Attachment E: Marshall Day assessment against NZS 6808:2010

MARSHALL DAY Acoustics

LAL LAL WIND FARM
NZS 6808:2010 NOISE ASSESSMENT

Report No.002 2015386ML | 11 September 2015

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Project: **LAL LAL WIND FARM**
NZS 6808:2010 Noise Assessment

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1.0 INTRODUCTION

This report, commissioned by WestWind Energy Pty Ltd, details the results of a noise assessment for the Lal Lal Wind Farm in accordance with the New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* as required by the Victorian Government's *Policy and planning guidelines for development of wind energy facilities in Victoria* dated June 2015.

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

2.0 PROJECT DESCRIPTION

2.1 Wind farm layout

The Lal Lal Wind Farm has been approved for development with planning permit PL-SP/05/0461 having been issued in April 2009.

The wind farm is located south of the township of Ballan, Victoria and comprises two sections, one to the north of Elaine (twenty-two (22) turbines) and the other to the east of Yendon (thirty-eight (38) turbines).

A plan of the proposed layout is presented in Appendix B together with coordinates for the wind turbines and nearby residential properties.

2.2 Wind turbines

2.2.1 Turbine type

The candidate turbine model for this project is a Senvion 3.2M114 turbine with a rated power of 3.2MW and a rotor diameter of 114m. Details for this turbine model are provided in Table 1 below.

Table 1: WTG manufacturer specifications

Detail	Description
Make	Senvion
Model	3.2M114
Rotor Diameter (m)	114
Hub Height (m)	104
Orientation	Upwind
Rotor speed (rpm)	6.6-12.0
Cut-in Wind Speed (hub height, m/s)	3
Rated Wind Speed (hub height, m/s)	12
Cut-out Wind Speed (hub height, m/s)	22
Sound Power L_{WA} at 10m/s (hub height, dB)	105.2*
Tonal audibility ($\Delta L_{a,k}$>0dB)	No**

* Guaranteed sound power level, including a 1dB margin to account for uncertainties (See Section 2.2.2)

** See Section 2.2.3

2.2.2 Sound power levels

Guaranteed sound power levels for the Senvion 3.2M114 turbine are provided in the Senvion document No. SD-3.2-WT.PC.00-B-D-EN *Power Curve & Sound Power Level 3.2M114 [50Hz]* dated 20 January 2014. It is our understanding that the guaranteed sound power levels do not include measurement uncertainty. An uncertainty margin of 1dB, as required by Senvion, has been added to the guaranteed sound power levels.

The profile of A-weighted sound power levels as a function of hub height wind speeds is presented in Figure 1.

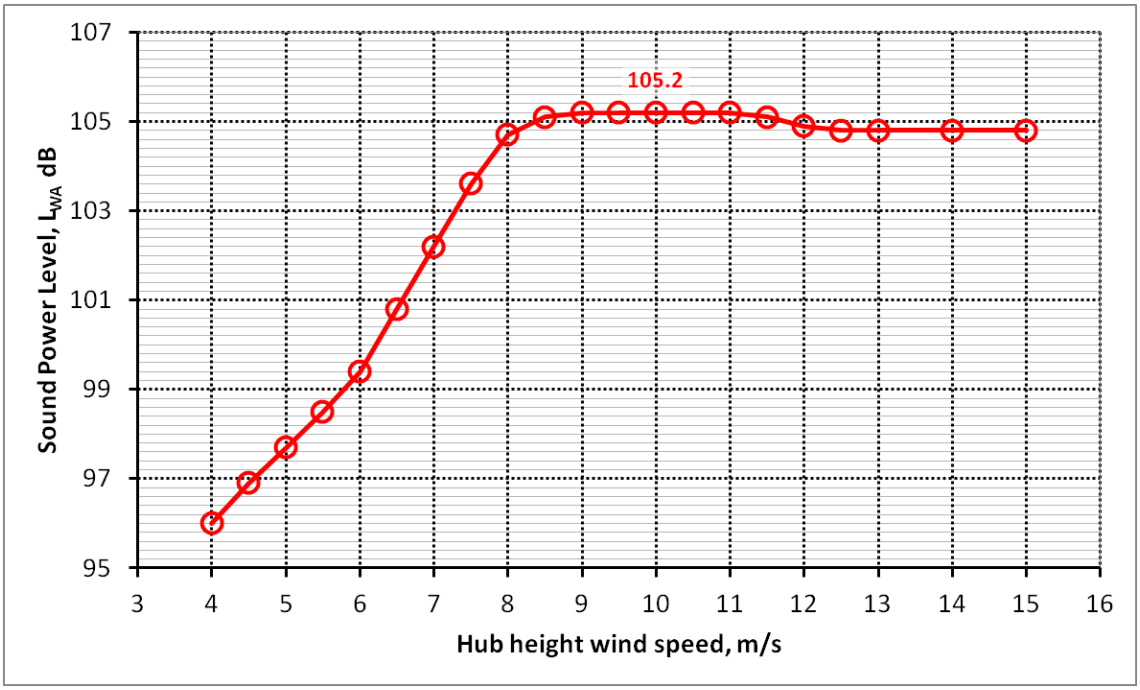


Figure 1: Guaranteed sound power level vs. hub height wind speed

A-weighted octave band sound power spectra were sourced from DNV-GL document No. GLGH-4286 14 12058 293-S-0002-A *Summary of results of a noise emission measurement in accordance with IEC 61400-11 Ed. 2.1* dated 23 July 2014. The octave band values provided for 8m/s at hub height have been adjusted to the highest sound power level of 105.2dB L_{WA} and are presented in Figure 2.

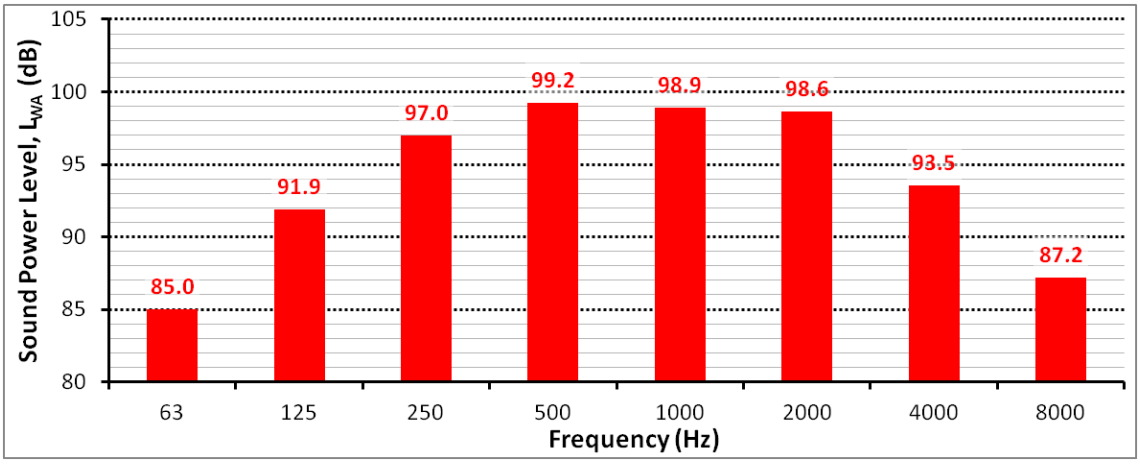


Figure 2: A-weighted octave band sound power level spectra

Tabular values are also presented in Appendix F.

2.2.3 Tonality

Senvion document No. SD-3.2-WT.PC.00-B-D-EN states that Senvion SE warrants tonal audibility $\Delta L_{a,k}$ < 0dB (for wind speed at 10m AGL above 6 m/s).

Notwithstanding the above, we envisage that the procurement contract for the site would stipulate that the turbines must not produce emissions which would attract a penalty when assessed in accordance with the relevant noise criteria and any associated conditions of consent.

2.3 Residential properties

Twenty (20) residential properties have been identified by WestWind the vicinity of the proposed wind farm, of which six (6) are host landowners. These properties are presented in presented in Appendix B.

3.0 NOISE CRITERIA

At the time of approval of the Lal Lal Wind Farm, wind farm noise impact was assessed in accordance the New Zealand Standard 6808:1998 *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS 6808:1998). Condition 37 of the planning permit requires that compliance with the NZS 6808:1998 criteria be achieved at *any dwelling existing on land in the vicinity of the proposed wind energy facility as at the date of the issue of this permit*.

New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS 6808:2010) is currently used to assess wind farm noise as prescribed by the Victorian Government's *Policy and planning guidelines for development of wind energy facilities in Victoria* dated June 2015 (Victorian Guidelines).

3.1 Objective

Section C1.1 of NZS 6808:2010 discussed the intent of the standard, which is:

> […] *to avoid adverse noise effects on people caused by the operation of wind farms while enabling sustainable management of natural wind resources.*

Furthermore, the *Outcome Statement* of NZS 6808:2010 reads as follows:

> *This Standard provides suitable methods for the prediction, measurement, and assessment of sound from wind turbines. In the context of the Resource Management Act, application of this Standard will provide reasonable protection of health and amenity at noise sensitive locations.*

To deliver on this objective the standard specifies noise criteria which are used to assess wind farm noise.

3.2 Noise limit

Section 5.2 *Noise limit* of NZS 6808:2010 defines acceptable noise limits as follows:

> *As a guide to the limits of acceptability at a noise sensitive location, at any wind speed wind farm sound levels ($L_{A90(10\,min)}$) should not exceed the background sound level by more than 5dB, or a level of 40dB $L_{A90(10\,min)}$, whichever is the greater.*

This arrangement of noise limits, generally consistent with the planning permit requirements, requires the noise associated with wind farms to be restricted to a permissible level above background noise, except in instances when both the background and source noise levels are low. In this respect, the criteria indicate that it is not necessary to continue to adhere to a margin above background when the background values are below the range of 30-35dB.

Compliance with the criteria may result in wind turbine noise being audible at some locations for some of the time. The forwarding comments of NZS 6808:2010 note that:

> *Wind farm sound may be audible at times at noise sensitive locations, and this Standard does not set limits that provide absolute protection for residents from audible wind farm sound. Guidance is provided on noise limits that are considered reasonable for protecting sleep and amenity from wind farm sound received at noise sensitive locations.*

3.3 High amenity areas

Section 5.3.1 of NZS 6808:2010 states that the base noise limit of 40dB L_{A90} detailed in Section 3.2 is "*appropriate for protection of sleep, health, and amenity of residents at most noise sensitive locations*." It goes on to note that high amenity areas may require additional consideration:

> […] *In special circumstances at some noise sensitive locations a more stringent noise limit may be justified to afford a greater degree of protection of amenity during evening and night-time. A high amenity noise limit should be considered where a plan promotes a higher degree of protection of amenity related to the sound environment of a particular area, for example where evening and night-time noise limits in the plan for general sound sources are more stringent than 40 dB $L_{Aeq(15\ min)}$ or 40 dBA L_{10}. A high amenity noise limit should not be applied in any location where background sound levels, assessed in accordance with section 7, are already affected by other specific sources, such as road traffic sound.*

The definition of a high amenity area provided in NZS 6808:2010 is specific to New Zealand planning legislation and guidelines. A degree of interpretation is therefore required when determining how to apply the concept of high amenity in Victoria.

Section 5.3 of NZS 6808:2010 provides details of high amenity noise limits, requiring that where a residential property is deemed to be located within a high amenity area as defined in Sections 5.3.1 and 5.3.2 of NZS 6808:2010, wind farm noise levels (L_{A90}) during evening and nigh-time periods should not exceed the background noise level (L_{A90}) by more than 5dB or 35dB L_{A90}, whichever is the greater, for wind speeds below 6m/s at hub height. High amenity noise limits are not applicable during the daytime period.

3.4 Special audible characteristics

Section 5.4.2 of NZS 6808:2010 requires the following:

> *Wind turbine sound levels with special audible characteristics (such as tonality, impulsiveness and amplitude modulation) shall be adjusted by arithmetically adding up to +6dB to the measured level at the noise sensitive location.*

Notwithstanding this, the standard requires that wind farms be designed with no special audible characteristics at nearby residential properties while concurrently noting in Section 5.4.1 that:

> […] *as special audible characteristics cannot always be predicted, consideration shall be given to whether there are any special audible characteristics of the wind farm sound when comparing measured levels with noise limits.*

While the standard emphasises assessment of special audible characteristics during the post-construction measurement phase of a project, an assessment of tonality is possible pre-construction, using tonality assessments carried out according to IEC61400-11.

3.5 Cumulative assessment

NZS 6808:2010 specifies limits which apply to the total combined noise at all wind farms at each noise sensitive locations for the cumulative impact from all affecting wind farms, as stated in Section 5.6.1:

> *The noise limits* [defined in Section 3.2 above] *should apply to the cumulative sound level of all wind farms affecting any noise sensitive location.*

4.0 NOISE ASSESSMENT METHODOLOGY

There are several key stages involved in a noise assessment undertaken in accordance with NZS 6808:2010.

Firstly, preliminary wind farm noise predictions[1] are carried out for all identified residential properties around the wind farm. The results of the preliminary analysis are used for the following:

- Identification of *noise sensitive locations,* where predicted wind farm noise levels exceed 35dB L_{A90}
- Identification of selected *noise sensitive locations* where background noise monitoring should be undertaken, if required

The background noise surveys allow quantification of the existing ambient noise environment around the proposed site. Section 7.1.4 of NZS 6808:2010 notes the following:

> *If there are no noise sensitive locations within the 35dB $L_{A90(10\,min)}$ predicted wind farm sound level contour then background sound level measurements are not required.*

Having identified noise sensitive locations and carried out any background noise monitoring that may be required, applicable limits for wind farm noise are determined.

Once noise limits have been established, further wind farm predictions are carried out. Compliance is assessed by comparing the predicted wind farm noise levels with the noise limits over a range of wind speeds.

5.0 NOISE SENSITIVE LOCATIONS

NZS 6808:2010 requires that the noise assessment be undertaken at all noise sensitive locations in the vicinity of the proposed wind farm which it defines 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.*

Noise sensitive locations therefore include residential dwellings, schools and hotels located outside the wind farm site where predicted wind farm noise levels exceed 35dB L_{A90}.

As host landowner properties are located within the wind farm site, they are not considered as noise sensitive locations as part of an assessment in accordance with NZS 6808:2010. However, they have been considered as part of this assessment for informative purpose.

[1] See Section 7.0

5.1.1 Preliminary noise predictions

Preliminary noise predictions have been undertaken at the twenty (20) residential properties identified by WestWind as detailed in Table 2. The noise prediction methodology is detailed in Section 7.0.

The preliminary noise predictions corresponding to the highest sound power level, at a hub height wind speed of 10m/s, are detailed in Section 2.2.2.

Table 2: Preliminary noise predictions, dB

House	L_{A90}	House	L_{A90}
Elaine Section		Yendon Section	
H18aa	39	J31aa (H)	38
J17aa (H)	45	K31aa (H)	40
J17ab	40	K31ab (H)	40
K15aa	36	K34aa	39
L17aa (H)	44	M29aa	40
L17ab (H)	43	N31aa	38
L18aa	36	N31ab	39
L19ab	33	N32aa	37
M18ab	34	N32ab	36
M19aa	33	N32ac	36

(H) Host landowner property

It can be seen from Table 2 that predicted noise levels at seventeen (17) of the identified residential properties in the vicinity of the proposed wind farm are above 35dB L_{A90}, including the six (6) host landowners.

Eleven (11) properties are therefore considered as noise sensitive locations in accordance with NZS 6808:2010.

5.1.2 Background noise monitoring

Background noise monitoring was undertaken in between November and December 2007 at eleven (11) properties including seven (7) noise sensitive locations. In 2010, the background noise survey was repeated at two (2) of the noise sensitive locations.

Results of these surveys are presented in the following documents:

- MDA report No. 001 R01 2007344 dated 5 February 2008
- MDA letter No. 001 2010178ML dated 4 April 2011
- MDA letter No. 002 2010178ML dated 4 April 2011.

These documents also detail the relevant noise limits derived in accordance with NZS 6808:1998, applicable at the time of the assessment.

6.0 NOISE LIMITS

6.1 High amenity areas

The area surrounding the proposed wind farm is zoned Farming Zone as in the planning map shown in Section C1 and C2 of Appendix C.

The Victoria Planning Provisions Practice Note prepared by the Department of Sustainability and Environment titled *Applying the rural zones* and dated March 2007 states the following:

> *The Farming Zone is designed to encourage diverse farming practices, some of which can have significant off-site impacts. For this reason, the level of amenity that can be expected in this zone will usually not be compatible with sensitive uses, particularly housing.*

Based on the above, the high amenity noise limit in NZS 6808:2010 is not considered applicable to residential properties within a Farming Zone. On this basis, the high amenity noise limit is not deemed to be applicable for residential properties in the vicinity of the Lal Lal Wind Farm.

6.2 Host landowner property

The definition given in NZS 6808:2010 of noise sensitive locations specifically excludes dwellings within the wind farm site boundary. For these properties, it is current practice to use the recommendations outlined in the final report by *The European Working Group on Noise from Wind Turbines* (ETSU-R-97) which allows for an increased base noise limit of 45dB L_{A90} in lieu of the 40dB L_{A90} minimum noise limit.

6.3 Applicable noise limits

The noise limits detailed in the MDA documents listed in Section 5.1.2 were derived in accordance with the 1998 version of NZS 6808 using background noise levels collected in 2009.

For the purpose of this assessment, NZS 6808:2010 base noise limit of 40dB L_{A90} at all wind speeds has been used for all noise sensitive locations. This provides a conservative assessment.

The base noise limit of 45dB L_{A90} has been used for host landowner properties.

7.0 NOISE PREDICTIONS

Noise from the Lal Lal Wind Farm has been predicted using ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO 9613-2:1996) as implemented in version 7.4 of SoundPLAN. Predictions have been carried out using the sound power level data presented in Section 2.2.2.

Section C6.2.1 of NZS 6808:2010 states that, *for the purposes of this Standard, the predicted wind farm* [L_{Aeq}] *at any receiver location is deemed to be equivalent to the* [L_{A90}] *value*.

Calculations have been performed using octave band data from 63Hz to 8kHz and each wind turbine has been modelled as a point source at hub height. All noise predictions use a receiver height of 1.5m AGL. Possible screening effects from the landscape are considered using 10m elevation contour information provided by the proponent. Atmospheric attenuation has been modelled using a temperature of 10°C and 70% humidity as recommended by NZS 6808:2010.

The hardness of the ground between the sources and the receivers needs to be defined in accordance with ISO 9613-2:1996. 100% hard ground (G=0) is considered to be fully reflective as would occur with concrete or asphalt, while 100% soft ground (G=1) would be considered absorptive and be appropriate for fields and grass. Our experience is that, in rural areas, it is appropriate to assume that the ground is 50% hard/50% soft. 50% soft ground (G=0.5) has been used in the predictions.

Further details regarding the use of ISO 9613-2 for wind farm nose predictions and the use of G=0.5 is presented in Appendix D.

Sound levels in environmental assessment work are typically reported to the nearest integer to reflect the practical use of measurement and prediction data. In the case of wind farm layout design however, 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 below are reported to one decimal place.

Noise levels from the Lal Lal wind farm predicted at all noise sensitive locations are presented in Table 3, based on the highest sound power level presented in Section 2.2.2.

Predicted noise levels are compared with the baseline NZS 6808:2010 noise limit of 40dB L_{A90}.

Table 3: Predicted noise from the Lal Lal Wind Farm, dB

House	L_{A90}	Compliance with applicable noise limits?	House	L_{A90}	Compliance with applicable noise limits?
Elaine Section			Yendon Section		
H18aa	38.5	✓	J31aa (H)	38.1	✓
J17aa (H)	44.5	✓	K31aa (H)	40.3	✓
J17ab	40.0	✓	K31ab (H)	39.5	✓
K15aa	36.2	✓	K34aa	38.9	✓
L17aa (H)	43.8	✓	M29aa	39.9	✓
L17ab (H)	42.7	✓	N31aa	37.7	✓
L18aa	36.3	✓	N31ab	39.3	✓
L19ab	33.3	✓	N32aa	37.2	✓
M18ab	33.9	✓	N32ab	36.3	✓
M19aa	33.2	✓	N32ac	36.2	✓

(H) Host landowner

It can be seen from Table 3 that predicted noise levels from the Lal Lal wind farm comply with the applicable limits at all noise sensitive locations.

Wind farm noise at all residential properties further from the wind farm will be lower than 35dB L_{A90} and therefore also comply with the lowest possible NZS 6808:2010 noise limit at all wind speeds.

A noise contour map is presented in Appendix E for the highest sound power levels at the hub height wind speed of 10m/s.

If the turbine selection and/or layout are to be changed, compliance with the relevant noise limit will need to be reassessed.

7.1 Special audible characteristics

Based on the information provided in Section 2.2.3, it is considered that a penalty for tonality is not applicable for any of the assessed wind speeds.

8.0 CONCLUSION

The Lal Lal Wind Farm is proposed to consist of sixty (60) turbines.

An assessment has been undertaken, using the Senvion 3.2M114 wind turbine model with a hub height of 104m, in accordance with NZS 6808:2010 as required by the current Victorian Guidelines at twenty (20) residential properties identified by WestWind in the vicinity of the project.

Wind farm noise levels predicted using ISO 9613-2:1996 have been assessed against a base noise limit of 40dB L_{A90} for properties identified as noise sensitive locations in accordance with NZS 6808:2010. Review of land zoning surrounding the proposed site indicates that high amenity noise limits are not applicable.

For host landowners, a base noise limit of 45dB L_{A90} was used as recommended by supplementary guidance commonly referenced in Victoria (ETSU-R-97).

Results of the NZS 6808:2010 noise assessment are as follows:

- Compliance with the lowest possible NZS 6808:2010 noise limit is achieved at all wind speeds at all identified noise sensitive locations
- Compliance with the raised ETSU-R-97 noise limit is achieved at all wind speeds at all host landowner properties
- Compliance with the lowest possible NZS 6808:2010 noise limit is achieved at all wind speeds at all remaining properties in the vicinity of the wind farm

If the turbine selection and/or layout are to be changed, compliance with the relevant noise limit will need to be reassessed.

9.0 SUMMARY OF PARAMETERS

Documentation of relevant parameters as required by NZS 6808:2010 is contained in Appendix F.

APPENDIX A GLOSSARY OF TERMINOLOGY

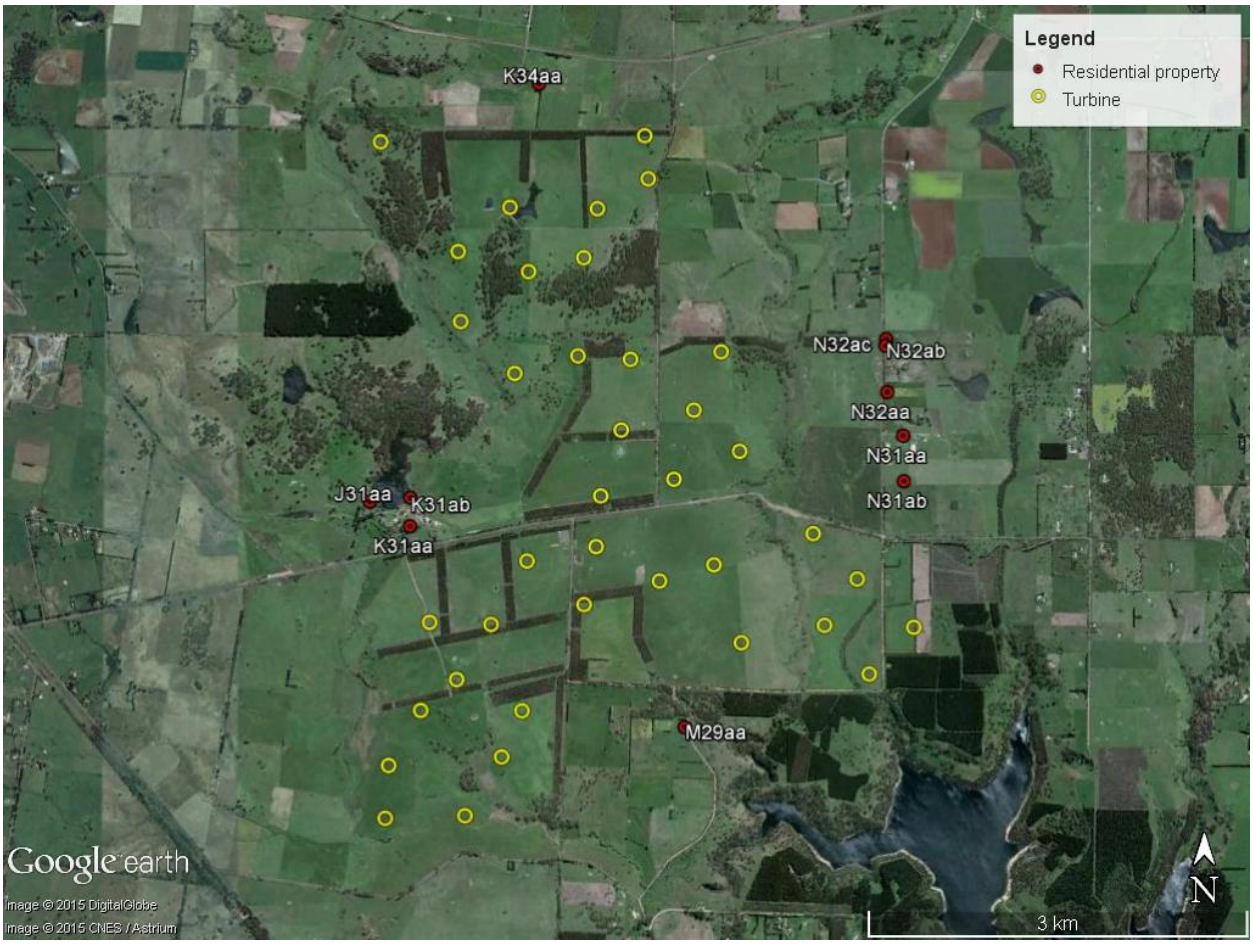
Ambient	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.
dB	Decibel. The unit of sound level.
Frequency	Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals. Sound is generally described over the frequency range from 63Hz to 8000Hz (8kHz). This is roughly equal to the range of frequencies on a piano.
Octave band	Sound, which can occur over a range of frequencies, may be divided into octave bands for analysis. The audible frequency range is generally divided into eight (8) octave bands. The octave band frequencies are 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz and 8kHz.

Noise is often not steady. Traffic noise, music noise and the barking of dogs are all examples of noises that vary over time. When such noises are measured, the noise level can be expressed as an average level, or as a statistical measure, such as the level exceeded for 90% of the time.

L_{A90}	The A-weighted noise level exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.
L_{Aeq}	The A-weighted equivalent continuous sound level. This is commonly referred to as the average noise level.

APPENDIX B LAL LAL WIND FARM LAYOUT

B1 Yendon section



B2 Elaine section

B3 Turbine coordinates (MGA94 Zone 55)

Turbine	Easting	Northing	Turbine	Easting	Northing
YSWT01	235749	5834082	YSWT33	237473	5830494
YSWT02	236335	5834001	YSWT34	238063	5830698
YSWT03	237834	5834197	YSWT35	238489	5830840
YSWT05	237479	5833611	YSWT36	239624	5830764
YSWT06	237872	5833859	YSWT37	238726	5830234
YSWT07	236389	5833239	YSWT38	239378	5830392
YSWT08	236950	5833099	YSWT39	240083	5830399
YSWT09	237383	5833222	YSWT40	239743	5830020
YSWT10	236427	5832689	ESWT01	233500	5817822
YSWT11	236867	5832295	ESWT02	233855	5818367
YSWT12	237362	5832449	ESWT03	234084	5817161
YSWT13	237778	5832435	ESWT04	234351	5817454
YSWT14	237722	5831876	ESWT05	234648	5817731
YSWT15	237577	5831353	ESWT06	235025	5817868
YSWT16	238492	5832517	ESWT07	236483	5818385
YSWT17	238291	5832052	ESWT08	236876	5818621
YSWT18	238663	5831739	ESWT10	234095	5815947
YSWT19	238151	5831503	ESWT11	234393	5816255
YSWT20	237011	5830822	ESWT12	234695	5816555
YSWT21	236257	5830315	ESWT13	234986	5816872
YSWT22	236743	5830314	ESWT14	234746	5815979
YSWT23	236485	5829872	ESWT15	235337	5816007
YSWT24	236209	5829620	ESWT16	236903	5817482
YSWT25	237009	5829643	ESWT17	236754	5816449
YSWT26	235970	5829179	ESWT18	237003	5816752
YSWT27	236860	5829275	ESWT19	237212	5817071
YSWT28	235956	5828763	ESWT20	237353	5817401
YSWT29	236585	5828803	ESWT21	237579	5817722
YSWT30	237553	5830953	ESWT23	233785	5815068
YSWT32	239265	5831110	ESWT24	233936	5815414

B4 Dwellings coordinates (MGA94 Zone 55)

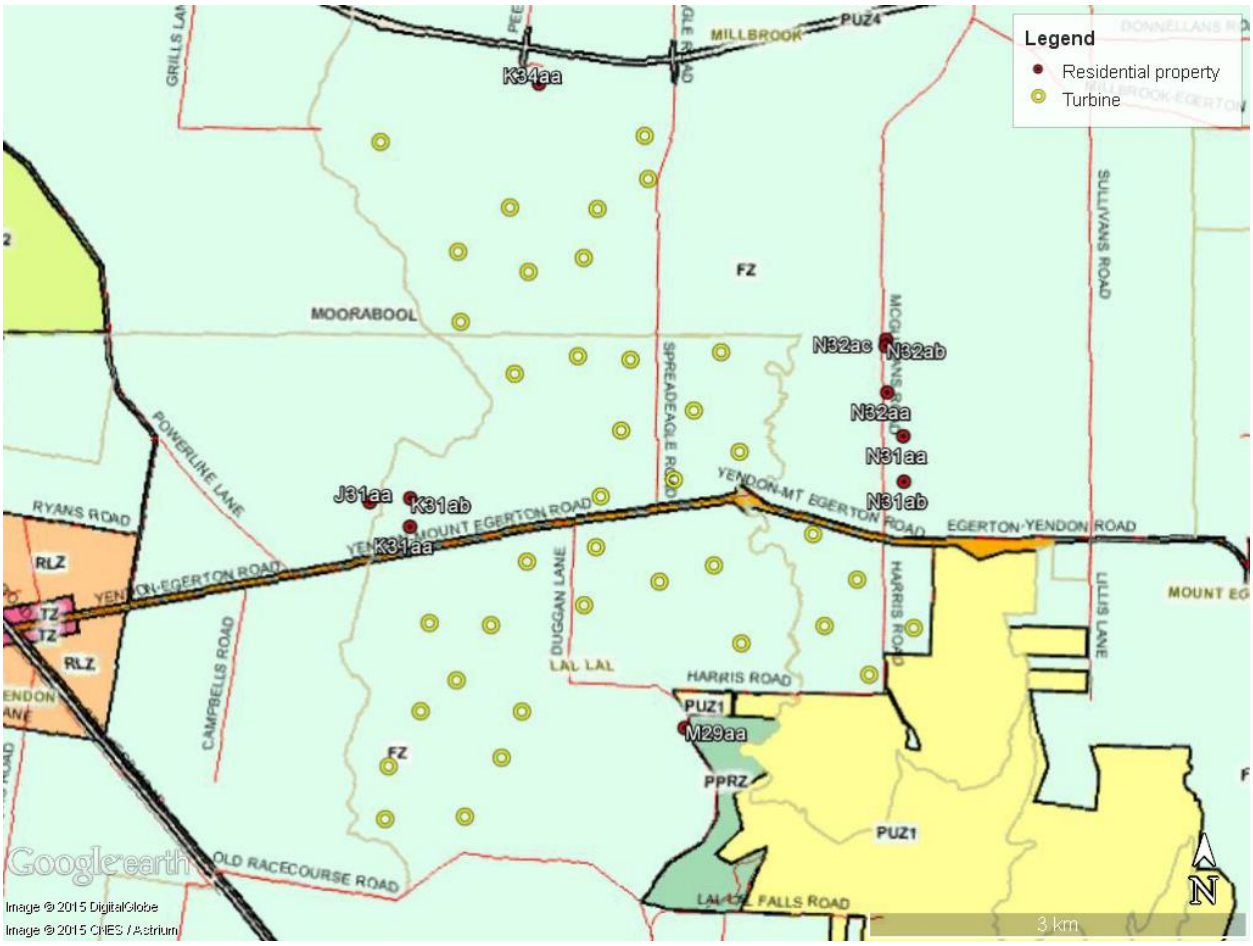
Property	Easting	Northing	Distance to nearest turbine (m)	Property	Easting	Northing	Distance to nearest turbine (m)
Elaine Section				*Yendon Section*			
H18aa	233189	5818529	693	J31aa (H)	235760	5831259	1072
J17aa (H)	235026	5817386	493	K31aa (H)	236084	5831076	787
J17ab	235924	5817263	1008	K31ab (H)	236079	5831300	1006
K15aa	236990	5815534	950	K34aa	236991	5834590	888
L17aa (H)	237170	5817965	487	M29aa	238304	5829565	798
L17ab (H)	237848	5817275	521	N31aa	239957	5831913	1065
L18aa	237913	5818705	1043	N31ab	239974	5831555	843
L19ab	237955	5819290	1274	N32aa	239820	5832252	1270
M18ab	238248	5818860	1324	N32ab	239795	5832616	1311
M19aa	238239	5819045	1431	N32ac	239798	5832667	1319

(H) Host landowner

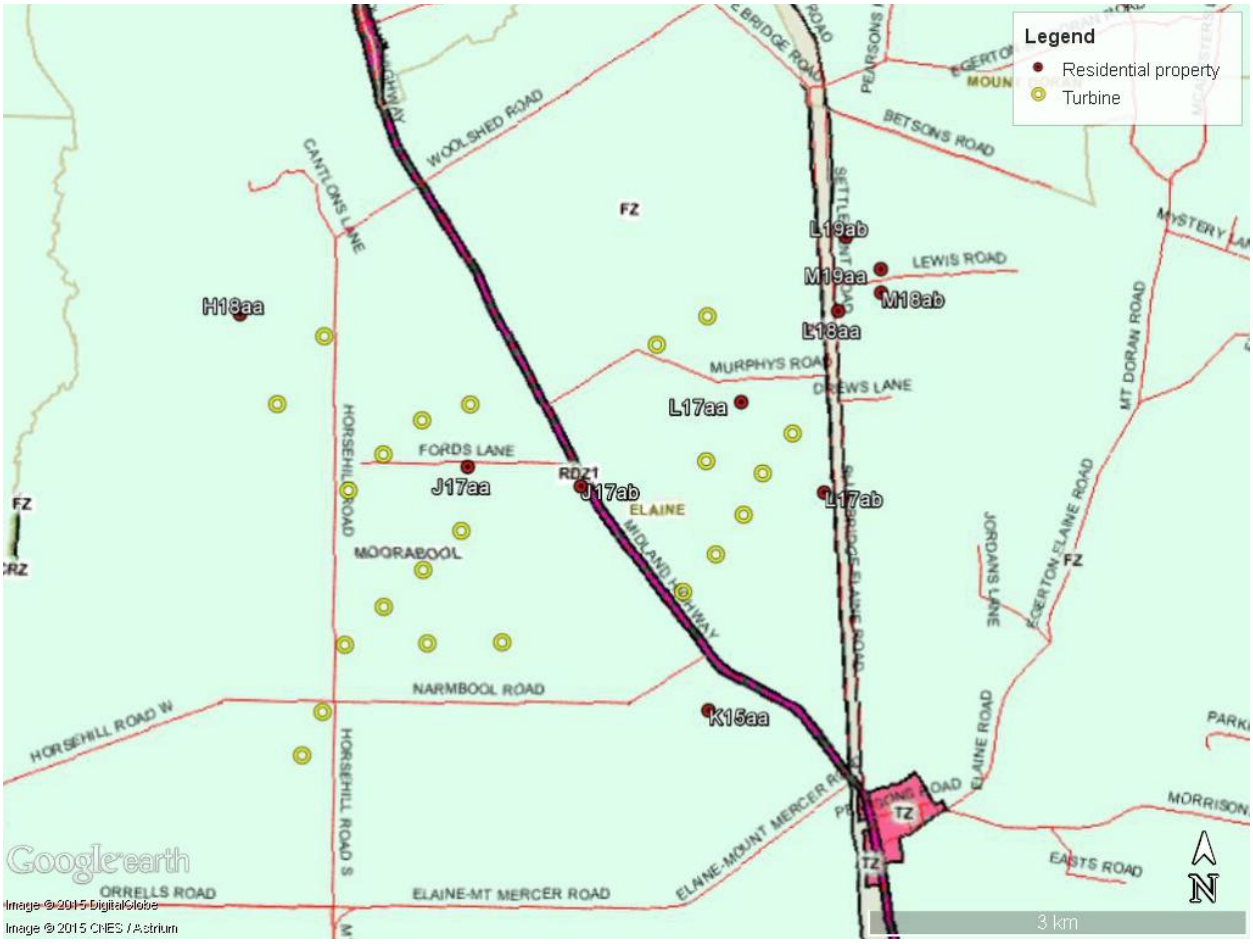
APPENDIX C ZONING MAP

The zoning maps used in the following maps were downloaded from the Department of Environment, Land, Water & Planning *Planning Maps Online* website on 21 August 2015.

C1 Yendon Section



C2 Elaine Section



APPENDIX D NOISE PREDICTION MODEL

Operational wind farm noise levels are predicted at all residential dwellings considered within this assessment using a three-dimensional noise model generated in SoundPLAN® version 7.4 software. Specifically, predictions have been carried out using the SoundPLAN implementation of ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO 9613-2:1996) to calculate noise propagation from the wind farm to each receiver location.

The use of this method is supported by international research publications, measurement studies conducted by Marshall Day Acoustics and direct reference to the standard in NZS 6808:2010 *Acoustics – Wind farm noise* (NZS 6808:2010).

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 1m/s and 5m/s, measured at a height of 3m to 11m 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 levels from wind turbines, atmospheric conditions do not favour the development of thermal inversions throughout the propagation path from the source to the receiver.

To calculate far-field noise levels according to the ISO 9613-2:1996, the noise levels 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 sound power level data to determine the corresponding octave band and total calculated noise level at relevant 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 9613-2:1996 when a certain set of input parameters are chosen in combination.

A number of Australian and international studies support 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. This ground absorption factor of G=0.5 is adopted in combination with several cautious 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 degrees and relative humidity of 70% (conditions which give rise to low atmospheric absorption). The studies demonstrate that applying the ISO 9613-2:1996 prediction methodology in this way provides a reliable representation of the upper noise levels expected in practice.

The following specific adjustments have been made:

- In instances where the ground terrain provides marginal or partial acoustic screening, the barrier effect should be limited to not more than 2dB
- Screening attenuation calculated based on the screening expected for the source located at the tip height of the turbine (in contrast to hub height in non-adjusted ISO 9613 predictions)
- In instances where the ground falls away significantly between the source and receiver, such as valleys, an adjustment of 3dB should be added to the calculated sound pressure level. A terrain profile in which the ground falls away significantly is defined as one where the mean sound propagation height is at least 50% greater than would occur over flat ground

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

- A factor of G=0.5 is frequently applied in Australia for general environmental noise modelling purposes as a way of accounting for the potential mix of ground porosity which may occur in regions of dry/compacted soils or in regions where persistent damp conditions may be relevant
- NZS 6808:2010 refers to ISO 9613-2:1996 as an appropriate prediction 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, part funded by the European Commission, Development of a Wind Farm Noise Propagation Prediction Model[2] found that the ISO 9613-2:1996 model provided a robust representation of upper noise levels which may occur in practice, and provided a closer agreement between predicted and measured noise levels than alternative standards such as CONCAWE and ENM. Specifically, the report indicated the ISO 9613-2:1996 method generally tends to marginally over predict noise levels expected in practice
- The UK Institute of Acoustics journal dated March/April 2009 published a joint agreement between practitioners in the field of wind farm noise assessment, including consultants routinely employed on behalf of both developers and community opposition groups, and indicated the ISO 9613-2:1996 method as the appropriate standard and specifically designated G=0.5 as the appropriate ground characterisation. It is noted that this publication specifically refers to predictions made to receiver heights of 4m in the interest of representing 2-storey dwellings which are more common in the UK. Predictions in Australia are generally based on a lower prediction height of 1.5m which tends to result in higher ground attenuation factors, however conversely, predictions in Australia do not generally incorporate a -2dB 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 comparative measurement and prediction studies[3, 4, 5] for wind farms in which Marshall Day Acoustics' staff have been involved in have provided further support for the use of ISO 9613-2:1996 and G=0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

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[2] Bass, Bullmore and Sloth - *Development of a wind farm noise propagation prediction model*; Contract JOR3-CT95-0051, Final Report, January 1996 to May 1998.

[3] 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.

[4] 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.

[5] 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.

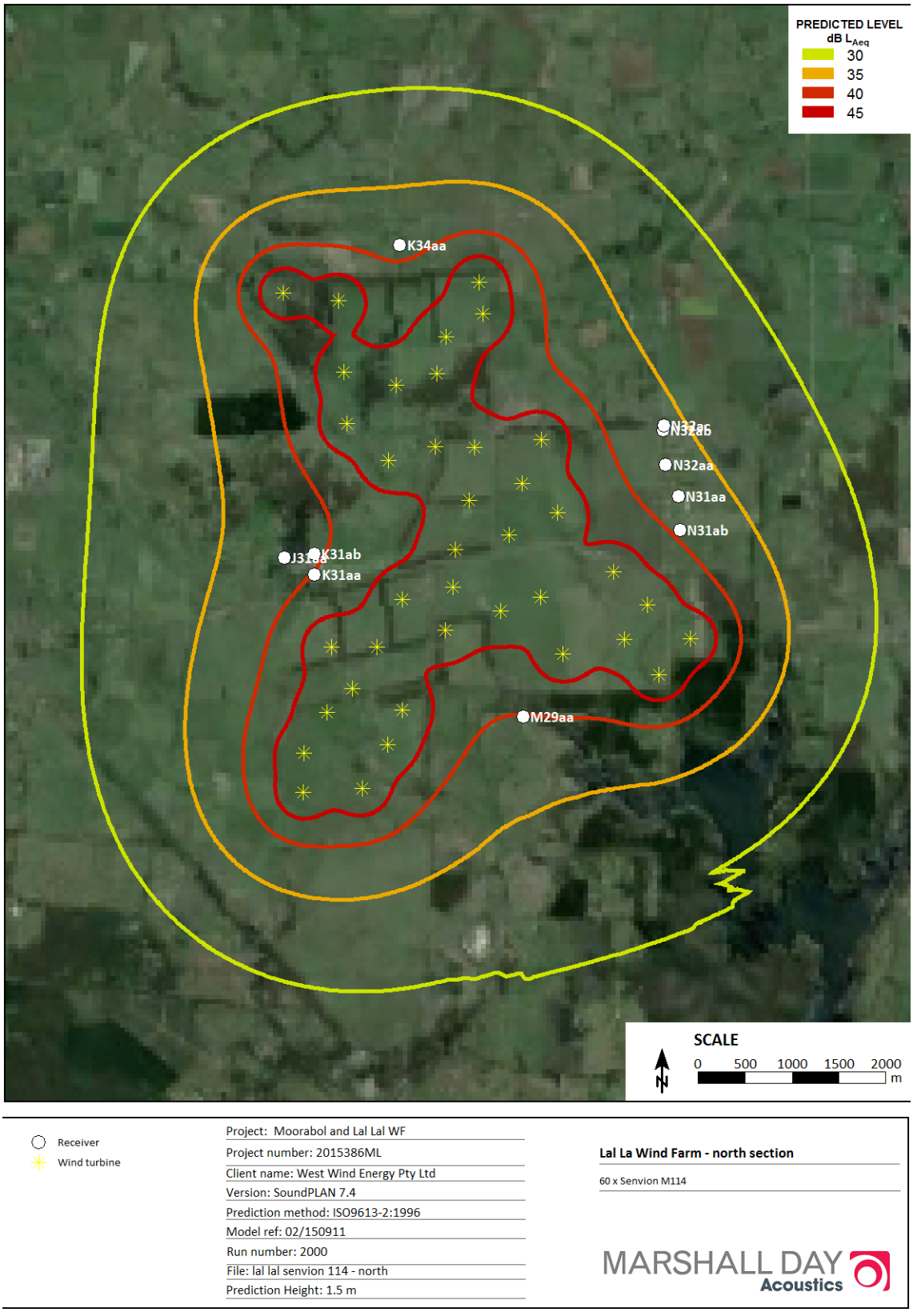
The key findings of these studies demonstrated the suitability of the ISO 9613-2:1996 method to predict the propagation of wind turbine noise for:

- the types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30m 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 5m/s.

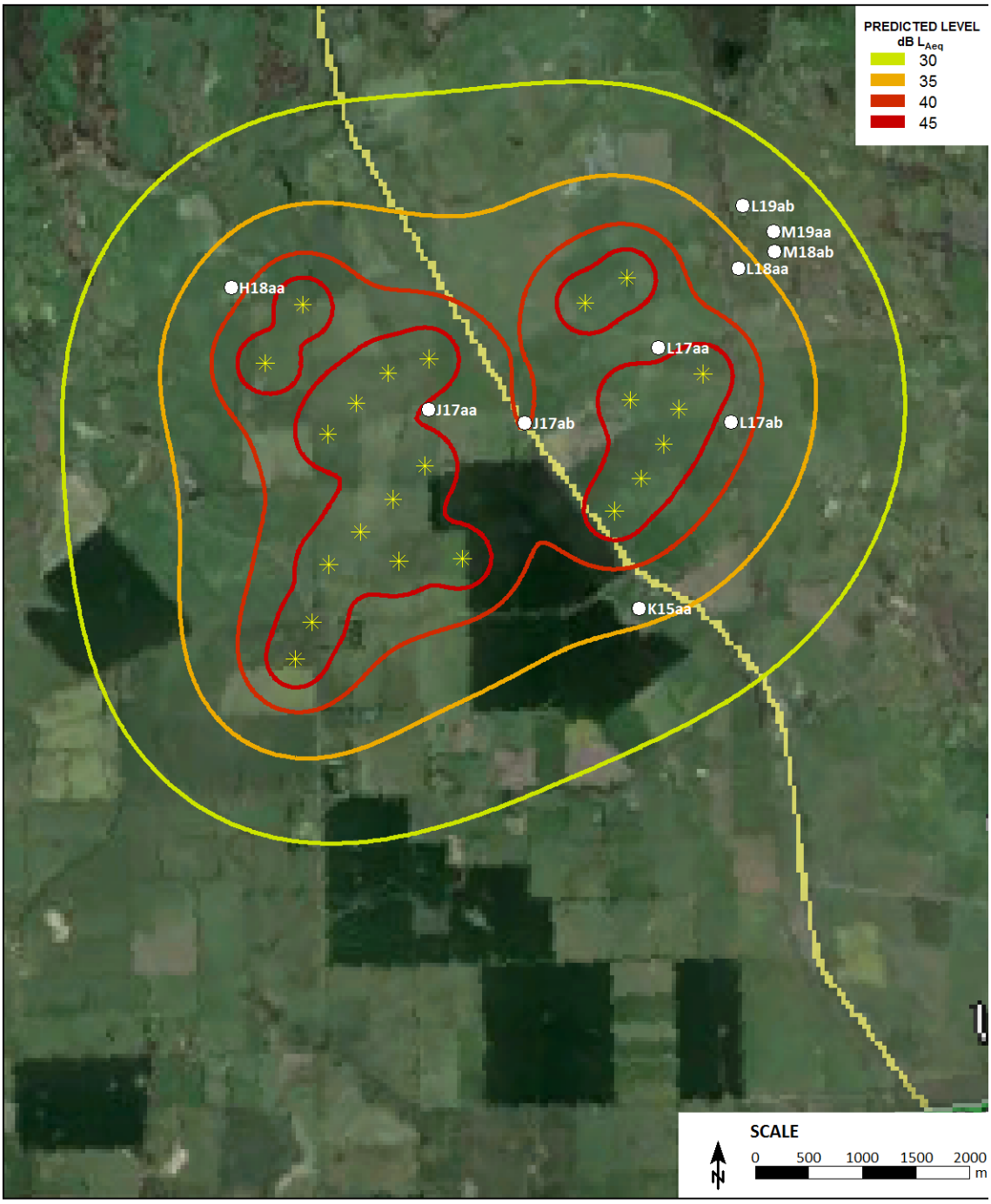
ISO 9613-2:1996 is primarily intended for the prediction of total A-weighted noise levels.

APPENDIX E NOISE CONTOUR MAP

E1 Yendon Section



E2 Elaine Section



Receiver
Wind turbine

Project:	Moorabol and Lal Lal WF
Project number:	2015386ML
Client name:	West Wind Energy Pty Ltd
Version:	SoundPLAN 7.4
Prediction method:	ISO9613-2:1996
Model ref:	02/150911
Run number:	2000
File:	lal lal senvion 114 - south
Prediction Height:	1.5 m

Lal La Wind Farm - south section

60 x Senvion M114

MARSHALL DAY Acoustics

APPENDIX F DOCUMENTATION

F1 Predictions

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

(b) Noise sensitive locations: See Section 5.0 and Appendix B

(c) Wind turbine sound power levels, L_{WA} dB (also refer to Section 2.2.2)

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

	Hub height wind speed (m/s)											
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
L_{WA} (dB)	96	97.7	99.4	102.2	104.7	105.2	105.2	105.2	104.9	104.8	104.8	104.8

Reference octave band spectrum for hub height wind speed of 8m/s adjusted to 105.2dB L_{WA}

	Octave Band Centre Frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
L_{WA} (dB)	83.5	91.7	98.1	100.2	98.3	97.0	92.5	89.3

(d) Wind turbine model: Senvion 3.2M114, details provided in Table 1 of Section 2.2.1

(e) Turbine hub height: 104m

(f) Distance of noise sensitive locations from the wind turbines: See Appendix Table B4 of Appendix B

(g) Calculation procedure used: ISO 9613-2:1996 prediction algorithm as implemented in SoundPLAN v7.4 (See Section 7.0 and Appendix D)

(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: 10m elevation contours, screening effects in accordance with ISO9613-2:1996 prediction algorithm as detailed in Appendix D

(k) Predicted far-field wind farm sound levels: See Table 3 of Section 7.0