MARSHALL DAY Acoustics

HAWKESDALE WIND FARM
PRE-CONSTRUCTION NOISE ASSESSMENT

Rp 003 R01 20180787 | 29 October 2020

Marshall Day Acoustics Pty Ltd
ABN: 53 470 077 191
6 Gipps Street
Collingwood VIC 3066
Australia
T: +613 9416 1855
www.marshallday.com

Project:	**HAWKESDALE WIND FARM**
Prepared for:	**Global Power Generation Australia Pty Ltd** **Suite 4, Level 3, 24 Marcus Clarke Street** **Canberra ACT 2600**
Attention:	**Guillermo Alonso Castro**
Report No.:	**Rp 003 R01 20180787**

Disclaimer

Reports produced by Marshall Day Acoustics Limited are based on a specific scope, conditions and limitations, as agreed between Marshall Day Acoustics and the Client. Information and/or report(s) prepared by Marshall Day Acoustics may not be suitable for uses other than the specific project. No parties other than the Client should use any information and/or report(s) without first conferring with Marshall Day Acoustics.

The advice given herein is for acoustic purposes only. Relevant authorities and experts should be consulted with regard to compliance with regulations or requirements governing areas other than acoustics.

Copyright

The concepts and information contained in this document are the property of Marshall Day Acoustics Limited. Use or copying of this document in whole or in part without the written permission of Marshall Day Acoustics constitutes an infringement of copyright. Information shall not be assigned to a third party without prior consent.

Document Control

Status:	Ver:	Comments	Date:	Author:	Reviewer:
Complete	-	For external issue	28 Oct 2020	T. Mower	J. Adcock
Complete	R01	Minor amendments	29 Oct 2020	T. Mower	J. Adcock

EXECUTIVE SUMMARY

This report presents the results of an updated assessment of operational wind turbine noise for the approved Hawkesdale Wind Farm (the wind farm) that is being developed by Global Power Generation Australia Pty Ltd (GPG).

The amended planning permit for the wind farm issued 21 December 2017 allows for the development of twenty-six (26) wind turbines with an overall height of up to 180 m above ground level, and related on-site infrastructure.

Condition 42 of the planning permit requires the operation of the wind farm to comply with the noise criteria specified in NZS 6808:2010 *Acoustics – Wind farm noise*, consistent with current wind farm noise guidelines in Victoria.

A noise assessment in accordance with NZS 6808:2010 was prepared in 2017 to accompany the application to amend the planning permit for the wind farm. The 2017 noise assessment was based on three (3) candidate wind turbines which were representative of the size and type of turbine being considered for the project. GPG have since nominated a preferred turbine model for the site and elected to remove three (3) turbines from the layout considered in the 2017 noise assessment. GPG therefore commissioned this report to update the operational noise compliance assessment for the preferred turbine selection and the reduced turbine layout.

The updated assessment has been carried out on the basis of the proposed layout comprising twenty-three (23) Vestas V136-4.2MW wind turbines with a hub height of 112 m.

Vestas performance specifications for the V136-4.2MW were provided as the basis for the assessment, comprising noise emissions data based on results in accordance with IEC 61400-11:2012 *Wind turbines – Part 11: Acoustic noise measurement techniques* (IEC 61400-11:2012) for a range of configurations of the turbine. The standard power optimised configuration of the turbine has been selected for the Hawkesdale Wind Farm, which incorporates serrated turbine blades and does not utilise sound management modes. The noise emission data for the standard configuration is consistent with the range of values expected for the class of turbine being installed at the site.

The noise emission data has been used with international standard ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation* (ISO 9613-2) to predict the level of noise expected occur at neighbouring sensitive receiver locations. The ISO 9613-2 standard has been applied on the basis of well-established input choices and adjustments, based on research and international guidance, that are specific to wind farm noise assessment.

The results of the noise predictions for the Hawkesdale Wind Farm demonstrate that the predicted noise levels for the preferred turbine model and reduced wind farm layout achieve the noise limits defined in the planning permit for the Hawkesdale Wind Farm.

The updated noise assessment therefore demonstrates that the Hawkesdale Wind Farm is expected to comply with the operational noise requirements of the planning permit.

TABLE OF CONTENTS

1.0 INTRODUCTION

This report presents the results of a pre-development operational noise assessment for the approved Hawkesdale Wind Farm.

The Hawkesdale Wind Farm (the wind farm) is a consented project located in Moyne Shire, near the township of Hawkesdale, Victoria, between Hamilton and Warrnambool. The planning permit for the wind farm includes conditions which specify requirements for the control of environment noise associated with the project.

The planning permit[1] for the wind farm allows for the use and development of a wind energy facility comprising a maximum of twenty-six (26) wind turbines and associated on-site infrastructure, subject to a set of conditions relating to matters including environmental noise levels.

Marshall Day Acoustics (MDA) prepared a noise assessment report in 2017[2] (the 2017 noise assessment) to accompany the application to amend the planning permit for the wind farm. The 2017 noise assessment was prepared in accordance with NZS 6808:2010[3], as required by the Victorian Government's *Development of Wind Energy Facilities in Victoria – Policy and Planning Guidelines* (current version dated March 2019).

Global Power Generation Australia Pty Ltd (GPG) is developing the wind farm and have nominated a preferred turbine for the site and propose to remove three (3) turbines from the layout considered in the 2017 noise assessment. GPG has therefore commissioned this report to address these changes and provide an updated pre-construction noise assessment.

The updated noise assessment presented in this report is based on:

- Operational noise limits derived in accordance with the planning permit
- Predicted noise levels for the proposed Hawkesdale Wind Farm design comprising a revised layout of twenty-three (23) Vestas V136-4.2MW wind turbines with rated power 4.2 MW per turbine
- A comparison of the predicted noise levels with the criteria derived in accordance with NZS 6808:2010 planning permit.

Acoustic terminology used in this report is presented in Appendix A.

Throughout this report, the term receiver refers to noise sensitive locations, comprising any dwelling existing on land in the vicinity of the proposed wind energy facility as of 28 February 2017 as stated in the planning permit.

[1] Planning permit No.: 20060221-A as amended 21 December 2017

[2] MDA report Rp 002 R04 2014362ML dated 21 April 2017

[3] New Zealand Standard NZS 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010)

2.0 PROJECT DESCRIPTION

2.1 Overview

The Hawkesdale Wind Farm is to comprise twenty-three (23) wind turbines, extending over an area spanning approximately 6 km from north to south and 4 km east to west.

The proposed layout corresponds to the endorsed layout of the wind farm, as accounted for in the 2017 noise assessment report, reduced by the removal of three (3) turbines (turbines A10, A13 and A17). The coordinates of the proposed turbine locations are tabulated in Appendix B.

A total of one hundred and sixty-eight (168) dwelling locations have been identified for the noise assessment, comprising:

- One hundred and sixty-two (162) dwellings located outside of the wind farm site boundary, which are collectively referred to as noise sensitive locations (receivers)
- Six (6) dwellings located within the wind farm site boundary, which are collectively referred to as stakeholder receivers herein.

In accordance with Section 2.4 of NZS 6808:2010, noise sensitive locations are defined as follows:

> *The location of a noise sensitive activity, associated with a habitable space or education space in a building not on the wind farm site.*

Accordingly, noise limits determined in accordance with the standard do not apply to the six (6) stakeholder receivers located within the wind farm site boundary.

The coordinates of the receivers are tabulated in Appendix C.

A site layout plan illustrating the turbine layout and receiver locations is provided in Appendix D.

2.2 Wind turbine model

The wind farm is to comprise twenty-three (23) Vestas V136-4.2MW wind turbines with a rotor diameter of 136 m and a hub height of 112 m.

The Vestas V136-4.2MW model is a variable speed wind turbine, with the speed of rotation and the amount of power generated by the turbines being regulated by control systems which vary the pitch of the turbine blades (the angular orientation of the blade relative to its axis).

The standard power optimised configuration of the turbine has been selected for the Hawkesdale Wind Farm, which incorporates serrated turbine blades and does not utilise sound management modes.

Details of the proposed wind turbines are provided in Table 1.

Table 1: Proposed wind turbine model

Detail	Description
Make	Vestas
Model	V136
Rated power	4.2 MW
Rotor diameter	136 m
Hub height	112 m
Tip height	180 m
Blade orientation	Upwind
Turbine regulation method	Variable blade pitch
Cut-in wind speed (hub height)	3.0 m/s
Rated power wind speed (hub height)	13.0 m/s
Cut-out wind speed (hub height)	25.0 m/s

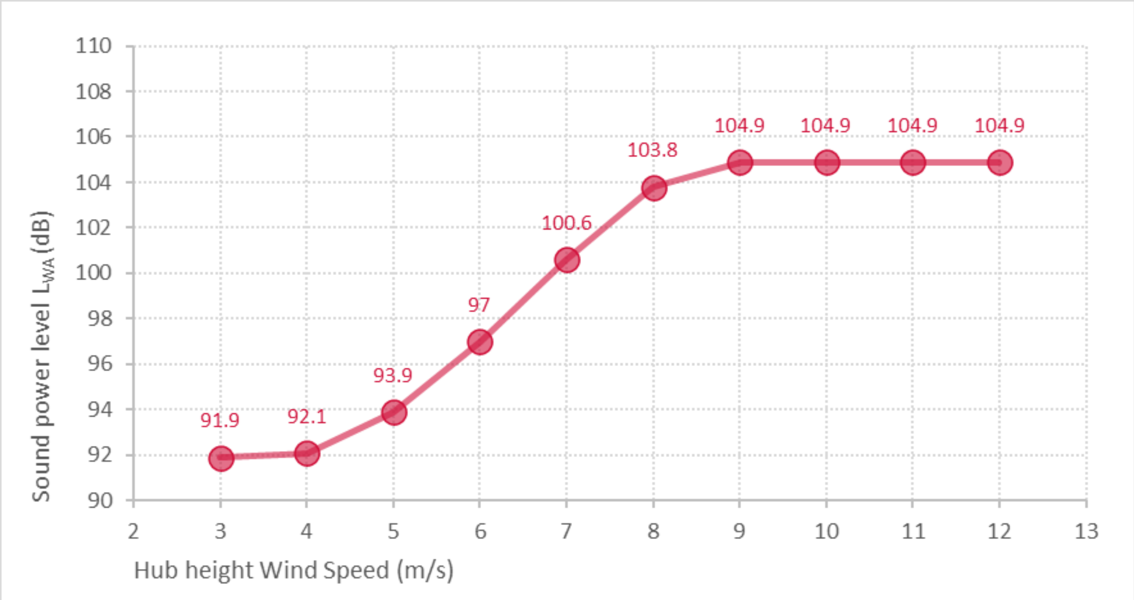
2.3 Wind turbine noise emissions

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

Sound power level data for the proposed turbine model were sourced from Vestas document *V136-4.0/4.2 MW Third octave noise emission (Document no. DMS 0067-4732 V03)* dated 3 March 2018 (data supplied by ERM on behalf of GPG on 10 September 2020). The sound power data has been adjusted by the addition of +1.0 dB at each wind speed to provide a margin for typical values of test uncertainty.

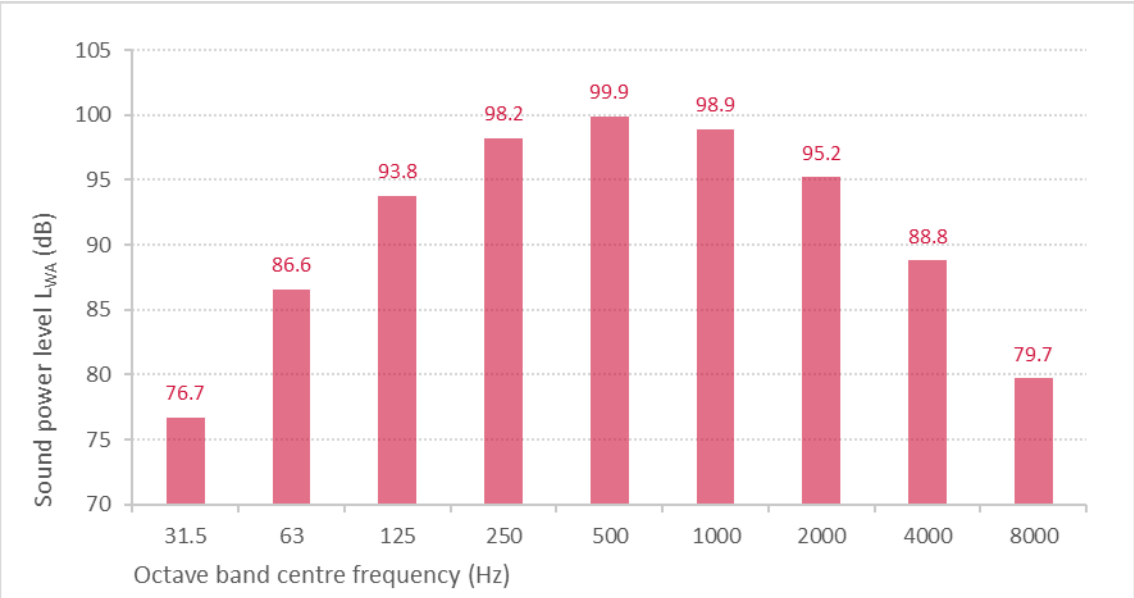
The sound power levels referenced in this assessment (including the +1 dB adjustment) for the standard configuration of the turbine (PO1 operating mode with serrated trailing edge – sound management modes not utilised), are summarised in Figure 1 and represent the total emissions of the turbines, including the secondary contribution of ancillary plant associated with the turbines (e.g. cooling fans).

Figure 1: Vestas V136-4.2MW sound power level versus hub height wind speed, dB L_{WA}



Frequency spectrum data is available for a range of wind speeds (3 m/s to 20 m/s) for the Vestas V136-4.2MW turbine. The data was reviewed to identify the spectrum which would result in the highest predicted noise levels, which typically occurs when the sum of the noise levels in the 31.5 Hz to 250 Hz octave bands is highest. For the Vestas V136-4.2MW turbine, this spectrum occurs at 18 m/s. The reference spectrum used as the basis for this assessment is illustrated in Figure 2, and corresponds to the highest overall sound power level of 104.9 dB L_{WA} (including the +1 dB adjustment) presented in Figure 1.

Figure 2: Vestas V136-4.2MW assessment sound power level spectrum, dB L_{WA}



The sound power levels illustrated in Figure 1 and Figure 2 are considered typical of the upper range of noise emissions associated with comparable multi-megawatt wind turbines.

Test emission data indicating tonal audibility levels (for the Vestas V136-4.2MW turbine were sourced from Vestas document titled *V136-4.2 MW 50 Hz, PO1, 230933 – Results of acoustic noise measurements according to IEC 61400-11 Edition 3.0* (Report No.: 10161571-A-1-A dated 9 September 2019), supplied by ERM on behalf of GPG on 22 October 2020.

The results are reproduced in Table 2.

Table 2: Measured tonal audibility and corresponding frequency

Hub height wind speed (m/s)	**8.0**	**8.5**	**9.0**	**9.5**	**10.0**	**10.5**	**11.0**	**11.5**
Tonal audibility, dB $\Delta L_{a,k}$	1.30	0.10	0.03	-0.75	-0.17	-1.23	-1.14	-2.91
Frequency, Hz	121	2185	1389	2187	2191	2190	2186	2193

The data presented in Table 2 indicates very low tonal audibility values determined from sound power level testing in proximity of the turbines (i.e. less than 200 m from a turbine). Tonal audibility levels at greater distances from the turbines, corresponding to the location of receivers, are generally lower than those measured close to the turbines. This is particularly the case for higher frequency tones (e.g. tones above 1000 Hz) which attenuate rapidly with distance as a result of the effects of atmospheric absorption. Accordingly, based on the data in Table 2, tonality is not expected to be a characteristic of the wind farm at receiver locations. Further, the occurrence of tonality in the noise emissions of contemporary multi-megawatt turbine designs is generally limited. Adjustments for tonality have therefore not been applied to the predicted noise levels presented in this assessment.

3.0 ASSESSMENT CRITERIA

3.1 Planning permit

Conditions 42 to 45 of the planning permit[4] for the Hawkesdale Wind Farm establish requirements relevant to operational noise associated with the project.

A brief summary of the conditions is provided in Table 3 below. Full details of the conditions are reproduced in Appendix E.

Table 3: Planning Permit – summary of operational noise related requirements

Condition	Summary Requirement
42	Specifies the criteria that operational wind farm noise must comply with at receivers, specifies exemptions for dwellings where an agreement exists between a land owner and the project developer, and specifies the application of penalties for special audible characteristics.
43	Establishes a requirement and time frame for post-construction noise assessments to be undertaken following commissioning of the first turbine.
44	Establishes a requirement for post-construction noise monitoring results to be forwarded to the Minister for Planning within a set time frame following commissioning of the first turbine of the wind farm.
45	Establishes a requirement for the post-construction noise compliance reports to be accompanied by a report from an environmental auditor.

The planning permit refers to NZS 6808:2010 as the applicable standard for:

- the measurement and analysis of background noise levels; and
- the measurement, rating and assessment of operational wind farm noise levels, including the assessment of any special audible characteristics associated with the sound of the wind farm.

[4] Planning permit No.: 20060221-A as amended 21 December 2017

3.2 Operational noise criteria

Condition 42(a) of the permit specifies the operational noise criteria in accordance with NZS 6808:2010 as 40 dB or the background L_{A90} + 5 dB, whichever is higher.

In relation to the background conditions in the area, background noise levels were measured at multiple receiver locations in the vicinity of the wind farm for the purpose of setting noise criteria in accordance with the planning permit. The results are documented in the background noise report[5], which also details the applicable noise limits determined in accordance with the planning permit. The noise limits detailed in Section 3.2 of the background noise report are reproduced in Table 4 and Table 5.

Table 4: All-time period operational wind farm noise limits, dB L_{A90}

Location	Hub height wind speed (m/s) [1]												
	3	4	5	6	7	8	9	10	11	12	13	14	15
59	40	40	40	40	40	40	40	40	40	40.4	41.9	43.6	45.4
60	40	40	40	40	40	40	40	41.3	43.2	45.1	47.2	49.2	51.3
62	40	40	40	40	40	40	40	40	40	41.1	43.1	45.2	47.4
89 (proxy)	40	40	40	40	40	40	40	40	40.2	41.9	43.6	45.5	47.6
169	40	40	40	40	40	40	40	40	40.7	41.9	43.2	44.6	46.2
170	40	40	40	40	40	40	40	40	40.7	42.1	43.5	45.1	46.7

Note 1: 112 m above ground level at 617273 m E, 5778426 N (AGD66 Zone 54)

Table 5: Night-time period operational wind farm noise limits, dB L_{A90}

Location	Hub height wind speed (m/s) [1]												
	3	4	5	6	7	8	9	10	11	12	13	14	15
59	40	40	40	40	40	40	40	40	40	40	40	40	40
60	40	40	40	40	40	40	40	40	40	41.3	42.8	43.9	44.5
62	40	40	40	40	40	40	40	40	40	40	40	41.4	43.4
89 (proxy)	40	40	40	40	40	40	40	40	40	40	40	40.1	40.7
169	40	40	40	40	40	40	40	40	40	40	40	40	41
170	40	40	40	40	40	40	40	40	40	40	40	40	40

Note 1: 112 m above ground level at 617273 m E, 5778426 N (AGD66 Zone 54)

In accordance with the planning permit and NZS 6808:2010, the noise criteria do not apply at stakeholder receiver locations.

[5] MDA report Rp 002 20180787 dated 20 August 2020

4.0 NOISE PREDICTION METHODOLOGY

Operational wind farm noise levels have been predicted on the basis of:

- The noise emissions of the Vestas V136-4.2MW wind turbines as outlined in Section 2.3
- A 3D digital model of the site and the surrounding environment
- International standards used for the calculation of environmental sound propagation, with input settings and adjustments specifically suited to wind farm noise assessment.

The prediction method is consistent with the guidance provided by NZS 6808:2010, as referenced in the planning permit, and the prediction method used for the 2017 noise assessment report. This method has been shown to provide a reliable method of predicting the upper level of noise expected in practice.

The noise prediction method is summarised in Table 6 below.

Table 6: Downwind prediction methodology

Detail	Description
Software	Proprietary noise modelling software SoundPLAN version 8.0
Method	International Standard ISO 9613-2:1996 *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (ISO 9613-2). Adjustments to the ISO 9613-2 method are applied on the basis of the guidance contained in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (the UK Institute of Acoustics guidance). The adjustments are applied within the SoundPLAN modelling software and relate to the influence of terrain screening and ground effects on sound propagation. Specific details of adjustments are noted below. Further discussion of the prediction method is provided in Appendix F.
Source characterisation	Each wind turbine is modelled as a point source of sound. The total sound of the wind farm is then calculated on the basis of simultaneous operation of all wind turbines and summing the contribution of each. Calculations of turbine to receiver distances and average sound propagation heights are made on the basis of the point source being located at the position of the hub of the turbine. Calculations of terrain related screening are made on the basis of the point source being located at the maximum tip height of each turbine. Further discussion of terrain screening effects is provided below.
Terrain data	10 m interval contour data, as referenced in the 2017 noise assessment report
Terrain effects	Adjustments for the effect of terrain are determined and applied on the basis of the UK Institute of Acoustics guidance and research outlined in Appendix F. Valley effects: + 3dB is applied to the calculated noise level of a wind turbine when a significant valley exists between the wind turbine and calculation point. A significant valley is determined to exist when the actual mean sound propagation height between the turbine and calculation point is 50 % greater than would occur if the ground was flat. Terrain screening effects: only calculated if the terrain blocks line of sight between the maximum tip height of the turbine and the calculation point. The value of the screening effect is limited to a maximum value of 2 dB.

Detail	Description
Ground conditions	Ground factor of G = 0.5 on the basis of the UK good practice guide and research outlined in Appendix F. The ground around the site corresponds to acoustically soft conditions (G=1) according to ISO 9613-2. The adopted value of G = 0.5 assumes that 50 % of the ground cover is acoustically hard (G = 0) to account for variations in ground porosity and provide a cautious representation of ground effects.
Atmospheric conditions	Temperature 10 °C and relative humidity 70 % These represent conditions which result in relatively low levels of atmospheric sound absorption and are chosen on the basis of the UK Institute of Acoustics guidance. The calculations are based on sound speed profiles[6] which increase the propagation of sound from each turbine to each receiver location, whether as a result of thermal inversions or wind directed toward each calculation point.
Receiver heights	1.5 m above ground level

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

5.0 ASSESSMENT

5.1 Hawkesdale Wind Farm

This section of the report presents the predicted noise levels of the Hawkesdale Wind Farm at surrounding receivers, and an assessment of compliance with the applicable noise limits.

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

The receiver locations where operational wind farm noise levels are predicted to be higher than 35 dB L_{A90} are listed in Table 7, along with the predicted noise levels when the wind farm's noise emissions have reached their highest level (corresponding to hub-height wind speeds of 9 m/s and above). The location of the predicted 35 dB and 40 dB L_{A90} noise contours is illustrated in Figure 3.

Table 7: Predicted noise level at receivers on or within the 35 dB L_{A90} predicted noise contour

Receiver	Highest predicted noise level dB L_{A90}	Compliance with NZS 6808:2010 base noise limit of 40 dB L_{A90}
53	35.0	Yes
61 (s)	37.2	Not applicable
89	35.4	Yes
90 (s)	38.4	Not applicable
101	36.8	Yes
164 (s)	37.1	Not applicable
165	35.5	Yes
166 (s)	37.2	Not applicable
169	37.5	Yes

(s) Stakeholder receiver

The results presented in Table 7 demonstrate that the predicted noise levels are below the minimum limit of 40 dB at all non-stakeholder receivers.

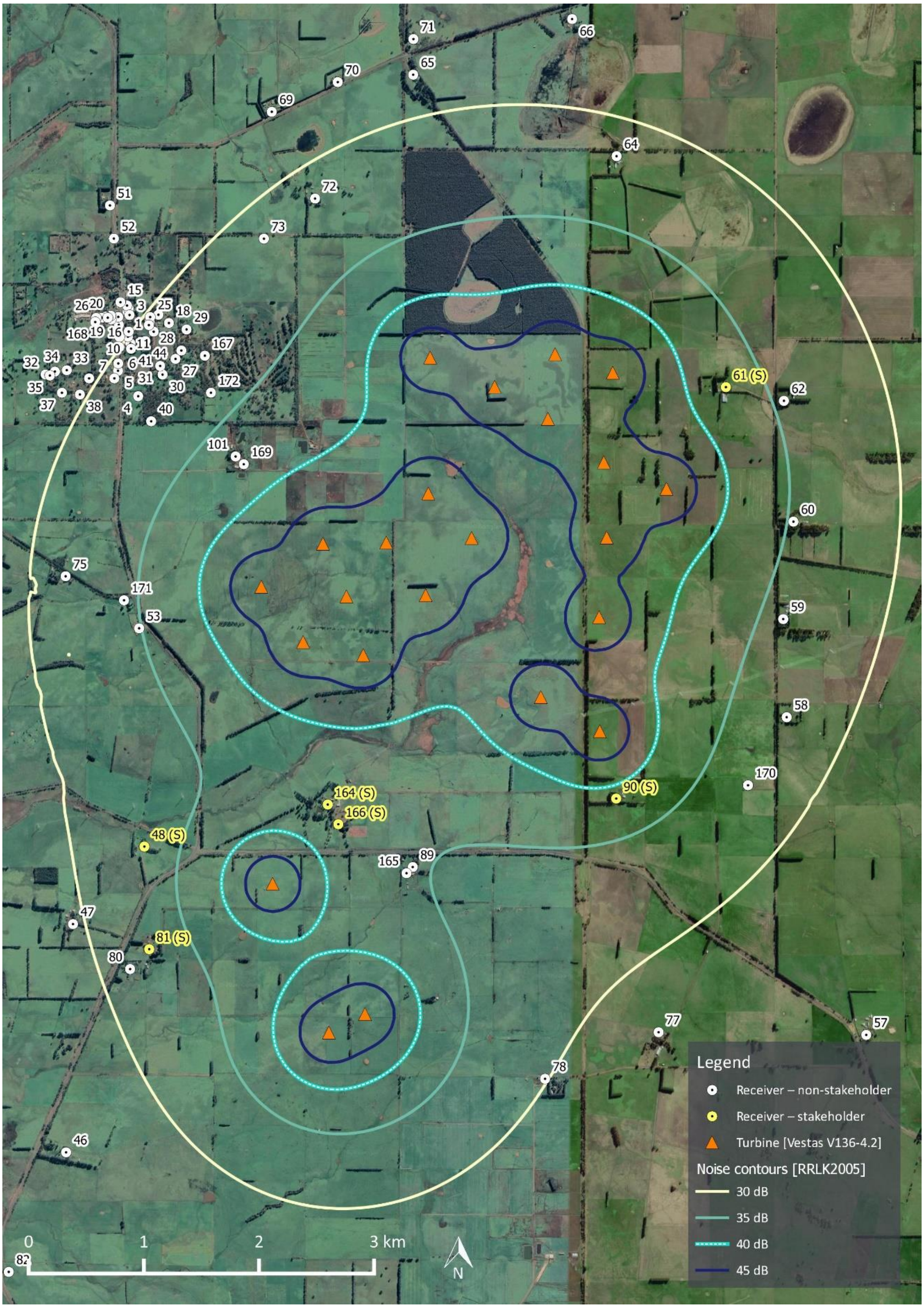
The predicted noise levels at all other receivers not listed in Table 7 are less than 35 dB L_{A90} (see Appendix G for results at these locations).

The results therefore demonstrate that the Hawkesdale Wind Farm is predicted to comply with the operational noise requirements of the permit.

Further, while the noise criteria do not apply at stakeholder receivers, the results presented in Table 7 also demonstrate predicted noise levels below 40 dB L_{A90} at stakeholder receivers.

In addition to the assessment of compliance presented in this section, a comparison of the updated predicted noise levels and those of the 2017 noise assessment is presented in Appendix H.

Figure 3: Hawkesdale Wind Farm - highest predicted noise level contours (corresponding to hub-height wind speeds of 9 m/s or greater)



5.2 Cumulative noise levels

Woolsthorpe Wind Farm is a proposed wind farm located to the southeast of the Hawkesdale Wind Farm. An assessment of cumulative noise levels with the Woolsthorpe Wind Farm was undertaken as part of the 2017 assessment. The 2017 noise assessment report noted the following:

> *The cumulative noise assessment indicates that, for receiver locations where predicted noise levels from the Hawkesdale Wind Farm are greater than the Woolsthorpe Wind Farm, predicted cumulative noise levels satisfy the relevant base noise limit applicable to the Hawkesdale Wind Farm. Where predicted noise levels are dominated by the Woolsthorpe Wind Farm, the contribution from the Hawkesdale Wind Farm is not more than 0.4 dB.*

The updated predicted noise levels presented in this report are generally lower than previously presented in the 2017 assessment for Hawkesdale Wind Farm at the majority of receiver locations. At three (3) non-stakeholder locations the predictions have increased by not more than 0.1 dB and are still well below the applicable minimum noise limit.

Therefore, based on the Woolsthorpe layout considered in the 2017 noise assessment report, the cumulative assessment findings remain valid for the updated noise assessment of the Hawkesdale Wind Farm presented in this report. Accordingly, no further assessments of cumulative noise levels were warranted or undertaken as part of this assessment.

6.0 SUMMARY

An updated assessment of operational wind turbine noise for the Hawkesdale Wind Farm has been carried out.

The assessment has been undertaken on the basis of the proposed layout comprising twenty-three (23) Vestas V136-4.2MW wind turbines. Vestas performance specifications for the V136-4.2MW were provided as the basis for the assessment. The data for the standard power optimised configuration incorporating serrated turbine blades and without sound management modes was referenced for the updated assessment. The noise emission data for this standard power optimised configuration is consistent with the range of values expected for the class of turbine being installed at the site.

The results of the noise predictions for the Hawkesdale Wind Farm demonstrate that the predicted noise levels for the preferred turbine model and the reduced turbine layout achieve the noise criteria established by the planning permit. The updated noise assessment therefore demonstrates that the Hawkesdale Wind Farm is expected to comply with the operational noise requirements of the planning permit.

APPENDIX A GLOSSARY OF TERMINOLOGY

Term	Definition	Abbreviation
A-weighting	A method of adjusting sound levels to reflect the human ear's varied sensitivity to different frequencies of sound.	See discussion below this table.
A-weighted 90th centile	The A-weighted sound pressure level that is exceeded for 90 % of a defined measurement period. It is used to describe the underlying background sound level in the absence of a source of sound that is being investigated, as well as the sound level of steady, or semi steady, sound sources.	L_{A90}
Decibel	The unit of sound level.	dB
Hertz	The unit for describing the frequency of a sound in terms of the number of cycles per second.	Hz
Octave Band	A range of frequencies. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.	-
Sound power level	A measure of the total sound energy emitted by a source, expressed in decibels.	L_W
Sound pressure level	A measure of the level of sound expressed in decibels.	L_p
Special Audible Characterises	A term used to define a set group of Sound characteristics that increase the likelihood of adverse reaction to the sound. The characteristics comprise tonality, impulsiveness and amplitude modulation.	SAC
Tonality	A characteristic to describe sounds which are composed of distinct and narrow groups of audible sound frequencies (e.g. whistling or humming sounds).	-

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

APPENDIX B TURBINE COORDINATES

The following table sets out the coordinates of the proposed locations of twenty-three (23) wind turbines of the Hawkesdale Wind Farm (data supplied by ERM on behalf of GPG on 28 September 2020).

Table 8: Hawkesdale Wind Farm turbine coordinates – AGD66 zone 54

Turbine	Easting	Northing	Turbine	Easting	Northing
A1	619551	5780999	A20	618826	5779402
A2	620052	5780838	A21	618085	5779362
A3	618466	5780969	A22	618427	5778904
A4	619026	5780716	A23	617535	5779352
A5	619489	5780437	A24	617739	5778894
A7	619974	5780059	A25	617885	5778384
A8	620518	5779829	A26	617000	5778978
A9	619999	5779406	A27	617363	5778498
A11	619933	5778714	A28	617098	5776397
A14	619427	5778019	A30	617900	5775264
A15	619939	5777722	A31	617587	5775103
A19	618450	5779788			

APPENDIX C RECEIVER LOCATIONS

The following table sets out the one hundred and sixty-eight (168) receivers considered in the noise assessment, including two additional receiver locations identified since the 2017 noise assessment report was prepared. Locations annotated with the text (S) indicate stakeholder receivers.

Table 9: Hawkesdale Wind Farm receiver locations – AGD66 zone 54

Receiver	Easting (m)	Northing (m)	Distance to nearest turbine (m)	Receiver	Easting (m)	Northing (m)	Distance to nearest turbine (m)
1	615838	5781370	2639	88	612592	5775761	4552
2	615848	5781395	2652	89	618315	5776542	1188
3	615834	5781422	2673	90 (s)	620082	5777137	612
4	615931	5780634	1974	91	609818	5776327	7281
5	615756	5780855	2254	92	621472	5785306	4689
6	615758	5780919	2307	93	621474	5785983	5339
7	615724	5780789	2218	94	621478	5786033	5388
8	615856	5781340	2604	95	621470	5786016	5370
9	615864	5781092	2402	96	622628	5784873	4788
10	615842	5781151	2465	97	623372	5784951	5287
11	615849	5781196	2501	98	624002	5785036	5765
12	615763	5781254	2593	99	624716	5785077	6303
13	615769	5781149	2498	100	625114	5785071	6600
14	615767	5781061	2423	101	616777	5780110	1077
15	615777	5781451	2734	102	624578	5773200	6479
16	615758	5781323	2656	103	624070	5771647	7153
17	615667	5781316	2693	104	623289	5771802	6406
18	616198	5781270	2290	105	623278	5771810	6393
19	615696	5781301	2666	106	623077	5771849	6203
20	615693	5781334	2696	107	622969	5771875	6099
21	615650	5781325	2710	108	622910	5771882	6046
22	615613	5781316	2721	109	622836	5771893	5978
23	616107	5781342	2391	110	621126	5772170	4471
24	616031	5781282	2449	111	621198	5772157	4532
25	616035	5781322	2459	112	624280	5770203	8144
26	615567	5781315	2744	113	615019	5769085	6544
27	616255	5780958	2057	114	615823	5769083	6274
28	616306	5781031	2084	115	615920	5769083	6247
29	616351	5781214	2132	116	618059	5768498	6623
30	616143	5780822	2027	117	614544	5767596	8101
31	616122	5780897	2097	118	614645	5770679	5314

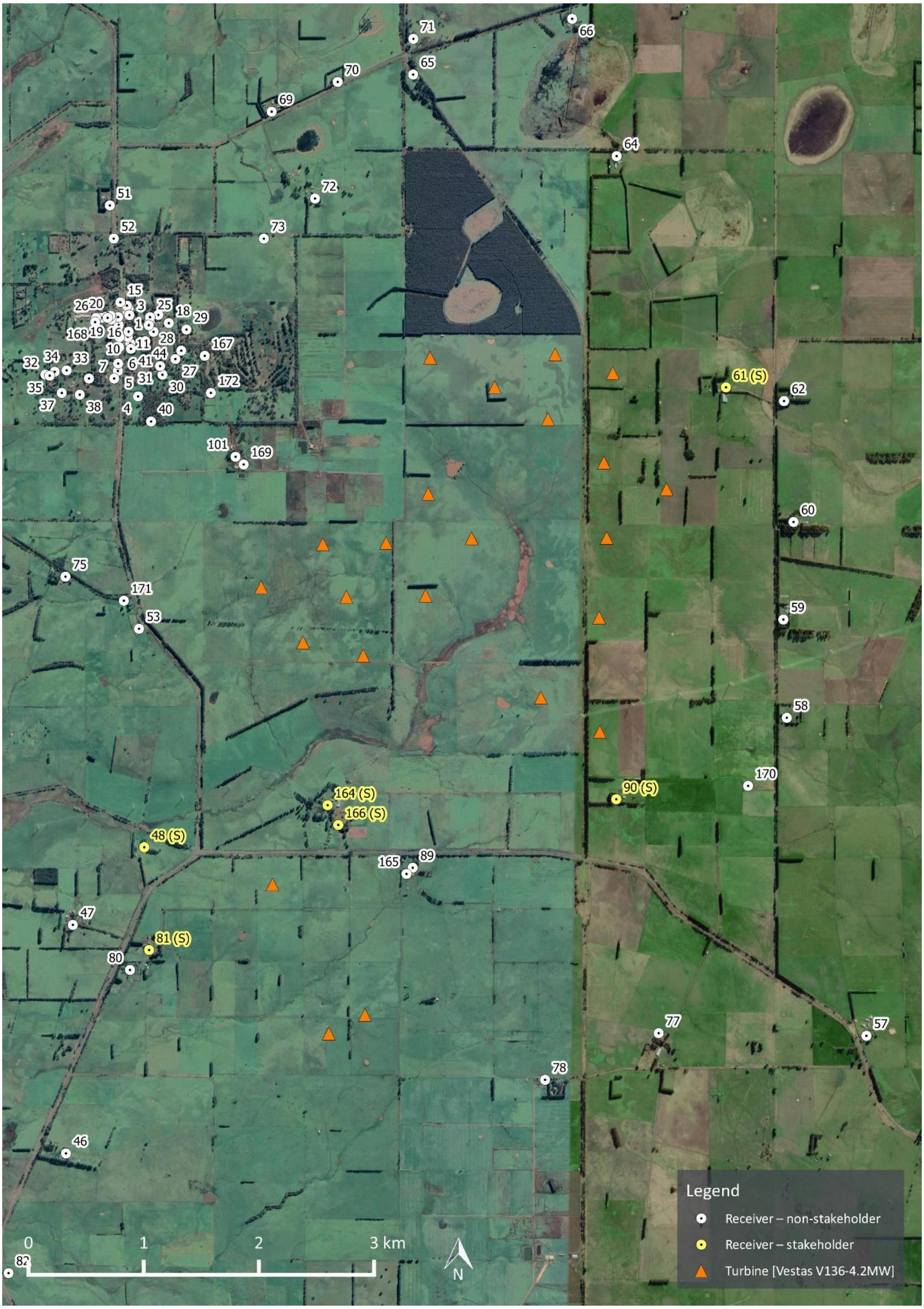
Receiver	Easting (m)	Northing (m)	Distance to nearest turbine (m)
32	615127	5780823	2631
33	615311	5780860	2531
34	615208	5780848	2592
35	615164	5780814	2599
36	615505	5780789	2351
37	615269	5780664	2419
38	615425	5780649	2299
39	615667	5781316	2693
40	616044	5780416	1730
41	615869	5781047	2360
42	616066	5781195	2359
43	616024	5781252	2430
44	615994	5781113	2343
45	614522	5774130	3218
46	615305	5774062	2511
47	615365	5776046	1772
48 (s)	615985	5776720	1164
49	614661	5773009	3600
50	615388	5770814	4821
51	615686	5782292	3081
52	615720	5782004	2937
53	615956	5778615	1111
54	614278	5777092	2906
55	613253	5776851	3873
57	622253	5775083	3512
58	621562	5777844	1299
59	621532	5778697	1144
60	621614	5779538	1139
61 (s)	621034	5780713	996
62	621538	5780594	1280
64	620085	5782720	1805
65	618319	5783428	2466
66	619699	5783912	2919
67	620013	5784514	3547
68	620679	5784116	3317

Receiver	Easting (m)	Northing (m)	Distance to nearest turbine (m)
119	614176	5770948	5377
120	613508	5771329	5558
121	613091	5771578	5714
122	611897	5772988	6071
123	610950	5774098	6565
124	612490	5771532	6224
125	612127	5771538	6522
126	611550	5771536	7013
127	610124	5771401	8331
128	609517	5771181	8973
129	609637	5771358	8789
130	609850	5775326	7328
131	611067	5775711	6071
132	611067	5775684	6074
133	610954	5775313	6240
134	610585	5774627	6750
135	614750	5784569	5175
136	614815	5784191	4871
137	614815	5784191	4871
139	612203	5782565	5991
140	612150	5782659	6090
141	611937	5782969	6448
142	607581	5782800	10165
143	608527	5782800	9296
144	606776	5781497	10530
145	606771	5780585	10355
146	608491	5779620	8534
147	609063	5779604	7962
148	611109	5779583	5923
149	624663	5773553	6301
150	626173	5785005	7406
151	625211	5777826	4908
152	625103	5777633	4819
153	625053	5777517	4785
154	625022	5777463	4762

Receiver	Easting (m)	Northing (m)	Distance to nearest turbine (m)	Receiver	Easting (m)	Northing (m)	Distance to nearest turbine (m)
69	617091	5783106	2543	155	625006	5777433	4751
70	617664	5783364	2528	156	624915	5777276	4690
71	618321	5783738	2775	157	624819	5776868	4695
72	617467	5782352	1710	158	624733	5776364	4783
73	617023	5782003	1779	159	624705	5774253	5896
74	613607	5779530	3439	160	624611	5773783	6112
75	615301	5779069	1705	161	625657	5781121	5300
77	620450	5775106	2506	162	625657	5781121	5300
78	619464	5774701	1666	163	624991	5781122	4657
79	613767	5773192	4273	164 (s)	617577	5777085	845
80	615861	5775655	1447	165	618261	5776488	1172
81 (s)	616027	5775828	1218	166 (s)	617669	5776914	778
82	614807	5773023	3474	167	616510	5780986	1932
83	614930	5769891	5851	168	615558	5781279	2718
84	615001	5784248	4772	169	616848	5780043	980
85	614084	5786998	7454	170	621225	5777282	1297
86	615119	5784218	4666	171	615809	5778860	1202
87	612261	5777081	4886	172	616564	5780664	1636

(S) Stakeholder receiver

APPENDIX D SITE LAYOUT PLAN



APPENDIX E PLANNING PERMIT – NOISE REQUIREMENTS

The planning permit for the Hawkesdale Wind Farm (Permit No.: 20060221-A), as amended 21 December 2017, contains the following requirements that are relevant to the background noise monitoring.

NOISE STANDARD

42. Except as provided below in this condition, the operation of the wind energy facility must comply with New Zealand Standard 6808:2010 Acoustics – Wind farm noise in relation to any dwelling existing on land in the vicinity of the wind energy facility as at 28 February 2017, to the satisfaction of the Minister of Planning. In determining compliance with the standard, the following requirements apply:

(a) The Sound level from the wind energy facility, when measured outdoors within 10 metres of a dwelling at any relevant nominated wind speed, must not exceed the background level (LA90) by more than 5 dB or a level of 40 dB LA90, whichever is greater. If access cannot be gained to undertake testing within 10 metres of a property, consent from the Minister of Planning may be sought to test at another location.

(b) Compliance at night must be separately assessed with regard to night-time data. For these purposes the night is defined as 10.00pm to 7.00am.

(c) Where special audible characteristics, including tonality, impulsive sound or excessive amplitude modulation occur, the measured noise level with the identified special audible characteristics will be modified by applying a penalty of up to +6 dB L_{A90} in accordance with Section 5.4 of the Standard.

The limits specified under condition do not apply if an agreement has been entered into with the relevant landowner waiving the limits. Evidence of the agreement must be provided to the satisfaction of the Minister for Planning upon request, and be in a form that applies to the land for the life of the wind energy facility.

NOISE COMPLIANCE ASSESSMENT

43. An independent post-construction noise monitoring program must be commissioned by the proponent within 2 months from the commissioning of the first turbine and continue for 12 months after the commissioning of the last turbine, to the satisfaction of the Minister of Planning. The independent expert must have experience in acoustic measurement and analysis of wind turbine noise. The program must be carried out in accordance with New Zealand 6808:2010 as varied by Condition 42 above. The operator under this permit must pay the reasonable costs of the monitoring program.

44. The results of the post-construction noise monitoring program, data and details of compliance and non-compliance with the New Zealand Standard must be forwarded to the Minister for Planning within 14 months after the commissioning of any turbine. The results must be written in plain English and formatted for reading by laypeople.

45. All noise compliance reports must be accompanied by a report from an environmental auditor appointed under the Environment Protection Act 1970 with their opinion on the methodology and results contained in the noise compliance testing plan. If a suitable auditor cannot be engaged, the proponent may seek the written consent of the Minister for Planning to obtain an independent peer review of the noise report instead.

APPENDIX F NOISE PREDICTION MODEL

Environmental noise levels associated with wind farms are predicted using engineering methods. The international standard ISO 9613 *Acoustics – Attenuation of sound during propagation outdoors* has been chosen as the most appropriate method to calculate the level of broadband A-weighted wind farm noise expected to occur at surrounding receptor locations. This method is considered to be the most robust and widely used international method for the prediction of wind farm noise.

The use of this standard is supported by international research publications, measurement studies conducted by Marshall Day Acoustics and direct reference to the standard in the South Australian EPA 2009 wind farm noise guidelines, AS 4959:2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators* and NZS 6808:2010 *Acoustics – Wind farm noise*.

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

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

- Geometric divergence
- Air absorption
- Reflecting obstacles
- Screening
- Vegetation
- Ground reflections

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

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

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

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

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

A range of measurement and prediction studies[7, 8, 9] for wind farms in which Marshall Day Acoustics' staff have been involved in have provided further support for the use of ISO 9613 and G=0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

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

- the types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30 m maximum source heights considered in the original ISO 9613;
- the types of environments in which wind farms are typically developed, and the range of atmospheric conditions and wind speeds typically observed around wind farm sites. Importantly, this supports the extended scope of application to wind speeds in excess of 5 m/s.

---

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

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

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

In addition to the choice of ground factor referred to above, adjustments to the ISO 9613 standard for screening and valleys effects are applied on the basis of recommendations of the Joule Report, UK IOA 2009 joint agreement and the UK IOA good practice guide. The following adjustments are applied to the calculations:

- screening effects as a result of terrain are limited to 2 dB
- screening effects are assessed on the basis of each turbine being represented by a single noise source located at the maximum tip height of the turbine rotor
- an adjustment of 3 dB is added to the predicted noise contribution of a turbine if the terrain between the turbine and receiver in question is characterised by a significant valley. A significant valley is defined as a situation where the mean sound propagation height is at least 50 % greater than it would be otherwise over flat ground.

The adjustments detailed above are implemented in the wind turbine calculation procedure of the SoundPLAN 8.0 software used to conduct the noise modelling. The software uses these definitions in conjunction with the digital terrain model of the site to evaluate the path between each turbine and receiver pairing, and then subsequently applies the adjustments to each turbine’s predicted noise contribution where appropriate.

APPENDIX G TABULATED PREDICTED NOISE LEVEL DATA

Table 10: Highest predicted noise levels at all receivers

Receiver	Predicted noise level, dB L_{A90}	Receiver	Predicted noise level, dB L_{A90}	Receiver	Predicted noise level, dB L_{A90}
1	29.5	58	32.3	116	17.1
2	29.5	59	33.9	117	15.2
3	29.4	60	34.7	118	19.1
4	31.5	61 (s)	37.2	119	19.1
5	30.4	62	34.4	120	19.0
6	30.3	64	31.5	121	18.8
7	30.4	65	28.6	122	18.9
8	29.6	66	27.2	123	18.6
9	30.2	67	25.4	124	18.2
10	30.0	68	25.9	125	17.8
11	29.9	69	28.0	126	17.2
12	29.5	70	28.1	127	15.7
13	29.8	71	27.6	128	15.0
14	30.0	72	31.2	129	15.3
15	29.1	73	31.2	130	17.8
16	29.4	74	25.5	131	19.7
17	29.1	75	31.4	132	19.7
18	30.8	77	28.3	133	19.3
19	29.3	78	30.1	134	18.4
20	29.2	79	21.7	135	22.0
21	29.1	80	31.3	136	22.6
22	29.0	81 (s)	32.5	137	22.6
23	30.3	82	23.1	139	20.7
24	30.3	83	18.2	140	20.6
25	30.2	84	22.7	141	20.0
26	28.9	85	16.1	142	14.9
27	31.8	86	22.9	143	15.9
28	31.8	87	22.3	144	14.5
29	31.4	88	22.3	145	14.7
30	31.8	89	35.4	146	16.7
31	31.5	90 (s)	38.4	147	17.5

Receiver	Predicted noise level, dB L_{A90}	Receiver	Predicted noise level, dB L_{A90}	Receiver	Predicted noise level, dB L_{A90}
32	28.5	91	18.2	148	20.5
33	29.0	92	22.6	149	19.7
34	28.7	93	21.2	150	17.9
35	28.6	94	21.1	151	22.3
36	29.7	95	21.1	152	22.4
37	29.2	96	22.3	153	22.4
38	29.7	97	21.3	154	22.5
39	29.1	98	20.4	155	22.5
40	32.5	99	19.6	156	22.6
41	30.3	100	19.1	157	22.5
42	30.6	101	36.8	158	22.2
43	30.3	102	19.4	159	20.3
44	30.6	103	18.3	160	20.0
45	24.4	104	19.2	161	21.3
46	26.2	105	19.2	162	21.3
47	29.6	106	19.5	163	22.7
48 (s)	32.9	107	19.6	164 (s)	37.1
49	22.8	108	19.7	165	35.5
50	19.9	109	19.7	166 (s)	37.2
51	27.2	110	21.8	167	32.6
52	27.9	111	21.7	168	28.9
53	35.0	112	14.8	169	37.5
54	26.8	113	17.1	170	32.6
55	24.2	114	17.5	171	34.2
57	25.0	115	17.5	172	33.7

(s) Stakeholder receiver

APPENDIX H COMPARISON WITH 2017 NOISE ASSESSMENT REPORT

The following table summarises the predicted noise levels for the three candidate turbines and turbine layout used in the 2017 noise assessment report, alongside the predictions for the Vestas V136-4.2MW turbine and reduced turbine layout presented in the revised assessment herein. The results are presented for the receivers where predicted noise levels were greater than 35 dB L_{A90} in the 2017 noise assessment report.

A difference range has been included to illustrate the changes between the maximum and minimum predicted noise levels for each receiver and candidate turbine in the 2017 noise assessment report, and the results of the updated assessment. A negative number represents a decrease in predicted noise level, and a positive number likewise represents an increase. The results demonstrate that the updated predicted noise levels are below, or at the lower end of, the range of predicted noise levels presented in the 2017 noise assessment report.

Table 11: Results of 2017 assessment comparison to Vestas V136-4.2MW

	2017 assessment turbine models			**Updated assessment**	
Receiver Location	**Vestas V126**	**Senvion 3.0M122**	**GE 3.2-130**	**Vestas V136-4.2MW**	**Difference range**
48 (S)	34.4	32.8	35.0	32.9	-2.1 to +0.1
53	36.4	34.9	37.0	35.0	-2.0 to +0.1
58	35.8	34.3	36.4	32.3	-4.1 to -2.0
59	37.4	35.9	38.0	33.9	-4.1 to -2.0
60	37.2	35.6	37.8	34.7	-3.1 to -0.9
61 (S)	38.9	37.4	39.5	37.2	-2.3 to -0.2
62	36.1	34.6	36.8	34.4	-2.4 to -0.2
89	37.7	36.2	38.3	35.4	-2.9 to -0.8
90 (S)	41.4	39.9	42.0	38.4	-3.6 to -1.5
101	38.2	36.7	38.8	36.8	-2.0 to +0.1
164 (S)	38.9	37.3	39.4	37.1	-2.3 to -0.2
165	37.7	36.2	38.3	35.5	-2.8 to -0.7
166 (S)	39.0	37.4	39.5	37.2	-2.3 to -0.2
169	38.9	37.4	39.5	37.5	-2.0 to +0.1
170	35.9	34.4	36.5	32.6	-3.9 to -1.8

(S) Stakeholder receiver

APPENDIX I DOCUMENTATION

(a) Map of the site showing topography, turbines and residential properties: See Appendix D

(b) Noise sensitive locations: See Section 2.1 and Appendix C

(c) Wind turbine sound power levels, L_{WA} dB (also refer to Section 2.3)

Sound power levels (including + 1dB margin for uncertainty)

	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	≥12
dB L_{WA}	91.9	92.1	93.9	97	100.6	103.8	104.9	104.9	104.9	104.9

Reference octave band spectrum adjusted to 104.9 dB L_{WA}

	Octave Band Centre Frequency (Hz)								
	31.5	63	125	250	500	1000	2000	4000	8000
dB L_{WA}*	76.7	86.6	93.8	98.2	99.9	98.9	95.2	88.8	79.7

* Based on octave band spectral information at 18 m/s

(d) Wind turbine model: Vestas V136-4.2MW, details provided in Table 1 of Section 2.2

(e) Turbine hub height: 112 m

(f) Distance of noise sensitive locations from the wind turbines: See Appendix C

(g) Calculation procedure used: ISO 9613-2:1996 prediction algorithm as implemented in SoundPLAN v8.0 (See Section 4.0 and Appendix F)

(h) Meteorological conditions assumed:

- Temperature: 10 °C
- Relative humidity: 70 %
- Atmospheric pressure: 101.325 kPa

(i) Air absorption parameters:

	Octave band mid frequency (Hz)							
Description	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Atmospheric attenuation (dB/km)	0.12	0.41	1.04	1.93	3.66	9.66	32.8	116.9

(j) Topography/screening: 10 m elevation contours, screening effects in accordance with ISO 9613-2:1996 prediction algorithm as detailed in Section 4.0 and Appendix F

(k) Predicted far-field wind farm sound levels: See Table 7 of Section 5.0 and Appendix G.