# Wind Farm Noise — The High Amenity Limit in NZS6808:2010

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## Abstract

The 2010 edition of NZS6808 "Acoustics – Wind farm noise", introduced a "high amenity noise limit" in addition to the primary limit. This paper will discuss the reasons behind the introduction of this additional limit and explain how the high amenity noise limit is implemented. Examples will be used to illustrate how the high amenity noise limits compare with the ad-hoc secondary limits imposed on wind farms in New Zealand. The examples used are a selection from Project West Wind, a wind farm near Wellington, where the secondary limits there are based on modifications to the limits set out in the 1998 version of the Standard and have been put in place by the Environment Court. The paper shows how the secondary limits in the 2010 version are much easier to implement and also provide a higher level of protection to the wind farm's neighbours.

## Introduction

The purpose of this paper is to provide some background and explanation on the high amenity limit which was introduced into the 2010 version of NZS6808: Acoustics–Wind Farm Noise[1]. NZS6808 was first released in 1998[2] and has been used at all the operational wind farms in New Zealand since its release. It has also been cited in the Resource Consent conditions of a number of wind farms which have not yet been constructed.

## Broadband Limit Used in the 1998 Version of NZS6808

As wind farms only operate, and therefore generate noise, when the wind is blowing and also have noise levels which increase as a function of wind strength, an acoustic standard specific to wind farm has been developed in New Zealand.

The 1998 version of NZS6808 ("Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators") proposed a limit in two parts, a fixed lower limit and a variable limit, based on the existing background levels.

The 1998 standard recommends a limit of 40 dB $L_{A95(10\ min)}$ or the background plus 5 dB, whichever is the greater. In practice the fixed limit of 40 dB $L_{A95(10\ min)}$ applies where the background is less than or equal to 35 dB $L_{A95(10\ min)}$. For conditions where the background is greater than 35 dB $L_{A95(10\ min)}$, the wind farm limit becomes 5 dB more than the background level. An example of the limit, based on 165 nights of monitored $L_{A95(10\ min)}$ background levels is shown in Figure 1. Note that the Standard doesn't require such a lengthy set of monitored background data.

In clause 4.4.4, the 1998 standard does state that there is nothing to stop the local territorial authority setting another limit, however no guidance is given on what would give rise to a change in the suggested limit or by how much the limit could be modified.

The limit is set in terms of an $L_{A95(10\ min)}$ to allow noise measurements to be undertaken in wind speeds greater than those generally acceptable for environmental noise measurements.

The 40 dB $L_{A95(10\ min)}$ fixed limit is based on a sleep disturbance criteria. At the time of its development, NZS6808 considered that an internationally accepted indoor level of 30 to 35 dB $L_{Aeq}$ was commonly used as a design level to protect against sleep disturbance.

Using a value of 10 dBA attenuation from outdoors to indoors with open windows, results in an acceptable exterior level of 40 to 45 dB $L_{Aeq}$. For a wind turbine the $L_{A95(10\ min)}$ level is approximately 1.5 to 2.5 dB lower than the $L_{Aeq(10\ min)}$ level and on that basis, a $L_{A95(10\ min)}$ of 40 dB was adopted as the fixed lower part of the limit in the 1998 version of NZS6808.

The background plus 5 dB was adopted instead of what was a more commonly used background plus 10 dB as both the wind farm noise and the background noise are measured in terms of an $L_{A95}$.

The background plus 10 approach was generally used in cases where the background is measured in terms of an $L_{A95}$ and the "noise" in terms of an $L_{A10}$. The difference between and $L_{A95}$ and an $L_{A10}$ is approximately 5 dB and therefore a background plus 5 dB is appropriate where both the background and the noise are measured in terms of $L_{A95}$.

## Noise Limits Placed on Wind Farms in New Zealand

Prior to the 2010 version of NZS6808 being issued, a number of wind farms had gained Resource Consent in New Zealand. The noise limits placed on those wind farms are listed in Table 1.

From these Resource Consent decisions, it is clear that the primary wind farm noise control is the limit set out in the 1998 version of NZS6808, i.e. 40 dB $L_{A95(10\ min)}$ or the background plus 5 dB, whichever is the greater.

Despite NZS6808:1998 allowing the limit to be modified, in all but one of

| Wind Farm | Primary Limit | Secondary Limit | Date |
|---|---|---|---|
| Polhil | No limit set | | 1993 |
| Hau Nui, Stage 1 | No limit set | | Jun 1995 |
| Tararua, Stages 1&2 | 40 dB LA95 or bckgnd + 5 | | Feb 1996 |
| Hau Nui, Stage 2 | 40 dB LA95 or bckgnd + 5 | | Jun 2002 |
| Gebbies Pass | No more than prediction (35 dBA) | | Jan 2003 |
| Te Apiti | 40 dB LA95 or bckgnd + 5 | | Sep 2003 |
| Tararua Stage3 (T3) | 40 dB LA95 or bckgnd + 5 | Manage when "unduly audible" | May 2004 |
| White Hill | 40 dB LA95 or bckgnd + 5 | | Dec 2004 |
| Te Rere Hau | 40 dB LA95 or bckgnd + 5 | | May 2005 |
| Awhitu | 40 dB LA95 or bckgnd + 5 | | Sep 2005 |
| Titiokura | 40 dB LA95 or bckgnd + 5 | Noise management plan | May 2006 |
| West Wind | 40 dB LA95 or bckgnd + 5 | 35 dBA in low wind & bckgnd | May 2007 |
| Hawkes Bay | 40 dB LA95 or bckgnd + 5 | Noise management plan | Jun 2007 |
| Mahinerangi | 40 dB LA95 or bckgnd + 5 | 35 dB LA95 or bckgnd + 5 at two houses only | Aug 2008 |
| Hayes | 40 dB LA95 or bckgnd + 5 | Noise management plan | 2008 |
| Motorimu | 40 dB LA95 or bckgnd + 5 | 35 dBA, bckgnd + 5 | 2008 |
| Kaiwera Downs | 40 dB LA95 or bckgnd + 5 | <35 dBA in low wind & bckgnd at night | 2008 |
| Te Uku | 40 dB LA95 or bckgnd + 5 | Noise management plan | 2008 |
| Project Central Wind | 40 dB LA95 or bckgnd + 5 | Noise management plan | 2010 |

**Table 1. Limits for wind farms in New Zealand**

the developments listed in Table 1, the noise limits from the 1998 Standard have been adopted. In some cases, the limits have been modified under specific conditions rather than applying all the time. This gives rise to rise to wind farms having to meet additional or secondary limits under specified conditions.

It is evident from Table 1 that for nearly all the wind farms listed, the primary control is 40 dB $L_{A95(10\ min)}$ or the background plus 5 dB, whichever is the greater.

For some of the more recent wind farms, a secondary limit applies under certain local conditions. These additional limits have at times been referred to as "sub–6808 levels" but are referred to as secondary limits here. In the 2010 version of NZS6808 they have been called high amenity limits.

## Wind Farm Resource Consent Conditions Which Modified NZS6808:1998 in NZ

The first time the concept of a secondary limit was introduced was at the time of the T3 (Tararua Stage 3) consent hearing in the Manawatu.

The concept was proposed by the Council and as written in the conditions, a noise management plan is needed to identify times when the wind farm is "unduly audible". It is important to note that the objective of this limit is clearly to control the level of audibility rather than the sleep disturbance criteria to which the 40 dB $L_{A95(10min)}$ seeks to control.

In concept this additional control is attempting to restrict the wind farm to a lower limit in cases where the background is potentially very low, i.e. to protect amenity to a greater level. Figure 1 gives an example of the NZS6808:1998 limit derived from background noise levels measured at night at a location neighbouring Project West Wind.

It is the 10 minute data periods identified in the ellipse that the unduly audible criterion in the T3 conditions seeks to give further protection to.

This same "unduly audible" requirement was proposed for Project West Wind at the Council hearing. During the Environment Court process, it was however agreed that the term "unduly audible" needed to be objectively well defined if used in a consent condition.

For Project West Wind the term "unduly audible" changed into a secondary limit which placed stricter noise limits on the wind farm when the background was less than or equal to 25 dB $L_{A95(10min)}$ and simultaneously the local wind speed is less than 1.5 m/s. Under these conditions the wind farm had to meet a fixed limit of 35 dB $L_{A95(10min)}$.

This secondary noise limit for Project West Wind meant that the wind farm needed to meet a lower limit in specific conditions, i.e. when the background and the local wind speed are both very low. It should be noted that this new condition required local (residential) wind speeds to be measured together with the background noise measurements and wind speeds at the wind farm.

Once those measurements were completed two relationships needed to be derived; one between the background noise and wind farm wind speed (conventional NZS6808 analysis) and a second between the local wind speed and the wind farm wind speed.

Based on these two separate relationships, it was possible to determine at which wind farm wind speeds the lower 35 dB $L_{A95(10\ min)}$ limit applied. The range of wind speeds over which the lower limit applied were different for all locations and different

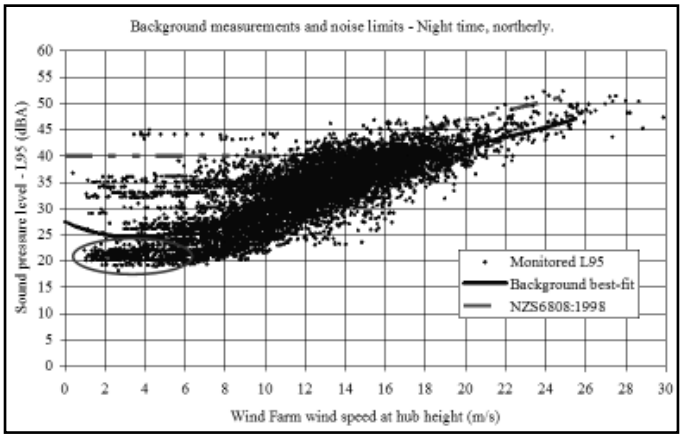


**Figure 1. An example of background measurements used to determine the wind farm limits.**

between northerly and southerly wind directions at the same residential location. It is a complicated and confusing procedure.

The analysis of background noise measurements and local wind speed measurements at 10 locations around Project West Wind have been reported in the project West Wind Noise Management Plan[3]. This data is used here to demonstrate the differences between secondary noise limits derived through the modification of the 1998 version of NZS6808 and the high amenity limit as set out in the 2010 version of the Standard.

It should be noted that NZS6808:2010 requires the background and wind farm levels to be measured in terms of a $L_{A90(10\ min)}$ while in the 1998 version of the Standard a $L_{A95(10\ min)}$ was required for the measurement of both background and wind farm noise. In this paper, where equivalent 2010 limits are shown, they are shown in terms of an $L_{A95}$ rather than an $L_{A90}$. This has been done to demonstrate a point rather than to determine an absolute limit however where NZS6808:2010 is used in the future, all analysis should be undertaken in terms of $L_{A90(10\ min)}$.

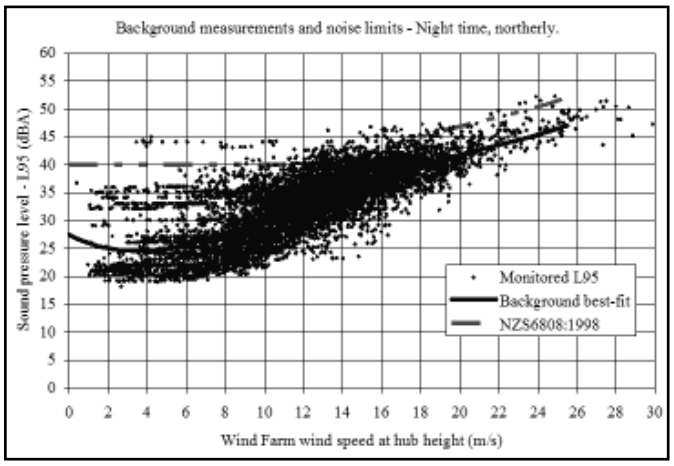


**Figure 2. Example of background noise measurements and limit derived in accordance with NZS6808:1998**

## The High Amenity Limits as set out in NZS6808:2010

In special circumstances at some noise sensitive locations, NZS6808:2010 suggests that a more stringent noise limit may be justified to afford a greater than normal degree of amenity. Where the high amenity limit applies it only applies during evening and night times.

NZS6808:2010 outlines these special circumstances when it may be appropriate for a high amenity limit to apply but the intent is for this limit only to apply where planning documents specifically set out to protect areas to a greater than normal level from sounds for all sources (and not just wind farms). The intention is that the limit applied should be consistent with the general sound limits applied to all noise sources at that location.

NZS6808:2010 recommends that the high amenity limit should apply when the wind farm wind speed is 6 m/s or lower (corresponding to the quieter periods) but allows for an alternative wind speed threshold where it can be justified. As stated in the Standard, the intent of the high amenity limit is to limit the frequency of occurrence of wind farm sound intruding on recognised low sound environments.

The Standard recognises it is not feasible to eliminate all such potential events but that that the proposed high amenity limit is an appropriate way to reduce such events.

## How the West Wind Limits Compared to the Limits Set Out in NZS6808:2010

The noise limit set out in NZS6808:1998, based on a set of monitored background levels is shown in Figure 2 for a single location at night in a northerly wind direction. The monitored background levels are for a location neighbouring Project West Wind in Wellington.

The limits derived for this same location but based on the Project West Wind noise conditions, which include a secondary limit, are shown in Figure 3.

The wind speeds at which the lower 35 dB $L_{A95(10\ min)}$ limit apply have been derived from simultaneous measurements of local wind speeds (at the residential location), wind speeds at hub height at the wind farm and background noise levels at the noise sensitive receiver.

The wind speed threshold at which the noise limit changes from 35 dB $L_{A95(10\ min)}$ to 40 dB $L_{A95(10\ min)}$ can only be derived after the noise and local wind monitoring has been completed and varies both between residential locations and wind directions.

Figures 4 to 9 show a sample of the West Wind noise limits which include both primary and secondary noise

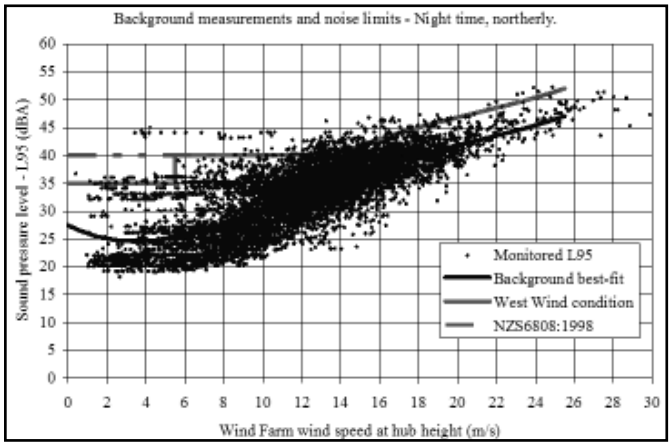


**Figure 3. Limit in a northerly wind direction**

limits (modified 1998 limits). The limits shown in the figures are based on background noise measurements around the project and the conditions placed on that development. The night time limits at three locations, labelled A, B and C are represented separately for northerly and southerly wind directions. Also shown in those figures are the high amenity noise limits as set out in the 2010 version of NZS6808. The West Wind noise limits are shown as the solid line and the limits recommended in NZS6808:1998 and NZS6808:2010 have also been included in each of these six plots by the dashed lines.

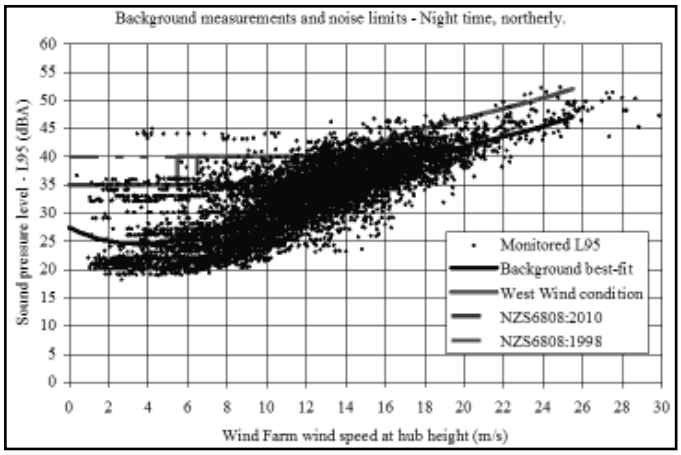


**Figure 4. Site A, Limits based on NZS6808 1998 & 2010 compared to West Wind conditions, night northerly**

From Figures 4 to 9 the following observations can be made:

- The West Wind secondary limits, based on modifications to the 1998 version of NZS6808, do not apply in all cases.
- The West Wind secondary limits are more stringent than the limit in NZS6808:1998, where they apply.
- The West Wind secondary limits vary from location to location and by wind direction.
- In all cases, the high amenity limits set out in the 2010 version of NZS6808, are more stringent than the West Wind secondary limits.
- The high amenity limit in NZS6808:2010 can in all cases be easily derived from the data that has been collected when establishing the primary limit. No additional data is required and it eliminates the burden of local wind speed measurements.

## The Frequency of Occurrence of Different Wind Strengths

We are all very aware that the wind speed at any given location is not constant but varies with time and this is true for wind farm sites too. The percentage of time different wind strengths are experienced at a wind farm site can be well represented by a Weibull wind speed frequency distribution.

The Weibull curve is very dependent on the annual mean wind speed at the site. Figure 10 shows the Weibull wind speed distribution at 3 different potential wind farm locations which have annual mean wind speeds of 8m/s, 9m/s and 10 m/s.

The first wind farms developed in New Zealand were typically those with very high mean wind speeds i.e. 9 to 10 m/s (e.g. Manawatu and Wellington). More recently, sites with slightly lower mean wind speeds, i.e. 8m/s to 9 m/s are being developed (Te Uku, Central Wind, Mahinerangi). The wind speed

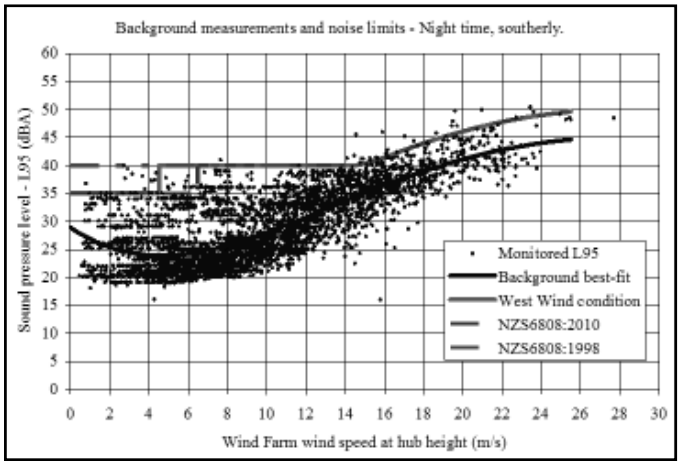


Figure 5. Site A, Limits based on NZS6808 1998 & 2010 compared to West Wind conditions, night southerly

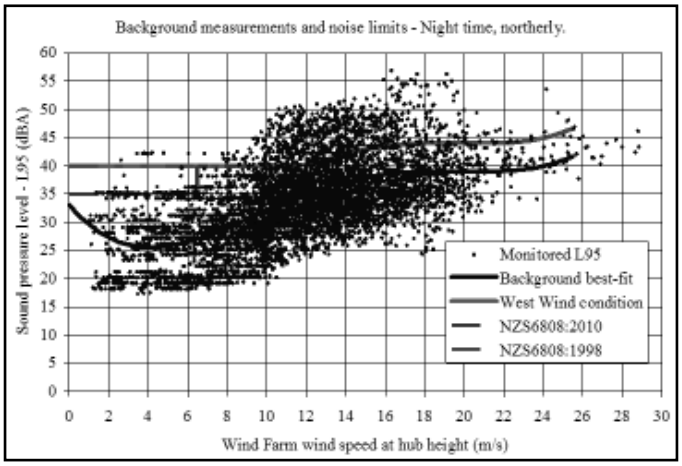


Figure 6. Site B, Limits based on NZS6808 1998 & 2010 compared to West Wind conditions, night northerly

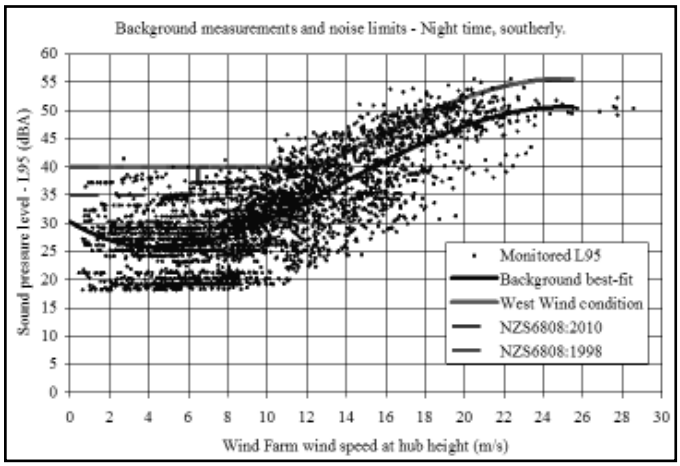


Figure 7. Site B, Limits based on NZS6808 1998 & 2010 compared to West Wind conditions, night southerly

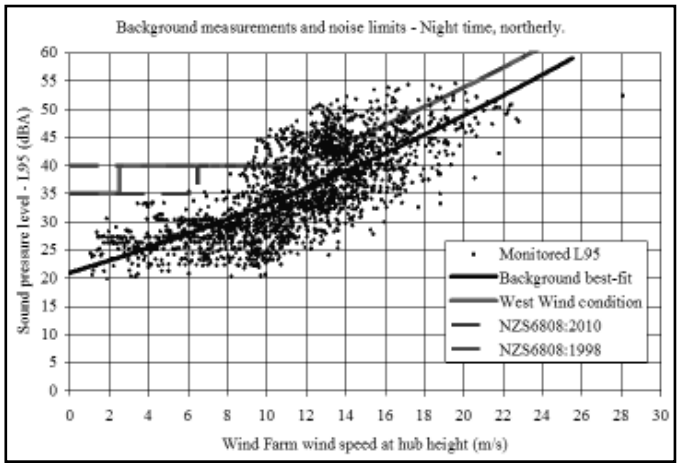


Figure 8. Site C, Limits based on NZS6808 1998 & 2010 compared to West Wind conditions, night northerly

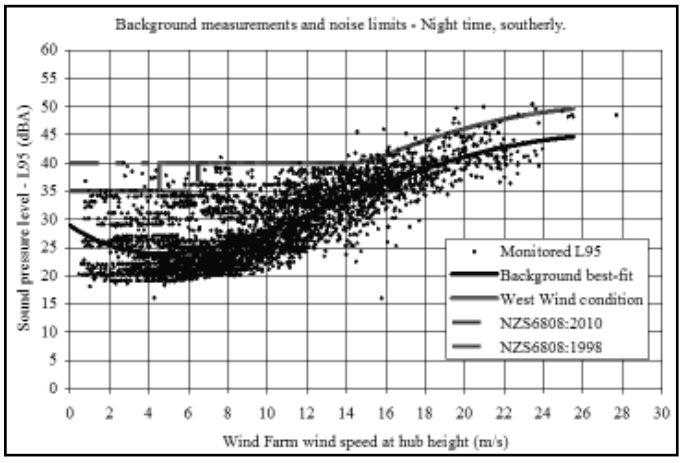


Figure 9. Site C, Limits based on NZS6808 1998 & 2010 compared to West Wind conditions, night southerly

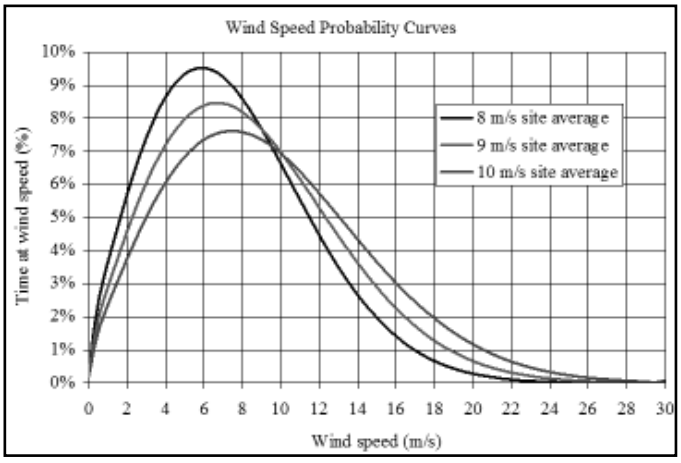


Figure 10. Weibull wind speed distribution at three different class wind farm locations

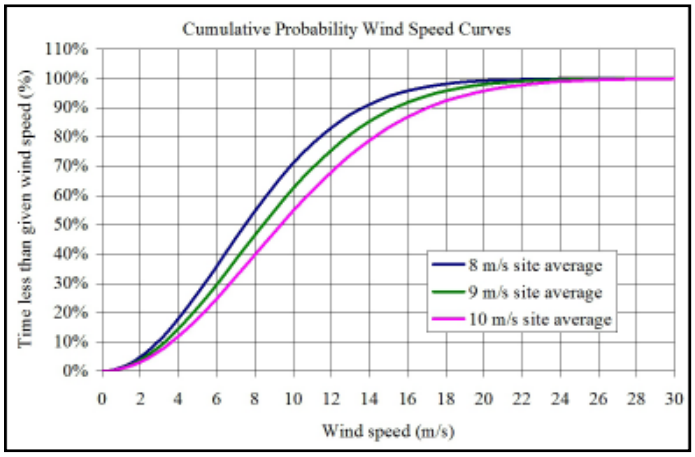


**Figure 11. Cumulative probability wind speed curves at three different class wind farm locations**

| | Site Mean Wind Speed | | |
|---|---|---|---|
| | 8m/s site | 9 m/s site | 10 m/s site |
| High amenity limit | 41% | 34% | 29% |

**Table 2. Percentage of evening and night time the high amenity limit in NZS6808:2010 applies**

distribution at Project West Wind can be represented by the 10 m/s curve shown in Figure 10.

The Weibull distributions shown in Figure 10 have been rearranged and shown as cumulative probability curves in Figure 11. From these curves it is a simple process to determine the percentage of time a range of wind speeds prevail at a given wind farm site, it the long term mean wind speed is known.

From Figure 11 it can be determined that in cases where the high amenity noise limit, set out in NZS6808:2010 applies, that limit will apply for the proportion of evening and night time hours listed in Table 2.

If the wind farm site exhibits a diurnal bias where wind speeds may be, on average, lower at night, the percentage of night time for which the high amenity limit applies will increase.

The way that the high amenity limit is implemented in the 2010 version is such that greater protection is given in cases where wind speeds are low and so then the background sound levels have a higher probability of being low too.

Where these low wind speeds occur for a high proportion of time the high amenity limit will also apply for a greater proportion of time, i.e. the high amenity noise limits are in place in the same proportion of time as the low wind speeds.

Table 3 lists the percentage of night time that the High amenity limit set out in

| | Site A | Site B | Site C |
|---|---|---|---|
| West Wind – secondary limit – night northerly | 21% | 0% | 5% |
| West Wind – secondary limit – night southerly | 15% | 0% | 15% |
| High amenity limit – NZS6808:2010 –night northerly | 29% | 29% | 29% |
| High amenity limit – NZS6808:2010 – night southerly | 29% | 29% | 29% |

**Table 3. The percentage of night time that the secondary West Wind limits apply in comparison with the high amenity limit in NZS6808:2010**

NZS6808:2010 would apply at each of the three locations analysed above, if the high amenity noise limit were applied to these locations.

Also listed in the table is the percentage of time that the West Wind secondary limits apply at these same three locations.

From Table 3 it is apparent that the West Wind secondary limits apply far less of the time than if the high amenity limit from NZS6808:2010 had been applied.

It is also clear that the high amenity limit would have applied to all dwellings in consistent manner.

Lastly, the high amenity limit would apply equally across different wind directions.

## Typical Variation in Sound Power Level of a Wind Turbine

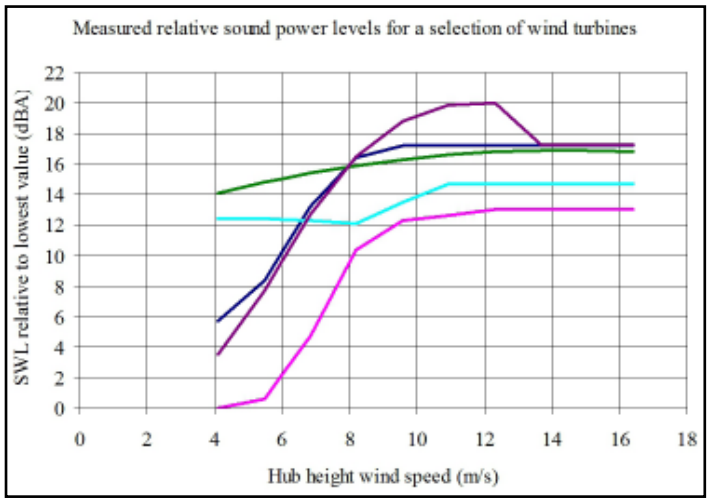


**Figure 12. Relative measured sound power levels for a selection of wind turbines**

The sound power level of all wind turbines varies as a function of the wind speed and increases with increasing wind speed up to the wind speed at which the turbine's rated power is achieved.

The rate at which the sound power level increases is dependent on the turbine design and can vary by as much as 16 dB over the operational wind speed range of the wind turbine or by as little as little as 2 to 3 dB.

Today's modern day variable speed turbines tend to have a greater variation in sound power level over their operating wind speed range whereas fixed speed turbines, typically have far less variation. The relative maximum sound power level of wind turbines has decreased steadily over the last 10 or so years.

The variation in sound power level with wind speed is however still very dependent on the particular turbine. Furthermore, with the move towards larger diameter wind turbines, the cut–in wind speeds at which turbines commence operation have decreased.

Due to the variation in sound power levels between different turbines and the variation in sound power level with wind speed, assessing the impact of wind farms (predictions and monitored compliance levels) will be more straight forward and far less confusing if the high amenity noise limit under NZS6808:2010 is used rather than the variety of secondary limits than have been applied to date.

This is simply because both the wind farm noise and the wind farm limits (primary and high amenity) can be more simply characterised as a function of wind farm wind speed.

## Conclusions

NZS6808:2010 includes a high amenity noise which was not included in the 1998 version of that same Standard.

The majority of wind farms which have

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# Art on Acoustic Pinboards: Do they Still Work?

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Do Acoustic Pinboards still provide useful sound absorption in a classroom environment once the inevitable artwork and miscellaneous papers are liberally added? This paper reports on laboratory tests aimed at finding out.

## Introduction

Over the last 10 years New Zealand has had the biggest investment into our schools for generations.

New Schools have been constructed, and many existing schools have had new facilities added to accommodate modern methods of teaching.

One of the major requirements equally as important as fresh air and lighting levels is the requirement to ensure the modern teaching space has the correct and appropriate acoustic conditions for clear communication between teachers and students.

There is a saying; "You wouldn't teach people to read and write in the dark so why would you try and teach in a noisy environment?" Doesn't work, never has, never will!

As of July 2010, I understand that the Ministry of education (MOE) is requiring all new and refurbished spaces to meet the standards set out in the publication "Designing Quality Learning Spaces (acoustics)".

In conjunction with this publication, an assessment tool is being piloted and when it is finalised it will be used to evaluate a range of criteria for all public New Zealand Schools.

*Continued from page 31*

gained Resource Consents in New Zealand have had operational wind farm limits set in accordance with NZS6808:1998. A number of these have had ad–hoc secondary limits applied, an example of which is Project West Wind, a wind farm near Wellington.

A comparison has been made between the secondary wind farm noise limits imposed on Project West Wind and the high amenity limits set out in NZS6808:2010. From that analysis it has been shown that in all of the examples, the NZS6808:2010 high amenity noise limits are more stringent than the secondary limits imposed on Project West Wind.

From the experienced gained with the noise monitoring at Project West Wind, the secondary limits imposed on that project have been both confusing and require a very complex monitoring program. The secondary limits are extremely dependent on local conditions at each residential location.

The high amenity limits set out in NZS6808:2010 would have been far simpler to implement, less confusing to the community and provided a higher level of protection.

The high amenity limit set out in NZS6808:2010 requires no more monitoring than what is required for the primary limit. The limit provides a higher level of protection in those periods where there is the greatest probability of low background sound level.

## References

1. **New Zealand Standard**, "NZS6808:2010 Acoustics – Wind farm noise". Standards New Zealand.

2. **New Zealand Standard**, "NZS6808:1998 Acoustics – The assessment and measurement of sound from wind turbine generators". Standards New Zealand.

3. **Paul Botha**, "Project West Wind, wind farm noise man-agement plan, Version 4". Meridian Energy, September 2009. ❑