REPORT TO THE ONTARIO MINISTRY OF THE ENVIRONMENT
SOUND PRESSURE LEVEL COMPLIANCE TESTS
WITH APPLICATION TO AMHERST ISLAND

Summary

It is argued that the method for predicting the turbine sound pressure level at a receptor allowed by the present Ontario wind turbine noise regulation significantly under-estimates the actual sound pressure level when the turbines are built and operating. Three compliance tests demonstrate the under-estimation by up to 15 dBA, up to 12 dBA and up to 8 dBA respectively. Some of this under-estimation can be put down to bad engineering; some can be put down to the science of sound generation and propagation that has been published over the past two decades but not acknowledged by the Ministry of the Environment. There is serious need for a full re-evaluation of the way that wind turbine site plans are being approved. The longer that the Ministry of the Environment holds off on this re-evaluation the larger that the problem becomes for the province.

Introduction

There are very good reasons to expect that wind turbine noise will be out of compliance with the predicted 40 dBA worst case sound pressure level at receptors on Amherst Island. Among the reasons are that the Ministry of the Environment neglects the following:

- The specified uncertainty of the sound power level of the turbine.
- The specified uncertainty of the predicted sound pressure level when using ISO 9613-2 and software based upon it.
- The limitation of ISO 9613-2; it is limited to noise sources such that the average height of the source and receptor is 30 metres. In the case of Amherst Island this average would cover the range 24 to 80 metres as the blades rotate.
- The excess noise caused by ambient turbulence and turbulence at downwind turbines caused by the upwind turbine wake. This is a particular problem with the proposed site plan because of the high density of large-blade-diameter turbines.
- The excess noise that results from blade rotation in a large wind speed gradient.
- The probability that for part of the time the combination of vertical temperature gradient and wind speed gradient will result in downward refraction of sound and cylindrical rather than spherical spreading.

None of this is new to the Ministry of the Environment. All REA documents must include the sound power level of the turbines; these specifications include the uncertainty. All noise predictions must use ISO-9613-2 and Ministry staff will be aware of the content of this technical bulletin. Turbulent inflow noise was discussed nearly two decades ago in the “bible” of wind turbine noise: the book by S. Wagner, R. Bareiss and G. Guidati. Further definitive research, experimental and theoretical, dates back a decade to the work at the National Renewable Energy Laboratory in the USA and more recently in Denmark. The excess noise due to blade rotation in a large wind speed gradient has been reported on by R. James and others. The downward refraction of sound and resulting cylindrical spreading, over land and water, also has a long history. Ministry of the Environment engineers have attended conferences and will have been exposed to all of these impacts on the sound pressure level at receptors. In any case, as the Environmental Approvals Branch of MOE will be aware, I have been sending fully referenced reports on these impacts to the Ministry for the past 6 years or so.

The proof of the efficacy or otherwise of the MOE protocol lies with compliance testing. I have access to only 4 compliance tests and none were final stage tests. In fact, Mr. Denton Miller in his witness statement to the Ostrander Point ERT noted that there had been no final stage tests to date. The following outlines my analysis of compliance tests at the Lormand home, the Libby home, and an unknown home among the Melancthon wind energy project. I have recently received a copy of the report on the compliance test at the Horton home; however, it does not include original measurements and is proving impossible to un-ravel. I would be very pleased to receive the original acoustic measurements from MOE.

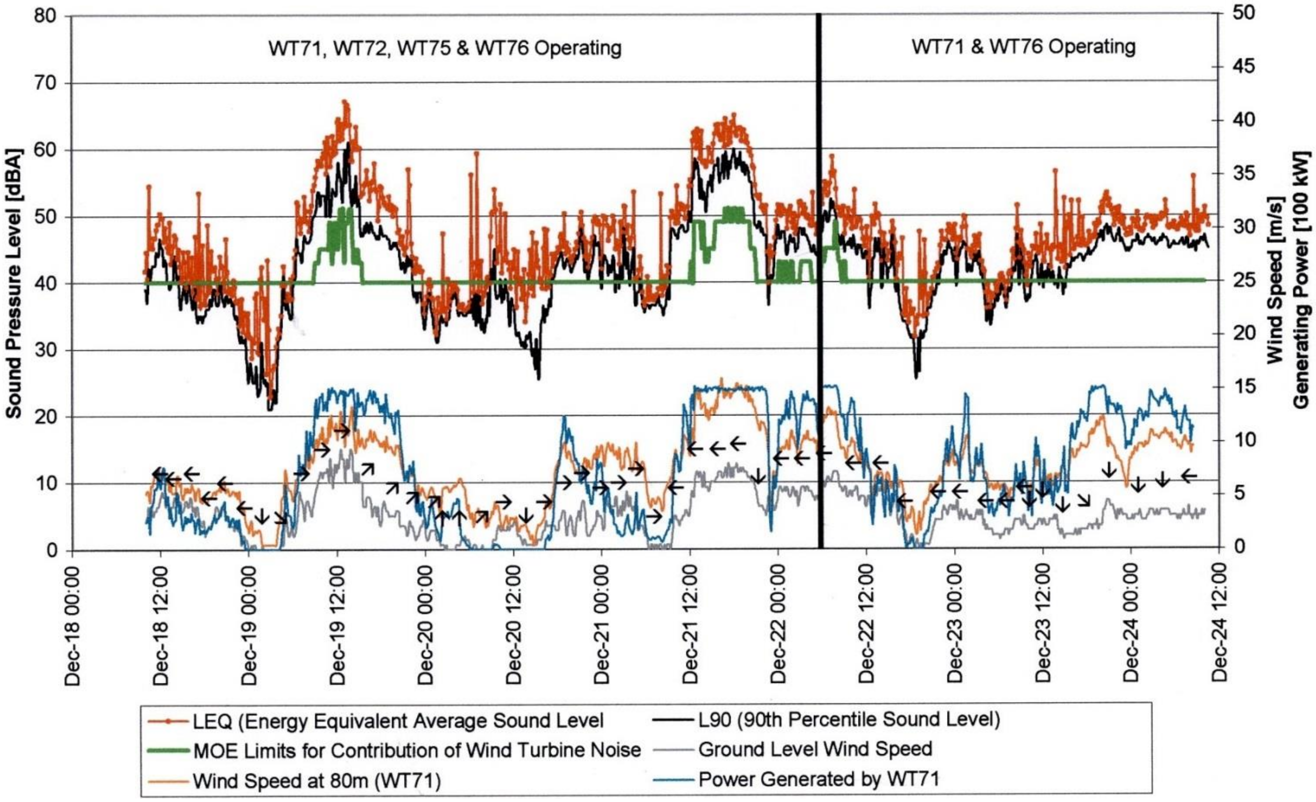
(a) Review of the HGC Turbine Noise Compliance Test at the Lormand Home
(Reference: HGC Report on Lormand Residence)

The figure, taken from a February 2009 report written by HGC Engineering for Canadian Hydro Developers, is self-explanatory. The red data points show the measured turbine noise, L_{EQ}, used in the Ontario regulation. The green data points show the Ontario regulation limit for the wind speed at that time. Over the 6-day period the measured noise level is above the limit almost all of the time and by up to 15 dBA. Note that the measurements were made in December. See the note below concerning the extra impact of turbine noise expected during the summer months.

The difference between L_{90} (black line) and L_{EQ} (red line) is about 2 dBA. This is reasonable given the amplitude modulation and thumping noise characteristic of turbine noise.These sounds will be missed by L_{90} and averaged by L_{EQ}. The ear will detect sound pressure levels closer to L_{10}, probably 2 dBA above $L_{EQ.}$

This figure is used with permission of the Lormand family and of HGC.

Figure 2: Sound Levels Measured at the Lormand Residence.
Comparison to Wind Speeds and Criteria. Canadian Hydro, Melancthon EcoPower Center.



(b) Review of the MOE Turbine Noise Compliance Test at the Libby Home

(Reference: Mr. Libby MOE Report)

Background

As a result of complaints of noise intrusion at the Libby home, measurements of sound pressure level at the home were made by Ministry of the Environment officials. The Libby home is 659 and 1060m respectively from the nearest two turbines of the Talbot Wind Farm. Noise modelling using the MOE protocol predicted a sound pressure level at the home of 38 dBA. The sound meter was placed 1.5 m above ground on the turbine side of the house, together with an anemometer at the same height.

Note that the sound meter was placed 10m from the wall nearest to the turbine, this was neither 30m from the wall nearest the turbine nor 4.5m above ground level at the centre of the house. These are the two positions defined in section 6.3.1 of the regulations. 10m wind speed measurements were provided by the developer. The measurements were made over 5 days in December 2011. The relevant measurements are collected in the following Table 1.

Date Dec. 2011	Time	V(1.5m) (m/s)	V(10m) (m/s)	SPL (dBA)	Power (MW)
16th	1:32 am	2.4	9.0	54.5	91
18th	5:32 pm	1.0	4.1	41.3	30
18th	8:10 pm	1.0	6.6	45.8	78
19th	9:11 pm	1.0	7.9	43.4	69
19th	9:56 pm	1.7	5.9	44.0	67
19th	11.55 pm	1.4	6.2	40.6	68
21st	4:50 pm	2.0	7.8	47.0	94
21st	5:51 pm	2.0	6.9	43.8	84
21st	9:13 pm	1.7	5.8	39.7	50

Table 1: Measurements Made at the Libby Residence

Columns 3 and 4 give the wind speeds at heights of 1.5 and 10 metres above the ground. Column 5 is the sound pressure level measured by the sound meter. The sound meter was fitted with a wind shield. The maximum contribution to the measured sound pressure level from wind noise in the microphone would have been 0.1 dBA. The power output of the nameplate 99MW wind farm is shown in the final column. These numbers were retrieved from the Independent Energy System Operator archive.

Figure 1 is a plot of the measured sound pressure level as a function of the 10 metre wind speed, V(10m). The upper solid line corresponds to the MOE noise limit for a class III environment. It is 40 dBA up to a 10m wind speed of 6 m/s, rising to 51 dBA at 10 m/s. There are no qualifiers for humidity. Clearly, the turbine noise is out of compliance for much of the time. Remember that the prediction was 38 dBA.

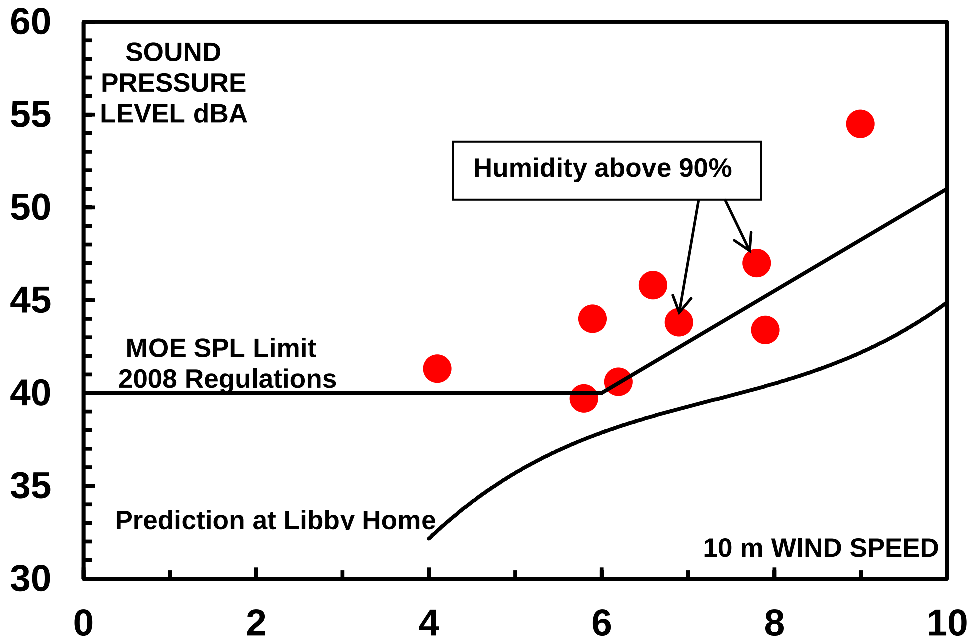


Figure 1: Measured sound pressure level (SPL) as a function of 10m wind speed.

Height Correction

The 2008 MOE noise regulations specify that for a two-storey home the prediction is to be made for a location at the centre of the residence at a height of 4.5m. For a one-storey home the developer can choose to use a location 30 metres from the home, in the direction of the turbine or at the centre of the building at a height of 4.5 metres. For simplicity, consultants choose to work with the centre of the building at a height of 4.5 metres. Therefore, the predicted sound pressure level at the Libby home of 38 dBA would be for the centre of the home at a height of 4.5 metres. The sound pressure level at this location is typically 2 dBA higher than at a location 1.5m above ground outside the home[1]. Therefore, the predicted turbine sound pressure level at the one-storey Libby home would have been 36 dBA.

Excess Sound Pressure Level

The lower solid line in Figure 1 is the predicted noise level at the home. This was determined by combining the predicted turbine sound pressure level and the L_{90} Reference Wind Induced Background Sound Level given in Figure 1 of the 2008 Noise Guidelines for Wind Turbines.

[1] The Hatch environmental noise impact assessment for the Windlectric proposed project on Amherst Island was used for this comparison. The assessment provided the prediction for the two locations for all residences within the study area. For the first 30 residences on the list the average difference was 2.11 ± 0.25 dBA

The excess sound pressure level ranges from 2 to 12 dBA above the prediction with an average of 6 dBA; this discounts the 2 data points with humidity above 90%.

Errors in the MOE Analysis

Whoever provided the analysis of the MOE measurements at the Libby residence has no idea of what they were doing. This is serious because the analysis purports to show that the measured sound pressure levels are not so bad. What was done was to take the measured sound pressure level, subtract the regulation sound pressure level at the same wind speed and compare the difference with the regulation sound pressure level. This is nonsense.[2]

10 min Leq (dBA)	Ambient (dBA)	Turbines Sound Level (dBA)	Level criteria based on wind speed (dBA)
54.5	51	51.9	51
41.3	40	35.4	40
45.8	43	42.6	43
43.4	45	0.0	45
44.0	40	41.8	40
40.6	43	0.0	43
47.0	45	42.7	45
43.8	43	36.1	43
39.7	40	0.0	40

Table 2. Analysis Extracted from the MOE Report

The erroneous MOE analysis is demonstrated in Table 2 below, extracted from the MOE report. The first column shows the measured sound pressure levels. The order is the same as that given in Table 1, which includes the dates, times and wind speeds. The second column was labelled ambient but that is wrong. The numbers are in fact the sound pressure level limits under the MOE 2008 Noise Guidelines for Wind Farms. The MOE reference ambient sound pressure level in fact varies from 30 dBA at 4 m/s to 44 dBA at 10 m/s (10m wind speeds). The sound pressure level limits have the reference ambient sound pressure level built in.

[2] For those unfamiliar with sound pressure level and the dBA scale, consider the following analogy: A car is stopped on the highway for travelling at 130 km/h, 30 km/h above the speed limit. The MOE approach is to subtract 100 km/h from the 130 km/h, leaving 30 km/h. 30 km/h is well within the speed limit and so there is no problem!

The author of the analysis has then subtracted[3] the numbers in column 2 from the measurements in column 1; these are shown in column 3. It is claimed in the report that that these numbers represent the measured sound pressure level corrected for the ambient sound pressure level. As noted above, this is nonsense; the third column has no meaning.

Impact of Turbine Noise

The noise from a turbine has more impact when the wind speed gradient is high. There are two reasons:

- The wind speed at hub height is significantly higher than it is at 10m. Therefore there can be the full sound pressure level from the turbine with very little masking noise at the residence.
- When the blades are rotating in a large wind-speed gradient, the blades are continually moving from high wind speed to low wind speed. The blade pitch is therefore not optimized and the sound pressure level can be 5 dBA higher. Acousticians are well aware of this although do not acknowledge it when consulting for the wind-energy developers. This is discussed in the Richard James review of the Environmental Noise Impact Assessment for the Algonquin Power wind energy project on Amherst Island in Ontario.

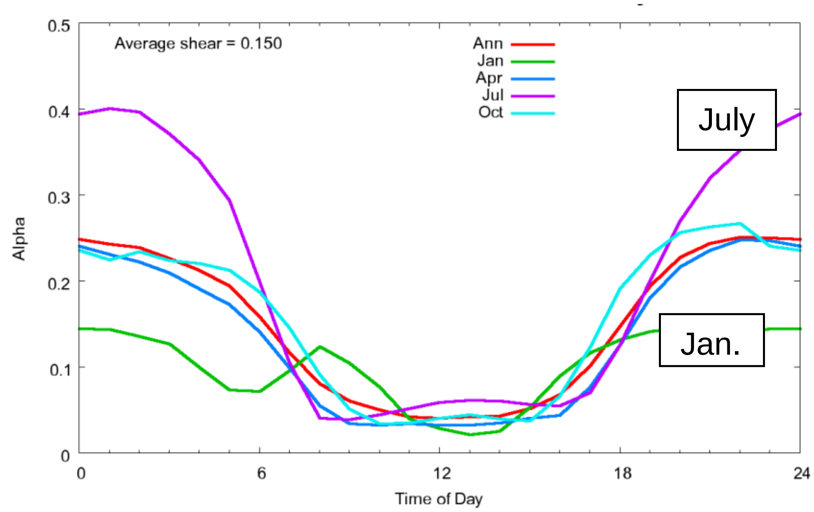


Figure 2: Diurnal wind shear exponent pattern at Lamar, CO, for 52-113-m levels.

Figure 2 shows measurements of the wind-speed gradient parameter, measured by M. Schwartz and D. Elliott (NREL); these measurements are typical as will be well-known to the

[3] Subtracting, say, 4 dBA from 7 dBA proceeds as follows:
Difference = 10 log($10^{7/10}$ – $10^{4/10}$) = 3.98 dBA

acousticians at MOE. Typically, at night during the summer month the turbine noise is going to be higher and more noticeable than during the winter months. Therefore the measurements made in December do not catch the full impact of the turbine noise at the Libby home.

(c) Comment on Howe and McCabe: "Recent developments in assessment guidelines for sound from wind power projects in Ontario, Canada, with a comparison to acoustic audit results." Inter-noise 2009, Ottawa.

Howe and McCabe (HM) have audited an Ontario residence within 1 km of a wind turbine. Just how close we do not know and whether there were other near-by turbines we do not know.

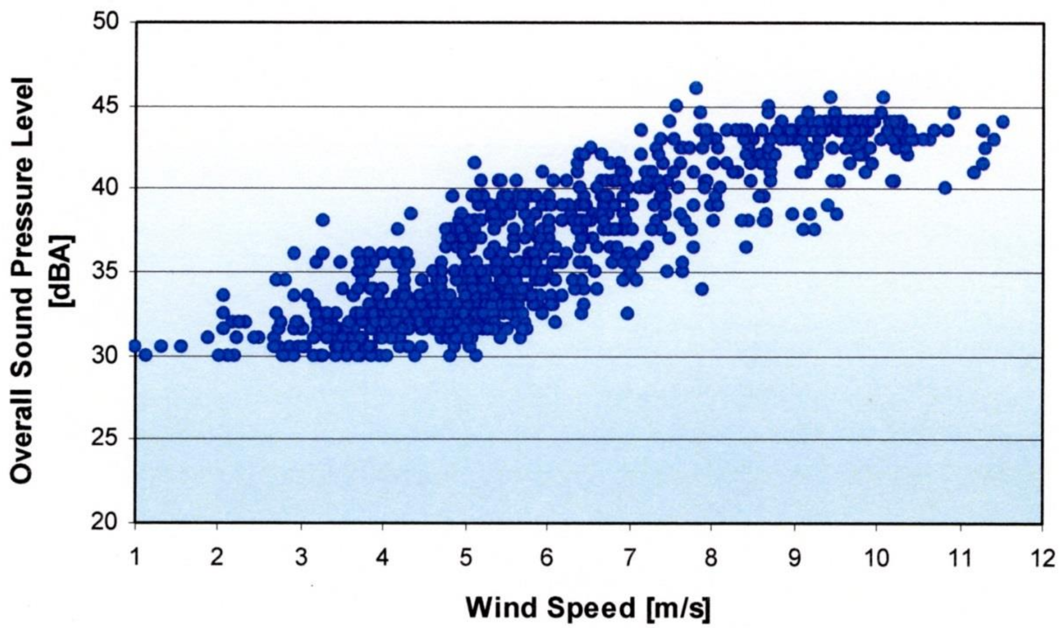
HM have chosen to use L_{90} (in dBA) as a function of the nacelle wind speed in presenting a summary of their measurements. The Ontario noise guidelines are in terms of L_{EQ} as a function of the wind speed at a height of 10 metres. The noise limit is 40 dBA up to a 10 metre wind speed of 6 metres/second up to 51 dBA at a wind speed of 10 metres/second. HM justify using L_{90} by arguing that it misses intermittent noise such as passing cars. However, it also misses amplitude modulation that is a dominant characteristic of wind turbine noise. Amplitude modulation has been reported as low as 3 dBA and as high as 15 dBA. It is conservative to assume that in these measurements L_{EQ} is 2 dBA higher than L_{90} due to amplitude modulation. In other words, the Ontario noise limit expressed in terms of L_{90} is 38 dBA up to a 10 metre wind speed of 6 metres/second, up to 49 dBA at a wind speed of 10 metres/second.

The relationship between the nacelle wind speed and the 10 metre wind speed depends upon the wind speed gradient, described by a parameter α. This can vary between 0.15 and 0.45 or above. In turn, this means that the nacelle wind speed can be in the range 1.3 to 2.5 (or higher) times the 10 metre wind speed. Therefore, in terms of L_{90} and the nacelle wind speed the Ontario noise limit is 38 dBA up to a wind speed of 8 to 15 metres/second rising to 49 dBA at a wind speed of 13 to 25 metres/second.

Consider a conservative value of $\alpha = 0.2$; the Ontario limit translates to L_{90} = 38 dBA up to a nacelle wind speed of 9 metres/second rising to 49 dBA at a nacelle speed of 15 metres/second.

Refer to Figure 3 of HM. This shows their measurements of L_{90} recorded at the residence. Added to the figure is the Ontario limit as the solid black line. Almost all of the L_{90} values are in excess of this limit for a nacelle wind speed of 7.5 metres/second and above.

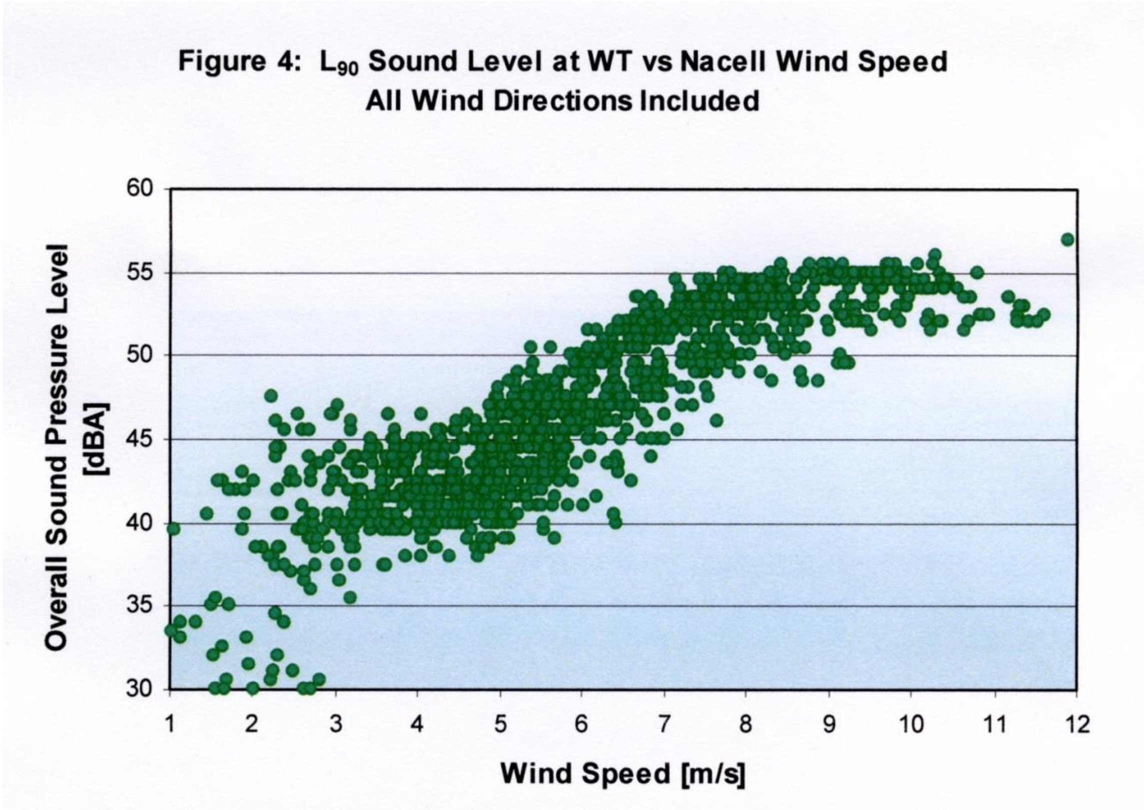
Figure 3: L_{90} Sound Level at Residence vs Nacell Wind Speed
All Wind Directions Included



Converting back to the 10 metre wind speed, the turbine noise was out of compliance for virtually all of the time that the wind speed was above about 5 metres/second.

Had the wind speed gradient been typical of summer night-time (α = 0.45 or higher) the turbine noise was out of compliance for virtually all of the time the 10 metre wind speed was above 3 metres/second. Howe and McCabe have effectively proved non-compliance for this turbine at the residence investigated. If the Ministry of the Environment had understood these measurements the turbine(s) would have been shut down.

Post-script: Figure 4 shows a graph of L_{90} as a function of nacelle wind speed; this time for a site 100 metres from the turbine. Comparing figures 3 and 4 shows that the sound pressure levels are about 10 to 12 dBA lower at the residence. This is what one would expect for an eight-fold increase in distance and a decrease of 2 to 3 dBA due to atmospheric absorption. That is the measurements at the residence were recording the wind turbine noise.



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