Improving the accuracy of noise compliance monitoring of wind farms

Chris Turnbull

Sonus Pty Ltd, Adelaide, South Australia

ABSTRACT

The most common method for measuring the noise from an operational wind farm is long term logging and correlation of noise level with wind speed. The noise at residences from wind farms is often lower than the noise from other sources and this presents significant challenges in noise compliance monitoring. Further, there has been a focus on the accuracy of noise compliance monitoring in the media and this highlights the need for the most accurate method of compliance monitoring to be adopted. This presentation describes a number of techniques recently used to monitor noise compliance at various wind farms to overcome the inherent challenges of separating wind farm noise from the noise of other sources.

1. INTRODUCTION

The noise criteria for wind farms in Australia are determined as the higher of a base level (either 35 dB(A) or 40 dB(A)) or 5 dB(A) above the measured background noise level (EPA SA, 2003) (EPA SA, 2009) (Standards Australia, 2010) (Standards New Zealand, 2010). The background noise level is determined by measuring the noise at residences in 10 minute intervals and pairing the L_{A90} noise level in each ten minute interval with the hub height wind speed. A line of best fit through the data is drawn and this is taken as the background noise level at each wind speed. Figure 1 shows an example of the data pairs, the line of best fit and a line 5 dB(A) above the background noise level (representing the objective criteria).

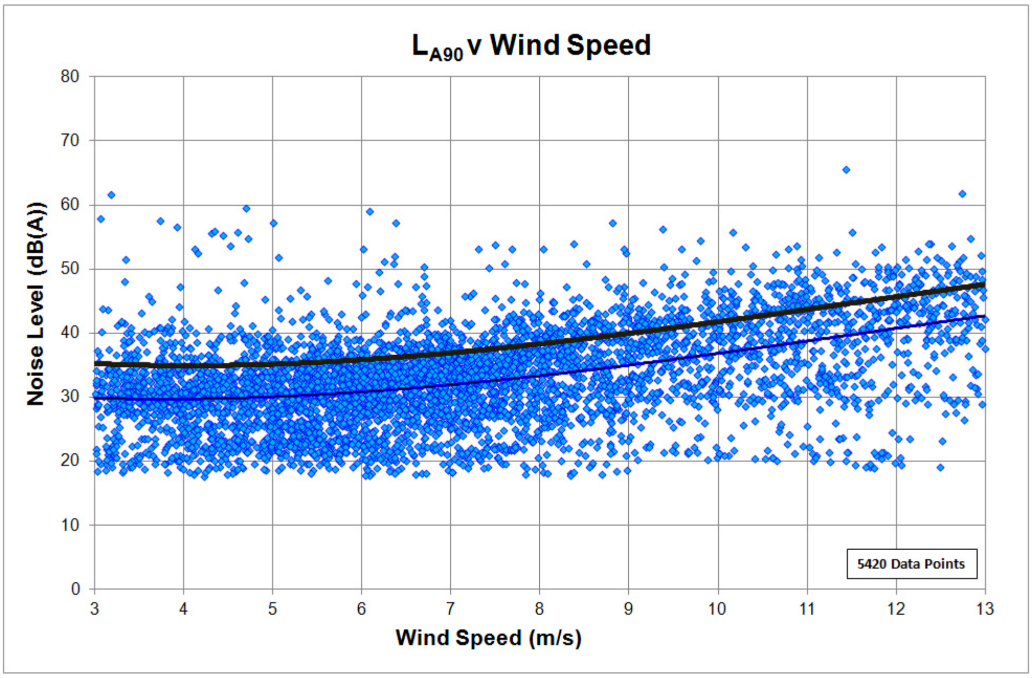

Figure 1: Correlation of wind speed with background noise (L_{A90}) and derivation of criteria

There is a general perception in the community that following construction, the noise from a wind farm can be easily measured and compared against the objective criteria without any averaging of data or analysis of variation (Madigan JJ 2015). However, measuring the noise from an operating wind farm in the presence of varying ambient noise is not a simple task. This is demonstrated by the example of Figure 2 and Figure 3, which show the L_{Aeq} and L_{Amax} respectively for the same noise logging period as Figure 1. The objective criteria derived from Figure 1 have been shown for context.

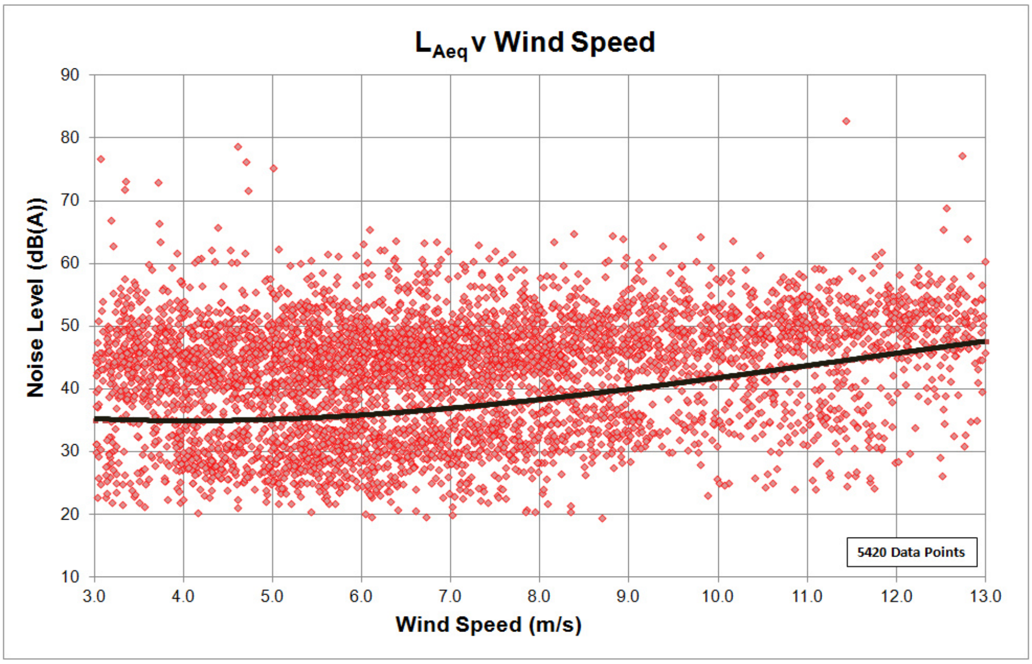

Figure 2: Correlation of wind speed with L_{Aeq}

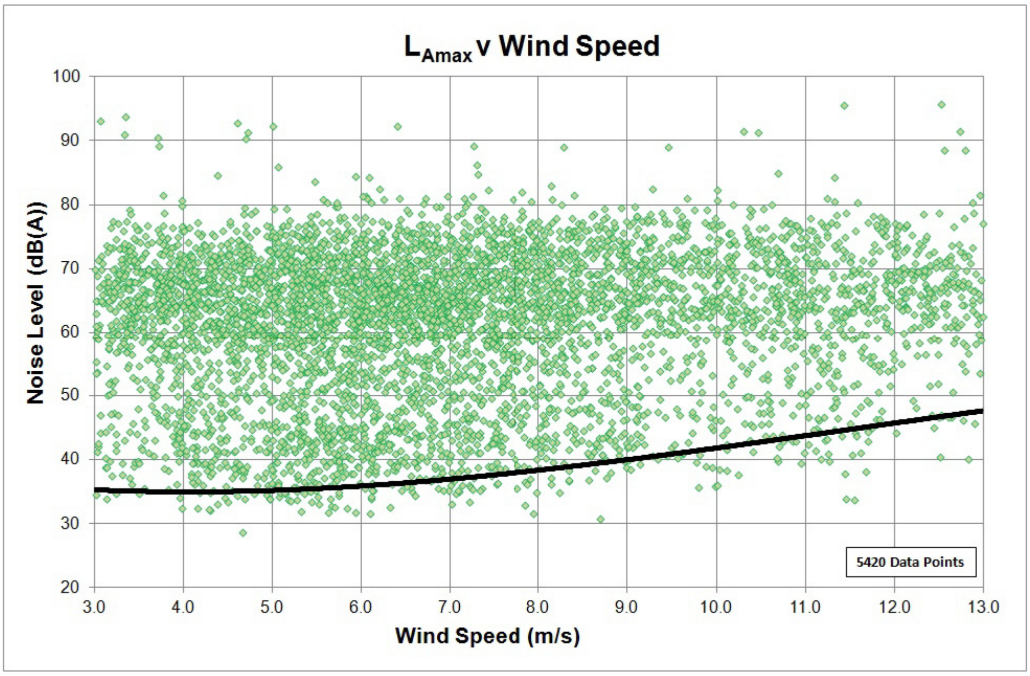

Figure 3: Correlation of wind speed with L_{Amax}

The figures show that the ambient noise in the environment varies greatly and is often higher than objective wind farm criteria. Therefore, the measured noise during wind farm operation will be a combination of ambient noise and wind farm noise and cannot be attributed entirely to the wind farm. On/off testing is often referenced as a defining test where the identification is difficult but even when on/off testing is conducted, the accuracy is dependent on level of ambient noise at the time of the test and the assumption that the ambient noise does not change from one test period to the next. In these circumstances, the most common method of wind farm compliance measurements is to repeat the pre-construction logging and compare the pre-construction levels with the post-construction levels. Any increase is attributed the operation of the wind farm.

Given the potential for, and implications of, false results, techniques have been used to improve the accuracy of wind farm compliance measurements at sensitive receptors. These techniques include:

- Extensive data collection;
- The use of frequency analysis;
- The comparison of upwind and downwind data points.

In addition to these techniques at sensitive receptors, which are described in detail below, conducting measurements between the wind farm and the residences provides an opportunity to improve the wind farm to ambient noise ratio. This technique involves predicting the noise at an intermediate location and comparing the measured level with the predicted level. Where the measured level is no greater than the predicted level, the noise model can be considered to be verified. Therefore if the noise model predicts that the criteria are achieved at residences and the noise model is verified, it can be inferred that the noise at residences complies with the criteria. However, the method relies on the stakeholders accepting that a prediction model can form part of a compliance checking procedure.

2. DATA REQUIREMENTS

When comparing the operational noise with pre-construction noise, it is important to have sufficient data to account for any natural variation in ambient noise. This is particularly the case when the data are required to be separated into wind directions or day and night periods. Table 1 lists the minimum recommended data requirements for the various Standards and Guidelines used in Australia.

Table 1: Data requirements of Guidelines and Standards used in Australia

Standard or Guideline	Minimum recommended number of data points	
	Background noise measurements	Compliance noise measurements
(EPA SA, 2003)	2000	2000 downwind
(EPA SA, 2009)	2000 with 500 downwind	2000 with 500 downwind
(Standards Australia, 2010)	2000	2000
(Standards New Zealand, 2010)	1440	1440

Note: (Standards New Zealand, 2010) requires the number of measurements made to be sufficient to allow dependable correlations to be obtained between the sound levels and the wind speed.

When the data collected during the night time period are separated, the requirements of the various Standards and Guidelines result in less than 1000 data points. To provide an indication of the variation in ambient noise for a given size of dataset, six weeks of data were separated into datasets of 250, 1000 and 1400 data points. Figure 4 shows the datasets of 250 points, Figure 5 shows the datasets of 1000 points and Figure 6 shows the datasets of 1400 points.

With 250 point datasets, the variation is 15 dB(A) at 12m/s. That is, if the lower dataset had been recorded before the wind farm had been constructed and the higher dataset had been recorded after the wind farm had been constructed the data would imply exceedance by 10 dB(A), without any contribution from the wind farm. Conversely if the higher dataset had been recorded before the wind farm had been constructed and the lower dataset had been recorded after the wind farm had been constructed the reliance on the data would allow the windfarm to contribute noise well above the background noise level without showing any non-compliance. With 1000 point datasets, the variation is 10 dB(A) at 14m/s and with the 1440 point datasets the maximum variation is 6 dB(A) at 14m/s.

It is noted that in some circumstances, where separation of the data into subsets (such as wind direction) is required, the separation has the potential to minimise the spread of data, although this has not been found to be the general case in practice.

The example demonstrates the importance of extensive datasets and highlights the risk of creating subsets of data, which result in inadequate sized datasets. The practice, which is becoming more common, of collecting six weeks of data (approximately 6,000 data points) appears to provide an appropriate amount of data.

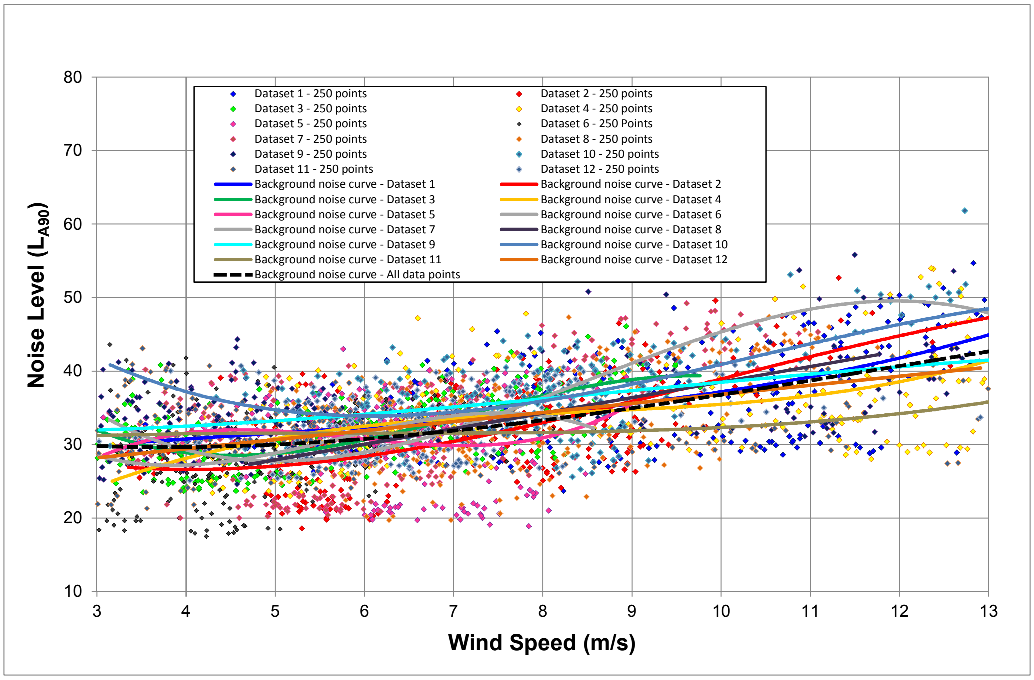

Figure 4: Correlation of wind speed with L_{A90} divided into 250 point datasets

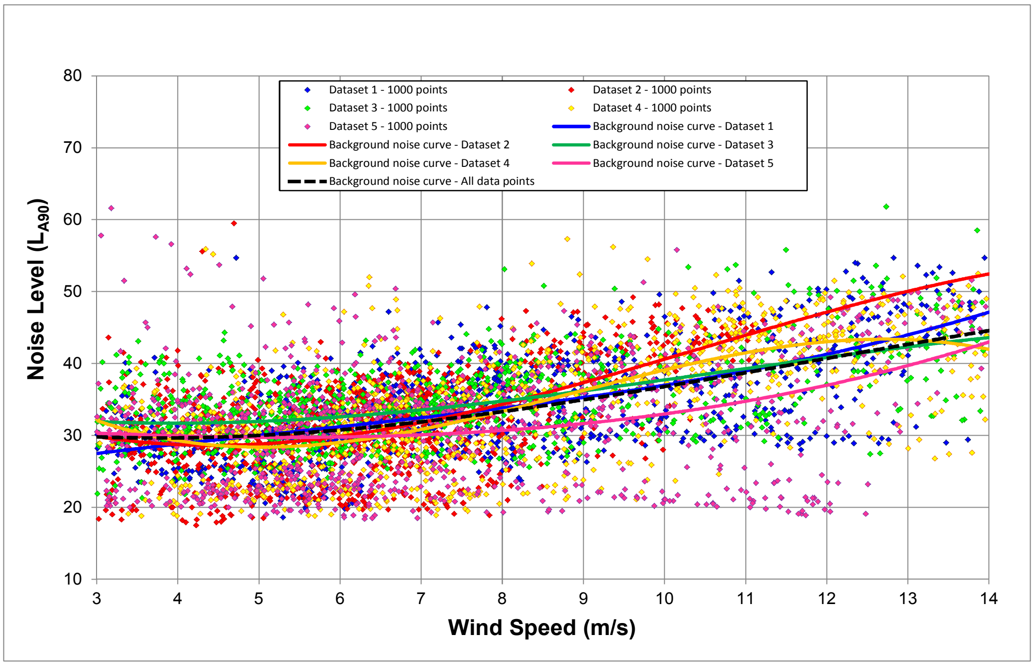

Figure 5: Correlation of wind speed with L_{A90} divided into 1000 point datasets

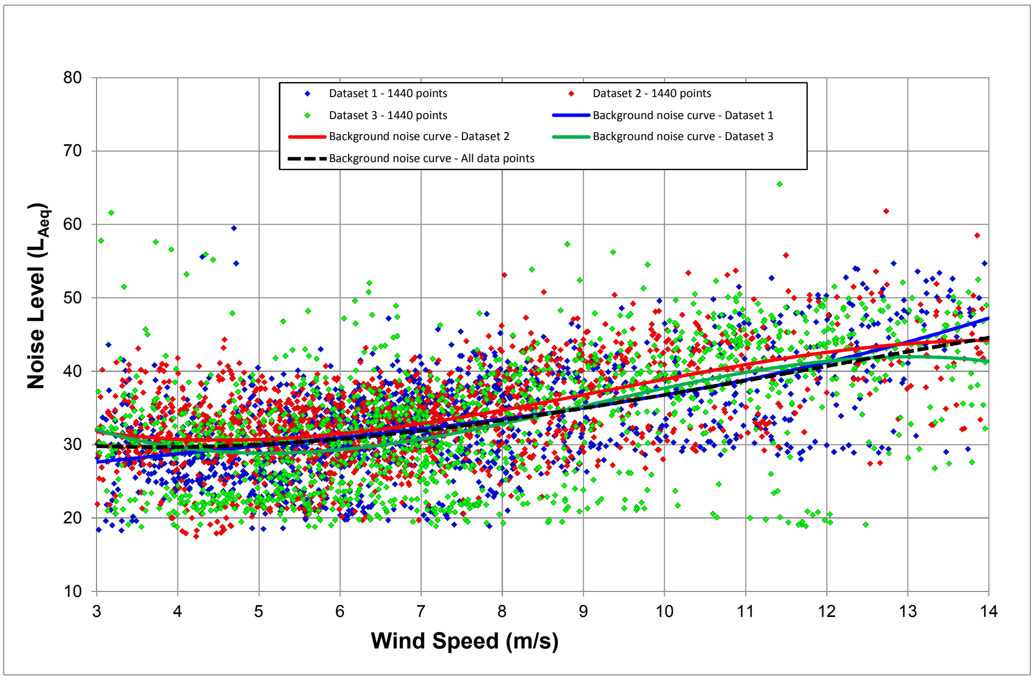

Figure 6: Correlation of wind speed with L_{A90} divided into 1440 point datasets

3. FREQUENCY ANALYSIS

The noise emitted from wind turbines is broadband, with content in the low, mid and high frequencies. However, at residential setback distances, typically in the order of one to two kilometres, the high frequency noise is attenuated by air absorption, leaving no significant contribution in the 2000Hz octave band or above.

In contrast to the lack of high frequency content from wind turbines at residences, the ambient noise often has significant high frequency content. This is particularly the case where insects are present. This difference in frequency content provides the opportunity to apply a low pass filter to remove all high frequency content without removing any significant contribution from the wind farm. Figure 7 shows the noise in the vicinity of an operating wind farm with and without the high frequency content removed.

Figure 7 demonstrates the potential to reduce the extraneous noise from the measurement of noise from an operational wind farm with a reduction of approximately 6 dB(A). This difference could easily amount to the difference between a wind farm being considered compliant and non-compliant.

4. COMPARISON OF UPWIND AND DOWNWIND DATA POINTS

Over the past 15 years, the technique of background noise monitoring has continually improved. This includes an increase in the amount of data collected, the use of sound level meters with lower noise floors and improvement in wind shields to minimise noise from wind on the microphone. Therefore, for wind farms approved in recent years, there is generally reasonable background noise data available, which were collected prior to construction. However, for wind farms approved and constructed previously, there is often little data or the data have been collected prior to the improved techniques being implemented. In circumstances where limited ambient noise data are available it is even more difficult to separate the component of wind turbine noise from the noise produced by other sources.

At residential setback distances, the noise from a windfarm is greater when the wind is in a downwind direction (in the direction from turbines to residence) than an upwind direction. The difference is generally considered to be in the order of 10 dB(A) (Institute of Acoustics, 2013). Therefore, one method of providing an indication of the noise contribution from a wind farm is to compare the noise collected in an upwind direction with data collected in a downwind direction. Where there is no significant difference at a particular wind speed, it is reasonable to assume that the wind farm is not contributing significantly to the overall noise level. Conversely, if there is a significant difference, the contribution of noise from the wind farm can be estimated from the difference. Figure 8 shows an example of compliance noise data collected at a location where there were no suitable pre-construction background noise data. If all noise had been attributed to the wind farm at high wind speeds, the result would indicate non-compliance with the criterion of 35 dB(A). However when the upwind and downwind data are compared, it indicates that the wind farm makes no significant contribution at high wind speeds.

When using this technique, it is important to collect as much data as practical because separation into sectors reduces the amount of data available and, depending on prevailing winds, can result in very few data points. It is also important to consider that the ambient noise might be different for different wind directions. This might occur at locations where the wind in a certain direction is shielded by topography, resulting in lower noise from wind in trees.

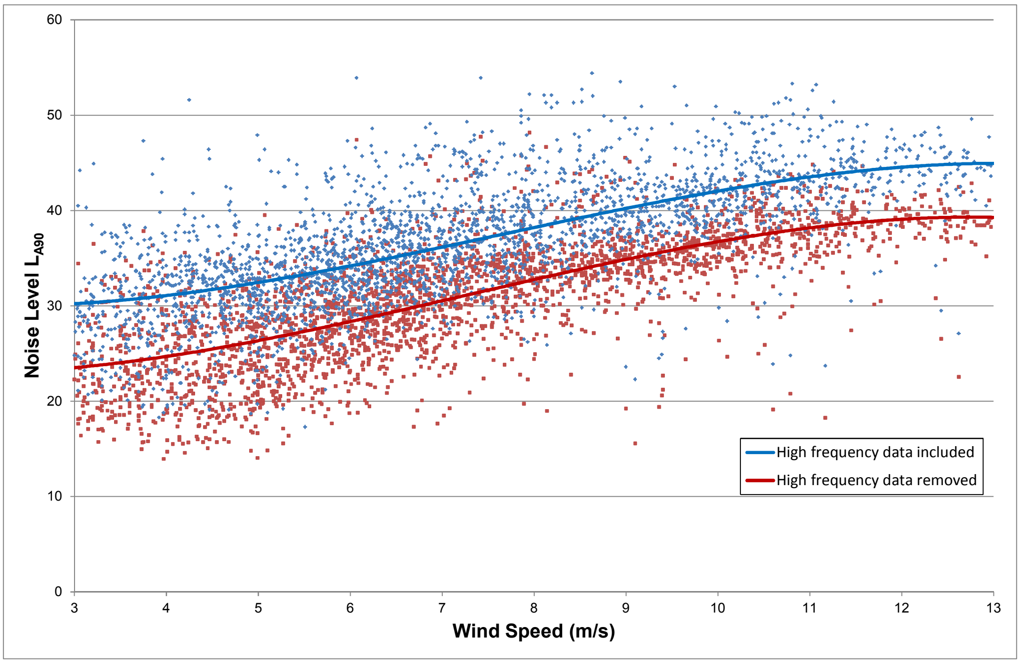

Figure 7 Noise in the vicinity of an operating wind farm with and without high frequency content

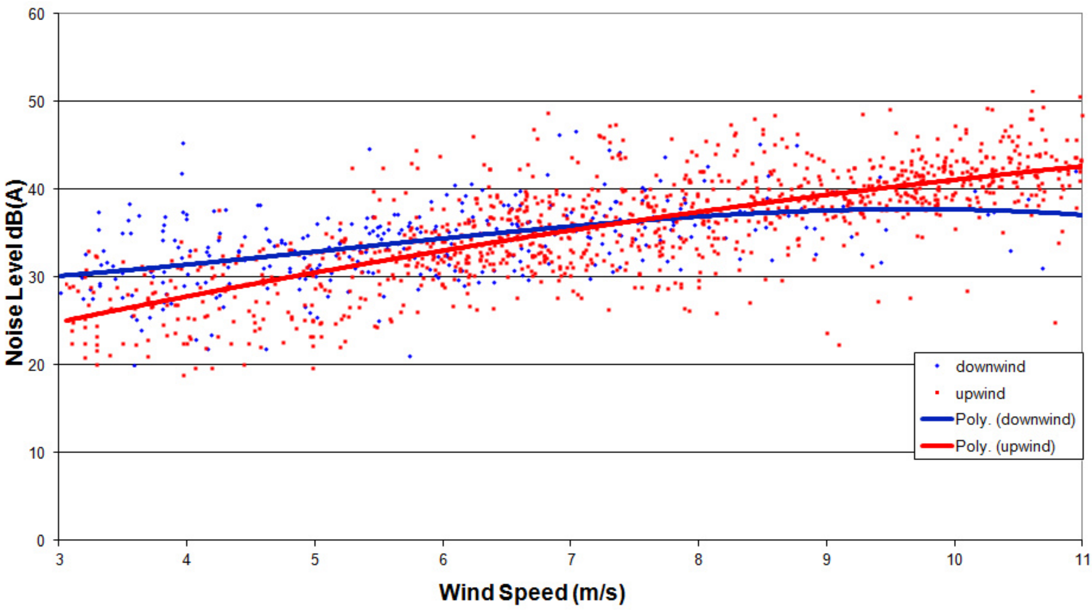

Figure 8: Comparison of upwind and downwind data to estimate wind farm noise contribution

5. CONCLUSION

The noise from a wind farm, when measured at residences, is often lower than the ambient noise from other sources. In these circumstances, it is important to consider techniques to separate the wind farm noise from the noise from the other sources. These techniques include:

- Extensive data collection;
- The use of frequency analysis;
- The comparison of upwind and downwind data points.

While these techniques can assist in understanding the contribution of wind turbine noise to the overall noise level, there is still no single method which accurately separates wind turbine noise from other noise in all circumstances. Rather, it is expected that a combination of these methods will need to be employed depending on the specific circumstances and the important factor for stakeholders is to understand that such methods will need to be utilised in some scenarios.

ACKNOWLEDGEMENTS

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