BEFORE THE OHIO POWER SITING BOARD

In the Matter of the Application of Black Fork Wind Energy, LLC for a Certificate to Install Numerous Electricity Generating Wind Turbines in Crawford and Richland Counties, Ohio	)))))	**Case No. 10-2865-EL-BGN**

DIRECT TESTIMONY OF KENNETH KALISKI

Q.1 Please state your name and business address?

A.1 My name is Kenneth Kaliski and I am employed at Resource Systems Group, Inc. (RSG), located at 55 Railroad Row, White River Junction, VT 05001.

Q.2 What is your educational background?

A.2 I have a BA in Biology and Environmental Studies from Dartmouth College and a BE in Engineering from the Thayer School of Engineering at Dartmouth College. My educational experience includes coursework in sound level monitoring, noise control engineering, active noise control, indoor and outdoor acoustical modeling, vibration control, sound level meter design, and the physics and mathematics involving sound and its propagation. I am the co-holder of a patent for an environmental noise monitoring system.

Q.3 What is your professional background?

A.3 I have worked with RSG since its founding in 1986, and served on its Board of Directors for fifteen years. At RSG, I am a Managing Director, responsible for the division of the company that works on projects in noise, acoustics, air pollution, and energy.

I am a professional engineer, with licenses in Vermont, New Hampshire, Massachusetts, and Michigan. I am Board Certified through Institute of Noise Control Engineering (INCE), and within INCE, serve as its Vice President for Board Certification. I am a member of the Acoustical Society of America and RSG is a member of the National Council of Acoustical Consultants. I am a Qualified Environmental Professional as certified through the Institute of Professional Environmental Practice.

I have been involved with wind projects since 1993, when RSG was asked by the Maine Land Use Regulatory Commission to review a large wind farm in the western part of that state. Subsequently, we have done analyses and reviews of many projects throughout the U.S., including Kansas, Michigan, Arizona, Massachusetts, Pennsylvania, Illinois, and Vermont. I am the author or co-author of a dozen publications and presentations on wind turbine noise, with invitations to speak on wind turbine noise issues to the American Wind Energy Association, National Wind Coordinating Collaborative, and New England Wind Energy Education Project. I have chaired or co-chaired conference sessions on wind turbine noise, including those at Internoise 2009 in Ottawa, the Acoustical Society of America (ASA)/NoiseCon 2010 conference in Baltimore, the ASA 2011 conference in Seattle, and the INCE 2011 Portland conference.

A copy of my resume is attached as Exhibit A.

Q.4 On whose behalf are you offering testimony?

A.4 I am testifying on behalf of the Applicant, Black Fork Wind Energy, LLC.

Q.5 What is the purpose of your testimony?

A.5 The purpose of my testimony is to describe the studies my firm undertook on behalf of the Applicant, to briefly summarize the results of those studies, and to *discuss operational noise and Staff's recommended conditions regarding operational sound.*

Q.6 Please describe the history of your involvement with the project and the studies that you and your firm undertook on behalf of the Applicant.

A.6 RSG has been involved in the noise analysis of the project since 2009. In June of 2009, we set up sound level meters at eight sites within the project area to record background sound levels over an eight-day period. Subsequently, we modeled sound levels from construction and operation of the project wind turbines and prepared a noise impact study, attached as Appendix H to the Application.

Q.7 Please explain your studies and findings regarding sound pressure levels resulting from turbine operation?

A.7 Our first step was to establish the design standard for the project. Previous projects that have gone before the OPSB,Timber Road II, Horizon, and Blue Creek, established a precedent standard of 5 dB over the background equivalent continuous sound level (Leq). To determine this background level for Black Fork, sound monitoring was conducted at eight locations within the project area. Daytime and nighttime sound levels were calculated. While there was variation hour to hour and between the monitoring locations, the overall average nighttime Leq was 43 dBA. This average excludes Location D which had high nighttime noise primarily due to early-morning bird calls. The average daytime sound level was 53 dBA. Using the nighttime Leq as the basis for the standard, "Leq plus five" for the Black Fork project would make the design standard a maximum of 48 dBA.

We then modeled the project using a computer implementation of the ISO 9613-2 standard, with additional factors added to make the model more conservative. We modeled three scenarios of wind turbine models: the Vestas V100, GE 1.6 XLE, and Siemens SWT 2.3-101 for a configuration of 91 wind turbines, along with one step-up transformer. The turbine model with the highest modeled sound levels is the GE 1.6 XLE where 52 non-participating residences exceeded 48 dBA. The turbine with the lowest impact is the V100 where no non-participating home exceeded 48 dBA.

Q.8 Did your study address low frequency noise and tonal noise, as well?

A.8 Yes. We calculated sound levels at the 31.5 and 63 Hz octave bands where sound power data were available from the turbine manufacturer. We then compared those levels to Table 6 of the ANSI S12.2-2008 standard, which is for moderately perceptible noise-induced building vibration. We found that the Vestas V100 turbine was 2 dB lower than the standard at 31.5 Hz and 11 dB lower than the standard at 63 Hz for the worst-case home. The Siemens and GE turbines had lower impacts at 63 Hz than the Vestas, but no data was available for these turbines at 31.5 Hz.

The Siemens and GE manufacturers provided tonality data, which both showed levels of tonal audibility, a measure of tonal prominence, to be less than or equal to 4 dB. While Vestas has not yet provided this data, we expect it to be similar.

Q.9 In your opinion, will the project meet a standard of background Leq plus 5 dB?

A.9 Assuming we establish the background sound level at 43 dBA, as noted in the Staff Report of Investigation, then the nighttime Leq plus 5 dB would be 48 dBA. A project designed with the Vestas V100 turbine, or a turbine with similar sound power, should meet this standard at all participating residences. If the project is designed with other turbines, such as the Siemens SWT 2.3 101 or GE 1.6 XLE, then additional mitigation may need to be provided for some of the turbines.

Q.10 What mitigation do you recommend?

A.10 The following mitigation is proposed:

a. Neighbors will be provided with a telephone number to report any excessive or undesirable construction or operational noise.

b. Neighbors will be notified prior to any major nighttime construction.

c. Mufflers will be installed and well-maintained on construction vehicles.

d. Contractors will abide by all local speed limits, as well as federal limits on truck noise.

e. Other than extended concrete pours and similar events, major construction will take place during normal business hours. Aside from road construction, these activities will take place at over 1,000 feet from the nearest residences.

f. *Mitigation of wind turbine noise will be made on a case-by-case basis as* needed to meet applicable standards.

Q.11 If there are excessive levels of wind turbine noise after the project is in operation, what steps can be made to reduce the impact?

A.11 The most common method of noise mitigation is putting select turbines into a noise-reduced operating mode (NRO). In NRO, the turbine tips speed is reduced by controlling the turbine torque and/or changing blade pitch. The side effect of NRO is that it reduces the electric output from the turbine, which reduces the amount of renewable energy generated by the project. Automatic curtailment during specific wind or meteorological conditions can also be implemented.

Q.12. Can these methods be applied to this project?

A.12 Yes. NRO and curtailment controllers are offered by Vestas, GE, and Siemens. They can be applied to individual turbines, as needed, before or after construction of the project. If the Vestas V100 is used on the project, then NRO will not be immediately implemented, but can be if needed to address a complaint. If the GE or Siemens turbines are used throughout the project, then certain turbines will need NRO mitigation on a regular basis to meet the 48 dBA standard. It is expected that once turbines are selected and a final layout is prepared, noise modeling will be redone, if the layout and turbine type are materially different than provided in the application. At that time, if necessary to meet standards, a final mitigation plan will be prepared.

Q.13 Have you reviewed the Staff Report issued in this proceeding?

A.13 Yes.

Q.14 The Staff Report refers to the New York State Department of Environmental Conservation document to refer to a 6 dB increase in background sound level in creating complaints? Are you familiar with this document?

A.14 Yes.

Q.15. Do you agree with that noise levels in non-industrial settings exceeding ambient levels by more than 6 dBA can cause complaints?

A.15 I do not agree that a change in 6 dB can be said to cause complaints under all situations. The 6 dB Leq in the NYS guidance document does not account for the actual ambient noise levels and the degree of annoyance of different levels of intruding noise. For example, going from 20 dBA to 26 dBA does not change what would be a very quiet environment in both cases (see Figure 2 of Appendix H of the Application). But going from 84 to 90 dBA, has a much lower level of tolerance, as we start to get into significant impacts with the higher level. That is, according to OSHA (29 CFR 1910, for example), employees exposed to 84 dBA do not require hearing protection, but unprotected exposure to 90 dBA over eight hours can cause hearing loss.

The biggest problems occur when a moveable standard is applied based on the relative difference in project and background sound levels determined after the project is constructed. If the standard is not fixed at the time the permit is issued, then permit compliance is virtually impossible to guarantee, because several problems are created:

1) The background sound level is constantly changing over time and can never be determined as an absolute level or even a minimum guarantee. As an example, in our sound monitoring for Black Fork Wind, one-hour background Leqs varied by 60 dB between locations and over time. The sound levels from a wind turbine also vary over time, due to different wind and other meteorological conditions. Therefore, a standard that depends on an unknowable background level at every time and location in the project area does not provide the applicant or community with any finality as to what the standard is and whether the project can meet the standard.
2) While facilities can control the noise that they generate, they cannot control the background sound level at adjoining properties, thus making it impossible for a source to guarantee compliance. For example, a homeowner may make changes to their property that lowers or raises the sound level, changing the allowable levels on their property.

I have attached two papers I have co-authored as Exhibits B and C, which further discuss problems associated with this relative standards when the compliance level is not fixed in the facility's permit.

Q.16 In Condition 50 of the Staff Report, Staff recommends a condition that it be provided for review and acceptance sound levels from the turbine models to be used, including A- and C-

weighted levels, low frequency 1/3 octave bands, tonal audibility, and low frequency and impulsivity levels in accordance IEC 61400-11, Annex A.3 (low frequency noise) and Annex A.4 (impulsivity). Do you believe that the Applicant can comply with this condition?

A.16. Yes, provided that this condition be clarified to take into account the fact that this data may not exist. For example, Annex A.3 and A.4 of the IEC 61400-11 standard are optional tests, and many manufacturers do not choose to conduct them. With these specified changes, the applicant can comply:

> That at least thirty (30) days prior to the pre-construction conference and upon selection of the turbine model to be developed, the Applicant shall provide the following to OPSB Staff to the extent such information exists and is released to the Applicant by the turbine manufacturer ~~for review and acceptance~~:
>
> (a) The low frequency sound values (SPL, dB, Hz) expected to be produced.
>
> (b) The A-weighted and C-weighted sound ~~pressure~~ power levels, as well as one-third octave band measurements for the 20 and 25 Hz bands, and a separate evaluation of the data for low frequency and impulsivity in accordance with the methodologies set forth within IEC 61400-11, Annex A, A.3, *Low Frequency Noise,* and A.4, *Impulsivity.*
>
> (c) The tonal audibility.

Q.17 In Condition 51 of the Staff Report, Staff recommends a condition that preconstruction modeling show that ambient Leq is not exceeded by more than 5 dB? Do you believe that the Applicant can comply with this condition?

A.17 Yes, provided the condition is clarified to specify the standard the project will be based upon, as is done in the body of the Staff Report. That is, it should be clear that the standard is the average nighttime Leq for the Project of 43 dBA plus 5 dBA (48 dBA). I recommend that the standard be clarified to read:

> That if pre-construction acoustic modeling indicates a facility contribution that exceeds the project ambient nighttime Leq (43 dBA) plus 5 dBA~~ambient LEQ by greater than five~~ at the exterior of any non-participating residences within one mile of the facility boundary, the facility shall be subject to further

> study of the potential impact and possible mitigation prior to construction. Mitigation, if required, shall consist of either reducing the impact so that the facility contribution ~~does not exceed the ambient LEQ by greater than five dBA,~~ at the exterior of the non-participating residence does not exceed the project ambient nighttime Leq (43 dBA) plus 5 dBA, or other means of mitigation approved by OPSB Staff in conjunction with the affected receptor(s).

Q.18 In Condition 52 of the Staff Report, Staff recommends a condition that during the post-construction phase of the project, and in response to noise complaints, mitigation is required if the ambient Leq is exceeded by more than 5 dBA. Do you have any concerns with this condition?

A.18 Yes. The condition as written does not provide a clear standard for the facility. Instead the condition is written to use a standard of 5 dBA above the ambient Leq at the location of the complaint. As I stated above, the biggest problems occur when a moveable standard is applied based on the relative difference in project and background sound levels determined after the project is constructed. If the standard is not fixed at the time the permit is issued, then the background sound level is constantly changing over time and can never be determined as an absolute level or even a minimum guarantee. Also while facilities can control the noise they generate, they cannot control the background sound level at adjoining properties, thus making it impossible for the source to guarantee compliance. For these reasons, most noise ordinances fix the levels for compliance. Exhibits B and C to my testimony further discuss problems associated with this relative standards when the compliance level is not fixed in the facility's permit.

Considering the problems with a relative standard, I recommend changing Condition 52 to follow a form approved by the OPSB in prior proceedings:

> That after commencement of commercial operation, the Applicant shall conduct further review of the impact and possible mitigation of all project noise complaints. Mitigation shall be required if the project contribution at the exterior of any non-participating residence within one mile of the project

boundary exceeds the greater of (a) the project ambient nighttime Leq (43 dBA) plus 5 dBA, or (b) the validly measured ambient Leq plus five dBA at the location of the complaint and during the same time of day or night as that identified in the complaint. Mitigation, if required, shall consist of either reducing the impact so that the project contribution does not exceed the greater of (a) the project ambient nighttime Leq (43 dBA) plus 5 dBA, or (b) the validly measured ambient Leq plus 5 dBA at the location of the complaint and at the same time of day or night as identified in the complaint, ~~validly measured ambient LEQ plus five dBA,~~ or other means of mitigation approved by OPSB Staff in coordination with the affected receptor(s).

Q.19 Does this conclude your direct testimony?

A.19 Yes, it does.

CERTIFICATE OF SERVICE

I certify that a copy of the foregoing document was served by hand delivery upon John Jones and Stephen Reilly, Assistant Attorneys General, Public Utilities Section, 180 E. Broad Street, 6th Floor, Columbus, OH 43215 and via U.S. Mail upon the following persons listed below this 8th day of September 2011:

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EXHIBIT A

RSG INC.

Kenneth H. Kaliski, P.E., Managing Director
Environment, Energy and Acoustics

Biographical Summary

Mr. Kaliski is the Director of Resource Systems Group's Environmental Division. Mr. Kaliski has been with the firm since its founding in 1987. He manages projects and has served as an expert witness in the areas of noise, air pollution, and transportation. His Environmental Services Division takes on projects in community noise, architectural acoustics, greenhouse gas measurement and verification, mobile and point source air emissions modeling, and quantification of emissions offsets from renewable fuels. His projects include work throughout the U.S. Mr. Kaliski is the co-holder of Patent 7,092,853 for an Environmental Noise Monitoring System.

Education

- B. E. Engineering, Dartmouth College, NH (2002)
- A.B. Biological Sciences and Environmental Studies, Dartmouth College, NH (1985)

Selected Responsibilities and Relevant Engagements

- *Noise Forecasting for a Wind Turbine Demonstration Project, VT* – conducted noise measurements and modeling for a proposed 12-tower wind turbine project by the Green Mountain Power Company in Searsburg, Vermont. Used the NTerrain model to quantify the effects of atmospheric loss, vegetation, wind, and terrain features on octave-band noise levels in the area.
- *Deerfield Wind Farm, VT* – Prepared a noise study for Vermont's Section 248 filing on a 34 MW wind power project proposed for southern Vermont. The project included background sound monitoring, sound propagation modeling of the wind turbines and substation, and preparation of reports and exhibits. Sound modeling included analyses of 8760 hours of meteorology. A report was prepared and testimony was presented to the Section 248 Board
- *Noise Forecasting for a Wind Turbine Demonstration Project, VT* – conducted noise measurements and modeling for a proposed 12-tower wind turbine project by the Green Mountain Power Company in Searsburg, Vermont. Used the NTerrain model to quantify the effects of atmospheric loss, vegetation, wind, and terrain features on octave-band noise levels in the area.
- *Wind Turbine Noise Impact Study, MA* – Conducted a noise analyses and feasibility study a 20-turbine wind farm in Western Massachusetts.
- *Wind Farm Noise Analysis, MA* – Conducted a study of the noise impacts of the Brodie Mountain Wind Project specifically with respect to a nearby condominium development. Sound levels were monitored continuously over several days and these monitored levels were then correlated against ridgeline wind speed. A report was issued. The project is ongoing.
- *Review of Wind Turbine Impact Study, ME* – For the Maine Land Use Regulatory Council, reviewed the noise impacts for a proposed 580 turbine, 210 MW wind farm in the Boundary Region in western Maine.
- *Wind Farm Noise Impact Analysis, VT* – Conducted a study of the noise impacts from a proposed 30 to 45 MW wind farm in southern Vermont. The analysis included correlation of hub height wind speed with background sound levels measured at seven locations around the proposed facility, modeling of 8,760 days of meteorology, preparation of a report, and testimony to the Public Service Board.
- *Northern Vermont Wind Turbine Noise Review, VT* – Reviewed the noise impacts of a 52 MW wind turbine in Northern Vermont. Analyzed both monitoring and modeling data to determine whether the project conformed with the Public Service Board's Section 248 criteria.

- *Plains Wind Farm Noise Analysis* – Conducted an analysis of the noise impacts of a proposed wind farm in the Midwestern U.S. The project includes community sound monitoring over a 14-day period in the winter and summer, and modeling sound levels against a "relative" standard. This wind farm is expected to generate approximately 150 MW of power. The project is ongoing.
- *Wind Farm Substation Noise, NY* – analyzed the noise impacts from a large utility substation associated with a wind farm in northern New York.
- *Kansas Wind Farm Study* – Conducted sound propagation modeling for a proposed 100 MW wind farm in Kansas. Measured background sound levels at several locations around the proposed site. Calibrated the sound model using measurements at an operating wind farm in Kansas. Prepared a report comparing the impacts to a noise standard and suggested mitigation necessary to meet the standard.

Selected Publications

- Kaliski, K., Wilson, D.K., Vecherin, S., Duncan, E., "Improving Predications of Wind Turbine Noise Using PE Modeling," *Proceedings of the 2011 Institute of Noise Control Engineers NOISECON 2011*
- Kaliski, K., "Topics in Public Acceptance, Human Impacts: Sounds and Shadow Flicker," New England Wind Energy Education Project Conference *Wind Energy in New England: Understanding the Issues Affecting Public Acceptance*, 2011
- Kaliski, K., "Wind Turbine Noise Regulation," (webinar) New England Wind Energy Education Project, 2010
- Kaliski, K., and Duncan, E. "Calculating Annualized Sound Levels for a Wind Farm," *Acoustical Society of America, Proceedings of Meetings on Acoustics*, Vol. 9, 2010.
- Kaliski, K. "Calibrating Sound Propagation Models for Wind Power Projects," *State of the Art in Wind Siting Seminar*, October 2009, National Wind Coordinating Collaborative.
- Kaliski, K. and Duncan, E. "Propagation modeling Parameters for Wind Power Projects," *Sound & Vibration Magazine*, Vol. 24 no. 12, December 2008.
- Duncan, E. and Kaliski, K. "Improving Sound Propagation Modeling for Wind Turbines," *Acoustics 08*, Paris 2008.
- Kaliski, K. "Sound Advice: Evaluating Noise Impacts in a Changing Landscape," American Wind Energy Association Fall Symposium, November 2008.
- Kaliski, K., and Duncan, E. "Propagation Modeling Parameters for Wind Turbines," *Proceedings of the 2007 Institute of Noise Control Engineers NOISECON* 2007.
- Hathaway, K, and Kaliski, K. "Assessing Wind Turbines using Relative Noise Standards," *Proceedings of the 2006 Institute of Noise Control Engineers INTERNOISE* 2006.

Licenses and Certifications

- Qualified Environmental Professional, Institute of Professional Environmental Practice
- Licensed Professional Engineer (PE), States of Vermont, New Hampshire, Massachusetts, and Michigan
- Board Certified, Institute of Noise Control Engineering

Memberships/Affiliations

- Acoustical Society of America
- Air and Waste Management Association
- Institute of Professional Environmental Practice
- Institute of Transportation Engineers
- Institute of Noise Control Engineering, Vice President for Board Certification
- Tau Beta Pi Engineering Society

EXHIBIT B

Baltimore, Maryland
NOISE-CON 2004
2004 July 12-14

A Critique of "Relative" Community Noise Standards

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ABSTRACT

Community noise standards in the United States come in two main classes: 1) "not-to-exceed", and 2) relative increase above ambient levels. This paper examines the merits of the "relative" noise standard. This type of standard limits increases in noise from a source to a certain level above "ambient." An example of this type of regulation is the Massachusetts DAQC Policy which limits sound levels to 10 dBA above the L90. This paper presents evidence that the standard is significantly flawed. The determination of the background sound level is a moving target and ambiguous, the standard is impractical to meet for most outdoor activities such as construction and quarrying, and the standard runs counter to principals of "environmental justice." That is, the only areas that are suitable for industries that create significant noise are in communities that already experience significant noise. Finally, relative standards are difficult to monitor and enforce. Modeling and GIS analyses are presented that show that property line setbacks for an 85 dB source (at 15 meters), as an example, would require as much as 1,130 ha (2,800 acres) of land depending on terrain. For these reasons, relative standards should not be used when creating new community noise ordinances.

1. INTRODUCTION

While the United States has no nationwide community noise standard, an increasing number of states, counties, and municipalities are taking it upon themselves to create a quantitative standard. While most of these communities and organizations use a "not-to-exceed" standard, some use a standard relative to some background level. This paper evaluates the drawbacks of such a standard and presents an analysis of the practical nature of the standard for many outdoor industries and activities.

2. FORMS OF THE RELATIVE STANDARD

The most well-known of these relative standards is from the Massachusetts Division of Air Quality Control.[1] In fact, this is not a standard at all, but a policy guideline used for enforcing a more loosely defined regulation. In any event, this guideline sets a property line and nearest inhabited residence limit of 10 dB above ambient, which is defined as the LA90. The descriptor of the source level is not defined. That is, it is commonly assumed that one compares the instantaneous maximum level from a source to the L90. There are no exceptions to policy, although the regulation exempts:

1. parades, public gatherings, or sporting events, for which permits have been issued provided that said parades, public gatherings, or sporting events in one city or town do not cause noise in another city or town;
2. emergency police, fire, and ambulance vehicles;
3. police, fire, and civil and national defense activities;

4. domestic equipment such as lawn mowers and power saws between the hours of 7:00 A.M. and 9:00 P.M.

The only other communities outside of Massachusetts that use this as a standard, as far as this paper's authors are aware, are in Minneapolis, Minnesota and Miami, Florida. However, Minneapolis's standard is measured inside the home and Miami's standard is only subject to mechanical and fire equipment, such as air handling units.

Two other agencies use a relative standard as guidance for predicting annoyance. The New York State Department of Environmental Conservation has a "Program Policy"[2] that discusses the potential level of annoyance based on a source's increase above ambient as well as its absolute level.

The New York Policy is, in part, adopted from a chart in Down & Stocks[3] taken from British Standard 4142.[4] Like the New York Policy, BS 4142 also discusses the potential for annoyance based on a source's relative increase in LAeq sound level above background, but does not set any standard.

For the purposes of this paper, we will use the Massachusetts Policy as the basis for critique.

3. SCIENTIFIC JUSTIFICATION FOR STANDARD

There exists a rich literature on rating measures, descriptors and criteria pertaining to human response to noise, annoyance and standards for community noise. The purpose of this paper is restricted to a consideration of the descriptors used in the subject standard. The two references cited are (1): *Encyclopedia of Acoustics*,[5] Chapter 80 on descriptors and criteria prepared by Malcolm Crocker and Chapter 89 Community Response to Environmental Noise by Sanford Fidell and Karl Pearsons and (2) Fundamentals of Hearing[6] by William Yost.

The most widely used measure for evaluating community noise is the Equivalent Sound Level, Leq, which represents the average of the A-weighted sound pressure level of fluctuating noise over a given period of time. The second widely used descriptor is the Day-Night Equivalent Sound Level, Ldn, which adds 10dB to measured nighttime levels to account for greater human sensitivity to nighttime noise. Neither of these two descriptors is included in the subject standard. The characteristics of the measured noise, e.g noise levels, steady state, impulsive, broadband, narrowband, are recognized as fundamental factors in determining the degree of noise intrusiveness and annoyance.

The use of Percentile sound levels is a common method of accounting for the nature of fluctuations in community, transportation and industrial noise. For example, L10 represents the statistical distribution of noise levels exceeded 10% of the time over which the measurements are taken. L50 is defined as the median noise level and approximates the measured Leq. L90, on the other hand, is often used to represent a residual noise level while L1 is only used to account for high level, short-duration events. In the subject standard, there does not appear to be a rationale for using L90 as the *minimum* ambient or background noise level and L1, or Lmax, as the *maximum* level for intruding noise. The allowable difference of 10dB for the Lmax, cited in the standard, between these two different descriptors is difficult to justify. The annoyance levels of intruding noise have been analyzed at length by Fidell and Parsons and increases of a few dB at low ambient noise levels are known to be more noticeable to people than added noise at high ambient levels. Both Fidell and Yost give specific information on signal-to-noise detectability or audibility of intruding noise which are the determining factors in annoyance criteria. Again, the 10dB allowance in the subject standard, even if it were based on comparable measures, does not account for the actual ambient noise levels and the degree of annoyance of different levels of intruding noise.

It is evident that the subject standard simply is not realistic nor adequately robust as a basis for decision with major environmental and economic implications.

4. PROBLEMS WITH AN L90 STANDARD

A. The Moving Target

The use of the L90 or any other descriptor for ambient sound is a moving target. The L90 changes by hour, day, season, and year. It is impossible to define with relative certainty at all property line and residence locations, even with extensive monitoring. Figure 1 shows five days of sound level monitoring at a remote location in Massachusetts. The graph shows five points for each hour of the day. These five points represent hourly L90's for each of the five days of monitoring. As shown, LA90's during the night averaged 24 dB with a standard deviation of 6 dB. Overall, nighttime levels varied by as much as 21 dBA. During the day, a similar pattern is found. The daytime average LA90 is 26 dB with a standard deviation of 4 dB. The LA90's during the day were within a 13 dBA range. A longer term monitoring effort would likely show even greater variation given changes in weather conditions, wildlife (frogs, crickets, and insects), and background traffic.

B. Environmental Justice

To meet a relative standard, historically noisy industries must chose to locate in areas with already high background levels. The EPA "Levels" document[7] show average sound levels for urban, suburban, and rural residential areas in the United States to be approximately 60 dB, 55, dB, and 45 dB Ldn, respectively. The L90s in these areas would be even less. The authors have measured LA90s in rural areas in parts of the northeast below 20 dB during the night and below 30 dB during the day. As a result, facilities that are subject to the relative noise standard would shy away from rural area in favor of more highly populated urban areas. As a result, given higher population densities, more people are exposed to the noise of the facility – while those people already experience higher than average levels of noise.

C. Negative Feedback

By locating noisy sources in already noisy areas, high density urban areas continue to get noisier and noisier. Every additional source increases the background level, increasing the bar for the next source. Relative standards ignore well-established activity interference effects of high noise levels.

D. Statistical Difficulties

A standard that relies on a moving target is statistically impossible to set in advance. For example, suppose a manufacturing facility is proposed that generates some noise. Before investors are willing to sink their money into the project, they require some guarantee that the facility will meet the relative noise standard. While it may be possible to say that the equipment used in the facility will generate no more than, say 50 dBA, it is impossible for the facility to guarantee the ambient L90. The facility has no control over background sources of noise. Since L90 varies significant hour-by-hour, it is statistically possible that, even with the best noise control measures, the L90 will drop below, in this example, 40 dB, putting the facility out of compliance. As a result, the authors have seen cases where investors are wary because there is no guarantee that the facility would be in compliance with noise rules. We have also seen cases of the "battle of the L90's", where different parties in a development project measure different L90's. As demonstrated in Figure 1, it would be easy for project intervenors to measure lower L90's than project proponents, simply be measuring over a longer period.

E. Outdoor Activities Generate Noise

Many types of commercial and industrial uses inherently generate noise that is difficult to control. With a relative standard applied as a maximum property line level, some land uses would require excessive setbacks to meet the standard. Some of these land uses include:

- Wind turbines – Even though modern wind turbines generate on the order of 62 dB at 30 meters (100 feet), this is still higher than most rural L90's.
- Quarries and gravel pits – An excavator dropping a load of rock into a dump truck generates about 82 dBA at 15 meters (50 feet). Just assuming geometric spreading at 6 dB/doubling of distance would require 910 meters to bring the source to a level of 40 dB.
- Trucks – A truck under maximum acceleration at 10 mph generates about 80 dB.
- Golf courses – Even though golf seems to be a quiet sport, an Lmax standard at the property line can easily be exceeded by a good hit with a driver.
- Parks – Baseball hits have been measured at 87 dB at 15 meters (50 feet). It is not hard to imagine that a single hit can exceed background L90's at the property line in quiet rural and suburban parks.
- Building material stores – loading and unloading materials, backup alarms, and trucks can easily create sounds that exceed 10 dB above ambient.
- Rail depots – While urban planners are pushing for more materials to be shipped by rail, locomotives at rail sidings can exceed a relative standard.
- Construction – Noise from heavy equipment at construction sites are difficult to control and often involve loud impact noises as well as engine noise.

- Other – Other land uses and activities include public school sports, church bells, air parks, asphalt and concrete plants, race tracks, amusement parks, rubbish removal, and utility transformers.

Figure 2 shows the locations of all buildings in Vermont, based on the E-911 address database maintained by the Vermont E-911 Board. As shown, even in a state with a relatively low population density, there are few areas that have no population at all. Assuming that rural areas in Vermont have daytime L90's in the 20's, 10 dB above L90 would be, say 35 dB. For a source with a sound pressure level of 85 dBA at 15 meters (50 feet), it would take approximately 1.9 kilometers to reduce that sound to 35 dBA. This assumes flat terrain, geometric spreading, atmospheric absorption, a moderate temperature inversion, and ground attenuation over soft ground. This translates into a property with a land area of 1,130 hectares (2,800 acres). Very few construction sites or other similar outdoor uses would have this size of buffer, even in rural areas.

5. CONCLUSIONS

Many communities are adopting quantitative noise standards as part of a justifiable effort to reduce nuisance noise impacts. We believe that, following the example set by most agencies, states, and communities, standards should be set relating to absolute sound pressure levels. Standards that are based relative to some background sound level are not appropriate for the following reasons:

1) The background sound level is constantly changing over time and can never be determined as an absolute level or even a minimum guarantee.
2) Appropriate locations for noisy industries are where the background levels are highest. These tend to be in locations with high population densities with already-high noise exposure levels.
3) Relative standards do not take into account well-known activity interference impacts at higher sound levels.
4) Because noise-generating facilities consistently seek areas with high background sound levels, noisy areas consistently get noisier with no upper limit.
5) While facilities can control the noise that they generate, they cannot control the background sound level, thus making it impossible for a source to guarantee compliance.
6) Some outdoor activities that inherently generate noise, such as quarrying, would require enormous, impractical, and unnecessary setbacks, especially in rural areas.

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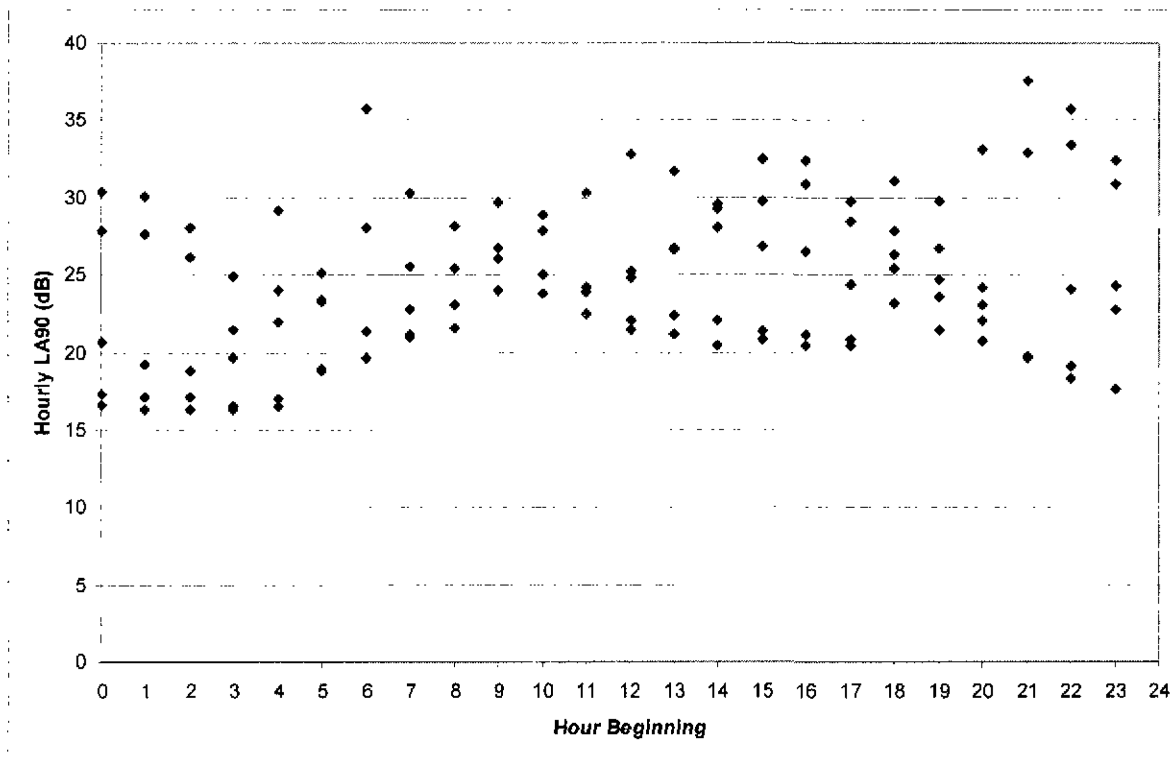

Figure 1: Variation in Hourly L90 at a Remote Location in Massachusetts over 5 Days

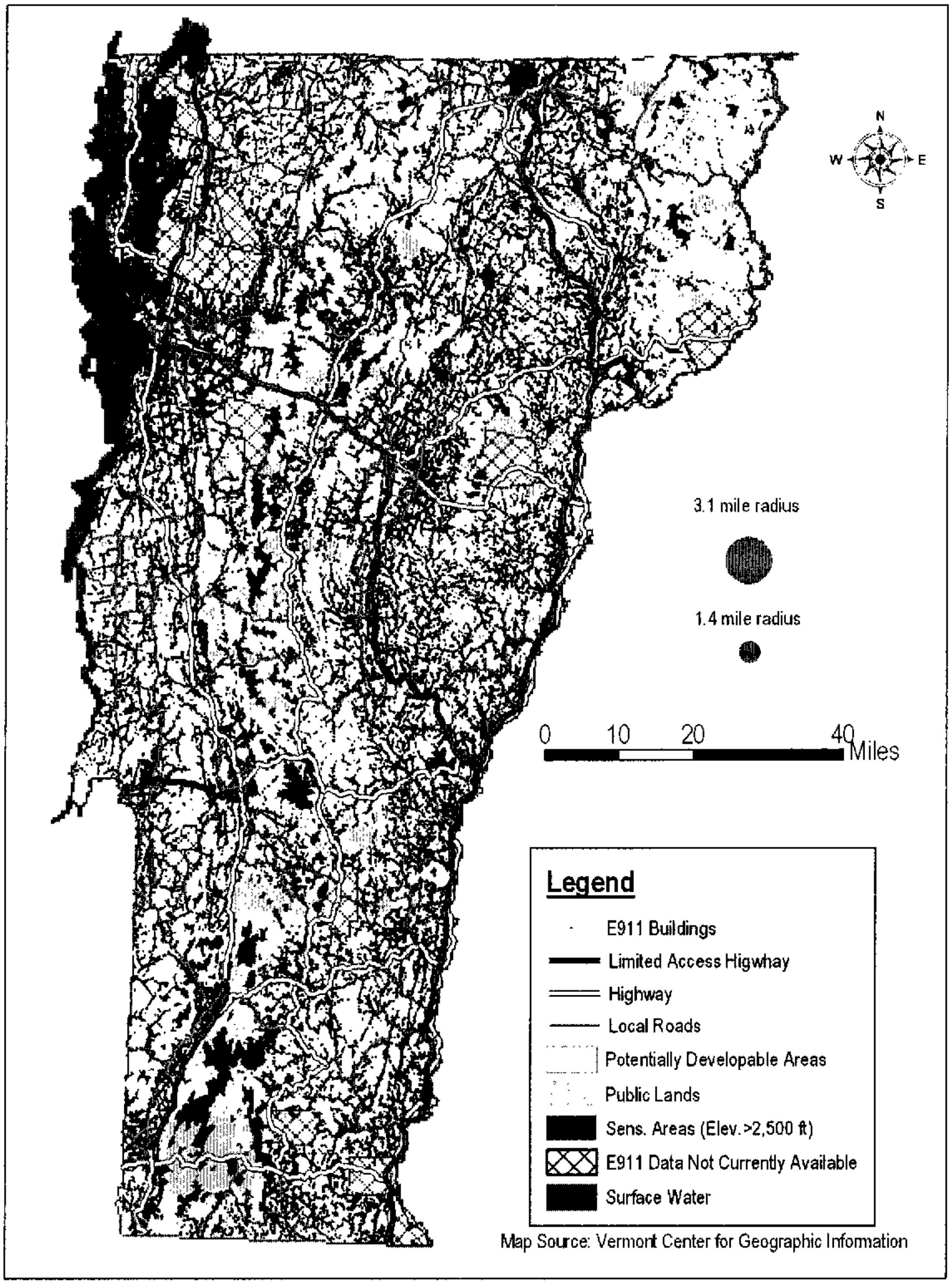

Figure 2: Locations of Buildings in Vermont based on E911 Database

EXHIBIT C

INTER-NOISE 2006

3-6 DECEMBER 2006
HONOLULU, HAWAII, USA

Assessing wind turbines against relative noise standards

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ABSTRACT

Some community noise standards are "relative", meaning that they limit noise from a source to a certain decibel level above the ambient level. While this may be predicted with some certainty for fixed industrial sources in urban areas, wind turbines present a unique challenge. First, wind turbine noise emissions vary by wind speed, and second, background ambient noise levels also vary – both due to anthropogenic factors, and in more rural areas, due to wind speed. Thus the standard by which the wind turbine is assessed against is constantly changing. This paper presents a method to determine the probability of exceedences of a relative noise standard given the ambient and wind turbine noise levels as functions of wind speed. It applies this method to a proposed wind turbine project in the United States. The findings show that it is difficult, if not impossible, to forecast with 100% certainty that exceedences of the noise standard will not take place. This calls into question the appropriateness of relative noise standards for variable noise sources operating in rural areas, such as wind turbines.

1 INTRODUCTION

Despite significant improvements in reducing mechanical noise from wind turbines over the last decade [1], the development of wind energy continues to create highly contested community discussions about their noise impacts. Technical experts are commonly needed to quantify these impacts, requiring background sound level monitoring, propagation modeling, technical reports and public testimony. This task for acoustics professionals can be made particularly difficult if the applicable noise standards are poorly written or complicated to assess. Some noise guidelines quantify violations in relation the pre-development ambient sound levels. As an example, one U.S state's noise policy determines a source of noise to be in noncompliance with their regulation if that source:

1) Increases the broadband sound level by more than 10 dB(A) above ambient (L_{90}), or
2) Produces a "pure tone" condition – when any octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more.

Analysis for a wind energy project relating to Part 1 above presents particular challenges, since as the ambient level rises and falls with both anthropogenic (e.g. traffic) and biogenic factors (e.g. wind speed, wind direction, and stability), the standard level also changes. At the same time, the noise generated from the wind turbines is affected by many of the same biogenic factors.

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Effectively, at each given wind speed, wind direction, and stability, the likelihood that turbine noise will be in noncompliance at a particular property would need to be evaluated individually. Natural variations in ambient sound levels make any prediction efforts less certain.

This paper presents the use of common statistical tools in combination with sound level monitoring and sound propagation modeling as a method for such an evaluation.

2 BACKGROUND SOUND LEVEL MONITORING

Background sound level monitoring was conducted at three residential locations near a proposed wind energy project. Figure 1 depicts the study area with the proposed turbine locations and the three residential background monitoring stations. ANSI Type I and Type II sound level meters were used for the background monitoring. All meters were enclosed in an environmental kit and attached to an external microphone via a 2 meter cable. Each microphone was fitted with a 2 inch weather-proof wind screen. The microphone height was approximately 1.2 meters at each location. The monitors were set to record 10-second L_{Aeq}, L_{AS10}, L_{AS50}, L_{AS90}, L_{ASmin}, and L_{ASmax}. All of the sound level monitors were calibrated before and after the measurement period and were found to have negligible drift.

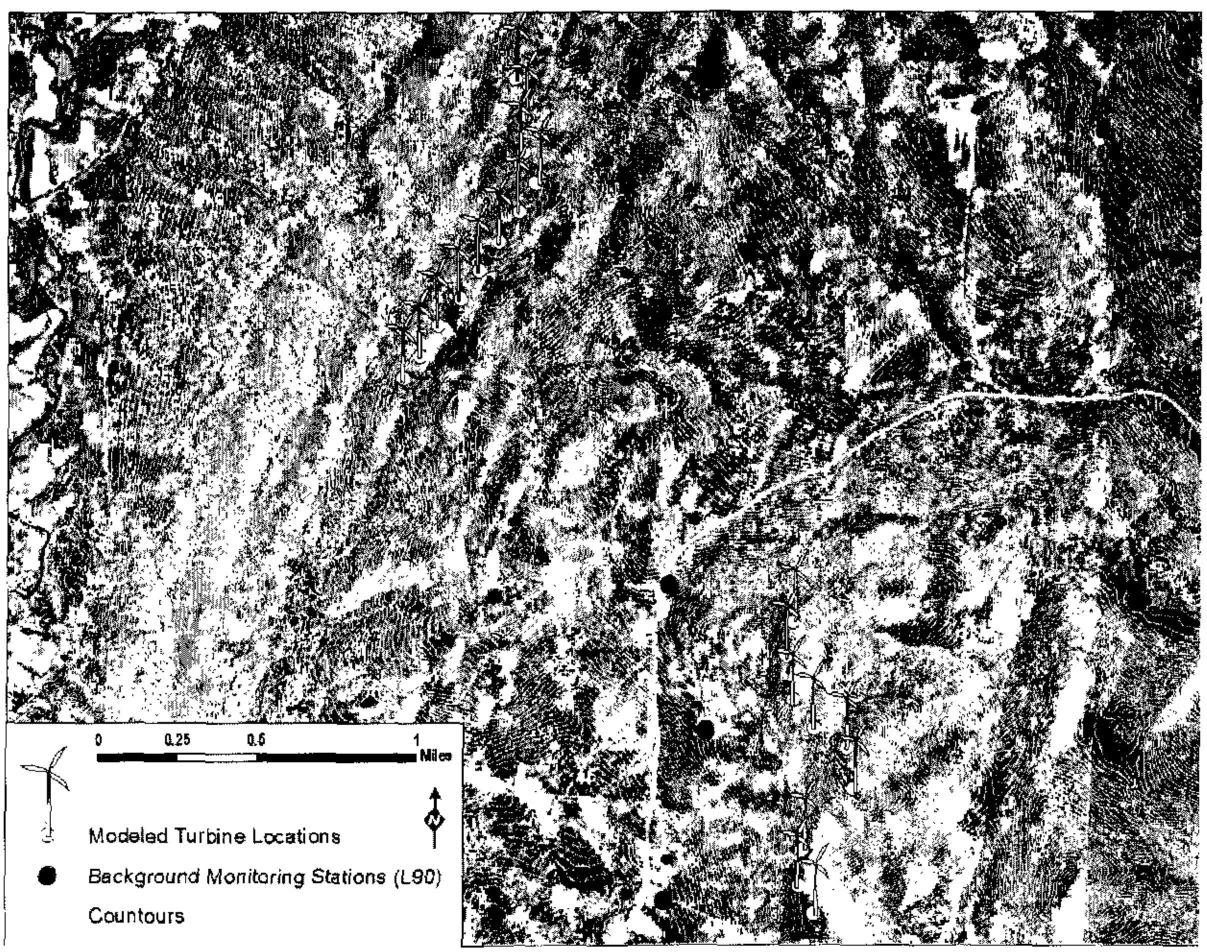

Figure 1: Map of Study Area

At the same time, meteorological data from 30 meter and 40 meter towers at the site of the proposed turbines along a ridgeline were summarized and time-matched to the sound level data. These data included the average temperature, and average, minimum, maximum, and standard deviation of the wind speed, and wind direction for each 10-minute period during the monitoring.

We also collected precipitation data from a nearby weather station. This was needed to separate the L_{90}s for periods without rain, as the rain can increase background levels significantly.

3 TURBINE NOISE PROPAGATION MODELING

Noise propagation modeling was conducted using the CADNA/A acoustical model, and included appropriate terrain and site detail for the area. In this case, we specified 96 modeling scenarios to cover six wind speeds, eight wind directions, and two atmospheric stability classes. In all, one can consider:

- *wind speeds* – 5, 6, 7, 8, 9, and 10 m/s, at hub-height, as appropriate for the chosen stability class
- *wind directions* – N, NE, E, SE, S, SW, W, and NW
- *stability classes* – B through E (*Based on a turbine cut-in speed of 3 m/s measured at a 10 meter height*)

Source sound power data from the turbine manufacturer were entered for each wind speed modeled. Table 1 summarizes the sounds powers assumed.

Table 1: Turbine Sound Power Levels (in dBA) for Modeling

	1/1 Octave Band Center Frequency (Hz)										
Wind Speed	31.5	63	125	250	500	1000	2000	4000	8000	$L_{W\text{-}A}$	$L_{W\text{-}Z}$
5 m/s	62.9	72.7	85.4	85.9	86.1	82.1	82.4	80.4	68.7	92.1	106.3
6 m/s	68.2	78.3	88.9	91.4	92.1	88.1	88.1	86.4	76.6	97.5	111.2
7 m/s	73.3	84.0	89.6	94.1	95.9	92.9	91.9	90.2	80.4	100.9	115.6
8 m/s	74.3	84.4	90.7	95.2	96.6	93.9	93.6	92.9	83.2	102.1	116.4
9 m/s	73.4	83.7	91.1	96.4	96.2	93.6	93.9	93.7	84.3	102.4	115.9
10 m/s	72.2	82.5	91.0	96.7	96.0	93.9	94.6	94.6	84.9	102.7	115.0

4 STATISTICAL MODELING

Log-transformed linear regression using least-squares (SPSS ®, V 12.0.1) was performed to estimate the effect of wind speed on background L_{90} sound levels at the residential monitoring stations. The resulting model helped predict future mean sound levels for the six wind speeds considered. In reality, we know that ambient sound levels are most accurately specified with multivariate models, since other sources of sound besides wind contribute to the L_{90}. However, bivariate specification is adequate in this context, since our goal is to estimate only two simple parameters:

1) The mean L_{90} at each wind speed
2) The variation in the L_{90} at each wind speed

To estimate the distribution of future individual sound levels at these wind speeds, 95% prediction intervals were calculated using Equation 1 [2], Equation 1: 95% Prediction Interval for an Individual Y Observation Given X

$$\hat{Y}_0 = \hat{\mu} \pm t_{0.025}\, s \sqrt{1 + \frac{1}{n} + \frac{(x_0 - \bar{x})^2}{\sum_i (x_i - \bar{x})^2}} \tag{1}$$

Where:

$\hat{\mu}$ = predicted mean L_{90} given some wind speed
$t_{0.025}$ = critical two tailed t-statistic at 95%
s = estimated standard deviation of the L_{90}s
x_0 = the wind speed for which Y_0 is being predicted
x-bar = mean wind speed
x_i = the i[th] wind speed (this denominator term is the sum of squares for all wind speeds).
n = sample size

With these intervals assigned, we infer that 95% of future L_{90} levels measured during comparable periods will be contained within these boundaries.

The second component in our statistical model involves estimating the probability that noise from turbines be in violation over the future L_{90}s. Interpreting the noise standard in Section 1, turbine noise would need to be 10 dBA above some future L_{90} to be a problem. To calculate this probability, we referred the sample of ambient sound levels to the standard normal distribution. Equation 2 represents the number of standard deviations each threshold is away from the predicted mean L_{90} at each wind speed,

Equation 2: Formula for Determining the Z-statistic

$$Z = \frac{(X_{mi} - 10) - \bar{x}_i}{SD_i} \tag{2}$$

Where:

X_{mi} = the modeled turbine noise at a residential receiver for the i^{th} wind speed
$\bar{x}_i$ = the mean L_{90} at i,
SD_i = the standard deviation of the L_{90} for i.

Subtracting 10 dB(A) from X_{mi} provides the threshold. Referring the Z-statistic to a 1-tailed standard normal distribution, we then know the probability that the L_{90} will be at or below the threshold. This probability (P_t) in combination with the probability of such a meteorological scenario occurring (P_m) results in the joint probability of exceedence. This is summed across all modeled scenarios, as defined in equation 3.

Equation 3: Formula for Total Joint Probabilities

$$P_J = \sum_{1}^{k} P_t P_m \tag{3}$$

Where:

P_J = the joint probability of an exceedence (10 dB above the L90)
P_t = the probability of observing an L_{90} at or below the violation threshold
P_m = the probability of a given meteorological scenario (k)
k = the number of meteorological scenarios

To demonstrate this graphically, consider a distribution of L_{90}s at a residential receiver for nearby[c] wind speeds of 5 m/s (Figure 2). In this example, the modeling scenario for turbine noise assumes D atmospheric stability with winds from the west. The predicted turbine noise level at the residential home is 29 dBA, thus an L_{90} of 19 dBA or less would be required to have a violation. This probability, P_t, is then multiplied by the corresponding event probability for the meteorological scenarios (P_m), yielding the joint probability. Again, this is done for *each* of the 96 modeled scenarios. The summed probability of all 96 scenarios estimates the percentage of time that turbine noise will violate the noise regulation. Figure 3 provides an example L_{90} regression with modeled turbine noise.

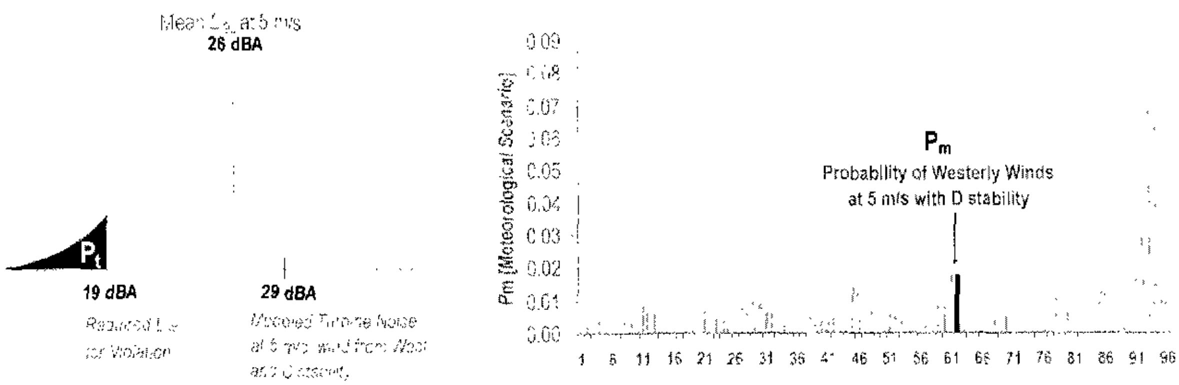

Figure 2: Graphical Representation of Probabilities

[c] The actual wind speeds at the residential home are not known – they refer to wind speeds at the turbine.

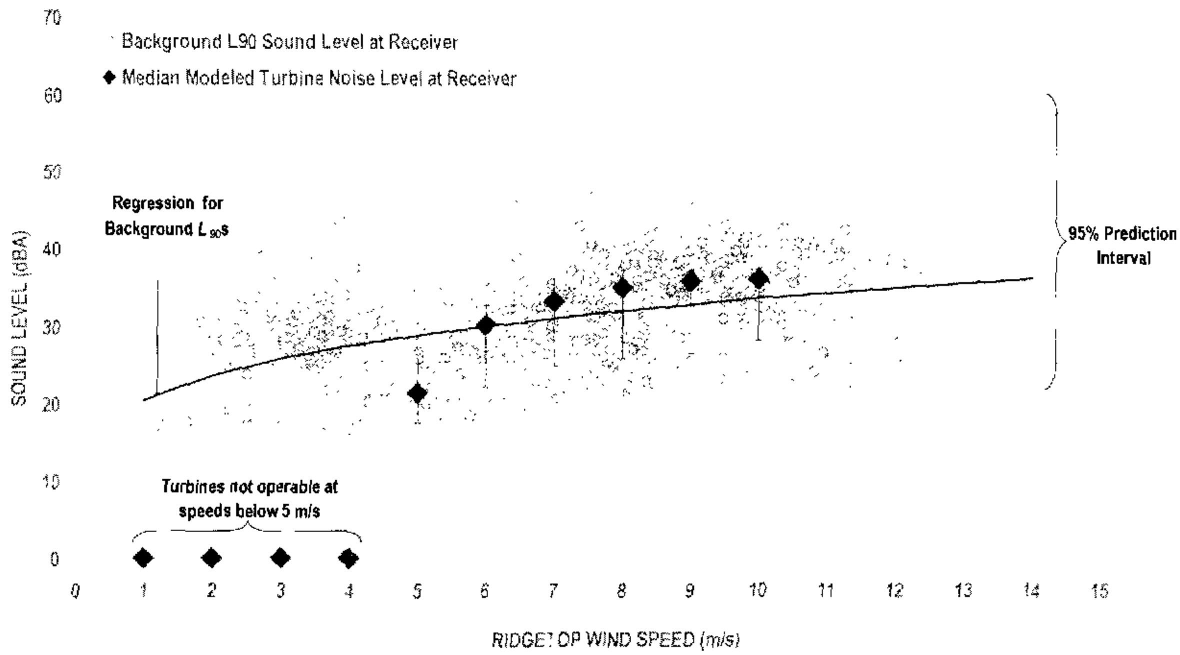

Figure 3: L_{90} Regression with Modeled Turbine Noise at One Residential Receiver

5 IMPLEMENTATION

Some improvements to this approach are important to note. Primarily, by extending the baseline monitoring period, we get a greater confidence in the outcome. By conducting monitoring over several seasons or under various meteorological conditions, the estimates for the corresponding predicted means, standard error, and predicted future L_{90}s would improve. Further, the distribution assumptions for least-squares regression are sensitive to outliers, and while our data did not present problems, this should always be evaluated in any future sample.

If enough data are available, more modeling scenarios can be considered. Specific variations that may also be relevant are temperature and forest cover. However, increasing propagation model scenarios requires the calculation of the corresponding probabilities of that meteorological scenario. Similarly, with enough background sound level data, this too can be further partitioned and regressed in greater detail.

In the end, however, we are left with a statistical probability that a standard will be exceeded. As in any probability, there is a certain degree of uncertainty, however small. In noise propagation modeling, the uncertainty is magnified by interactions among geometric spreading, diffraction, refraction, ground effects, and the complexities of three-dimensional meteorology, not to mention variability in source emission levels [3].

Standards however, are written for absolutes. They generally say that noise from a source cannot exceed a certain level. Therefore, any noise study that evaluates the *probability* of exceedence must also educate its readers regarding statistical distributions and their applicability to fixed (or variable) standards. Preferably, poorly written standards will come to be modified with probability in mind.

6 CONCLUSIONS

The purpose of our method has been to place both the ambient monitoring and propagation modeling results into real-world context. Often times, modeling results are interpreted so one can state that a noise standard will (or will not) be violated under 'worst-case conditions', however, this language alone can be inadequate given the complexities surrounding noise modeling – interactions of atmospheric conditions, varying ground factor, changing anthropogenic conditions, varying source levels etc. [3].

There is a finite likelihood that an event can happen, even if it is extremely small. With any probability distribution, there is no "zero probability." Further, there may be several different conditions that produce violations, but they might not occur with comparable prevalence. Noise standards that are referenced to a background sound level may result in particularly ambiguous conclusions, since they add even further variation that must be accounted for in determining the probability of exceedence.

Ultimately, a thorough and proper assessment can reveal important information pertinent to planners. In our case study, we found that the probability that turbine noise could exceed 10 dB above the L_{90} was 2% to 8% for different residences. It was possible to offer specific information on wind speeds, directions, and times of year in which this was most likely to occur at each home. This added detail placed the turbine noise into perspective, and thus enhanced the discussion and decision-making regarding its impacts.

Though we believe methods employing statistical models are useful in noise assessment, their use is often confusing to regulators. While it is important to effectively communicate how probability works, it is equally important to modify state and community noise standards to account for statistical uncertainty.

7 REFERENCES

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