ Provide justification for the nominated average background noise level used in the assessment process, considering any significant difference between day time and night time background noise levels;

→ Identify any risks with respect to low frequency or infra-noise;

→ If any noise agreements with residents are proposed for areas where noise criteria cannot be met, provide sufficient information to enable a clear understanding of what has been agreed and what criteria have been used to frame any such agreements;

→ Clearly outline the noise mitigation, monitoring and management measures that would be applied to the project. This must include an assessment of the feasibility, effectiveness and reliability of the proposed measures and any residual impacts after these measures have been incorporated; and

→ Include a contingency strategy that provides for additional noise attenuation should higher noise levels than those predicted result following commissioning and/or noise agreements with landowners not eventuate.

The assessment must be undertaken consistent with the following guidelines for each aspect of the project.

4.2 Applicable Noise Policies and Guidelines

To address the DGR's, this report assesses the proposed Paling Yards Wind Farm against the requirements of each of the following:

→ *Wind Turbines - the South Australian Environment Protection Authority's Wind Farms - Environmental Noise Guidelines (2003);*

→ *Electrical Substation – NSW Industrial Noise Policy (EPA 2000)*

→ *Site Establishment and Construction – Interim Construction Noise Guidelines (DECC, 2009);*

→ *Traffic Noise – Environmental Criteria for Road Traffic Noise (NSW EPA, 1999); and*

→ *Vibration – Assessing Vibration: A Technical Guideline (DECC, 2006).*

Wind turbine noise has also been assessed against the World Health Organisation Guidelines for project involved locations.

Further, in December 2011, the NSW Department of Planning and Infrastructure (DPI) released the *Draft NSW Planning Guidelines Wind Farms – Appendix B: NSW Wind Farm Noise Guidelines* (Draft Guidelines). Whilst no supplementary DGRs have been issued for the Paling Yards Wind Farm requiring consideration of the Draft Guidelines, this assessment also considers the requirements of the Draft Guidelines to the extent practicable (See **Section 10**).

4.3 SA EPA Wind Farm Noise Guidelines

The South Australia EPA Noise Guidelines for Wind Farms (SA EPA Guidelines) recommends the following noise criteria for new wind farms,

> "*The predicted equivalent noise level ($L_{Aeq,\ 10min}$), adjusted for tonality in accordance with these guidelines, should not exceed:*
>
> - 35 dBA, or
> - the background noise level by more than 5 dBA,
>
> *whichever is the greater, at all relevant receivers for each integer wind speed from cut-in to rated power of the WTG.*"

The SA EPA Guidelines also provide information on measuring the background noise levels, locations and requirements on the number of valid data points to be obtained and the methodology for excluding invalid data points. It also outlines the process for determining lines of best fit for the background data, and determination of the noise limit.

The SA EPA Guidelines explicitly state that the "swish" or normal modulation noise from wind turbines is a fundamental characteristic of such turbines; however, it specifies that tonal or annoying characteristics of turbine noise should be penalised.

A 5 dBA penalty should be applied to the measured noise level if an "authorised" officer determines that tonality is an issue and that tonality should be assessed in a way acceptable to the EPA.

The SA EPA Guidelines do not require an assessment for the potential of low frequency noise or infrasound, but states that recent turbine designs do not appear to generate significant levels of infrasound, as the earlier turbine models did.

The SA EPA Guidelines accept that wind farm developers commonly enter into agreements with private landowners in which they are provided compensation. The SA EPA Guidelines are accordingly only intended to be applied to premises that do not have an agreement with the wind farm developers. The guideline lists that there is unlikely to be unreasonable interference if:

- a formal agreement is documented between the parties
- the agreement clearly outlines to the landowner the expected impact of the noise from the wind farm and its effect on the landowner's amenity
- the likely impact of exposure will not result in adverse health impacts (e.g. the level does not result in sleep disturbance)

The proponent Union Fenosa has discussed the possible noise implications with the involved residents on whose property the turbines would be located (project involved properties). The following dwellings are located on the project involved properties 7, 7A, 8, 8A, 9, 9A and 9B. Of these, dwellings 7A, 8A, 9A and 9B are secondary dwellings within the project involved properties of Paling Yards, Quobleigh and Mingary Park, respectively (the secondary dwellings). Based on discussions between Union Fenosa and the landowners it is understood these secondary dwellings are not permanent residences and are only used for part of the year as rental cottages or as temporary houses during shearing season.

The owners of the project involved properties have been provided copies of this Noise Impact Assessment for their information, and have been advised that SA EPA Guidelines may be exceeded under certain turbine configurations.

Union Fenosa proposes to enter into noise agreements with the owners of the project involved properties prior to construction. These agreements would specify that:

a Union Fenosa would ensure that the properties met the World Health Organisation noise guidelines (see **Section 4.5**); and,

b Union Fenosa would implement an adaptive management approach which could include the use of building treatments and turbine operation / management strategies if operational noise causes significant impact to the amenity of involved residents.

In addition, it is proposed that the noise agreements will make specific provision for ‘secondary dwellings’ so as to ensure that no adverse health impacts result to any person as a result of turbine noise impacts. Based on discussions between Union Fenosa and the landowners it is understood these secondary dwellings are not permanent residences and are only used for part of the year as rental cottages or as temporary houses during shearing season. Specific provisions may include documenting the agreement of the landowners to not to allow any of the secondary dwellings to be occupied if post construction noise testing show that the turbine noise is in breach of the WHO criteria. As an alternative, acoustic treatments to the secondary dwellings or adaptive management techniques may be considered. These are discussed further in **Section 9.3.**

The noise agreements would only be required for those turbine configurations where the SA EPA Guidelines would be exceeded for a particular project involved property.

4.4 NSW Industrial Noise Policy (INP)

The NSW Industrial Noise Policy (INP) requirements include site selection for background measurements, description of the site, the equipment used, graphing of results and amenity noise criteria during each of the three periods (Day, Evening and Night).

The proposed site for the Paling Yards Wind Farm is in a rural area and therefore the Amenity Criteria for rural residential receivers, as detailed in Table 2.1 in the NSW INP, is applicable.

The criteria vary as a function of time of day. The Day, Evening and Night Periods are defined as,

Day Period	7:00 am - 6:00 pm 8:00 am - 6:00 pm (Sundays and Public Holidays)
Evening Period	6:00 pm - 10:00 pm
Night Period	10:00 pm - 7:00 am 10:00 pm - 8:00 am (Sundays and Public Holidays)

The Amenity Criteria (L_{Aeq} level) for the residential noise sensitive locations for the Paling Yards Wind Farm project are,

Day Period	50 dBA
Evening Period	45 dBA
Night Period	40 dBA

The Intrusiveness Criterion in the INP is based on the rating background level (RBL), where the Criterion is,

$L_{Aeq,\ 15\ min} \leq$ RBL + 5 dBA

This is almost identical to the SA EPA Guidelines (**Section 4.3**), the difference being the measurement interval (15 and 10 minute) and the determination of the background noise level (rating level, based on the 10th percentile of measured background levels, or using a line of best fit through the data points).

The INP states where the measured RBL is less than 30 dBA, then the RBL is considered to be 30 dBA.

In summary it is evident that the non project involved residential receivers assessed under the *SA EPA Wind Farm Guideline* will generally comply to INP amenity criteria. Furthermore, intrusiveness is covered by the *SA EPA Wind Farm Guideline.*

4.5 World Health Organisation Guidelines

As discussed in **Section 4.3**, the proponent intends to enter into noise agreements with the owners of project-involved residences in accordance with World Health Organisation (WHO) guidelines, as it is necessary to ensure that the project does not result in an 'unreasonable interference' with the amenity of these areas or cause any adverse health effects.

The WHO publication '*Guidelines for Community Noise'* identifies the main health risks associated with noise and derives acceptable environmental noise limits for various activities and environments.

The appropriate guideline limits are listed in **Table 1** below**.**

Table 1 WHO Guideline values for environmental noise in specific environments

Specific Environment	Critical Health Effect(s)	LAeq (dBA)	Time base (hours)	LAMax (dBA, Fast)
Outdoor living area	Serious Annoyance, daytime & evening	55	16	-
	Moderate annoyance, daytime & evening	50	16	-
Dwelling indoors	Speech Intelligibility & moderate annoyance, daytime & evening	35	16	
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance – window open, night-time	45	8	60

For the assessment of the dwellings on the project involved properties the adopted external criteria of 45 dBA or the level given by the SA EPA Guideline criteria, where higher, will be adopted. Effectively this becomes 45 dBA or background + 5 dBA, whichever is the higher.

4.6 Construction Noise Guidelines

The Department of Environment, Climate Change and Water (DECCW) issued the "*Interim Construction Noise Guideline"* in July 2009. The main objectives of the guideline are stated in Section 1.3, a portion of which is presented below:

- promote a clear understanding of ways to identify and minimise noise from construction works.
- focus on applying all 'feasible' and 'reasonable' work practices to minimise construction noise impacts.
- encourage construction to be undertaken only during the recommended standard hours unless approval is given for works that cannot be undertaken during these hours.

The guideline sets out Noise Management Levels (NMLs) at residences, and how they are to be applied, as presented in **Table 2**. This approach intends to provide respite for residents exposed to excessive construction noise outside the recommended standard hours whilst allowing construction during the recommended standard hours without undue constraints.

Table 2 Noise at Residences Using Quantitative Assessment

Time of Day	Management Level $L_{Aeq(15minute)}$[1]	How to Apply
Recommended standard hours: Monday to Friday 7.00 am to 6.00 pm Saturday 8.00 am to 1.00 pm No work on Sundays or public holidays	Noise affected RBL + 10 dBA	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq(15minute)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to minimise noise. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the proponent should consider very carefully if there is any other feasible and reasonable way to reduce noise to below this level. If no quieter work method is feasible and reasonable, and the works proceed, the proponent should communicate with the impacted residents by clearly explaining the duration and noise level of the works, and by describing any respite periods that will be provided.
Outside recommended standard hours	Noise affected RBL + 5 dBA	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5 dBA above the noise affected level, the proponent should negotiate with the community.

Note 1: Noise levels apply at the property boundary that is most exposed to construction noise. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence.

4.7 Vibration Guidelines

Impacts from vibration can be considered both in terms of effects on building occupants (human comfort) and the effects on the building structure (building damage). Of these considerations, the human comfort limits are the most stringent. Therefore, for occupied buildings, if compliance with human comfort limits is achieved, it will follow that compliance will be achieved with the building damage objectives.

The DECCW's *Assessing Vibration: A Technical Guideline* provides acceptable values for continuous and impulsive vibration based upon guidelines contained in BS 6472–1992, *Evaluation of human exposure to vibration in buildings (1–80 Hz)*.
Both preferred and maximum vibration limits are defined for various locations and are shown in **Table 3**, with the preferred night-time PPV criteria of 0.2 mm/s being the most relevant to the project.

Table 3 Preferred and maximum values for continuous and impulsive vibration

Location	**Assessment period**[1]	**Preferred values** RMS acceleration m/s^2		**Maximum values** RMS acceleration m/s^2		**Peak Velocity PPV mm/s**	
		z-axis	x- and y-axes	z-axis	x- and y-axes	Preferred	Maximum
Continuous vibration							
Critical areas[2]	Day- or night-time	0.0050	0.0036	0.010	0.0072	0.14	0.28
Residences	Daytime	0.010	0.0071	0.020	0.014	0.28	0.56
	night-time	0.007	0.005	0.014	0.010	0.20	0.40
Offices, schools, educational institutions and places of worship	Day- or night-time	0.020	0.014	0.040	0.028	0.56	1.1
Workshops	Day- or night-time	0.04	0.029	0.080	0.058	1.1	2.2
Impulsive vibration							
Critical areas[2]	Day- or night-time	0.0050	0.0036	0.010	0.0072	0.14	0.28
Residences	Daytime	0.30	0.21	0.60	0.42	8.6	17.0
	night-time	0.010	0.0071	0.020	0.014	2.8	5.6
Offices, schools, educational institutions and places of worship	Day- or night-time	0.64	0.46	1.28	0.92	18.0	36.0
Workshops	Day- or night-time	0.64	0.46	1.28	0.92	18.0	36.0

1 Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am

2 Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specified above. Stipulation of such criteria is outside the scope of this policy, and other guidance documents (e.g. relevant standards) should be referred to. Source: BS 6472–1992

These limits relate to a long-term (16 hours for daytime), continuous exposure to vibration sources. Where vibration is intermittent, a higher level of vibration is typically acceptable.

In regard to potential building damage, the German Standard DIN4150 recommends a limit of 10 mm/s PPV within any building and the British Standard BS7385: Part 2 - 1993 sets a limit within buildings which depends upon the vibration frequency, but is as low as 7.5 mm/s PPV (at 4.5Hz). For the purposes of ensuring a reasonable factor of safety a conservative limit of approximately 5 mm/s PPV has been applied for this project.

4.8 Blasting Criteria

The ground vibration and airblast levels which cause concern or discomfort to residents are generally lower than the relevant building damage limits.

The DECCW advocates the use of the Australian and New Zealand Environment Conservation Council (ANZECC) guideline *"Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration"* for assessing potential residential disturbance arising from blast emissions. The ANZECC guidelines for control of blasting impact at residences are as follows:

→ The recommended maximum level for airblast is 115 dB Linear. The level of 115 dB Linear may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 120 dB Linear at any time.

→ The recommended maximum for ground vibration is 5 mm/s, Peak Vector Sum (PVS) vibration velocity. It is recommended however, that 2 mm/s (PVS) be considered as the long term regulatory goal for the control of ground vibration. The PVS level of 5 mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 10 mm/s at any time.

→ Blasting should generally only be permitted during the hours of 9:00 am to 5:00 pm Monday to Saturday. Blasting should not take place on Sundays and public holidays.

→ Blasting should generally take place no more than once per day.

The Australian Standard 2187.2-1993 "*Explosives - Storage, Transport and Use. Part 2: Use of Explosives*" does not present human comfort criteria for ground vibration from blasting. It does however make mention of human comfort level for airblast in saying "a limit of 120 dB for human comfort is commonly used". This is consistent with the ANZECC guidelines.

AS 2187.2-1993 nominates building damage assessment criteria as presented in **Table 4**.

Table 4 Blast Emission Building Damage Assessment Criteria (AS 2187)

Building Type	Vibration Level	Airblast Level (dB re 20 µPa)
Sensitive (and Heritage)	PVS 5 mm/s	133 dB(Linear) Peak
Residential	PVS 10 mm/s	133 dB(Linear) Peak
Commercial/Industrial	PVS 25 mm/s	133 dB(Linear) Peak

4.9 Traffic Noise

The NSW *Environmental Criteria for Road Traffic Noise* (ECRTN May 1999) as required by the Director General Requirements presents guidelines for the assessment of road traffic noise arising from new or redeveloped roads.

Subsequent to the issuing of the DGR's the Department of Environment, Climate Change and Water NSW (DECCW) superseded ECTRN with the publication of NSW Road Noise Policy (RNP) in March 2011. The document provides road traffic noise guidelines for a range of road or residential developments, as well as guidelines that apply for other nominated sensitive land uses.

The road traffic guidelines recommended are based on the functional categories of the subject roads, as applied by the Roads and Maritime Services (RMS) previously called Roads Traffic Authority (RTA).

The functional categories are as follows:

→ Arterial roads (including freeways) carrying predominantly through-traffic from one region to another, forming principal avenues of communication for urban traffic movements.

→ Sub-arterial roads connecting the arterial roads to areas of development and carrying traffic from one part of a region to another. They may also relieve traffic on arterial roads in some circumstances.

→ Local roads, which are the subdivisional roads within a particular developed area. These are used solely as local access roads

For this project, traffic associated with the construction stage has the potential to increase noise levels on existing arterial and local roads during the day (no night period construction proposed). As such, the relevant traffic noise criteria, as provided in Table 3 of the NSW RNP, are provided in **Table 5** below.

Table 5 Road Traffic Noise Criteria

Type of Development	Criteria	
	Day 7am - 10pm (dBA)	Where Criteria are Already Exceeded
Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments	$L_{Aeq(15hour)}$ 60 dBA	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dBA.
Existing residences affected by additional traffic on existing local roads generated by land use developments	$L_{Aeq(1hour)}$ 55 dBA	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dBA.

5 GENERAL SITE DESCRIPTION

The proposed Paling Yards Wind Farm site is located approximately 60 km north of Goulburn and 35 km north-east of Crookwell, in NSW. To the west lies the Abercrombie River National Park and to the east is Mount Werong State Forest. The proposed wind farm covers approximately 3893 hectares.

The location of Paling Yards Wind Farm is shown in **Figure 1** below.

Figure 1 Location of proposed Paling Yards Wind Farm

5.1 Characteristics of the site

The proposed project site incorporates 2 landowners. A noise assessment has been carried out for all dwellings within 6 kilometres of a turbine under SA EPA Guidelines.

For project involved receptor locations, those who have agreements with Union Fenosa about turbines on their land, a noise assessment has been carried out under WHO Guidelines to ensure there is no unreasonable impact on amenity. (See Section **4.2** below for details of each of these assessment methodologies)

Topographically, the proposed site runs along a plateau, bisected by Goulburn Oberon Rd. This plateau is approximately 800 m to 1000 m above sea level. The surrounding district is primarily used for agricultural (grazing) purposes with areas surrounding project site covered in native vegetation.

The Abercrombie River is to the south of the project site and plateaus in a steep gully. All properties surrounding the proposed Wind Farm site have an ambient background noise environment that is determined by pre-dominantly natural sources which are largely wind influenced.

Prevailing winds are easterlies and westerlies. The district receives approximately 700 mm – 800 mm of rainfall annually.

5.2 Dwelling Locations

Properties are situated on either side of Goulburn-Oberon Rd (Also known as Abercrombie Rd) and predominantly to the south, as well as a cluster on a plateau to the east of the wind turbines.

The assessment locations include all dwellings located within 6 km of a proposed WTG. **Figure 2** shows the nearby dwellings assessed for the project in white and locations where baseline noise monitoring was completed are denoted in blue. The indicative turbine positions are shown in red, wind masts locations are shown in orange.
(Refer to **Section 8.1 - Measurement Locations**)

Figure 2 Dwelling Locations and Indicative WTG Layout

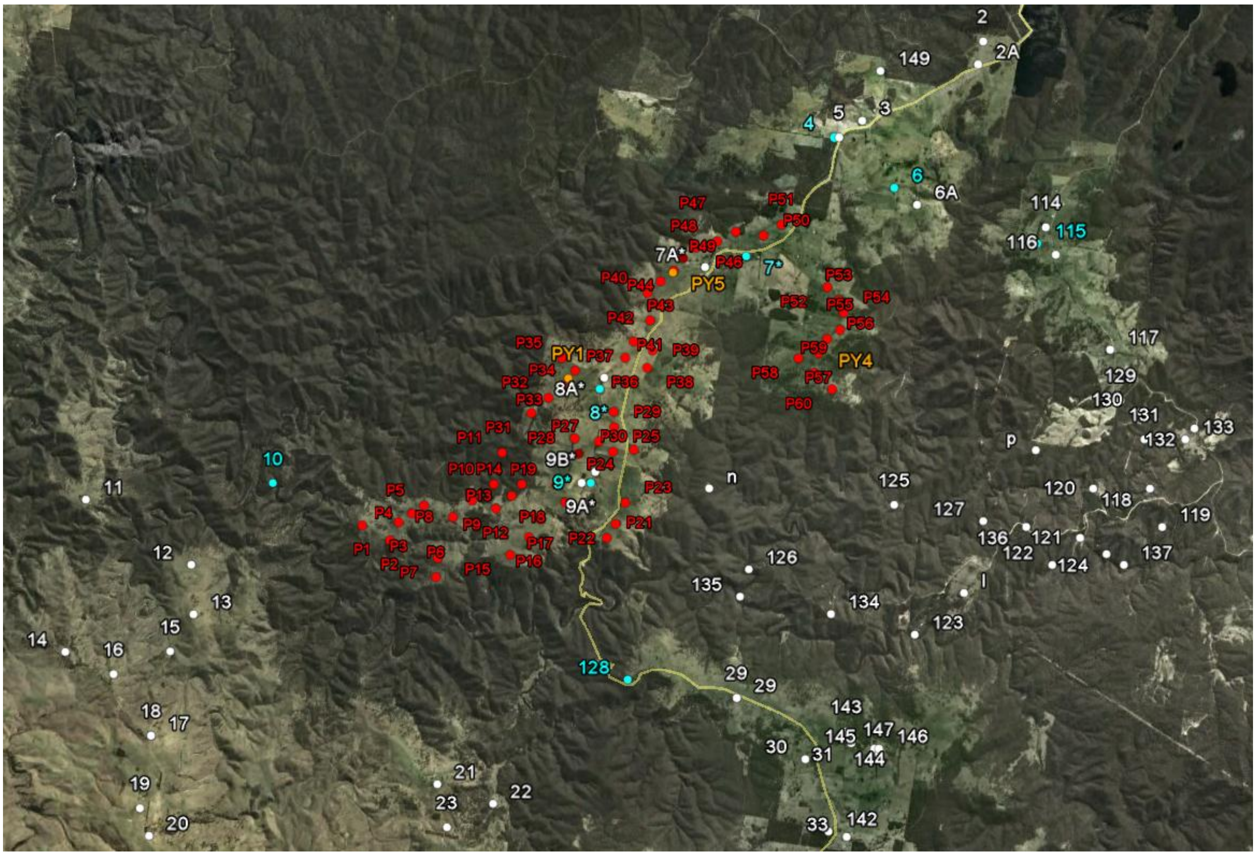


Table 6 lists all receiver locations, their positions and identifies those that are project involved. Other dwellings located beyond 6 km of a proposed WTG are not considered within this assessment, primarily as WTG noise is unlikely to be audible at these distances and compliance to noise criteria is more critical at closer receivers.

Table 6 Surrounding Receivers (Map Datum and Coordinate System Zone 55, GDA94)

Location	East (m)	North (m)	Location	East (m)	North (m)
1	759405	6228570	115	761553	6220052
2	760521	6224074	116	761946	6219796
2A	760453	6223577	117	762928	6217831
3	758065	6222550	118	763826	6215060
4	757528	6222283	119	764059	6214251
5	757652	6222233	120	762729	6215059
6	758725	6221219	121	762418	6214140
6A	759168	6220843	122	761829	6213571
7*	755733	6219927	123	759010	6212248
7A*	754852	6219783	124	762906	6213740
8*	752720	6217349	125	758644	6214826
8A*	752775	6217645	126	755608	6213611
9*	752455	6215508	127	760498	6214494
9A*	752297	6215538	128	753128	6211506
9B*	752581	6215711	129	763229	6216854
10	745869	6215678	130	763712	6216648
11	742104	6215447	131	763704	6216081
12	744181	6213996	132	764803	6216225
13	744279	6213071	133	764539	6215996
14	741601	6212297	134	757264	6212656
15	743708	6212250	135	755459	6213072
16	742570	6211923	136	761256	6214418
17	743420	6210570	137	763294	6213540
18	743420	6210570	142	757075	6208414
19	743160	6209175	143	757485	6210384
20	743375	6208668	144	757915	6209813
21	749190	6209529	145	757995	6209968
22	750230	6208962	146	758156	6210003
23	749326	6208543	147	758097	6209945
29	755333	6211123	149	758486	6223537
30	756669	6209876	l^	759962	6213024
31	757574	6210107	n^	754842	6215362
33	757449	6208284	p^	761552	6215874
114	761708	6220400			

Note: * Denotes that the location is involved with the project

Note: ^ Denotes that the location is not identified as an official dwelling

The distances between the surrounding receivers and WTG's are compiled in **Appendix C.**

6 PROPOSED WIND FARM LAYOUT

6.1 WTG Type and Details

The WTG manufacturer and model has not yet been finalised, and accordingly it is necessary to evaluate a selection of models that may comprise a layout. The layout assessed in this report is a 59 turbine layout and comprises of the following turbine types which are currently under consideration by the proponent.

→ 14 X Vestas V90 1.8/2.0MW

→ 14 X Vestas V100 1.8/2.0MW

→ 31 X Vestas V112 3.0MW

The number of each type of turbine was determined from iterative predictive assessments of preliminary layouts. All turbines are three bladed, upwind, pitch regulated and active yaw. A detailed description of the layout, including which turbine type is assumed for each location is provided in **Appendix E.**

→ Should an alternative selection of turbines be ultimately made and/or the final layout of the Wind Farm differ from that assessed in this report, a revised noise impact assessment prediction will be completed prior to construction commencing.

Table 7 and **Table 8** summarise the relevant turbine input data used for noise level prediction.

Table 7 WTG Manufacturers Data

Make, model, power	Vestas V90 1.8/2.0MW	Vestas V100 1.8/2.0MW	Vestas V112 3.0MW
Rotor diameter	90 m	100 m	112 m
Hub height	95 m	95 m	94 m
Cut-in wind speed	4 m/s	3 m/s	3 m/s
Rated wind speed	12 m/s	20 m/s	12 m/s
Rotor speed	9.0 – 14.9 rpm	14.9 rpm	4.4 – 17.7 rpm
'Standard Mode' Sound Power Level, $L_{WA,ref}$	103.7 dBA	105.0 dBA	106.0 dBA

Table 8 WTG Sound Power Curves

Wind Turbine Model	Wind speed Vs (10m AGL) (m/s)									
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Vestas V90 2.0MW		94.3	99.7	102.2	104.0	103.7	103.5	103.5		
Vestas V100 1.8MW	94.0	96.2	100.1	103.9	105.0	105.0	105.0			
Vestas V112 3MW		96.8	100.4	104.8	106.9	106.5	105.9	105.5	105.4	105.5

Noise emissions for the proposed WTG's have been provided by the WTG manufacturers and have either been independently tested according to International Standard IEC 61400-11 or are warranted noise levels calculated in accordance with the International Standard. Copies of the certification test or manufacturers documentation that give the sound power level variation with wind speed, frequency spectra and tonality assessment have been provided by Union Fenosa and will be made available to the DP&I on request.

6.2 Assessment of Tonality and Infrasound

WTG manufacturers are obliged to conduct independent tests in accordance with IEC 61400-11. A part of this assessment is to conduct a tonal audibility test. The tonal audibility $\Delta L_{t,a}$ is typically assessed using the methodology outlined in *Joint Nordic Method Version 2 – Objective Method for Assessing the Audibility of Tones in Noise*.

The warranted tonal audibility data $\Delta L_{A,k}$ values have been supplied by the WTG manufacturers as follows:

Table 9 Audible tonality assessment to IEC 61400-11

Wind speed m/s	Tonality $\Delta L_{A,k}$ for turbine type		
	Vestas V90	Vestas V100	Vestas V112
3			
4			
5		-3.9	
6	-5.26	-10.4	-1.97
7	-8.36	-10.7	-3.04
8	-6.79	-10.2	-13.27
9	-5.7	-5.2	-11.88
10	-7.32	-5.2	-9.19
11		-9.3	

A more detailed assessment of tonality has been undertaken for the V112 model, which has the highest $\Delta L_{A,k}$ values for this layout. This analysis is presented in **Section 7.3**.

Infrasound is not tested as an obligatory part of IEC 61400-11. It is noted that, in general, modern WTG's do not exhibit significant infrasound emissions. Refer to **Section 7.4.2** for a more detailed discussion.

7 OPERATION NOISE LEVELS

7.1 Introduction

As discussed in **Section 3.2**, a three-dimensional computer noise model was used to predict L_{Aeq} noise levels from all WTG's at all surrounding residential dwellings.

The ISO 9613 noise model incorporates a 'hard ground' assumption and includes one-third octave band calculated effects for air absorption, ground attenuation and topographic shielding. It is noted that ISO 9613 equations predict for average downwind propagation conditions and also hold for average propagation under a well-developed moderate ground-based temperature inversion.

The estimated accuracy of the prediction model is approximately ±3 dBA.

7.2 Wind Turbine Noise

For indicative purposes the WTG noise levels from the proposed WTG layout was calculated for the reference wind condition of 8 m/s at 10m AGL. The resulting WTG noise levels for each receiver are listed in **Table 10.** The predicted noise contour plot is presented in **Figure 3.**

Table 10 WTG L_{Aeq} noise level (dBA) at $V_{ref,10m}$ = 8 m/s, V_{100m} = 11.5m/s

Receiver Name	Predicted Noise Level	Receiver Name	Predicted Noise Level
1	-	115	22.3
2	-	116	17.1
2A	-	117	-
3	25.6	118	-
4	30.2	119	-
5	30.8	120	-
6	30.9	121	-
6A	27	122	-
7*	45	123	-
7A*	48.1	124	-
8*	44.7	125	21.3
8A*	45.3	126	22.1
9*	44.9	127	15.3
9A*	45.6	128	25
9B*	45.5	129	-
10	27.5	130	-
11	-	131	-
12	20.7	132	-
13	23.5	133	-
14	-	134	21.2
15	5.1	135	22.1
16	-	136	16.8
17	-	137	-
18	-	142	-
19	-	143	-

Receiver Name	Predicted Noise Level	Receiver Name	Predicted Noise Level
20	-	144	-
21	18.3	145	-
22	8	146	-
23	-	147	-
29	14.2	149	16.5
30	-	l^	7.6
31	-	n^	34.1
33	-	p^	24.2
114	18.3		

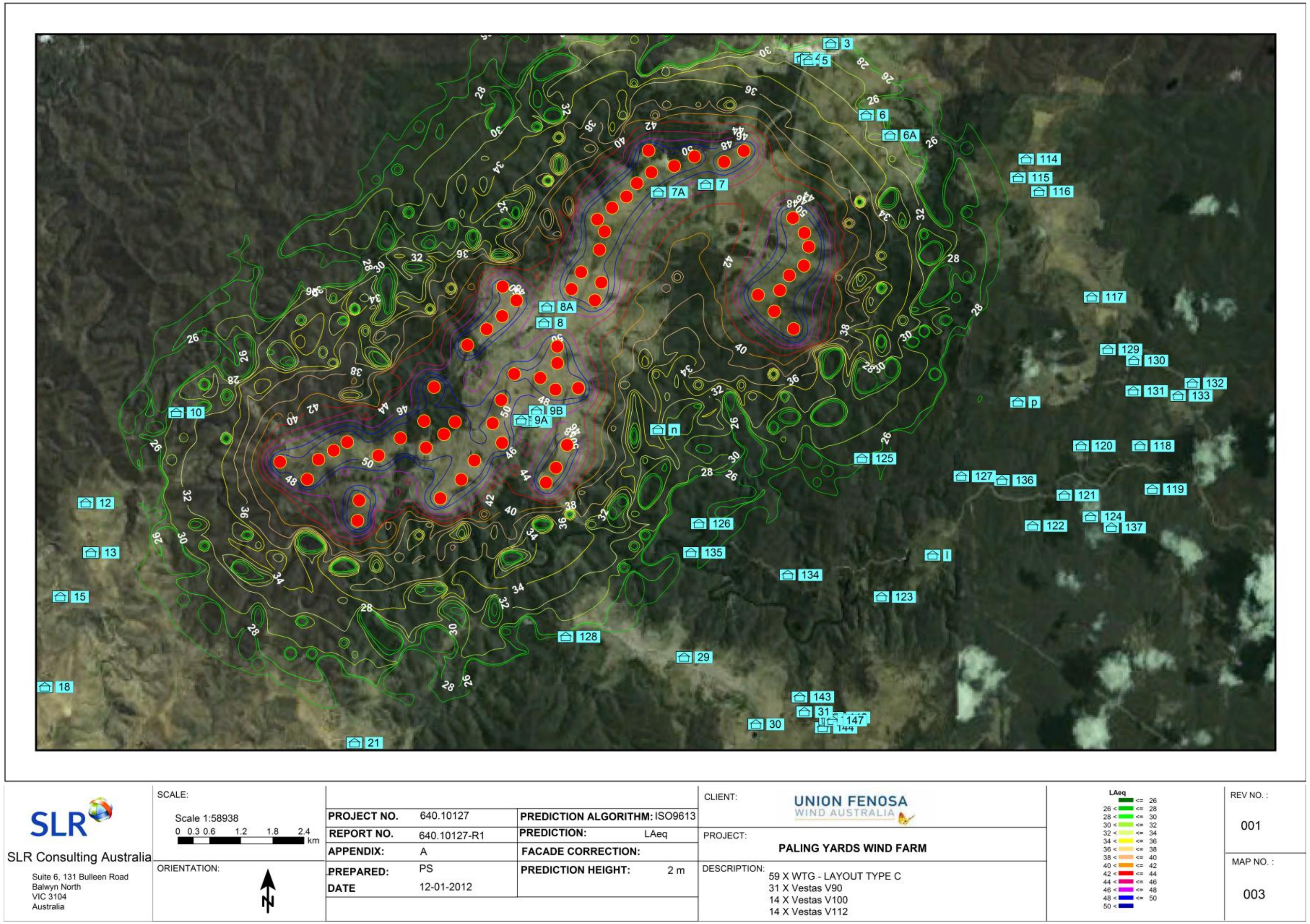
Note that '*' denotes a project involved property
Note that '-' denotes a result lower than 0 dB i.e. is below the normal range of hearing
Note that '^' denotes a location of building not identified as an official dwelling

Furthermore, noise levels from the proposed wind farm were calculated for all integer wind speeds in the range of 5 to 10 m/s (at 10m AGL) at all surrounding assessment receivers within 6 km of a turbine. Whilst the rated wind speed of the WTG's is typically 13 to 14 m/s, published manufacturers sound power level test data (IEC 61400-11) has only been generated as high as 10 m/s. It should be noted that noise produced by WTG's begins to 'plateau off' at higher wind speeds and because of the higher masking background noise level at higher wind speeds, noise impacts and compliance are not critical at these speeds. The assessed wind range sufficiently covers the most noise critical operational conditions.

To compare predicted noise levels with the assessment criteria, the wind speed data, normally measured at 10 m AGL, was extrapolated to a hub height of 100 m using the logarithmic profile law.[1] (Refer to Section **9.1**) The assessment graphs of WTG operational noise levels were prepared for and are depicted in **Appendix A.**

[1] (Section 8 Data reduction procedures, page 20, International Standard IEC61400-11 ©IEC:2002+A1:2006 (E) *'Wind Turbine Generator Systems – Part 11: Acoustic noise measurement techniques'*).

Figure 3 Predicted Noise Levels Contour Map, L_{Aeq}, v_{ref}=8m/s



7.3 Vestas V112 Detailed Tonality assessment

IEC 61400-11:2002 is the measurement standard used for determining the sound power in one-third octave bands for wind turbines, as measured in the near field. In addition, the standard uses narrow band analysis to quantify tones in the measured sound power spectrum. The result of this test is the tonal audibility criterion $\Delta L_{A,k.}$ In general, $\Delta L_{A,k}$ values greater than -3 should be reported as per the standard.

The origin of the $\Delta L_{A,k}$ test can be found in the *Objective Method for Assessing the Audibility of Tones in Noise, Joint Nordic Method* developed by DELTA. While not fully explained in the IEC 61400-11 standard, the tonality penalty is determined according to the following formula.[2]

$$for\ \Delta L_{ta} < 4dB: k = 0\ dB$$

$$for\ 4 \leq \Delta L_{ta} \leq 10dB: k = \Delta L_{ta} - 4$$

$$for\ \Delta L_{ta} > 10dB: k = 6dB$$

Note: k is not restricted to integer values

Examining the Vestas V112 data provided by the manufacturer[3] $\Delta L_{A,k}$ is less than 4 dB at all wind speeds and therefore does not attract a penalty under the Joint Nordic Method.

In addition to this test a one-third octave band test was completed using the noise levels as predicted by the model. Levels were assessed against the description of tonality as defined in the NSW Industrial Noise Policy. The policy states that the presence of excessive tonality is defined as when the level of one-third octave band measured in the equivalent noise level L_{eq}(10 minute) exceeds the level of the adjacent bands on both sides by:

→ **5 dB or more** if the centre frequency of the band containing the tone is above 400Hz

→ **8 dB or more** if the centre frequency of the band containing the tone is 160 to 400Hz inclusive

→ **15 dB or more** if the centre frequency of the band containing the tone is below 160Hz

The predicted noise level in one third octave bands did not meet the descriptions as stated above and would therefore be deemed ‘non tonal’ in the field.

[2] Source: Equation 4 from Objective Method for Assessing the Audibility of Tones in Noise. Joint Nordic Method – Version 2. AV 1952/99 14 April 2000, pg 5.

[3] Source: Garad Hassan report, GLGH-4286 12 09255 258-A-00001-B dated 20 August 2012

8 BACKGROUND LEVELS AND NOISE LIMITS

8.1 Measurement Locations

The locations for the background noise measurements were selected based on the potential for acoustic impact to the nearest receivers, as recommended by Table 3.1 of the NSW INP. The SA EPA Guidelines recommend that the measurement locations should be located at least 5 metres from a reflecting surface (other than the ground) and within 20 metres of a residence.

Monitoring equipment was generally placed in the vicinity of the residence at a suitable location that would be protected from the prevailing wind direction in order to protect the microphone from excessive wind induced noise effects. Care was taken not to place the equipment in locations that would be adversely affected by extraneous noise sources.

Background noise monitoring locations were selected based on the predicted wind farm noise level from the preliminary layout at reference conditions.

The relative proximity of some receiver locations to one another and their similar wind exposure and surrounding environment meant that background noise monitoring could be conducted at one representative location and be considered indicative of other similar locations.

Monitoring was commenced at 8 locations around the proposed wind farm site. For the purposes of assessment, receivers nearest to a particular background monitoring site were allocated to that location. The background noise monitoring locations, along with locations allocated to that site, are listed in **Table 11**. Refer to **Figure 4** for a map showing background locations.

Table 11 Measurement Locations

Location	Indicative of		Notes / Similar Characteristic for wind induced noise
9	9 9A 9B 11 12 13 14	15 16 17 18 19 20 n	Geographic proximity, similar region, exposure to wind
8	8 8A		Geographic proximity, similar region, exposure to wind
7	7 7A		Geographic proximity, similar region, exposure to wind
4	1 2 2A 3	4 5 149	Geographic proximity, similar region, exposure to wind
6	6 6A		Geographic proximity, similar region, exposure to wind

115	114 115 116 117 118 119 120 121 124	129 130 131 132 133 136 137 p	Geographic proximity, similar region, exposure to wind
128	21 22 23 29 30 31 33 128	134 142 143 144 145 146 147 l	Geographic proximity, similar region, exposure to wind
10	10 122 123 125	126 127 135	Geographic proximity, similar region, exposure to wind

It is anticipated that further baseline background noise monitoring will be conducted before project commissioning in order to obtain further comprehensive and representative data.

At each location noise monitoring equipment was placed in the vicinity of the residence and the position of the monitoring equipment was documented with photographs.

A weather station was deployed at Location 9 for the period of the survey. This data was used to identify and exclude any data collected during rain periods, which may have affected the background noise levels. The measured data for rain confirmed that the monitoring period was generally dry and as a result only a small number of data points were rejected due to rain.

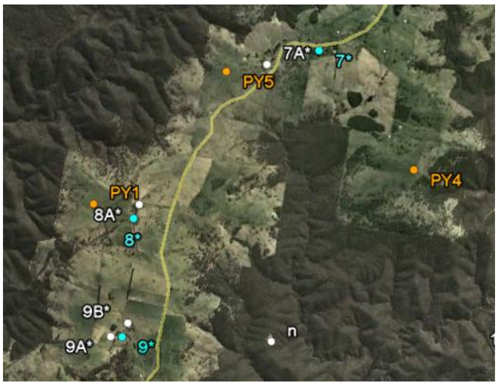
Any periods of data that were clearly affected by extraneous noise sources (eg pumps, insects, birds, etc) were removed from the analysis data set.

The SA EPA Guidelines require measurements to be conducted in 10 minute intervals, while the NSW INP request 15 minute interval data. Given that almost all wind data, including the wind farm site monitored data, is in 10 minute intervals, this period was used for all measurements.

Simultaneous noise monitoring and wind monitoring was conducted during the period 7th June 2011 through to 24th June 2011. Wind speed was monitored 3 wind masts throughout the proposed site. Wind speed for a given background monitoring location was allocated to the wind mast nearest to that location. Where the receptor was approximately equidistant to two wind masts, the background noise was correlated to the wind mast with the highest correlation coefficient (R^2 value).

Table 12 Wind mast details

Wind Mast	Easting	Northing	Nearest Background Locations
PY1	752098	6217660	9,8,10,128
PY4	757109	6218007	7,4,6,115
PY5	754257	6219651	-



Wind speed at a height of 100 metres AGL was derived using the wind profile power law. Local noise data was then correlated to the 100 m AGL extrapolated wind speed.

8.2 Measurement Details

The measurement location, monitoring period, equipment type and serial number of the noise loggers used for all testing are summarised in **Table 13**, along with the number of valid data points for each location.

The SA EPA Guidelines require a set of approximately 2,000 valid data points. All data points below the cut-in wind speed of the proposed turbines and any adversely affected data should be excluded. The cut-in wind speed for the proposed turbines is 3 m/s.

The measured background noise levels (L_{A90}) are then plotted against the extrapolated 100 metre wind speed to obtain a background versus wind speed characteristic for each location.

The line of best fit for the data set is then determined, as required by the SA EPA Guideline, using a linear, second order (quadratic) or third order (cubic) polynomial. The Guideline requires that the correlation coefficient (R^2 value) for each line type be reported and the line of best fit with the highest correlation coefficient used. At each location the cubic polynomial gave the highest correlation and was therefore used for the line of best fit. The SA EPA Guideline does not specify a minimum acceptable correlation coefficient, although we note that almost all correlation coefficients are between 0.52 and 0.65 which is reasonably consistent and in our experience suggests reasonably good correlation.

Table 13 Measurement Details for each Location

Measurement Location	Measurement Period	Noise Logger Model # Serial number	Total No. of monitoring intervals	No. of valid data points		Correlation Coefficient (R^2)		
				All	Night	Linear	Quad.	Cubic
Location 9	7th June 2011- 24th June 2011	ARL EL-316 16-203-530	2439	2264	865	0.5325	0.5348	0.5372
Location 8	7th June 2011- 24th June 2011	ARL EL-316 16-004-033	2438	2264	865	0.5324	0.5354	0.5354
Location 7±	7th June 2011- 19th June 2011	ARL EL-316 16-306-044	1680	1585	637	0.5828	0.5836	0.5836
Location 4±	7th June 2011- 23th June 2011	ARL EL-316 16-306-040	2258	1061	374	0.524	0.526	0.5288
Location 6	7th June 2011- 24th June 2011	ARL EL-316 16-203-528	2415	2233	859	0.5215	0.5223	0.5236

Measurement Location	Measurement Period	Noise Logger Model # Serial number	Total No. of monitoring intervals	No. of valid data points		Correlation Coefficient (R^2)		
				All	Night	Linear	Quad.	Cubic
Location 115±	7th June 2011-15th June 2011	ARL NGARA 878049	1108	1064	417	0.6292	0.6521	0.6521
Location 128	7th June 2011-24th June 2011	ARL EL-316 16-207-041	2436	2264	865	0.5475	0.5514	0.5515
Location 10	7th June 2011-24th June 2011	ARL EL-316 16-203-526	2432	2244	865	0.242	0.2661	0.2683

Note that '±' denotes a location with fewer than 2000 monitoring intervals

Measurement data at three of the monitoring locations fell short of the preferred 2000 intervals (due to battery depletion or muffling of the measurement microphone for part of the measurement period) however, as more than 50% of the data had been collected and the correlation coefficient was relatively good (greater than 58%) the result for the full period was deemed as still statistically relevant.

8.3 Night Period Analysis

A reduced data set was created for the night period (10:00 pm to 7:00 am). The resulting data sets typically included 400 to 800 data points and were fitted with a cubic polynomial regression line of best fit.

The regression line for night-only data is generally lower than that for all data by between 1 dB to 5 dB and varies considerably from location to location. Lower night data is attributed to two main factors. Firstly that extraneous noise sources (animals, traffic etc) are lower during the night period and secondly that the wind shear for the night period is usually greater compared to the day period. This results in lower ground level wind speeds for a given hub height reference wind speed, when compared to that during the day period., and hence lower wind related background noise levels.

The resulting effect on project involved receptors' criteria with consideration to only the lower night period background data is generally minimal with the criteria being exactly the same (criteria is a constant 35 dBA as background noise regression lines are always less than 30 dBA) or marginally higher at high wind speeds where compliance is more easily achieved.

The criteria for project uninvolved receptors with consideration to only the night period background data is generally marginally lower at higher wind speeds. As this is typically not the most critical wind range for compliance the net effect of night data based criteria is negligible with regards to compliance.

8.5 Location 9 – Paling Yards

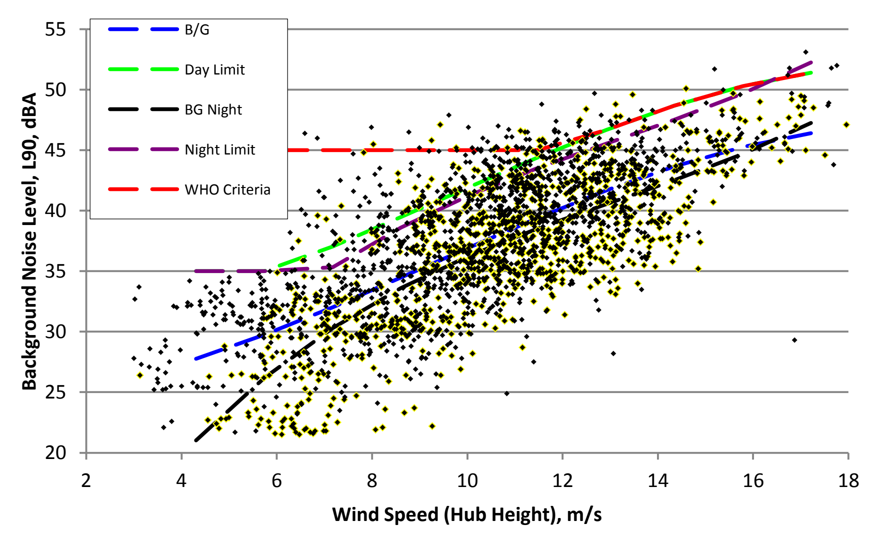
The property of Paling Yards is located within the proposed wind farm site. The residence is set back approximately 500 m from Golburn-Oberon Rd. The nearest proposed turbine to this location is approximately 620 m away.

This residence is occupied by one of the landowners that make up part of the proposed Paling Yards Wind Farm site and is therefore considered 'project involved'.

Figure 4 Paling Yards Measurement Location

The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 5**.

Figure 5 Background Noise Measurements and Noise Criteria Curve – Location 9



Order	Equation	R^2
Linear	$y = 1.5648x + 21.093$	0.5325
Quadratic	$y = -0.0269x^2 + 2.1216x + 18.429$	0.5348
Cubic	$y = -0.0062x^3 +0.1734x^2 +0.1239x +24.509$	0.5372
Order Used:	**Cubic**	

8.6 Location 8 – Quobleigh

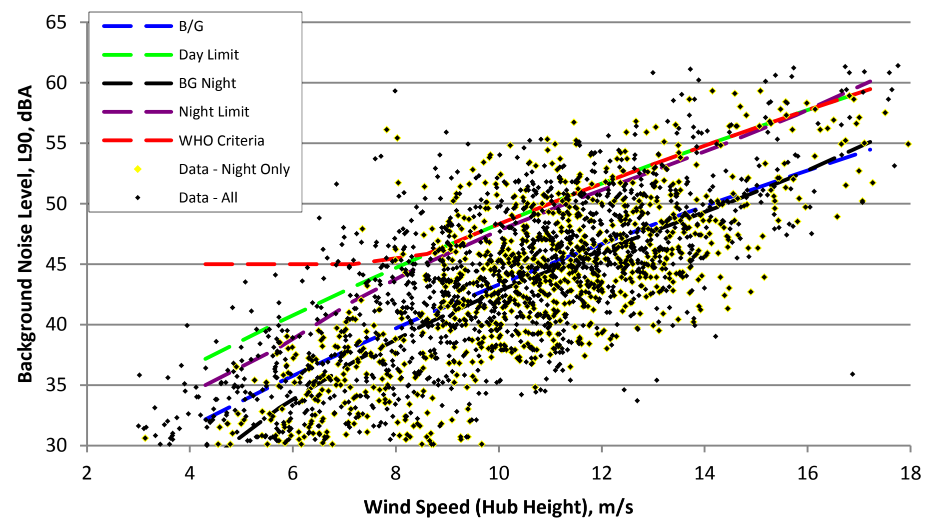
The property of Quobleigh is located within the proposed wind farm site. The residence is located near Golburn Oberon Rd, north of location 9. The nearest proposed turbine to this location is 500 m away.

This residence is occupied by one of the landowners that make up part of the proposed Paling Yards Wind Farm site and is therefore considered 'project involved'.

Figure 6 Quobleigh Background Noise Measurement Location

The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 7**.

Figure 7 Background Noise Measurements and Noise Criteria Curve – Location 8



Order	Equation	R^2
Linear	$y = 1.7238x + 25.757$	0.5325
Quadratic	$y = -0.033x^2 + 2.4012x + 22.547$	0.5348
Cubic	$y = 0.0009x^3 - 0.0602x^2 + 2.6712x + 21.732$	0.5372
Order Used:	**Cubic**	

8.7 Location 7 – Mingary Park

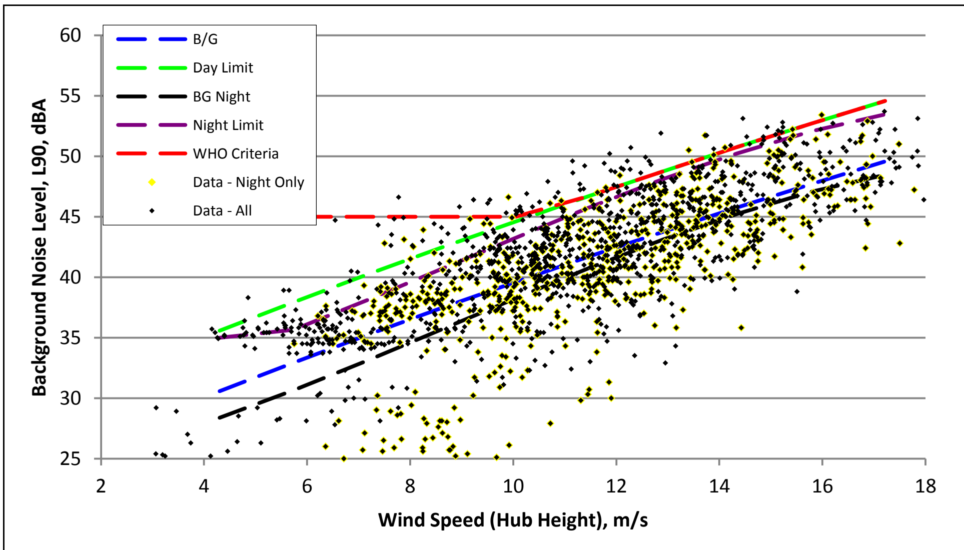
The property of Mingary Park is located within the proposed wind farm site. The residence is located near Golburn Oberon Rd, north east of location 8. The nearest proposed turbine to this location is 540m away.

This residence is occupied by one of the landowners that make up part of the proposed Paling Yards Wind Farm site and is therefore considered 'project involved'.

Figure 8 Mingary Park Background Noise Measurement Location

The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 9**.

Figure 9 Background Noise Measurements and Noise Criteria Curve – Location 7



Order	Equation	R^2
Linear	y = 1.4609x + 24.824	0.5828
Quadratic	y = -.0142x² + .7731x + 23.235	0.5836
Cubic	y = 9E-5x³ -0.0171x² + 1.803x + 23.142	0.5836
Order Used:	**Cubic**	

8.8 Location 4 – Lucas Grove

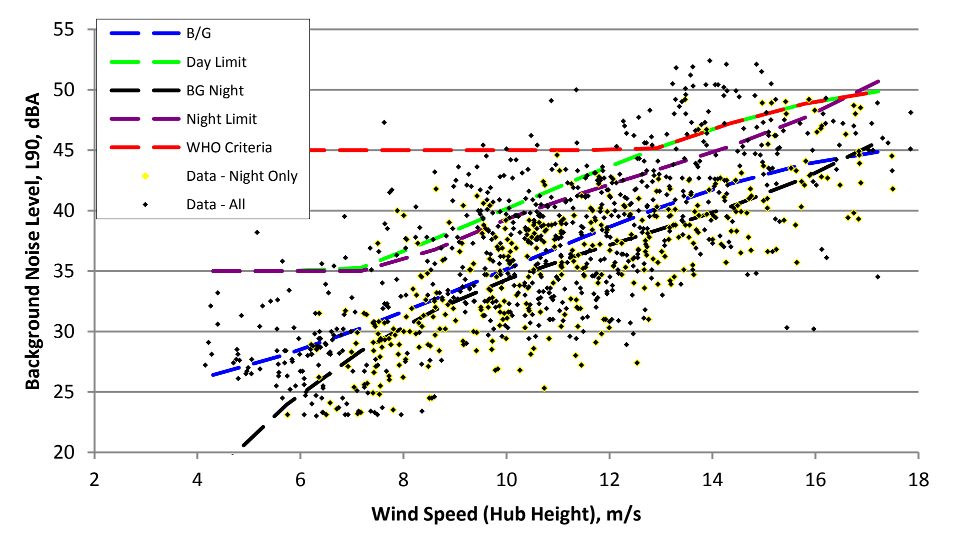
The property of Lucas Grove is located near Golburn Oberon Rd, north east of location 7. It sits atop of same ridgeline as the proposed wind farm. The nearest turbine to this location is 2 km away.

The time trace of background noise for Location 4 showed a sharp decrease in level after the 15th of June 2011 (Refer to **Appendix F**).The resulting noise data clearly did not correlate to the wind speed data and did not vary in a manner typical of background noise measurements. It is presumed that the logger's microphone was muffled or blocked for this period and as such this section of data has been excluded from the regression analysis.

Figure 10 Lucas Grove Background Noise Measurement Location

The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 11**.

Figure 11 Background Noise Measurements and Noise Criteria Curve – Location 4



Order	Equation	R^2
Linear	1.5971x + 19.187	0.524
Quadratic	$-0.0299x^2 + 2.2539x + 15.833$	0.5264
Cubic	$-0.0082x^3 + 0.2436x^2 - 0.6209x + 25.209$	0.5288
Order Used:	**Cubic**	

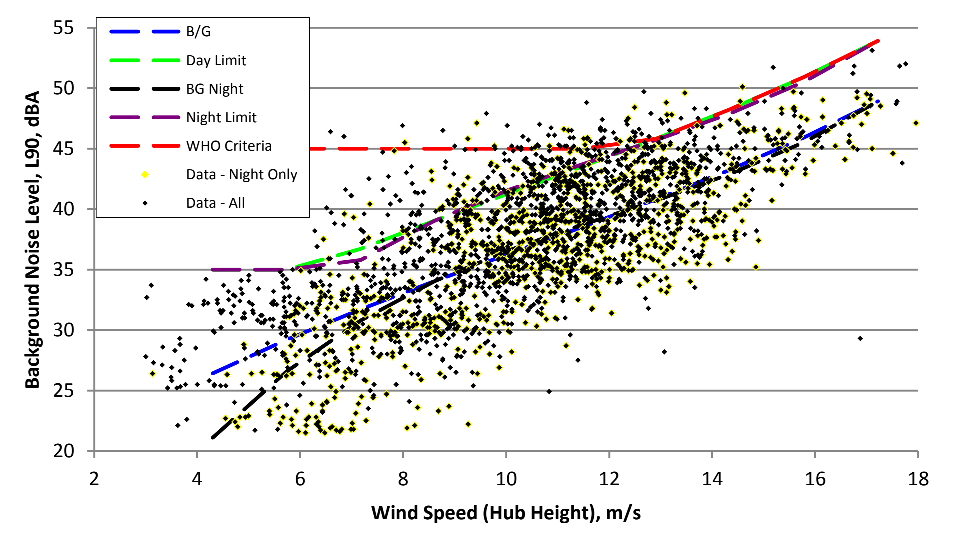
8.9 Location 6

Location 6 is located near Golburn Oberon Rd, south east of Location 4, north of the proposed wind farm. The nearest proposed turbine to this location is 2.3 km away.

Figure 12 Location 6 Background Noise Measurement Location

The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 13**.

Figure 13 Background Noise Measurements and Noise Criteria Curve – Location 6



Order	Equation	R^2
Linear	1.6847x + 19.359	05215
Quadratic	0.0165x^2 + 1.312x + 21.307	0.5223
Cubic	0.0046x^3 - 0.142x^2 + 3.0064x + 15.764	0.5236
Order Used:	**Cubic**	

8.10 Location 115 – Maxwelton

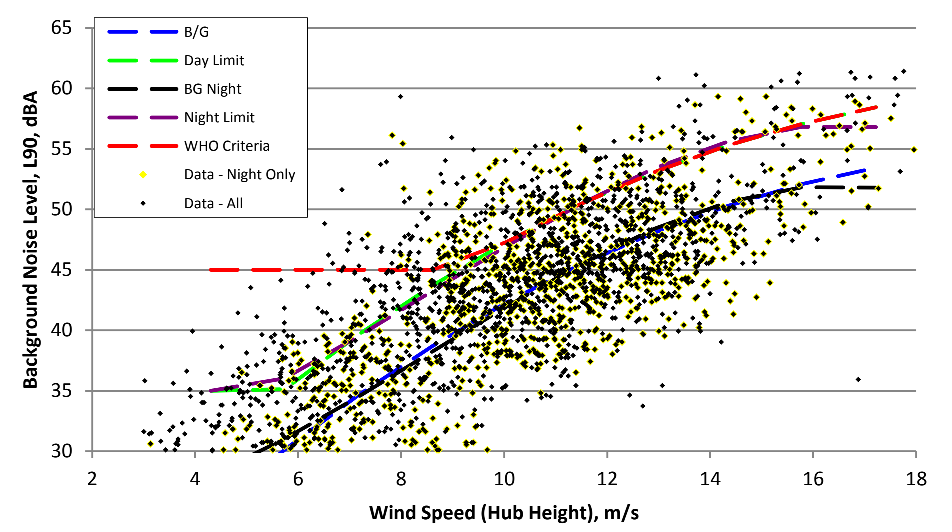
The property of Maxwelton is located off Jerrong Rd, east of location 7. It sits at the top of the ridgeline that runs parallel to the north end of the proposed wind farm. The nearest proposed turbine to this location is 4.1 km away.

Due to a premature battery depletion at Location 115, data was only recorded until the 15th of June 2011 at which point the logger ceased to function. While this yielded fewer than 2000 data points (refer to **Table 13**), the existing data shows good correlation between background noise and wind speed (R^2>0.65).

Figure 14 Maxwelton Background Noise Measurement Location

The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 15.**

Figure 15 Background Noise Measurements and Noise Criteria Curve – Location 115



Order	Equation	R^2
Linear	y = 2.1157x + 20.167	06292
Quadratic	y = $0.1114x^2$ +4.5764x + 7.545	0.6521
Cubic	y = $0.0005x^3$ - $0.1276x^2$ +4.7461x + 6.9904	0.6521
Order Used:	**Cubic**	

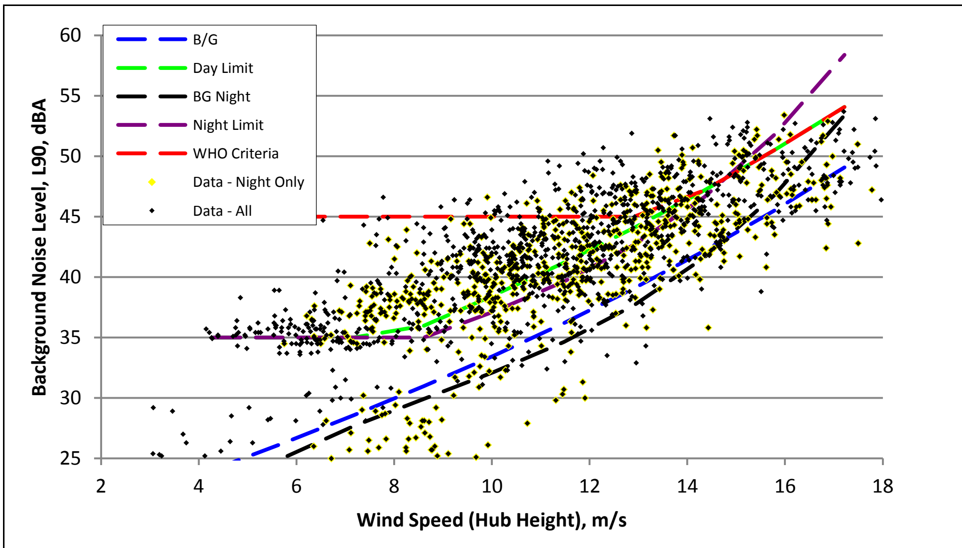
8.11 Location 128

Location 128 is located off Taralga Rd, south of location 9. It sits at the top of the ridgeline south of the proposed wind farm. The nearest proposed turbine to this location is 2.9 km away.

Figure 16 Location 128 Background Noise Measurement Location

The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 17**.

Figure 17 Background Noise Measurements and Noise Criteria Curve – Location 128

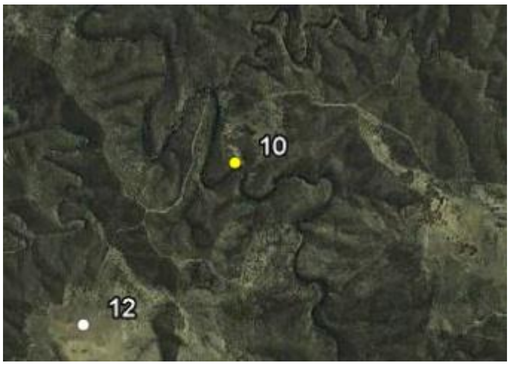


Order	Equation	R^2
Linear	$y = 1.8587x + 15.112$	0.5475
Quadratic	$y = 0.0404x^2 + 1.0312x + 19.027$	0.5514
Cubic	$y = 0.0014x^3 - 0.0034x^2 + 1.4653x + 17.717$	0.5515
Order Used:	**Cubic**	

8.12 Location 10

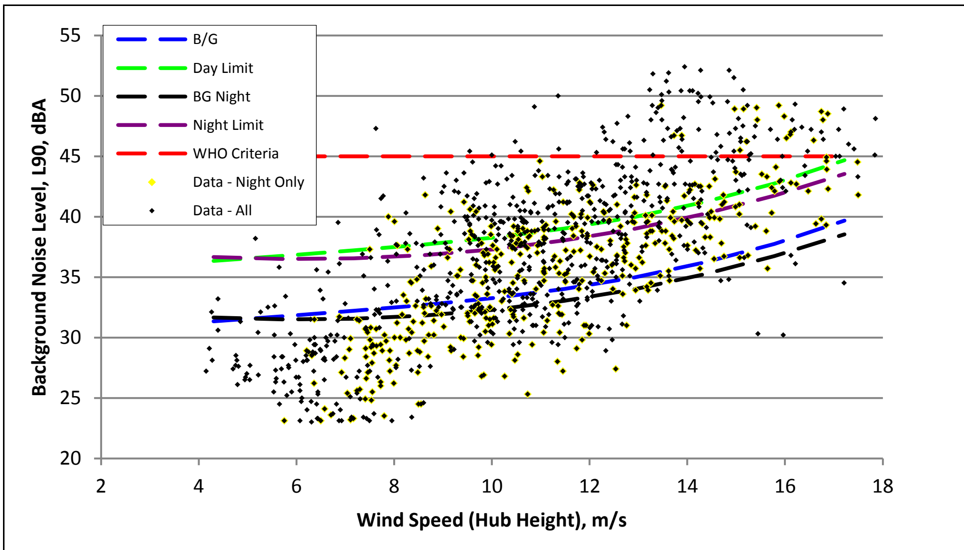
Location 10 is located near the river that runs south of the proposed wind farm site, west of location 9. It is near the bottom of a steep valley and is accessed through the property to the north (location 9). The nearest proposed turbine to this location is 2.1 km away.

Figure 18 Location 10 Background Noise Measurement Location



The results of the background noise monitoring taken in June 2011, showing the data points, line of best fit and criteria curve for that group is shown in **Figure 19**.

Figure 19 Background Noise Measurements and Noise Criteria Curve – Location 10



Order	Equation	R^2
Linear	$y = 0.5556x + 28.012$	0.242
Quadratic	$y = 0.045x^2 - 0.3763x + 32.478$	0.2661
Cubic	$y = 0.0031x^3 - 0.0548x^2 + 0.62x + 29.446$	0.2683
Order Used:	**Cubic**	

We note that for this location, background noise did not strongly correlate with wind speed, decreasing the R^2 value. This may be due to shielding effects or differences between wind speed measured at the wind mast and at this location.

9 ACOUSTIC ASSESSMENT OF PROPOSED WIND FARM

An assessment of the acceptability of wind farm noise levels at all receivers located within a distance of 6 km of the proposed wind farm was made in accordance with the SA EPA Guideline criteria and the pre-existing background noise level regression analysis detailed in **Section 7.3**.

As outlined in **Section 4.3**, the proponent Union Fenosa intends to enter into noise agreements with some project involved residences prior to construction. Under the SA EPA Guidelines these project involved residences are not required to comply to the 35 dBA or 'background + 5 dBA' limits. However, it is necessary to ensure that the project does not result in an 'unreasonable interference' with the amenity of these areas or cause any adverse health effects. Therefore for the assessment of the project involved residences the external criteria of 45 dBA (as per the WHO guidelines) or the level given by the SA EPA Guideline criteria, where higher, will be adopted. Effectively this becomes 45 dBA or background + 5 dBA, whichever is the higher. (See **Section 4.5** for details)

Predicted external noise levels will be further mitigated by the shielding effects of the building, with the anticipated internal noise levels similarly reduced by the façade of the dwelling.

It should be further noted that all predicted noise levels are considered to be conservative with the model assuming 'hard ground', average downwind propagation from all WTG's to each receiver or a well-developed moderate ground based temperature inversion, a scenario which is not able to be re-created in reality.

Predicted noise levels for a wind speed of 8 m/s are shown in **Table 10** (See **Section 7.2**.)

The assessment figures contained in **Appendix A** depict the predicted WTG noise level curves for the proposed WTG layout, superimposed over SA EPA Guideline Criteria and WHO based noise limits.

All non-project involved receivers were below the SA EPA Guideline criteria and are therefore deemed to comply. Furthermore, all receptors (including the project involved receivers) would achieve their respective criteria with consideration to the night-time only regression line based limits. In addition, most non project involved receivers are predicted to be below the background noise regression line.

For project involved residences, **Table 14** below shows the exceedances for each location.

Table 14 Noise Criteria Exceedances

Location	Exceedance at Hub Height Wind Speed										MAX
	4.3	5.7	7.2	8.6	10.0	11.5	12.9	14.3	15.8	17.2	
7A*				2.4	3.4	3.3	3.1	3.0	2.0	0.6	3.4
9A*					0.8	0.6	0.4	0.4	0.4	0.1	0.8
9B*					0.7	0.5	0.4	0.3	0.3	0.1	0.6
8*					0.3						0.3
8A*					0.2						0.2
9*					0.1						0.1
7*					0.1						0.1

For locations 7, 8 and 9, the exceedance occurs only at one wind speed and is less than 0.5 dB in magnitude. This can be considered a minor exceedance and is unlikely to cause any additional effect on the amenity of the area or health of the occupants.

As outlined in **Section 4.3**, locations, 7A, 8A, 9A and 9B are project involved secondary dwellings and it is proposed that the noise agreements will make specific provision for these secondary dwellings to ensure that no adverse health impacts to any person as a result of WTG noise.

9.1 Atmospheric stability and wind profile

The wind velocity at a location can be represented by a vertical profile (gradient) that generally is at a minimum at ground level and increases with altitude. The wind velocity profile is primarily determined by physical factors such as surface roughness and topographic (relief) effects, which are reasonably constant over time, however can also be affected by more variable local atmospheric conditions including atmospheric stability and turbulence.

Atmospheric stability is determined by the total heat flux to the ground, primarily being the sum of incoming solar and outgoing thermal radiation and heat exchanged with the air. During clear summer days (incoming radiation dominates) air is heated from below and rises, causing significant thermal mixing, vertical air movements and turbulence. This process limits large variations in the vertical wind velocity profile.

During clear nights when outgoing radiation dominates, air is cooled from below, air density is greatest closer to the ground and minimal thermal mixing occurs. This leads to a stable atmosphere where horizontal layers of air are largely decoupled and allows for a higher wind velocity gradient.

The noise assessment methodology outlined in the SA EPA Guidelines, as in many other similar wind farm noise assessment methodologies, by necessity rely on the independently verified reference sound power data available for specific wind turbines measured at a manufacturer's test site. The measurement procedure has been standardised (IEC 61400-11) to require sound power data to be measured coincidentally with reference wind speed measurements at an altitude of 10 metres.

As discussed in **Section 7.2** the SA EPA Guideline methodology has been adapted to the alternative reference wind speed at a height of 100 metres AGL which is more representative of hub height wind speed. Accordingly the turbine sound power level data has been amended to the appropriate 100 m AGL wind speed. This approach goes some way to alleviating the variability that changing wind profiles has with respect to a 10 metre reference height.

While the assessed layout meets the requirements of the SA EPA Guidelines, some uncertainty remains as to the likely noise conditions that will result under specific atmospheric conditions over time. The SA EPA Guidelines noise limits are generally set within the requirements of the WHO Guidelines that relate to health impacts, and it is highly unlikely that the remaining uncertainty could lead to health impacts. However, it is possible that under certain conditions the amenity of existing dwellings could be reduced notwithstanding compliance with SA EPA Guidelines. These conditions are likely to be variable and intermittent, and not result in a long-term loss in amenity.

An adaptive management approach could be implemented if undue noise impacts are identified during WTG operation that are related to elevated WTG noise levels during stable atmosphere conditions. Refer to **Section 4.3** for more details.

9.2 Temperature Inversions

Temperature inversion is an atmospheric condition in which temperature increases with height above ground. Such conditions may increase noise levels by focussing sound wave propagation paths at a single point. Temperature inversions occurring within the lowest 50m to 100m of atmosphere can affect noise levels measured on the ground. Temperature inversions are most commonly caused by radiative cooling of the ground at night leading to cooling of the air in contact with the ground. Such conditions are especially prevalent on cloudless nights with little wind.

The SA EPA Guidelines do not require or suggest temperature inversions be included during wind farm noise assessments. The NSW INP states that temperature inversions be included in an assessment if they are deemed to be a prevalent feature of the environment, which generally requires they occur for greater than 30% of the total night-time during winter (approximately two nights per week between 6:00 pm and 7:00 am). Currently there is insufficient data available to accurately determine the prevalence of temperature inversions.

Conventional approaches to assessing noise propagation under temperature inversion conditions require knowledge of the temperature gradient and assume that the noise source is located below the temperature inversion, typically near to the ground. The effect of temperature inversions on noise propagation from highly elevated noise sources, such as WTG's is therefore not typical of other sources.

WTG's for the Paling Yards Wind Farm project are located on top of elevated ridges. The hub height (assumed acoustic centre of the WTG) is located typically located 80 m (or more) higher than receiver locations on the surrounding area. It is therefore unlikely that conventional temperature inversion conditions, in the lower 100m of the atmosphere, would significantly affect noise propagation from such an elevated source.

A further consideration must be that temperature inversions require little to no wind in order to minimise atmospheric mixing and hence develop. During calm conditions the WTGs are unlikely to operate, as their cut-in speed is typically 3m/s.

Notwithstanding the above, an adaptive management approach (See **Section 9.3**) could be implemented if undue noise impacts are identified during WTG operation that are related to temperature inversion effects.

9.3 Adaptive Management

If undue WTG noise impacts are identified during operations due to temperature inversion, atmospheric stability or other reasons, then an 'adaptive management' approach can be implemented to mitigate or remove the impact. This process could include;

→ Receiving and documenting noise impact complaint through 'hotline' or other means.

→ Investigating the nature of the reported impact.

→ Identifying exactly what conditions or times lead to undue impacts.

→ Operating WTG's in a reduced 'noise optimised' mode during identified times and conditions (sector management).

→ Providing acoustic upgrades (glazing, façade, masking noise etc) to affected dwellings.

→ Turning off WTG's that are identified as causing the undue impact.

9.4 Wind Turbine Vibration

Vibration or more specifically the oscillatory movement of receptor structures could potentially propagate from a source (in this case a wind farm) through either a ground path (ground borne vibration) or an airborne path as sound which could couple with lightweight structures and produce a movement in the structure.

9.4.1 Ground borne

Ground borne vibration levels attenuate with distance with varying amounts dependant upon such variables as frequency and geotechnical parameters. There are a few documented research reports with regards to wind farm generated ground vibration.

The Snow Report (*Low Frequency Noise & Vibration Measurements at a Modern Wind Farm*, ETSU W/13/01392/REP, D J Snow, 1997) describes measurements taken at a wind farm consisting of eleven 450 kW WTG's, where noise and vibration measurements were taken at increasingly distant points up to 1 kilometre. Low frequency vibration was determined down to 0.1 Hz with varying wind speeds and on/off operation. The research found that the absolute level of vibration signals measured at any frequency at 100 metres from the nearest WTG were significantly below the most stringent criteria given by BS 6472:1992 *Evaluation of human exposure to vibration in buildings (1Hz to 80Hz).* Furthermore vibration in the 0.5Hz to 1Hz range remained at similar levels when the wind farm was not operating, suggesting that the vibration measured may have been due to other (ambient) sources.

Detailed *Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Wind Farms* were undertaken by the Applied and Environmental Geophysics Group of Keele University as part of a comprehensive report giving '*Recommendations on The Siting of Wind Farm in the Vicinity the Eskdalemuir, Scotland*'. The Eskadelmuir Seismic Array (EKA) is in the southern uplands of Scotland and is sited on a very quiet magnetic and seismic environment with twin 9 km long lines of seismometer instrumentation which are sensitive enough to pick up nuclear explosions from up to 15,000 km away. It should be noted that the objective of the study was to measure vibration levels many orders of magnitude lower than project criteria detailed in **Section 0**

The Eskdalemuir report details results taken from St Breock Downs wind farm (possibly the same measurements taken in the Snow Report). From the documented seismic vibration measurements taken at 25 metres from a single WTG a peak particle velocity (PPV) of approximately $8x10^{-5}$ mm/s has been calculated. This is approximately 2500 orders of magnitude lower than project criteria. Whilst we note that turbines proposed for Paling Yards Wind Farm are larger than those measured above we are confident that ground vibration will be completely imperceptible at surrounding receptors. Furthermore, our own experience and observations at other operating wind farms has not indicated perceptible ground vibration at any distance from turbines.

9.4.2 Air borne

A good deal of misunderstanding and attention has been given in recent times to low frequency noise and infrasound generated by wind farms. Infrasound at sufficient levels has the potential to be perceived as vibration or alternatively cause the movement of lightweight structures which then in turn are perceived as vibration. It should be noted that the sometimes audible cyclical modulation of aerodynamic noise, the '*swish swish'* of blades, is often mistakenly identified as low frequency noise, where it actually is the low frequency modulation of audible noise.

The subject is most complex, dealing with frequencies that are sub audible, requiring alternative frequency weighting scales, specialist measurement equipment and techniques, and evaluating the variance of hearing sensitivity in a population at low frequency. Furthermore, it will depend on many variables including turbine type and size, wind conditions (including turbulence), propagation distance, building structure and materials, room sizing and positioning within room.

Comprehensive review, measurement testing and evaluation are offered in numerous technical reports investigating infrasound and low frequency noise from wind farms including;

- *A Review of Published Research on Low Frequency Noise and its Effects* - Report for Defra by Dr Geoff Leventhall assisted by Dr Peter Pelmear and Dr Stephen Benton - 2002 (refer http://www.defra.gov.uk/environment/quality/noise/research/lowfrequency/documents/lowfreqnoise.pdf)
- *The Measurement of Low Frequency Noise at Three UK Wind Farms* - report for DTI by Hayes McKenzie Partnership – 2006 (refer http://www.berr.gov.uk/files/file31270.pdf)
- *Wind turbines & Infrasound 2006* - Report for Canadian Wind Energy Association (CanWEA) by Howe Gastmeier Chapnik Limited (HGC Engineering) - 2006 (refer http://www.canwea.ca/images/uploads/File/CanWEA_Infrasound_Study_Final.pdf)
- *Wind Farms Technical Paper – Environmental Noise* – report for Clean Energy Council Australia by Sonus Pty Ltd – 2010 (refer http://www.cleanenergycouncil.org.au/cec/mediaevents/media-releases/November2010/sonus-report.html)

The consensus drawn by all investigations is that infrasound noise emissions from modern WTG's are significantly below the recognised threshold of perception for acoustic energy within this range.

9.5 Substation Transformer Noise Levels

The appropriate noise criteria for Substation Noise are provided in *NSW INP* (See **Section 4.2** and **4.4**). Australian Standard AS 60076 Part 10 2009: *"Power Transformers – Determination of sound* *levels"* indicates that the 200 MVA transformer facility may produce sound power levels up to 99 dB. The dominant frequency of such a transformer is 100 Hz.

Noise predictions for transformer substations have been made using CONCAWE algorithms assuming an absolute 'worst case' meteorology enhancement condition of downwind 3 m/s and Pasquill Stability Class F temperature inversion. The results are presented in **Table 15** for the nearest receptor locations, along with the appropriate NSW INP limit (See **Section 10** for RBL derivation).

Table 15 Predicted 'worst case' 200 MVA switching substation noise

		NSW Industrial Noise Policy Criteria		
Location	**Predicted Noise Level, Leq dB(A)**	**RBL (Night)**	**Noise Limit (Amenity Criteria)**	**Complies?**
8A	35.3	40	45	Yes
8	33.4	40	45	Yes
2A	29.5	28	33	Yes
7A	27.8	37	42	Yes
9	26.8	35	40	Yes
9A	26.7	35	40	Yes

9.6 Transmission Line Noise (Corona Noise)

Corona noise is caused by the partial breakdown of the insulation properties of air surrounding the conducting wires. It generally only occurs in humid conditions, as provided by fog or rain. A minimum line potential of 70 kV or higher is required to generate corona noise depending on the electrical design. Corona noise does not occur on domestic distribution lines.

Corona noise has two major components, a low frequency tone associated with the frequency of the AC supply (100 Hz for 50 Hz source) and broadband noise. The tonal component of the noise is related to the point along the electric waveform at which the air begins to conduct. This varies with each cycle and consequently the frequency of the emitted tone is subject to great fluctuations. Corona noise can be characterised as broadband 'crackling' or 'buzzing' and is generally only a feature during foggy or raining conditions.

We have previously measured corona noise (reference GEHA Report 045-109/2 dated 9 November 2004) at a site near Officer in outer Melbourne, Victoria. We found it possible to measure corona noise at close distances, at high frequencies only, as other noise sources, namely traffic and birds, caused some interference at times. A 500 kV line was measured during damp foggy conditions.

At a distance of 30m along the ground from the line an L_{eq} noise level of approximately 44 dBA was measured. At a distance of 100m the corona noise was calculated to be approximately 39 dBA.

Assuming a minimum RBL value of 30 dBA, the minimum intrusive criteria as determined by the NSW Industrial Noise Policy (INP) would be 35 dBA. We therefore conservatively estimate that the minimum criteria level of 35 dBA would be complied with at a distance of 240 metres.

The proposed route for the transmission lines has not been finalised but it is expected that it will traverse largely remote and uninhabited land. It is anticipated that sufficient buffer distances will render the occasional corona noise inaudible at residential receivers.

10 NSW DRAFT WIND FARM GUIDELINES

In December 2011 the NSW Department of Planning and Infrastructure released the *Draft NSW Planning Guidelines Wind Farms – Appendix B: NSW Wind Farm Noise Guidelines.*

Whilst the guidelines are yet to be finalised (and may be subject to change) and no supplementary DGRs have been issued requiring consideration of the proposed draft guidelines, the Department of Planning and Infrastructure has that during the interim period due consideration should be given to a number of the additional requirements of the proposed draft guideline. These are presented below.

10.1 Daytime vs. Night-time Background Noise

The background noise data was reprocessed to define background noise curves for the daytime period (7.00 am to 10.00 pm) and night-time period (10.00 pm to 7.00 am) as defined by the draft guideline. The corresponding 3rd order regression curve and correlation coefficient are presented in **Table 16** below.

Table 16 Background Noise Regression Curves and Correlation Coefficient

Location	Daytime	Daytime R^2	Night-time	Night-time R^2
Location 9	-0.0072x^3 + 0.2096x^2 - 0.368x + 27.401	R² = 0.538	0.0115x^3 - 0.4504x^2 + 7.252x - 2.7754	R² = 0.6022
Location 8	0.0015x^3 - 0.0811x^2 + 2.8258x + 22.128	R² = 0.546	0.0088x^3 - 0.3386x^2 + 5.9214x + 8.6209	R² = 0.5443
Location 7	0.0058x^3 - 0.2184x^2 + 3.9291x + 17.384	R² = 0.6598	-0.0047x^3 + 0.1255x^2 + 0.6831x + 23.498	R² = 0.5417
Location 4	-0.004x^3 + 0.098x^2 + 0.9419x + 20.74	R² = 0.538	0.0162x^3 - 0.6073x^2 + 8.8977x - 10.159	R² = 0.5951
Location 6	0.0019x^3 - 0.0462x^2 + 1.9084x + 19.844	R² = 0.5268	0.0162x^3 - 0.587x^2 + 8.4844x - 5.8308	R² = 0.5231
Location 115	0.0053x^3 - 0.2857x^2 + 6.3246x + 2.2794	R² = 0.6613	-0.0139x^3 + 0.3565x^2 - 0.4233x + 24.338	R² = 0.6245
Location 128	-0.0008x^3 + 0.034x^2 + 1.401x + 17.703	R² = 0.5775	0.0174x^3 - 0.4591x^2 + 5.5582x + 5.0001	R² = 0.5604
Location 10	0.0026x^3 - 0.0444x^2 + 0.6459x + 29.228	R² = 0.2725	0.0007x^3 + 0.0364x^2 - 0.5221x + 33.175	R² = 0.4057

Daytime regression curves were typically 0.5 to 1dB higher than the regression curve based on the full data set. Night-time regression curves were typically 1 to 2 dB lower than the regression curves based on the full data set.

The new background noise curves were used to update the noise limit curves for all receptors and all predicted results were assessed against these criteria. There were no exceedances of the daytime only or night-time only criteria for non-project involved receivers. The maximum exceedance for project-involved receivers was determined by the 45 dBA criteria, rather than the Background + 5 criteria and so is identical to the maximum exceedance presented in **Table 14 (See Section 9).**

Table 17 below shows the exceedances for project involved locations for the night-time criteria. Note that this is determined as 45 dBA or Background + 5 dBA, as per WHO guidelines.

Table 17 NSW Draft Wind Farm Guidelines Exceedances – Night-time Criteria

Location	Exceedance at Hub Height Wind Speed										MAX
	4.3	5.7	7.2	8.6	10.0	11.5	12.9	14.3	15.8	17.2	
7A*				2.4	3.4	3.3	3.1	3.0	3.0	1.4	3.4
9A*					0.8	0.6	0.4	0.4	0.4	0.4	0.8
9B*					0.7	0.5	0.4	0.3	0.3	0.3	0.6
8*					0.3						0.3
8A*					0.2						0.2
9*					0.1						0.1
7*					0.1						0.1

The maximum exceedance for each of these locations is the same as for the original assessment; however, the exceedances at other wind speeds have very slightly increased. Comments regarding noise levels at these locations with respect to their use throughout the year can be found in **Section 9**.

10.2 Special Audible Characteristics

The Draft NSW Guidelines have been developed with the fundamental characteristics of wind turbine noise taken into consideration including reasonable levels of swish, modulation, discrete tones and low frequency noise.

The Draft NSW Guidelines introduce recommendations for procedures to assess excessive levels of special audible character and these procedures (if adopted) are to be used to evaluate noise character from an operational wind farm. Notwithstanding the above, the proposed procedures have been adapted to evaluate the predicted likelihood of excessive levels of special audible character.

10.2.1 Low Frequency Noise

An assessment of the potential for low frequency noise was completed with C-weighted noise levels predicted for the assessed layout.

A criteria of 65 dBC daytime and 60 dBC night-time as proposed by the Draft NSW Guidelines was used to determine if further investigation into low frequency noise was warranted.

The results from the SoundPlan model predict that wind turbine noise would only exceed 60 dBC for one receiver location, Location 7A, the predicted exceedance was 0.8 dBC. A full set of results for this analysis is shown in **Appendix G.** This is a relatively small exceedance of the critera, however, as post-construction monitoring is already planned for this location **(See Section 9),** it is recommended that low frequency noise is investigated at that time.

10.2.2 Tonality

The simplified 1/3 octave band method for assessing tonality as proposed by the Draft NSW Guidelines was completed for the assessed layout using the same method evaluated in **Section 7.3.**

The tonality tests showed no presence of tonality in the predicted results. A full set of results for this analysis is shown in **Appendix G.**

10.2.3 Amplitude Modulation

Amplitude modulation (AM) refers to the cyclical modulation of audible aerodynamic noise from WTGs. The modulation typically occurs at rate corresponding to blade passing frequency which is approximately once per second (i.e. ~1 Hz). This is not to be confused with infrasound, that is, sound waves at frequencies below the range of human hearing; rather it refers to the fluctuation of noise level in the audible range.

Noise from a wind turbine typically includes an inherent level of amplitude modulation, often referred to as ‘swish’ and the criteria in the Draft NSW Guidelines have been determined with the inherent characteristics of wind turbine noise – including reasonable levels of amplitude modulation – taken into consideration. The Draft NSW Guidelines propose an excessive level of modulation is taken to be a variation of greater than 4 dBA at the blade passing.

The issue of AM of WTG noise is now the subject of considerable research and investigation and whilst ‘normal’ amplitude modulation (swish) is generally well characterised and the source mechanism better understood, the hypothesised potential causes of excessive (Other) AM are somewhat more complex and not well understood.

Research into AM undertaken by Salford University in 2007, found that out of the total number of operational wind farms investigated (133) in the UK approximately 20% at some point had registered a noise complaint(s); but AM was considered to be a factor in noise complaints at only 3% of the sites and a possible factor at 6% of the sites. Furthermore, the periods when AM complaints were registered at four wind farms determined that the necessary conditions were relatively infrequent. From this it appears that whatever the actual number of occurrences of potential excessive AM, it only occurs at a minority of wind farm sites for a small amount of the time.

There currently is no means to predict the eventuality, severity or frequency of occurrence of excessive AM and the proposed Draft NSW Guideline methodology is limited to the assessment of operational wind farms. Research evidence would suggest that excessive AM has only been confirmed at a small number of wind farm sites and when it occurs it is relatively infrequent.

Nevertheless, should excessive AM be found to be a problem with the wind farm, it would be possible to limit the impact on the residents through adaptive management techniques (See also **Section 9.3**).

11 ASSESSMENT OF CONSTRUCTION NOISE & VIBRATION LEVELS

11.1 Project Construction Noise

The appropriate criteria for construction noise are provided in the Interim Construction Noise Guidelines (DECC, 2009) (See **Sections 4.2** and **4.6**).

Construction activities include;

→ construction of access roads,

→ establishment of turbine tower foundations and electrical substation,

→ digging of trenches to accommodate underground power cables,

→ erection of turbine towers and assembly of WTG's.

The equipment required to complete the above tasks will typically include:

→ bucket loader, rock breaker, drill rig, excavator/grader, bulldozer, dump trucks,, vibratory roller flat bed truck, concrete truck

→ cranes, fork lift, and various 4WD and service vehicles.

The anticipated construction period is anticipated to be less than 18 to 24 months, with civil works expected to span approximately 12 to 15 months, however, due to the large area of the wind farm site, intensive works will be located within a distance of potential impact for each surrounding residential receiver for only very short and intermittent periods of time.

It is anticipated that most construction will occur during standard construction hours and it is therefore considered appropriate that construction noise levels up to 10 dBA above the RBL's would be acceptable. Construction noise levels greater than 10 dBA above RBL could be considered as 'noise affected' as defined by the Policy. At levels greater than 75 dBA receptors would be considered 'highly noise affected' by construction noise as defined by the Policy.

11.2 Ambient Background Noise Levels

Noise monitoring data presented in **Section 7.3** was used to determine the RBL for each period in accordance with the DECCW Guidelines. **Table 18** shows the RBL for each monitoring location.

Table 18 Summary of Rating Background Levels (RBL's) for Monitoring Locations

	RBL (dBA)		
Measurement Location	**Day (0700 h – 1800 h)**	**Evening (1800 h – 2200 h)**	**Night (2200 h – 0700 h)**
9	33	34	35
8	41	41	40
7	38	39	37
4	28	29	28
6	32	36	34
115	40	43	41
128	30	30	28
10	32	31	32

11.3 Noise Modelling Parameters

In order to calculate the noise levels at the various noise sensitive receiver locations from construction equipment associated with the project, a SoundPLAN (Version 7) environmental computer model was developed.

The computer model predicts noise levels by taking into account such factors as the source sound power levels and locations of sound, distance attenuation, ground absorption, air absorption and shielding attenuation, as well as meteorological conditions, including wind effects. The noise model uses prediction algorithms in accordance with the Conservation of Clean Air and Water Europe (CONCAWE) prediction methodology which allows for conservative 'worst case' meteorological propagation conditions.

Sound power levels used to derive the predicted construction noise were based on data provided in the SLR Consulting noise source database. Computer noise models of typical construction scenarios were developed which included all anticipated mobile equipment for the activity operating simultaneously at full load. **Table 19** shows typical sound power levels of equipment used in wind farm construction.

Table 19 Typical Construction Equipment

Equipment	Octave band mid frequency - L_{eq} Sound Power Levels dB							
	63	**125**	**250**	**500**	**1 K**	**2 k**	**4 K**	**dBA**
Excavator	121	126	111	107	106	101	96	113
Grader	118	124	115	114	115	114	113	120
Dump Truck	111	105	108	106	107	104	99	111
Rock Breaker	113	115	117	122	121	120	118	126
Concrete Truck	104	101	96	95	94	93	91	100
Front End Loader	120	117	101	101	92	88	88	104
Crane	108	105	109	107	111	105	97	113
Bulldozer	113	119	110	109	110	109	108	115
Concrete Batching	100	97	92	91	90	89	87	96
Delivery Trucks	118	110	99	104	99	95	91	105
4WD vehicles	96	92	88	84	84	80	75	88

To examine the possible worst case construction noise impacts for all nearby receivers, four different construction scenarios were modelled at each turbine location and the highest noise levels for each receiver predicted. These are:

→ Construction of Access Roads

→ Establishment of Turbine Foundations

→ Trench Excavation

→ WTG Erection and Assembly

11.4 Normal Working Hours Operation

Table 20 shows the predicted construction level for those receivers who are deemed noise affected, together with the Rating Background Level (RBL) obtained during the background noise monitoring campaign and applicable noise limit for the daytime period.

Table 20 Construction Noise Levels – Noise Affected Receivers

Location	Construction Activity				RBL	Limit
	Construction of Access Roads	Establishment of Turbine Tower Foundations	Trench Excavation	WTG Erection & Assembly	Day	Day (RBL+10)
7A	56	48	62	50	41	51
8A	51	45	58	46	41	51
9B	53	46	59	47	33	43
9A	52	45	58	46	33	43
9	50	44	57	44	33	43
8	49	42	56	44	41	51
7	52	45	58	46	41	51

The highlighted cells would be classified as 'noise affected' when turbine foundation civil works are located nearby and should the operation of a rock breaker be necessary, however, due to the anticipated short period of localised works this would likely be considered acceptable. Operation of the rock-breaker is dependent upon the geotechnical conditions of the foundation site and would be operated intermittently at most. Consideration for mitigation measures such as localised shrouding may be needed if adverse conditions are experienced if and when operating the rock-breaker at the most exposed positions.

No predicted levels exceed 75 dBA and therefore no receptors would be considered as being 'highly noise affected' as defined by the policy.

In consideration that the predicted levels represent 'worst case' construction scenarios and are within limits which would be considered acceptable, it is unlikely that construction noise within normal operating hours will cause any unnecessary impact.

11.5 Outside Normal Operating Hours Operation

The only operation likely to occur at night is the erection of WTG's, as low wind conditions are preferable while the towers are being erected by large cranes. **Table 23** below shows all noise affected receivers for this construction activity for the night period.

Table 21 Night Construction Noise Levels – Noise Affected Receivers

Location	Construction Activity	RBL	Limit
	WTG Erection & Assembly	Night	Night (RBL+ 5)
7A	50	40	45
8A	46	40	45
9B	47	35	40
9A	46	35	40
9	44	35	40
7	46	40	45

While no predicted levels exceed 75 dBA and therefore no receptors would be considered as being highly noise affected, tower erection near these locations should occur during the daytime, if possible. We note that the affected locations are the secondary dwellings discussed in **Section 4.3** and as such may not be occupied during this stage of construction.

11.5.1 Concrete Batching Plants

A portable concrete batching plant (combined Sound Power Level of 115 dBA) will be required to supply concrete onsite. The proposal location of this batching plant is shown in **Figure 20** below.

Using the existing SoundPlan noise model, predicted noise levels for the proposed batch plant site at the nearest affected properties were calculated under worst case conditions. These results are shown in **Table 22**, along with the RBL and night-time limit (the lowest noise limit) for each location.

Figure 20 Concrete Batching Plant Location

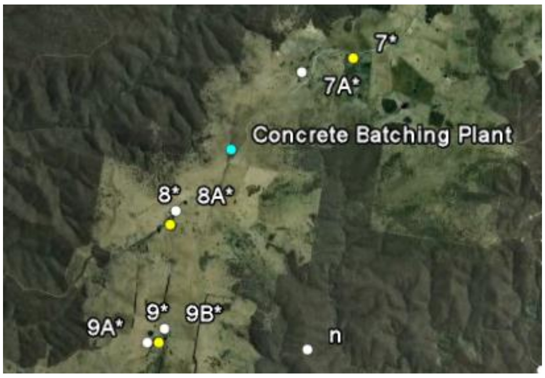


Table 22 Concrete Batch Plant Noise Level Prediction

Location	Predicted Noise Level, dBA	RBL - Night	Night Limit
8A	41	40	45
8	39	40	45
7A	37.7	40	45
7	32.7	40	45
9	28.7	35	40
9A	28.6	35	40
n	26.7	35	40
9B	20.5	35	40

All locations are predicted to be below the night-time noise limit and most locations are predicted to be below the relevant rating background level for that location.

11.6 Construction Vibration Assessment

The activities and equipment with the potential to generate the highest levels of ground vibration are the operation of the vibratory roller during construction of access roads and the operation of the rock breaker during establishment of turbine tower foundations. Typical vibration levels from these sources are presented in **Table 23**.

Table 23 Typical Vibration Emission Levels from Construction Plant

Activity	PPV Vibration Level (mm/s) at Distance		
	10m	**20m**	**30m**
4-Tonne Vibratory Roller	2.0 - 2.4	0.4 - 1.2	0.2 - 0.8
Hydraulic Hammer (30t)	3	1.5	1.0

It is evident that given the large distances between receptors and structures where construction works are likely to be undertaken (refer to **Appendix C**), the building damage and human comfort vibration criteria will easily be met during construction.

11.7 Blasting

11.7.1 Blasting Assessment

Blasting may be required in some areas to clear large rock outcrops to prepare turbine foundations.

The proposed wind farm site is a green field site where no previous blasting or blast monitoring has been conducted and therefore no specific site laws exist. We have therefore adopted a site law derived from measurement data at a different site to give an indicative result.

The 5% site laws for ground vibration and airblast are:

Ground Vibration PVS (5%) = 16202 $(SD_1)^{-2.03}$

Airblast SPL(5%) = 189.3 - 31.8 log (SD_2)

where PVS (5%) and SPL (5%) are the levels of ground vibration (Peak Vector Sum - mm/s) and airblast (dB Linear) respectively, above which 5% of the total population (of data points) will lie, assuming that the population has the same statistical distribution as the underlying measured sample.

SD_1 and SD_2 are the ground vibration and airblast scaled distances, where:

$$\mathrm{SD_1} = \frac{\mathrm{Distance}}{\sqrt{\mathrm{MIC}}} = \left(\mathrm{m.kg^{-0.5}}\right) \text{ and } \mathrm{SD_2} = \frac{\mathrm{Distance}}{\sqrt[3]{\mathrm{MIC}}} = \left(\mathrm{m.kg^{-0.33}}\right)$$

Based on the blast emissions site laws, calculations were also conducted to indicate the allowable MIC's for compliance with the general EPA Human Comfort criteria of 115 dB Linear (airblast) and 5 mm/s (ground vibration).

The closest anticipated distance between blasting and residences would be approximately 400 metres (7A). At this distance, based on a site constant K_a of 15, the predicted maximum MIC of up to 20 kg is likely to produce an airblast overpressure below the acceptable level of 115 dB Linear. An MIC of 20 kg is expected to result in a vibration level (Peak Vector Sum) of 0.011 mm/s, well within the recommended maximum level of 5 mm/s in the ANZECC Guidelines.

It is evident that the anticipated blasting is likely to meet all human comfort limits and building damage assessment criteria are easily met. All other sources of vibration would be less then above.

11.8 Traffic Noise

Traffic generated by the project during its construction phase has been evaluated in *Paling Yards Wind Farm, Transport Impact Assessment* prepared by URS Australia Pty Ltd. A key finding of this report was as follows:

> *"It is evident that no significant impact will occur to the performance of the road network from the vehicles generated during the peak construction period of the Paling Yard wind Farm Development."*

Project construction traffic for Paling Yards Wind Farm will primarily utilise the Golburn-Oberon Road which runs north-south through the site. The projected maximum construction traffic on proposed access roads represent in some cases a significant increase in traffic movements as shown in **Table 24.**

The projected increase in road traffic noise levels on all local roads is expected to be greater than 2 dBA during peak construction periods, however, road traffic noise levels are anticipated to meet the *Environmental Criteria for Road Traffic Noise (ECRTN) and subsequent Road Noise Policy (RNP)* target for a local road of daytime $L_{Aeq(1\ hour)}$ = 55 dBA at modest setback distances. We note that being a rural farming community, most receptors are at much greater setback distances from their road frontage and therefore will easily meet the ECRTN requirement.

Table 24 Construction Traffic Noise

Proposed Access Road	VPD Current	VPD Projected Maximum Construction Traffic	Projected increase in existing road traffic noise level	ECRTN/RNP classification	ECRTN/RNP requirement
Abercrombie Road 5km north of river crossing	205	329	3 dBA	Local	Local
Abercrombie Road 1km south west of intersection with Rupert Street, Oberon	1968	2036	0.5 dBA	Local	Local
Abercrombie Road, east of Black Springs	1036	1086	1 dBA	Local	Local

11.8.1 Night-time deliveries

There could potentially be deliveries of equipment scheduled for out of hours, necessitated by traffic congestion considerations and safe passage of heavy vehicle convoys or especially long loads. Night-time traffic has the potential to cause sleep disturbance to residential receivers along the route. This potentially affects receivers situated closer to the road such as locations 5, 115 and 29.

Preliminary calculations indicate that maximum noise levels at a residence approximately 10 metres from the road as a result of a heavy vehicle pass-by would be in the range 45-80 dBA. We would anticipate that night-time background noise levels along affected routes could be as low as 30 dBA and as such maximum noise levels from pass-bys may have the potential for sleep disturbance.

To minimise potential noise impacts associated with night-time deliveries some potential measures to be considered are:

→ Prior notification of affected public where night-time convoys are scheduled

→ Restricted use of exhaust/engine brakes in built up areas

12 CONCLUSION

Noise from wind turbines for the proposed Paling Yards Wind Farm has been predicted and assessed against the relevant criteria prescribed by the SA EPA Guideline and World Health Organisation (WHO) goals where appropriate using the indicative layout and an assumed mix of turbines. An evaluation of night-time baseline data was also included.

All non-project involved receptors were found to be below the noise criteria stipulated in SA EPA Guidelines. Some project involved receptors are predicted to slightly exceed the WHO noise criteria, however these locations are used for part of the year only and it is proposed to enter into a noise agreement regulating their use and that these will not be used should post construction noise testing definitively show an exceedance of the criteria.

The project is yet to select and finalise the WTG layout and WTG makes/models. Upon finalising the layout and WTG models a revised noise prediction and assessment will be completed in which the noise impact mitigation techniques listed in **Section 9.3** will be investigated thoroughly to produce a fully compliant layout.

WTG vibration levels have been evaluated and based upon overseas research available were found to be acceptable.

Construction noise and vibration impacts have been assessed and the 'worst case' scenarios modelled were found to be generally acceptable.

Blasting impact has been assessed and found to be acceptable. With a maximum instantaneous charge (MIC) of up to 20 kg, the airblast overpressure is anticipated to be below the acceptable level of 115 dB Linear for all existing residences. Similarly, vibration levels are anticipated to be well below the acceptable criteria.

Construction traffic noise impact has been assessed and the 'worst case' maximum construction traffic generated scenario would increase existing traffic noise levels along local roads by up to 4-7 dBA but due to the typically large setback of dwellings from the road network would result in noise level that would be considered acceptable under the ECRTN and RNP.

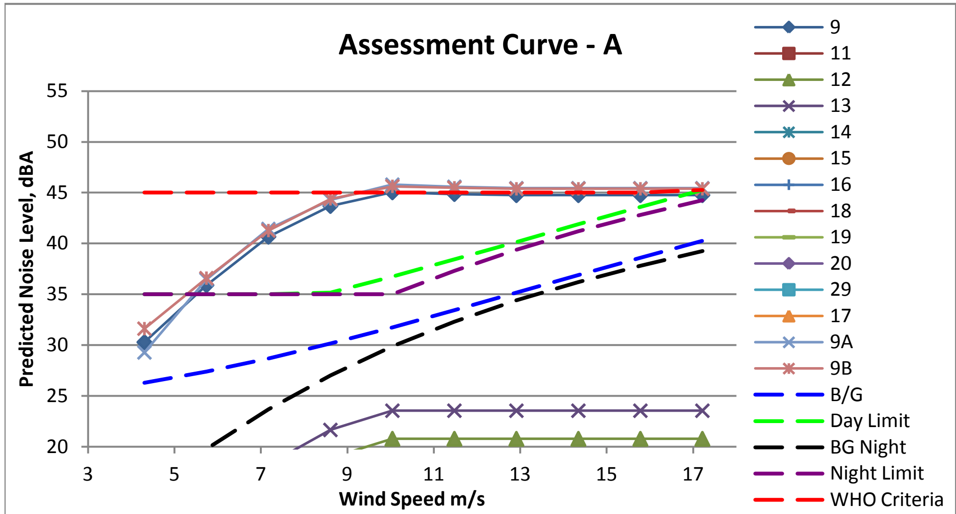
Subsequent to a request by the Department of Planning, due consideration has been paid to a number of the additional requirements of the proposed *Draft NSW Planning Guidelines Wind Farms – Appendix B: NSW Wind Farm Noise Guidelines* released in December 2011. These include consideration to separate daytime and night-time periods and alternative methods of evaluation for Special Audible Character.

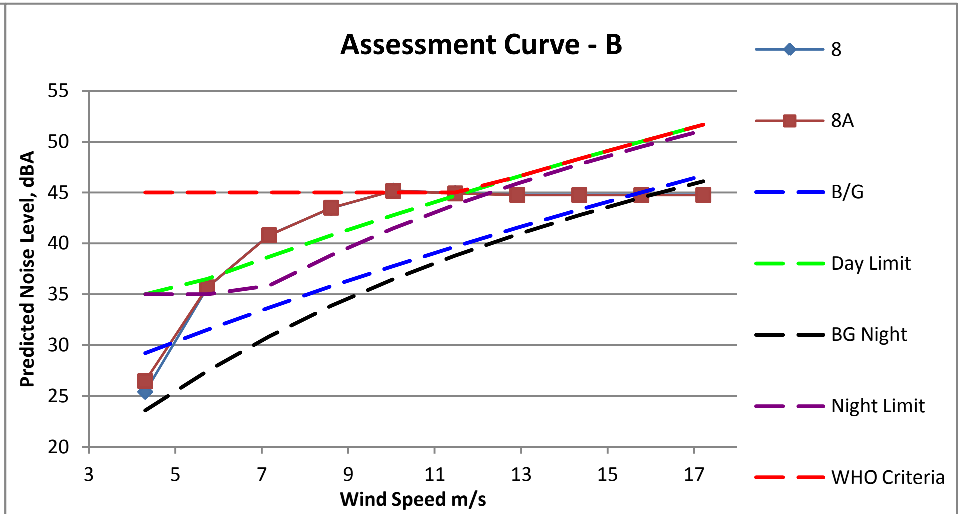
13 CLOSURE

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Union Fenosa Wind Australia Pty Ltd. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR Consulting.

SLR Consulting disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.


Assessment Curve - A
Predicted Noise Level, dBA
Wind Speed m/s
55
50
45
40
35
30
25
20
3
5
7
9
11
13
15
17
9
11
12
13
14
15
16
18
19
20
29
17
9A
9B
B/G
Day Limit
BG Night
Night Limit
WHO Criteria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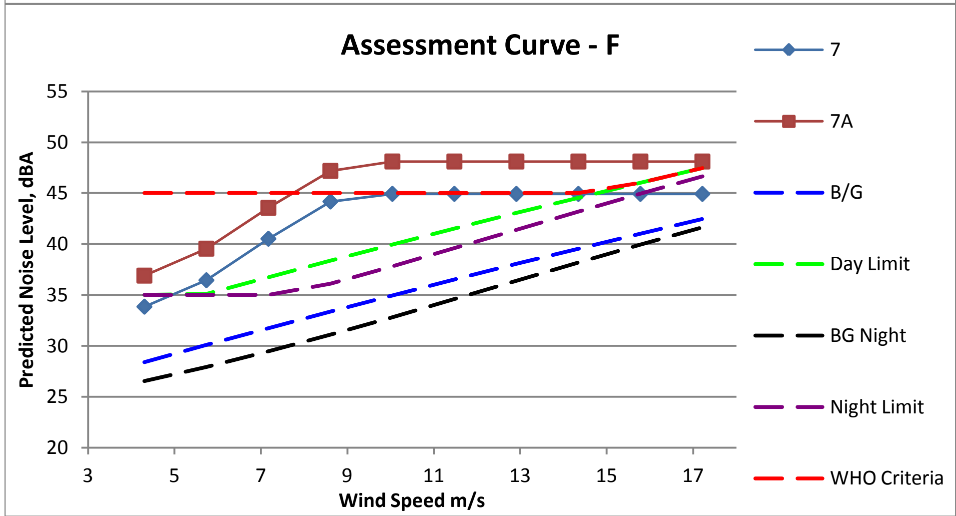
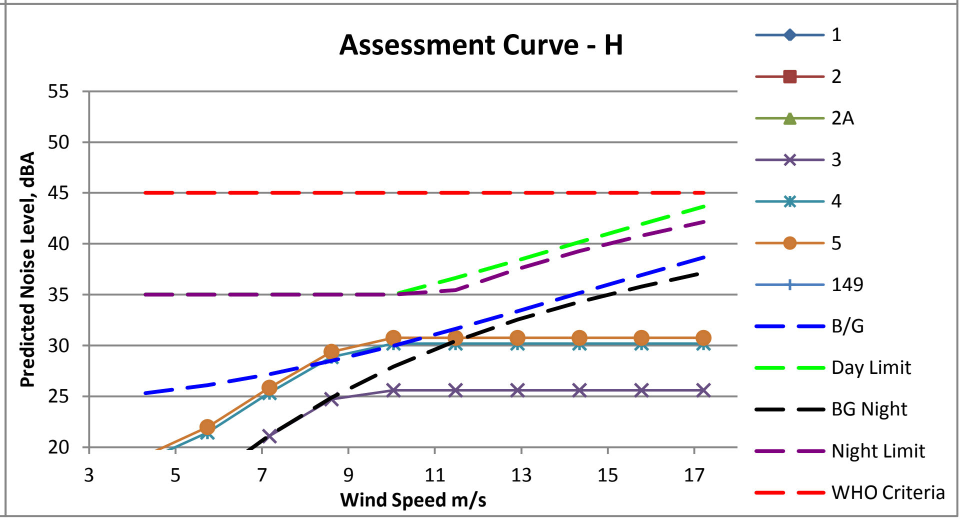
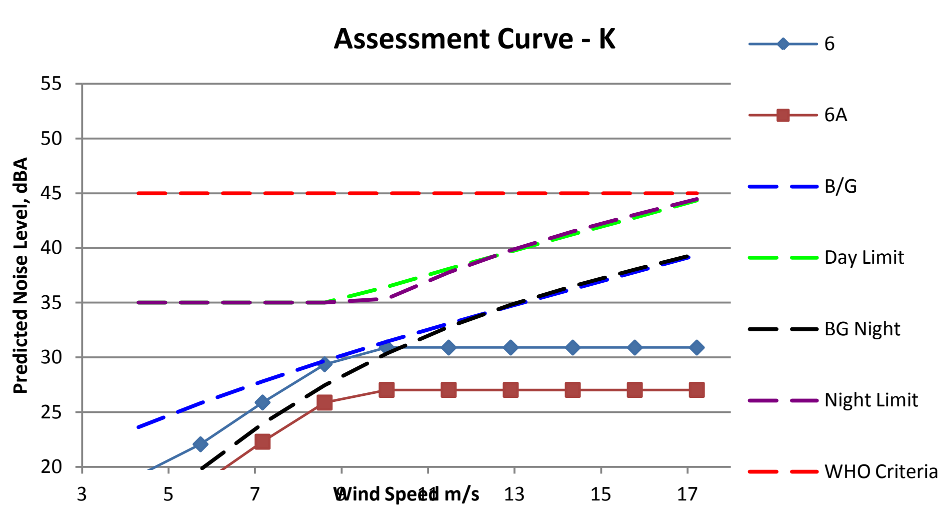
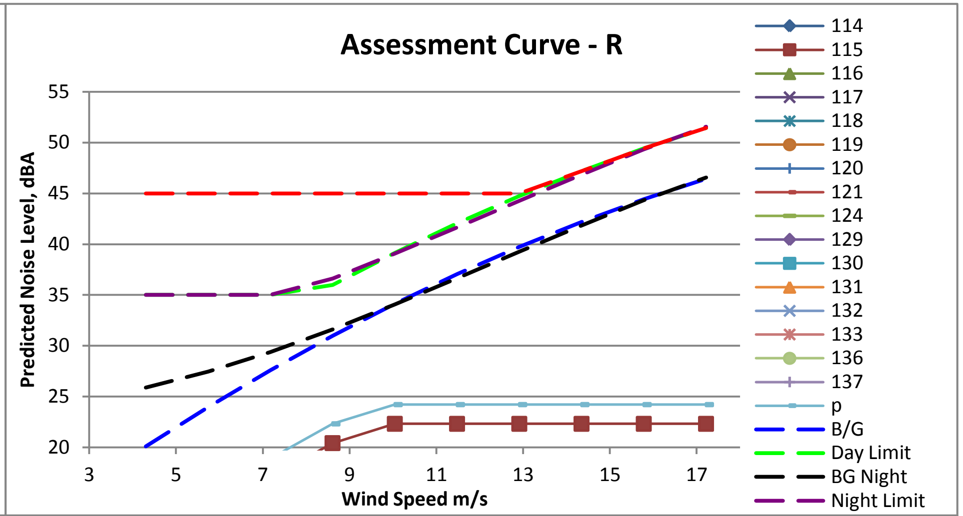
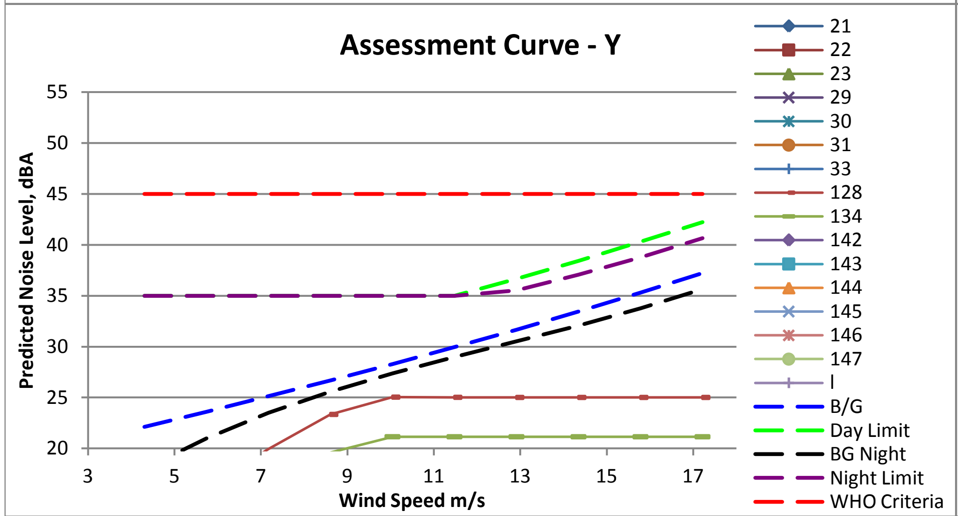
Predicted Noise Level, dBA
Wind Speed m/s
55
50
45
40
35
30
25
20
3
5
7
9
11
13
15
17
8
8A
B/G
Day Limit
BG Night
Night Limit
WHO Criteria


Assessment Curve - F
Predicted Noise Level, dBA
Wind Speed m/s
55
50
45
40
35
30
25
20
3
5
7
9
11
13
15
17
7
7A
B/G
Day Limit
BG Night
Night Limit
WHO Criteria


Assessment Curve - H
Predicted Noise Level, dBA
Wind Speed m/s
55
50
45
40
35
30
25
20
3
5
7
9
11
13
15
17
1
2
2A
3
4
5
149
B/G
Day Limit
BG Night
Night Limit
WHO Criteria


Assessment Curve - K
Predicted Noise Level, dBA
Wind Speed m/s
6
6A
B/G
Day Limit
BG Night
Night Limit
WHO Criteria


Assessment Curve - R
Predicted Noise Level, dBA
Wind Speed m/s
114
115
116
117
118
119
120
121
124
129
130
131
132
133
136
137
p
B/G
Day Limit
BG Night
Night Limit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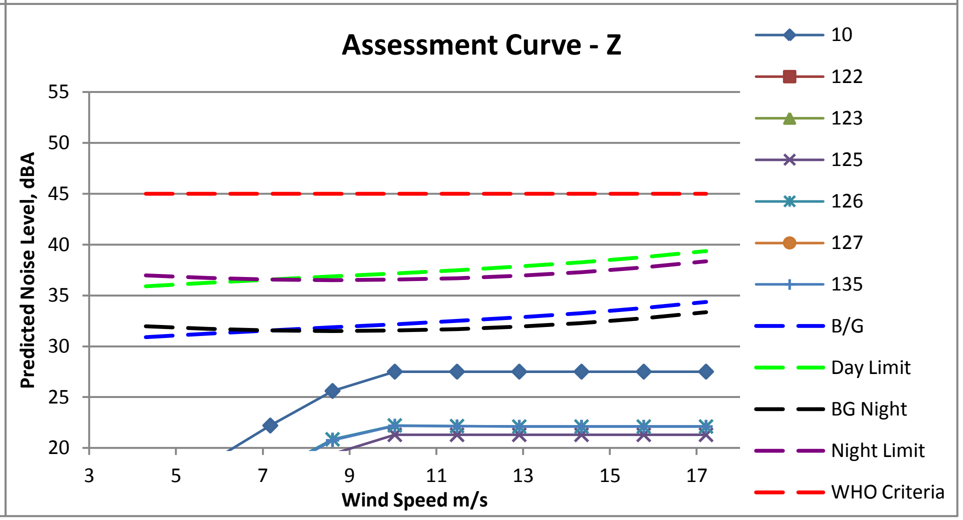
Predicted Noise Level, dBA
Wind Speed m/s
21
22
23
29
30
31
33
128
134
142
143
144
145
146
147
l
B/G
Day Limit
BG Night
Night Limit
WHO Criteria


Assessment Curve - Z
Predicted Noise Level, dBA
Wind Speed m/s
10
122
123
125
126
127
135
B/G
Day Limit
BG Night
Night Limit
WHO Criteria

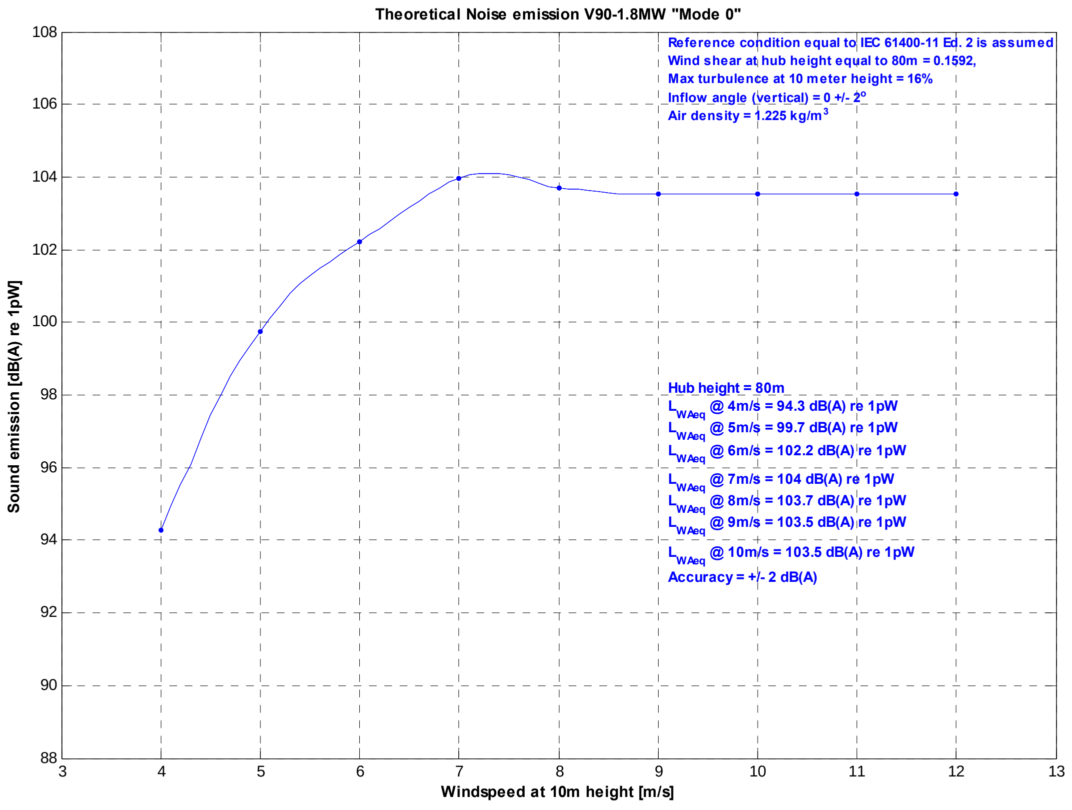
WIND TURBINE GENERATOR (WTG)

SOUND POWER LEVEL SPECIFICATION

AS PER IEC-61400-11:2002 (WIND TURBINE GENERATOR SYSTEMS – PART 11: ACOUSTIC NOISE MEASUREMENT TECHNIQUES)

The following are the official test reports from Vestas for the V90, V100 and V112 models. This data forms the basis of the noise predictions for Paling Yards Wind Farm. The data is considered commercial in confidence and may not be reproduced without the permission of the manufacturer.

2.4 Noise Curves, Calculated



	Theoretical Sound Power Level at Hub Height, V90-1.8MW "Mode 0"				
	Conditions for Sound Power Level	Verification standard : IEC 61400-11 Ed. 2 Wind shear as described in table below. Max turbulence at 10 meter height: 16% Inflow angle (vertical): 0 ± 2° Air density: 1.225 kg/m³ Accuracy: ± 2 dB(A)			
	Hub height	HH 80 m			
	Wind shear	0.1592			
	Verification Report: "Theoretical"				
		dB(A) re 1pW			
	L_{WA} @ 4m/s (10 meter above ground)	94.3			
	L_{WA} @ 5m/s (10 meter above ground)	99.7			
	L_{WA} @ 6m/s (10 meter above ground)	102.2			
	L_{WA} @ 7m/s (10 meter above ground)	104.0			
	L_{WA} @ 8m/s (10 meter above ground)	103.7			
	L_{WA} @ 9m/s (10 meter above ground)	103.5			
	L_{WA} @ 10m/s (10 meter above ground)	103.5			
	L_{WA} @ 11m/s (10 meter above ground)	103.5			
	L_{WA} @ 12m/s (10 meter above ground)	103.5			
	L_{WA} @ 95% Rated Power (7.6 m/s, 10 meter above ground)	104.0			

Annex 4.3: A-weighted sound pressure 1/3-octave spectrum at 8 m/s

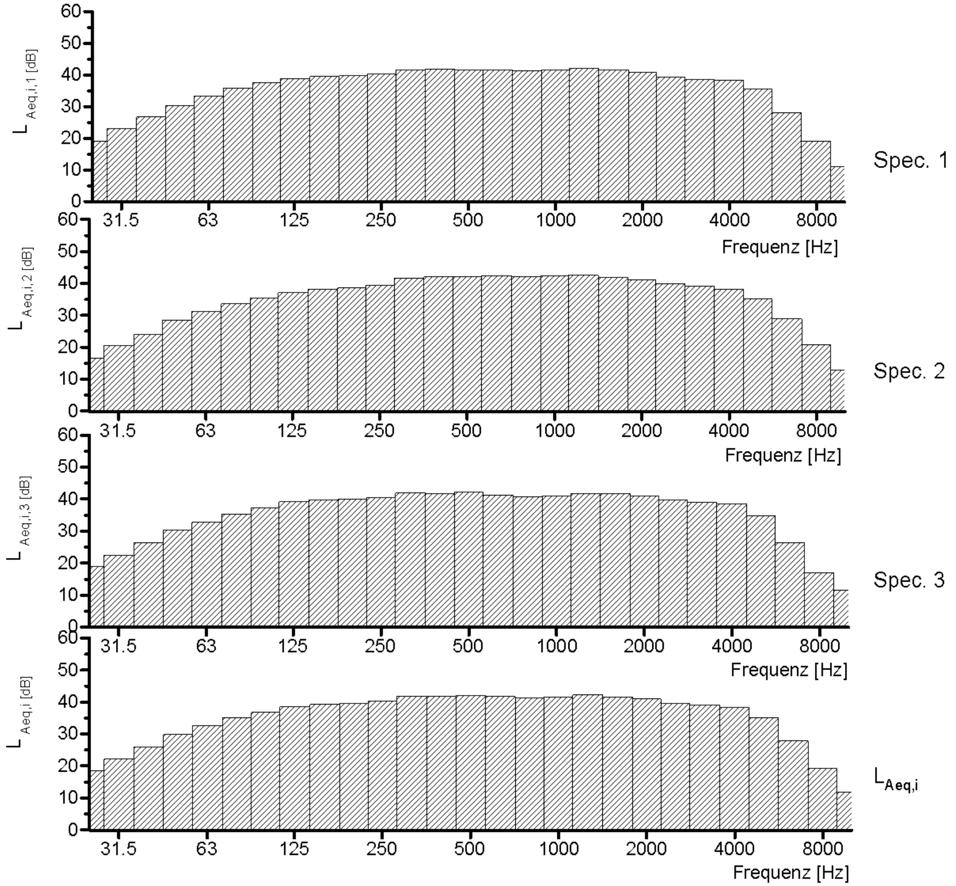
reference sound pressure/ Referenz - Schalldruck - Betrieb $L_{Aeq,c}$ = 52.6 dB

reference background sound pressure Referenz - Schalldruck - Hintergrund $L_{Aeq,n}$ = 44.2 dB

reference sound power Referenz - Schallleistung L_{WA} = 102.8 dB

reference wind speed Referenz - Windgeschwindigkeit WS 10m = 8 m/s

f [Hz]	Spec. 1 [dB]	Spec. 2 [dB]	Spec. 3 [dB]	$L_{Aeq,i}$ [dB]	$L_{WA,i}$ [dB]	U_a [dB]	U_c [dB]
25	19.1	16.7	19.1	18.4	68.0	1.4	2.4
31.5	23.1	20.5	22.5	22.1	71.7	1.3	2.4
40	26.8	24.1	26.4	25.9	75.5	1.5	2.5
50	30.2	28.6	30.5	29.9	79.5	1.0	2.2
63	33.3	31.2	32.8	32.5	82.1	1.1	2.3
80	35.9	33.5	35.5	35.1	84.7	1.3	2.4
100	37.5	35.4	37.4	36.9	86.5	1.2	2.3
125	39.0	37.0	39.2	38.5	88.1	1.2	2.3
160	39.5	38.1	39.8	39.2	88.8	0.9	2.2
200	39.8	38.6	40.1	39.5	89.1	0.8	2.1
250	40.5	39.5	40.7	40.2	89.8	0.7	2.1
315	41.8	41.5	41.9	41.8	91.4	0.2	2.0
400	41.8	42.0	41.8	41.9	91.5	0.1	2.0
500	41.8	42.2	42.4	42.1	91.7	0.3	2.0
630	41.5	42.4	41.2	41.7	91.3	0.7	2.1
800	41.4	42.1	40.8	41.5	91.1	0.7	2.1
1000	41.6	42.3	41.0	41.7	91.3	0.7	2.1
1250	42.2	42.6	41.8	42.2	91.8	0.4	2.0
1600	41.6	41.9	41.6	41.7	91.3	0.2	2.0
2000	40.7	41.2	41.1	41.0	90.6	0.2	2.0
2500	39.4	40.0	39.8	39.7	89.3	0.3	2.0
3150	38.7	39.2	39.1	39.0	88.6	0.3	2.0
4000	38.4	38.2	38.5	38.4	88.0	0.2	2.0
5000	35.7	35.2	34.9	35.3	84.9	0.4	2.0
6300	28.2	28.9	26.4	28.0	77.6	1.3	2.4
8000	19.2	20.7	16.9	19.2	68.8	1.9	2.8
10000	11.2	12.9	11.6	12.0	61.6	0.9	2.2



Graphic file / Grafikdatei: S:_em_\VV90-2MWSchoenhagen\Mode 0\Terz\IEC\Terz_8 04.04.2005
Source file / Quelldatei: Terz_8_erg

WINDTEST Kaiser-Wilhelm-Koog GmbH

V90-2MW (Mode 0) V18864

One third octave analysis / Terzanalyse

Site / Standort:	Schönhagen
Measurem. / Messdatum:	2005-03-11
Standard / Messung:	FGW / IEC
In charge / Bearbeiter:	Dipl.-Ing. Jörg Dedert

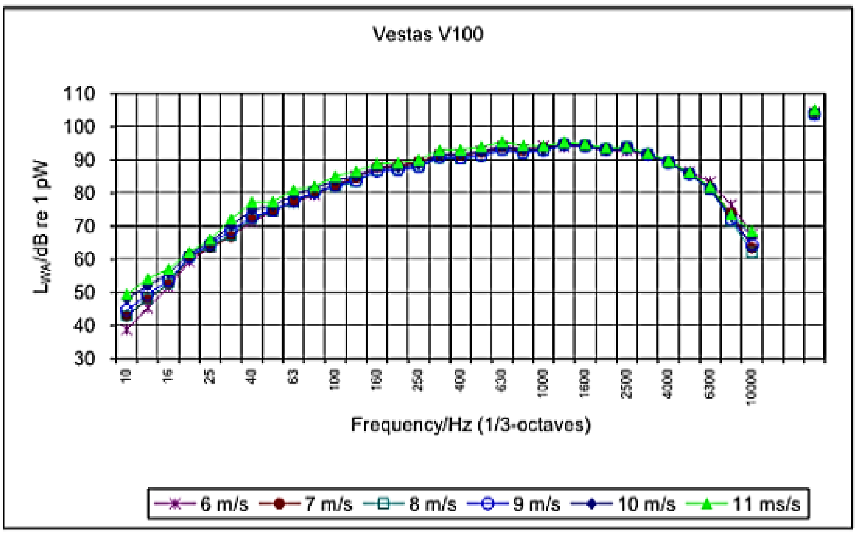
12.1.3 Mode 0, Sound Power Levels

Sound Power Level at Hub Height, Mode 0		
Conditions for Sound Power Level	**Verification standard: IEC 61400-11 Ed. 2.** **Wind shear 0.15.** **Max turbulence at 10 meter height: 16%** **Inflow angle (vertical): 0 ± 2°** **Air density: 1.225 kg/m^3**	
Hub Height	80 m	95 m
LwA @ 3 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.2 5.6	96.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	100.1 7.0	100.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.9 8.4	104.4 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 18.1	105.0 18.6

Table 12-3: Sound power level at hub height: Mode 0.

Graph Sheet 4: 1/3-octave band spectra from reference position

Numbers in *Italic* indicates that the difference between total noise and background noise was less than 3 dB.



Frequency		6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	11 ms/s
10		38.8	42.8	43.0	44.7	48.1	49.5
12.5		45.4	47.9	48.1	49.4	52.0	54.1
16		51.6	52.6	52.7	53.7	55.8	57.1
20		59.4	60.6	60.7	60.9	61.6	62.2
25		63.9	63.6	64.1	64.7	65.4	66.0
31.5		67.2	66.9	67.3	68.7	70.2	72.2
40		71.4	72.3	72.4	72.9	75.0	77.3
50		74.4	74.7	74.7	74.8	76.1	77.4
63		77.2	77.5	77.3	77.7	79.5	80.9
80		79.4	80.3	80.2	80.2	81.5	82.1
100		82.6	82.5	82.1	82.4	83.9	85.1
125		85.0	84.6	83.5	83.9	85.1	86.7
160		87.9	87.8	86.8	86.7	87.7	89.0
200		88.5	88.2	87.1	87.0	87.8	89.1
250		89.3	89.4	88.1	88.0	88.7	90.1
315		91.5	91.7	90.7	90.9	91.6	93.0
400		91.6	91.4	90.5	90.7	91.7	93.1
500		92.7	92.2	91.2	91.3	92.4	94.0
630		94.2	93.8	93.2	93.1	94.0	95.5
800		93.3	92.7	92.1	92.2	93.0	94.4
1000		94.3	93.6	92.9	92.8	93.3	94.3
1250		94.0	94.8	94.9	94.6	94.8	95.4
1600		94.2	94.5	94.4	94.1	94.2	94.8
2000		93.0	93.3	93.3	93.1	93.2	93.7
2500		92.7	93.5	93.8	93.6	93.7	93.9
3150		91.6	91.7	91.7	91.6	91.8	92.0
4000		89.5	89.2	89.2	89.2	89.5	89.7
5000		86.5	85.8	85.7	85.8	86.0	86.3
6300		83.3	81.9	81.2	81.3	81.7	81.9
8000		76.5	73.8	71.6	72.2	73.0	73.6
10000		67.7	63.4	*62.1*	64.3	67.0	68.5
L_{WA}		104.3	104.3	103.9	103.8	104.4	105.3

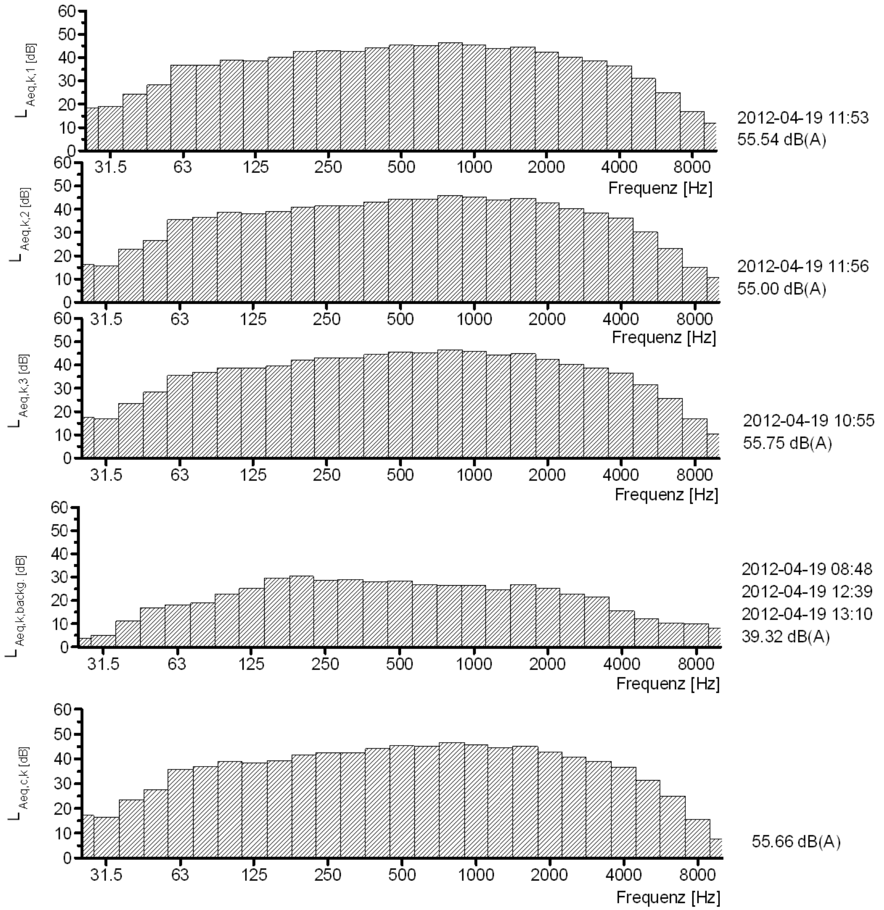
12.1.3 Noise Curve, Noise Mode 0

Sound Power Level at Hub Height, Noise Mode 0			
Conditions for Sound Power Level:	**Measurement standard IEC 61400-11 ed. 2 2002** **Wind shear: 0.16** **Maximum turbulence at 10 metre height: 16%** **Inflow angle (vertical): 0 ±2°** **Air density: 1.225 kg/m^3**		
Hub Height	**84 m**	**94 m**	**119 m**
LwA @ 3 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	94.5 4.2	94.5 4.3	94.7 4.5
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	97.3 5.6	97.5 5.7	98.1 5.9
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	100.9 7.0	101.2 7.2	101.9 7.4
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	104.3 8.4	104.6 8.6	105.1 8.9
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	106.0 9.8	106.5 10.0	106.5 10.4
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	106.5 11.2	106.5 11.4	106.5 11.9
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	106.5 12.7	106.5 12.9	106.5 13.4
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	106.5 14.1	106.5 14.3	106.5 14.9
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	106.5 15.5	106.5 15.7	106.5 16.3
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	106.5 16.9	106.5 17.2	106.5 17.8
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	106.5 18.3	106.5 18.6	106.5 19.3

Table 12-3: Noise curve, noise mode 0

Annex 4.3: A-weighted sound pressure 1/3-octave spectrum at 8 m/s

f [Hz]	Spec. 1 [dB]	Spec. 2 [dB]	Spec. 3 [dB]	Backg. [dB]	$L_{Aeq,c,k}$ [dB]	$L_{WA,k}$ [dB]	U_a [dB]	U_c [dB]
10	-5.5	-8.6	-6.5	-16.5	-7.6	41.8	1.6	2.5
13	2.9	0.0	1.7	-9.0	0.9	50.3	1.5	2.5
16	4.8	0.8	2.7	-9.1	1.9	51.3	2.0	2.8
20	17.1	16.7	16.1	-0.2	16.7	66.0	0.5	2.1
25	18.5	16.4	17.6	3.7	17.2	66.6	1.0	2.2
32	18.9	15.5	17.0	4.9	16.4	65.8	1.7	2.6
40	24.4	22.9	23.5	11.1	23.3	72.7	0.8	2.1
50	28.3	26.7	28.4	16.9	27.6	77.0	1.0	2.2
63	36.8	35.4	35.5	18.1	35.8	85.2	0.8	2.1
80	36.8	36.6	37.0	18.9	37.1	86.5	0.2	2.0
100	39.0	38.7	38.7	22.8	39.0	88.4	0.2	2.0
125	38.6	38.1	38.7	25.1	38.6	88.0	0.3	2.0
160	40.0	39.1	39.6	29.6	39.3	88.6	0.5	2.0
200	42.6	41.0	42.1	30.4	41.6	91.0	0.8	2.1
250	43.0	41.5	43.1	28.8	42.6	92.0	0.9	2.2
315	42.9	41.5	43.1	29.0	42.6	92.0	0.9	2.2
400	44.2	43.2	44.5	28.2	44.2	93.5	0.7	2.1
500	45.3	44.5	45.7	28.5	45.4	94.8	0.6	2.1
630	45.0	44.4	45.4	26.9	45.2	94.6	0.5	2.0
800	46.4	45.9	46.6	26.5	46.6	96.0	0.4	2.0
1000	45.5	45.2	45.9	26.5	45.9	95.2	0.3	2.0
1250	43.9	43.9	44.3	24.6	44.4	93.8	0.2	2.0
1600	44.4	44.7	44.9	26.9	45.1	94.5	0.2	2.0
2000	42.4	42.7	42.6	25.2	42.9	92.3	0.2	2.0
2500	40.1	40.2	40.3	22.7	40.6	89.9	0.1	2.0
3150	38.6	38.5	38.8	21.6	38.9	88.3	0.2	2.0
4000	36.5	36.2	36.4	15.4	36.7	86.0	0.2	2.0
5000	31.1	30.1	31.6	12.1	31.3	80.6	0.8	2.1
6300	25.0	23.3	25.6	10.2	24.8	74.2	1.2	2.3
8000	16.8	15.0	17.2	9.9	15.5	64.9	1.1	2.3
10000	11.9	10.7	10.4	8.2	7.6	57.0	0.8	2.1
12500	9.2	8.1	7.3	5.7	4.4	53.7	1.0	2.2
16000	5.7	4.9	4.0	2.6	1.0	50.4	0.8	2.2



Graphic file / Grafikdatei: S:_em_\WV112Niebüll_40890_2012_04_19\SEM\Terz_FGW\V40890_IEC_8 08.05.2012
Source file / Quelldatei: V40890_IEC_8m_

created with WINDTEST TuNES version: 11.1-0004

GL Garrad Hassan

Vestas V112, WEA 4.1, Mode 0

One third octave analysis / Terzanalyse

Site / Standort:	Niebüll
WTGS-SNo. / WEA-SNr.:	V40890
WS / WG:	8 m/s
Date of meas. / Messdatum:	2012-04-19
Standard / Messung:	IEC 61400-11 Ed. 2.1
Averaging / Mittelung:	60 sec.
In charge / Bearbeiter:	Dipl.-Ing. Ulf Kock

5 Summary

As ordered by Vestas Wind Systems A/S, 8940 Randers, Denmark, GL Garrad Hassan Deutschland GmbH took measurements of the acoustic noise emissions on the WTGS Vestas V112 - 3.0 MW with a hub height of 94 m.

All measurements and analysis of the sound power level and tonality described in this report were made on the basis of the international standard [IEC 61400-11 Ed. 2.1]. The analysis of the sound power level was carried out using the standardised wind speed which was calculated from the calculated power curve provided by the customer (see annex).

The data of the WTGS Vestas V112 - 3.0 MW (mode 0) have been evaluated by using a fourth order regression because this is the best fitting approximation over all relevant points.

The results of this measurement are given in table 4.

Table 4: Summary of results

wind speed in 10 m height [m/s]	***6***	***7***	***8***	***9***	***10***
electrical power output calculated from the power curve [kW]	*1676*	*2548*	*3032*	*3074*	*3075*
measured pitch angle [degrees]	*-2,1*	*-3,4*	*0*	*5*	*8*
measured rotor speed [min^{-1}]	*12,3*	*12,7*	*12,9*	*12,9*	*12,9*
sound power level [dB]	*103,6*	*104,7*	*103,3*	*101,3*	*103,0**
combined uncertainty in the sound power level, U_C [dB]	*1,1*	*1,2*	*1,8*	*2,3*	*1,9*
tonality, ΔL_k [dB]	*-5,31*	*-5,05*	*-15,28*	*-13,9*	*-11,21*
tonal audibility, $\Delta L_{a,k}$ [dB]	*-1,97*	*-3,04*	*-13,27*	*-11,88*	*-9,19*
frequency of the most prevalent tone [Hz]	*1690*	*126*	*126*	*126*	*126*

* The sound power level has to be calculated by used of the 4th order regression. This leads to an unexpected high value for the sound power level. (see annex 2.1)

It is assured that this report has been drawn up impartially and with best knowledge and conscience.

Appendix C - Distances to Wind Turbines

147	146	145	144	143	142	14	137	136	135	134	133	132	131	130	13	129	128	127	126	125	124	123	122	121	120	12	119	118	117	116	115	114	11	10	1	Northing	Easting	Receiver
6.9	6.9	6.8	6.9	6.2	7.4	6.7	7.0	4.8	3.0	4.6	7.3	7.5	6.4	6.4	3.9	5.9	2.9	4.2	2.9	2.7	6.5	5.2	5.8	5.9	5.8	3.7	7.3	6.8	5.4	4.4	4.1	4.4	5.7	2.1	8.5			**Closest Turbine Distance**
11.4	11.4	11.3	11.3	10.6	11.2	6.7	15.5	13.5	7.8	9.7	16.8	17.1	16.0	16.0	3.9	15.6	6.2	12.7	7.9	10.8	15.1	11.5	14.1	14.6	14.9	3.7	16.3	16.0	15.4	15.0	14.7	15.0	5.7	2.1	18.0	6214761	747801.1	**P1**
10.8	10.8	10.7	10.7	10.0	10.6	7.0	15.0	12.9	7.3	9.1	16.3	16.6	15.5	15.6	4.3	15.1	5.6	12.2	7.3	10.3	14.6	10.9	13.5	14.1	14.4	4.2	15.7	15.5	15.0	14.6	14.4	14.7	6.3	2.7	18.0	6214437	748312.2	**P2**
10.7	10.8	10.6	10.6	10.0	10.7	7.4	14.8	12.7	7.2	9.0	16.1	16.3	15.2	15.3	4.6	14.9	5.7	12.0	7.2	10.1	14.4	10.8	13.4	13.9	14.2	4.4	15.5	15.3	14.7	14.3	14.1	14.3	6.4	2.8	17.6	6214803	748519.7	**P3**
10.6	10.6	10.5	10.5	9.8	10.6	7.7	14.6	12.5	6.9	8.8	15.8	16.0	14.9	15.0	4.9	14.5	5.5	11.7	6.9	9.8	14.2	10.6	13.1	13.6	13.9	4.7	15.3	15.0	14.4	14.0	13.7	14.0	6.7	3.0	17.2	6214973	748803.6	**P4**
10.4	10.4	10.3	10.3	9.7	10.5	8.0	14.3	12.2	6.7	8.6	15.5	15.8	14.7	14.7	5.2	14.3	5.5	11.5	6.7	9.6	13.9	10.4	12.9	13.4	13.7	5.0	15.0	14.8	14.1	13.7	13.4	13.7	7.0	3.2	17.0	6215129	749054.8	**P5**
9.6	9.6	9.5	9.5	8.9	9.4	7.8	14.0	12.0	6.2	8.1	15.5	15.8	14.7	14.8	5.0	14.3	4.4	11.3	6.4	9.5	13.7	9.9	12.6	13.2	13.6	5.1	14.8	14.6	14.3	14.1	13.9	14.2	7.4	3.9	18.0	6213667	749245.3	**P6**
9.7	9.8	9.6	9.6	9.0	9.6	7.9	14.0	12.0	6.3	8.1	15.4	15.7	14.6	14.7	5.1	14.2	4.6	11.2	6.3	9.4	13.6	9.9	12.6	13.1	13.5	5.1	14.8	14.6	14.2	13.9	13.7	14.0	7.3	3.8	17.7	6214044	749277.9	**P7**
9.8	9.8	9.7	9.7	9.0	9.9	8.4	13.7	11.6	6.1	7.9	14.9	15.2	14.1	14.2	5.7	13.7	4.9	10.9	6.1	9.0	13.3	9.7	12.3	12.8	13.1	5.5	14.4	14.2	13.6	13.3	13.0	13.3	7.6	3.9	16.8	6214879	749637.9	**P8**
9.6	9.6	9.5	9.5	8.9	9.8	8.9	13.4	11.2	5.8	7.7	14.5	14.8	13.7	13.7	6.1	13.3	4.8	10.5	5.8	8.6	12.9	9.4	11.9	12.4	12.7	6.0	14.0	13.8	13.1	12.8	12.5	12.8	7.9	4.2	16.3	6215203	750046	**P9**
9.4	9.4	9.3	9.4	8.7	9.7	9.5	13.0	10.8	5.5	7.4	14.1	14.3	13.2	13.3	6.7	12.8	4.8	10.1	5.5	8.2	12.5	9.1	11.5	12.0	12.2	6.5	13.6	13.3	12.7	12.2	12.0	12.2	8.4	4.6	15.8	6215520	750487.7	**P10**
9.7	9.7	9.6	9.6	8.9	10.0	9.9	12.9	10.7	5.7	7.5	13.9	14.1	13.0	13.0	7.1	12.6	5.3	10.0	5.6	8.1	12.5	9.2	11.5	11.9	12.1	6.8	13.5	13.2	12.4	11.8	11.6	11.8	8.6	4.8	15.2	6216153	750672.8	**P11**
9.1	9.1	9.0	9.0	8.4	9.3	9.3	12.9	10.8	5.3	7.1	14.1	14.3	13.2	13.3	6.5	12.8	4.4	10.0	5.3	8.1	12.5	8.9	11.4	11.9	12.2	6.4	13.6	13.3	12.7	12.4	12.1	12.4	8.4	4.7	16.2	6215025	750521.2	**P12**
9.0	9.0	8.9	8.9	8.2	9.3	9.7	12.6	10.4	5.1	6.9	13.7	14.0	12.9	12.9	6.9	12.5	4.4	9.7	5.0	7.8	12.1	8.7	11.1	11.6	11.9	6.8	13.2	13.0	12.3	12.0	11.7	12.0	8.8	5.0	15.8	6215277	750856.4	**P13**
9.0	9.0	8.9	8.9	8.2	9.3	10.0	12.4	10.2	5.0	6.8	13.5	13.8	12.7	12.7	7.2	12.2	4.5	9.5	4.9	7.6	12.0	8.6	10.9	11.4	11.7	7.0	13.1	12.8	12.1	11.7	11.4	11.7	9.0	5.2	15.5	6215503	751065.1	**P14**
8.4	8.4	8.3	8.3	7.6	8.5	9.4	12.5	10.5	4.8	6.6	13.9	14.2	13.1	13.2	6.6	12.7	3.5	9.7	4.8	7.9	12.1	8.4	11.1	11.6	12.0	6.6	13.3	13.1	12.7	12.5	12.3	12.6	8.8	5.2	16.9	6214083	750790.7	**P15**
8.2	8.3	8.1	8.2	7.5	8.4	9.8	12.1	10.1	4.5	6.3	13.4	13.7	12.6	12.7	7.0	12.3	3.5	9.3	4.5	7.5	11.7	8.1	10.7	11.2	11.6	7.0	12.9	12.7	12.2	12.0	11.8	12.1	9.1	5.5	16.4	6214433	751180.8	**P16**
8.2	8.3	8.1	8.2	7.5	8.5	10.1	11.9	9.8	4.4	6.2	13.2	13.5	12.3	12.4	7.3	12.0	3.7	9.1	4.3	7.2	11.5	8.0	10.5	11.0	11.3	7.3	12.6	12.4	11.9	11.7	11.4	11.7	9.3	5.6	15.9	6214787	751425	**P17**
8.0	8.0	7.9	8.0	7.3	8.4	10.7	11.5	9.3	4.1	5.9	12.6	12.9	11.8	11.9	7.9	11.4	3.8	8.6	4.0	6.7	11.050	7.627	10.0	10.5	10.8	7.8	12.1	11.9	11.3	11.0	10.8	11.1	9.8	6.1	15.4	6215115	751941.7	**P18**
8.4	8.4	8.3	8.4	7.7	8.8	10.7	11.7	9.6	4.4	6.2	12.8	13.1	12.0	12.0	7.9	11.5	4.2	8.8	4.3	6.9	11.276	7.933	10.2	10.7	11.0	7.7	12.4	12.1	11.4	11.1	10.8	11.1	9.7	5.9	15.2	6215480	751765.1	**P19**
8.6	8.6	8.5	8.5	7.8	9.1	10.9	11.6	9.5	4.5	6.3	12.6	12.9	11.8	11.8	8.2	11.3	4.6	8.7	4.3	6.8	11.195	7.977	10.2	10.6	10.8	8.0	12.2	11.9	11.2	10.7	10.5	10.8	9.8	6.1	14.7	6215913	751924.4	**P20**
6.9	6.9	6.8	6.9	6.2	7.4	11.3	10.6	8.5	3.0	4.8	11.9	12.2	11.1	11.2	8.6	10.8	2.9	7.7	3.0	5.9	10.2	6.6	9.1	9.7	10.0	8.6	11.3	11.1	10.7	10.7	10.5	10.8	10.7	7.0	15.7	6214377	752758.6	**P21**
7.0	7.0	6.9	6.9	6.2	7.5	11.6	10.4	8.3	3.0	4.8	11.7	12.0	10.9	11.0	8.8	10.5	3.2	7.6	2.9	5.7	10.0	6.5	8.9	9.5	9.8	8.8	11.1	10.9	10.5	10.4	10.2	10.5	10.9	7.2	15.3	6214652	752945.2	**P22**
7.1	7.1	7.0	7.1	6.4	7.7	11.9	10.3	8.1	3.1	4.8	11.4	11.7	10.6	10.7	9.1	10.2	3.6	7.4	2.9	5.5	9.8	6.5	8.8	9.3	9.6	9.0	10.9	10.7	10.2	10.0	9.8	10.1	11.1	7.3	14.9	6215077	753153.9	**P23**
7.8	7.8	7.7	7.8	7.1	8.6	12.4	10.3	8.1	3.7	5.2	11.2	11.4	10.3	10.4	9.6	9.9	4.6	7.3	3.4	5.4	9.8	6.9	8.8	9.3	9.4	9.4	10.9	10.5	9.7	9.3	9.1	9.4	11.3	7.5	13.8	6216136	753359	**P24**
8.0	8.0	8.0	8.0	7.3	8.7	12.0	10.7	8.5	3.9	5.5	11.6	11.9	10.8	10.8	9.2	10.3	4.6	7.7	3.7	5.8	10.2	7.2	9.2	9.7	9.8	9.0	11.3	10.9	10.1	9.7	9.5	9.8	10.9	7.1	14.0	6216108	752937	**P25**
8.4	8.4	8.3	8.4	7.7	9.1	11.8	11.0	8.8	4.3	5.9	11.9	12.1	11.1	11.1	9.0	10.6	4.8	8.1	4.0	6.2	10.6	7.6	9.6	10.0	10.2	8.8	11.6	11.2	10.4	9.9	9.6	9.9	10.6	6.8	14.0	6216325	752654.5	**P27**
8.8	8.8	8.7	8.7	8.0	9.4	11.3	11.5	9.3	4.7	6.3	12.4	12.6	11.5	11.5	8.6	11.1	5.0	8.5	4.4	6.7	11.1	8.0	10.1	10.5	10.6	8.3	12.1	11.7	10.9	10.4	10.1	10.3	10.1	6.3	14.2	6216399	752167.2	**P28**
8.4	8.4	8.3	8.4	7.7	9.2	12.2	10.8	8.6	4.3	5.8	11.6	11.8	10.7	10.7	9.4	10.3	5.1	7.8	4.0	5.9	10.3	7.4	9.4	9.8	9.9	9.2	11.3	11.0	10.0	9.5	9.3	9.5	10.9	7.2	13.6	6216601	752969.5	**P29**
8.6	8.6	8.6	8.6	7.9	9.4	12.3	10.9	8.7	4.6	6.0	11.6	11.9	10.8	10.7	9.5	10.3	5.4	7.9	4.2	6.0	10.4	7.6	9.5	9.8	9.9	9.3	11.4	11.0	10.0	9.4	9.1	9.4	11.0	7.2	13.3	6216909	752971.4	**P30**
9.8	9.8	9.7	9.7	9.0	10.3	10.7	12.5	10.3	5.7	7.3	13.3	13.5	12.4	12.4	8.0	11.9	5.7	9.5	5.4	7.6	12.0	9.0	11.1	11.5	11.6	7.7	13.0	12.7	11.7	11.0	10.7	11.0	9.3	5.6	14.2	6216935	751295.5	**P31**
9.7	9.7	9.6	9.7	9.0	10.4	11.2	12.2	10.0	5.6	7.2	12.9	13.2	12.1	12.1	8.5	11.6	5.9	9.3	5.4	7.4	11.8	8.9	10.8	11.2	11.3	8.1	12.8	12.4	11.3	10.6	10.3	10.5	9.7	6.0	13.7	6217234	751654	**P32**
9.7	9.7	9.6	9.7	9.0	10.4	11.6	12.0	9.8	5.6	7.2	12.7	12.9	11.8	11.8	8.8	11.3	6.1	9.1	5.3	7.2	11.6	8.8	10.6	11.0	11.1	8.5	12.5	12.1	11.0	10.3	10.0	10.2	10.0	6.3	13.4	6217474	751942.3	**P33**
9.8	9.8	9.7	9.8	9.1	10.5	11.9	11.9	9.6	5.7	7.2	12.5	12.7	11.6	11.6	9.2	11.1	6.3	8.9	5.4	7.1	11.4	8.8	10.5	10.8	10.9	8.9	12.4	11.9	10.7	9.9	9.6	9.9	10.4	6.7	13.0	6217766	752209.4	**P34**
10.2	10.1	10.1	10.1	9.4	10.9	11.8	12.2	10.0	6.1	7.6	12.7	13.0	11.9	11.8	9.1	11.3	6.6	9.2	5.7	7.4	11.8	9.1	10.8	11.2	11.2	8.8	12.7	12.2	11.0	10.1	9.8	10.0	10.2	6.5	12.9	6218025	751952.9	**P35**
9.4	9.4	9.3	9.4	8.7	10.3	12.9	11.0	8.8	5.4	6.7	11.5	11.7	10.6	10.6	10.2	10.1	6.5	8.1	5.0	6.3	10.6	8.1	9.7	10.0	9.9	9.9	11.4	11.0	9.7	8.9	8.6	8.8	11.4	7.7	12.3	6217980	753234.5	**P36**
9.6	9.6	9.5	9.6	8.9	10.5	13.2	11.0	8.7	5.6	6.8	11.4	11.6	10.5	10.4	10.5	9.9	6.8	8.0	5.2	6.3	10.5	8.2	9.7	9.9	9.9	10.2	11.4	10.9	9.5	8.7	8.3	8.6	11.7	8.0	11.9	6218296	753414.3	**P37**
9.0	9.0	8.9	9.0	8.3	10.0	13.3	10.5	8.3	5.0	6.2	11.0	11.2	10.2	10.1	10.5	9.6	6.3	7.6	4.6	5.8	10.1	7.7	9.2	9.5	9.5	10.2	11.0	10.5	9.3	8.5	8.2	8.5	11.8	8.1	12.2	6217768	753669.5	**P38**
9.2	9.2	9.2	9.3	8.6	10.2	13.5	10.5	8.3	5.3	6.5	11.0	11.2	10.1	10.0	10.8	9.5	6.6	7.6	4.8	5.9	10.1	7.8	9.2	9.5	9.4	10.5	11.0	10.5	9.1	8.3	8.0	8.2	12.0	8.3	11.9	6218102	753790.4	**P39**
10.3	10.3	10.2	10.4	9.7	11.4	14.0	11.2	9.0	6.4	7.5	11.3	11.5	10.5	10.3	11.3	9.8	7.8	8.3	6.0	6.6	10.7	8.8	9.9	10.1	9.9	10.9	11.5	11.0	9.3	8.2	7.9	8.1	12.2	8.6	10.9	6219273	753715.8	**P40**
9.8	9.8	9.7	9.8	9.1	10.8	13.7	10.8	8.6	5.9	7.0	11.1	11.3	10.3	10.2	11.0	9.7	7.2	8.0	5.4	6.2	10.4	8.3	9.6	9.8	9.7	10.7	11.2	10.7	9.2	8.3	7.9	8.1	12.1	8.4	11.4	6218710	753755.5	**P41**
10.0	10.0	10.0	10.1	9.4	11.1	14.0	10.9	8.7	6.2	7.2	11.1	11.3	10.3	10.2	11.3	9.6	7.6	8.1	5.7	6.4	10.5	8.5	9.7	9.9	9.7	10.9	11.3	10.7	9.2	8.1	7.8	8.0	12.3	8.7	11.0	6219051	753850.5	**P42**
10.4	10.4	10.3	10.4	9.8	11.5	14.3	11.0	8.9	6.6	7.6	11.1	11.3	10.3	10.1	11.6	9.6	8.0	8.2	6.1	6.6	10.6	8.8	9.8	10.0	9.8	11.2	11.4	10.8	9.1	8.0	7.6	7.8	12.6	9.0	10.6	6219495	753989.9	**P43**
10.5	10.5	10.4	10.5	9.9	11.6	14.7	10.9	8.8	6.7	7.7	10.9	11.1	10.1	9.9	12.0	9.4	8.3	8.1	6.2	6.6	10.5	8.8	9.7	9.9	9.7	11.6	11.2	10.6	8.9	7.7	7.3	7.5	12.9	9.3	10.3	6219703	754258.2	**P44**
10.6	10.6	10.6	10.7	10.0	11.8	15.0	10.9	8.8	7.0	7.8	10.8	11.0	10.0	9.8	12.3	9.3	8.5	8.1	6.4	6.6	10.5	8.9	9.8	9.9	9.6	11.9	11.2	10.6	8.7	7.5	7.1	7.3	13.1	9.6	9.9	6219950	754452.8	**P45**
10.8	10.7	10.7	10.8	10.2	12.0	15.3	10.8	8.7	7.1	7.9	10.7	10.8	9.9	9.6	12.6	9.1	8.8	8.1	6.6	6.6	10.4	9.0	9.7	9.8	9.5	12.2	11.0	10.4	8.5	7.2	6.8	7.0	13.5	9.9	9.6	6220154	754723.7	**P46**
11.2	11.1	11.1	11.2	10.6	12.4	15.5	11.1	9.0	7.5	8.3	10.9	11.0	10.1	9.8	12.8	9.3	9.2	8.4	7.0	7.0	10.7	9.4	10.0	10.1	9.8	12.4	11.3	10.7	8.7	7.3	6.9	7.0	13.6	10.1	9.3	6220559	754672.5	**P47**
10.7	10.7	10.7	10.8	10.2	12.0	15.7	10.6	8.5	7.2	7.9	10.3	10.5	9.5	9.3	13.0	8.8	9.0	7.9	6.7	6.5	10.1	8.9	9.5	9.5	9.2	12.6	10.8	10.1	8.2	6.8	6.4	6.6	13.9	10.4	9.3	6220270	755148.6	**P48**
10.8	10.8	10.8	10.9	10.3	12.1	16.1	10.4	8.3	7.4	8.0	10.1	10.2	9.3	9.0	13.4	8.5	9.3	7.8	6.8	6.4	10.0	8.9	9.3	9.3	9.0	13.1	10.5	9.9	7.8	6.5	6.0	6.2	14.3	10.8	9.0	6220446	755526.9	**P49**
10.6	10.5	10.6	10.7	10.1	12.0	16.6	9.9	7.9	7.3	7.8	9.5	9.6	8.7	8.5	13.9	8.0	9.3	7.3	6.8	6.1	9.5	8.6	8.9	8.9	8.5	13.5	10.0	9.4	7.3	5.9	5.5	5.6	14.8	11.2	8.9	6220346	756080.4	**P50**
10.7	10.7	10.7	10.8	10.2	12.2	17.0	9.8	7.8	7.5	7.9	9.3	9.4	8.5	8.2	14.3	7.7	9.6	7.3	7.0	6.1	9.4	8.7	8.8	8.8	8.3	13.9	9.9	9.2	7.0	5.6	5.1	5.3	15.2	11.6	8.5	6220552	756446.5	**P51**
9.4	9.3	9.4	9.5	8.9	10.9	17.2	8.3	6.2	6.5	6.6	7.9	8.1	7.1	6.9	14.5	6.4	8.9	5.7	6.0	4.7	7.9	7.2	7.3	7.2	6.8	14.2	8.4	7.7	5.8	4.6	4.3	4.5	15.7	12.0	9.5	6219305	757359.7	**P52**
9.1	9.0	9.1	9.2	8.6	10.6	17.3	7.9	5.9	6.3	6.4	7.6	7.8	6.8	6.6	14.6	6.1	8.7	5.4	5.8	4.3	7.5	6.9	6.9	6.9	6.5	14.3	8.1	7.4	5.5	4.4	4.1	4.4	15.9	12.2	9.7	6219025	757574.6	**P53**
8.8	8.8	8.8	9.0	8.4	10.4	17.3	7.7	5.6	6.1	6.1	7.4	7.6	6.6	6.4	14.5	5.9	8.6	5.1	5.5	4.1	7.3	6.7	6.7	6.6	6.3	14.3	7.8	7.2	5.4	4.4	4.1	4.4	15.9	12.2	10.0	6218768	757655.8	**P54**
8.5	8.4	8.5	8.6	8.0	10.0	17.1	7.5	5.4	5.7	5.8	7.4	7.6	6.6	6.4	14.3	5.9	8.2	4.9	5.2	3.7	7.1	6.3	6.5	6.5	6.2	14.1	7.7	7.1	5.4	4.6	4.3	4.6	15.7	12.0	10.3	6218414	757564.5	**P55**
8.3	8.3	8.3	8.4	7.9	9.8	16.8	7.6	5.5	5.5	5.6	7.6	7.8	6.8	6.6	14.0	6.1	7.9	4.9	4.9	3.7	7.2	6.2	6.5	6.6	6.3	13.8	7.9	7.3	5.6	4.9	4.6	4.9	15.4	11.7	10.5	6218235	757293.2	**P56**
8.1	8.0	8.0	8.2	7.6	9.5	16.5	7.6	5.4	5.2	5.3	7.7	7.9	6.8	6.7	13.7	6.2	7.6	4.8	4.6	3.5	7.2	6.0	6.4	6.5	6.3	13.5	7.9	7.3	5.8	5.2	4.9	5.2	15.2	11.5	10.9	6217956	757116.8	**P57**
8.0	8.0	8.0	8.1	7.5	9.5	16.1	7.9	5.7	5.0	5.2	8.0	8.3	7.2	7.1	13.3	6.6	7.3	5.1	4.4	3.6	7.4	6.1	6.7	6.8	6.6	13.1	8.2	7.6	6.2	5.6	5.3	5.6	14.8	11.1	11.0	6217869	756710.8	**P58**
7.7	7.6	7.7	7.8	7.2	9.2	16.3	7.5	5.3	4.8	4.9	7.7	7.9	6.9	6.8	13.5	6.3	7.2	4.6	4.2	3.2	7.0	5.7	6.3	6.4	6.2	13.3	7.8	7.3	5.9	5.4	5.2	5.5	15.1	11.3	11.3	6217565	757015.7	**P59**
7.3	7.3	7.3	7.4	6.9	8.8	16.5	7.0	4.8	4.6	4.6	7.3	7.5	6.4	6.4	13.7	5.9	7.1	4.2	4.0	2.7	6.5	5.2	5.8	5.9	5.8	13.6	7.3	6.8	5.6	5.2	5.0	5.4	15.4	11.6	11.5	6217236	757375.3	**P60**

Appendix C - Distances to Wind Turbines

p	n	l	9B	9A	9	8A	8	7A	7	6A	6	5	4	33	31	30	3	2A	29	29	23	22	21	20	2	19	18	17	16	15	149	Receiver
4.4	1.7	4.9	0.5	0.5	0.6	0.6	0.5	0.4	0.5	2.4	2.4	2.1	2.0	7.7	6.4	6.0	2.6	5.0	4.1	4.1	5.1	4.8	4.1	7.5	5.4	7.3	6.1	6.1	6.0	4.8	3.6	**Closest Turbine Distance**
13.8	7.1	12.3	4.9	4.6	4.7	5.7	5.6	8.7	9.5	12.9	12.7	12.4	12.3	11.6	10.8	10.1	12.9	15.4	8.4	8.4	6.4	6.3	5.4	7.5	15.8	7.3	6.1	6.1	6.0	4.8	13.8	**P1**
13.3	6.6	11.7	4.5	4.1	4.3	5.5	5.3	8.4	9.2	12.6	12.4	12.2	12.1	11.0	10.2	9.5	12.7	15.2	7.8	7.8	6.0	5.8	5.0	7.6	15.6	7.4	6.2	6.2	6.3	5.1	13.6	**P2**
13.1	6.3	11.6	4.2	3.8	4.0	5.1	4.9	8.1	8.8	12.2	12.1	11.8	11.7	11.1	10.2	9.5	12.3	14.8	7.7	7.7	6.3	6.1	5.3	8.0	15.2	7.8	6.6	6.6	6.6	5.4	13.3	**P3**
12.8	6.1	11.3	3.8	3.5	3.7	4.8	4.6	7.7	8.5	11.9	11.7	11.4	11.4	10.9	10.0	9.4	12.0	14.5	7.6	7.6	6.5	6.2	5.5	8.3	14.8	8.1	7.0	7.0	6.9	5.8	12.9	**P4**
12.5	5.8	11.1	3.6	3.3	3.4	4.5	4.3	7.4	8.2	11.6	11.4	11.2	11.1	10.8	9.9	9.3	11.7	14.2	7.4	7.4	6.6	6.3	5.6	8.6	14.5	8.4	7.2	7.2	7.2	6.1	12.6	**P5**
12.5	5.8	10.7	3.9	3.6	3.7	5.3	5.1	8.3	9.0	12.2	12.1	12.0	12.0	9.8	9.1	8.3	12.5	15.0	6.6	6.6	5.1	4.8	4.1	7.7	15.3	7.6	6.6	6.6	6.9	5.7	13.5	**P6**
12.4	5.7	10.7	3.7	3.4	3.5	5.0	4.8	8.0	8.7	12.0	11.9	11.7	11.7	10.0	9.2	8.5	12.2	14.7	6.7	6.7	5.5	5.2	4.5	8.0	15.1	7.8	6.8	6.8	7.0	5.9	13.2	**P7**
12.0	5.2	10.5	3.1	2.7	2.9	4.2	3.9	7.2	7.9	11.2	11.1	10.9	10.8	10.2	9.3	8.6	11.4	13.9	6.8	6.8	6.3	5.9	5.4	8.8	14.2	8.6	7.6	7.6	7.7	6.5	12.4	**P8**
11.5	4.8	10.2	2.6	2.3	2.4	3.7	3.4	6.6	7.4	10.7	10.6	10.4	10.3	10.1	9.1	8.5	10.9	13.4	6.7	6.7	6.7	6.2	5.7	9.3	13.7	9.2	8.1	8.1	8.2	7.0	11.9	**P9**
11.1	4.4	9.8	2.1	1.8	2.0	3.1	2.9	6.1	6.9	10.2	10.0	9.8	9.8	10.0	8.9	8.4	10.3	12.8	6.5	6.5	7.1	6.6	6.1	9.9	13.2	9.7	8.6	8.6	8.7	7.5	11.3	**P10**
10.9	4.2	9.8	2.0	1.7	1.9	2.6	2.4	5.5	6.3	9.7	9.5	9.3	9.2	10.4	9.2	8.7	9.8	12.3	6.9	6.9	7.7	7.2	6.8	10.5	12.6	10.3	9.2	9.2	9.1	8.0	10.8	**P11**
11.1	4.3	9.7	2.2	1.8	2.0	3.5	3.2	6.4	7.2	10.4	10.3	10.1	10.1	9.7	8.6	8.0	10.7	13.1	6.2	6.2	6.6	6.1	5.7	9.6	13.5	9.4	8.4	8.4	8.5	7.4	11.7	**P12**
10.7	4.0	9.4	1.8	1.5	1.6	3.0	2.8	6.0	6.7	10.0	9.9	9.7	9.7	9.6	8.5	7.9	10.2	12.7	6.1	6.1	6.9	6.3	6.0	10.0	13.1	9.8	8.8	8.8	8.9	7.8	11.2	**P13**
10.5	3.8	9.2	1.5	1.2	1.4	2.7	2.5	5.7	6.4	9.7	9.6	9.4	9.4	9.6	8.5	7.9	9.9	12.4	6.1	6.1	7.2	6.6	6.3	10.3	12.8	10.1	9.1	9.1	9.2	8.0	10.9	**P14**
10.9	4.2	9.2	2.4	2.1	2.2	4.1	3.8	7.0	7.7	10.8	10.7	10.7	10.6	8.8	7.9	7.2	11.2	13.5	5.4	5.4	5.7	5.2	4.8	9.2	13.9	9.1	8.2	8.2	8.5	7.3	12.2	**P15**
10.5	3.8	8.9	1.9	1.6	1.7	3.6	3.3	6.5	7.1	10.2	10.1	10.1	10.1	8.8	7.7	7.1	10.6	13.0	5.3	5.3	6.2	5.6	5.3	9.7	13.4	9.6	8.7	8.7	9.0	7.8	11.7	**P16**
10.2	3.5	8.7	1.5	1.2	1.3	3.2	2.9	6.1	6.7	9.8	9.7	9.7	9.7	8.9	7.7	7.2	10.2	12.6	5.4	5.4	6.6	5.9	5.7	10.1	13.0	10.0	9.0	9.0	9.3	8.1	11.2	**P17**
9.6	2.9	8.3	0.9	0.6	0.6	2.7	2.4	5.5	6.1	9.2	9.1	9.1	9.1	8.8	7.5	7.1	9.6	12.0	5.2	5.2	7.1	6.4	6.2	10.7	12.4	10.6	9.7	9.7	9.9	8.7	10.7	**P18**
9.8	3.1	8.6	0.8	0.5	0.7	2.4	2.1	5.3	6.0	9.1	9.0	9.0	8.9	9.2	7.9	7.4	9.5	11.9	5.6	5.6	7.4	6.7	6.5	10.8	12.3	10.7	9.7	9.7	9.9	8.7	10.5	**P19**
9.6	3.0	8.5	0.7	0.5	0.7	1.9	1.6	4.9	5.5	8.8	8.6	8.5	8.5	9.4	8.1	7.7	9.0	11.5	5.9	5.9	7.8	7.2	6.9	11.2	11.9	11.1	10.0	10.0	10.2	9.0	10.1	**P20**
8.9	2.3	7.3	1.3	1.2	1.2	3.3	3.0	5.8	6.3	9.1	9.1	9.3	9.2	7.7	6.4	6.0	9.7	12.0	4.1	4.1	6.8	6.0	6.0	11.0	12.4	10.9	10.1	10.1	10.5	9.3	10.8	**P21**
8.7	2.0	7.2	1.1	1.1	1.0	3.0	2.7	5.5	6.0	8.8	8.7	8.9	8.9	7.8	6.5	6.1	9.4	11.7	4.3	4.3	7.1	6.3	6.4	11.3	12.1	11.2	10.4	10.4	10.7	9.5	10.5	**P22**
8.4	1.7	7.1	0.9	1.0	0.8	2.6	2.3	5.0	5.5	8.3	8.3	8.5	8.4	8.0	6.7	6.3	8.9	11.2	4.5	4.5	7.6	6.8	6.8	11.7	11.6	11.6	10.7	10.7	11.0	9.9	10.0	**P23**
8.2	1.7	7.3	0.9	1.2	1.1	1.6	1.4	3.9	4.5	7.5	7.4	7.5	7.4	8.9	7.4	7.1	8.0	10.3	5.4	5.4	8.6	7.8	7.8	12.5	10.7	12.3	11.4	11.4	11.6	10.4	9.0	**P24**
8.6	2.0	7.7	0.5	0.9	0.8	1.5	1.3	4.1	4.7	7.8	7.7	7.7	7.7	9.0	7.6	7.3	8.2	10.6	5.5	5.5	8.4	7.6	7.6	12.1	11.0	12.0	11.0	11.0	11.2	10.0	9.3	**P25**
8.9	2.4	8.0	0.6	0.9	0.8	1.3	1.0	4.1	4.7	7.9	7.8	7.7	7.7	9.4	7.9	7.6	8.2	10.6	5.9	5.9	8.5	7.8	7.6	12.0	11.0	11.9	10.9	10.9	11.0	9.8	9.3	**P27**
9.4	2.9	8.5	0.8	0.9	0.9	1.4	1.1	4.3	5.0	8.3	8.1	8.0	8.0	9.7	8.3	7.9	8.5	11.0	6.2	6.2	8.4	7.7	7.5	11.7	11.3	11.5	10.5	10.5	10.6	9.4	9.5	**P28**
8.6	2.2	7.9	1.0	1.3	1.2	1.1	0.8	3.7	4.3	7.5	7.4	7.3	7.3	9.4	8.0	7.7	7.8	10.2	6.0	6.0	8.8	8.1	8.0	12.4	10.6	12.3	11.3	11.3	11.4	10.2	8.9	**P29**
8.6	2.4	8.0	1.3	1.5	1.5	0.8	0.5	3.4	4.1	7.3	7.2	7.1	7.0	9.7	8.2	7.9	7.6	10.0	6.2	6.2	9.1	8.4	8.3	12.6	10.4	12.5	11.5	11.5	11.5	10.4	8.6	**P30**
10.3	3.9	9.5	1.8	1.7	1.8	1.6	1.5	4.6	5.4	8.8	8.6	8.3	8.2	10.6	9.3	8.9	8.8	11.3	7.1	7.1	8.6	8.0	7.7	11.4	11.7	11.2	10.1	10.1	10.1	8.9	9.8	**P31**
10.0	3.7	9.3	1.8	1.8	1.9	1.2	1.1	4.1	4.9	8.3	8.1	7.8	7.7	10.7	9.3	8.9	8.3	10.8	7.1	7.1	9.0	8.4	8.1	11.9	11.2	11.7	10.6	10.6	10.5	9.4	9.3	**P32**
9.7	3.6	9.2	1.9	2.0	2.0	0.9	0.8	3.7	4.5	8.0	7.7	7.4	7.4	10.7	9.3	8.9	8.0	10.5	7.2	7.2	9.3	8.7	8.4	12.3	10.8	12.1	11.0	11.0	10.9	9.8	8.9	**P33**
9.5	3.6	9.1	2.1	2.2	2.3	0.6	0.7	3.3	4.1	7.6	7.4	7.0	7.0	10.8	9.4	9.1	7.6	10.1	7.3	7.3	9.7	9.0	8.8	12.7	10.4	12.5	11.4	11.4	11.3	10.1	8.5	**P34**
9.8	3.9	9.4	2.4	2.5	2.6	0.9	1.0	3.4	4.2	7.7	7.5	7.1	7.0	11.2	9.7	9.4	7.6	10.2	7.7	7.7	9.8	9.2	8.9	12.7	10.5	12.5	11.3	11.3	11.2	10.1	8.5	**P35**
8.6	3.1	8.4	2.4	2.6	2.6	0.6	0.8	2.4	3.2	6.6	6.4	6.1	6.1	10.6	9.0	8.8	6.6	9.1	7.2	7.2	10.2	9.5	9.4	13.6	9.5	13.4	12.3	12.3	12.3	11.1	7.6	**P36**
8.5	3.3	8.4	2.7	3.0	2.9	0.9	1.2	2.1	2.8	6.3	6.1	5.8	5.7	10.8	9.2	9.0	6.3	8.8	7.4	7.4	10.6	9.9	9.7	13.9	9.2	13.7	12.6	12.6	12.6	11.4	7.3	**P37**
8.1	2.7	7.9	2.3	2.6	2.6	0.9	1.0	2.3	3.0	6.3	6.1	6.0	5.9	10.2	8.6	8.4	6.5	8.9	6.9	6.9	10.2	9.5	9.4	13.7	9.3	13.6	12.5	12.5	12.5	11.4	7.5	**P38**
8.1	2.9	8.0	2.7	3.0	2.9	1.1	1.3	2.0	2.7	6.0	5.8	5.7	5.6	10.5	8.8	8.7	6.2	8.6	7.1	7.1	10.6	9.8	9.7	14.1	9.0	13.9	12.8	12.8	12.8	11.7	7.2	**P39**
8.5	4.1	8.8	3.7	4.0	4.0	1.9	2.2	1.2	2.1	5.7	5.4	4.9	4.9	11.6	9.9	9.9	5.4	8.0	8.3	8.3	11.6	10.9	10.7	14.8	8.3	14.6	13.5	13.5	13.4	12.2	6.4	**P40**
8.3	3.5	8.4	3.2	3.5	3.5	1.4	1.7	1.5	2.3	5.8	5.6	5.3	5.2	11.1	9.4	9.3	5.8	8.3	7.7	7.7	11.1	10.4	10.3	14.4	8.6	14.3	13.2	13.2	13.1	11.9	6.8	**P41**
8.3	3.8	8.6	3.6	3.8	3.8	1.8	2.0	1.2	2.1	5.6	5.3	5.0	4.9	11.4	9.7	9.6	5.5	8.0	8.1	8.1	11.4	10.7	10.6	14.7	8.4	14.6	13.4	13.4	13.3	12.2	6.5	**P42**
8.4	4.2	8.8	4.0	4.3	4.3	2.2	2.5	0.9	1.8	5.4	5.0	4.6	4.5	11.7	10.0	10.0	5.1	7.6	8.5	8.5	11.9	11.2	11.1	15.2	8.0	15.0	13.8	13.8	13.7	12.6	6.0	**P43**
8.2	4.4	8.8	4.3	4.6	4.6	2.5	2.8	0.6	1.5	5.0	4.7	4.2	4.2	11.9	10.2	10.1	4.8	7.3	8.6	8.6	12.2	11.5	11.4	15.5	7.6	15.3	14.2	14.2	14.0	12.9	5.7	**P44**
8.2	4.6	8.8	4.6	4.9	4.9	2.9	3.1	0.4	1.3	4.8	4.5	3.9	3.9	12.0	10.3	10.3	4.5	7.0	8.9	8.9	12.5	11.8	11.7	15.8	7.3	15.6	14.5	14.5	14.3	13.2	5.4	**P45**
8.1	4.8	8.8	4.9	5.2	5.2	3.2	3.4	0.4	1.0	4.5	4.1	3.6	3.5	12.2	10.4	10.5	4.1	6.7	9.1	9.1	12.8	12.1	12.0	16.1	7.0	15.9	14.8	14.8	14.7	13.6	5.1	**P46**
8.3	5.2	9.2	5.3	5.6	5.5	3.5	3.8	0.8	1.2	4.5	4.1	3.4	3.3	12.6	10.8	10.9	3.9	6.5	9.5	9.5	13.2	12.4	12.3	16.4	6.8	16.2	15.0	15.0	14.9	13.8	4.8	**P47**
7.8	4.9	8.7	5.2	5.5	5.5	3.5	3.8	0.6	0.7	4.1	3.7	3.2	3.1	12.2	10.4	10.5	3.7	6.3	9.1	9.1	13.1	12.3	12.3	16.5	6.6	16.3	15.2	15.2	15.1	14.0	4.7	**P48**
7.6	5.1	8.6	5.6	5.9	5.8	3.9	4.2	0.9	0.6	3.7	3.3	2.8	2.7	12.3	10.5	10.6	3.3	5.8	9.3	9.3	13.4	12.6	12.6	16.9	6.2	16.7	15.6	15.6	15.5	14.4	4.3	**P49**
7.1	5.1	8.3	5.8	6.1	6.0	4.3	4.5	1.4	0.5	3.1	2.8	2.5	2.4	12.1	10.3	10.5	3.0	5.4	9.3	9.3	13.6	12.8	12.8	17.3	5.8	17.1	16.0	16.0	15.9	14.8	4.0	**P50**
6.9	5.4	8.3	6.2	6.5	6.4	4.7	4.9	1.8	0.9	2.7	2.4	2.1	2.0	12.3	10.5	10.7	2.6	5.0	9.5	9.5	14.0	13.2	13.2	17.7	5.4	17.5	16.4	16.4	16.3	15.2	3.6	**P51**
5.4	4.7	6.8	6.0	6.3	6.2	4.9	5.0	2.6	1.7	2.4	2.4	2.9	3.0	11.0	9.2	9.5	3.3	5.3	8.4	8.4	13.4	12.6	12.7	17.6	5.7	17.4	16.5	16.5	16.5	15.4	4.4	**P52**
5.1	4.6	6.5	6.0	6.3	6.2	5.0	5.1	2.8	2.1	2.4	2.5	3.2	3.3	10.7	8.9	9.2	3.6	5.4	8.2	8.2	13.3	12.5	12.7	17.6	5.8	17.5	16.5	16.5	16.6	15.4	4.6	**P53**
4.9	4.4	6.2	5.9	6.3	6.1	5.0	5.1	3.0	2.2	2.6	2.7	3.5	3.5	10.5	8.7	8.9	3.8	5.6	8.0	8.0	13.2	12.3	12.5	17.5	6.0	17.4	16.4	16.4	16.6	15.4	4.8	**P54**
4.7	4.1	5.9	5.7	6.0	5.9	4.9	5.0	3.0	2.4	2.9	3.0	3.8	3.9	10.1	8.3	8.6	4.2	5.9	7.6	7.6	12.9	12.0	12.2	17.2	6.4	17.1	16.2	16.2	16.3	15.2	5.2	**P55**
4.9	3.8	5.9	5.3	5.7	5.6	4.6	4.7	2.9	2.3	3.2	3.3	4.0	4.1	10.0	8.1	8.4	4.4	6.2	7.4	7.4	12.5	11.7	11.9	16.9	6.7	16.8	15.8	15.8	16.0	14.8	5.4	**P56**
4.9	3.5	5.7	5.1	5.4	5.3	4.4	4.4	2.9	2.4	3.5	3.6	4.3	4.3	9.7	7.9	8.1	4.7	6.5	7.1	7.1	12.2	11.3	11.6	16.6	7.0	16.5	15.6	15.6	15.7	14.6	5.7	**P57**
5.2	3.1	5.8	4.7	5.0	4.9	3.9	4.0	2.7	2.3	3.9	3.9	4.5	4.5	9.6	7.8	8.0	4.9	6.8	6.9	6.9	11.9	11.0	11.2	16.2	7.3	16.1	15.2	15.2	15.3	14.2	5.9	**P58**
4.8	3.1	5.4	4.8	5.1	5.0	4.2	4.3	3.1	2.7	3.9	4.0	4.7	4.7	9.3	7.5	7.7	5.1	6.9	6.7	6.7	11.9	11.0	11.2	16.3	7.4	16.2	15.3	15.3	15.5	14.3	6.2	**P59**
4.4	3.2	4.9	5.0	5.4	5.2	4.6	4.7	3.6	3.2	4.0	4.2	5.0	5.0	9.0	7.1	7.4	5.4	7.0	6.4	6.4	11.8	10.9	11.2	16.4	7.5	16.3	15.5	15.5	15.7	14.5	6.4	**P60**

NOISE FUNDAMENTALS

Noise

Hearing is a fundamental human sense and is used constantly for communication and awareness of the environment.

Noise is generally described as being ‘unwanted’ or ‘unfavourable’ sound and, to some extent, is an individual or subjective response as what may be sound to one person, may be regarded as noise by another.

The measurement and assessment of sound has been developed steadily over the last century, taking into account human response measures such as hearing damage and other potential health affects such as stress. Complex sound measurement and analytical devices have also been developed.

A-weighting and ‘dBA’

The overall level of a sound is usually expressed in terms of dBA, which is measured using the ‘A-weighting’ filter incorporated in sound level meters. These filters have a frequency response corresponding approximately to that of human hearing. People’s hearing is most sensitive to sounds at mid frequencies (typically 500 Hz to 4,000 Hz) and less sensitive at lower and higher frequencies. The level of a sound in dBA is a considered a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally as loud, although the perceived loudness can also be affected by the character of the sound (e.g. the loudness of human speech and a distant motorbike may be perceived differently, although they can be of the same dBA level).

A change of up to 3 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness.

Table 1 below presents examples of typical noise levels.

Table 1 Typical Noise Levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120 110	Heavy rock concert Grinding on steel	Extremely noisy
100 90	Loud car horn at 3 m Construction site with pneumatic hammering	Very noisy
80 70	Kerbside of busy street Loud radio or television	Loud
60 50	Department store General Office	Moderate to quiet
40 30	Inside private office Inside bedroom	Quiet to very quiet
20	Unoccupied recording studio	Almost silent

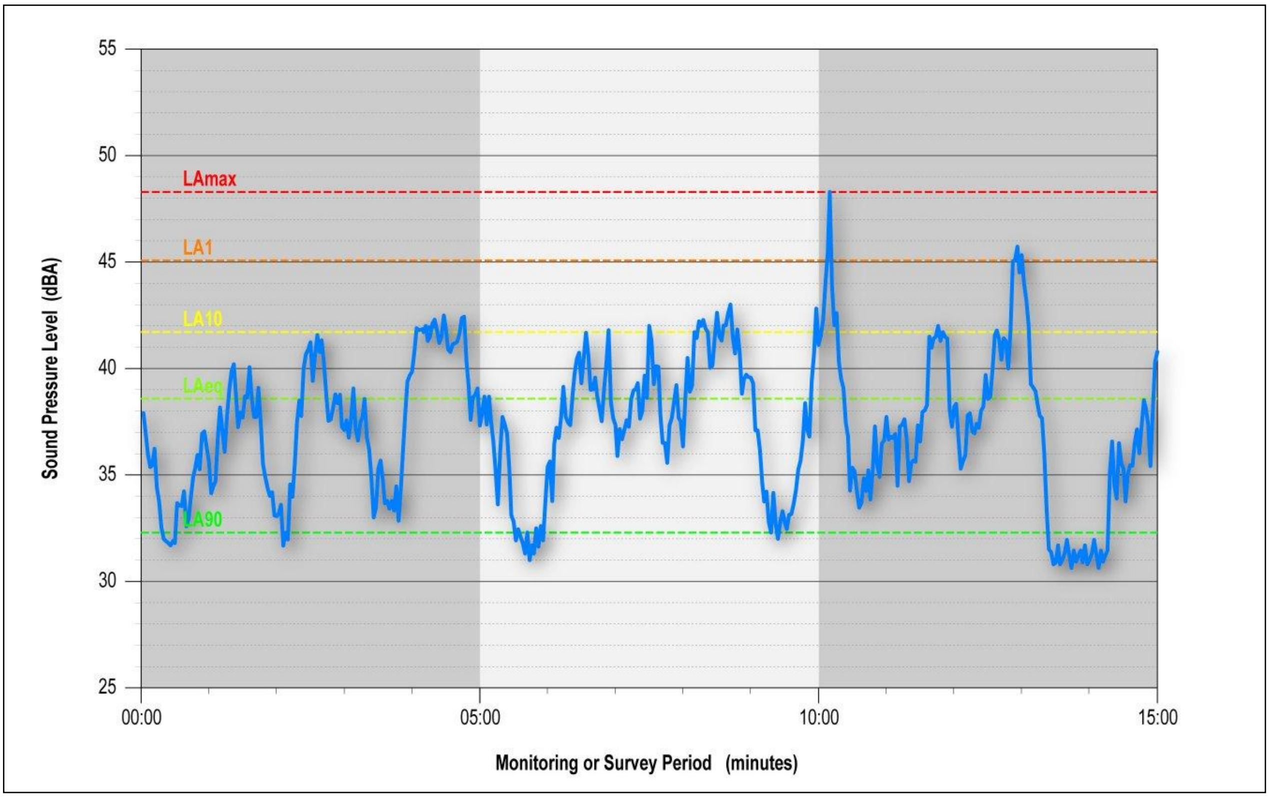
Statistical Noise Level Descriptors

As environmental noise usually varies in level over time, it is common to present the results of environmental noise testing in the form of statistical descriptors.

An explanation of noise level descriptors typically used for assessing the noise environment are illustrated in **Figure 1** and described below.

L_{Amax}	The maximum A-weighted noise level associated with a noise measurement interval.
L_{A1}	The noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given interval.
L_{A10}	The A-weighted sound pressure level exceeded 10% of a given measurement interval and is utilised normally to characterise average maximum noise levels.
L_{Aeq}	The A-weighted equivalent continuous sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time-varying sound over the same measurement interval. Can be loosely thought of as the 'average'.
L_{A90}	The A-weighted sound pressure level exceeded 90% of a given measurement interval and is representative of the average minimum sound level. Often used to describe the 'background' level.

Figure 1 Graphical Display of Typical Noise Descriptors



Character

The A-weighted noise level alone is a simplistic parameter and may not be sufficient in providing a thorough assessment of noise. The subjective character of a sound is also a significant parameter that needs to be considered.

Some basic characteristics of sound which can make a sound more or less intrusive include:

- The frequency content of a sound – i.e. low frequency sound such as exhaust noise or high frequency sound such as birds or insects,
- the 'tonality' of a sound – i.e. sound contains one or more prominent tones such as a horn or a whistle,
- the 'impulsiveness' of a sound – i.e. hammering, dog barking or a intermittently operating power saw.

The above parameters can usually be indicatively subjectively assessed, but more thorough assessment can be made with advanced sound measuring devices (i.e. narrow band or one-third octave analysis). Many noise policies provide an assessment method which applies penalties to sounds that exhibit particular characteristics such as the above.

Frequency Analysis

Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

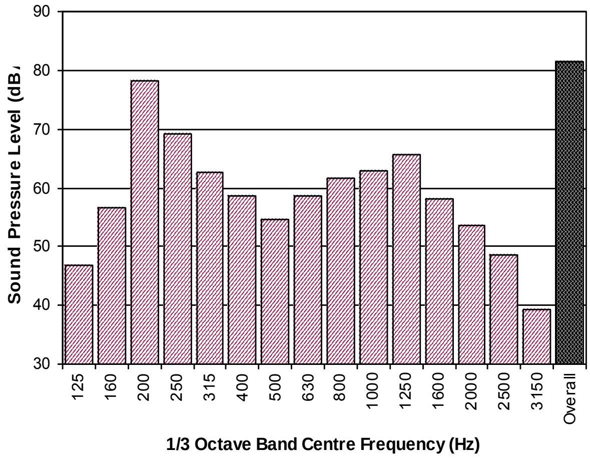
The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

Figure 2 shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.

Figure 2 Representative 1/3 Octave Band Analysis



Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of "peak" velocity or "rms" velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as "peak particle velocity", or PPV. The latter incorporates "root mean squared" averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (1E-6 mm/s). Care is required in this regard, as other reference levels are used by some organizations.

Human Perception of Vibration

People are able to "feel" vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Over-Pressure

The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

Layout Descriptions & Turbine Locations

Turbine	X	Y	Turbine Type	Turbine Model
P1	747801.12	6214761.19	Type 1	Vestas V112
P2	748312.15	6214436.95	Type 1	Vestas V112
P3	748519.70	6214803.26	Type 1	Vestas V112
P4	748803.60	6214973.12	Type 1	Vestas V112
P5	749054.78	6215129.11	Type 1	Vestas V112
P6	749245.34	6213666.85	Type 1	Vestas V112
P7	749277.89	6214044.19	Type 1	Vestas V112
P8	749637.93	6214879.49	Type 1	Vestas V112
P9	750045.99	6215202.86	Type 1	Vestas V112
P10	750487.73	6215520.35	Type 1	Vestas V112
P11	750672.77	6216152.60	Type 1	Vestas V112
P12	750521.21	6215025.33	Type 1	Vestas V112
P13	750856.37	6215277.14	Type 1	Vestas V112
P14	751065.13	6215503.43	Type 1	Vestas V112
P15	750790.66	6214083.06	Type 1	Vestas V112
P16	751180.75	6214432.91	Type 1	Vestas V112
P17	751425.00	6214787.11	Type 1	Vestas V112
P18	751941.69	6215114.62	Type 3	Vestas V90
P19	751765.12	6215480.35	Type 3	Vestas V90
P20	751924.43	6215913.25	Type 3	Vestas V90
P21	752758.57	6214376.75	Type 2	Vestas V100
P22	752945.24	6214652.27	Type 2	Vestas V100
P23	753153.94	6215076.51	Type 2	Vestas V100
P24	753358.95	6216136.19	Type 2	Vestas V100
P25	752936.95	6216108.06	Type 2	Vestas V100
P27	752654.50	6216324.83	Type 3	Vestas V90
P28	752167.15	6216398.80	Type 3	Vestas V90
P29	752969.48	6216601.43	Type 3	Vestas V90
P30	752971.37	6216909.14	Type 3	Vestas V90
P31	751295.48	6216935.08	Type 1	Vestas V112
P32	751654.02	6217233.66	Type 3	Vestas V90
P33	751942.30	6217474.14	Type 3	Vestas V90
P34	752209.40	6217766.32	Type 3	Vestas V90
P35	751952.91	6218024.61	Type 3	Vestas V90
P36	753234.49	6217980.31	Type 3	Vestas V90
P37	753414.26	6218295.67	Type 2	Vestas V100
P38	753669.52	6217768.20	Type 3	Vestas V90
P39	753790.39	6218102.49	Type 3	Vestas V90
P40	753715.79	6219273.15	Type 1	Vestas V112
P41	753755.52	6218710.05	Type 2	Vestas V100
P42	753850.54	6219051.06	Type 1	Vestas V112
P43	753989.92	6219495.01	Type 1	Vestas V112
P44	754258.21	6219702.61	Type 1	Vestas V112
P45	754452.80	6219949.71	Type 2	Vestas V100
P46	754723.69	6220153.76	Type 2	Vestas V100
P47	754672.54	6220558.81	Type 2	Vestas V100
P48	755148.59	6220270.48	Type 2	Vestas V100
P49	755526.92	6220445.70	Type 2	Vestas V100
P50	756080.37	6220346.27	Type 2	Vestas V100

Layout Descriptions & Turbine Locations

Turbine	X	Y	Turbine Type	Turbine Model
P51	756446.50	6220552.20	Type 2	Vestas V100
P52	757359.69	6219304.77	Type 1	Vestas V112
P53	757574.56	6219024.68	Type 1	Vestas V112
P54	757655.77	6218768.36	Type 1	Vestas V112
P55	757564.51	6218414.10	Type 1	Vestas V112
P56	757293.24	6218234.95	Type 1	Vestas V112
P57	757116.83	6217956.78	Type 1	Vestas V112
P58	756710.89	6217869.76	Type 1	Vestas V112
P59	757015.67	6217565.13	Type 1	Vestas V112
P60	757375.27	6217236.88	Type 1	Vestas V112

Turbine Count Summary

Type 1			31	
Type 2			14	
Type 3			14	
Total			59	

1 Low Frequency Noise

Low frequency noise has been evaluated by determining the C-weighted noise for each receptor. The overall results in dBC for each layout, for each receptor are shown in the table below.

Receiver Name	Predicted Noise Level	Receiver Name	Predicted Noise Level
1	42.6	115	39.6
2	42.6	116	35.4
2A	42.6	117	42.6
3	42.6	118	42.6
4	47.5	119	42.6
5	48.7	120	42.6
6	47.9	121	42.6
6A	44.3	122	42.6
7*	57.4	123	42.6
7A*	60.8	124	42.6
8*	59.0	125	40.0
8A*	59.0	126	41.0
9*	58.5	127	34.9
9A*	58.7	128	43.5
9B*	42.6	129	42.6
10	45.2	130	42.6
11	42.6	131	42.6
12	39.7	132	42.6
13	41.8	133	42.6
14	42.6	134	40.7
15	26.4	135	41.2
16	42.6	136	36.6
17	42.6	137	42.6
18	42.6	142	42.6
19	42.6	143	42.6
20	42.6	144	42.6
21	35.0	145	42.6
22	27.8	146	42.6
23	42.6	147	42.6
29	29.8	149	35.4
30	42.6	l^	58.7
31	42.6	n^	27.5
33	42.6	p^	49.7
114	35.6		

Note that '*' denotes a project involved property
Note that '^' denotes a location of building not identified as an official dwelling

One location (Location 7A) exceeds the night-time criteria of 60 dBC which is the trigger level for further low frequency noise investigation in the NSW Draft Wind Farm Guidelines. As discussed in the report, this is a relatively small exceedance of the critera. Aas post-construction monitoring is already planned for this location (See **Section 9** of the report)**,** it is recommended that low frequency noise is investigated at that time.

2 Tonality

Tonality is assessed using the one-third octave field testing methodology. The table below shows the level of each one third octave band relative to its sidebands. Noise is said to be tonal when the one third octave band level exceeds the level of the adjacent sidebands on both sides by:

- **5 dB or more** if the centre frequency of the band containing the tone is above 400Hz
- **8 dB or more** if the centre frequency of the band containing the tone is 160 to 400Hz inclusive
- **15 dB or more** if the centre frequency of the band containing the tone is below 160Hz

The results presented in the tables below in each column are for either side-band, respectively.

Tonality Test

	Frequency (Hz)																					
Receiver	**31**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	**1.6k**	**2k**	**2.5k**	**3.15k**	**4k**	**5k**
1	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,1	-1,0	0,1	-1,-2	2,0	0,1	-1,2	-2,4	-4,5	-5,7	-7,13	-13,17	-17,25	-25,-55
2A	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
3	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,1	-1,0	0,1	-1,-3	3,-1	1,1	-1,3	-3,6	-6,10	-10,13	-13,23	-23,-44	44,0	0,0
4	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,0	0,0	0,1	-1,-2	2,0	0,1	-1,3	-3,6	-6,10	-10,13	-13,22	-22,-40	40,0	0,0
5	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,2	-2,0	0,1	-1,-2	2,0	0,0	0,1	-1,6	-6,10	-10,13	-13,23	-23,-45	45,0	0,0
6	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
6A	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
7	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
7A	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,2	-2,0	0,1	-1,-2	2,1	-1,1	-1,3	-3,5	-5,8	-8,11	-11,20	-20,-39	39,0	0,0
8	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
8A	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
9	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
9A	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
9B	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
10	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,1	-1,0	0,1	-1,-2	2,0	0,1	-1,3	-3,5	-5,7	-7,9	-9,16	-16,22	-22,-52	52,0
11	N/A	2,-5	5,-3	3,-6	6,0	0,-4	4,1	-1,-1	1,-1	1,1	-1,0	0,1	-1,-1	1,0	0,2	-2,3	-3,3	-3,7	-7,10	-10,13	-13,23	-23,-50	50,0
12	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,2	-2,1	-1,2	-2,-1	1,1	-1,2	-2,3	-3,6	-6,10	-10,13	-13,23	-23,-54	54,0	0,0
13	N/A	1,-4	4,-3	3,-8	8,1	-1,-5	5,2	-2,-1	1,-2	2,1	-1,0	0,1	-1,-2	2,-1	1,1	-1,2	-2,5	-5,8	-8,11	-11,16	-16,25	-25,-52	52,0
14	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
15	N/A	0,-4	4,-3	3,-9	9,2	-2,-6	6,2	-2,-1	1,-2	2,2	-2,0	0,2	-2,-1	1,1	-1,2	-2,3	-3,6	-6,9	-9,12	-12,21	-21,-41	41,0	0,0
16	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
17	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
18	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

	Frequency (Hz)																						
Receiver	**31**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	**1.6k**	**2k**	**2.5k**	**3.15k**	**4k**	**5k**
19	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20	N/A	1,-5	5,-3	3,-8	8,1	-1,-5	5,2	-2,-1	1,-1	1,1	-1,0	0,2	-2,-1	1,1	-1,2	-2,3	-3,5	-5,10	-10,14	-14,22	-22,-48	48,0	0,0
21	N/A	2,-5	5,-3	3,-7	7,1	-1,-4	4,2	-2,-1	1,-1	1,1	-1,0	0,1	-1,-1	1,0	0,2	-2,3	-3,3	-3,8	-8,10	-10,13	-13,24	-24,-52	52,0
22	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,2	-2,1	-1,2	-2,-1	1,1	-1,2	-2,4	-4,7	-7,11	-11,14	-14,24	-24,-56	56,0	0,0
23	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
29	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
30	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
31	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
33	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
114	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
115	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
116	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
117	N/A	2,-5	5,-3	3,-7	7,0	0,-4	4,2	-2,-2	2,-1	1,1	-1,-1	1,2	-2,0	0,0	0,3	-3,3	-3,4	-4,9	-9,12	-12,17	-17,-42	42,0	0,0
118	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,0	0,-1	1,2	-2,1	-1,2	-2,-1	1,2	-2,3	-3,4	-4,7	-7,12	-12,15	-15,-52	52,0	0,0	0,0
119	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
120	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
121	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
122	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
123	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
124	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
125	N/A	0,-4	4,-3	3,-10	10,2	-2,-6	6,2	-2,-2	2,-3	3,2	-2,0	0,1	-1,-2	2,0	0,0	0,2	-2,6	-6,10	-10,13	-13,22	-22,-45	45,0	0,0
126	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,2	-2,1	-1,2	-2,-1	1,1	-1,2	-2,4	-4,7	-7,11	-11,14	-14,-41	41,0	0,0	0,0
127	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

	Frequency (Hz)																					
Receiver	**31**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	**1.6k**	**2k**	**2.5k**	**3.15k**	**4k**	**5k**
128	N/A	3,-5	5,-2	2,-3	3,-3	3,-2	2,-1	1,-3	3,0	0,0	0,-2	2,1	-1,-1	1,-2	2,3	-3,1	-1,2	-2,9	-9,13	-13,19	-19,-41	41,0	0,0
129	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
130	N/A	2,-5	5,-2	2,-5	5,0	0,-3	3,1	-1,-2	2,0	0,0	0,-1	1,1	-1,0	0,-1	1,2	-2,1	-1,2	-2,7	-7,9	-9,12	-12,21	-21,-38	38,0
131	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
132	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
133	N/A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
134	N/A	1,-5	5,-3	3,-9	9,1	-1,-5	5,2	-2,-2	2,-1	1,1	-1,-1	1,1	-1,-1	1,-1	1,2	-2,2	-2,2	-2,6	-6,8	-8,9	-9,17	-17,27	-27,-51
135	N/A	1,-5	5,-3	3,-8	8,1	-1,-5	5,2	-2,-1	1,-1	1,1	-1,-1	1,1	-1,-1	1,0	0,2	-2,2	-2,2	-2,6	-6,8	-8,10	-10,18	-18,27	-27,-52
136	N/A	1,-5	5,-3	3,-8	8,1	-1,-5	5,2	-2,-2	2,-2	2,1	-1,-1	1,1	-1,-2	2,0	0,1	-1,2	-2,3	-3,6	-6,8	-8,13	-13,19	-19,29	-29,-59
137	N/A	1,-5	5,-3	3,-7	7,1	-1,-4	4,1	-1,-2	2,-1	1,1	-1,-1	1,1	-1,-1	1,0	0,2	-2,2	-2,3	-3,6	-6,9	-9,13	-13,21	-21,-38	38,0
142	N/A	2,-5	5,-3	3,-6	6,-1	1,-3	3,0	0,-3	3,-1	1,-1	1,-2	2,1	-1,-1	1,-2	2,1	-1,0	0,-1	1,2	-2,3	-3,2	-2,7	-7,9	-9,13
143	N/A	2,-5	5,-3	3,-6	6,-1	1,-4	4,1	-1,-3	3,-1	1,0	0,-2	2,0	0,-1	1,-1	1,1	-1,0	0,-1	1,2	-2,3	-3,2	-2,5	-5,8	-8,11
144	N/A	3,-5	5,-4	4,-4	4,-2	2,-3	3,-1	1,-1	1,-1	1,-1	1,0	0,0	0,-2	2,0	0,0	0,0	0,1	-1,3	-3,3	-3,4	-4,5	-5,8	-8,11
145	N/A	3,-5	5,-4	4,-3	3,-2	2,-2	2,-1	1,-1	1,-1	1,-1	1,-1	1,0	0,-2	2,0	0,0	0,0	0,1	-1,3	-3,3	-3,4	-4,6	-6,8	-8,12
146	N/A	3,-5	5,-3	3,-3	3,-2	2,-2	2,-1	1,-1	1,-1	1,-1	1,-1	1,0	0,-2	2,-1	1,0	0,0	0,0	0,2	-2,3	-3,4	-4,7	-7,10	-10,14
147	N/A	3,-5	5,-3	3,-3	3,-2	2,-2	2,-2	2,-1	1,-1	1,-1	1,-1	1,0	0,-2	2,-1	1,0	0,0	0,0	0,2	-2,3	-3,3	-3,5	-5,8	-8,11
149	N/A	3,-5	5,-3	3,-3	3,-2	2,-2	2,-1	1,-2	2,-1	1,-1	1,-1	1,0	0,-2	2,-1	1,1	-1,0	0,0	0,2	-2,3	-3,3	-3,6	-6,9	-9,13
l	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,2	-2,1	-1,2	-2,-1	1,1	-1,2	-2,4	-4,7	-7,11	-11,15	-15,-43	43,0	0,0	0,0
n	N/A	2,-5	5,-3	3,-6	6,0	0,-4	4,1	-1,-2	2,-1	1,0	0,-2	2,0	0,-1	1,-1	1,2	-2,1	-1,1	-1,5	-5,7	-7,8	-8,15	-15,23	-23,-35
p	N/A	0,-4	4,-3	3,-9	9,2	-2,-5	5,3	-3,-1	1,-2	2,2	-2,1	-1,2	-2,-1	1,1	-1,2	-2,4	-4,7	-7,10	-10,14	-14,24	-24,-47	47,0	0,0