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Assessment of Wind Turbine Noise Using NZ Standard NZS6808:2010 – Fit For Purpose

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Abstract

This paper describes the development of the updated New Zealand wind farm noise standard NZS6808:2010 and the methodology it recommends for both assessing potential noise impacts for proposed wind farms, and the methods recommended for field monitoring of noise from existing wind farms to verify compliance where necessary.

The paper explains how the 2010 version of NZS6808 underwent a rigorous Standards New Zealand review process which resulted in a large number of comments following the release of the draft revised Standard (DZ6808) in 2008. The review process was required to address a wide range of alleged technical short-comings of NZS6808:1998 raised by so-called experts, members of the public, in the media and at planning hearings.

This paper records a summary of the technical amendments and enhancements made as part of the Standards review process, including allowing for recommended compliance limits to be lowered to 35 dB at sensitive receiver sites where special conditions may arise – the "high amenity" noise limit.

Wind farm projects currently or recently adopting the 2010 version of NZS6808 are identified. It is concluded methods used to assess wind farm noise in New Zealand have been strengthened with the uptake of NZS6808:2010.

Introduction

NZ Standard NZS6808 provides methods suitable for the prediction, measurement, and assessment of sound from wind turbines. In the context of the relevant New Zealand planning law, it is said compliance with this Standard will provide reasonable protection of health and amenity at noise sensitive locations (SNZ 2010).

The 2010 revised version of NZS 6808 updates and enhances the original 1998 version. This paper discusses the process and outcome of a review of the original 1998 Standard, including describing the additions and amendments that have been incorporated into NZS6808:2010. The review of the Standard initiated submissions

and comments from many parties, covering a wide range aspects of the Standard. This paper summarises some of the concerns raised, and the methods adopted to improve the Standard, which although having undergone technical re-evaluation and public scrutiny remains fit for purpose, on the basis of available evidence and observations.

NZS6808:1998

NZS6808:1998 was developed specifically for the measurement and assessment of noise from Wind Turbine Generators (WTG's) and wind farm developments. The stated purpose of NZS6808:1998 was to aid both wind farm development and Territorial Local Authority planning procedures by providing a suitable method for the measurement and assessment of sound from WTG's. NZS6808:1998 provides guidance on limits of acceptability for sound received at residential and noise sensitive locations emitted from both wind farms and single WTG's.

In New Zealand, the role of such a Standard is to provide guidance in the land use planning process for the establishment of new or extended wind farms. This is achieved (in part) by being adopted into "District Plans" which are plans that set out mandatory planning requirements for various zones within a district. NZS6808 becomes relevant when preparing a wind farm planning application which a Territorial Local Authority must assess in accordance with the Resource Management Act 1991.

NZS6808 was developed during the mid-1990's in response to perceived needs, particularly because adopting the normal District Plan noise limits used for assessing usual noise sources (factories and power stations for example) presented some practical difficulties when used for wind farm noise assessment. The use of traditional L_{AMAX}, L_{A10}, L_{Aeq}, etc. measures require noise compliance to be determined without the influence of local weather conditions and were found to be technically inappropriate for assessing wind turbine noise. The concerns centred around the need for a method to assess WTG noise impact across a range of operational wind speeds, under the acoustic conditions that would occur at those times, but with allowance for some locations which may experience "quiet" levels of ambient sound at these times, such as in sheltered locations near wind farms where ambient sound levels may not be affected by natural wind sounds.

The methods adopted were based on the approach recommended by the UK Working Group on Wind Turbine Noise (ETSU 1996) which utilises background sound level (L_{A90}) data, measured continuously on 10 minute basis, over a period of at least 10 days at affected noise sensitive locations expected to receive wind farm sound. L_{A90} measurement data is plotted against simultaneous wind speed data, measured at the proposed wind farm to provide for regression analysis. Wind farm sound levels are then calculated across the range of operational wind speeds for that assessment location. The assessment of noise impact is made by comparing the calculated wind farm noise level with the average measured background noise level, across the range of operational wind speeds to determine if the wind farm sound level falls within an acceptable range. There is no requirement to consider background sound if the expected level is 35 dB or less. Where the wind farm sound is expected to be received at levels above 35 dB, wind farm noise [L_{A90}] is permitted

up to 5 dB above the regression line for background noise [L_{A90}]. For example at a given wind speed the average background sound level is 38 L_{A90}, then the permitted wind farm noise level at that wind speed would be 43 L_{A90}.

An example of the relationship between measured background sound level (L_{A95} in this case) and wind speed measured on the wind farm site, at the hub height of the selected and proposed WTG model is shown in **Figure 1**.

Adapting the UK ETSU recommendations, NZS6808:1998 recommends a wind farm noise limit of 40 dB $L_{A95(10\ min)}$ or the background plus 5 dB, whichever is the greater, as measured at noise sensitive locations such as rural residences. **Figure 2** below shows how this limit is derived based on the average background sound level, across the operational wind speed range.

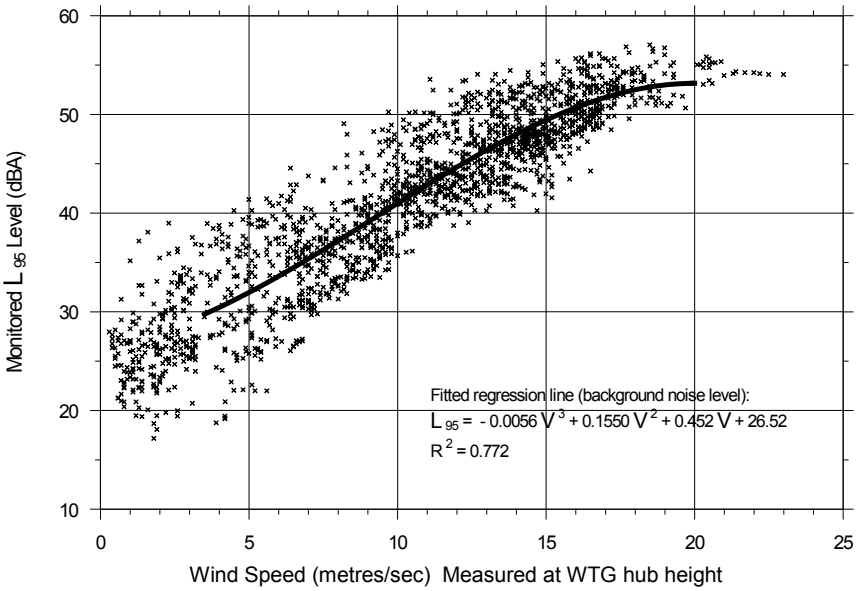

Figure 1 Scattergraph of background sound level survey, in accordance with NZS6808:1998.

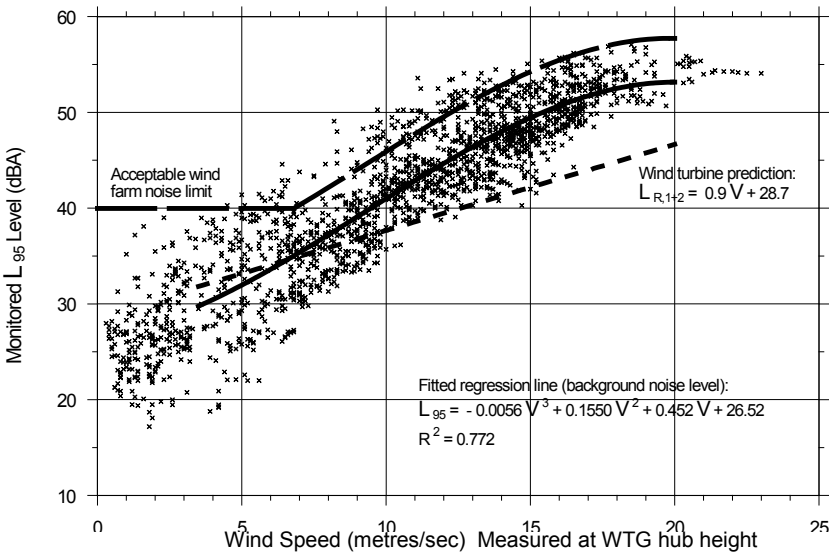

Figure 2 Predicted total wind farm sound levels and the "acceptable" NZS6808:1998 wind farm noise limit (based on 40 dBA or the background sound level + 5 dB).

In practice the fixed limit of 40 dB $L_{A95(10\ min)}$ applies where the average background is less than or equal to 35 dB $L_{A95(10\ min)}$. For conditions where the average background is greater than 35 dB $L_{A95(10\ min)}$, the wind farm limit becomes 5 dB more than the background level. The recommended noise limits of NZS6808:1998 are said to adequately protect against unacceptable noise disturbance[1].

The methods of NZS6808:1998 were, at the time, considered adequate to account for the effects of wind farm noise received at times of little or no natural wind sounds, that is, other sounds from non-wind farm sources. The potential impact of wind farm sound during times of low ambient sound has since been re-examined, leading to the adoption of a "High Amenity" recommended noise limit (described below).

NZS6808:1998 Review Process

The 1998 version of this Standard was written prior to significant wind farm development in New Zealand. The basic methodology proved robust during its use as the preferred noise assessment method for many wind farm developments taking place between 1998 and 2010. Botha (2010) cites 14 wind farm projects using NZ Standard NZS6808:1998 for guidance on noise impact[2].

Experience and research over the following decade brought to light potential refinements and enhancements which triggered a revision of the Standard. The project to revise NZS 6808 was partly funded by the Energy Efficiency and Conservation Authority and the New Zealand Wind Energy Association.

The committee conducting the review consisted of representatives from a number of sectors, including engineering and scientific experts in acoustics, practitioners in planning, resource management and environmental health, wind farm developers, and individuals who represented local authority and community interests. The committee initially split into working groups addressing different issues such as noise limits, measurements and predictions. Each working group submitted recommendations back to the main committee, where they were vigorously debated and tested against the evidence.

The make-up of the review committee has been commented on by anti-wind farm campaigners and a disgruntled committee member. Firstly, anti-wind farm protesters expressed views such as "...*committee members have not sufficiently declared, nor has Standards New Zealand sufficiently acknowledged, conflicts of interest*" and with accusations that some committee members were *"...individuals enjoying financial arrangements with the sponsoring organisations*"[3].

Secondly, newspaper articles in *The Press* ('*Revisit noise standards – academics*' and *'Opposition to decision making process*' dated 18 August) called into question the integrity of Standards New Zealand's development process and its committee

[1] NZS6808:1998 states at clause 4.4.1 that the recommended noise limits represent "... *an upper limit of acceptable WTG sound levels outdoors at residential locations."*

[2] In addition, NZS6808:1998 were adopted (at one time or other) as the preferred noise assessment method within some of the states in Australia and is therefore referred to within many noise assessment reports regarding proposed Australian wind farm projects.

[3] See: http://turiteawindfarm.blogspot.com/2010/09/blog-post.html

members. In particular claims are made that the wind-energy industry had exerted undue influence in revising of NZS 6808:2010.

Thirdly, Dr Dickinson, a representative of Massey University on the NZS6808 review committee is on record as an expert witness at the Mill Creek wind farm appeal hearing as saying he considered committee members did not bring to bear an "impartial and independent" perspective to the review of NZS6808. The reasons for Dr Dickinson's objections to NZS6808:2010 were set out in the public domain following the public release of certain committee documents as a result of a request under the Official Information Act.

These accusations of committee bias and mismanagement have been thoroughly investigated at the highest levels within Standards New Zealand with no conflict found to exist. The Chairperson of the NZS6808 Review Committee wrote to parties in 2010 to assure them that the NZS6808 review committee was properly convened and that procedures followed during the committee process were beyond reproach. The Chief Executive of Standards NZ formally responded to the above claims with a media release stating:

> *"The revised wind farm noise standard, NZS 6808:2010 was developed through well-established, robust standards development processes, consistent with the development of international standards."*

Given the strong public interest in the revision, an evidence-based approach was used throughout the review process to make decisions which needed to be documented to a greater degree than normal. The process was focussed on achieving consensus, which requires general agreement, but not unanimity. The rules for voting on all Standards New Zealand standards require at least 80 per cent agreement among committee members, a more stringent requirement than many international standards bodies. In the case of this standard, the committee achieved and exceeded this requirement.

During deliberations the NZS6808 revision committee considered more than 200 reference documents, including overseas research relevant to wind-farm noise. More than 600 public comments were received on the proposed standard. Each comment was individually considered by the committee, and changes agreed with a final draft released in mid 2009.

It is not uncommon for standards development committee members and experts to have differing views. Through the creation and refinement phases of the standards development process, these views are robustly facilitated and debated. Each committee member puts forward their views (which are to be evidence-based as per the terms of reference), and are required to discuss the merits of their proposal with their peers.

The last action for a technical committee is a 'postal ballot' to approve the final version of the Standard for publication. In this instance, several unexpected issues emerged at the ballot through a number of negative votes. The draft was therefore amended over the following months until consensus was reached at the second postal ballot later in 2009. There remained one negative vote at the second postal ballot, from the representative of Massey University. That individual has publicised his views [Dickinson 2009] which promotes points of view that have not garnered any technical support from the local or international acoustic fraternity. The remainder of

the committee could not reconcile the arguments he advanced against the Standard, given all the available scientific evidence, and the framework for noise assessment in New Zealand set out within other NZ Standards.

Due to the negative vote and public sensitivity around this Standard, the Standards Council would not issue its final approval to publish the revision of NZS 6808 until it was demonstrated in detail that Standards New Zealand had followed correct procedures, and there were legitimate technical reasons not to accept the issues raised by the negative vote. Special text was inserted into the new Standard to recognise Dr Dickinson's position. Inside the front cover of the 2010 Standard is a sentence which reads *"The representative of Massey University, while recognising the revised Standard is an improvement on the original, does not support the Standard."*

The process ended with final publication of the new Standard on 1 March 2010, 'NZS 6808:2010'.

Although Dr Dickinson consistently provided a negative vote including at the final ballots, the committee process for arriving at the changes was inclusive and robust with a willingness to listen to alternative views when they arose. Impartial decisions were reached and new wording developed using, as far as possible, the consensus views of expert opinion from around the committee table.

NZS6808:2010 – Summary Of Changes

Regarding assessment methods and the recommended limits for wind farm noise, the generic assessment method (based on the relationship between measured background sound levels at receiver locations and the wind speed measured on the wind farm site) has not changed. Section 5.2 of NZS6808:2010 sets out recommended noise limits similar in effect to the 1998 version. The 2010 standard expresses these recommended limits as follows:

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

The background +5 dB variable part of the noise limit requires a relationship to be determined between background sound levels and wind farm wind speed. In some cases good correlations of the data are not achieved, such as when sound levels are dominated by road-traffic, or when a location is sheltered by terrain in certain wind directions. The committee determined that a prescriptive procedure for the correlations would not be practical as there are too many site specific factors. However, significant additional guidance has been provided, with various factors now required to be taken into account. It is now explicit the degree to which data may need to be separated into different times or wind conditions. Also, notes are provided for issues such as measurements near water courses and trees.

Dr Dickinson has criticised the use of relationships between hub height wind speed and background sound levels at noise sensitive locations as insufficient to describe

local conditions. However it is implicit that the users of the Standard would act responsibly where field sampling is concerned. This means the user should be able to justify the selected locations for monitoring, the representativeness of sampling periods, etc. The minimum sampling periods can be exceeded if the user thought sampling inadequate to describe local conditions. As with any Standard the methods of NZS6808 could be mis-used or mis-applied by some users, however the well informed user will find the Standard provides clear and concise guidance on how to conduct a wind farm noise assessment free from errors or bias.

The 2010 version of NZS6808 requires that sound power data for wind turbines quoted at 10 m AGL wind speed be corrected to hub height wind speeds using *equation 7* from IEC 61400 – Part 11, across a range of operating wind speeds measured at hub height. This ensures wind farm sound output can be accurately predicted as it removes the possibility of under-predicting wind farm sound levels based on incorrect wind shear assumptions and is a clear improvement. The revised standard provides detailed guidance on this matter in section 7.4 of NZS6808:2010.

The issues raised by Dr Dickinson are largely addressed by following the assessment steps and instructions in the Standard NZS6808:2010, such as production of separate plots for different conditions. There is unavoidable scatter in background sound levels as the measurements include sound from varying natural processes. The effect of this scatter is mitigated by conducting a large number of measurements to give robust datasets, as recommended by NZS6808:2010.

The simple prediction method in the 1998 version has been replaced by methods using octave-band calculations and accounting for a wider range of factors influencing sound propagation. The 1998 version of NZS 6808 provided a simple propagation algorithm accounting just for distance attenuation and air absorption, based on 500 Hz. While this is generally conservative, the use of air absorption only at 500 Hz can introduce significant errors.

NZS 6808 now specifies a wide range of factors that must be taken into account in propagation modelling and references ISO 9613-2 [ISO 1996] as an appropriate method. A simplified method is still provided in an appendix, but the limitations are clearly set-out and octave-bands are required for air absorption. The simplified version of ISO 9613-2 described in NZS6808:2010 is said to be only appropriate typically for “small distributed generation or community scale wind farms, or where there are no nearby neighbours” (section C6.1.3). The use of the ISO 9613-2 prediction method that has been in use for wind farms in New Zealand and internationally for over a decade. Other than Dr Dickinson, the committee were not aware of any cases where significant errors have been found using this method. Dr Dickinson is correct that this method was not written for wind farms and that wind turbines do not comply with the stated limitations of the method. However, in practice the method has been shown to be accurate. The most recent example is the measurements at the West Wind wind farm, which validated the predictions using ISO 9613-2 [Chiles 2010].

Dr Dickinson proposes that wind farms should be modelled as line sources, which would result in attenuation of 3 dB with a doubling of distance. A line source is a theoretical construct to represent a series of point sources. As computer models can directly model an array of point sources there is no benefit in using the intermediate step of a line source, and in fact it will cause a loss of accuracy.

Using either approach will result in the same theoretical attenuation with distance. Sound from an individual point source will attenuate at 6 dB with a doubling of distance. However, for both a long array of point sources and a long line source the attenuation will be 3 dB with a doubling of distance. Thus, these concerns of Dr Dickinson were not accepted among the other technical experts on the review committee.

Measurement procedures have been clarified. The Standard also provides alternative simpler measurement procedures at clauses 7.1.2 and 7.7.

The assessment method has also been clarified with a useful guide in Figure 1 of NZS6808:2010 setting out the steps to follow when using that Standard within the statutory planning processes prior to wind farm construction. The recommended sequence of steps are set out in NZS6808:2010 (together with a reference to the relevant section of NZS6808:2010) are as follows;

1. Consider any specific district or regional plan provisions relating to wind farms (section 4)
2. Conduct initial predictions to determine the location of the 35 dB LA90(10 min) contour (section 6)
3. If necessary, measure background sound at selected locations in the 35 dB LA90(10 min) contour (7.4)
4. Determine site specific wind farm noise limits (section 5)
5. If necessary, refine predictions of wind farm sound levels at each noise sensitive location (section 6)
6. Prepare a report to form part of the assessment of environmental effects (section 8)
7. If necessary, conduct post installation sound level measurements (7.5 and 7.6)

Compared to the earlier 1998 version of NZS6808, the recommended procedures and processes set out within NZS6808:2010 appear to be more aligned with Resource Management Act procedures used in New Zealand for the assessment, management and control of the adverse effects (if any) of land use activities, including wind farms.

Wind Farm Noise Limits & Health Effects

The guidance set out in NZS6808:2010 is to limit cumulative wind farm sound to no more than 40 dBA outside dwellings, unless existing average background sound levels are exceeding 35 dBA, under which circumstances the recommended noise limit becomes the average $L_{A90(10\ min)}$ plus 5 dB.

In arriving at this guideline a review of wind farm noise limits and health was undertaken by the NZS6808 review committee. According to the World Health Organisation (WHO) (1999) annoyance is an adverse health effect. Studies of wind turbine effects on health have tended to be concentrated on the self-reported perception of annoyance.

One study of wind turbine noise and annoyance found that no adverse health effects other than annoyance could be directly correlated with noise from wind turbines. The

authors concluded that reported sleep difficulties, as well as feelings of uneasiness, associated with noise annoyance could be an effect of the exposure to noise, although it could just as well be that respondents with sleeping difficulties more easily appraised the noise as annoying (Pedersen & Persson Waye, 2008).

The Pedersen and Waye study found that being able to see wind turbines from one's residence increased not just the odds of perceiving the sound, but also the odds of being annoyed, suggesting a multimodal effect of the audible and visual exposure from the same source leading to an enhancement of the negative appraisal of the noise by the visual stimuli (Pedersen & Persson Waye, 2008).

Another study of residents living in the vicinity of wind farms from the Netherlands found that annoyance was strongly correlated with a negative attitude toward the visual impact of wind turbines on the landscape, however the proportions of respondents expressing annoyance at wind turbine sound levels of 40 dBA or less were quite small whether or not the turbines could be seen, see Figure 3.

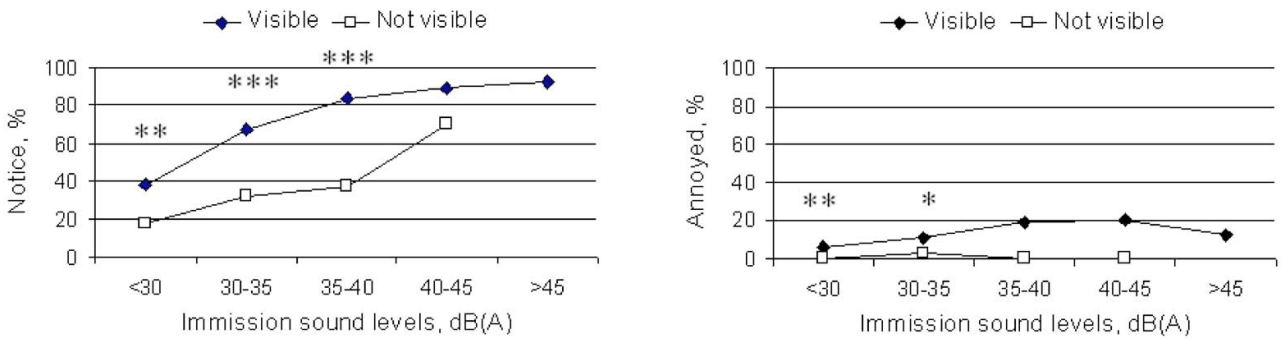

Figure 3 Comparison in proportion of respondents experiencing wind turbine noise who (left side) notice wind farm sound outdoors at each grouped receiver level of wind turbine sound, and (right side) expressed annoyance reported for respondents who could see at least one wind turbine from their dwelling and those who could not *=p0.05, **=p0.01, ***=p0.001 Mann–Whitney U-test. Ref. (Pedersen *et al*, 2009).

The study also concluded that people who benefit economically from wind turbines were less likely to report noise annoyance, despite exposure to similar sound levels as those people who were not economically benefiting (Pedersen *et al*, 2009).

WHO guidelines sets guideline limits for all sources of noise. These recommendations and other internationally accepted guidelines were examined and drawn on during the revision committee's work. Recommended WHO criteria for during the daytime states that few people are seriously annoyed by activities when outdoor sound levels are below 55 dB; or moderately annoyed at outdoor levels below 50 dB. Sound pressure levels outdoors during the evening and night should be 5–10 dB lower than during the day.

For sleep within bedrooms, WHO recommend an equivalent indoor level of 30 dBA or L_{max} 45 dBA. The recommended wind farm noise limits of NZS6808:2010 meets these WHO criteria.

The recommended criteria of NZS6808:2010 are based on a 10 to 15 dB noise reduction from outdoors to indoors. This is consistent with the reduction of 15 dB described in the WHO Community Noise Guidelines for sound travelling from outside

to inside a house with the windows partially open for ventilation. Dr Dickinson disputes this value, although he does not reference any actual sound insulation measurements to support an alternative to the 10 to 15 dB losses assumed through an open window.

The committee's review of relevant wind farm noise limits concluded there was no peer-reviewed scientific evidence indicating that noise from wind turbines received at levels at or below the NZS6808:2010 guideline limits cause an adverse impact on human health. This is supported by other specific internationally published reviews of health effects of wind turbine noise, such as reviews conducted by the Canadian and American Wind Energy Associations (CanWEA, 2009 and Colby *et al* 2009) and the Australian National Health and Medical Research Council (NHMRC 2010).

From a holistic health impact perspective, it has been found that wind energy is associated with fewer health effects than other forms of traditional energy generation and in fact results in an overall positive health benefit (WHO, 2004).

Some of the most common assertions regarding potential adverse noise impacts of wind turbines concerns low frequency sound and infrasound. Dr Dickinson also commented negatively on the ability of NZS6808:2010 to adequately assess and control this aspect of wind turbine sound. However, he appears to be inconsistent on this issue. Environment Court transcripts for the Mill Creek wind farm hearing reveal that during the discussions regarding the original development of the 1998 version of NZS6808 the issues of low frequency wind turbine noise and infrasound were noted at the time by Dr Dickinson as not giving rise to any concerns. Dr Dickinson stated at the time (1998) that no special techniques were needed to address these effects.

Regardless of the concerns raised, the review committee noted there has been significant research on the emission of low frequency sounds from wind turbines since the 1998 version of NZS6808 was published. The collective results of this research were found to support the notion that low frequency sound and infrasound associated with modern wind turbines is not a source which will result in noise emissions that may be injurious to the health of people living near wind farms (DTI, 2006).

Several claims of potential adverse health effects of WTG noise were made within submissions received following the release of the draft DZ6808. These included the possibility of "Vibro-acoustic disease", VAD (Alves-Pereira & Branco, 2007) and "Wind Turbine Syndrome", WTS, a syndrome identified in the work of Dr Nina Pierpont who has released a book "*Wind Turbine Syndrome: A report on a Natural Experiment".*

VAD was initially described as a consequence of long term exposure to large pressure amplitude low frequency noise - noise at levels greater than 90dB in the frequency range below 500Hz. The VAD researchers in Portugal have dropped the "greater than 90dB" criterion and now appear to be saying that VAD will result from exposure to almost any level of infrasound and low frequency noise at any frequency below 500Hz. The work identifying VAD as a valid disease of concern has been severely criticised when it has been presented at conferences. VAD papers are only presented by few authors, all closely associated with Ms Alves-Pereira and her colleagues. These papers are not backed by peer reviews. The papers are available only as conference papers which have not been independently evaluated prior to

presentation. Until the uncertainty is clarified, and a receptor mechanism revealed, no reliance can be placed on the claims that the low levels of infrasound and low frequency noise are a cause of vibroacoustic disease (Hayes 2006).

In relation to WTS, this is said to be caused by infrasound and low frequency noise. The symptoms of WTS are said to include:

- Sleep problems: noise or physical sensations of pulsation or pressure make it hard to go to sleep and cause frequent awakening
- Headaches which are increased in frequency or severity
- Dizziness, unsteadiness, and nausea
- Exhaustion, anxiety, anger, irritability, and depression
- Problems with concentration and learning
- Tinnitus (ringing in the ears).

Dr Pierpont's assertions regarding WTS are yet to be published in a peer-reviewed journal, and have been heavily criticised by other experts. WTS was identified based on a case-series study of phone interviews with 10 self-reported households, with no dose/response relationship determined for this syndrome. The literature on WTS does not identify a rational "cause and effect".

The NZS6808 review committee specifically investigated low frequency sound and infrasound from wind turbines. The majority view was that infrasound and low frequency sound generated by properly operated modern wind farms is well below demonstrated human health thresholds and the literature shows no dangers of added health risks that are not adequately controlled by adherence to the wind turbine noise limits recommended within NZS6808:2010.

High Amenity Areas

The original recommended noise limits are retained within NZS6808:2010 but were modified by the provision of a more stringent noise limit to be applied at some sites under some certain local circumstances. This is referred to as the "High Amenity" noise limit. The 1998 version of NZS6808 allowed for the situation where a limit of less than 40 dBA may be applied at receiver sites, however the 1998 Standard provided no guidance on methods to be used to assess whether or not a sub 40 dBA wind farm noise limit was appropriate at any particular site.

NZS6808:2010 recommends at clause 5.3.1: *'…a more stringent noise limit may be justified to afford a greater degree of protection of amenity during evening and night-time'.* This means residences or other noise sensitive sites situated in high amenity areas receive maximum wind farm sound at levels 5 dB less than the normally recommended limit of 40 dBA, or the background sound level + 5 dB (whichever is the greater). In designated high amenity areas, the noise limit becomes 35 dBA or the background noise level +5 dBA whichever is greater.

The high amenity limit is recommended to be applied at sites were;

1. The nature of the receiving site is such that little or no additional ambient sound is experienced at times when the wind farm is operating, and that the site is close enough to be affected by significant wind farm noise;

2. The site is located within a “high amenity” area. Under New Zealand planning procedures this would be the case for site where a District Plan “..*promotes a higher degree of protection of amenity related to the sound environment of a particular area*”.

The High Amenity limit was introduced into NZS6808 because the committee were concerned about some wind farm consents being granted with a sub 40 dBA noise limit applied inconsistently, with little or no scientific basis to the reasoning given for the more stringent noise limits. The committee had already decided the 40 dBA limit was sufficient for sleep protection, however it was decided to address evening and night time aural amenity at sheltered receiver sites in the vicinity of wind farms where low ambient sound levels are experienced when the wind farm is operating normally. The NZS6808 review committee reviewed information regarding the *Noise Perception Index* (NPI) as a means of determining whether sub 40 dBA wind farm noise limits may be appropriate under some conditions.

NPI was presented as an ambient-based noise assessment concept developed by Hessler (2009) as a measure of the true pressure average measure of the “new” noise by examining in detail the increases above ambient levels, during night time in particular in the case of NZS6808:2010.

The NPI method utilises the measured L_{A90} background sound levels together with a consideration of the wind farm sound level, across the range of operational wind speeds. A high calculated NPI value for a given site indicates wind farm sound levels are likely to regularly be received at levels 5 to 10 dB above normal ambient sound levels. Where the baseline monitoring shows this could occur for significant periods during night time, NZS6808:2010 recommends the High Amenity limit be applied.

Botha (2010) looked at the High Amenity limit and compared its usefulness alongside some sub 40 dBA noise limits that had been included within the consent conditions attached to some approved wind farms in New Zealand. The sub 40 dBA noise limits were found to be less than straight forward in their operation, were inconsistently applied between projects, and required further extensive monitoring. Botha found assessing the impact of wind farms (predictions and monitored compliance levels) is more straight forward and far less confusing if the high amenity noise limit under NZS6808:2010 is used rather than the variety of sub 40 dBA limits that 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.

Special Audible Characteristics

NZS6808:2010 has updated the earlier recommendations (NZS6808:1998) for assessing the potential for special audible characteristics, such as tonality or impulsiveness, to cause adverse community response. That is, adverse community response at lower sound levels than sound without such characteristics would normally be expected to generate.

Special audible characteristics within wind farm sound may be caused by:

(a) Tonal sound, for example, a hum or a whine from sources such as transformers or gear boxes;
(b) Impulsive sound, for example, bangs or thumps;
(c) Amplitude modulation, asynchronous or synchronous beating.

NZS6808:2010 sets out recommended assessment methods within a new Appendix (Appendix B) which is normative. The recommendations are based around objective and subjective assessment methods. NZS6808:2010 states subjective assessment can be sufficient in some circumstances to assess special audible characteristics.

Methods for assessing amplitude modulation present within wind farm sounds has been added into the 2010 version. These potentially additionally annoying qualities of wind farm sound are "penalised" in the assessment process by adjusting the wind farm sound level upwards by up to +6 dB for noise sensitive locations (see NZS6808:2010, clause 5.4.3). This adjustment is intended to account for the adverse subjective response likely to be aroused by sounds containing such characteristics.

Current & Future Use Of NZS6808:2010

Despite some media reports decrying the new Standard, NZS6808:2010 has been positively received by the industry and by Standard's users. The methodology is improved and better guidance provided on how to undertake the assessment. As above, the Standard now includes a step by step guide on what to do and how to follow the correct assessment procedures. Obviously, the new Standard covers the topic more thoroughly than the previous version and overall is a more comprehensive guideline. The size of the Standard has increased from 22 Pages (1998) to the 48 pages found in the 2010 version.

The chief executive of the NZ Wind Energy Association, Mr Fraser Clark, welcomed the new Standard[4] saying "*...it provides councils, communities and wind farm developers with a way forward through an emotive and contentious issue. Overall, it enables the appropriate development of wind farms while still protecting nearby residents' health and the amenity of their properties – an approach that is consistent with how other sources of sound are managed....*"

NZS6808:2010 has been used for wind farm noise assessment for all wind farm proposals being considered since the new Standard was released in March 2010. NZS6808:2010 is adopted as the noise assessment Standard for the following wind farms in New Zealand and Australia currently being developed or in the consent process;

[4] http://www.infonews.co.nz/news.cfm?id=48686

- Castle Hill Wind Farm - Genesis Energy
- Mt Cass wind farm - MainPower
- Hurunui Wind Farm - Meridian Energy
- Central Wind – Rangitikei - Contact Energy
- Ararat Wind Farm Project - RES Australia

Summary & Conclusion

This paper has considered the technical review of NZS6808:1998 which took place between 2008 and 2010 and resulted in a new Standard for the measurement and assessment of wind farm noise in New Zealand. The review and development of the new Standard has resulted in a number of technical amendments which improve noise assessment for wind farms in New Zealand. The amendments include a new "High Amenity" noise limit, improved assessment of wind farm sounds containing special audible characteristics, and better integration with the New Zealand planning procedures.

The development of NZS6808:2010 dealt with a range of technical and non-technical matters raised by some anti-wind farm advocates and one member of the technical committee. Concerns from these parties focussed on expressing doubts about the technical content of the Standard and promoted the view that the Standards NZ committee set up to develop the new Standard were unduly influenced by the wind industry. Following a review by Standards NZ the conclusion was that the Standards review process was conducted in an appropriate manner, consistent with the accepted methods by which all New Zealand Standards are revised from time to time.

NZS 6808:2010 balances sustainable management of natural wind resources with the protection of the community. Applying the noise limits recommended in NZS 6808:2010 will help avoid significant adverse noise effects from wind farms, although the wind farm may be audible at times.

On the basis of the above, the review of 1998 Standard NZS6808:1998 has resulted in an improved Standard NZS6808:2010 that is considered fit for purpose.

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