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# Closing in on the Wind Turbine "Sasquatch" – Whose Name is "Annoyance"

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## Summary

A research project under way is described, the objective of which is to determine an objective measure to predict annoyance from wind turbines. Some would state categorically that there is nothing specific in the noise profile of wind turbines to cause annoyance. Claims have declared that wind turbine annoyance is the result of stress, and that stress is the result of misinformation about adverse impacts. Annoyance from wind turbines is perceived like the "Sasquatch", a mythical being, for which there is no actual evidence. Yet, a fraction of credible individuals attest that when near operating wind turbines they are irritated, or annoyed, and suffer adverse impacts. When they separate themselves from wind turbines, or when the wind turbines shut down, the individuals find the adverse conditions diminish. However, when they are again exposed, the conditions reoccur. Over time a sensitivity seems to develop, so that the annoyance and adverse conditions occur with reduced exposure. This research project examines the acoustic, environmental, and wind turbine operational conditions existing when impacted individuals report annoyance. Factors such as wind turbine visibility, wind speed and direction, as well as the noise resulting from ambient winds are also considered. The project seeks to determine if the annoyance could be arising independent of the wind turbine noise profile, or from misinformation. Insights arising from the research are discussed, as the project circles closer, and closer, to substantiate a verifiable measure of the character of the wind turbine "Sasquatch."

## 1. Introduction

The proceedings of the Wind Turbine Noise Conferences indicate that the subject of annoyance from wind turbine noise has not gone away. While the number of papers has gone up and then down, the number of mentions of the word "annoyance" continued to rise.

| Conference | # of Papers | # of Mentions "annoyance" |
|---|---|---|
| WTN 2005 | 29 | 78 |
| WTN 2013 | 72 | 406 |
| WTN 2021 | 40 | 438 |

Table 1 – Mentions of "Annoyance" at International Wind Turbine Noise Conferences

The word commonly found used with “annoyance” is “subjective.” The challenge this presents is that “subjectivity” is in the mind of the beholder. We are told, the only way to make a fair “subjective” assessment is to assemble an impartial panel of observers, commonly called a “jury.” Yet, even in a court of law, this presents challenges. Lawyers make their arguments as to whether potential jurors are representative “peers” for their client or the community, or if they should be rejected as having an ingrained bias. Anyone who has been called as part of the pool of potential jurors for a court case can speak to the mystery of determining “a panel of your peers.” There are many tests reported in the wind turbine noise literature, where panels of observers are assembled, to listen to recordings of wind turbine noise and make an assessment of “annoyance.” However, any subjective test is open to challenge. Were the test subjects really peers? Were the conditions or setting the same as experienced by residents reporting impact? Were the tests sustained for days on end? In reports of community observations, questions might be asked such as were the turbine parameters (output, size, height, number, and separation distance) representative? Subjective assessments such as, “I am annoyed by the noise from wind turbines,” are often countered by, “You do not like wind turbines because you are jealous that your neighbours profit, while you don’t.” There must be a better way to demonstrate respect for each other. Sitting down with, and really listening to those reporting concerns is a beginning place.

Clearly, an “objective” measure of annoyance, that is not dependent on a representative jury exposed in a similar setting, sustained for a similar duration would be preferred. There are objective measures for measuring noise, most commonly perhaps by A-weighted sound level. However, even when these measures are modified in various ways such as Leq, or Lden, they are still challenged by other sound in the environment from wind, human activity, wildlife, or the special qualities of sound to be able to measure annoyance. This paper gives an overview of am approach to find an objective measure for the annoyance from wind turbine sound.

## 2. Listening to those Impacted

Listening to real people pour out their heart raises concerns about the ethical principles of doing so. Will their confidentiality be assured? Will they remain anonymous? (Unless they specifically gave permission to share their specific details, as some did.) Can they be assured that the listener will not substitute the interviewer’s opinions or biases, in place of those of the one being listened to? University studies, the Code of Ethics of Professional Engineers Ontario, the Institute of Noise Control Engineers, and the Acoustical Society of America, have specific requirements regarding ethical practices, with regard to conducting surveys of the public. For clarity, the information reported in this paper are not the result of a formal survey, in which informants are asked to give formal informed consent, to whom specific questions were asked. Instead, they were the result of informal conversations, in which the participants volunteered information casually, or of their presentations before public forums. Often, this information was predicated by a statement such as, “you are involved in wind turbine noise, isn’t there something you can do?” At no point were the participants offered benefit, or harm from providing or withholding information, and ethical principles of regarding the duty to public welfare were held paramount in including comments in this paper.

Those who volunteered information were not considered to be expressing an attitude of disdain for care of the environment. A tutorial presented by George A. Luz, PhD titled, “Some People are More Noise Sensitive than Others” presented at the 161th Meeting of the Acoustical Society of America in Seattle, WA, in May 2011 comes to mind. Luz noted that, “The most outstanding impression of those people who were noise sensitive was that they were typically friendly, generous and sociable and very much aware of their environment.” If a common perception might be summarized, it was that the informants expressed hurt. They had honestly reported their concerns and impacts to those considered to be responsible to act, but their reports had been dismissed or not acted on.

Many of that volunteered information did so publicly in deputations before the members of the Multi Municipal Wind Turbine Working Group. (MMWTWG). This working group is formally constituted

under the regulations of the Ontario Municipal Act, with public meetings, and public record of meeting minutes. The Working Group is composed of elected representatives from Municipal Councils and a citizen appointee from member councils, from a number of Municipalities in the Province of Ontario concerned about the impact of wind turbines on citizens.

### 2.1 Summarizing Issues Raised (not necessarily attributed to wind turbines, but by those living in the environment of multiple wind turbines within less than 1 km)

- Some reported change in behaviour of domesticated animals (such as horses, goats, dogs or cattle) after the commencement of operation of wind turbines in their environment. Presumably these animals had no attitude of jealousy, or miss-information.
    - One man reported on a specific change in behaviour of ponies, trained to draw a cart. The man showed me the stable previously housing his cart ponies. After the wind turbines had started up, the ponies which had been stabled fine before, had kicked holes in the walls in the stable. He noted that after the wind turbine start-up he would sometimes visit the stable to find the ponies "all lathered up" as if they had been out for a run, even though they were only standing in the stable. On another occasion, the ponies, while harnessed to their cart had suddenly bolted, and run through a wire fence, cutting themselves up. He noted that after this event, he had given the ponies away to relocate them away from the wind turbines, and they had reverted to their previously docile behaviour.
    - The same man reported on changes in behaviour of the family dog, to not want out, as it had previously. Others reported in change in behaviour of their family pet dogs as well.
    - Another family reported changes in behaviour of goats, and another in changes in behaviour of a dairy herd, requiring the family to relocate.
- The same man who had reported the change in behaviour of his ponies reported changes in his personal health, including a bleed (a stroke was how he described it) in an eye. He reported that his wife, who was away from the house most of the day, at work, experienced no adverse effects. Anecdotally he reported adverse impacts occurring in several neighbours, which were not followed up on. They left the home.
- Another gentleman reported difficulty in sleeping after the wind turbine started up. His family physician had prescribed sleeping tablets. He noted that when away from home on vacation, the "slept like a baby" but on return home, again his sleep deprivation recurred. He also reported balance instability. His wife was not impacted. They moved from the environment, and the condition disappeared, although the gentleman passed away shortly after. Sleep deprivation was reported by a number of others, again, a condition which disappeared when away from home, but returning when back at home. As before, not all family members appeared to be impacted.
- Digestive issues, or nausea, were reported by some.
- Headaches were a common report, for the one reporting, or for other family members.
- Some reported changes in control of diabetes, or changes in control of blood pressure, or other cardio-vascular issues, with some requiring relocation to address the issue.
- Tinnitus or sensations of vibration transmitted into homes were reported by some.
- Some addressed the necessity to change work schedules, to relocate residence, or to retire prematurely from work due to difficulty in sleeping, due to concerns of work errors, or due to health deterioration.
- Some identified specific issue with tonality of the sound, reporting a rising and falling "wooing".
- Specific changes in sound during conditions of freezing rain or hot, still summer nights were reported by a number of people, using terms such as, "pounding" intensity.

- Some reported being able to perceive if nearby wind turbines were operating or not on awakening, even without viewing the turbines, or hearing specific sounds.

### 2.2 Investigation of Issues Raised

- While it was not possible by the author to do a detailed investigation of each issue raised, for a period of over 15 years, the author has conducted investigations and collected acoustic data at over 20 sites in over 8 different wind power developments, with at least 4 different wind turbine types (Vestas V80, Vestas V82, Enercon E82, and Siemens SWT 2.3 – 101) and at a number of sites at least 5 km distant from wind turbines. The level of detail collected in each investigation has increased over the 15-year period.
    - Initially the information collected was a simple record of 1 minute duration readings at the sites using calibrated A-weighted and C-weighted sound level meter readings and wind speed monitoring at 1.5 metres above ground level, along with the associated wind power development output level and the nearest Environment Canada weather station information.
    - By 2010, the data collected progressed to 1 to 2 minute recordings of the sound pressure level from a calibrated Knowles BL-21994 microphone with a 60-mm primary and 300 mm secondary wind screen. All those recordings are on file.
    - By 2013, data collection progressed to making recordings of the sound pressure level using a calibrated Earthworks M30-BX microphone with a flat frequency response from 9 Hz to 30 kHz (although measured to be flat lower then 9 Hz) using a 90-mm primary and 450 mm secondary wind screen.
    - From 2017, data collection progressed from intermittent records to a continuous record collected at first one, and then several sites using a “2 channel SAM Scribe” monitoring system that collects and records a continuous string of 10-minute sound samples. The SAM-Scribe was purchased by an Ontario resident to collect data at their home, with assistance in setup and monitoring by the author. Since 2020, the resident has loaned the SAM Scribe system to the author for monitoring at the homes of other impacted residents. Roughly a 5-year continuous record of data is now available from the SAM Scribe system, principally at two different wind power developments, with Siemens SWT-101 and Vestas V82 wind turbines, as well as some recordings distant from the wind turbines.
    - Additional data has been collected from time to time to verify the data collected by the SAM Scribe using an ACO Pacific system. This system uses an IEC 61094-4 (Measurement Microphone) compliant 7046 free-field microphone and a 4012 pre-amplifier. The pair have a rated frequency response ±2 dB from 2 Hz to 20 kHz. Additionally, data has been collected using the Earthworks M30BX microphone, and using a pair of Superlux ECM-999 measurement microphones.
    - A further source of data has been recordings performed at sites using an external MOVO omnidirectional Measurement Microphone (rated as flat from 35 Hz to 18 kHz) protected with a primary “muff” type windscreen, used in a protected location away from direct wind exposure, as an external microphone on an iPhone. While not initially thought of as an acoustical monitoring device, performance of the pair give remarkable results. They permit recording a calibration signal from a 94-dB calibrator, and provide a simple method for recording a simultaneous video and calibrated audio file that can be easily transmitted for later analysis.
- Analysis of the collected acoustical data from the various methods has been conducted using the Faber Acoustics application Electroacoustics Toolbox version 3.9.10 on a 3.6 GHz intel Core i5 iMac computer system running macOS 10.13.6.

## 3. Progression to determine an objective measure for annoyance

Listening to those impacted suggested that annoyance might arise from a number of different pathways. Initially, to determine if a common parameter might be identified, analysis focused on the times identified by the residents at the monitoring sites as annoying, or irritating, to the regulator, the Ontario Ministry of the Environment. While residents do not identify every situation considered as annoying, they do log sample times they consider as typical examples. Recording is by phone to a Ministry "Spills Line" and generally includes a brief description of the condition, the local environmental conditions, and a "rating" of annoyance from 1-10 as requested by the Ministry contact person, although there are no specific criteria for this rating. Progression from analysis of these "annoyance" conditions to a full analysis near and far from wind turbines is described in this section.

### 3.1 Results of the initial analysis

The key to the analysis technique used on this paper arose from a comment made in discussion at the Wind Turbine Noise Conference in 2021 by Andy McKenzie PhD BSc FIOA, of Hayes McKenzie in the UK. Andy noted that in the UK it was common to use LA90, the A-Weighted sound pressure level exceeded 90% of the time, effectively as the background sound pressure level. This suggested a clue to determine an annoyance measure of the classical signature "swish / or / swoosh" sound variation of a wind turbine.

A simplified display of the cyclical nature of the wind turbine sound might be considered as a sine wave. In reality the situation is considerably more complex. Impacted residents are often impacted by more than one wind turbine. Thus, the composite sound level, while varying cyclically, will be more complex than a simple sine wave.

The difference between the L90 value (the quiet times) and the L10 value (the loud times) gives an assessment of the change in sound level from quiet to loud. While not an exact measure of the value of the "swoosh" it is a simply determined parameter. The parameter gives a readily available measure of cyclical change in sound pressure level near wind turbines. The difference was calculated for both LZ10-LZ90, and for LA10-LA90. These values can be found from modern sound level meters or assessment applications such as the electroacoustics toolbox. The analysis results consistently showed that in the situations identified by the residents as annoying, LZ10 exceeded LZ90 by a value in the order of 6 dB or more, while LA10 was not more than 3 dB higher than LA90. Hence, an initial assessment of an objective measure to signify annoyance was LZ10-LZ90 > 6 dB, while LZ10-LA90 was less than 3 dB.

Figure 1 shows a display of the electroacoustic toolbox sound level meters for LZ10, LZ90, LA10 and LA90. These are for a 2-minute recording sample at a site with 4-Vestas V82 wind turbines within 1000 metres. The 181.5 MW array of 110 wind turbines generated 129 MWh for the hour of the sound sample, The Environment Canada average wind speed for the same hour at the nearest monitoring site was 6.9 metres per second. The display shows the difference between LZ10 and LZ90 to be greater than 10 dB, while the difference between LA10 and LA90 was less than 3 dB. A factor not seen in the static figures, but will be shown in the conference presentation, is how the lower frequency 1/3 octaves "dance" up and down, while the higher frequency 1/3 octaves change little.

Listening to such examples, as will be demonstrated in the conference presentation, shows that such a case clearly portrays the "swoosh." However, in cases where the LA10 exceeds LA90 significantly, (as for example if there is a lot of traffic noise, or bird cries) then the wind turbine "swoosh" is less apparent, and is less likely to be identified as annoying. Similarly, it was found that if the turbines were shutdown then the LZ10-LZ90 was reduced, and again the situation was perceived as less annoying. Thus, the 6dB minimum for LZ10-LZ90, and a 3dB maximum for LA10-LA90 seemed to be reasonable criteria for further analysis.

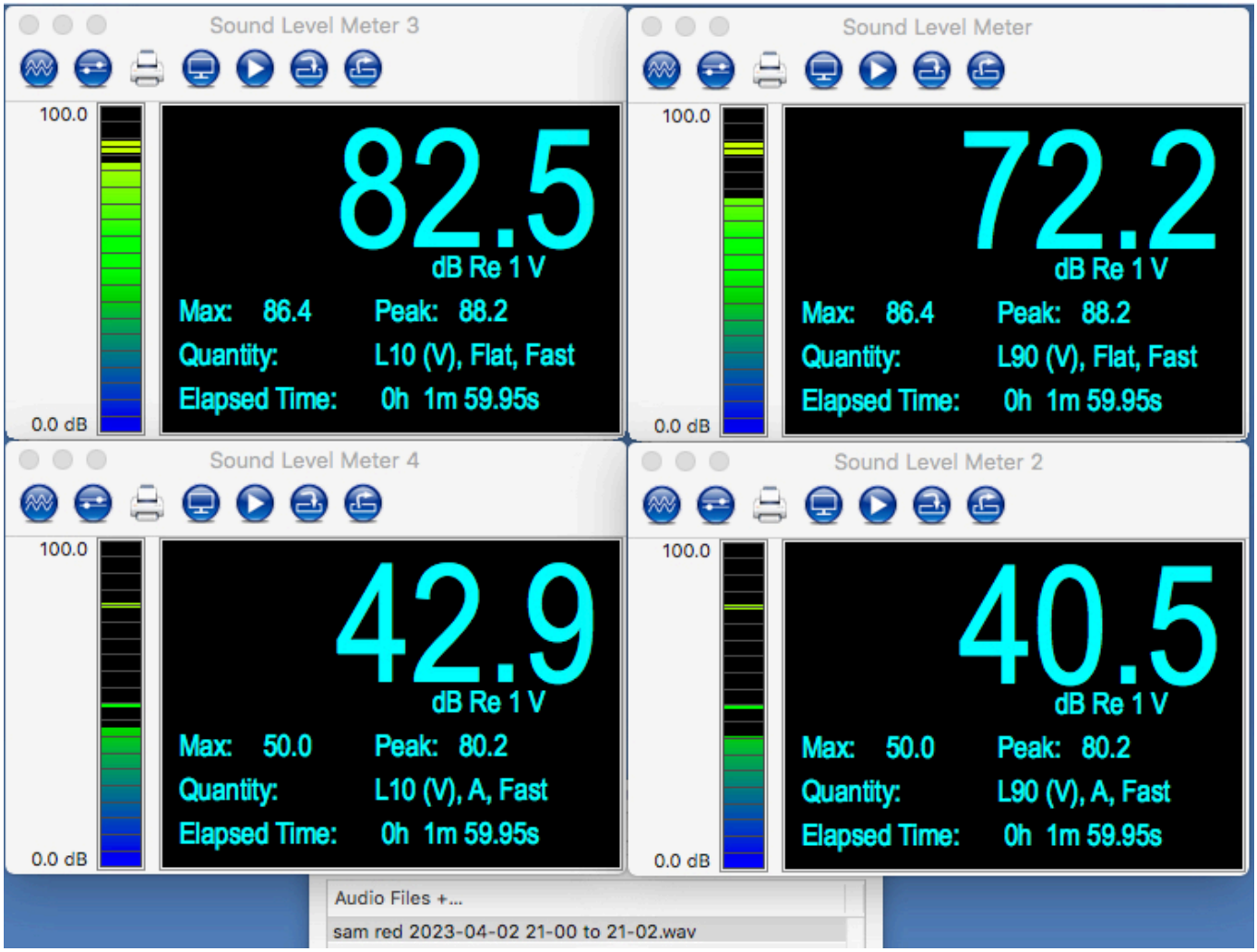


Figure 1 – A typical case perceived as annoying (electroacoustic toolbox LZx and LAx results)

### 3.2 Verification of the initial analysis as a measure of a wind turbine parameter

To verify that the measurement was not simply a measurement of wind noise, a simultaneous set of recordings were taken at a site > 6 km distant from the nearest wind turbine. This is considered as the "remote site" if further discussion. Turbines at the monitoring site are within view from remote site. The remote site also has on site wind speed and direction monitoring which show close correlation to the nearest Environment Canada monitoring location. The results at the remote site are shown in Figure 2. At this remote site, LZ10 was the same as LZ90 close to the wind turbines, and LA10 was within 1 dB of LZ90 at the site close to the turbines. LZ10-LZ90 was somewhat higher at 14.8 dB, and LA10-LA90 was also higher at 7.3 dB. Five 2-minute data samples in the 10 minutes prior to and after the presented data for both the wind turbine site and the remote site were calculated. The five samples were similar, although particularly intense gusts in the last sample near the wind turbines would have placed it outside the criteria for being considered as annoying.

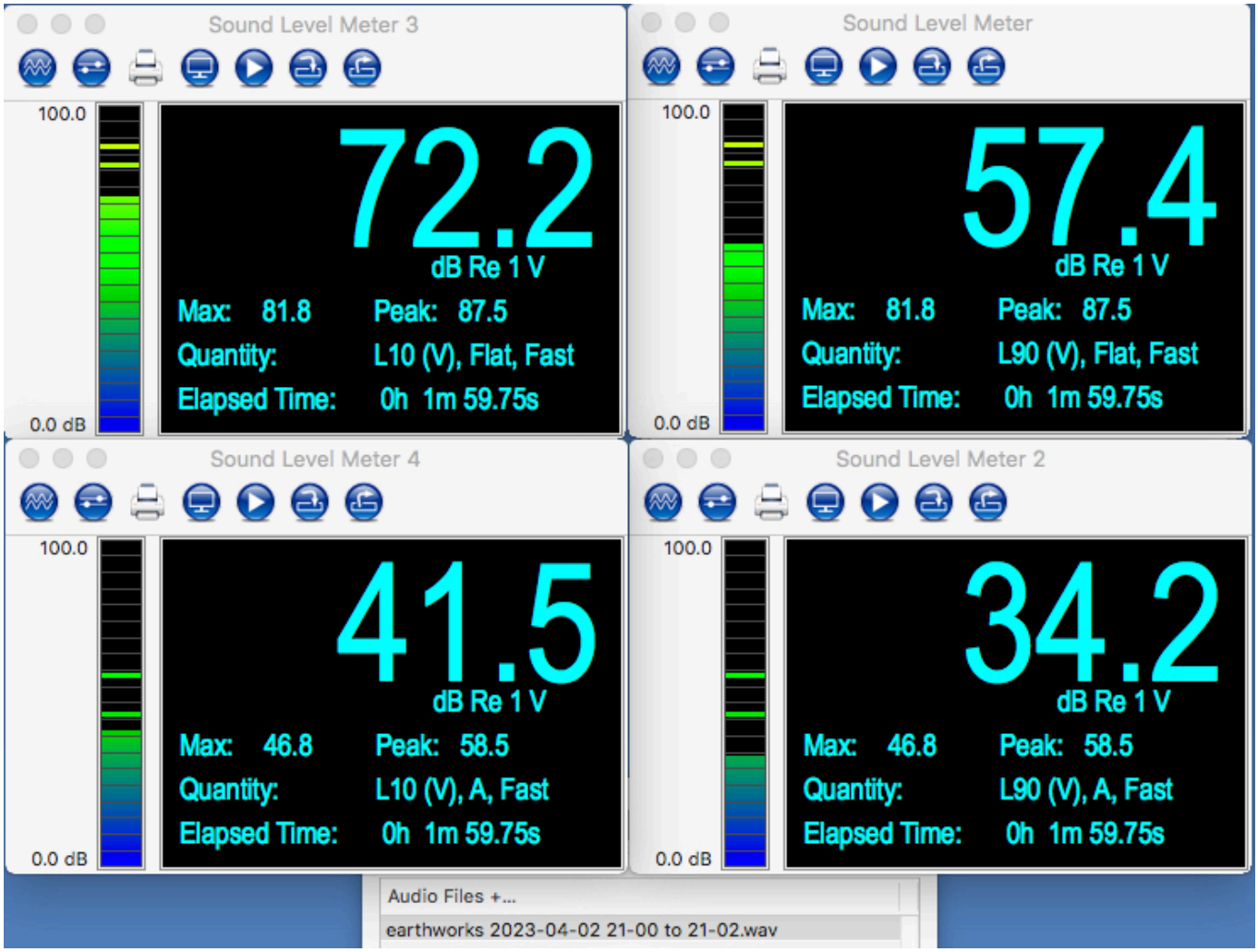


Figure 2 – Analysis of data recorded at same time as in Figure 1, remote from wind turbines

| Date 2023-04-02 Time as Shown | Near Wind Turbines | | Remote from Wind Turbines | |
|---|---|---|---|---|
| | LZ10-LZ90 (dB) | LA10-LA90 (dB) | LZ10-LZ90 (dB) | LA10-LA90 (dB) |
| 20-50 to 20-52 | 7.6 | 2.1 | 13.1 | 6.4 |
| 20-55 to 20-57 | 8.5 | 2.1 | 9.4 | 3.2 |
| 21-00 to 21-02 | 10.3 | 2.4 | 14.8 | 7.3 |
| 21-05 to 21-07 | 9.7 | 2.9 | 14.0 | 4.3 |
| 21-10 to 21-12 | 14.7 | 5.4 | 10.5 | 4.5 |

Table 2 – Five samples near and remote from wind turbines in period of Figures 1 and 2

### 3.3 Further analysis underway to verify annoyance criteria

Ongoing analysis continues to verify the criteria indicating conditions consistent with a judgement by residents of annoying conditions. Simultaneous data collection at a site near wind turbines and remote from wind turbines continues. Analysis of over 100 hours of data continues to confirm that the criteria of LZ10-LZ90 > 6 dB and LA10-LA90 < 3 dB only present themselves remote from wind turbines rarely (at a frequency of about 7 times per 100 cases), This has been detected only during conditions of heavy rain, particularly when water droplets are falling from the secondary windscreen to hit the protection at the top of the primary windscreen. The microphone records this similar to a “drum thump”, and are not representative of actual conditions. Ontario regulations as an example do not permit collection of wind turbine noise samples during precipitation, and these are only a subset of those conditions.

Near the wind turbines, conditions meeting the criteria of LZ10-LZ90 > 6 dB and LA10-LA90 < 3 dB occur quite frequently. The frequency of this condition being met had been approximately 20 times per 100 cases. This criteria has been tested against previous cases identified to the Ministry of the Environment by residents as annoying with high correlation.

Data collected in the past at various wind turbine locations is being tested against the criteria. The criteria are showing that it has good potential for use as a screening technique. The technique provides a measurable assessment criteria, independent of subjective assessment.

## 4. Conclusions

Work underway is getting closer to presenting a formal paper demonstrating a measurable criteria to match subjective assessments of annoyance. The criteria shown to be effective is:

**LZ10-LZ90 > 6 dB and LA10-LA90 < 3 dB**

This is important as it reduces the need to assemble, and expose, a representative panel of "peers" of noise sensitive persons to assess annoyance. It also demonstrates respect for complaints filed by individuals of adverse impacts when exposed to wind turbines for sustained periods. A criteria to assess, and thus enable prevention of adverse impacts is particularly important due to planned expansion of wind turbine to meet rising electricity needs. Work has shown that the criteria responds well to the conditions near wind turbines, while being largely independent of wind noise. Work to date has shown that the criteria can provide a useful screening tool. Further development is ongoing to help remove the necessity for a listening test to address outside influences. To date a listening test is needed to differentiate influences such as road traffic, aircraft, and spurious noise arising from rain droplets penetrating the microphone windscreen, or windscreen "bumping" during gusts.

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