Acoustic Assessment of Wind Farms – A Practical Perspective

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ABSTRACT

The assessment of noise from wind farms is a significant element of the development approval process for proposed wind farms in Australia. This paper addresses the current requirements for acoustic measurement, modelling and reporting for wind farm developments in Australia and relevant issues arising from these requirements. In particular, the practical application of the assessment requirements is discussed, and the implications of these for new wind farm proposals are investigated. Lessons which have been learned through experience with wind farm noise assessments have been used to provide a practical perspective.

INTRODUCTION

Wind turbines and wind farms have unique noise generating characteristics. Unlike typical industrial noise sources, the sound power level of wind turbines varies with wind speed. The main noise source associated with a wind turbine is centred on the hub, which is located at a significant height above the local ground level (up to 100m agl).

The environments surrounding wind farm sites are usually rural and often have low background noise; however, background noise increases with wind speed (due to wind induced noise from foliage etc) and provides a masking effect.

To predict and assess noise generated by wind farms therefore warrants special requirements for acoustic measurement, analysis, modelling, reporting and assessment. In Australia, there is a draft Australian Standard (Draft AS, 2006) and South Australia has published wind farm noise guidelines (EPA-SA, 2003). This paper presents a mixture of experience related advice and standard/guideline requirements.

MEASUREMENT OF BACKGROUND NOISE

The existing noise environment at potential receiver locations (in the vicinity of a proposed wind farm site) must be adequately determined for a representative range of conditions. This requires obtaining sufficient background noise measurements correlated with wind speed at the wind farm site.

Site Selection

Any residential premises within at least 1.5km of the nearest turbine of the proposed wind farm array need to be identified. Private landowners who enter into agreements with the wind farm developer to place wind turbines on their properties (ie. “windfarmers”) are classified as non-relevant receivers. Other premises (where someone resides or where a dwelling has development approval) which are not associated with the wind farm are classified as relevant receivers (RRs).

Background noise measurements should be undertaken at a sufficiently representative sample of the RRs. This sample should include the nearest RRs to the wind farm site and where the predicted noise from the wind farm is likely to exceed the base noise criterion for wind speeds of $10ms^{-1}$ or less. In a group of RRs, it may be sufficient to measure at one RR within the group if it is representative of the worst case (highest potential noise exposure). The choice of measurement locations will require discussion and agreement with the wind farm developer and the regulatory authorities.

Particular attention should be made in regard to sheltered receivers (eg. that may be shielded from prevailing winds by terrain) where the wind-induced background noise may be low when wind speeds (and turbine operation) are high at the wind farm site.

Relevant receivers where measurements are not taken need to be characterised for their likely type of background environment and linked with a measured RR.

Site Access

Wind farm sites are typically situated in remote areas away from major centres, near coastal or hilly terrain where winds are high. The travel time from the nearest city can be substantial and can involve driving on minor/unsealed rural roads.

It is important to obtain clear instructions on how to get to the various relevant receiver locations. As the RR sites are often on rural properties, access and permission requirements need to be determined with the developer/landowner.

Before setting up the measurement equipment at RR sites, sufficient notice needs to be given to landowners on when, where and for how long the measurement equipment will be set up. Extra care needs to be taken when setting up as returning again to the remote site will be a time consuming exercise (and not presenting a professional image to the public/client).

Background Noise Data

Sound levels meters (SLMs) or statistical noise loggers of at least Type 2 certification (in accordance with AS 1259 or IEC 61672) are required for background noise measurements (Draft AS, 2006; EPA-SA Guidelines, 2003).

There may be a requirement in the near future to use only Type 1 SLMs. In addition to the measurement accuracy, it is important to have low noise floor equipment (< 20dBA) for measuring low background levels at “quiet” rural sites. L_{A90} levels in 10-minute intervals need to be measured at a height of 1.2 to 1.5m above the local ground level.

All equipment must be within calibration (with a current certificate) and the calibration should be checked (eg. with a piston-phone calibrator) before and after the measurements.

Windshields must be used in accordance with manufacturer's instructions to reduce the influence of wind-induced noise on the microphone. Special windshields may be needed if wind speeds are likely to exceed $5ms^{-1}$ at the receiver location. From experience, this is not a common occurrence and measurements of wind speed at receiver sites can be used to discard measured data for when wind speed exceeds $5ms^{-1}$, or is determined to be at such a level, based on manufacturer's test data, to have influenced results.

Measurement equipment needs to be autonomous and have sufficient battery life to last over a minimum of 3 weeks. It is recommended that solar panel or other power backup is used and that the equipment is checked to have sufficient on-board memory for the amount of data to be collected. The on-board clocks on different monitoring equipment need to be on the correct local time and synchronised with each other.

Equipment security needs to be considered such that equipment can not be tampered with or stolen. Bird spikes should also be affixed to microphone poles. There should not be any appendages or tape affixed to the equipment which could flap in the wind and cause extraneous noise generation that could affect the L_{A90}.

The noise logging equipment must be placed greater than 5m from the nearest reflecting surface/facade and within 20m of the main residence in the direction towards the wind farm. The equipment should not be placed close to overly noisy trees/shrubs and should be representative of the general environment in the vicinity of the residence. If a wind measuring anemometer is used it should not be placed close to the noise logging equipment such as to influence noise measurements.

It is important to take photographs of the equipment setup with the residence in the field of view and also in the direction of the wind farm site. Residents should note the times of any unusual or extended noise sources (eg. farm machinery near loggers) that occur during the monitoring period.

It is recommended that localised wind and rain data is collected at a subset of the relevant receiver locations. Bureau of Meteorology (BOM) data may also be used (particularly for rain data) if a BOM station is close enough to the site and representative of site conditions.

Variations in the terrain/topography and prevailing wind directions in the vicinity of a wind farm site may cause significant variations in wind and rain levels for different sites. In addition, seasonal variations (eg. atmospheric stability) or unusual prevailing wind variations may cause measurements to be sensitive to the time of year.

Wind Speed Data

Wind data needs to be measured at the wind farm site during the background noise monitoring period. Wind speed and direction is measured in 10-minute intervals at a height of 10m above the local ground level. This matches the international measurement standard (IEC 61400-11, 2002) requirement to measure the sound power level of wind turbines at 10m above ground level (agl).

Some wind farm sites have wind measuring anemometers at higher heights (up to the hub height of the proposed wind turbines). Great care is needed to convert the higher height wind data to the equivalent at 10m agl, using site-specific wind profile information (usually a power law relationship).

Recent research (van den Bergh, 2003; Fowler, 2005) does suggest that some sites may show variations in the vertical wind profile or shear between day and night (eg. due to greater atmospheric stability at night compared to day). In addition, the site wind profile (and terrain roughness) may be different to that at the initial turbine sound power measurement site. This may cause errors in the assumed turbine sound power level versus wind speed for different conditions at the site.

It is therefore important to define the inherent wind profile at the proposed wind farm site and use this to adjust the sound power level of the proposed turbines. In addition, it may necessitate separating the day and night data collected during the background noise monitoring period (Fowler, 2005). Stable conditions at night could cause lower background noise at the receiver for a particular wind speed at 10m agl.

In the absence of hard data regarding the influence of this effect in Australian conditions, measurement of wind speed at heights approaching hub height in conjunction with the "normal" 10m agl measurements may provide the necessary site specific data on wind shear to enable informed decisions with regard to its influence, and any need to account for it.

Data Collection

The background noise data (L_{A90}) and wind farm site wind data need to be collected simultaneously and the 10-minute measurement intervals need to be synchronised. It is important to ensure which time interval relates to the record time stamp in the noise and wind data (which can vary).

A minimum of 2000 valid noise/wind data pairs need to be collected during the monitoring period to ensure a sufficiently representative dataset, in accordance with current practice driven by overseas and local experiences. The data must sufficiently cover or represent the wind speed range at the site and cover all wind directions as far as practicable.

Time intervals for which the wind speed exceeds $5ms^{-1}$ at the receiver microphone need to be excluded from the data-set. Data also needs to be removed for time intervals that are rain affected (eg. heavy rain/storms or intervals with >2mm rain). Care should also be taken for sites adjacent local creeks and waterways following periods of heavy rains.

To account for excluded/invalid data (and to ensure sufficient data in the applicable wind speed range), a period of 3 weeks should be allowed for the collection of data for planning purposes. If possible, a check of recorded data during the monitoring period can help to determine total period required to ensure sufficient points are collected (after removal of invalid data).

CRITERIA DETERMINATION

Assessment Standard

An acceptable level of noise from wind farms is usually based on background noise levels. In Australia, there is a draft Australian Standard (Draft AS, 2006) and South Australia has published wind farm noise guidelines (EPA-SA, 2003).

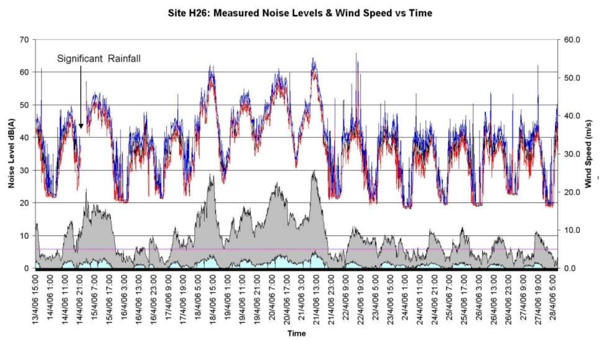

Figure 1. Wind-Noise Data throughout Monitoring Period.

The draft AS establishes a guide to the methodology to be used when undertaking wind farm noise measurements, predictions and assessments. The SA EPA guidelines specify the noise criteria to be used for compliance in addition to specific methodology requirements.

Other applicable standards include the New Zealand Standard (NZS 6808, 1998), which also provides criteria. Assessment guides are also given in reports or guidelines by ETSU (UK), the Australian Wind Energy Association (AUSWEA) and the New Zealand Wind Energy Association (NZWEA).

The SA Gudielines have been widely adopted throughout Australia by regulatory authorities, although some local councils or shires use different approaches provided by the NZS. Care should be taken when determining the appropriate standard applied by the authority due to the differences between each of them.

From the SA EPA guidelines, the wind-speed dependent criterion is the maximum of the base criterion of 35dBA or background plus 5dB for each integer wind speed in the turbine operating range (between cut-in and rated power). The criteria assume the normal operational noise from a wind farm with the exception of unusual tonality effects.

These criteria are not applicable to non-relevant receivers, and other approaches developed in conjunction with these landowners, such as sleep disturbance criterion (WHO, 1999) of 45dBA (external $L_{Aeq, 8\,hr}$), can be used.

Data

The final data-set to be used for analysis (and criteria determination) must have all invalid data excluded. This includes removal of wind affected data (where wind speed exceeds 5ms^{-1} at the receiver microphone) and rain affected data (eg. heavy rain/storms or intervals with > 2mm rain).

A total of 2000 valid noise/wind data pairs need to be correlated and plotted on a graph. As a check, the plotted points must look realistic, ie. generally increase with increasing wind speed at all points, but expect a variation in noise levels for any given wind speed.

If there are known variations in the vertical wind profile at the site (or if it is suspected that background levels are dependent on time of day) it may be necessary to separately plot the day and night data. It may also be necessary to separately plot data for some wind directions if significant seasonal variations are known to occur (or if it is suspected that background levels are strongly dependent on wind direction).

Calculation of Regression Curve

A best-fit regression analysis needs to be applied to the valid data-set collected for each relevant receiver. A regression curve, defined by a second or third order polynomial, usually provides the best correlation coefficient. If the correlation coefficients are low, other lines of best fit should be tried.

The data-set used for regression curve fitting should include only wind speed data (at the wind farm site) inside the normal turbine operating range (from cut-in wind speed, usually around 3 to 4ms^{-1}, and up to rated power wind speed, usually around 12 to 14ms^{-1}, at hub height). Data at the extreme ends of the wind speed range can influence the slope of the regression curve.

The fitted regression curve (overlaid on the plotted data points), the polynomial equation describing the curve and the correlation coefficient must be displayed on the final graph.

The wind-speed dependent criteria are determined by adding 5dB to the regression curve and then taking the maximum of this or the fixed 35dBA base criterion.

Criteria then need to be applied to the other relevant receivers (where noise measurements were not taken), based on the characterisation of their likely type of background environment, by linking with a measured receiver.

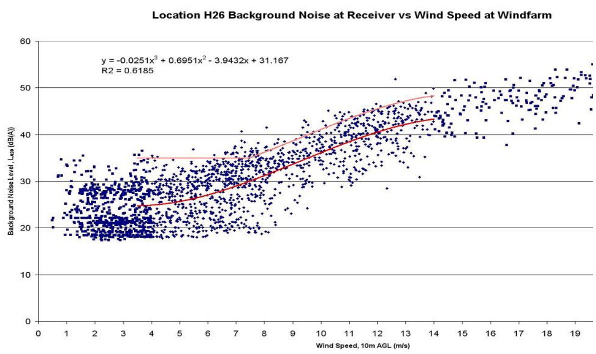

Figure 2. Wind-Noise Data with Regression/Criteria Curves.

MODELLING

Data Requirements

Data required to undertake noise modelling include the wind turbine locations (including local ground height data) and the residence locations out to at least 1.5km distance (including local ground height data). A consistent coordinate system should be utilised (eg. UTM WGS84). Ground topography data across the region (out to receiver locations) is required to reasonable accuracy (at least 5m height interval contours).

Wind turbine acoustic performance data should be determined in accordance with the international measurement standard (IEC 61400-11, 2002). Data should be provided as a sound power level for each wind speed (at a height of 10m agl) between cut-in and rated power. The sound power frequency spectrum should be provided in third octave bands to assess tonality.

The source height in the model should be set at the hub height above the local ground level for each turbine. It may be necessary to use the inherent wind profile (and terrain roughness) at the proposed wind farm site to adjust the wind speed dependency of the sound power level of the turbines.

Physical parameters such as air absorption and ground hardness need to be determined for the considered site. Assumptions need to be considered, such as whether barrier effects due to topography and structures are included and whether wind propagation effects are included; if not, then safety margins need to be added to account for these.

Prediction Software

A number of proprietary software packages are available for modelling the prediction of noise including SoundPLAN, ENM, CadnaA, Nord2000 and many others. Packages such as WindPRO and WiTuProp have been developed for specific application to wind turbine noise prediction.

The SoundPLAN and ENM packages provide a choice of theoretical algorithms to use for calculating the propagation of noise over distance.

The application of modelling software to specific situations needs to be carefully considered and, where possible, based on validations with actual measurement data to provide confidence and minimise associated inaccuracies.

Propagation Algorithm

The algorithm for calculating the propagation of noise over distance needs to be optimised for the situation considered. Calculation algorithms can be theoretical (based on physical theory), numerical, empirical or heuristic and they vary in their assumptions and applicability to certain situations. Some algorithms may have limitations if they are simplistic and do not incorporate the effects due to some processes or assume incorrect fixed values for some physical parameters.

Applicable algorithms include International Standard ISO 9613, British Standard BS5228, CONCAWE, GPM (General Prediction Method, Nordic), Nord2000 (Delta, Denmark), WiTuProp (Delta, Denmark) amongst others. There are a number of differences between the algorithms. ISO9613 and GPM are relatively simplistic methods whereas CONCAWE, Nord2000 and WiTuProp contain more complex methods.

Assumptions relating to processes and parameters (eg. ground effect/hardness, air absorption, screening/shielding effect) vary. CONCAWE is essentially the only algorithm that incorporates meteorological effects, including the wind propagation effect. The air absorption parameter is usually given by the ISO9613 formulation. The ground hardness (or absorption) parameter needs to be reasonable for the typical terrain (eg. partially soft) at the wind farm and receiver sites.

A comparison of models has been performed by others (Tickell, Ellis & Bastasch, 2004; Berndt, 2004). There can be significant differences in the prediction results over distance for different model algorithms. For example, the CONCAWE model tends to overpredict noise levels relative to WiTuProp. Quoted accuracies of models are typically in the range ±2dB to ±5dB.

A preliminary comparison of measured wind farm noise levels with predicted levels has been performed for the Starfish Hill Wind Farm in SA (Marchuk, 2006). Initial results show that the CONCAWE model may overpredict by about 3dB relative to measured wind farm levels at $8ms^{-1}$. The CONCAWE model overpredicted relative to the other models (by about 1dB relative to Nord2000, by about 4dB relative to GPM and by up to 6dB relative to ISO9613).

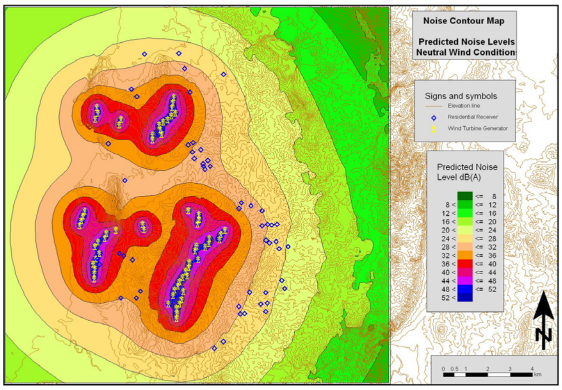

Figure 3. Predicted Noise Contour Plot.

Prediction Results

Using the chosen model, single point calculations with all turbines operating (at maximum power rating for each wind speed) should be performed for each receiver (relevant and non-relevant). The model should be run for neutral (no wind) and wind propagation scenarios. The wind propagation effect should be calculated for a subset of wind speeds (and at least $8ms^{-1}$) for the worst case wind direction for each receiver.

Noise contour plots should be produced (with reasonable grid resolution) showing the likely spread of noise over the whole area up to at least 1.5km from the wind farm (for neutral and worst case wind scenarios). However, noise contour plots should only be used for presentation purposes to show the general propagation of noise from the wind farm site.

Prediction results for each receiver should be tabulated, for neutral and worst case wind scenarios, for each integer wind speed between cut-in and rated. If necessary, data could be tabulated for a range of wind directions. Tables should display the applicable criterion level adjacent to the predicted levels (and where any exceedances occur).

Predicted noise levels should be rounded up or down to the nearest integer or, at best, to the nearest 0.5dB increment (modelling inaccuracies do not warrant any more accurate presentation of predicted levels). A list of the most dominant turbines (ranked in order of contribution to overall noise level) could be provided for critical receivers (which exceed, or are close to exceeding, the criterion level).

CHARACTERISTICS AND ASSESSMENT

Adjustments are required for tonality or other characteristics if they exist. The turbine manufacturer's report for sound power level must state whether any tones were measured or audible, using both a subjective and an objective method (IEC 61400-11, 2002).

Modern upwind turbines do not typically exhibit noise characteristics such as impulsiveness, modulation or low frequency components. Infrasound was a feature of some older downwind turbines; any low frequency noise from turbines has been found to be barely detectable and well under perception thresholds (Leventhall, 2003; Bellhouse, 2004; BWEA, 2005).

In the close vicinity of a turbine there is a slight swish-like modulation resulting from the rotor blade passing through the air and past the support tower in addition to a slight hum emanating from the turbine generator. These typically minor effects diminish rapidly over distance and, for an array of turbines, are usually randomly mixed to form low-level background white noise.

However, under some rare conditions such as extreme wind profile effect and the phasing of numerous turbines, cyclic variations could cause audible modulations that could be clearly discernible above the background for some distance.

The impact of any other wind farms in the vicinity needs to be taken into account (and likely combined noise levels should be presented) and existing or future stages of the wind farm in question also need to be addressed.

The predicted noise levels (with any safety margins applied to provide conservatism) need to be assessed against the criteria at each applicable wind speed (between cut-in and rated power speeds).

For relevant receivers, exceedances of the wind farm criteria at any wind speed need to be highlighted. It is recommended that non-relevant receivers are assessed relative to sleep disturbance criteria (eg. WHO, 1999). There may be special council or EPA requirements for additional criteria to be met.

If criteria are not met (or are close to be exceeded), then the most dominant turbines (ranked in order of contribution to overall noise level) should be determined for the critical receivers. The noise model should be rerun with turbines taken out or operation modified until the criteria are met at all relevant receivers.

The assessment should state whether turbine operational changes will need to be applied for compliance eg. for the major contributing turbines, use of lower power rating (derating) or noise minimisation mode or wind sector management (turn off at certain wind speeds and directions).

The likely noise impact of the electrical substation needs to be assessed against the applicable industrial noise regulations (eg. EPA, 1994). The noise impact due to the construction of the wind farm needs to be addressed, with attention paid to the likely period of time that certain equipment will be used and assessed relative to the applicable EPA guidelines.

REPORTING

The assessment report should include the time history plots of noise and wind over the whole monitoring period. Any locally obtained (at receiver) wind and rain data needs to be summarised, with the number/extent of affected intervals.

For each relevant receiver, the fitted regression curve (overlaid on the plotted data points), the polynomial equation describing the curve and the correlation coefficient must be displayed on graphs, along with a line showing the resultant criterion level. Separate plots of the day and night data and wind direction data may need to be provided if applicable.

The report should include a discussion of the noise model accuracies, assumptions and likely conservatism. The level of reporting required by the SA EPA could soon further increase (with a revision of the SA Wind Farm Noise Guidelines).

The report should contain the results described in the Prediction Results section above. The predicted impacts due to construction noise and electrical substation noise need to be included as well as the wind farm operation noise. Any other existing noise producing activities in the area need to be described and taken into account.

Regulatory authorities will generally want to sight any agreements between the developer and each windfarmer (landowner with turbines on their property). The agreements need to include the expected noise impact relative to accepted criteria such as sleep disturbance (WHO, 1999) and whether the impact is likely to cause significant interference or health effects.

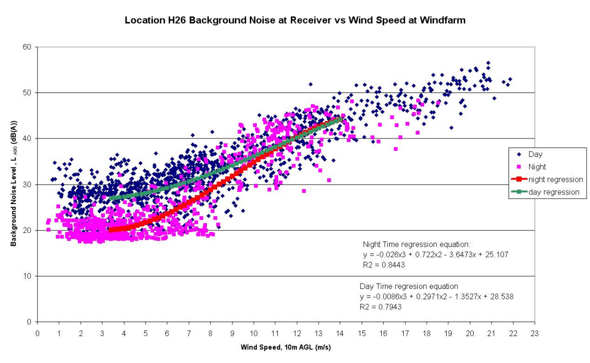

Figure 4. Day- and Night-Time Separated Data Plots.

OPERATION & COMPLIANCE

Measurements of noise levels are required post-installation of the wind farm. It must be ensured that this is undertaken for full operation of all wind turbines at nominal power settings.

Compliance measurements are required at a representative subset of relevant receivers and should generally include those receivers at which initial background noise measurements were taken. If valid noise complaints have been received from residents since operation then these additional receiver locations may also require monitoring.

In many cases the measured noise levels at receivers (with the wind farm operational) are dominated by background noise – it is often not possible to get a "clean" measurement of the wind farm impact. This may necessitate also measuring at a "near field" location close to (< 300m) the nearest turbine, or turning the turbines on and off to determine the influence of the ambient noise environment.

Background levels may vary due to seasonal changes, climatic conditions and environmental changes (including vegetation near dwelling). If this is the case, then it may need to be checked, which will require a significant down-time for the operational wind farm. The compliance measurements should collect sufficient data associated with the worst case wind direction (eg. ± 45º either side of direct line between nearest turbine and receiver). It is important to ensure or check that the compliance measurements are reasonably repeatable regardless of the time of the year.

As with the initial background measurements, it may be necessary to separately plot the day and night data (if background levels are dependent on time of day). It may also be necessary to separately plot data for some wind directions (if significant seasonal variations are known to occur).

A subjective assessment of noise from the wind farm must be undertaken during the compliance monitoring period to determine whether wind farm noise is discernible or clearly audible and whether there are special characteristics present. In addition, objective evidence may need to be collected including measuring the frequency spectrum (ideally narrow band but at least third-octaves) with a SLM at the "near field" location. Any extraneous noise or influence from other sources such as road/rail traffic (or other wind farms!) should also be noted.

Longer monitoring periods of 4 to 6 weeks or more could be required to account for variations and invalid data. For a statistically robust data-set, this could require double the amount of measurement data for separate day/night analysis (ie. 4000 data points) and 4 times the amount of data (ie. 8000 points) for a quadrant wind direction analysis to secure appropriate conditions. If any special characteristics are detected (subjectively or objectively) then a 5dB penalty needs to be added to the measured levels.

The measurements at the "near field" location (and other sites if clean wind farm impact measurements are obtained) can be used to compare with the predicted noise levels. There is limited compliance data currently available for validation of predictions. A preliminary comparison of measured wind farm noise levels with predicted levels has been performed for the Starfish Hill Wind Farm in SA (Marchuk, 2006). There will soon be validations for several new wind farms.

If the measured noise levels do not achieve the criteria, then the data may need further careful analysis. A longer and more comprehensive measurement programme may need to be performed. If the wind farm still does not meet the criteria, then turbine operational changes will need to be applied eg. for major contributing turbines, use lower power rating (derating) or noise minimisation mode or wind sector management (turn off at certain wind speeds and directions).

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REFERENCES

Bellhouse, G., 2004, Low Frequency Noise and Infrasound from Wind Turbine Generators: A Literature Review, Prepared for EECA, Bel Acoustic Consulting, NZ.

Berndt, A., 2004, *Uncertainties in Environmental Noise Modelling*, Proceedings of Acoustics 2004, Gold Coast.

BWEA Report, 2005, *Low Frequency Noise and Wind Turbines Technical Annex*, British Wind Energy Association.

Draft Australian Standard DR 04173, 2006, Acoustics – Measurement, prediction and assessment of noise from wind turbine generators, Standards Australia.

EPA (SA), 2003, *Environmental Noise Guidelines – Wind Farms*, SA Environment Protection Authority.

EPA (SA), 1994, *Environment Protection (Industrial Noise) Policy*, SA Environment Protection Authority.

ETSU-R-97 Report, 1996, *The assessment and rating of noise from wind farms*, Energy Technology Support Unit, UK.

Fowler, J.B., 2005, *Review of the environmental noise monitoring program - Toora wind farm*, Report 045-177/1, Graeme E. Harding & Associates for South Gippsland Shire Council, Victoria.

IEC International Standard 61400-11, 2002, *Wind turbine generator systems - Part 11: Acoustic noise measurement techniques*, International Electrotechnical Commission.

Leventhall, G., 2003, A Review of Published Research on Low Frequency Noise and its Effects, DEFRA Report.

Marchuk, A., 2006, *Private Communication*, SA Environment Protection Authority.

New Zealand Standard NZS 6808, 1998, Acoustics – The assessment and measurement of sound from wind turbine generators, New Zealand Standards.

Tickell, C.E., Ellis, J.T., Bastasch, M., 2004, *Wind Turbine Generator Noise Prediction – Comparison of Computer Models*, Proceedings of Acoustics 2004, Gold Coast.

van den Bergh, G.P., 2003, *Effects of the wind profile at night on wind turbine sound*, Journal of Sound and Vibration.

WHO, 1999, *Guidelines for Community Noise*, edited by Berglund, Lindvall & Schwela, World Health Organisation, Geneva.