

MT EMERALD WIND FARM
Noise impact assessment
Rp 001 R02 2012376ML

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Project: **MT EMERALD WIND FARM**

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1.0 INTRODUCTION

This report, commissioned by RATCH-Australia Corporation Limited, details a noise impact assessment of the Mount Emerald Wind Farm (MEWF) which is proposed to be located near Atherton in the Tablelands region of northern Queensland. The assessment primarily relates to operational noise associated with the proposed wind turbine generators. Noise associated with construction of the wind farm, or ancillary power infrastructure, has not been considered as part of this study.

The wind farm is proposed to consist of up to seventy (70) wind turbines. A plan of the proposed layout is presented in Appendix A.

This noise assessment recognises the requirements of applicable regional and state noise guidance, including the Tablelands Regional Council Planning Scheme Amendment 01/11 – *Wind Farms - Mareeba Shire Planning Scheme 2004*. The amendment requires that a proposed wind farm be designed, constructed and operated in accordance with recognised standards for the assessment of environmental noise. In relation to recognised standards, New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010) and the Queensland Government's Environment Protection (Noise) Policy 2008 (EPP 2008) are specifically noted in the planning scheme.

As the state government's noise guidance documents, including EPP 2008, apply to general noise sources, they do not offer guidance for sources with sound levels that vary with wind speed, as is typical of wind turbines. To address this issue directly, NZS6808:2010 serves as the primary guidance document referenced for this noise assessment.

There are several key stages involved with a noise assessment according to NZS6808:2010. Firstly, preliminary wind farm noise predictions are carried out for all identified residential properties around the wind farm. The results of the preliminary analysis can be used to identify relevant noise sensitive locations and establish suitable noise limits across a range of wind speeds relevant to the wind farms operation. Once noise limits have been established, further wind farm predictions are carried out and compliance is assessed by comparing the predicted wind farm noise levels with the noise limits over a range of wind speeds.

Additionally, an assessment of low frequency noise levels and a qualitative review of infrasound are included in this assessment to address the requirements of the Queensland EPA Ecoaccess draft document *Guideline: Assessment of low frequency noise* (LFN Guideline).

Acoustic terminology used throughout this report is presented in Appendix B. Note that wind speeds are referenced to hub height unless otherwise noted.

2.0 NOISE CRITERIA

2.1 Tablelands Regional Council

The Tablelands Regional Council (TRC) Planning Scheme Amendment 01/11 – *Wind Farms - Mareeba Shire Planning Scheme 2004* (PSA 01/11) commenced on 30 September 2013.

Key noise related aspects of the amendment are outlined below.

2.1.1 Wind farm code

The PSA 01/11 includes a wind farm code, titled *Division 23 – Wind Farm Code*, annotated as document Section 6. The code includes the following statement of intent:

The intent of the code is to facilitate the establishment of new wind farms or expansion of existing wind farms, in appropriate locations.

Wind farm development will not have unacceptably adverse impacts on the environment and on existing amenity (at both a local and wider area scale), and will have social, environmental and economic benefits to the community at both the local and regional level.

To satisfy this intent, Section 6.2 of the wind farm code provides the following compliance requirements:

Development that achieves the overall outcomes in section 6.3 and specific outcomes in section 6.4, complies with the Wind Farm Code.

2.1.2 Overall outcomes

Wind farm code Section 6.3 provides a list of ten intended overall outcomes. The following noise related overall outcomes are noted:

(f) Any variation to existing amenity, visual, light, noise, electromagnetic interference and aircraft safety conditions or circumstances as a result of the wind farm is maintained within acceptable limits.

[...]

(h) The operation of wind farms is controlled by site specific management plans that adequately control and monitor variable impacts such as turbine noise [...] over the operational life of the wind farm.

2.1.3 Specific outcomes

Section 6.4 of the wind farm code identifies a set of specific outcomes. Outcomes regarding noise impact are described in subsection S5 and are as follows:

(a) Wind farm turbines and associated infrastructure are located, designed, constructed and operated in accordance with recognised standards with respect to noise emissions.

(b) Audible and inaudible noise emissions resulting from wind farms that potentially impact on existing urban and rural development do not result in unacceptable levels (including cumulative impacts) of:

- (i) nuisance*
- (ii) risk to human health or wellbeing*
- (iii) ability to sleep or relax*

The *Probable Solutions* associated with subsection S5 are documented as follows:

PS5 No probable solution provided.

Editors note - development should consider the Environment Protection (Noise) Policy 2008 and the New Zealand Standard Acoustics – Wind farm noise (NZS6808:2010).

Key aspects of NZS6808:2010 are outlined below. A summary of the Queensland Government's state noise policies, including Environment Protection (Noise) Policy 2008 (EPP 2008) is provided in Appendix C.

2.2 NZS6808:2010

2.2.1 Objectives

Section C1.1 of NZS6808:2010 discusses 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.

The *Outcome Statement* of NZS6808:2010 expresses this intention in a planning context as follows:

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

The standard seeks to address health and amenity at noise sensitive locations by specifying noise criteria which are used to assess wind farm noise, as outlined below.

2.2.2 Noise limit

Section 5.2 *Noise limit* of NZS6808:2010 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 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.

It should be noted that compliance with the NZS6808:6808:2010 criteria may result in wind turbine noise being audible at some locations for some of the time

2.2.3 High amenity areas

Section 5.3.1 of NZS6808:2010 states that the baseline noise limit of 40dB L_{A90} detailed in Section 2.2.2 above 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 NZS6808:2010 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 Queensland.

Section 5.3 of NZS6808:2010 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 NZS6808:2010, wind farm noise levels (L_{A90}) during evening and night-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.

2.2.4 Special audible characteristics

Section 5.4.2 of NZS6808:2010 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.

Tonality

While the standard emphasises assessment of special audible characteristics during the post-construction measurement phase of a project, an assessment of tonality can be carried out pre-construction, using tonality audibility results that are commonly provided by manufacturers with their sound power level specifications based on IEC61400-11¹.

¹ Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques (IEC61400-11)

Low frequency noise and infrasound

Section 5.5 of NZS6808:2010 provides the following comments regarding low frequency noise and infrasound.

- 5.5.1 *Although wind turbines may produce some sound at (ultrasound and infrasound) frequencies considered to be outside the normal range of human hearing these components will be well below the threshold of human perception.*
- 5.5.2 *Claims have been made that low frequency sound and vibration from wind turbines have caused illness and other adverse physiological effects among a very few people worldwide living near wind farms. the paucity of evidence does not justify at this stage, any attempt to set a precautionary limit more stringent than those recommended in 5.2 and 5.3.*

Notwithstanding these comments, further consideration of low frequency noise and infrasound from wind turbines is considered as part of the assessment, to address the reference to inaudible noise included in Section 6.4 S5(b) of the PSA 01/11 wind farm code. Refer to Appendix F for further details.

2.2.5 Cumulative assessment

NZS6808:2010 requires that a unique noise limit apply at each noise sensitive location for cumulative impact from all affecting wind farms, as stated in Section 5.6.1:

The noise limits [defined in Section 2.2 above] should apply to the cumulative sound level of all wind farms affecting any noise sensitive location.

2.3 Assessment approach

A brief comparison of NZS6808:2010 and applicable Queensland state noise policies, including Environment Protection (Noise) Policy 2008 (EPP 2008), is provided in Appendix C. As noted in the appendix, on balance, it is considered that an assessment of audible wind farm noise in accordance with NZS6808:2010 is likely to provide an outcome that is broadly consistent with the noise management approaches described in the Queensland Government's noise policy documents, including EPP 2008.

Importantly, NZS6808:2010 is better equipped to address the fundamental variations in noise level with changes in wind speed that occur with a wind farm, as noted in Section 1.4 of the Standard:

This Standard deals specifically with the measurement of sound from wind farms in the presence of wind. The procedure involves measuring changes in wind farm sound levels and background sound levels as wind conditions change over time. This goes beyond the procedures described in more general measurement Standards [...]

Section 6.4 S5(b) of PSA 01/11 requires that a wind farm not result in unacceptable levels of nuisance, risk to human health or ability to sleep and relax. In relation to this the forwarding comments of the Standard note:

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.

NZS6808:2010 is used herein as the primary guidance document for assessment of audible, operational noise from the proposed Mount Emerald Wind Farm.

To address the additional PSA 01/11 requirement for consideration of inaudible noise, a supplementary assessment of low frequency noise and infrasound is also detailed in this report, referencing both the criteria detailed in the LFN Guideline and other relevant guidance documents..

3.0 PROJECT DESCRIPTION

The Mount Emerald Wind Farm is proposed to consist of up to seventy (70) wind turbines. A plan of the proposed layout is presented in Appendix A along with GPS coordinates for the wind turbines.

3.1 Wind turbines

3.1.1 Turbine type

A final turbine selection for the project is likely to be made during the detailed design and procurement phase. In lieu of a final selection, this assessment considers the emissions of a range of viable candidate turbine models for the site.

Specifically, three (3) candidate turbine models are considered here to represent the range of turbines which could be considered for the site. All of the candidate turbines comprise three upwind rotor blades with variable blade pitch to control rotational speed, power generation and noise emissions. Details of the proposed turbine models are summarised in Table 1 below.

Table 1: WTG manufacturer specifications

	Details		
Make	REpower	Siemens	Siemens
Model	3XM104	SWT-3.0-101	SWT-3.0-108
Rated electrical power (MW)	3.4	3	3
Rotor Diameter (m)	104	101	108
Hub Height (m)	80	80	80
Rotor orientation	Upwind	Upwind	Upwind
Rotor speed (rpm)	6.9-13.8	6-16	6-16
Cut-in Wind Speed (hub height, m/s)	3.5	3	3-5
Rated Wind Speed (hub height, m/s)	13.5	12	11-12
Cut-out Wind Speed (hub height, m/s)	25	22	25
Sound Power L_{WA} at 10m/s (10m AGL ⁺ , dB)	105.6	107	107
Tonality audibility ($\Delta L_{a,k} > 0$ dB)*	No*	–**	–**

* Refer to Section 3.1.3 for further details

** Tonal audibility levels have not been provided for the Siemens turbine. Refer to Section 3.1.3 for further details.

⁺ Above ground level (AGL)

3.1.2 Sound power levels

Sound power data for the candidate turbines has been sourced from the following documents.

Table 2: Candidate turbine sound level source documentation

Turbine	Documents
Repower 3XM104	<p><i>Sound Power Level REpower 3.4M104 [3.4M/104/50Hz] SD-3.1-WT.SL.01-A-EN</i> dated 25 February 2011</p> <p>Windtest document WT8140/10 (extract from WT 8139/10) <i>Summary of results of the noise emission measurement, in accordance with IEC61400-11, of a WTGS of the type Repower 3.4M,104</i> dated 29 April 2010</p>
Siemens SWT-3.0-101	<p>Siemens document <i>Standard acoustic emission, SWT-3.0-101 rev 4, Hub Height 79.5m</i> dated 9 May 2013 Document ID: E W EN OEN DES TLS 7-10-0000-1023-00</p> <p>Siemens document <i>Standard acoustic emission, SWT-3.0-101 rev 4, Hub Height 79.5m</i> dated 9 May 2013 Document ID: E W EN OEN DES TLS 7-10-0000-1194-00</p>
Siemens SWT-3.0-108	<p>Siemens document <i>Standard acoustic emission, SWT-3.0-108, Hub Height 79.5m</i> Document ID: E W EN OEN DES TLS-10-0000-0423-00 HST, SN / 2012.06.13</p> <p>Siemens document <i>Standard acoustic emission, SWT-3.0-108 rev 1, Hub Height 79.5m</i> Document ID: E W EN OEN DES TLS 7-10-0000-1195-00 HallT / 2013.09.19</p>

Figure 1 and Table 3 below present the reported sound power level data for each candidate turbine at standardised 10m AGL wind speeds.

Table 3 concurrently references wind speeds to non-integer hub height wind speeds² as well as presenting the sound power level data extrapolated to integer hub height wind speeds. As suggested by NZS6808:2010, hub height referenced sound power level data for integer wind speeds is used for this noise assessment.

² Based on a standardised roughness length of $z_0 = 0.05$, according to IEC 61400-11.

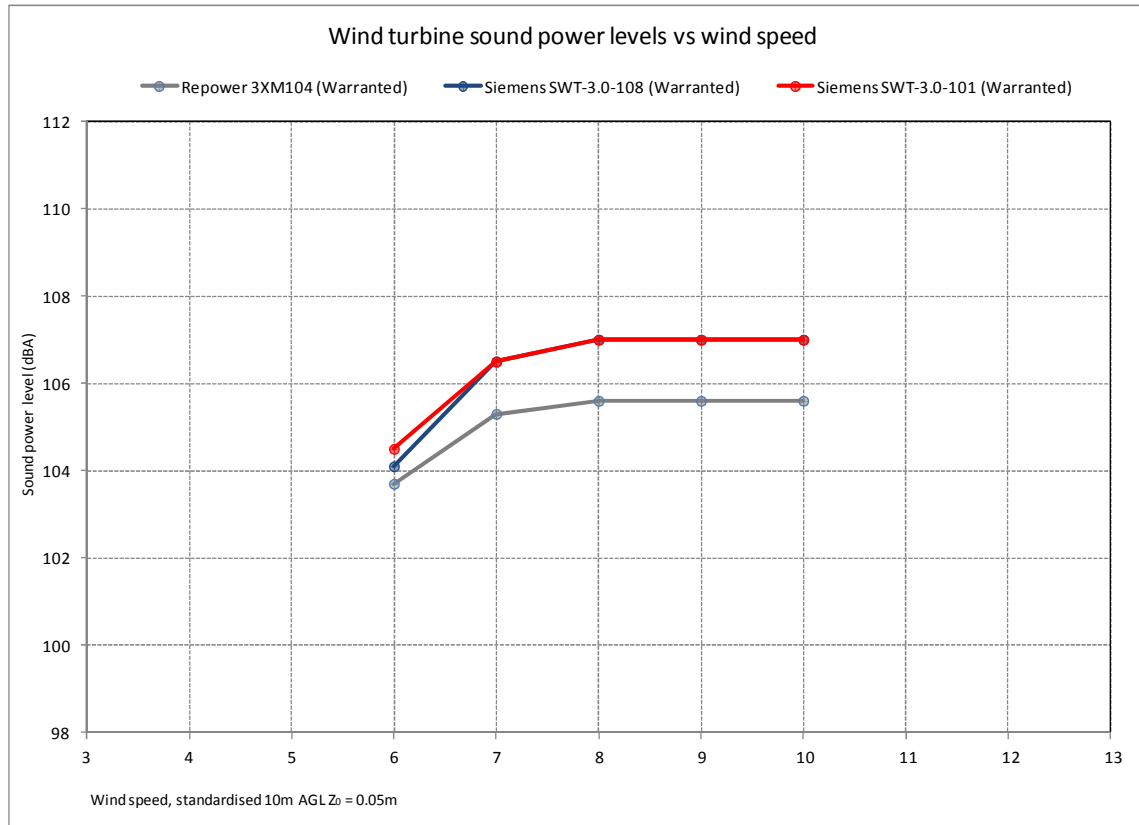


Figure 1: Sound power level vs. wind speed (10m AGL) for the candidate wind turbine models

Table 3: Sound power levels, L_{AW} dB, vs wind speed for the candidate turbine models

Wind speed (m/s)	10m AGL standardised	6	7	8	9	10		
Hub height		8.4	9.7	11.1	12.5	13.9		
Repower 3XM104*		103.7	105.3	105.6	105.6	105.6		
Siemens SWT-3.0-101*		104.5	106.5	107	107	107		
Siemens SWT-3.0-108*		104.5	106.5	107	107	107		
Extrapolated Integer hub height wind speed (m/s)		8	9	10	11	12	13	14
Repower 3XM104		102.9	104.6	105.4	105.6	105.6	105.6	105.6
Siemens SWT-3.0-101		103.6	105.6	106.7	107	107	107	107
Siemens SWT-3.0-108		102.9	105.6	106.7	107	107	107	107

* Warranted sound power levels

Predicted wind farm noise levels are calculated for the range of wind speeds between turbine cut-in and rated power. As sound power level data is not available for hub height wind speeds below approximately 8 m/s, the sound power level for each turbine at 8m/s is used here to estimate levels at lower wind speeds and, therefore, for assessment of wind speeds between cut-in and 8 m/s. In our experience, this assumption is considered to be conservative (i.e. the assumed sound power level of the turbines at these wind speeds is expected to be higher than the actual emissions in practice).

For each turbine type, predicted wind farm noise levels incorporate octave band sound power level data for the turbine being considered. Reference A-weighted octave band sound power spectra for each turbine type, adjusted to the maximum sound power level value, are presented in Figure 2.

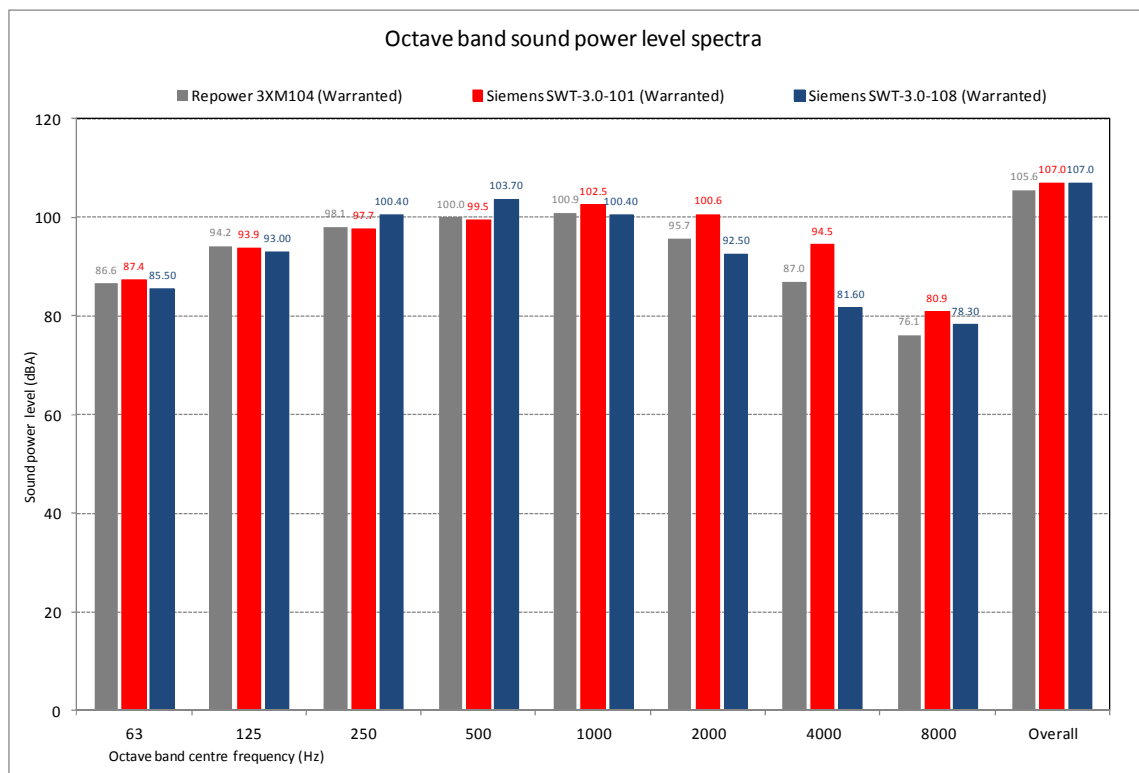


Figure 2: Reference A-weighted octave band sound power level spectra for candidate turbines

Tabular octave band values are presented in Table 4.

Table 4: Reference A-weighted octave band sound power levels for the candidate turbines

L _{WA} (dB)	Octave Band Centre Frequency (Hz)								Overall
	63	125	250	500	1000	2000	4000	8000	
Repower 3XM104	86.6	94.2	98.1	100.0	100.9	95.7	87.0	76.1	105.6
Siemens SWT-3.0-101	87.4	93.9	97.7	99.5	102.5	100.6	94.5	80.9	107
Siemens SWT-3.0-108	85.5	93.0	100.4	103.7	100.4	92.5	81.6	78.3	107

The available documentation for each turbine type only provides one octave band spectrum, which corresponds to a single wind speed condition. In the absence of detailed spectral information across the assessable range of wind speeds, the available spectral data presented in Table 4 has been scaled across the wind speed range to match the sound power levels as detailed in Table 3 above.

3.1.3 Tonality

REpower 3XM104

Results of a tonality assessment undertaken in accordance with IEC61400-11 *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques* (IEC61400-11) for the REpower turbine are provided in the documentation detailed in Section 3.1.2.

Tonal audibility ($\Delta L_{a,k}$) levels are provided for the most prevalent tone at each integer wind speed in the range 6-10 m/s at 10m AGL. The largest reported value for $\Delta L_{a,k}$ for measurements made close to the turbine at a distance of approximately 150m, is -3.29dB at 10m/s.

Siemens SWT-3.0-101 and SWT-3.0-108

Tonal audibility ($\Delta L_{a,k}$) levels determined in accordance with IEC61400-11 are not provided in the technical information provided by Siemens.

For the purposes of this assessment it is assumed that the turbines will have tonal audibility levels ($\Delta L_{a,k}$) of no greater than -3dB at all assessed wind speeds.

To confirm the appropriateness of this assumption, a tonal audibility assessment would be required from Siemens, and this noise impact assessment updated, before proceeding with any site works using this turbine.

3.2 Assessed receivers

RATCH has identified one hundred and twenty-three (123) receiver locations around the site of the proposed wind farm site. Geographic coordinates for the identified receivers are presented in Appendix A.

This noise assessment considers all of these identified receivers.

The project does not include any stakeholder receivers.

4.0 NOISE LIMITS

4.1 Base noise levels

As noted in Section 0 above, NZS6808:2010 states that 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 [...]*”.

We have reviewed the applicable planning documents for the Mareeba Shire Council, Atherton Shire Council and Tablelands Regional Council with a summary of this review provided in Appendix D. Across these three planning schemes, the land for the proposed MEWF and surrounding area is generally zoned for primary or rural production activities, typically with a rural zoning.

It is considered that the identified zonings do not promote a higher degree of protection of amenity related to the sound environment. On this basis, a 40 dB L_{Aeq} base noise level limit is used for this noise assessment and the high amenity noise limit has not been applied.

4.2 Noise sensitive locations

NZS6808:2010 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 include residential dwellings, schools and hotels located outside the wind farm site where predicted wind farm noise levels exceed 35dB L_{A90} .

Preliminary predictions of noise from the proposed wind farm have been calculated in accordance with NZS6808:2010 as well as the methodology outlined in Section 5.0 below to identify noise sensitive locations.

Table 5 below presents the preliminary predicted wind farm noise levels at the forty-four (44) locations with predicted wind farm noise levels of 35dB L_{A90} or greater.

Table 5: Evaluation of noise sensitive locations

House	Applicable base criterion* (dB)	Distance to nearest turbine (m)	Angle of nearest turbine (°)	Predicted noise level, L_{Aeq} (dB) ⁺		
				3XM104	SWT-3.0-101	SWT-3.0-108
R78	40	1104	155	39.3	39.5	41.6
R26	40	1531	151	37.8	38.0	40.2
R49	40	1829	263	37.9	38.0	40.0
R89	40	1056	125	37.1	37.3	39.9
R05	40	1739	54	37.5	37.6	39.5
R36	40	1848	234	37.3	37.4	39.1
R32	40	1897	213	37.0	36.9	38.8
R35	40	1959	225	36.8	36.8	38.5
R30	40	1973	205	36.8	36.8	38.5
R27	40	1875	196	36.4	36.5	38.3
R02	40	2113	71	35.7	35.8	37.9
R29	40	2178	210	35.8	35.8	37.7
R39	40	2385	249	35.9	36.0	37.6
R33	40	2251	209	35.8	35.9	37.6
R82	40	2179	200	35.6	35.6	37.6
R06	40	2279	42	35.6	35.6	37.5
R34	40	2262	214	35.7	35.9	37.5
R28	40	2203	198	35.6	35.6	37.4
R25	40	2157	179	35.3	35.4	37.3
R84	40	2305	180	35.2	35.3	37.2
R21	40	2035	230	35.0	35.0	37.1
R83	40	2524	244	35.4	35.3	36.9
R37	40	2527	231	35.0	35.1	36.8
R38	40	2577	241	35.0	35.0	36.7
R46	40	2610	231	35.0	35.0	36.7
R40	40	2756	245	34.7	34.8	36.4
R48	40	2701	240	34.7	34.7	36.2
R47	40	2731	233	34.7	34.6	36.2
R13	40	2316	81	33.9	33.9	36.2

House	Applicable base criterion* (dB)	Distance to nearest turbine (m)	Angle of nearest turbine (°)	Predicted noise level, L_{Aeq} (dB) ⁺		
				3XM104	SWT-3.0-101	SWT-3.0-108
R22	40	2410	226	34.0	34.1	36.1
R57	40	2776	252	34.4	34.5	36.1
R41	40	2904	223	34.5	34.5	36.1
R59	40	2250	244	33.8	33.7	36.0
R24	40	2764	228	33.8	33.8	35.9
R16	40	2887	61	33.8	33.8	35.8
R07	40	2751	48	33.9	33.9	35.7
R42	40	3024	225	34.0	34.1	35.7
R31	40	2849	214	33.9	34.0	35.7
R43	40	2947	230	34.2	34.1	35.7
R14	40	2975	54	33.6	33.6	35.6
R60	40	2132	265	33.0	32.9	35.5
R23	40	2461	218	33.6	33.5	35.4
R45	40	3030	236	33.8	33.8	35.4
R08	40	2994	43	33.1	33.1	35.0

⁺ at a hub height wind speed of 11m/s

* See Section Section 4.1

4.3 Background noise monitoring

Section 7.1.4 of NZS6808:2010 recommends that background noise monitoring be carried out at noise sensitive locations around a proposed wind farm where predicted wind farm noise levels exceed 35dB L_{A90} .

A background noise level measurement campaign has previously been carried out for this project, as detailed in Noise Mapping Australia document 090815ND02 dated 16 March 2012 (NMA report). Monitoring was carried out at six (6) locations which were designated as follows: R05, R06, R16, R26, R31 and R32³.

³ The NMA Report does not provide GPS coordinates for these receiver locations, however a visual inspection of layout maps in the NMA Report indicates that the location designations are consistent with those used here.

As noted in the NMA Report, the results of the two-week monitoring surveys show comparatively low levels of correlation between background noise levels and wind speed. The NMA Report notes that the poor correlations may be due to the significant difference in elevation, approximately 300m, between the wind farm met mast and the noise monitoring locations. It should also be noted that the background noise levels were measured at 15 minute intervals rather than the 10 minute intervals required by NZS6808:2010.

In light of these issues it is considered appropriate at this stage that predicted noise from the MEWF be assessed using the 40 dB L_{Aeq} base noise level limit at all relevant wind speeds.

Notwithstanding this approach to the assessment, further background noise monitoring will likely be worthwhile at a later stage, in order to quantify the existing baseline noise environment in the area, which can inform and be integrated into any required post-construction noise monitoring.

4.4 Noise limits

As noted above, this assessment is based on compliance with a base noise limit of 40 dB L_{Aeq} at all identified receiver locations.

5.0 ASSESSMENT OF WIND FARM NOISE

5.1 Noise predictions

Noise from the Mount Emerald Wind Farm has been predicted using the implementation of ISO9613-2:1996⁴ with SoundPLAN version 7.2 noise modelling software. Predictions have been carried out using the sound power level data presented in Section 3.1.2.

The ISO 9613-2:1996 method has been used with input parameters specifically chosen for the purpose of modelling wind farm noise, taking account of a range of national and international research publications. These publications include a comprehensive 1998 study⁵ (commonly cited as the Joule Report) part funded by the European Commission which found the ISO 9613 model provides a robust representation of upper noise levels which may occur in practice.

Calculations have been performed using octave bands 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.

Atmospheric attenuation has been modelled using a temperature of 10°C and 70% humidity as recommended by NZS6808:210.

ISO9613-2:1996 requires that hardness of the ground between the sources and the receivers be characterised. 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 to be 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 and 50% soft ($G=0.5$). A ground factor of $G=0.5$ has been used in the predictions.

The ISO 9613 predictions have been applied with the terrain adjustments recommended in the Joule Report.

Further details regarding the use of ISO9613-2 for wind farm noise predictions and the use of $G=0.5$ are provided in Appendix E.

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.

⁴ ISO9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO9613-2:1996)

⁵ Bass, Bullmore and Sloth - Development of a wind farm noise propagation prediction model; Contract JOR3-CT95-0051, Final Report, January 1996 to May 1998.

5.2 REpower 3XM104

Predicted levels of wind farm operational noise based on installation of REpower 3XM104 turbines is presented in Table 6 for the range of receiver locations referenced in Table 5 and for each integer wind speed between turbine cut-in and rated power.

Table 6: Predicted noise from the Mount Emerald Wind Farm, L_{Aeq} dB, 3XM104 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	36.6	36.6	38.3	39.1	39.3	39.3	39.3	39.3	✓
R26	35.1	35.1	36.8	37.6	37.8	37.8	37.8	37.8	✓
R49	35.2	35.2	36.9	37.7	37.9	37.9	37.9	37.9	✓
R89	34.4	34.4	36.1	36.9	37.1	37.1	37.1	37.1	✓
R05	34.8	34.8	36.5	37.3	37.5	37.5	37.5	37.5	✓
R36	34.6	34.6	36.3	37.1	37.3	37.3	37.3	37.3	✓
R32	34.3	34.3	36.0	36.8	37.0	37.0	37.0	37.0	✓
R35	34.1	34.1	35.8	36.6	36.8	36.8	36.8	36.8	✓
R30	34.1	34.1	35.8	36.6	36.8	36.8	36.8	36.8	✓
R27	33.7	33.7	35.4	36.2	36.4	36.4	36.4	36.4	✓
R02	33.0	33.0	34.7	35.5	35.7	35.7	35.7	35.7	✓
R29	33.1	33.1	34.8	35.6	35.8	35.8	35.8	35.8	✓
R39	33.2	33.2	34.9	35.7	35.9	35.9	35.9	35.9	✓
R33	33.1	33.1	34.8	35.6	35.8	35.8	35.8	35.8	✓
R82	32.9	32.9	34.6	35.4	35.6	35.6	35.6	35.6	✓
R06	32.9	32.9	34.6	35.4	35.6	35.6	35.6	35.6	✓
R34	33.0	33.0	34.7	35.5	35.7	35.7	35.7	35.7	✓
R28	32.9	32.9	34.6	35.4	35.6	35.6	35.6	35.6	✓
R25	32.6	32.6	34.3	35.1	35.3	35.3	35.3	35.3	✓
R84	32.5	32.5	34.2	35.0	35.2	35.2	35.2	35.2	✓
R21	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R83	32.7	32.7	34.4	35.2	35.4	35.4	35.4	35.4	✓
R37	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R38	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R46	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R40	32.0	32.0	33.7	34.5	34.7	34.7	34.7	34.7	✓
R48	32.0	32.0	33.7	34.5	34.7	34.7	34.7	34.7	✓
R47	32.0	32.0	33.7	34.5	34.7	34.7	34.7	34.7	✓
R13	31.2	31.2	32.9	33.7	33.9	33.9	33.9	33.9	✓

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R22	31.3	31.3	33.0	33.8	34.0	34.0	34.0	34.0	✓
R57	31.7	31.7	33.4	34.2	34.4	34.4	34.4	34.4	✓
R41	31.8	31.8	33.5	34.3	34.5	34.5	34.5	34.5	✓
R59	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R24	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R16	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R07	31.2	31.2	32.9	33.7	33.9	33.9	33.9	33.9	✓
R42	31.3	31.3	33.0	33.8	34.0	34.0	34.0	34.0	✓
R31	31.2	31.2	32.9	33.7	33.9	33.9	33.9	33.9	✓
R43	31.5	31.5	33.2	34.0	34.2	34.2	34.2	34.2	✓
R14	30.9	30.9	32.6	33.4	33.6	33.6	33.6	33.6	✓
R60	30.3	30.3	32.0	32.8	33.0	33.0	33.0	33.0	✓
R23	30.9	30.9	32.6	33.4	33.6	33.6	33.6	33.6	✓
R45	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R08	30.4	30.4	32.1	32.9	33.1	33.1	33.1	33.1	✓

It can be seen from Table 6 that predicted noise levels from the proposed wind farm comply with the 40 dB L_{Aeq} base criterion within the range of assessed wind speeds at each of the listed receiver locations. Wind farm noise at all other identified receiver locations in the vicinity of the wind farm are predicted to be 5dB or more below the 40 dB L_{Aeq} base criterion and therefore also demonstrate compliance with NZS6808:2010 across the range of assessed wind speeds.

A representative noise level contour map relating to this turbine model is provided in Appendix F.

5.3 Siemens SWT-3.0-101

Predicted levels of wind farm operational noise based on installation of Siemens SWT-3.0-101 turbines is presented in Table 7 for the range of receiver locations referenced in Table 5 and for each integer wind speed between turbine cut-in and rated power.

Table 7: Predicted noise from the Mount Emerald Wind Farm, L_{Aeq} dB, SWT-3.0-101 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	36.1	36.1	38.1	39.2	39.5	39.5	39.5	39.5	✓
R26	34.6	34.6	36.6	37.7	38.0	38.0	38.0	38.0	✓
R49	34.6	34.6	36.6	37.7	38.0	38.0	38.0	38.0	✓
R89	33.9	33.9	35.9	37.0	37.3	37.3	37.3	37.3	✓
R05	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R36	34.0	34.0	36.0	37.1	37.4	37.4	37.4	37.4	✓
R32	33.5	33.5	35.5	36.6	36.9	36.9	36.9	36.9	✓
R35	33.4	33.4	35.4	36.5	36.8	36.8	36.8	36.8	✓
R30	33.4	33.4	35.4	36.5	36.8	36.8	36.8	36.8	✓
R27	33.1	33.1	35.1	36.2	36.5	36.5	36.5	36.5	✓
R02	32.4	32.4	34.4	35.5	35.8	35.8	35.8	35.8	✓
R29	32.4	32.4	34.4	35.5	35.8	35.8	35.8	35.8	✓
R39	32.6	32.6	34.6	35.7	36.0	36.0	36.0	36.0	✓
R33	32.5	32.5	34.5	35.6	35.9	35.9	35.9	35.9	✓
R82	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R06	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R34	32.5	32.5	34.5	35.6	35.9	35.9	35.9	35.9	✓
R28	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R25	32.0	32.0	34.0	35.1	35.4	35.4	35.4	35.4	✓
R84	31.9	31.9	33.9	35.0	35.3	35.3	35.3	35.3	✓
R21	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓
R83	31.9	31.9	33.9	35.0	35.3	35.3	35.3	35.3	✓
R37	31.7	31.7	33.7	34.8	35.1	35.1	35.1	35.1	✓
R38	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓
R46	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓
R40	31.4	31.4	33.4	34.5	34.8	34.8	34.8	34.8	✓
R48	31.3	31.3	33.3	34.4	34.7	34.7	34.7	34.7	✓
R47	31.2	31.2	33.2	34.3	34.6	34.6	34.6	34.6	✓
R13	30.5	30.5	32.5	33.6	33.9	33.9	33.9	33.9	✓

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R22	30.7	30.7	32.7	33.8	34.1	34.1	34.1	34.1	✓
R57	31.1	31.1	33.1	34.2	34.5	34.5	34.5	34.5	✓
R41	31.1	31.1	33.1	34.2	34.5	34.5	34.5	34.5	✓
R59	30.3	30.3	32.3	33.4	33.7	33.7	33.7	33.7	✓
R24	30.4	30.4	32.4	33.5	33.8	33.8	33.8	33.8	✓
R16	30.4	30.4	32.4	33.5	33.8	33.8	33.8	33.8	✓
R07	30.5	30.5	32.5	33.6	33.9	33.9	33.9	33.9	✓
R42	30.7	30.7	32.7	33.8	34.1	34.1	34.1	34.1	✓
R31	30.6	30.6	32.6	33.7	34.0	34.0	34.0	34.0	✓
R43	30.7	30.7	32.7	33.8	34.1	34.1	34.1	34.1	✓
R14	30.2	30.2	32.2	33.3	33.6	33.6	33.6	33.6	✓
R60	29.5	29.5	31.5	32.6	32.9	32.9	32.9	32.9	✓
R23	30.1	30.1	32.1	33.2	33.5	33.5	33.5	33.5	✓
R45	30.4	30.4	32.4	33.5	33.8	33.8	33.8	33.8	✓
R08	29.7	29.7	31.7	32.8	33.1	33.1	33.1	33.1	✓

It can be seen from Table 7 that predicted noise levels from the proposed wind farm comply with the 40 dB L_{Aeq} base criterion within the range of assessed wind speeds at each of the listed receiver locations. Wind farm noise at all other identified receiver locations in the vicinity of the wind farm are predicted to be 5dB or more below the 40 dB L_{Aeq} base criterion and therefore also demonstrate compliance with NZS6808:2010 across the range of assessed wind speeds.

A representative noise level contour map relating to this turbine model is provided in Appendix F.

5.4 Siemens SWT-3.0-108

Predicted levels of wind farm operational noise based on installation of Siemens SWT-3.0-108 turbines is presented in Table 8 for the range of receiver locations referenced in Table 5 and for each integer wind speed between turbine cut-in and rated power.

Table 8: Predicted noise from the Mount Emerald Wind Farm, L_{Aeq} dB, SWT-3.0-108 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	38.2	38.2	40.2	41.3	41.6	41.6	41.6	41.6	×
R26	36.8	36.8	38.8	39.9	40.2	40.2	40.2	40.2	×
R49	36.6	36.6	38.6	39.7	40.0	40.0	40.0	40.0	✓
R89	36.5	36.5	38.5	39.6	39.9	39.9	39.9	39.9	✓
R05	36.1	36.1	38.1	39.2	39.5	39.5	39.5	39.5	✓
R36	35.7	35.7	37.7	38.8	39.1	39.1	39.1	39.1	✓
R32	35.4	35.4	37.4	38.5	38.8	38.8	38.8	38.8	✓
R35	35.1	35.1	37.1	38.2	38.5	38.5	38.5	38.5	✓
R30	35.1	35.1	37.1	38.2	38.5	38.5	38.5	38.5	✓
R27	34.9	34.9	36.9	38.0	38.3	38.3	38.3	38.3	✓
R02	34.5	34.5	36.5	37.6	37.9	37.9	37.9	37.9	✓
R29	34.3	34.3	36.3	37.4	37.7	37.7	37.7	37.7	✓
R39	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R33	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R82	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R06	34.1	34.1	36.1	37.2	37.5	37.5	37.5	37.5	✓
R34	34.1	34.1	36.1	37.2	37.5	37.5	37.5	37.5	✓
R28	34.0	34.0	36.0	37.1	37.4	37.4	37.4	37.4	✓
R25	33.9	33.9	35.9	37.0	37.3	37.3	37.3	37.3	✓
R84	33.8	33.8	35.8	36.9	37.2	37.2	37.2	37.2	✓
R21	33.7	33.7	35.7	36.8	37.1	37.1	37.1	37.1	✓
R83	33.5	33.5	35.5	36.6	36.9	36.9	36.9	36.9	✓
R37	33.4	33.4	35.4	36.5	36.8	36.8	36.8	36.8	✓
R38	33.3	33.3	35.3	36.4	36.7	36.7	36.7	36.7	✓
R46	33.3	33.3	35.3	36.4	36.7	36.7	36.7	36.7	✓
R40	33.0	33.0	35.0	36.1	36.4	36.4	36.4	36.4	✓
R48	32.8	32.8	34.8	35.9	36.2	36.2	36.2	36.2	✓
R47	32.8	32.8	34.8	35.9	36.2	36.2	36.2	36.2	✓

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R13	32.8	32.8	34.8	35.9	36.2	36.2	36.2	36.2	✓
R22	32.7	32.7	34.7	35.8	36.1	36.1	36.1	36.1	✓
R57	32.7	32.7	34.7	35.8	36.1	36.1	36.1	36.1	✓
R41	32.7	32.7	34.7	35.8	36.1	36.1	36.1	36.1	✓
R59	32.6	32.6	34.6	35.7	36.0	36.0	36.0	36.0	✓
R24	32.5	32.5	34.5	35.6	35.9	35.9	35.9	35.9	✓
R16	32.4	32.4	34.4	35.5	35.8	35.8	35.8	35.8	✓
R07	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R42	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R31	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R43	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R14	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R60	32.1	32.1	34.1	35.2	35.5	35.5	35.5	35.5	✓
R23	32.0	32.0	34.0	35.1	35.4	35.4	35.4	35.4	✓
R45	32.0	32.0	34.0	35.1	35.4	35.4	35.4	35.4	✓
R08	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓

It can be seen from Table 8 that predicted noise levels from the proposed wind farm comply with the 40 dB L_{Aeq} base criterion within the range of assessed wind speeds at each of the listed receiver locations with the exception of R78 and R26.

Wind farm noise at all other identified receiver locations in the vicinity of the wind farm are predicted to be 5dB or more below the 40 dB L_{Aeq} base criterion and therefore also demonstrate compliance with NZS6808:2010 across the range of assessed wind speeds.

5.4.1 Operational noise mitigation option

To reduce predicted wind farm noise levels at receivers R78 and R26 to below the 40 dB L_{Aeq} base criterion, turbines T1, T2 and T62 have been excluded from the wind farm layout. In addition, turbines T61, T69 and T70 have been modelled based on a Noise Restricted Operation mode, using sound power level data as detailed in Table 9 and Table 10 below.

The information provided for noise restricted operations corresponds to a single reference wind speed of 8m/s at 10m AGL. As shown here, this reference value has been applied for all assessable wind speeds for the purposes of this assessment.

Table 9: '-5dB' Noise Restricted Operation Sound power levels L_{AW} (dB) vs wind speed for SWT-3.0-108

Wind speed (m/s)	10m AGL standardised	6	7	8	9	10		
	Hub height	8.4	9.7	11.1	12.5	13.9		
Siemens SWT-3.0-108* ('-5dB' mode)		102	102	102	102	102		
Extrapolated Integer hub height wind speed (m/s)		8	9	10	11	12	13	14
Siemens SWT-3.0-108 ('-5dB' mode)		102	102	102	102	102	102	102

* Warranted sound power levels

Table 10: Reference A-weighted octave band sound power levels for SWT-3.0-108 '-5dB' Noise Restricted Operation mode

Octave Band Centre Frequency (Hz)									
L_{WA} (dB)	63	125	250	500	1000	2000	4000	8000	Overall
Siemens SWT-3.0-108	84.5	91.2	95.4	97.8	96	88.4	79.4	76.4	102

Revised wind farm noise predictions at R78 and R26 based on the updated wind farm arrangement are shown in Table 11 and it can be seen that the predicted levels comply with the 40 dB L_{Aeq} base criterion. For information, revised predicted noise levels are also presented in Table 11 at the four (4) other receiver locations in Table 8 where predicted levels are 39 dB L_{Aeq} or greater.

Table 11: Predicted noise from the Mount Emerald Wind Farm based on a 67 turbine layout*, L_{Aeq} dB, SWT-3.0-108 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	34.9	34.9	36.9	38.0	38.3	38.3	38.3	38.3	✓
R26	33.7	33.7	35.7	36.8	37.1	37.1	37.1	37.1	✓
R49	36.1	36.1	38.1	39.2	39.5	39.5	39.5	39.5	✓
R89	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R05	35.6	35.6	37.6	38.7	39.0	39.0	39.0	39.0	✓
R36	34.9	34.9	36.9	38.0	38.3	38.3	38.3	38.3	✓

* Turbines T1, T2 & T62 removed, T61, T69 and T70 constrained to '-5dB' power reduced mode.

A representative noise level contour map relating to this turbine model is provided in Appendix F.

5.5 Tonality and other characteristics

5.5.1 Tonality

Based on the tonal audibility levels and information detailed in Section 3.1.3, a 5dB penalty for annoying characteristics (tonality) has not been applied to the predicted wind farm noise levels detailed above.

Regarding the Siemens SWT-3.0-101 and SWT-3.0-108 turbines, a tonal audibility test report should be provided by Siemens prior to commencing any site works, to confirm the significance of any tones from their turbine model.

5.5.2 Low frequency noise and infrasound

Predicted low frequency noise levels and a qualitative review of infrasound levels are provided here. Additional discussions of prediction methods, sound power level data and estimated infrasound levels are provided for reference in Appendix F.

Low frequency noise

As described in Appendix F, of the four assessment phases detailed in the LFN Guideline, Phase 1 and Phase 2 are considered to apply to complaints of existing noise.

The LFN Guideline Phase 3 assessment relates to low frequency tonal noise, for which the tonality discussions in Section 3.1.3 and Section 5.5.1 above are applicable, for frequencies greater than 50 Hz. For frequencies in the range 10 Hz to 160 Hz, a one-third octave band tonality assessment of available turbine sound power level data is detailed in Appendix F, which does not indicate the presence of tones.

The Phase 4 assessment of non-tonal low frequency noise is addressed here for assessment of the LFN Guideline internal noise criterion of 20 dB $L_{pAL,F}$. Table 12 below presents predicted low frequency noise levels for the range of receiver locations listed in Table 5 based on the Danish EPA 1284 method⁶. For each candidate turbine, the predictions relate to the seventy (70) turbine wind farm layout. A brief description of the method is outlined in Appendix F along with details of the input sound power level data for each turbine type and a discussion of the limitations of this data.

⁶ With adjustments to indoor-outdoor sound reduction as detailed in Appendix F

Table 12: Indicative low frequency internal noise levels from the Mount Emerald Wind Farm, $L_{pAL,F}$ dB

House	Turbine model*			Satisfies the LFN Guideline?
	3XM104	SWT-3.0-101	SWT-3.0-108	
R78	20	21	19	✗
R26	19	20	18	✓
R05	18	19	17	✓
R49	17	18	16	✓
R89	18	18	17	✓
R36	17	18	16	✓
R32	17	17	16	✓
R30	17	17	16	✓
R35	17	17	16	✓
R27	17	18	16	✓
R06	17	17	16	✓
R02	16	17	15	✓
R29	16	17	15	✓
R33	16	17	15	✓
R82	16	17	15	✓
R25	16	17	15	✓
R39	16	17	15	✓
R34	16	17	15	✓
R28	16	17	15	✓
R84	16	17	15	✓
R21	17	17	15	✓
R83	16	16	15	✓
R46	15	16	14	✓
R37	15	16	14	✓
R38	15	16	14	✓
R40	15	16	14	✓
R13	15	16	14	✓
R48	15	16	14	✓

House	Turbine model*			Satisfies the LFN Guideline?
	3XM104	SWT-3.0-101	SWT-3.0-108	
R47	15	16	14	✓
R57	15	16	14	✓
R22	16	16	15	✓
R07	16	16	15	✓
R16	15	16	14	✓
R41	15	16	14	✓
R24	15	16	14	✓
R59	15	16	14	✓
R14	15	16	14	✓

* Predicted low frequency noise levels for each candidate turbine relate to wind speed with the highest overall A-weighted sound power level. For all three (3) candidate turbines this corresponds to a wind speed of approximately 11 m/s at hub height.

It can be seen that predicted wind farm low frequency noise levels are less than or equal to the nominated 20 dB $L_{pAL,F}$ criteria at all listed receivers locations with the exception of R78, where predicted $L_{pAL,F}$ noise levels exceed 20 dB for the SWT-3.0-101 turbine.

At all other receiver locations, predicted wind farm low frequency noise levels are predicted to be less than 20 dB $L_{pAL,F}$ and therefore also comply with the LFN Guideline criterion.

Predicted indicative wind farm low frequency noise levels at receiver R78 for the SWT-3.0-101 turbine model can comply with the 20 dB $L_{pAL,F}$ base criterion if turbines T1, T2 and T62 are removed from the wind farm layout, as shown in Table 13 below.

Table 13: Indicative low frequency noise levels from the Mount Emerald Wind Farm at R78 based on a 67 turbine layout (T1, T2 and T62 removed), L_{Aeq} dB, SWT-3.0-101 Turbine

House	Turbine model (Hub height wind speed (m/s))	Satisfies the LFN Guideline?
	SWT-3.0-101	
R78	20	✓

Infrasound

An early study⁷ of infrasound in 1997 as part of a UK government funded investigation reported measured levels of infrasound, low frequency sound and vibration in the vicinity of a wind farm comprising 450 kW turbines. The results demonstrated noise levels complied with recommended residential criteria even on the wind turbine site itself, and the measured levels were below accepted levels of perception below 20Hz.

More recent measurements⁸⁹ have demonstrated that infrasound and low frequency sound produced by regularly encountered natural and man-made sources, such as the infrasound produced by the wind or distant traffic, is comparable to that of modern wind turbines, noting that:

Infrasound levels in the rural environment appear to be controlled by localised wind conditions. During low wind periods, levels as low as 40dB(G) were measured at locations both near to and away from wind turbines. At higher wind speeds, infrasound levels of 50 to 70dB(G) were common at both wind farm and non-wind farm sites

Organised shutdowns of the wind farms adjacent to [sic: measurement locations] indicate that there did not appear to be any noticeable contribution from the wind farm to the G-weighted infrasound level measured at either house. This suggests that wind turbines are not a significant source of infrasound at houses located approximately 1.5 kilometres away from wind farm sites

UK studies¹⁰ have also indicated measured infrasound levels in the vicinity of modern multi-megawatt wind farms to be substantially lower than the threshold of hearing for even the most sensitive members of the population. With respect to infrasonic noise levels below the hearing threshold, the World Health Organization has stated¹¹ that:

There is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects

In 2010, the UK Health Protection Agency published a report¹² on the health effects of exposure to ultrasound and infrasound. The exposures considered in the report related to medical applications and general environmental exposure. The report notes:

⁷ Snow - Low Frequency Noise and Vibration Measurements Near a Modern Wind Farm ; ETSU publication W/13/00392/REP

⁸ Sonus report for Pacific Hydro - *Infrasound measurements from wind farms and other sources* – November 2010 - see http://www.pacifichydro.com.au/media/192017/infrasound_report.pdf

⁹ Evans, T., Cooper, J. & Lenchine, V., *Infrasound levels near wind farms and in other environments*, South Australian Environment Protection Authority, Adelaide, 2013

¹⁰ Former UK Department of Trade and Industry, Hayes McKenzie Partnership - *The Measurement of Low Frequency Noise at Three UK Wind Farms*; contract number W/45/00656/00/00, 2006

¹¹ World Health Organization, Berglund, Lindvall - *Community Noise* - 1995

¹² Health Protection Agency UK – *Health Effects of Exposure to Ultrasound and Infrasound – Report of the independent Advisory Group on Non-ionising Radiation* - 2010

Infrasound is widespread in modern society, being generated by cars, trains and aircraft, and by industrial machinery, pumps, compressors and low speed fans. Under these circumstances, infrasound is usually accompanied by the generation of audible, low frequency noise. Natural sources of infrasound include thunderstorms and fluctuations in atmospheric pressure, wind and waves, and volcanoes; running and swimming also generate changes in air pressure at infrasonic frequencies.

[...]

For infrasound, aural pain and damage can occur at exposures above about 140 dB, the threshold depending on the frequency. The best-established responses occur following acute exposures at intensities great enough to be heard and may possibly lead to a decrease in wakefulness. The available evidence is inadequate to draw firm conclusions about potential health effects associated with exposure at the levels normally experienced in the environment, especially the effects of long-term exposures. The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects.

In response to ongoing concerns regarding potential health effects associated with these types of emissions, the Australian Government's National Health and Medical Research Council issued a public statement in July 2010 titled *Wind Turbines and Health* supporting the view that there is no published scientific evidence to positively link wind turbines with direct health impacts.

Further material published in July 2010 by RenewableUK¹³ reported the findings of three independent experts commissioned to investigate alleged issues relating to infrasound and low frequency noise from wind farms. The key reported conclusions from this study were that:

there is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects;

the ground-borne vibrations from wind turbines are too weak to be detected by, or to affect, humans; and

the sounds emitted by wind turbines are not unique. There is no reason to believe, based on the levels and frequencies of the sounds and the panel's experience with sound exposures in occupational settings, that the sounds from wind turbines could plausibly have direct adverse health consequences.

Also, a recent State Government of Victorian Department of Health document *Wind farms, sound and health - Technical information* concludes the following in relation to infrasound from wind farms:

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

These studies all indicate that infrasound levels from the MEWF are anticipated to be comparable with existing ambient levels. Estimated G-weighted noise levels are provided Appendix F for informative reference. These estimated levels satisfy the 90dBG criteria for infrasound nominated in the LFN Guideline at all assessed receiver locations.

¹³ RenewableUK – *Wind Turbine Syndrome – An independent review of the state of knowledge about the alleged health condition* - 2010

5.6 Review of cumulative impact

Separate wind farm developments that are in close proximity to each other have the potential to impact on the same receiver. It is therefore necessary to assess any potential cumulative noise impact on receivers, where such circumstances exist

We understand that there are no other wind farm developments currently planned or operating within 10km of the proposed MEWF. On this basis, cumulative impacts of noise from more than one operating wind farm are not considered further.

6.0 OPERATIONAL CONSIDERATIONS

Item 6.3(h) of the PSA 01/11 requires the operation of the wind farm to be controlled and monitored by a site specific management plan which is to include turbine noise.

Methods for monitoring noise at an operational wind farm are provided in NZS6808:2010. These methods could be incorporated into the MEWF operational management plan to facilitate the measurement of operational noise as may be required.

Additionally, while it is expected, as detailed in Section 5.0, that the project will satisfy the NZS6808:210 noise criteria, consideration has been given to available contingency strategies to reduce noise levels if required. The following summarises the two key measures available to reduce the noise:

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

7.0 CONCLUSION

It is proposed to develop the Mount Emerald Wind Farm near Atherton in northern Queensland, comprising up to (70) wind turbines. Three (3) candidate turbine models are currently being considered for this project: REpower 3XM104; Siemens SWT-3.0-101, and; Siemens SWT-3.0-108. One hundred and twenty-three (123) receiver locations have been identified in the area around the proposed wind farm.

Consistent with the Editor's note at Section 6.4 PS5 of the PSA 01/11, an assessment of operational wind farm noise has been carried out with consideration of NZS6808:2010 and the EPP 2008. This assessment has identified forty-four (44) noise sensitive locations where wind farm noise levels are predicted to be 35 dB L_{Aeq} or greater.

Predicted wind farm noise levels have been assessed against a base noise limit of 40 dB L_{Aeq} at all assessable wind speeds. Review of land zoning for the MEWF and surrounding area indicate that high amenity noise limits are not applicable.

Predicted broadband A-weighted noise levels have been calculated at all receiver locations using the ISO9613-2:1996 algorithm for the range of operating wind speeds between turbine cut-in and rated power. These predicted levels have been compared with the appropriate noise limits. It has been found that predicted broadband A-weighted wind farm noise complies with the proposed noise limits at all relevant receivers for the REpower 3XM104 and Siemens SWT-3.0-101 candidate turbines. For the Siemens SWT-3.0-108 candidate turbine, a reduced 67 turbine wind farm layout is required for predicted wind farm noise levels to comply with the applicable limits and, additionally, three (3) turbines would be required to operated in a '-5dB' noise restricted operational mode.

Tonal audibility data has been reviewed and, on the basis of the results, no penalty for tonality has been applied in this assessment. Notwithstanding this, further data for the Siemens turbines should be reviewed before commencing any works at site, to confirm levels of tonal audibility.

Low frequency noise levels have been predicted using the Danish EPA 1284 prediction method for $L_{pAL,F}$ levels, with appropriate variations to account for likely indoor-outdoor sound reductions away from the Danish context. Predicted wind farm noise levels ($L_{pAL,F}$) have been found to be less than the 20 dB internal criterion nominated in the LFN Guideline at all assessed locations with the exception of R78 for the SWT-3.0-101 turbine type. Compliance at this location, for this turbine type, can be achieved if turbines T1, T2 and T62 are excluded from the layout.

Additionally, a review of recent infrasound studies and measurements indicates that infrasound levels around the proposed wind farm are expected to be comparable to or less than existing ambient levels of infrasound. Estimated infrasound levels are below the LFN Guideline criteria values.

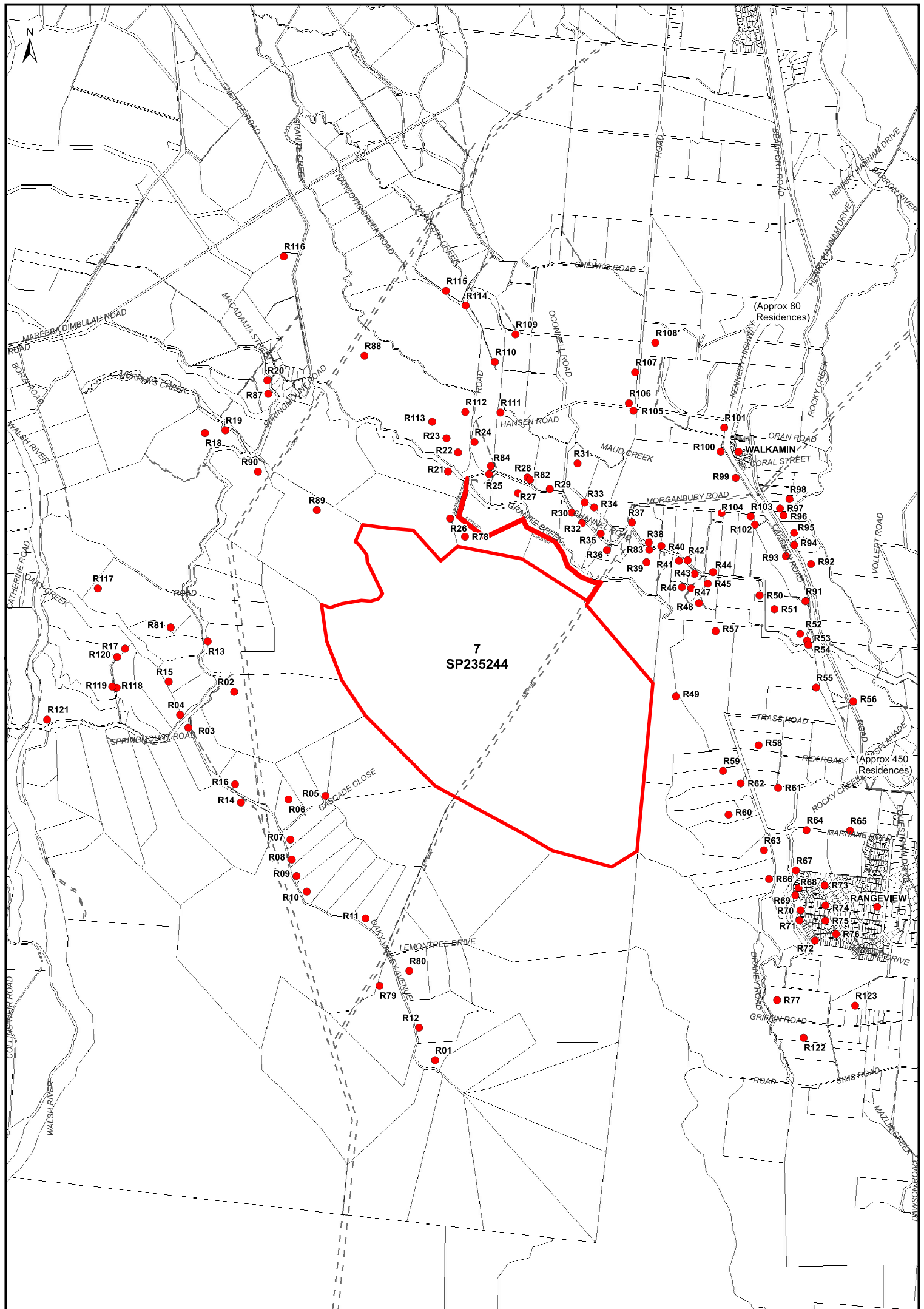
If the turbine selection and/or layout are to be changed, compliance with the relevant noise limit will need to be reassessed.

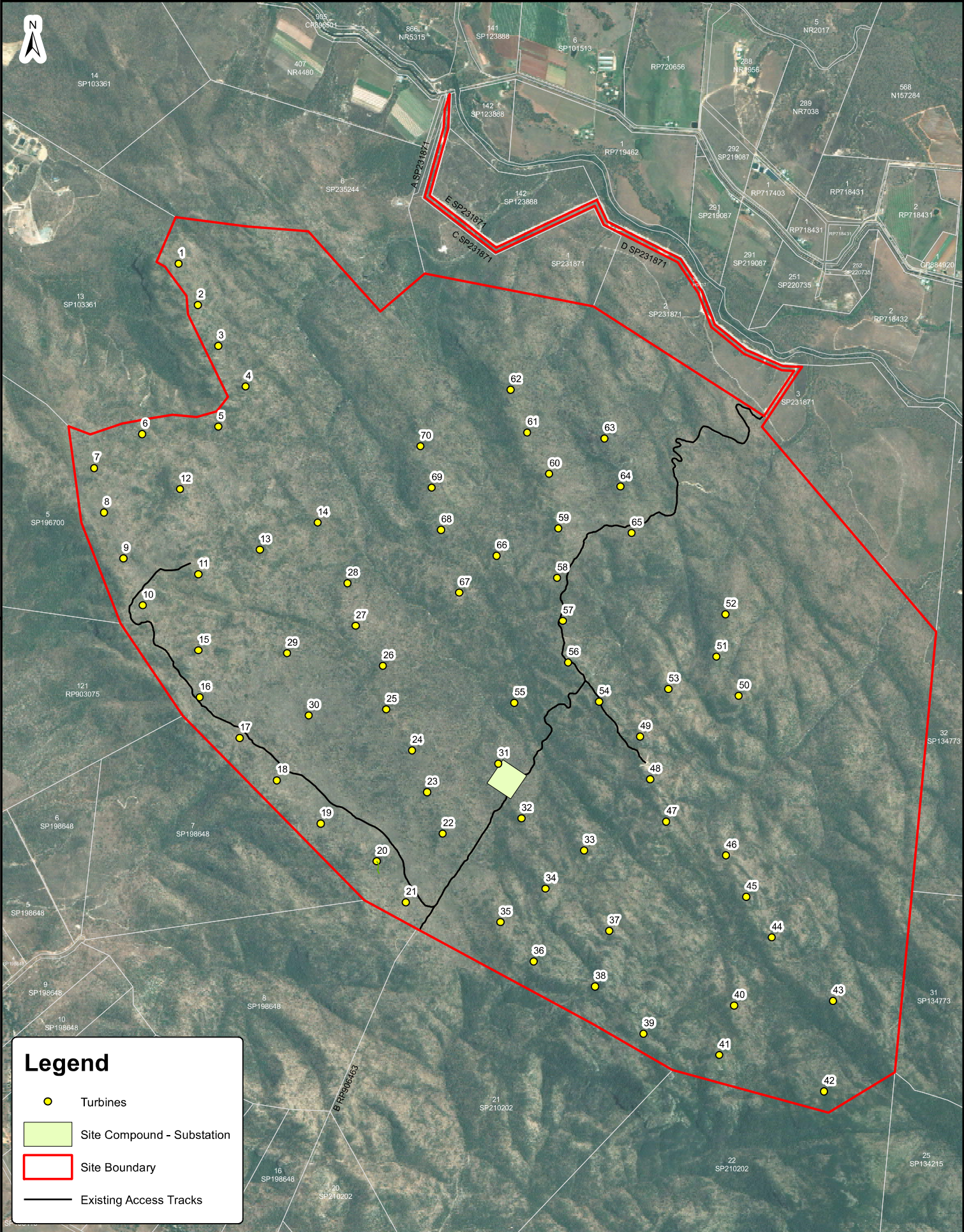
8.0 SUMMARY OF PARAMETERS

Documentation of relevant parameters as required by NZS6808:2010 is contained in Appendix A.

APPENDIX A WIND FARM LAYOUT DETAILS

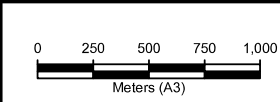
A1 Wind farm site plan





Legend

- Turbines
- Site Compound - Substation
- Site Boundary
- Existing Access Tracks



DIGITAL CADASTRAL DATA BASE - BOUNDARY INFORMATION.
AERIAL PHOTOGRAPHY.
Based on or contains data provided by the State of Queensland (Department of Environment and Heritage Management) 2018. In consideration of the State's ownership of the data, the user acknowledges and agrees that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws.
The aerial photography used in this plan has not been rectified.
The image has been overlaid as a best fit on the boundaries shown and position is approximate only.
Date of Capture: August 2008.
Drawn: SP248138 - areas to be regenerated as road
(GSDM ref 2011/006477)

Project Manager	M. Jess
Compiled by	N. Watts
Map Projection	MGAz55
Map Datum	GDA94
File Reference	PR100246-146.mxd
Sheet Number	1 of 1

Client
Ratch Australia Corporation Limited

Title
Proposed turbine layout and substation position at Mt Emerald.



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SCALE (A3) 1:24,000	DATE 20-9-2013	DRAWING NO. PR100246-146	ISSUE 1
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A2 Turbine locations

Turbine	GPS Coordinates (GDA94 Zone 55)		Turbine	GPS Coordinates (GDA94 Zone 55)	
	Easting	Northing		Easting	Northing
T1	325792	8103791	T36	328292	8098872
T2	325927	8103500	T37	328824	8099088
T3	326071	8103211	T38	328726	8098695
T4	326263	8102926	T39	329067	8098362
T5	326071	8102642	T40	329705	8098561
T6	325535	8102589	T41	329600	8098212
T7	325197	8102351	T42	330338	8097956
T8	325266	8102037	T43	330401	8098594
T9	325402	8101713	T44	329970	8099041
T10	325539	8101383	T45	329790	8099328
T11	325930	8101603	T46	329648	8099620
T12	325803	8102201	T47	329228	8099859
T13	326364	8101775	T48	329113	8100157
T14	326771	8101965	T49	329043	8100457
T15	325931	8101065	T50	329738	8100745
T16	325941	8100734	T51	329581	8101021
T17	326222	8100448	T52	329644	8101320
T18	326484	8100150	T53	329242	8100793
T19	326793	8099845	T54	328753	8100703
T20	327187	8099577	T55	328157	8100695
T21	327392	8099290	T56	328537	8100981
T22	327652	8099773	T57	328498	8101272
T23	327542	8100066	T58	328458	8101575
T24	327436	8100361	T59	328466	8101926
T25	327254	8100649	T60	328402	8102310
T26	327232	8100956	T61	328248	8102601
T27	327039	8101238	T62	328130	8102902
T28	326982	8101539	T63	328792	8102560
T29	326556	8101046	T64	328903	8102219
T30	326708	8100606	T65	328983	8101892
T31	328045	8100267	T66	328031	8101732
T32	328206	8099881	T67	327768	8101472
T33	328648	8099655	T68	327640	8101915
T34	328376	8099384	T69	327574	8102211
T35	328058	8099149	T70	327496	8102505

A3 Receiver locations

Receiver	GPS Coordinates (GDA94 Zone 55)		Receiver	GPS Coordinates (GDA94 Zone 55)	
	Easting	Northing		Easting	Northing
R01	327108	8094240	R63	333180	8098115
R02	323399	8101041	R64	333966	8098486
R03	322551	8100377	R65	334769	8098473
R04	322401	8100614	R66	333273	8097584
R05	325084	8099119	R67	333769	8097741
R06	324402	8099053	R68	333818	8097418
R07	324438	8098311	R69	333759	8097284
R08	324461	8097943	R70	333858	8097008
R09	324552	8097638	R71	333837	8096819
R10	324741	8097351	R72	334122	8096447
R11	325824	8096858	R73	334300	8097467
R12	326812	8094840	R74	334315	8097097
R13	322913	8101970	R75	334312	8096814
R14	323526	8098996	R76	334510	8096570
R15	322190	8101228	R77	333420	8095349
R16	323417	8099332	R78	327662	8103902
R17	321385	8101835	R79	326084	8095615
R18	322861	8105817	R80	326633	8095887
R19	323237	8105869	R81	322227	8102228
R20	324011	8106789	R82	328862	8104954
R21	327346	8105105	R83	331064	8103659
R22	327532	8105458	R84	328138	8105207
R23	327320	8105720	R87	324029	8106539
R24	327836	8105651	R88	325804	8107243
R25	328105	8105059	R89	324925	8104393
R26	327385	8104239	R90	323839	8105103
R27	328640	8104706	R91	333946	8102712
R28	328814	8104996	R92	334049	8103397
R29	329227	8104783	R93	333585	8103544
R30	329632	8104345	R94	333738	8103749
R31	329738	8105254	R95	333737	8103972
R32	329821	8104154	R96	333543	8104296
R33	329870	8104536	R97	333476	8104424
R34	330044	8104444	R98	333652	8104597
R35	330166	8103957	R99	332659	8104989
R36	330281	8103655	R100	332380	8105473

Receiver	GPS Coordinates (GDA94 Zone 55)		Receiver	GPS Coordinates (GDA94 Zone 55)	
	Easting	Northing		Easting	Northing
R37	330744	8104165	R101	332447	8105917
R38	331053	8103796	R102	333013	8104126
R39	331012	8103431	R103	332934	8104276
R40	331286	8103732	R104	332397	8104339
R41	331610	8103457	R105	330771	8106228
R42	331773	8103467	R106	330687	8106366
R43	331900	8103216	R107	330802	8106936
R44	332241	8103249	R108	331175	8107484
R45	332142	8103035	R109	328594	8107639
R46	331667	8102969	R110	328212	8107130
R47	331836	8102949	R111	328314	8106195
R48	331981	8102675	R112	327666	8106205
R49	331555	8100953	R113	327055	8106025
R50	333099	8102820	R114	327675	8108169
R51	333372	8102564	R115	327309	8108440
R52	333849	8102111	R116	324316	8109076
R53	333977	8101981	R117	320884	8102947
R54	334001	8101907	R118	321231	8101117
R55	334143	8101119	R119	321148	8101136
R56	334828	8100860	R120	321240	8101684
R57	332290	8102160	R121	319947	8100527
R58	333082	8100051	R122	333913	8094653
R59	332424	8099580	R123	334862	8095248
R60	332526	8098770	RANGEVIEW	335269	8097070
R61	333441	8099268	WALKAMIN	332711	8105470
R62	332750	8099348			

APPENDIX B ACOUSTIC 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.
dBA	A-weighted decibel. The A-weighting approximates the response of the human ear
dBG	G-weighted decibel. The G-weighting, as specified in ISO 7196:1996, approximates the response of the human ear to sound in the infrasound region.
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 4000Hz (4kHz). This is roughly equal to the range of frequencies on a piano.
Infrasound	Sound at frequencies less than 20 Hz.
Octave Band	A range of frequencies where the highest frequency included is twice the lowest frequency. 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.

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 noise level exceeded for 90% of the measurement period, measured in dBA. This is commonly referred to as the background noise level.
L_{Aeq}	The equivalent continuous sound level. This is commonly referred to as the average noise level and is measured in dBA.
L_{pAL,F}	The A-weighted sound pressure level at low frequencies, found by summing the sound pressure levels in each one-third octave band from 10 Hz to 160 Hz.
L_{WA}	The A-weighted sound power level is a logarithmic ratio of the acoustic power output of a source relative to 10 ⁻¹² watts and expressed in decibels. Sound power level is calculated from measured sound pressure levels and represents the level of total sound power radiated by a sound source.

APPENDIX C QUEENSLAND NOISE ASSESSMENT TOOLS

C1 Environmental Protection Act 1994

Queensland's *Environmental Protection Act 1994* provides a regulatory mechanism for managing noise. The objective of the act is:

... to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).

The act defines environmental nuisance as

...unreasonable interference or likely interference with an environmental value caused by –

(a) aerosol fumes, light, noise [...]

Section 440 of the act includes for local noise laws to be prescribed by local governments while also providing nominal guidance for a range of common noise sources such as pumps, air conditioners, indoor and outdoor venues and transport noise. No specific guidance is offered for wind farm noise.

C2 Environmental Protection Regulation 2008

To achieve the object of the EPA 1994, general noise guidance is provided in the *Environmental Protection Regulation 2008* and *Environmental (Noise) Protection Regulation 2008* (EPP Noise 2008) though not directly in relation to noise from wind farms.

EPP Noise 2008, in particular, details a series of acoustic quality objectives along with methods for controlling background creep¹⁴.

Acoustic quality objectives

The acoustic quality objectives for dwellings are detailed in Table 14 below.

¹⁴ An iterative increase in background noise levels in an area from the introduction, over time, of a range of noise sources which are required to satisfy noise limits based on background noise levels.

Table 14: EPP Noise 2008 Acoustic quality objectives

Sensitive receptor	Time of day	Acoustic quality objectives (measured at the receptor) dB			Environmental value
		$L_{Aeq,adj,1hr}$	$L_{A10,adj,1hr}$	$L_{A1,adj,1hr}$	
Dwelling (for outdoors)	Daytime and evening	50	55	65	Health and wellbeing
Dwelling (for indoors)	Daytime and evening	35	40	45	Health and wellbeing
	Night time	30	35	40	Health and wellbeing, in relation to the ability to sleep

Controlling background creep

Regarding the control of background creep, Section 10 of the EPP Noise 2008 states the following:

(2) To the extent that it is reasonable to do so, noise from an activity must not be—

(a) for noise that is continuous noise measured by $L_{A90,T}$ —more than nil dB(A) greater than the existing acoustic environment measured by $L_{A90,T}$; or

(b) for noise that varies over time measured by $L_{Aeq,adj,T}$ —more than 5dB(A) greater than the existing acoustic environment measured by $L_{A90,T}$.

C3 Ecoaccess draft document Guideline: Assessment of low frequency noise

Item S5(b) of the PSA 01/11 requires consideration of both audible and inaudible noise. We understand that inaudible noise is referenced to address levels of infrasound.

The Queensland EPA Ecoaccess draft document *Guideline: Assessment of low frequency noise* (LFN Guideline) provides assessment guidance for low frequency noise. The guideline discusses both low frequency noise and infrasound and while it claims to be “...intended for planning purposes as well as for the evaluation of existing problems,” much of the guidance relates only to in-situ measurements to address complaints. The application of the LFN Guideline to wind farm noise assessment is therefore somewhat unclear, particularly given that the document remains in draft form. Nonetheless, criteria proposed by the guideline are noted below.

Low frequency noise

The LFN Guideline defines low frequency sound as “sound in the frequency range of 10 Hz to 200 Hz” and outlines a four step assessment procedure as detailed in Table 15 below.

Table 15: LFN Guideline assessment phases

Phase	Outline	Comments
1. Initial screening	Where a noise imission occurs with an unbalanced frequency spectrum, the overall indoor sound pressure level us to be measured and where it exceeds 50 dB(Linear) further investigation is required.	While this initial screening process is intended to determine whether a detailed assessment is required, it does not provide a means of establishing whether a frequency spectrum is unbalanced or not.
2. Audibility assessment	<p>This phase is framed as a measurement tool as it, for example, requires review of recorded sounds and listening studies. The intent of this phase is to establish whether an alleged low frequency noise is likely to be audible.</p> <p>This phase requires comparison of L_{Aeq} and L_{LIneq} levels, measurement of 1/3 octave band levels from 10 Hz to 200 Hz and comparison with hearing threshold curves for the best 10% of the population aged 55-60 years.</p>	<p>The Guideline notes that this phase is:</p> <p><i>"...intended for use in cases where an individual complains about low frequency noise and a decision needs to be made as to whether the particular noise is audible.</i></p> <p><i>This assessment does no verify whether the noise is annoying or not. A sound that is audible is not necessarily unacceptable."</i></p> <p>For a planning phase assessment without measurements assessing the audibility of a sound is impractical.</p>
3. Annoyance due to tonal noise	The guideline provides a simple tonality assessment method based on comparison of adjacent one-third octave band levels and also details acceptable criteria for tonal noise based on time of day and tone frequency.	<p>One-third octave band turbine sound power level data in the low frequency regions can be reviewed for tones according to the method detailed in the LFN Guideline.</p> <p>Additionally, tonal audibility results assessed according to IEC61400-11 for candidate turbines can provide an indication of the presence of low frequency tones. It should be noted however, that the IEC standard typically does not include assessment of sound below approximately 50Hz.</p>
4. Annoyance due to non-tonal noise	Non-tonal noise is to be assessed by determining the A-weighted noise level in the frequency range 10 Hz to 160	<p>The guideline does not offer any method for predicting levels of low frequency noise prior during the planning phase. However, the Danish EPA 1284 document published in 2011* provides a method for estimating expected levels of low frequency noise from a wind farm, and similarly applies a criteria of 20 dB $L_{pAL,F}$.</p> <p>In the absence of a suitable methodology for predicting LFNs in the guideline, it is considered appropriate to reference this Danish document.</p>

* Danish EPA document *Statutory Order on Noise from Wind Turbines (Translation of Statutory Order no. 1284 of 15 December 2011)*

Phases 1 and 2 as outlined above appear to be exclusively intended to address complaints of existing noise.

On this basis, it is considered appropriate for a planning stage assessment of low frequency noise to address Phases 3 and 4.

Infrasound

The LFN Guideline defines “...sound in the frequency range below 20 Hz...” as infrasound and provides recommended indoor G-weighted noise limits as detailed in Table 16 below.

Table 16: Recommended limits for infrasound indoors

Type of Space	G-weighted sound level (dB)
Dwellings during day, evening and night	85
Inside classrooms and offices	85
Occupied rooms in commercial enterprises	90

C4 Recommended approach to assessment

The assessment of wind farm noise detailed in NZS6808:2010, as detailed in Section 2.0, involves measurements of the $L_{A90,10min}$ noise descriptor. It can also involve a regression analysis of two weeks or more of noise data correlated with wind speeds at the wind farm to establish variations in noise level with wind speed. This approach differs significantly from the more general noise assessment methods and guidance provided in the Queensland Government’s state noise policies. While this means that a direct comparison of the wind farm noise and general noise guidelines is not practicable there is, nonetheless, a degree of commonality across the various documents.

For example, NZS6808:2010 nominates a base noise level of 40 dB $L_{Aeq,10min}$, which is applicable outside of dwellings neighbouring a wind farm. Allowing for a sound reduction of 10-15 dB through an open window¹⁵, an estimated base noise limit of 25-30 dB L_{Aeq} would apply inside a dwelling, for example, in a bedroom. While a direct comparison with Queensland’s acoustic quality objective is not practicable due to differences in noise descriptor, it can be noted that the NZS6808:2010 approach is broadly consistent with the lowest acoustic quality objective of 30 dB $L_{Aeq,adj,1hr}$ for dwellings indoors during night-time.

Similarly, in relation to variation in background noise levels, NZS6808:2010 provides a mechanism for wind farm noise to be up to 5dB higher than the background noise level ($L_{A90,10min}$) except in low noise level conditions where the base noise level would apply. As wind farms do not operate during periods of little or no wind and the noise from wind farms is, on average, significantly reduced under conditions where the wind blows from a receiver to the wind farm (that is, the receiver is upwind), wind farms could be considered a non-continuous noise source in the context of the EPP Noise 2008.

¹⁵ DEFRA (UK) report NANR116: ‘Open/closed window research’ (April 2007)

Section 10 Item 2(b) of the EPP Noise 2008 allows for a 5dB margin above the background noise level ($L_{A90,T}$) as a means of controlling background creep from non-continuous sources. Again differences in noise descriptors mean direct comparison of NZS6808:2010 and the EPP Noise 2008 is not practicable. Nonetheless, the similarity of margins of the background noise levels indicates a degree of commonality across the documents.

On balance, it is considered that an assessment of audible wind farm noise in accordance with NZS6808:2010 is likely to provide an outcome that is broadly consistent with the noise management approaches described in the Queensland Government's noise policy documents. Moreover, NZS6808:2010 is better equipped to address the fundamental variations in noise level with changes in wind speed that occur with a wind farm. Accordingly, NZS6808:2010 are used herein as the primary noise assessment guidance document.

To address the additional PSA 01/11 requirement for consideration of inaudible noise, a supplementary assessment of low frequency noise and infrasound is also detailed in this assessment, referencing criteria detailed in the LFN Guideline and using a range of available planning phase assessment methods to account for the lack of guidance offered by the LFN Guidelines.

C5 Discussion

The level of a noise is one of many factors which influence how that noise is perceived; other factors are not related to the level, and include non-acoustic factors such as an individual's attitude to the noise in question, and the perceived benefits of the source of noise in question. Accordingly, whilst a policy may impose strict requirements to limit a noise source to low levels, the subjective nature of the way noise is perceived means that it is not possible to ensure an individual will consider the noise to be acceptable; there will always be a portion of the population which will experience a degree of annoyance to an audible sound. Importantly, no objective criterion can categorically define an audible level below which no individual would experience annoyance – it is a matter of individual opinion. The core objective of wind farm noise policies is to balance the advantage of developing wind energy projects, with protecting the amenity of the surrounding community from adverse noise impacts. Compliance with these policies may result in wind turbine noise being audible at some locations for some of the time.

APPENDIX D REVIEW OF LAND ZONING

The Tablelands Regional Council is currently in the process of developing a new planning scheme which will replace a set of four existing planning schemes for the Atherton, Eacham, Herberton and Mareeba Shires. We understand that the proposed MEWF is positioned across the Mareeba Shire and Atherton Shire.

D1 Mareeba Shire Council

2004 Mareeba Shire Council planning maps show the MEWF and surrounding area zoned as Rural. Item 4.77.2(b) of the Mareeba Shire Planning Scheme (Version 1/2007) notes the following:

- (2) The overall outcomes sought for the Rural zone code are to achieve an area:*
 - (a) that caters for a range of primary industries including forestry and aquaculture to contribute to the economic well being of the Mareeba Shire;*

D2 Atherton Shire council

Similarly, the 2002 Atherton Shire Planning Scheme shows the relevant sections of the MEWF and surrounding area which fall within the Atherton Shire zoned as Rural (GQAL). Part C, 1.1 of the planning scheme notes the following:

- The Rural Areas include all Good Quality Agricultural Land (GQAL) in the Shire and other rural areas.*
- The Structure Plan Map illustrates the preferred settlement pattern for the Shire. This pattern provides for urban and rural residential development in a manner that minimises the impact of these land uses on agriculture.*
- Maintaining efficient rural production is critical to the social and economic well-being of the Shire*

D3 Tablelands Regional Council

The TRC Draft Planning Scheme (downloaded 27 April 2003) shows the MEWF and surrounding area zoned as Rural, General Rural and Rural, Good Quality Agricultural Land. In relation to these zones, Section 6.2.1.2 Item (1) of the draft plan notes the following:

- The purpose of the Rural zone code is to:*
 - (a) provide for a wide range of rural uses including cropping, intensive horticulture, intensive animal industries, animal husbandry, animal keeping and other primary production activities;*

APPENDIX E A-WEIGHTED 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, AS4959:2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators* and NZS6808:2010 *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 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 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 degrees 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
- NZS6808:2010 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 study¹⁶ (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 *2009 joint IoA 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. It is noted that this publication specifically referred 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 for a given ground absorption factor, 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.

¹⁶ Bass, Bullmore and Sloth - *Development of a wind farm noise propagation prediction model; Contract JOR3-CT95-0051, Final Report*, January 1996 to May 1998.

- A range of comparative measurement and prediction studies^{17, 18, 19} 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 key findings of these studies demonstrated 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 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.

In addition to the choice of ground absorption factor referred to above, the ISO 9613 standard has also been used with due regard to the recommended adjustments for terrain recommended in the Joule Report. The following 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
- Barrier attenuation calculated based on the screening expected for the source located at the tip height of the turbine
- 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

These methodologies are also supported by the UK Institute of Acoustics document *A Good Practice Guide to the application of ESTU-R-97 for the Assessment and Rating of Wind Turbine Noise*.

¹⁷ 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

¹⁸ 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

¹⁹ Delaire, Griffin, & Walsh – *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*; Presented at the Fourth International Meeting on Wind Turbine Noise in Rome, April 2011

APPENDIX F NOISE CONTOUR MAPS

Operational noise levels from the proposed Mount Emerald Wind Farm have been predicted using the implementation of ISO9613-2:1996 in SoundPLAN version 7.2 with due consideration of recommendations from the Joule Report.

Assessing the Joule Report recommendations requires exporting ISO 9613-2:1996 predicted levels from SoundPLAN for post-processing. The post-processing involves consideration of each source-receiver pair and the intervening terrain between the source (wind turbine) and the receiver as well as consideration of the extent of barrier attenuation at each receiver. The Joule Report corrected noise levels will vary from those calculated according to ISO 9613-2:1996 alone, typically by 0dB to 3dB, though potentially up to 5dB in some cases²⁰.

It is not currently possible to directly apply Joule Report adjustments in the noise modelling software. The noise contour maps generated by SoundPLAN can therefore only relate to ISO 9613-2:1996 predicted levels and do not reflect the Joule Report adjustments.

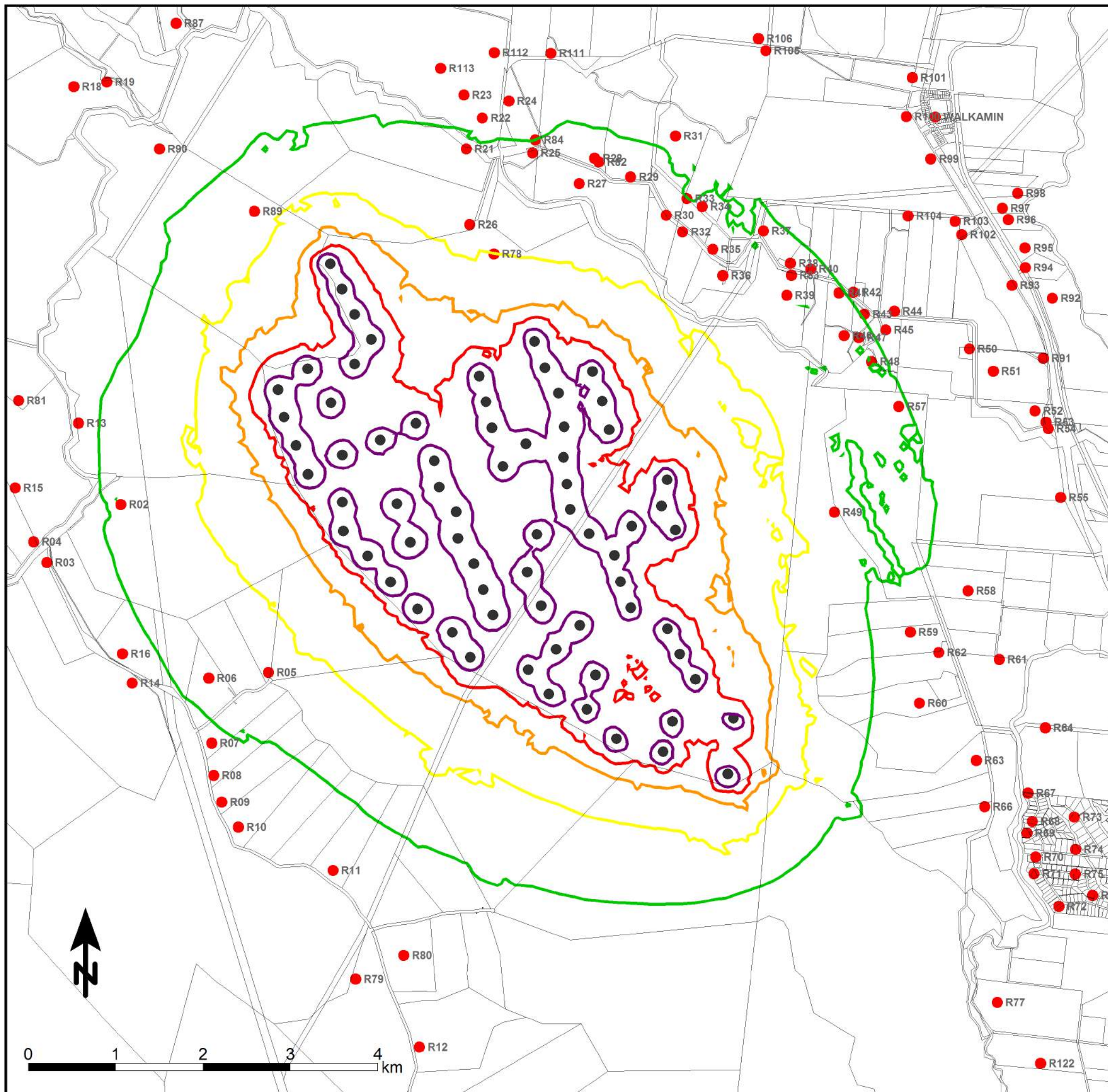
In order for the contour maps included in this appendix to broadly agree with the predicted levels presented in Section 5.0, the calculations for the noise contours maps have been adjusted. Specifically, the noise contour maps have been calculated using:

- a ground attenuation factor of $G=0$ in lieu of the ground attenuation factor of $G = 0.5$ documented in Section 5.0
- barrier attenuation limited to 0.5

Despite this adjustment, the noise level contours presented may vary from the levels reported in Section 5.0 by an amount in the range 0dB to 5dB.

The noise contour maps should therefore be considered as **indicative only**. Each map includes the note that the contours presents 'representative noise levels only'. For the predicted noise levels calculated with direct allowance for the Joule Report recommendations, please refer to Section 5.0.

²⁰ Please refer to Appendix E for details regarding the recommendations of the Joule Report.



Mt Emerald Wind Farm

70 x SWT101 turbines

Predictions in accordance with ISO9613-2
Calculated at 1.5m above ground level

Representative noise levels only
100% hard ground, barrier attenuation limited to 0.5,
Joule effects not applied.

Refer to body of report for further details.

Legend

- Receiver
- Turbine

Noise level (dB L_{Aeq})

- 35
- 40
- 45
- 50
- 55

16 April 2014

Project Number: 2012376ML

Run details:
412 - 14/4/2014: 70x SWT101 Hub height Eq12 Dz=0.5 G 0

Mt Emerald Wind Farm

67 x SWT108 turbines

Predictions in accordance with ISO9613-2
Calculated at 1.5m above ground level

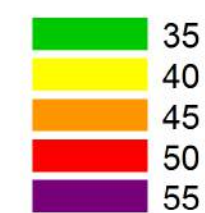
Representative noise levels only
100% hard ground, barrier attenuation limited to 0.5,
Joule effects not applied.

Refer to body of report for further details.

Legend

- Receiver
- Turbine

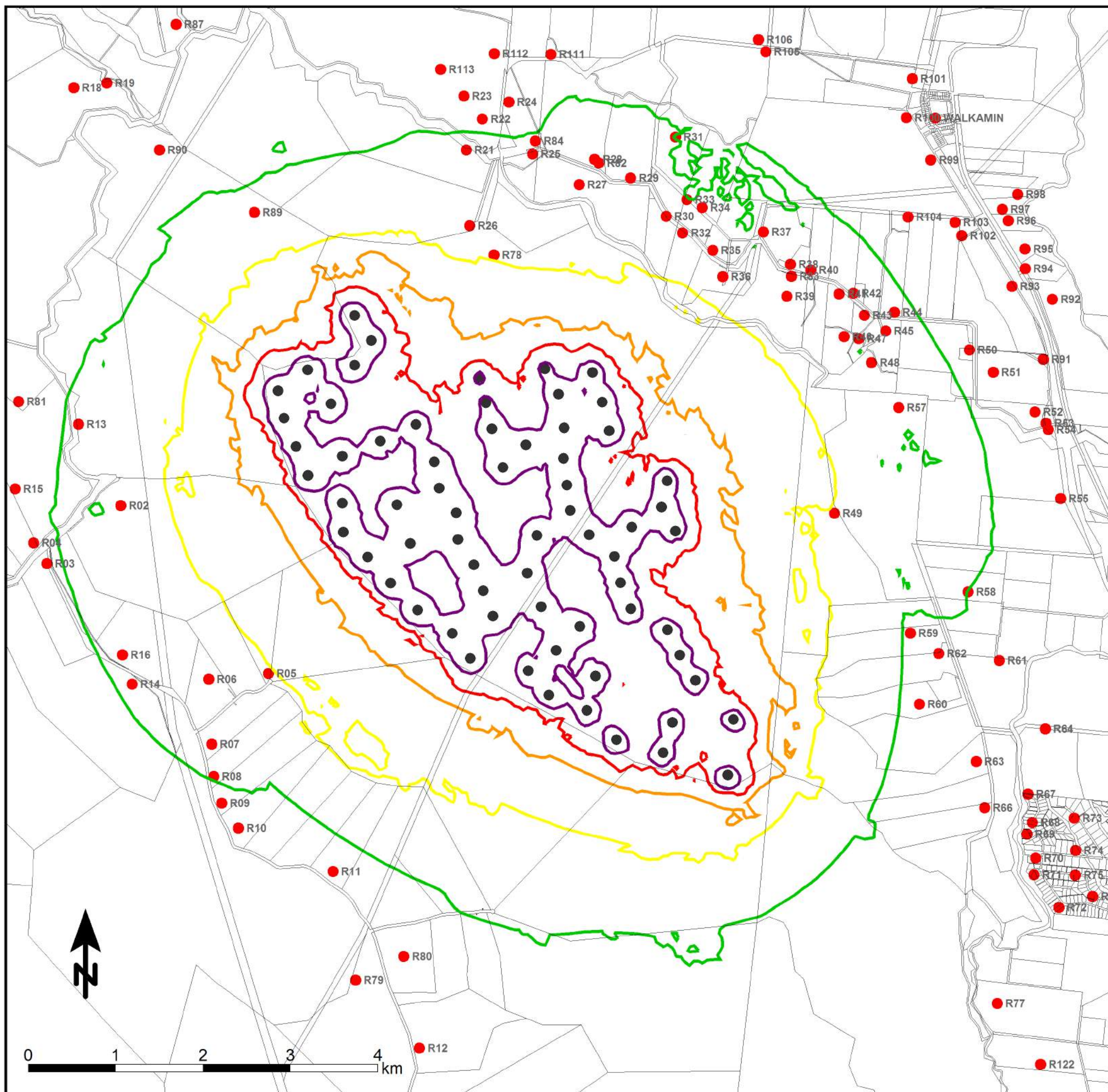
Noise level (dB L_{Aeq})



16 April 2014

Project Number: 2012376ML

Run details:
410 - 14/4/2014: 67xSWT-3.0-108 Hub height -5dB curtailed Dz=0.5 Eq12_AM



APPENDIX G NOISE PREDICTIONS AT LOW FREQUENCIES

G1 Discussion

In common with many other sources of noise, wind turbines emit infrasound, low frequency sound. These types of sounds are, however, a feature of the everyday environment and arise from a wide range of natural sources such as the wind and the ocean as well as man-made sources such as domestic appliances, transportation and agricultural equipment.

These types of emissions have been the subject of considerable misrepresentation in media commentary. Notably, the work of Dr Geoff Leventhall, a prominent UK consultant in the field of acoustics and vibration, and researcher in the field of low frequency noise is often cited in some documents which continue to claim concerns about infrasound and low frequency noise from wind turbines. However, Dr Leventhall has regularly made clear statements to assert that there is no significant infrasound from current designs of wind turbines and very little low frequency sound, neither of which are anywhere near the sorts of levels which would represent a direct health risk for neighbouring residents of modern wind farms. An example such publication, co-authored by Dr Leventhall, was published in the UK Institute of Acoustics Bulletin in March 2009²¹. This publication was prepared as an agreement between acoustic consultants regularly employed on behalf of wind farm developers, and conversely acoustic consultants regularly employed on behalf of community groups campaigning against wind farm developments. The intent of the article was to promote consistent assessment practices, and to assist in restricting wind farm noise disputes to legitimate matters of concern. On the subject of infrasound and low frequency noise, the article notes:

Infrasound is the term generally used to describe sound at frequencies below 20Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles. Sounds at frequencies from about 20Hz to 200Hz are conventionally referred to as low-frequency sounds. A report for the DTI in 2006 by Hayes McKenzie concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view.

A Portuguese group has been researching 'Vibro-acoustic Disease' (VAD) for about 25 years. Their research initially focussed on aircraft technicians who were exposed to very high overall noise levels, typically over 120dB. A range of health problems has been described for the technicians, which the researchers linked to high levels of low frequency noise exposure. However other research has not confirmed this. Wind farms expose people to sound pressure levels orders of magnitude less than the noise levels to which the aircraft technicians were exposed. The Portuguese VAD group has not produced evidence to support their new hypothesis that infrasound and low frequency noise from wind turbines causes similar health effects to those experienced by the aircraft technicians.

²¹ Institute of Acoustics Bulletin – Bowdler, Bullmore, Davis, Hayes, Jiggins, Leventhall, McKenzie - *Prediction and Assessment of Wind Turbine Noise* – March 2009

G2 Predictions methods

The ISO9613-2:1996 prediction method used here for assessment of broadband A-weighted noise levels, has been developed using octave-band algorithms for octave band centre frequencies from 63 Hz to 8 kHz. The nominal lower frequency limit for the method therefore does not encompass the low frequency noise region of the sound spectrum, defined by the LFN Guideline as 20 Hz to 200 Hz for low frequency noise and below 20 Hz for infrasound. Moreover, the method does not extend to the prediction of noise levels inside residential dwellings whereas the LFN Guideline nominates assessment of such levels indoors. On this basis, ISO9613-2:1996 is not preferred for prediction of either $L_{pAL,F}$ noise levels for the low frequency noise region nor L_{pG} noise levels for the infrasound region.

Alternatively, guidance provided in the Danish EPA 1284 document has been developed specifically to provide a suitable planning stage assessment of low frequency wind farm noise inside dwellings, using the $L_{pAL,F}$ descriptor. The Danish EPA method is therefore used here to assess predicted levels of low frequency noise.

Regarding prediction of G-weighted noise levels we are not currently aware of any reliable, validated methods for predicting how infrasound levels propagate away from any particular source, including wind turbines. However, while the Danish EPA method has not been developed specifically for assessment of G-weighted noise levels, the indoor one-third octave band noise levels predicted using the method for the frequency range 10 Hz to 160 Hz can be used to estimate indicative levels of G-weighted noise. In the absence of a suitable prediction method tailored to G-weighted noise levels, results of the Danish method are used here to provide estimates of G-weighted noise levels.

G3 Sound power level data

For the prediction of both G-weighted and $L_{pAL,F}$ noise levels it is important to note that predictions carry a greater margin of uncertainty than A-weighted predictions, owing to the greater uncertainty associated with the measured or reported sound power level data for the nominated turbines. Test standard IEC 61400-11²², which is the common reference for sound power level data reported by manufacturers, details a method for measuring wind turbine sound power levels at frequencies of 20-50 Hz and greater. The standard does not provide any detailed methodology for measuring within the frequency regions for infrasound or low frequency noise.

One-third octave band sound power level test data for the REpower 3XM104 turbine is available at low frequencies, from 10 Hz upwards, for standardised 10m AGL wind speeds in the range 6 m/s to 10 m/s.

Sound power level data for the SWT-3.0-101 and SWT-3.0-108 turbines is reported for one-third octave band centre frequencies of 10 Hz and greater.

²² *Wind Turbine Generator Systems – Part 11 Acoustic Noise Measurement Techniques*

Quoted uncertainty values for one-third octave band sound levels are not provided in the manufacturers' literature. In our experience, reported uncertainty values at low frequencies can range from +/-1dB up to approximately +/-6dB at frequencies below 63Hz. These uncertainty values are considered typical of the range likely to apply for other similar size turbines, depending on the specific circumstances in which the sound power test is carried out.

To provide a conservative appraisal of sound power levels for the 3XM104 turbine below 100 Hz, for each one-third octave band the highest sound power level has been selected from the quote range of wind speeds. For one-third octave bands of 100 Hz and greater, warranted levels have been used, consistent with the approach detailed in Section 5.4.

Sound power level data between 10 Hz and 160 Hz for the candidate turbines is presented in Table 17 below.

Table 17: Sound power level data in the low frequency region

L _{WA} (dB)	One-third octave band centre frequency (Hz)						
	A-weighted						
	10	12.5	16	20	25	31.5	40
Repower 3XM104	44.8	52.4	54.5	63.9	66.9	70.6	75.9
Siemens SWT-3.0-101	46.4	51.0	56.7	61.9	66.7	71.7	78.1
Siemens SWT-3.0-108	52.5	56.2	59.9	63.6	67.3	69.8	73
L _{WA} (dB)	50	63	80	100	125	160	
Repower 3XM104	78.8	81.5	83.6	87.2	88	91.8	
Siemens SWT-3.0-101	78.9	81.4	85.2	87.1	89.7	89.9	
Siemens SWT-3.0-108	76.9	80.8	82.7	86.2	88.2	89.5	

G4 Low frequency tones

For the data in Table 17, the level in any given one-third octave band is not more than 5 decibels greater than the average of the levels in the adjacent two one-third octave bands. On this basis, it is considered that the test for low frequency tones as outlined in the LFN Guidelines is not triggered.

G5 Low frequency noise predictions

In common with the ISO 9613-2:1996 methodology, to calculate far-field noise levels according to the Danish EPA 1284 method the noise emissions of each turbine are firstly characterised, in the form of one-third octave band frequency levels. A series of one-third octave band attenuation factors are then calculated for the following effects:

- Geometric divergence
- Air absorption
- Ground reflections
- Sound reduction from outdoors to indoors

The octave band attenuation factors are then applied to the noise emission data to determine the corresponding one-third octave band and total calculated noise level at receiver locations. The Danish EPA 1284 document details specific values for each of the above attenuation factors, which are applied directly in the calculations presented here. According to the guideline, the air absorption attenuation factors relate to humidity of 80% and an air temperature of 10%, consistent with the conditions used for A-weighted predicted noise levels as detailed in Section 5.0.

The attenuation factors for sound reduction have been developed for typical Danish building constructions. It's possible that the thermal insulation standards of Danish dwellings may result in higher sound reduction levels than those that could be expected in Queensland. To account for this possibility, alternative sound reduction levels have been used in the predictions for this assessment. The available sound reduction levels are detailed in Table 18.

Table 18: Outdoor to Indoor sound reduction levels for calculations of low frequency noise

Data Source	One-third octave band centre frequency (Hz)												
	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Danish EPA 1284	4.9	5.9	4.6	6.6	8.4	10.8	11.4	13.0	16.6	19.7	21.2	20.2	21.2
Hoffmeyer & Jakobsen ^{23*}	1.2	3.2	2.1	3.6	4.6	6.7	7.6	10.3	14.2	17.5	18.4	17.5	18.6
For assessment	1.2	3.2	2.1	3.6	4.6	6.7	7.6	10.3	14.2	17.5	18.4	17.5	18.6

* Level difference in dB expected to be exceeded in 80%-90% of typical Danish dwellings

G6 Estimated G-weighted noise levels

Table 19 below details estimated G-weighted noise levels inside dwellings for the set of receiver locations detailed in Table 5. It is important to note that these predictions do not predict noise levels across the full G-weighted frequency range²⁴ and therefore may under-represent that G-weighted noise levels that could occur in practice.

²³ Hoffmeyer, D. & Jakobsen, J., 2010, 'Sound insulation of dwellings at low frequencies', *Journal of low frequency noise and vibration*, Vol.29 No 1 pp 15-23.

²⁴ As detailed in International Standard 7196:1995 *Acoustics – Frequency-weighting characteristic for infrasound measurements*, the G-weighting applies to frequencies in the range 0.25 Hz to 315 Hz.

Moreover, while the derivation of sound power level data for the candidate turbines in the low frequency region, as detailed above, is considered conservative, additional prediction tolerances may be necessary to account for the unknown extent of measurement uncertainties for the sound power data and propagation uncertainties for the prediction method.

The highest predicted G-weighted noise level in Table 19 is approximately 72 dB L_{Geq} . This allows for a prediction tolerance of more than 10 dB, to account for the uncertainties outlined above, without expected G-weighted noise levels exceeding the LFN Guideline 85 dB criterion.

Table 19: *Estimated* G-weighted noise levels from the Mount Emerald Wind Farm, L_{pG} dB**

House	Turbine model (Hub height wind speed (m/s))			Satisfies the LFN Guideline?
	3XM104 (11 m/s)	SWT-3.0-101 (11 m/s)	SWT-3.0-108 (11 m/s)	
R78	68	68	72	✓
R26	67	67	71	✓
R05	67	67	70	✓
R49	66	66	70	✓
R89	66	66	70	✓
R36	66	66	69	✓
R32	65	65	69	✓
R30	65	65	69	✓
R35	65	65	69	✓
R27	65	65	69	✓
R06	65	65	69	✓
R02	65	65	69	✓
R29	65	65	68	✓
R33	65	64	68	✓
R82	65	65	68	✓
R25	65	65	69	✓
R39	65	65	68	✓
R34	64	64	68	✓
R28	65	65	68	✓
R84	65	64	68	✓
R21	65	65	69	✓

House	Turbine model (Hub height wind speed (m/s))			Satisfies the LFN Guideline?
	3XM104 (11 m/s)	SWT-3.0-101 (11 m/s)	SWT-3.0-108 (11 m/s)	
R83	64	64	68	✓
R46	64	64	68	✓
R37	64	64	68	✓
R38	64	64	68	✓
R40	64	64	68	✓
R13	64	64	68	✓
R48	64	64	67	✓
R47	64	64	67	✓
R57	64	63	67	✓
R22	64	64	68	✓
R07	64	64	68	✓
R16	64	64	67	✓
R41	64	63	67	✓
R24	64	64	67	✓
R59	64	64	68	✓
R14	64	63	67	✓

** G-weighted noise levels are estimated here using available data and assessment methods for the frequency range 10 Hz to 160 Hz. Estimated levels are likely to under predict actual G-weighted noise levels.

APPENDIX H SUMMARY OF MODELING PARAMETERS²⁵

H1 Predictions

- (a) Map of the site showing topography, turbines and residential properties: Refer to Appendix A (note the coordinates are referenced to GDA94 Zone 55)
- (b) Noise sensitive locations: See Section 4.2 and Appendix A
- (c) Wind turbine sound power levels, L_{WA} dB: Refer to Section 3.1.2
- (d) Wind turbine models: REpower 3XM104, Siemens SWT-3.0.101 & SWT-3.0-108, details provided in Table 1
- (e) Turbine hub height: 80m
- (f) Distance of noise sensitive locations from the wind turbines: Refer to Table 5
- (g) Calculation procedure used: A-weighted noise modelled developed in SoundPLAN v7.2 using ISO9613-2:1996 prediction algorithm, with adjustments as noted in Section 5.0.
- (h) Meteorological conditions assumed:
 - Temperature: 10°C
 - Relative humidity: 70%
 - Atmospheric pressure: 101.325 kPa
- (i) Air absorption parameters:

Description	Octave band mid frequency (Hz)							
	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) Ground attenuation: $G=0.5$ (See Appendix E)
- (k) Topography/screening: Screening effects in accordance with ISO9613-2:1996 prediction algorithm and the Joule Report as detailed in Appendix E
- (l) Predicted far-field wind farm sound levels: Refer to Section 5.0 and Appendix F.

²⁵ Consistent with information to be reported as detailed in Section 8 of NZS6808:2010.