



**HEGLEY ACOUSTIC  
CONSULTANTS**

**WELLINGTON CITY DISTRICT PLAN  
PROPOSED DISTRICT PLAN CHANGE  
32**

**RENEWABLE ENERGY**

**REVIEW OF NOISE CONDITIONS**

**Report No 6873**

**Prepared for:**  
*Makara Ohairu Community Board  
Wellington  
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**Prepared by:**   
*Neville Hegley MSc MICE CEng MIPENZ*

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## **1 INTRODUCTION**

The Wellington City Council has prepared a Proposed District Plan Change 32 – Renewable Energy, 26 May 2004. This document addresses methods to control noise from wind energy facilities and sets out proposed conditions for these facilities.

This report has been prepared for the Makara Ohairu Community Board who are concerned about the potential noise intrusion into their community should such a facility be developed in their area. The common concerns raised by affected residents are not anti wind, but believe that the siting of wind power stations needs very careful consideration to ensure that they are not located in areas where they will introduce social problems. This includes unreasonable noise.

This report considers the noise aspects of the proposed rule for wind energy facilities and makes recommendations on changes to those rules taking into account the proposed noise conditions and technical information available on the noise effects from wind energy facilities.

There are concerns about the potential noise effects for any community that may be located near a wind turbine. These concerns need to be considered to ensure that the proposed noise rules do in fact address the specific issues. Without a rule covering such issues, there would be the potential to achieve the requirements of the rule but not adequately protect the community.

To assist the reader with the understanding of the technical terms used in this report, a Glossary of Terms has been set out in Appendix A.

## **2 WELLINGTON CITY COUNCIL PROPOSED NOISE RULE**

The proposed Renewable Energy Rules in Chapter 26 sets out the following relevant conditions.

26.1.1 Where the rules in this chapter apply to any proposal the relevant area based rules do not apply to that proposal.

26.3.1.2 The actual or potential noise effects of the proposal, particularly the special audible characteristics and the proximity to and effect on settlements or dwellings; and the ability to meet NZS 6808:1998 (Acoustics - The Assessment and Measurement of Sound from Wind Turbine Generators).

26.3.1.3 The extent to which the proposal will adversely impact on the amenity of the surrounding environment. Particular regard will be given to the impact of the development on dwellings, including consideration of potential 'nuisance' issues including interference to broadcast or other signals; blade shadowing, glint or flickering

26.3.1.8 The extent of any required earthworks, including access tracks roads and turbine platforms and the rehabilitation proposed. Major alterations to natural landforms should be avoided.

Rule 26.3.1.3 is a general requirement and while it has a primary thrust to visual aspects of any assessment it does not exclude noise issues.

Rule 26.3.1.8 includes noise aspects of any development such as the construction phase of a project. Specific construction noise issues are an important aspect of any project so have been considered in the following.

It is considered that the proposed noise rules form the basis of a good noise control for any proposed wind farm. However, in order to test the effectiveness of these rules it is necessary to set out the areas of concern and determine if the concerns are valid. It is then necessary to determine if the proposed rules address the concerns adequately.

### 3 NOISE ISSUES RELATED TO WIND FARMS

Communities near proposed wind farms often express concerns in relation to the following noise issues:

- prediction of wind turbines noise cannot be relied on
- tonal noise is played down
- noise environment at the receiver position is not taken into account
- low frequency noise may be a health hazard
- absolute noise levels should be adopted rather than an exceedence over the background level

The noise rules should address each of these concerns and each of these design issues is considered in the following.

#### 3.1 PREDICTION OF NOISE FROM WIND TURBINES

The accuracy of the prediction of any noise source is dependent on a combination of the accuracy of the input data and the reliability of the noise prediction model.

There are two main noise sources from wind turbines, mechanical noise and aerodynamic noise. Mechanical noise sources are located within the turbine nacelle on the top of the tower. The noise from the gearbox and drive motors is controlled by the manufacturer's design, making any mechanical noise secondary to the aerodynamic noise from the wind turbine blades rotating in the modern turbine.



**Figure 1. Turbine Nacelle**

Noise specifications for the modern wind turbine are available from manufacturers. This data is generally based on measurements undertaken of a wind turbine when measured in accordance with the requirements of the International Standard IEC 61400 – 11 Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques. Based on this data, the sound power level, which is dependent on the wind speed, is determined.

It is noted that the noise from the wind turbine generators does not have any significant directivity characteristics so the direction that the turbine faces does not affect the analysis of the noise effects. The wind direction is more critical in the distribution of noise around the turbines and the resulting noise levels experienced at locations near the site.

When predicting noise from wind turbines it is important to consider the relevant atmospheric behaviour. One of the problems encountered with some prediction techniques of wind turbines is neglecting the positive effects to the propagation of noise downwind. This leads to the under prediction of the noise received at some dwellings. Clause 4.3.2 of NZS6808:1998, Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators adopts the same basic approach where it states:

The predicted outdoor sound level from the proposed WTG installation should be calculated according to equation 1. This equation is generally accepted as being slightly conservative (i.e. over-prediction of the sound levels) and is the same as used in IEC DIS 1400-1 1.

$$L_R = L_W - 10\text{Log}(2\pi R^2) - \Delta L_a$$

where

$L_R$  = the sound pressure level from a single WTG at 1.2m to 1.5m above local ground level in dBA at distance R

$L_W$  = the sound power level of the WTG in dBA. Measured according to IEA (International Energy Agency) procedures relating to WTG sound measurement or IEC DIS 1400-11

R = the distance between the source and the receiver in metres

$$\Delta L_a = \alpha_a R$$

$\alpha_a$  = attenuation of sound due to air absorption, in dBA/m for broad band sound which is typically 0.005 dBA (refer ISO 9613-1). This value is dependent upon the spectral character of the sound and the atmospheric conditions.

This equation does not take into account the positive effects of sound propagation downwind so will not predict the noise level as accurately as might otherwise be achieved if the downwind effects are considered. With the implementation of meteorological based algorithms the prediction of noise downwind can be calculated much more accurately. Noise predictions should consider this effect.

### 3.2 TONAL NOISE

There are three main noise sources in wind turbines.

- i) Turbulence from the blade tip, which is the highest frequency produced by the turbine and may be in the range 500 to 1000Hz.
- ii) Gear and other mechanical noise, which may be in the range 20Hz to 100Hz
- iii) Small pressure pulses caused when the blades interact with the wind flow at the tower. As these have a fundamental frequency of about 1Hz, analysis of their noise gives frequencies in the infrasound region, but at very low, inaudible levels.

The swish – swish – swish noise, which is associated with wind turbines, is a modulation of a higher frequency, the blade tip turbulence, and does not contain low frequency noise.

There are several methods of reducing the low frequency noise of wind turbines.

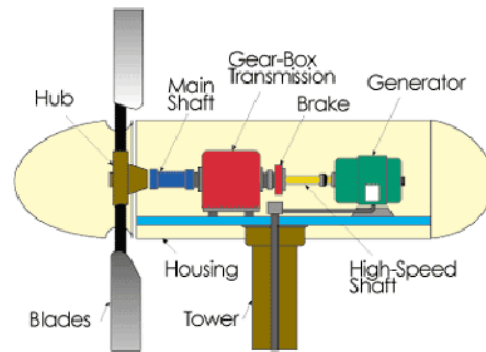
- Orienting rotors on the "upwind" side of the turbine tower (as shown in Figure 1) avoids the low frequency sounds associated with the passage of the blades through the tower's wind shadow, as

occurs on "downwind" machines. In this way, the pressure pulses, which were produced by early versions of downwind machines over 20 years ago, are considerably reduced. It was these pressure pulses which led to the perception that significant infrasound is associated with wind turbines. Modern turbines are all upwind and have very low levels of infrasound.

- Tubular towers and nacelles are streamlined, and produce little sound from the wind.
- As blade aerofoils have become more efficient, more of the wind is converted into rotational torque and less into acoustic noise.

In addition to wide band low frequency noise, tonal noise may also occur from wind turbines. The tonal noise may have both mechanical and aerodynamic origins.

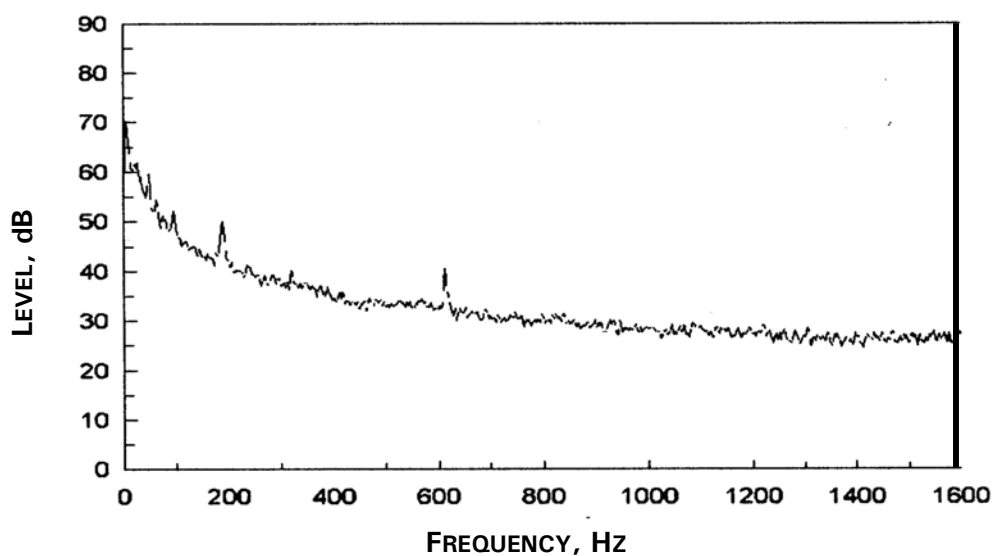
Tonal noise due to mechanical sources is typically associated with the rotation of mechanical equipment, and pure tones tend to be related to the rotational frequencies of shafts and generators and the meshing frequencies of the gears. Tonality differs between turbines and may vary between tests of the same turbine model. However, the control of tonal noise from the mechanical systems is similar to that of noise control of any machine and can be achieved by attention to gear teeth, adding baffles and acoustic insulation to the nacelle. Vibration isolators and vibration mounts can be used for major components, and the turbine can be designed to limit noises from being transmitted into the overall structure. These steps are part of the normal design of modern wind turbines.



**Figure 2. Nacelle Noise Sources**

Many wind turbines, even though from different manufacturers, have similar sound spectra. This is because modern wind turbines are of similar construction. Some examples of noise from wind turbines are set out below.

Figure 3 shows a typical spectrum, taken at about 80m from the wind turbine, from a Vesta V 52 – 850kW turbine. Figure 2 shows a spectrum, which rises up into the lower frequencies, reaching a maximum of about 70dB. The infrasound levels in Figure 3 are all below the hearing threshold.<sup>1</sup>



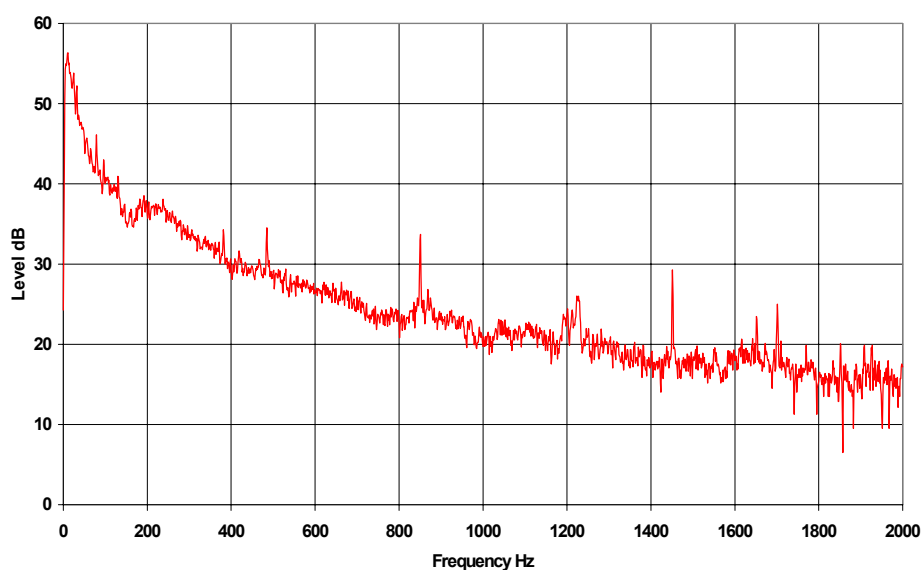
**Figure 3. Vestas V52 - 850kW wind turbine.  
Typical noise at 10m/s wind speed**

There are several small peaks below 100Hz, a peak at nearly 200Hz and a peak at 600Hz

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<sup>1</sup> To place infrasound in perspective, when a child is swinging high on a swing, the pressure change on its ears, from top to bottom of the swing, is nearly 120dB at a frequency of around 1Hz.

Figure 4 of a Bonus 1.3MW turbine show the spectrum plotted up to 2000Hz. In this figure, there are peaks at 1450Hz, 850Hz, 485Hz and a dip at about 150Hz. As the frequency lowers there is a rise on which other peaks are superimposed. The final maximum is at about 11Hz. The fall off below 11Hz may be an instrumentation effect.



**Figure 3. Bonus 1.3MW Wind Turbine at 100m**

It is noted that the analysis is an average over time, which obscures fluctuations. That is, the instantaneous levels will be both above and below the average. The variation will be small for the tone peaks from the turbine, which are due to machinery noise.

There are people who are more sensitive and others who are less sensitive than the average hearing threshold. Threshold measurements on groups of subjects indicate that the standard deviation of the threshold is about 6dB. Therefore, allowing 12dB (two standard deviations) for variations in sensitivity of the

hearing threshold, leaves the potential for about 2% of the population to be more sensitive than 12dB below average threshold.

Table 1 shows the predicted level in the open from a single turbine at 400m distance compared with the average hearing threshold (ISO:226, 2003).

Frequency Hz	Level at 100m	Predicted level at 400m in the open	Average hearing threshold	Level Below Threshold
25.0	50dB	32dB	69dB	37dB
31.9	48dB	30dB	60dB	30dB
32.8	47dB	29dB	59dB	30dB
78.8	42dB	24dB	31dB	7dB
97.0	37dB	19dB	26dB	7dB
130	35dB	13dB	21dB	8dB
174	33dB	15dB	16dB	1dB

**Table 1. Predictions for Bonus 1.3MW Turbine**

Although low frequency noise is produced by wind turbines, the low frequency noise levels from modern machines, for which we can take the Bonus 1.3MW and the Vestas V 52 850kW turbine as typical, are low and are very unlikely to be problem at a few hundred meters from the turbines.

In addition, Clause 5.3 of NZS6808:1998, Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators addresses any potential effects of tones from turbines where it is stated:

### **5.3 Special audible characteristic**

#### **5.3.1**

Sound from a WTG that has special audible characteristics (clearly audible tones, impulses, or modulation of sound levels) is likely to arouse adverse community response at lower levels than sound without such characteristics. At present, there is no simple objective procedure available to quantify special audible characteristics, and subjective assessment is therefore necessary, supported by objective evidence (e.g. frequency analysis) where appropriate.

### 5.3.2

When sound has a special audible characteristic, the measured sound level of the source shall have a 5dB penalty applied. This is because the subjective reaction to a sound containing a special audible characteristic is generally found to be similar to a sound 5dB louder, but without the special audible characteristic. A maximum penalty of 5 dB shall be applied by adjustment of the measured sound level by arithmetic addition of +5 dB.

Since NZS6808:1998 was written, NZS 6802:1999 Assessment of Environmental Noise has addressed the objective assessment of a tonal sound. A tone is defined as:

A test for the presence of tonality can be made by comparing the levels of neighbouring one-third octave bands in the sound spectrum. An adjustment for tonality shall be applied if the level ( $L_{eq}$ ) in a one-third octave band exceeds the arithmetic mean of the  $L_{eq}$  levels in the 2 adjacent bands by more than the values given in the table below.

**One-third octave band level differences**

<b>One-third octave band</b>	<b>Level difference</b>
25 - 125 Hz	12dB
160 - 400 Hz	8dB
500 - 10000 Hz	5dB

NOTE - There might be cases where this analysis does not result in a tonal component being defined although the sound is in fact tonal. For these cases it will be necessary to undertake a narrow-band analysis in order to determine if a sound is tonal.

#### **4 EXISTING ENVIRONMENTAL NOISE AT DWELLINGS**

There is concern that the dwellings in the rural community are in a different noise environment than the potential locations where any wind turbines may be located. Thus, should the noise level be assessed in terms of the noise environment where the wind turbines could be located, this would not take into account the relatively quiet nature of the house locations.

Section 4.5.1, Background Sound Level Measurements in NZS6808:1998, Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators address the noise level at the dwellings where it states:

This Standard recommends that background sound level measurements be carried out where predicted sound levels of 35dBA or higher are calculated for the relevant locations. It is recommended that measurement positions be selected to include locations at or within the nearest affected residential property boundary, (the notional boundary - if a rural property), and near the location of representative positions for any other residential locations within the vicinity of a WTG or windfarm.

Thus, by selecting the measurement locations at representative positions by the dwellings the existing noise environment at the dwellings will form the basis of the assessment of noise effects for any proposed wind turbines so allaying the concerns of the residents.

## 5 LOW FREQUENCY NOISE

- High levels of low frequency noise are required for perception, with the level of perception increasing as the frequency reduces.
- The ear is the most sensitive receptor in the body. If you cannot hear it you cannot feel it.
- Continuous audible low frequency noise can be a nuisance, as can any other noise, but it must be above threshold for this to occur.
- Problems often arise with predominantly low frequency noise because the A-weighted assessment methods do not cater for it. This leads to the noises being dismissed as not a nuisance, leaving unhappy complainants in a stressed state.

However, the above points must be considered in the light of the very low levels of low frequency noise from wind turbines.

Concerns have been expressed about the potential of low frequency noise from wind turbines. To decide if low frequency from the wind turbines is significant the level of noise that may constitute a nuisance or health problem must be determined and what is meant by low frequency noise.

The World Health Organization (WHO)<sup>2</sup> defines<sup>3</sup> health as *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"*. This is a wide conceptualisation, which explicitly covers impacts such as disturbance and impairment of human activities and related annoyance reactions.

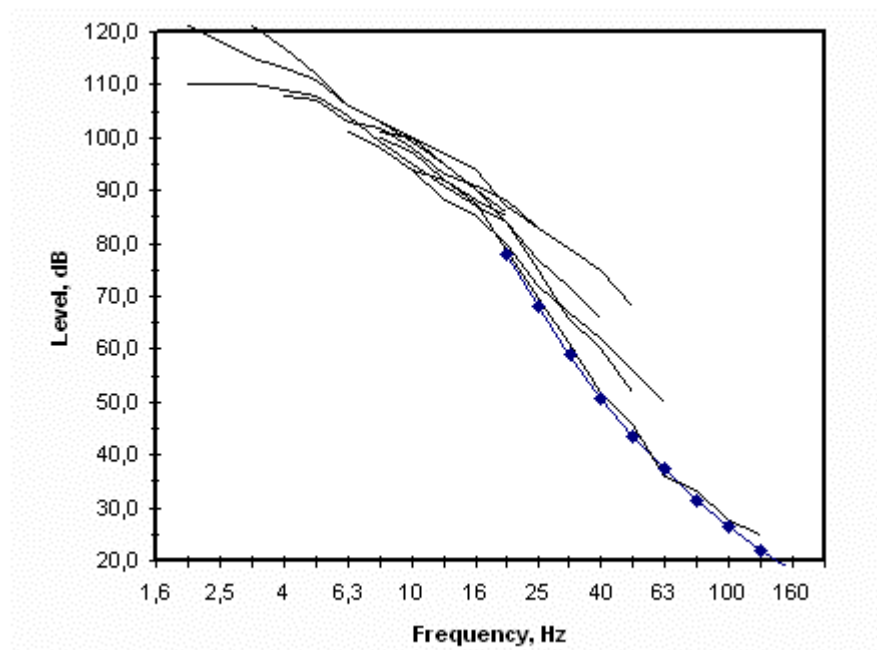
Low frequency is not clearly defined in the WHO document. However, what it does identify is that low-frequency noise is below approximately 200Hz. No lower limit is given. Various authorities addressing low frequency noise generally adopt this definition.

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<sup>2</sup> Community Noise edited by Birgitta Berglund & Thomas Lindvall Stockholm, Sweden, 1995

<sup>3</sup> Section 10.1

The Danish guidelines<sup>4</sup> adopt low frequency noise as being in the frequency range 10 – 160Hz. This guideline states that there is some conformity between the average thresholds found in different investigations in the literature, as is illustrated on Figure 4.



**Figure 4.** Examples of hearing thresholds. The standardised hearing threshold (ISO 389-7) is shown with diamond symbols.

The majority of the negative information available on wind turbine noise is critical of the use of the A-weighted scale to measure effects of low frequency and recommend the use of the “C” scale. Such an approach indicates that it is the frequencies between about 20Hz and 200Hz that are of interest, as the C scale weights frequencies below 20Hz and has a cut off at 10Hz

This is supported by the WHO document,<sup>5</sup> which states that *low frequency noise should be assessed with appropriate octave or 1/3 octave instruments. However,*

<sup>4</sup> Danish Guidelines on Environmental Low Frequency Noise, Infrasound and Vibration

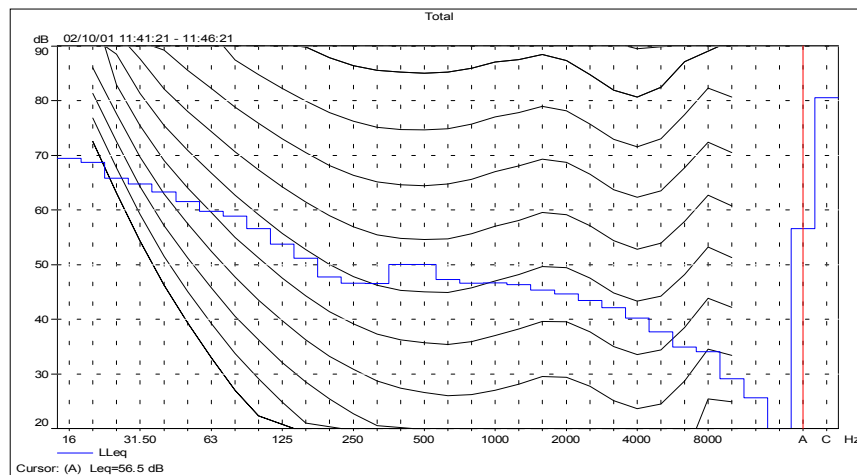
<sup>5</sup> Section 10.6.4

*the difference between dBlin (or dBC) and dBA will give a crude information about the contribution of low frequency sounds. If the difference is more than 20dB, it is recommended to perform a frequency analysis of the noise.*

The WHO document also states<sup>6</sup>, *Special attention should be given to noise sources in an environment with a low background level, to environments where a combination of noise and vibrations are produced and to sources with low frequency components where disturbances may occur even though the sound pressure level is below 45dB LAmax.*

Using the linear ("Lin") level or the "C-weighting" level will give a similar result for noise from wind turbines.

The sound spectrum of the Hau Nui wind farm is shown on Figure 5. The equal loudness curves have been included in this figure so the relative loudness at each frequency may be seen.



**Figure 5. Measured Level at 270m from Closest WTG**

As shown on Figure 5, the threshold of hearing is in excess of 75dB at 20Hz so even if a level of 60dB (or 70dB) did occur it would not be audible. Such a sound would not be significant for the receiver.

It is relevant that the older style turbines had two blades, not three and two bladed turbines are noisier than the modern three bladed turbines. In addition, orienting rotors on the "upwind" side of the turbine tower avoids the low frequency sounds associated with the passage of the blades through the tower's wind shadow, as occurs on "downwind" machines. In this way, the pressure pulses, which were produced by early versions of downwind machines over 20 years ago, are considerably reduced. It was these pressure pulses which led to the perception that significant infrasound is associated with wind turbines. Modern turbines are all upwind and have very low levels of infrasound.

Based on research available and the sound spectrum for the modern wind turbine, there is not expected to be any adverse effects from low frequency noise from wind turbines. However, to ensure that this remains the case with future development, one of the requirements of any noise rule should be to confirm this for any proposed wind farm.

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<sup>6</sup> Section 7.5.10

## **6 ABSOLUTE NOISE LEVELS SHOULD BE ADOPTED, NOT $L_{95} + 5\text{dBA}$**

There is concern in the community that the lower limit of 40dBA may be too high in a quiet area and there is no cap on the background sound plus 5dBA criterion as adopted in NZS6808:1998, Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators so the noise could increase to an unacceptable level.

A level of 35 - 40dBA is generally considered as an acceptable noise limit in quiet rural areas. The Wellington City Council District Plan specifies the lower limit of 35dBA ( $L_{10}$ ) during the night time period for the rural area. It is noted that the 35 - 40dBA  $L_{95}$  design level for a wind farm is similar to a  $L_{10}$  level of approximately 38 - 43dBA  $L_{10}$ . NZS 6802:1991 Assessment of Environmental Sound adopts an upper level of 45dBA to allow undisturbed sleep for residents with the windows open.

For a wind farm, the noise environment where the dwellings are sheltered from the wind will not be as quiet as a rural environment when there is no wind in the area. Thus, an upper limit of 40dBA  $L_{95}$  (43dBA  $L_{10}$ ) is within normally accepted night time limits and it would be difficult to justify a lower noise limit in an area under the above circumstances. In the case of wind turbines, the turbines only generate noise when wind speeds are sufficient to raise the background sound.

The  $L_{10}$  level for the measured ambient sound without a wind farm is typically 8dBA or more above the  $L_{95}$  value due to the effects of wind generated noise. Thus, the  $L_{95}$  plus 5 design approach for the wind turbine is conservative for a wind farm. It must be kept in mind that the noise referred to is the noise that is determined at the dwelling, not the location of the turbine.

It is generally accepted that if the background sound is high, then there will be little adverse effects on a community from an “industrial” sound providing excessive noise is not generated by the new sound. The noise from a wind farm

must be designed for the most noise sensitive conditions. This is generally taken as a wind speed of 10m/s.

The sound of a wind turbine is at the nominal maximum at 10m/s. At this wind speed (and at wind speeds up to approximately 15m/s) the turbines are rotating at typically 24rpm ( $\approx 1$  revolution in 3 seconds). Although a turbine normally operates in 4 to 25m/s winds, the rotation rate does not increase above a wind speed of 13 – 15m/s. At higher wind speeds, the turbine is temporarily shut down to prevent any possible damage to the equipment. Thus, although the wind speed continues to increase with a resulting increase to the background noise environment, the noise from a wind turbine does not continue to increase. There is therefore a limit to the noise from a wind turbine. This limit will generally be below the ambient sound in the area at the higher wind speeds.

## **7 CONCLUSIONS**

The noise from wind farms can be predicted with a good level of confidence providing the effects of the wind assistance on the propagation of sound considered. In any assessment of the noise it is important to include any effects of a tonal component, which should be minimal for the modern wind turbine. This is part of the requirements of NZS6808:1998, Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators.

The background noise environment in the rural area can be expected to be lower at houses on the floor of the gullies than will be experienced at any wind turbine location. It will therefore be necessary to take this into account when assessing the effects of any wind turbines in the area. The assessment of the existing noise environment, including the special nature of some rural environments, is a requirement of NZS6808.

Low frequency noise is not expected to be a nuisance from the modern wind turbine. However, NZS6808:1998 does not address the potential effect of low frequency noise. The potential effects of low frequency noise should be included as part of the analysis for wind farms in the Proposed District Plan Change 32.

## 8 RECOMMENDATIONS

It is recommended that:

- i) Proposed Rule 26.3.1.2 is supported in part. The rule should be extended to address some shortfalls in NZS6808:1998, Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators.

It is recommended that the rule be modified to:

**All activities during the construction period of the proposal should comply with the requirements of NZS 6803:1999 Acoustics – Construction Noise**

The actual or potential noise effects of the proposal ~~with particular consideration of special audible characteristics~~ and the proximity to and effect on settlements or dwellings **shall be measured and assessed in accordance with requirements of** ~~and the ability to meet~~ NZS 6808:1998 (Acoustics - The Assessment and Measurement of Sound from Wind Turbine Generators).

*(It is noted that section 5.3 of NZS6808 specifically addresses the special audible characteristic of wind turbines. Thus there is no need to repeat this requirement.)*

**The prediction of noise from wind turbines shall include the positive effects on the propagation of sound downwind.**

**The potential effects of tonal\* and low frequency noise on the residential community shall be evaluated.**

- \* **A test for the presence of tonality can be made by comparing the levels of neighbouring one-third octave bands in the sound spectrum. An adjustment for tonality shall be applied if the level ( $L_{eq}$ ) in a one-third octave band exceeds the arithmetic mean of the  $L_{eq}$  levels in the 2 adjacent bands by more than the values given in the table below.**

**One-third octave band level differences**

<b>One-third octave band</b>	<b>Level difference</b>
25 - 125 Hz	12dB
160 - 400 Hz	8dB
500 - 10000 Hz	5dB

**NOTE - There might be cases where this analysis does not result in a tonal component being defined although the sound is in fact tonal. For these cases it will be necessary to undertake a narrow-band analysis in order to determine if a sound is tonal.**

- ii) Proposed Rule 26.3.1.8 is supported to the extent that a condition requiring the implementation of NZS 6803:1999 Acoustics – Construction Noise be adopted. This is addressed above.

\* \* \*

## APPENDIX A

### Guide To Noise Terms

The following sets out an explanation of the acoustic terms that will be referred to throughout this report. The aim is not to necessarily provide technical definitions, but to enable a basic understanding of what is meant.

The setting of specific noise levels to control any adverse effects does not necessarily mean that noise will not be heard. Audibility depends on the level of a sound, the loudness of the background sound and any special frequency composition or characteristics that a sound may have.

Research suggests that a small number of people (approximately 10%) will find any noise not of their own making unacceptable. Conversely, there are approximately 25% of the population that are essentially immune to any noise. Neither of these two extremes is normally designed for. In establishing the appropriate noise levels the aim is to try and represent the typical expected community reaction, this will generally be approximately 90% of the people.

In order to reflect community response to noise it is necessary to establish a measure that reflects our attitude to the sounds that we hear. Due to the variability of many sounds (level, tone, duration, intrusiveness above the existing sound, etc) no single descriptor will totally describe the potential community reaction to a sound. For this reason there are a number of terms that need to be understood.

#### **dBA**

The basic unit to quantify a sound is the decibel. The A-weighted sound level, or dBA, is a good environmental noise descriptor because of the similarity between A-weighting and the frequency response of the human ear at moderate sound levels. It can also be measured easily. However, it provides no indication of

tonal frequency components or unusual frequency distributions of sound that may be the cause of annoyance. Where appropriate, this must be assessed separately.

We can hear a change in sound pressure that varies from 1 (taken as the threshold of hearing) through to 1,000,000,000,000 (taken as the threshold of pain). In order to bring these numbers to a more manageable size a logarithmic scale is normally adopted. This reduces the above values to 0 and 12 respectively. The decibel is then described as 10 times the logarithm of the ratio of the pressure level of interest, to a reference pressure level. Thus the scale becomes 0 to 120dBA.

Some typical subjective changes in noise levels are:

- A change of 3dBA is just perceptible
- A change of 5dBA is clearly perceptible
- A change of 10dBA is twice (or half) as loud

Because we use a logarithmic scale care must be taken when adding sound levels. Two equal noise sources raises the level of one source by 3dBA. It takes 10 equal noise sources to raise the level of one source by 10dBA. ie  $60\text{dBA} + 60\text{dBA} = 63\text{dBA}$  and  $60\text{dBA} \times 10 = 70\text{dBA}$ .

#### **Maximum Sound Level ( $L_{\text{max}}$ )**

This unit equates to the highest (maximum) sound level for a defined measurement period. It is adopted in NZS6802:1991 Assessment of Environmental Sound, mainly as a method of protecting sleep.

#### **$L_{10}$**

The sound level which is equaled or exceeded for 10% of the measurement time. This level is adopted in NZS6802:1991 Assessment of Environmental Sound to measure intrusive sound. This level may be considered as the average maximum sound level.

**Background Sound  $L_{95}$** 

The sound level which is equaled or exceeded for 95% of the measurement time. This level is adopted in NZS6802:1991 Assessment of Environmental Sound to measure the background sound. This level may be considered as the average minimum sound level and is the component of sound that subjectively is perceived as continuously present.

**Equivalent Sound Level ( $L_{eq}$ )**

The  $L_{eq}$  may be considered as the continuous steady noise level that would have the same total A-weighted acoustic energy as a fluctuating noise over the same time period.

**Ambient Sound**

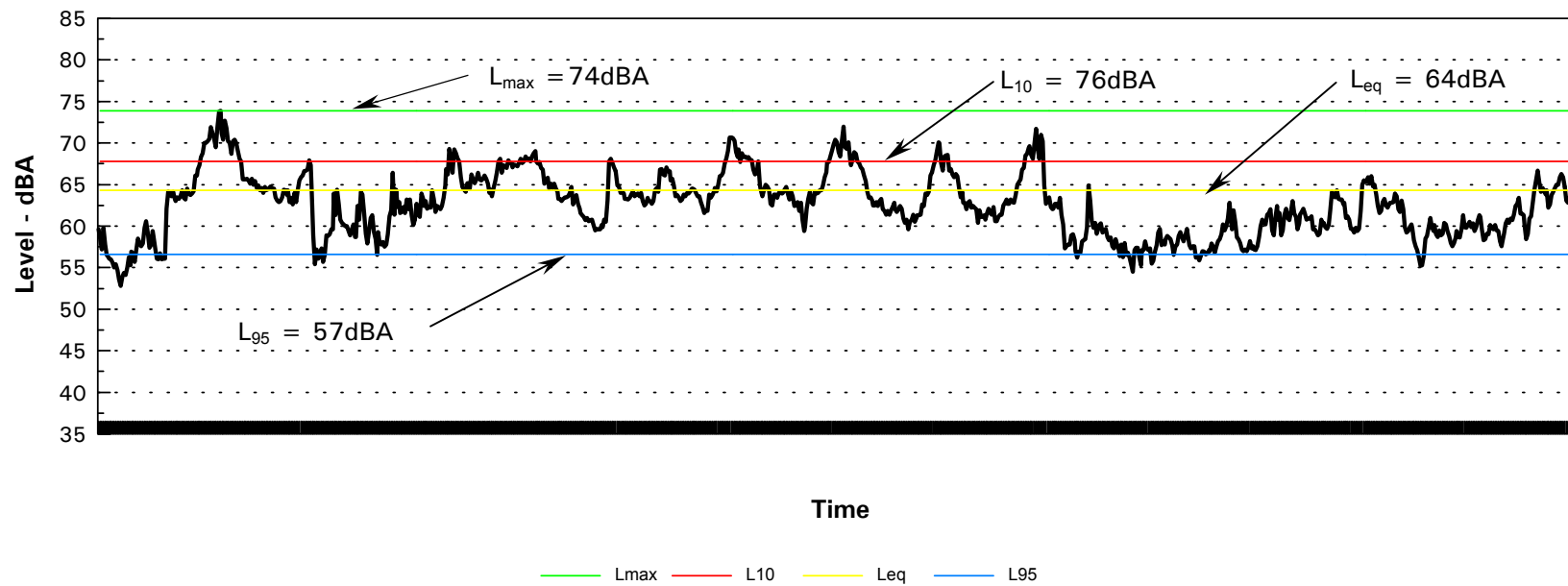
The ambient sound is normally used to describe the total noise environment. The ambient sound is often measured as the 24 hour  $L_{eq}$ , which is an average value over the 24 hour period. Shorter times are often used, such as the daytime period

**Notional Boundary**

The notional boundary is defined as a line 20 metres from the facade of any rural dwelling or the legal boundary where this is closer to the dwelling.

Figure 1A shows a noise trace with the relationship of  $L_{max}$ ,  $L_{10}$ ,  $L_{95}$  and  $L_{eq}$  values when including all events over the 15 minute measurement period and Figure 2A some typical noise levels.

\* \* \*



$L_{\max}$  is the maximum noise level

$L_{10}$  is the noise level that is equaled or exceeded for 10% of the measurement period

$L_{95}$  is the noise level that is equaled or exceeded for 95% of the measurement period

$L_{\text{eq}}$  is the noise level that contains the same energy as the time varying noise

Figure A1

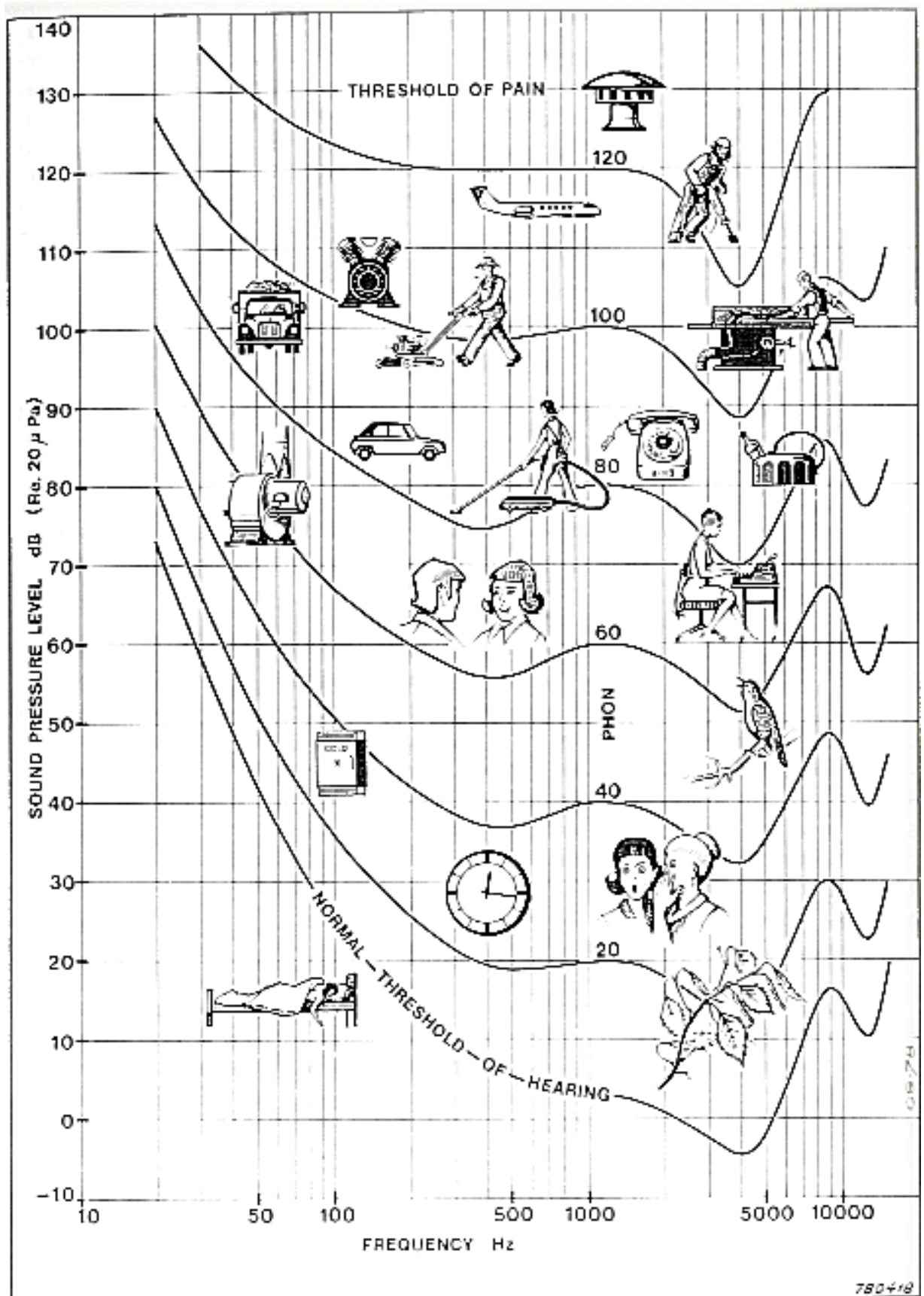


Figure A2