

HEALTH & FAMILY SERVICES
PUBLIC HEALTH SERVICES
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June 1, 2009

His Worship Mayor Randy Hope and Councillors
The Municipality of Chatham-Kent
315 King Street West
Chatham, ON N7M 5K8

Dear Mayor and Councillors:

RE: REQUEST FOR FURTHER CLARIFICATION ON HEALTH EFFECTS OF WIND TURBINES

I am aware that Council has received a great deal of conflicting information on this issue, including health complaints in our own Municipality alleged to be caused by proximity to wind turbines. I will explain the position of the Health Unit that there is currently no substantial basis to conclude that wind turbines are directly eroding the health of people.

Evidence for medical conclusions is categorized into three levels, with level I providing the strongest evidence and level III the weakest.

- Level I: Evidence obtained from at least one properly designed randomized controlled trial.
- Level II-1: Evidence obtained from well-designed controlled trials without randomization.
- Level II-2: Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one center or research group.
- Level II-3: Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled trials might also be regarded as this type of evidence.
- Level III: Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees.

Unfortunately, statistical analysis is limited with regard to wind turbine effects because of the paucity of level I and II evidence. Most of the so-called studies purporting to document adverse health effects caused by wind turbines are self-reported accounts or

open surveys of health issues that are nonspecific and common irrespective of wind turbine exposure, such as insomnia, hypertension, anxiety, digestive disturbances and subjective sensory changes. These accounts have been reported by the media and have created an impression in the public before a rigorous analysis has confirmed that there is either excess morbidity or an association with wind turbines. Uncontrolled self-reporting eliminates any chance of scientific analysis as there is no motivation or reason to report a lack of symptoms or a way to include all people in proximity to turbines. There is no mechanism to exclude people from participating in a self-reported survey multiple times. The boundaries of proximity are often not even defined. The lack of controls (a sample of people not exposed to wind turbines), failing to blind the surveyors (they should not know the exposure history before asking the questions) and not defining the study population result in what researchers call preselection bias. Similar surveys in the past have tended to distort and overestimate the prevalence of many things from "cancer clusters" to sexual practices (Kinsey's infamous sex surveys). There is no local data on the prevalence of these symptoms before wind turbines were installed, so it cannot be determined whether or not there has been an increase. The most eloquent spokesman for the anti-wind turbine activists, former UWO Dean of Medicine Dr Robert McMurtry, has admitted that there are no controlled studies, and he has called on the province to conduct such a study. This has been supported by at least one Ontario Health Unit, but this would be methodologically difficult. It is not possible to design a study to conclusively prove a lack of association, such as that wind turbines cannot cause health effects or that there are no ghosts.

At the present time we have people who have concluded, with gut-felt certainty, that they have health problems caused by wind turbines. These reports have received a great deal of media attention and organized political action groups have been formed which advocate for government action to address these health problems and suspend the construction of wind farms. These objectors operate web sites and write letters which promulgate dubious explanations such as infrasound induced DNA alterations, "wind turbine syndrome", coined by anti-wind turbine activist Dr Nina Pierpont of Malone, New York for a complex of nonspecific symptoms and "vibro-acoustic disease", tissue fibrosis first ascribed to extreme sound and vibration exposure in aviation environments by Portuguese investigators Alves Pereira and Castelo Branco, but later associated with the much lower sound levels of wind turbines and even automobiles. No other researchers have confirmed these findings. Wind turbine syndrome and vibro-acoustic disease impress lay persons as legitimate diseases which account for how they are feeling, but neither is listed in the International Classification of Diseases nor is described in any standard medical textbook. Most experts are skeptical that they exist.

So can we make sense of these complaints?

Most health complaints regarding wind turbines have centered on sound as the cause. Three kinds of sound are emitted by wind turbines: infrasound (oscillation frequencies less than approximately 10 Hz), low frequency sound of approximately 10-200 Hz and

the fluctuating aerodynamic "swish" from the turbine blades which is also low frequency, approximately 500-1000 Hz.

Infrasound from natural sources (meteors, volcanic eruptions, ocean waves and wind) surrounds us and is below the audible threshold. The infrasound emitted from wind turbines is at a level of 50 to 70 dB, also well below the audible threshold. There is a consensus among acoustic experts that the infrasound from wind turbines is of no consequence whatsoever. A problem is that objectors often use the term infrasound incorrectly when they are referring to low frequency sounds.

Low frequency sounds below 40 Hz cannot be distinguished from background noise due to the wind itself. Perceptible (meaning above the background noise) low frequency noise can be produced by wind turbines under conditions of unusually turbulent wind conditions, but the actual sound level depends on the distance of the listener from the turbine, as the sound attenuates (falls off). The higher the frequency and the higher the temperature, the greater the sound attenuates with distance. Terrain and humidity are other factors. The low frequency noise emitted by spinning wind turbines could possibly be annoying to some when winds are unusually turbulent, but there is no evidence that this level of noise could be harmful to health. If so, city dwelling would be impossible due to the similar levels of ambient noise levels normally present in urban environments. It is not usually the low frequency nonfluctuating noise component that provokes complaints.

The fluctuating aerodynamic sound (swish) in the 500-1000 Hz range is from the wind turbine blades disturbing the air, modulated by the blades passing the tower which changes the sound dispersion characteristics in an audible manner. This fluctuating aerodynamic noise is the cause of most noise complaints regarding wind turbines, as it is harder to become accustomed to fluctuating noise than to noise that does not fluctuate. The noise limits imposed by the Ministry of the Environment for wind turbines are designed to prevent noise issues but some wind turbines produce noise levels that may be irritating and even stressful to some people who are more sensitive to noise. Sleep disturbance can occur. Others exposed to the same noise levels may experience no difficulty. There is no evidence of direct effects to health by this level of noise but there could be indirect effects from annoyance-induced stress. One paper categorically states that the only health effect of wind turbine noise is annoyance.¹

There is a large body of medical literature on stress and psychoacoustics. There is a great deal of individual variation in the response to any given stimulus and legislated limits to noise and other annoyance factors are not designed to prevent problems in the most sensitive members of the population. Three factors that seem particularly

¹ Regan B., (2) June 200

40Hz이하의 저주파 소음은 바람의 소리로 인해 배경음과 구분할 수가 없다. 저주파 소음인 배경음은 이례적으로 바람이 흔들릴 때 풍력발전기에서 발생할 수도 있다. 하지만 실질적인 소음 수준은 듣는이가 풍력발전기와 의 거리에 달려있다. 주파수가 높으면 높을수록 온도가 높으면 높을수록 소리는 크게 들리는데 소리는 거리가 멀수록 줄어든다. 지형과 습도는 별개의 것이다. 바람이 이례적으로 흔들릴 때 풍력발전기에서 저주파 소음이 발생할 수 있는데 어떤 사람한테는 싫게 들릴 수도 있다. 하지만 소음수준이 건강에 위해 요소가 된다는 근거는 없다. 만일 건강에 위해 요소가 된다면 도시 환경의 소음수준이 이와 비슷하므로 도시에서 살수가 없다. 이는 불만을 제기할 만한 저주파 소음요소가 되지 않는다.

pertinent to the discussion of wind turbine effects are the fear factor, also called the nocebo effect, and two medical conditions, sensory integration dysfunction and somatoform disorders.

The large volume of media coverage devoted to the alleged adverse health effects of wind turbines understandably creates an anticipatory fear in some that they will also experience adverse effects from wind turbines. Every person is suggestible to some degree. The resulting stress, fear and hypervigilance may exacerbate or even create problems which would not otherwise exist. In this way, anti-wind farm activists may be creating with their publicity some of the problems which they describe. This is the nocebo effect and it is the negative counterpart to the placebo effect where belief in an intervention may produce positive results.

Sensory integration dysfunction is a little-understood condition of abnormal sensitivity to any or all sensory stimuli (sound, touch, light, smell, taste). The afflicted experience unpleasant overpowering sensations to ambient conditions considered normal by most people. There is little data on the prevalence of this condition and it may be more common than is realized. Such individuals would be more sensitive to wind turbine noise than most.

Somatoform disorders are characterized by physical symptoms which reflect psychological states rather than physical causes. Conversion is the unconscious expression of stress and anxiety as a physical symptom and it is very common. Common conversion symptoms are vague sensations of tingling or discomfort, fatigue, poorly localized abdominal pain, headaches, back or neck pain, weakness, loss of balance, hearing and visual abnormalities. The wind turbine controversy has raised the rhetoric to stressful levels, and the similarities of human stress responses and conversion symptoms to those described as so-called wind turbine syndrome are striking.

In summary, there is no scientifically valid evidence that wind turbines are causing direct health effects, although the body of valid evidence is limited. It is unlikely that evidence of adverse health effects will emerge in the future because there is no biologically plausible mechanism known by which wind turbines could cause health effects. There are wind turbines in urban environments, including Toronto, that have not been causing problems. The European experience would indicate that wind farms can be compatible with rural environments. An annoyance factor undoubtedly exists to which there is individual variability. Associated stress from annoyance, exacerbated by all the negative publicity, is the likely cause for the purported erosion of health that some people living near rural wind turbines are reporting. Stress has multiple causes and is additive.

Unfortunately, there has been some misunderstanding regarding the role of the Medical Officer of Health and the Health Unit in these matters. It is beyond the scope of the

Chatham-Kent Health Unit to address this in any but a general manner. In my opinion the issue of wind turbine noise and associated stress needs to be managed at the Provincial level. If the Ministry of the Environment noise guidelines for wind turbine installations are exceeded, affected people have the option to pursue compensation, but the Chatham-Kent Board of Health has confirmed that it is not the role of the Health Unit to become involved in private litigation matters. From the outset, when requested by Council, the Health Unit and I have attempted to provide a balanced, evidence-based and scientifically valid appraisal of this whole situation to Council. As a result, anti-wind farm activists have attacked me personally on internet sites, accused me of being financially influenced by wind turbine manufacturers (untrue) and even made complaints about my conduct to regulatory bodies. Letters to the Chatham Daily News have castigated me for neglecting the health of Chatham-Kent citizens with the kind of inflammatory phrases spoken, it seems to me, in the language of people with a higher regard for their own convictions than for the facts.

Sincerely,

W. David Colby, MSc, MD, FRCPC
Acting Medical Officer of Health
Chatham-Kent Health Unit

Encl.:

Ramakrishnan R. Acoustic Consulting Report for the Ontario Ministry of the Environment, December 2007.

Leventhall, G. Infrasound from Wind Turbines – Fact, Fiction or Deception, Canadian Acoustics Special Issue 34(2), June 2006.

ACOUSTIC CONSULTING REPORT

Prepared for the Ontario Ministry of the Environment

WIND TURBINE FACILITIES NOISE ISSUES

**Aiolos Report Number: 4071/2180/AR155Rev3
DECEMBER 2007**

Author Ramani Ramakrishnan, Ph. D., P. Eng.
 Lead Acoustician



Signature

Date: 28 December 2007

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EXECUTIVE SUMMARY

All proponents of a wind farm development need to apply for a Certificate of Approval from the Ministry of the Environment of Ontario. The noise assessment report required for the approval process uses the guideline Ministry document, “Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators” released in 2004. The above guidance document was to assist proponents of wind turbine installations in determining the list of necessary information to be submitted when applying for a Certificate of Approval (Air and Noise) under Section 9 of the *Environmental Protection Act*. The noise guidelines in MOE publications NPC-205/NPC-232 as well as the wind generated noise levels were applied to set the noise limits.

The Ministry has now initiated a review of the interpretation of the above policies, due to expanding body of knowledge of the noise impacts of wind turbines. The main aim of the proposed review is to assess the appropriateness of the Ministry’s approach to regulating noise impacts of wind turbines.

The scope and requirements of the review can be summarized as: a) Review of the 2006 doctoral dissertation by van den Berg; b) Review of available noise policies and guidelines; review of relevant scientific literature; and review of MOE’s current noise policies as applied to wind turbine noise and c) Provide expert opinion based on the above findings; and d) Prepare a report that provides advice on the state of the science regarding wind turbine noise, and on MOE policies and procedures that relate to wind turbine facilities. The results of the investigations are described below.

Van den Berg’s research was initiated as a result of complaints, in Netherlands, against an existing wind farm in Germany very close to the Dutch border. The main hypotheses of the research are: a) atmospheric stability, particularly stable and very stable conditions happen mostly at night time and the hub-height wind speeds can be higher than those predicted from the 10 m high wind speeds using standard methods, such as the logarithmic profiles of the IEC standard. And hence, the wind turbine noise levels can be higher than expected. It was also conjectured that these discrepancies are prevalent during summer months; and b) beat-sounds

can become very pronounced during stable and very stable conditions. Although, the data of van den Berg's research did not provide conclusive scientific evidence to support the above hypotheses, further review of the literature showed that some of the basic conjectures may well be true. Hence, the research of van den Berg must be considered as the catalyst that started serious discussion on many noise aspects of wind farm. Future research must therefore provide strong scientific data to validate these different noise concerns.

The noise policies from different Canadian provinces, USA states and a few other countries were reviewed. General comparison of the noise regulations was presented. The main differences between the different regulations seem to be: i) in the acceptable noise limits; and ii) in the evaluation of receptor noise levels from the cumulative operation of the turbines in the wind farm. Further, some jurisdictions have special legislation concerning wind turbines, while others apply general recommendations. The Ministry of the Environment assessment process in Ontario is similar to other jurisdictions.

A literature review, focussed mainly on a) Metrological effects on wind turbine noise generation; b) Assessment procedures of wind turbine noise levels and their impact; c) Particular characteristics of wind farm noise; and d) Human responses to wind farm noise levels, was conducted. It showed that - local terrain conditions can influence meteorological conditions and can affect the expected noise output of the wind turbines; assessment procedures of sound power levels and propagation models, applied in different jurisdictions are quite similar in their scope; wind farm noise do not have significant low-frequency (infrasound) components; and modulations effects can impact annoyance;

The Ministry of the Environment's procedures to assess wind farm noise levels follow a simple procedure that is sound for most situations. However, additional concerns still need to be addressed in the next round of revisions to their assessment process. These revisions may need to be addressed after the results from future research provide scientifically consistent data for effects such as meteorology, human response and turbine noise source character.

1.0 INTRODUCTION

1.1 BACKGROUND

The Ministry of the Environment released a guideline document, “Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators” in 2004. The above guidance document was to assist proponents of wind turbine installations in determining the list of necessary information to be submitted when applying for a Certificate of Approval (Air and Noise) under Section 9 of the *Environmental Protection Act*. The noise guidelines in MOE publications NPC-205/NPC-232 as well as the wind generated noise levels were applied to set the noise limits. The revisions to NPC-205/NPC-232 (in draft form) did not change the evaluation of noise limits and/or procedures applicable to wind turbines. The three Ministry documents are enclosed in Appendices A through C.

The Ministry has now decided to initiate a review of the interpretation of the above policies, due to expanding body of knowledge of the noise impacts of wind turbines. The main aim of the proposed review is to assess the appropriateness of the Ministry’s approach to regulating noise impacts of wind turbines. And the Ministry, to support the proposed review, has retained Aiolos Engineering to provide acoustical technical expert advice on the recent findings about low frequency and wind profiles on wind turbine noise impacts.

The scope and requirements of the technical advice can be summarized as shown below:

- (1) *Review of the 2006 doctoral dissertation by van den Berg;*
- (2) *Review of*
 - 2.1 *available noise policies and guidelines;*
 - 2.2 *Review of relevant scientific literature; and*
 - 2.3 *Review of MOE’s current noise policies as applied to wind turbine and*
- (3) *Provide expert opinion based on the above findings;*
- (4) *Participate in a focus group discussion; and*
- (5) *Prepare a report that provides advice on the state of the science regarding wind turbine noise and on MOE policies and procedures that relate to wind turbine facilities.*

2.0 REVIEW OF G. P. VAN DEN BERG'S DISSERTATION

2.1 BACKGROUND

Dr. G. P. van den Berg of the University of Groningen conducted research on the noise characteristics of wind turbines, the impact of wind profiles on its propagation as well as the subjective response of sensitive receptors. The results of the above research are summarized in the 2004 Journal of Sound and Vibration article (Reference 2) with the details given in his 2006 doctoral dissertation (Reference 1).

A list of documents used for this assessment is enclosed in the reference list. *NOTE:* References 2, 3 and 4 by van den Berg presents only summary results of his research and the complete details are included in his dissertation (Reference 1). Hence, references 2, 3 and 4 will not be commented upon in this review.

The main aims of van den Berg's dissertation can be summarized as follows:

- i) A group of residents complained against the perceived noise effects from a wind farm located along the border between Germany and Netherlands and were unable to obtain satisfactory resolution from the authorities and hence the university's Science Shop for Physics was retained to investigate the validity of the residents' claims;
- ii) The main complaints seem to centre around perception during evening and night hours, and hence the dissertation focussed on atmospheric stability and the resulting noise effects;
- iii) The main hypotheses are: a) atmospheric stability, particularly stable and very stable conditions happen mostly at night time and the hub-height wind speeds can be higher than those predicted from the 10 m high wind speeds using standard methods, such as the logarithmic profiles of the IEC standard. And hence, the wind turbine noise levels can be higher than expected. It was also conjectured that these discrepancies are prevalent during summer months; and b) beat-sounds can become very pronounced during stable and very stable conditions.

The research uses a set of measurements near one wind farm as well as wind data from locations between 10 km and 40 km from the wind farm area. The whole thrust of the dissertation is to prove the hypotheses listed above.

The dissertation is broken into ten chapters, four general sections and four appendices. The chapter titles are: I) Wind power, society and this book: an introduction; II) Acoustical practice and sound research; III) Basic Facts; IV) Loud sound in weak winds; V) The beat is getting stronger; VI) Strong winds blow upon all turbines; VII) Thinking of solutions; VIII) Rumbling sound; IX) General conclusions and X) Epilogue.

Chapter I is basically an introduction and a justification for conducting the doctoral research by van den Berg. The reasons are seen to be based on anecdotal responses rather than from a truly scientific and statistical analysis of response surveys. Chapter II is a strong criticism of acoustic consultants and their inadequate effort in finding the true wind turbine noise levels and their potential impacts.

Chapters III, IV, V and VI are the relevant chapters for this review and assessment. The assessment will be presented in subsequent sections. Chapters VII through X are not critical for the current assessment and will not be commented upon. The assessments are presented next.

2.2 CHAPTER III – BASIC FACTS

Chapter 3 contains four sections and Sections 2 and 4 provide relevant background materials. Section 2 discusses wind profiles and Section 4 presents the many sources of wind turbine sound.

2.2.1 Wind Profiles and Atmospheric Stability

The main contention of this dissertation is that the hub-height velocity can be much higher than predicted with simple formula used currently in standards and other literature. This section presents two simple velocity profile equations to obtain wind velocities at different heights (Equations III.1 and III.3). Eq. III.3 is the standard logarithmic profile used in current literature.

This equation is being questioned as to its validity by this dissertation. Equation III.1 is a simple power law relationship with a shear coefficient as the exponent. Even though the dissertation states that Eq. III.1 has no physical basis, the dissertation applies this equation with ‘suitably chosen’ shear coefficient ‘m’ throughout the dissertation. Equation III.1 has been applied in many areas of engineering application and it is based both on dimensional analysis and empirical relationship obtained from field measurements. These two equations from Reference 1 are presented here for completeness sake.

$$V_{h2} / V_{h1} = (h_2/h_1)^m \quad \text{III.1}$$

where ‘m’ is the shear coefficient, h_1 and h_2 are the two heights and V are the wind velocities at heights h_1 and h_2 .

$$V_{h2 \log} / V_{h1} = \log(h_2/z_0) / \log(h_1/z_0) \quad \text{III.3}$$

where z_0 is a roughness length of the surrounding terrain.

2.2.2 Main Sources of Wind Turbine Sound

A brief summary is presented of the different mechanism of noise generation including the interaction between the mast and the blade. Considerable amount of literature is available that outlines the noise from rotating aerofoil from early 1900s onwards. Hence, the information presented is a summary of earlier research.

However, it must be pointed that the dissertation mentions and/or presents information throughout the dissertation either heuristically or by presenting only scant data. One such case can be seen in Chapter III where it is stated, “An overview of stability classes with the appropriate value of m is given in Table III.1.” No documentary evidence is given for the chosen values of ‘m’ or how the appropriateness of ‘m’ was determined. The reason this point is made here is the ‘stability class’ designation can change drastically depending on the value of ‘m’. Table III.1 of Reference 1 is reproduced below.

Table III.1: stability classes and shear exponent m

Pasquill class	name	comparable stability class [TA-Luft 1986]	m
A	very unstable	V	0.09
B	moderately unstable	IV	0.20
C	neutral	IV2	0.22
D	slightly stable	IV1	0.28
E	moderately stable	II	0.37
F	(very) stable	I	0.41

2.3 CHAPTER IV: LOUD SOUNDS IN WEAK WINDS – EFFECT OF THE WIND-PROFILE ON TURBINE SOUND LEVEL

This is one of the most important chapters in the dissertation. The main hypothesis of the chapter is to show that the hub-height velocity can be higher than predicted from the 10 m high wind speeds using standard methods during stable and very stable atmospheric conditions and hence the wind turbine noise levels can be higher than expected even though the ground level velocities can be small at 2 m and 10 m heights. Such a wind-profile is possible when the atmospheric stability class is a combination of Pasquill Classes E and F with quiet winds and no cloud cover.

Chapter IV is supposed to prove the above hypothesis with scientific support.

2.3.1 Basic Assessment

The first three sections of the chapter provide background information on the Rhede wind farm in northwest Germany that abuts Netherlands. Even though, the noise assessment showed that the wind farm complies with both German and Dutch guidelines, nearby Dutch residents complained about the noise levels. The Science Shop for Physics of the University of Groningen (van den Berg's faculty) was retained to assist the residents to resolve their concerns. Section 3 presents anecdotal responses of two residents and their perception of wind turbine noise – 'pile driving sound', 'thumping sound', 'endless train sound' and such. There is no subjective polling under a blind survey to accompany the technical data presented.

2.3.2 Sound Emission and Sound Immission Levels

Long-term noise measurements were conducted at two receptor locations near the Rhede Wind Farm at two different time periods. Location A is 400 m west of the wind farm and Location B is 1500 m west of the wind farm. Wind velocities at 2 m and 10 m heights were measured only at Location A. ***NOTE: It must be pointed out that wind speeds at hub-height were not measured.*** The area around Location B has both low and tall trees in its vicinity. The following explanation and we quote, “As, because of the trees, the correct (potential) wind velocity and direction could not be measured on location B, wind measurements data provided by the KNMI were used from their Nieuw Beerta site 10 km to the north. These data fitted well with the measurements on location A” was offered to justify the use of data from a far-off wind-measuring location. The above statement is heuristic at best since no data (figures and/or tables) were provided to back the above claim. Hence, it was very difficult to make sense of the data presented in the dissertation document. Similarly, meteorological data from Elde site (40 km to the west) was used to establish neutral and stable atmospheric classes for the above two sites. Even though the section states that not all Elde observations would be valid for Locations A and B, the report still used the Elde information without qualifying its validity.

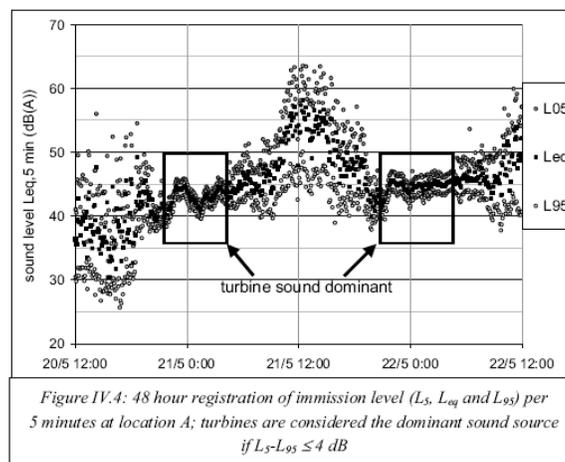
The main aim of the fourth chapter was to show that the atmospheric class during night is ‘stable’ or ‘very stable’. The stable classes, supposedly, produce hub-height wind speeds that are higher than day time values, even though the 10 m high wind speeds could be low at night and the standard wind profiles are not able to predict the high hub-wind speeds at night. The outcome of the above hypothesis is that the night time noise levels, therefore, are higher than expected. However, as shown above, the establishment of atmospheric classes itself becomes suspect. Hence, the subjective perception that the noise levels were high may be due to low ambient sound levels during the late evening and night time hours, thereby making the wind farm noise audible.

2.3.2.1 Sound Emission Levels

Sound emission levels are the sound levels generated by the wind turbines and it is crucial to extract the levels from field measurements of overall levels. The noise levels from nine turbines were measured (Section 6) and an empirical relationship between the sound power and turbine rpm was established. The resulting sound power levels were used to calculate the noise levels at receiver locations and compare them with local measurements.

2.3.2.2 Sound Immission Levels

Sound immission, a phrase used in Europe, refers to the sound levels at receptor locations. Sound immission levels at Locations A and B were discussed in Section 7 of Chapter IV of Reference 1. The data provided is very difficult to analyse and at times very confusing. 371 hours of data for Location A and 1064 hours of data for Location B were collected. Since the monitors were un-manned, the differences in A-weighted sound levels between the 5th and 95th percentiles over 5-minute intervals were used to determine the dominance of turbine sound. The report uses a value, $L_5 - L_{95} \leq 4$ dBA, to deduce (Figure IV.4 of Reference 1) the duration of high sound levels at night time and at day time. There was no reason given as to the selection of the 4 dBA number. One would have expected a lower value, if the wind turbines were the main dominant noise sources. Actually, the value was close to 3 dB as described in Chapter V of Reference 1 (page 71 – $R_{bb,90}$ at Location P was around 3 dB). Figure IV.4 is reproduced below.



The criterion of $L_5 - L_{95} \leq 4$ dBA to determine the dominance of wind turbine noise is critical to the assessment. If the sound was steady during the 5-minute period, the above difference would be zero. Since outdoor sound levels are never steady, one would expect some variability. However, it is our belief that 4 dBA range is too high. If one were to reduce the difference to 2 dBA or 3 dBA, the night time duration for dominant sound levels would reduce substantially compared to the results presented in Table IV.3 of Reference 1. Table IV.3 is reproduced below.

Table IV.3: total measurement time in hours and selected time with dominant wind turbine sound

Location	total time (hours and % of total measurement time at location)	Night	Evening	Day
		23:00-6:00	19:00-23:00	6:00-19:00
A: total	371 h	105	75	191
A: selected	92 h 25%	76 72%	9 12%	7 4%
B: total	1064 h	312	183	569
B: selected	136 h 13%	119 38%	13 7%	4 0,7%

The sound immission levels from all the measurements (the entire 1435 hours of data) were organized into the dominant turbine noise levels based on the 4 dBA difference and presented in Figure IV.5 of Reference 1, which is reproduced below. This figure with four sub-plots, is the most difficult figure to decipher. This is one of the most important figures used to conclusively provide evidence for the main argument of the dissertation. If one does not accept the 4dBA argument, the whole data structure of Figure IV.5 of Reference 1 is suspect. Further to cloud the issue, stable and neutral atmospheric classes, gleaned from Elde data (located 40 kms away) was superimposed. [Reference 1 on Page 47 does state that not all Elde data would be valid for Locations A and B, but continues, anyway, to use the invalid data to determine stability classes]. One must also infer that ‘stable’ classes occur only at night time and ‘neutral’ classes occur during the day time, even though the above was not stated explicitly in the report. No proper explanation was given for applying the above inference.

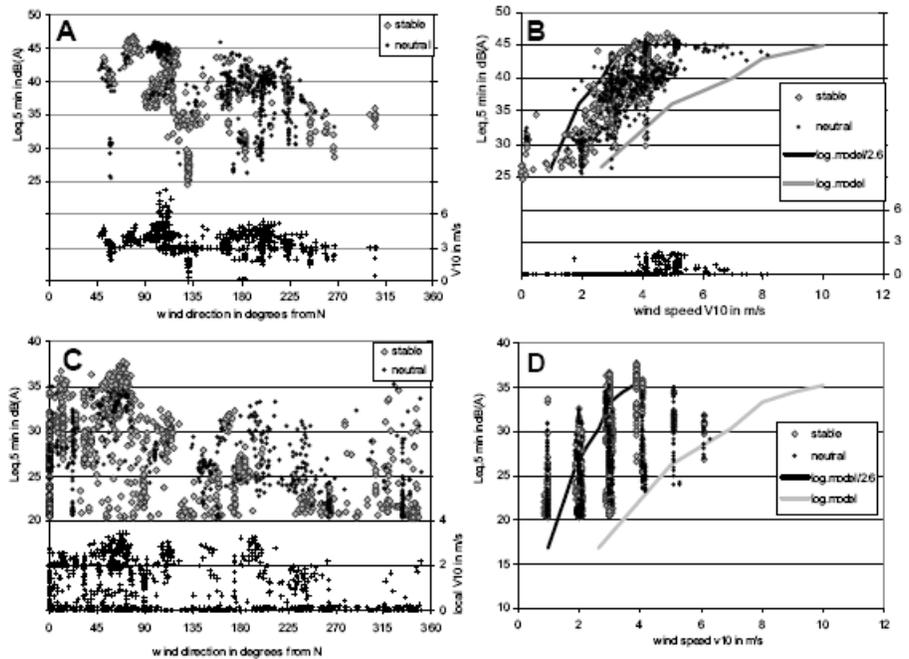


Figure IV. 5: measured sound levels $L_{eq,5 min}$ at locations A (above) and B (below) as a function of median wind direction (left) and average wind speed (right) at reference height (10 m), separated in classes where the atmosphere at Eelde was observed as stable (open diamonds) or neutral (black dots). Also plotted are expected sound levels according to logarithmic wind profile and wind speed at reference height (grey lines in B and D), and at a 2.6 times higher wind speed (black lines in B and D). Figures A, B and C also contain the wind speed $v_{10}(A)$, v_2 (B), and the local v_{10} (C) disturbed by trees, respectively.

Figures IV.5 B and IV.5D Reference 1 present the variation of ‘dominant’ turbine noise levels as a function of wind speed measured at a height of 10 m. **NOTE:** It must be pointed out that no wind speeds were measured for Location B. The data points ($L_{eq, 5 min}$ in dBA) were also separated into ‘stable’ and ‘neutral’ atmospheric classes. In addition, the calculated sound levels from the sound power data from Section IV.6 were also plotted in these two figures. The wind speed at 10 m height for the calculated plot was evaluated using the logarithmic wind profile of Equation III.3 shown in Section 3 of the current assessment report. Since the logarithmic wind profile was supposed to be incorrect, a corrected noise level plot, by applying a factor of 2.6, was also included in Figures IV.5B and IV.5D of Reference 1. These two figures were used to make two strong statements against the procedures used to assess wind-turbine and wind farm noise impacts.

Statement I: ‘Stable’ atmospheric conditions occur at night time and wind turbine noise levels are higher than expected due to high wind-velocities at hub-height.

Statement II: Logarithmic wind profile, generally used in standard procedures, is incapable of predicting current wind speeds at various heights for ‘Stable’ atmospheric classes, occurring at night time. And hence, these higher than expected noise levels occur at night time with low ground wind speeds, thereby, increasing the impact on residents.

However, the two figures do not provide conclusive evidence to support the above two statements for the following reasons. Contrary evidence to Statement I will be further discussed in the next section with field data from New Zealand and Australia.

- a) The ‘stable’ and ‘neutral’ class designations used in the two figures are applied from a location 40 kms away and hence not valid for Locations A and B;
- b) Both classes seem to produce high as well as low sound levels as clearly seen for Location B (Figure IV.5D Reference 1);
- c) The light grey sound level line supposed to represent the ‘neutral’ class quite accurately (as stated in Chapter III of the dissertation). If that were to be true, all of the ‘neutral’ class data points would have collapsed near that line. However, that was not the case, as the data points are scattered all over the figures;
- d) Even at a distance of 400 m from the wind farm (Location A), only a small percentage of the ‘neutral’ class noise levels is near the neutral line;
- e) Finally, if the $L_5 - L_{95}$ value is close to 2 or 3 dBA, the entire dominant sound levels at night time could occur well below the 25% to 35% time presented in this dissertation.

As part of the current investigation Aiolos Engineering undertook a brief review of summer weather data near a wind farm located adjacent to Lake Huron in Southern Ontario. Summer data was reviewed as the main hypothesis of van den Berg is that the wind speed discrepancies due to stability classes are severe during the evening and night hours of summer months. The

objective of this review was to test the rigour of the two “van den Berg” Statements I and II. Since this review was conducted in the context of the current investigation and this report, the scope of the review was limited both in its duration and site selection. The review of this data will show that limited data of the type that van den Berg relied on cannot be used to draw strong conclusions.

Aiolos Engineering compiled wind speed data from one weather station in Ontario for a period of three summer months (June, July and August 2006). The Environment Canada’s weather station at Goderich, Ontario is situated within a few kms of a wind farm with 21 wind turbines. The Kingsbridge wind farm has the capacity to generate 40 MW of power. The data for the three month period was compiled in different formats and the results are presented in Appendix D. The atmospheric stability classes were approximated using the information from the AIR-EIA website (Reference 19). Even a cursory perusal of the Appendix D data would show that the correlation between stability classes and power generation is quite inconsistent. The power generated by the wind farm was obtained from the Independent Electricity System Operator’s data base for Ontario (Reference 34). Unless a detailed study of the wind power generation and wind speed behaviour at the wind farm location is conducted, one cannot make strong conclusions as presented by van den Berg’s work. Another salient observation from Appendix D data is that the wind farm power generation and wind speed behaviour is highly localised, controlled by the local conditions

One must point out at this juncture, that the conjectures presented in van den Berg’s Statements I and II may well be true. However, the research presented in van den Berg’s dissertation has not provided strong scientific evidence for the same. In addition, the data of figures IV.5 clearly shows that the sound levels at Location A, 400 m west of the wind farm is less than 40 dBA and the noise levels at Location B, 1500 m west of the wind farm, is less than 35 dBA for a substantial portion of the measurement period.

2.4 CHAPTER V: THE BEAT IS GETTING STRONGER – LOW FREQUENCY MODULATED WIND TURBINE SOUND.

Chapter V deals with the effect of frequency modulation of the wind turbine noise levels. This chapter is an important chapter since it is supposed to provide evidence that the beating phenomena gets stronger with worst results during the ‘stable’ atmospheric classes. The ‘stable’ atmospheric classes are supposed to occur only during late evening and night time hours and the turbine is supposed to generate higher than expected noise levels with the ambient sound levels at the receivers being low due to lower than expected ground speeds. The inference here, therefore, is that any modulation of higher noise levels would cause additional hardships on the receiver. This chapter aims to show that the above is true.

Chapter V is broken into 3 main sections. Section V.1 discusses the effects of atmospheric stability on wind turbine noise generation. It discusses, three possible effects, purely as theoretical conjunctures that beating (or modulation) can be due to - a) the increase in the angle of attack changes between the blade at its highest location and at its lowest location during stable conditions; or b) increase in the wind direction gradient between the blade at its highest location and at its lowest location during stable conditions; or c) reduced wind turbulence during stable conditions. No supporting experimental evidence was forthcoming. We agree that purely from theoretical consideration that the three possible mechanisms can produce amplitude modulation phenomena. But, does this happen only for ‘stable’ and ‘very stable’ atmospheric conditions and only at night time?

The other major misconception arising out of this chapter is the terms used to describe the said phenomenon – ‘swishing’, ‘thumping’, and ‘beating’. The beating phenomenon in acoustics called *beat* is a special event when two sounds occur with their dominant frequencies very close to each other. A general description of *beating* is presented in Appendix E. The amplitude modulation phenomenon is different from *beating*. The acoustical principles that describe the amplitude modulation phenomenon are generally considered to be related to the movement of the turbine blades through air and the interaction of the blades with the stationary mast. In addition, the amplitude modulation could be caused by the nature of wind itself – random both in speed

and direction. Irrespective of the underlying principles, the amplitude modulation produced by wind turbines is a different phenomenon from acoustical *beating*.

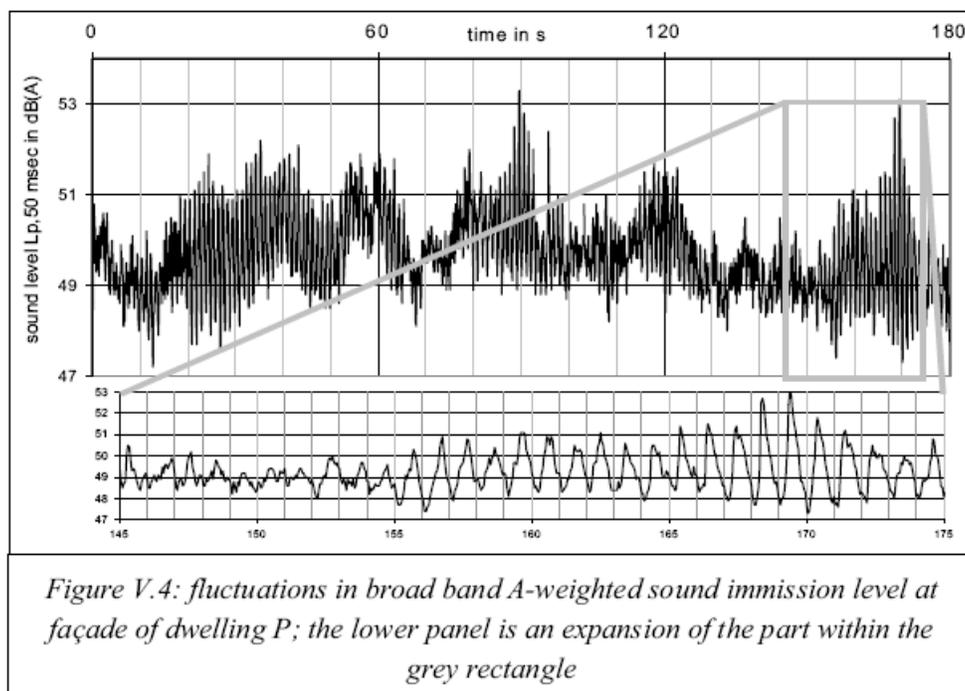
The UK working group on Wind Farm noise (Reference 30) studied the phenomenon of amplitude modulation and found the levels inside residential bedrooms to be below the sleep disturbance level. Importantly, the UK report recommended that further studies be conducted to understand the amplitude modulation better. [Further descriptions of the aerodynamic modulation will be presented in Section 4].

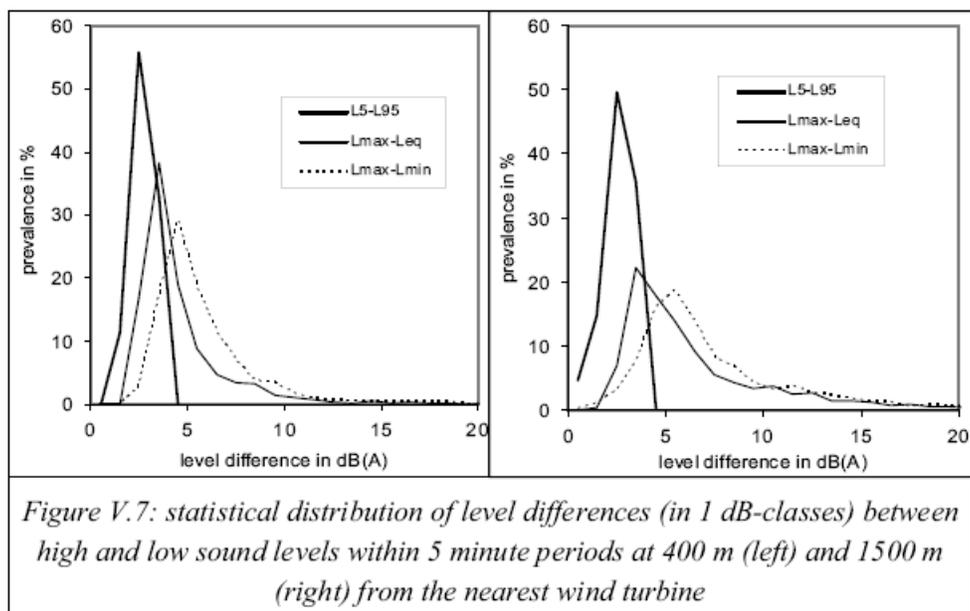
Section V.2 presents measurement at three locations; two near the Rhede wind farm and the third location (Location Z) is near a single small wind turbine. Between 10 and 15 minutes of data were collected. The measurement results are presented in terms of spectral variations. The wind velocity was measured only near one location and the wind speed data for Location Z was obtained from a number of nearby weather stations. Two conclusions were obvious from the results:

- a) the infra-sound, when measured as dBG with the G-weighting scale, was found to be not audible, approximately between 15 – 20 dB below the threshold of perception, indicating that modern wind farms do not generate infrasound levels that are perceptible. For information on G-weighting network, please see Reference 31;
- b) the A-weighted sound levels correlated with spectra around 400 Hz which indicates the major source is the trailing edge noise.

The main thrust of this chapter was to discuss the amplitude modulation phenomena. The modulation at Location P was audible during the measurements period, but very small at Locations R and Z. The main effect of the modulation is not to produce low frequency sounds, but change the amplitudes which are discernable by the receivers. The results showed amplitude modulation at Location P with a variation of about 5 dBA between maximum and minimum. Even though the measurements were conducted for a long duration, only 180 second of measured data was shown to prove the existence of the modulation (beating) in Figure V.4 of

Reference 1. The modulation was seen to be strong only for 30 seconds. Even though the variation was 1 dB more at Location R, no modulation was discernable. No explanation was given for these discrepancies. Even though the level variation did not indicate beating at Location R, the level variations for Locations A and B from Chapter IV were shown in Figure V.7 of Reference 1 to conjecture that modulation would happen at these locations, 28% of the time and 18% of the time respectively. Since the measurements at Locations R, P and Z were conducted at early morning hours (midnight), it was assumed to be stable weather conditions. No data was provided to substantiate the absence of modulation during other weather conditions, such as 'neutral' and/or 'unstable' atmospheric classes. Hence, one cannot immediately conclude that modulation occurs only during the 'stable' and 'very stable' atmospheric class. Figures V.4 and V.7 of Reference 1 are reproduced below,





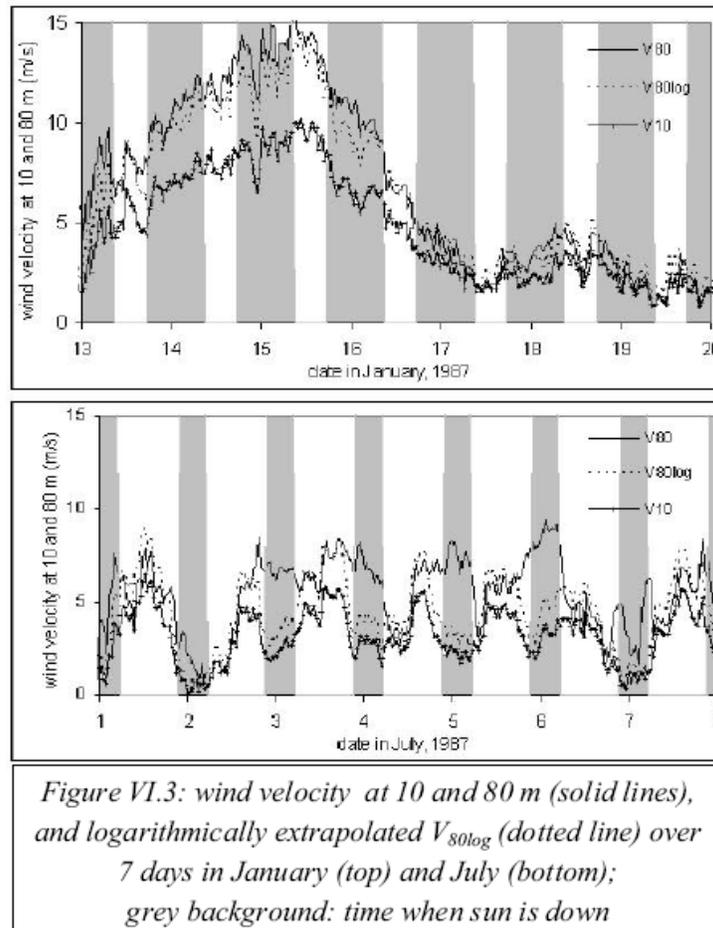
Finally, Section V.3 discusses the perception of the modulated sound. It begins by quoting the subjective response work of Pedersen and Waye (Reference 5) that about 20% of residents would be annoyed with noise levels in the range of 37.5 dBA to 40 dBA. It then jumps to anecdotal responses of two residents near the Rhede farm. There are no studies cited in van den Berg's work that show a correlation between modulated sound and annoyance and hence van den Berg conjectures the annoyance would be worse since the expected amplitude variations make the perception of the sound strong. However, no evidence other than anecdotal responses was forthcoming.

2.5 CHAPTER VI: STRONG WINDS BLOW UPON TALL TURBINES – WIND STATISTICS BELOW 200 M ALTITUDE

This chapter deals with actual wind speed data from one site in western part of the Netherlands. The wind velocities at different heights, 10 m, 20 m, 40 m, 80 m, 140 m and 200 m were measured at half-hour intervals. The results, averaged for the entire year showed that higher wind velocities compared to the predicted wind speeds from the 10 m high wind velocity, indicating a stable atmosphere. Even the daily variations over seven days in summer months are small during the night time hours (Figure VI.3 of Reference 1, reproduced below).

The data described in Section 2.3.2.2 and presented in Appendix D was further analysed to look at the daily variations in wind speeds. In addition to Goderich weather station, the data from a few more weather stations located within 30 km radius of existing wind farms were compiled by Aiolos Engineering. Figures 2.1 thru' 2.6 show results of one-hour averaged wind speeds from three weather stations near three wind farm sites in southern Ontario. The weather data was collected at a height of 10 m above ground. The daily variations for a few summer days shown in Figures 2.1, through 2.6 seen to indicate substantial variations in wind speeds from day to day. As was explained in Section 2.3, summer data was reviewed as the main hypothesis of van den Berg is that the wind speed discrepancies due to stability classes are severe during the evening and night hours of summer months.

The measurement results of Botha [Reference 22] for four sites in New Zealand and Australia showed contradictory results of wind speed gradient. They will be discussed in Section 4. Hence, the main conclusion here is that the data presented in Chapter VI of Reference 1 is valid only for that one site in Netherlands.



The chapter then calculates expected power production at these velocities as well as calculates noise levels from the wind farm. The results show that the discrepancy for the Cabauw site between stable noise and standard logarithmic wind profiles is of the order of 2 dB. These differences are averaged from one site. The main drawback of the results of this chapter is that they are not transferable to every wind farm site in the world.

One must point out that it may be possible that during summer months stable and very stable conditions may exist at night time producing higher than expected noise levels and hence increasing the impact. However, the data presented so far does not lead one directly to that conjecture.

Figure 2.1 Elora Wind speeds

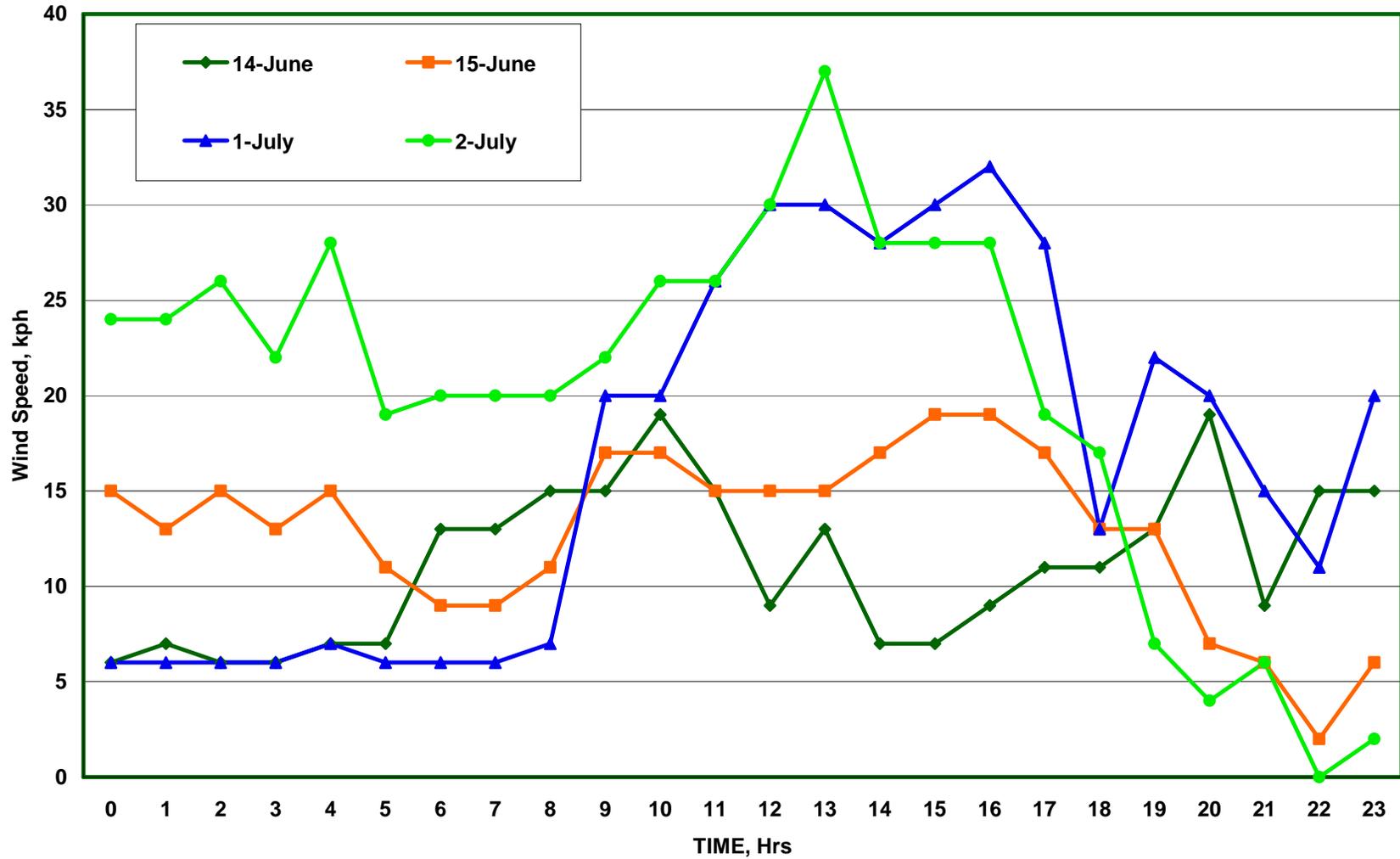


Figure 2.2 Elora Wind speeds - 2.

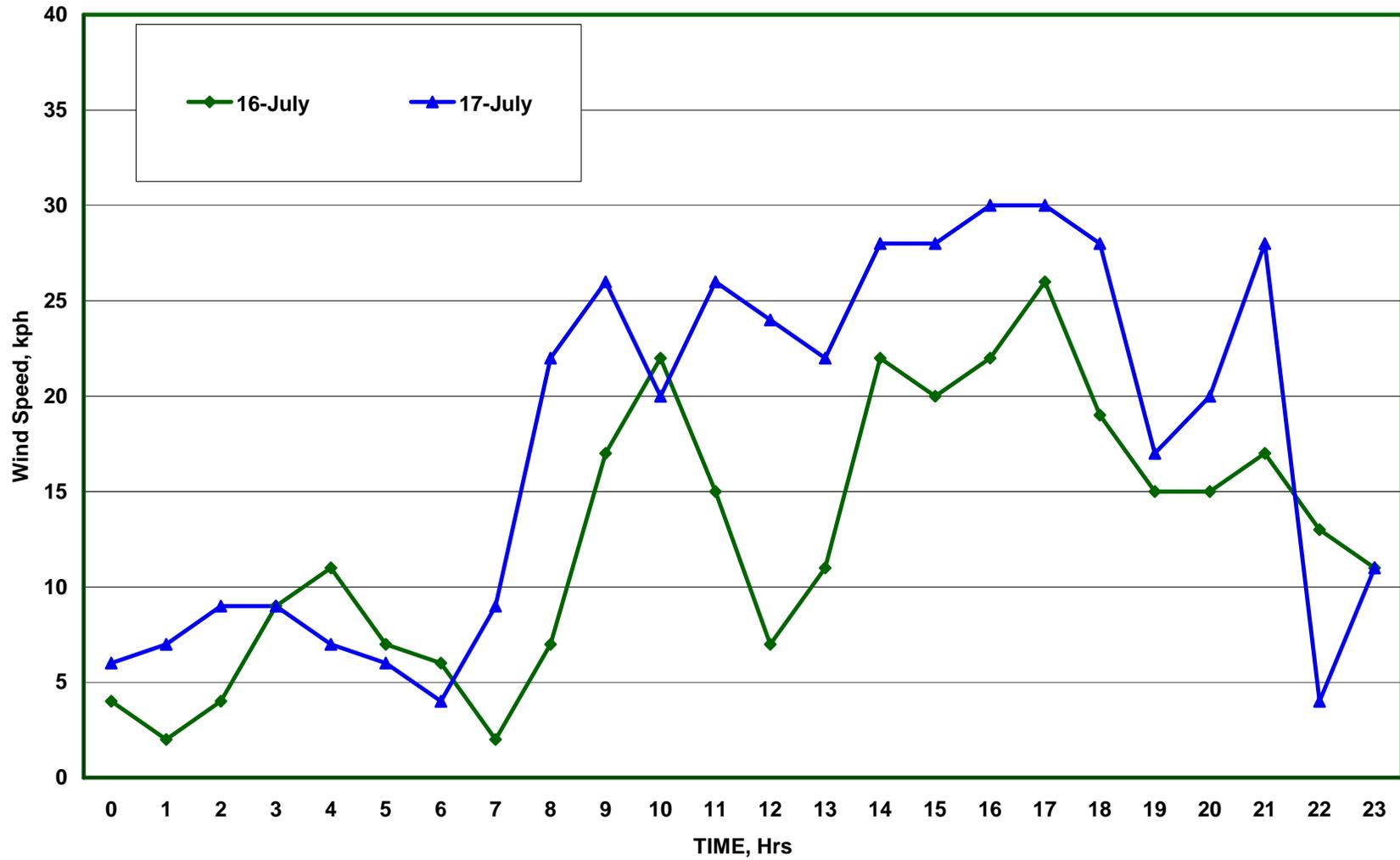


Figure 2.3 Goderich Wind speeds

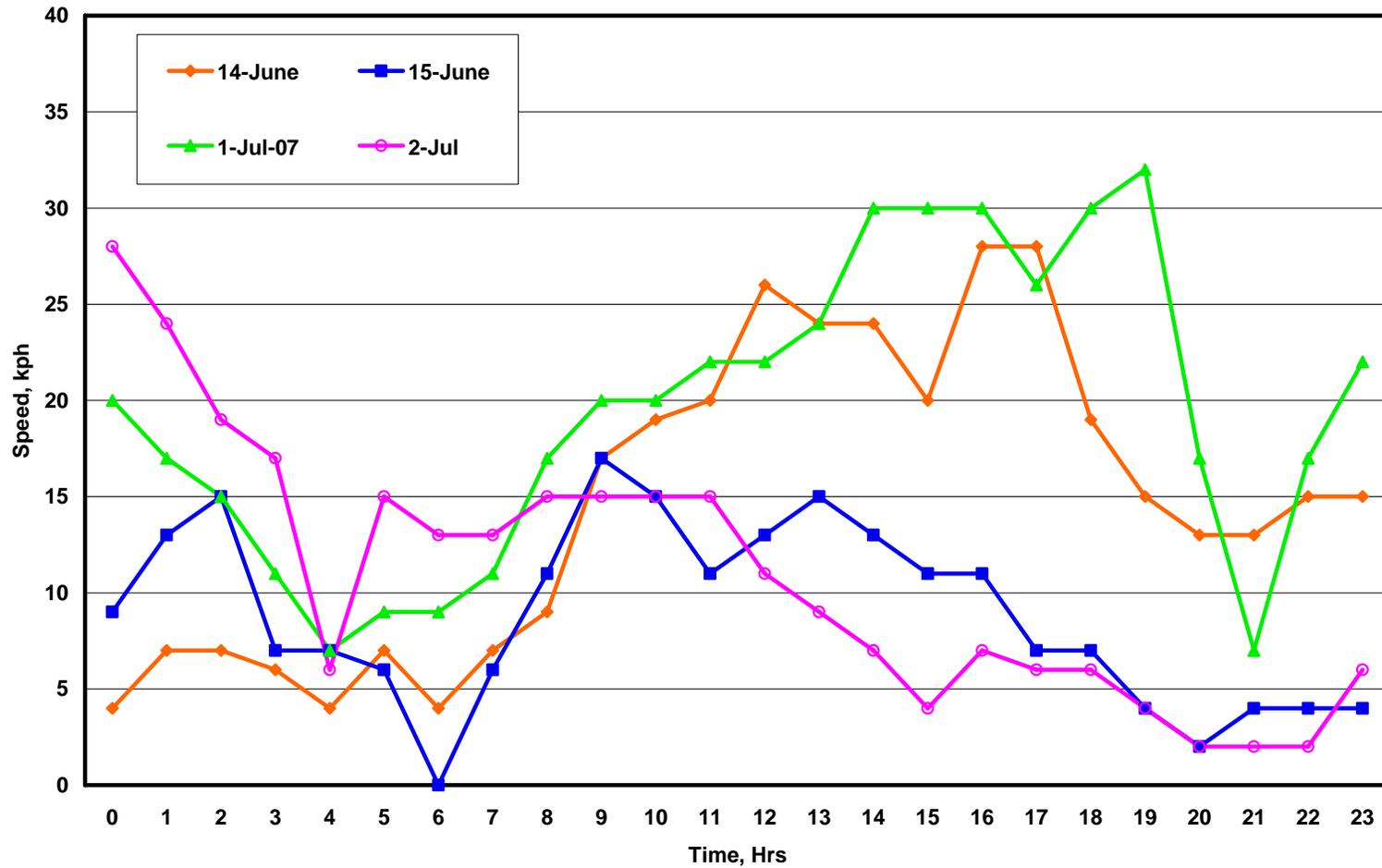


Figure 2.4 Goderich Wind speeds - 2

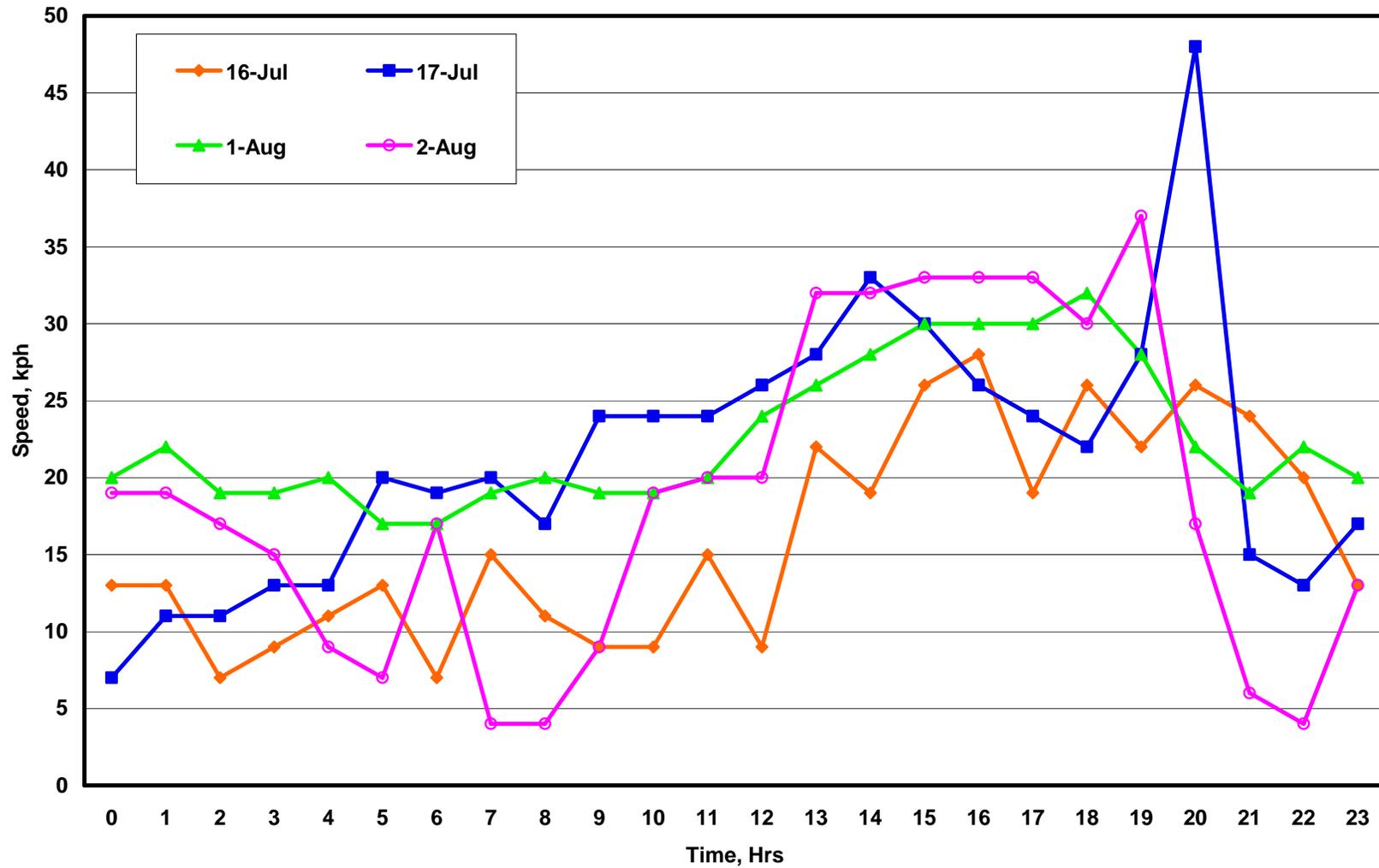


Figure 2.5 Elora and Goderich Wind speeds.

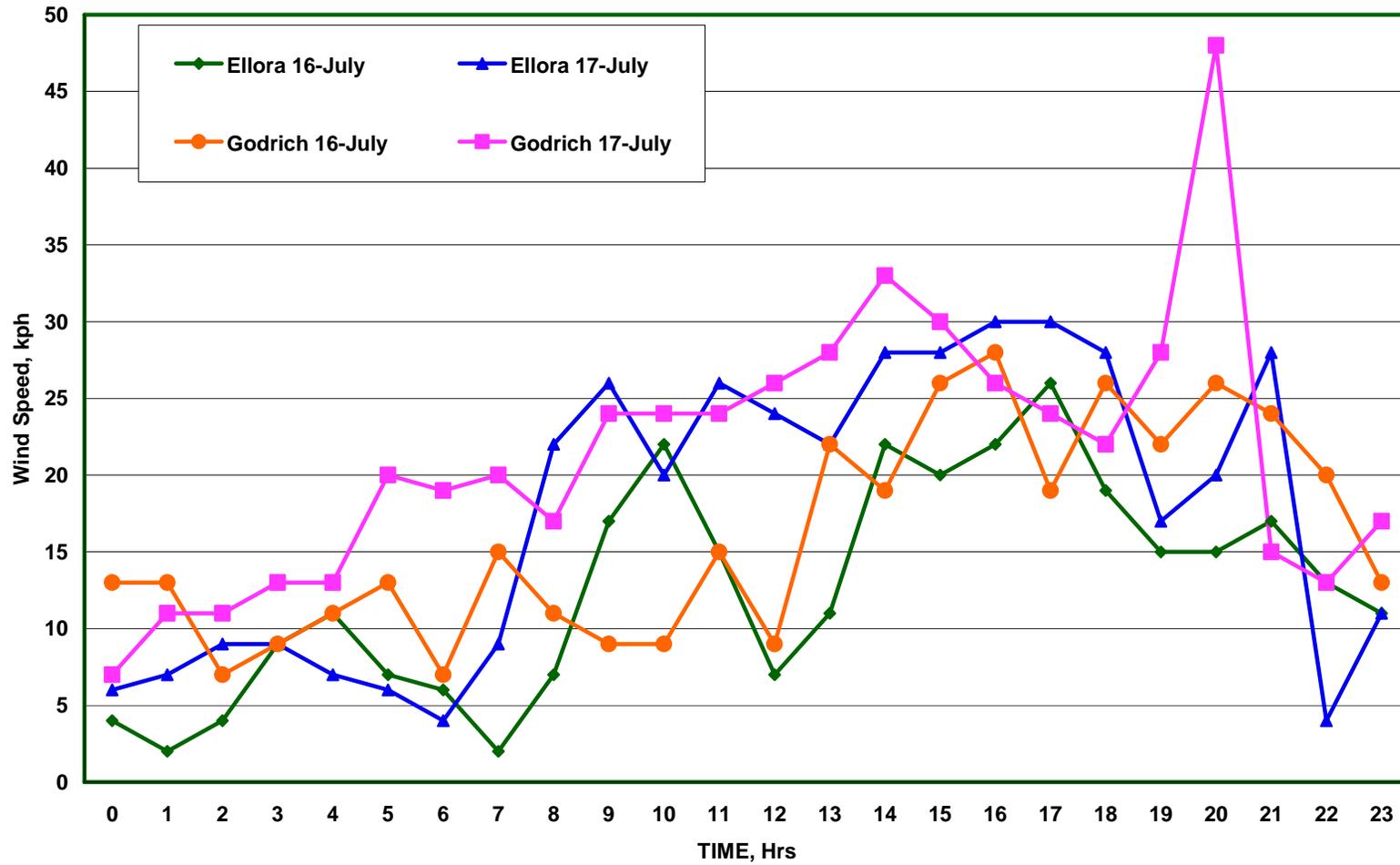
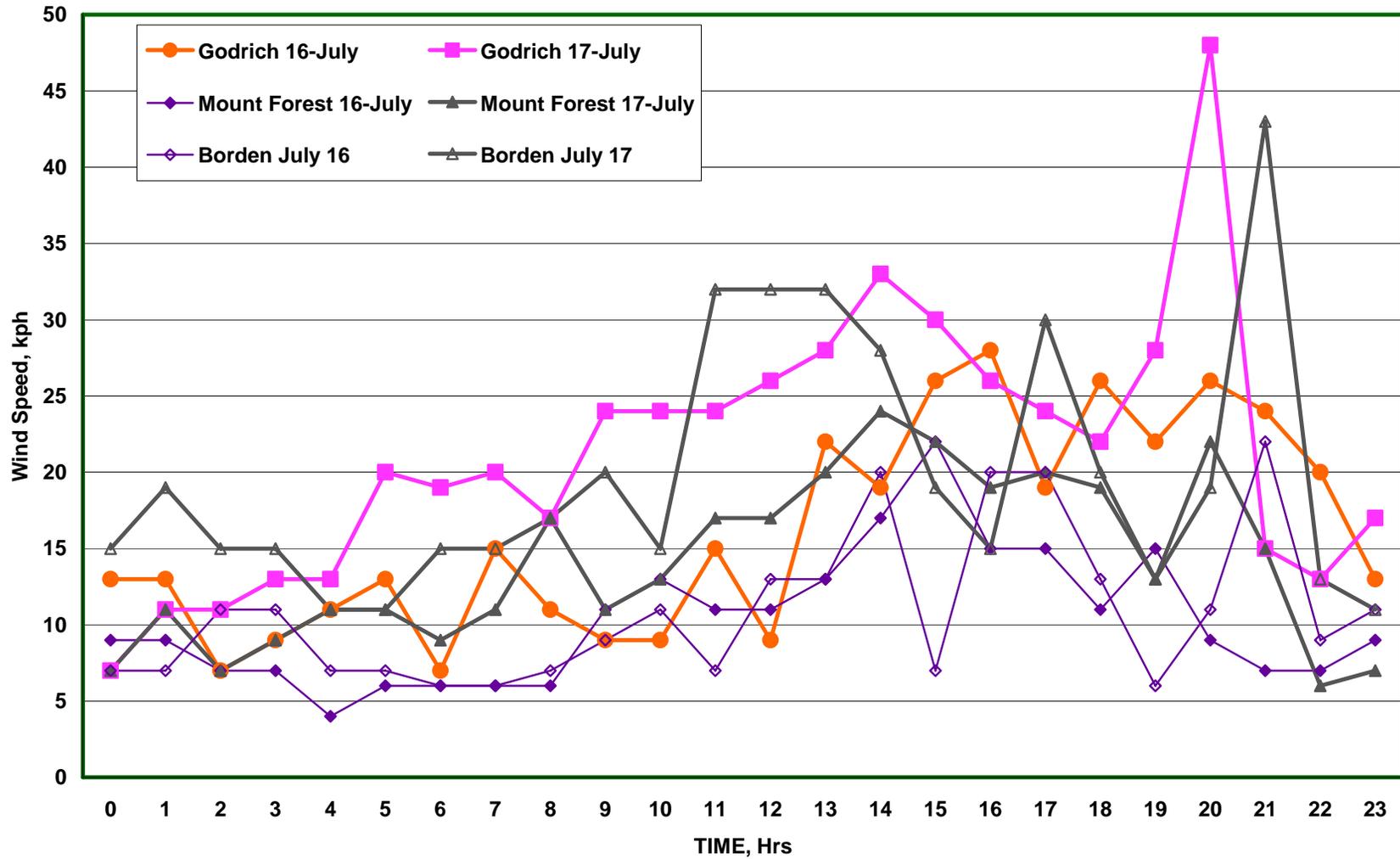


Figure 2.6 Borden, Mount Forest and Goderich Wind speeds.



2.6 SUMMARY

The doctoral dissertation of G. P. van den Berg was reviewed and comments were provided in this section. The dissertation was to provide scientific evidence for increased annoyance from wind farm during evening and night time hours. The review showed the above was not the case and the review comments are summarized below.

One of the main criticisms of the doctoral dissertation of van den Berg is that the conjectures of his research have not been supported by solid scientific data.

The major deficiencies of the doctoral dissertation are highlighted below:

- A) Simultaneous noise measurements and subjective response from a random sample of the residents were not performed other than a few anecdotal responses;
- B) The wind velocities at various heights were not conducted either at the turbines or near them to evaluate the atmospheric classes, but applied weather data from a location 40 kms away;
- C) The wind farm noise levels at receptors were unmanned and the procedure to evaluate the dominance of turbine noise may not be correct.
- D) The immission levels measured at 400 m and 1500 m distances had a large scatter to provide strong conclusions. **NOTE:** It must be pointed out that the receptor noise levels, for a substantial portion of the measurement period, were less than 40 dBA at a location 400 m away and less than 35 dBA at a location 1500 m away.
- E) The *beat* of acoustics is being identified, wrongfully, with amplitude modulations and no strong evidence was provided to show the modulation gets worse at night compared to day time in the summer.

Despite the rather strong conclusions of Reference 1 some of the basic conjectures in the dissertation merit further examination. Hence, the research of van den Berg may be considered as the catalyst that started serious discussion on many aspects of wind farm noise. Future research must therefore provide stronger scientific data to validate these different noise concerns.

3.0 REVIEW OF AVAILABLE NOISE POLICIES AND GUIDELINES

The second task for the current project was to provide an evaluation of the noise policies on Wind Turbine noise applied in jurisdictions other than the Province of Ontario.

The noise policies from different Canadian provinces, USA states and a few other countries were reviewed. The regulations from Germany and the Netherlands were gathered from other review papers. [See for example Reference 18].

General comparison of the noise regulations is presented in Table 3.1.

3.1 WHO GUIDELINES FOR COMMUNITY NOISE (Reference R1)

The community noise guidelines are the result of significant amounts of research in the relationship between noise and health. There is an understanding that noise pollution can be the cause of serious health effects through short term and long term, or cumulative, exposure. The guidelines include the values of what the World Health Organization feels to be the thresholds to health effects in various situations. The limit that has been listed in an outdoor living area, such as around a dwelling, is 50 dBA for moderate annoyance. Once the sound level has increased to 55 dBA, it is considered to be a serious annoyance. For indoors, the World Health Organization recommends the noise level to stay below 35 dBA before moderate annoyance occurs, and below 30dBA to avoid sleep disturbance at nighttime. For conditions at nighttime with an open window, the suggested limit is 45 dBA to avoid sleep disturbance. Many of the documents below reference these guidelines in the justification of selecting certain noise limits, although the Ontario Ministry of the Environment publication does not. They are also widely referred to in other literature relating to noise level limits.

Table 3.1 Comparison of Noise Regulations.

Jurisdiction	Daytime Limit	Nighttime Limit	Background SPL Establishment	Wind Turbine SPL Establishment	Minimum Setback	How Impact is Assessed
ONTARIO	Whichever is greatest: - Urban Areas, wind speeds below 8m/s: 45 dBA or hourly background level - Rural Areas, wind speeds below 6m/s: 40 dBA or hourly background level - Wind speeds above 8 and 6 m/s each type: wind induced background level LA ₉₀ plus 7dBA or hourly background level		NPC-205 or NPC-232 whichever is higher	IEC 61400-11, to be provided by manufacturer	N/A	Impact Assessment to ISO 9613 method to be submitted prior to approval for critical points of reception up to 1000 m.
Alberta	Nighttime + 10 dBA	40 dBA – 56 dBA minimum	Pre-assumed based on proximity to transportation and number of dwellings OR 24 hours, 10 min. intervals in special cases	Modeling at wind speeds of 6 to 9 m/s to achieve worst-case scenario	N/A	Noise Impact Assessment Required to be submitted for application – form given in document Noise measurements, including CSLs <i>recommended</i> for speeds 4 to 6 m/s between 1.2 and 10 m above grade
British Columbia	40 dBA at residential property		N/A	Modeling of 8-10m/s wind speeds at 10m height to be provided by manufacturer	Siting to conform to ISO 9613-2	Risk assessment required if the difference between modeled SPL and acceptable limit is close -Measurements made if complaint is filed

Jurisdiction	Daytime Limit	Nighttime Limit	Background SPL Establishment	Wind Turbine SPL Establishment	Minimum Setback	How Impact is Assessed
Quebec	Sensitive Land: Type I = 45 dBA Type II = 50 dBA Type III = 55 dBA Non Sensitive Land: Type IV = 70 dBA Dwelling on Industrial Land: 55 dBA	Sensitive Land: Type I = 40 dBA Type II = 45 dBA Type III = 50 dBA Non Sensitive Land: Type IV = 70 dBA Dwelling on Industrial Land: 50 dBA	Length of time to current practiced standards – not specified. Measurements to fully cover reference intervals favoured	N/A	N/A	Measurements taken post-construction to ensure conformity, assess impact
New York (Town of Clinton)	50 dBA or Ambient + 5 dBA		Highest whole number in dBA exceeded for more than 5min per hour (requires independent certification)	IEC 61400-11 or other accepted procedures	- 500 ft from property line or road - 1200 ft from nearest off-site residence - 2500 ft from a school, hospital or nursing facility	Independent certification required before and after construction that noise limits are met.
Maine	Residential: 60dBA Comm/Ind.: 70 dBA Rural: 55 dBA	Residential: 50dBA Comm/Ind.: 60 dBA Rural: 45 dBA	Estimation based on population within 3000m radius or measurements during all hours the development will operate	N/A	N/A	Post-development one-hour equivalent measurements to be made
Pennsylvania	Fifty (55) dBA (note: this is what is in the document, not a typo here)		N/A	AWEA Standard 2.1 - 1989	1.1 x turbine height (consenting) or 5 x hub height (non-consenting)	N/A
Washington	Residential: 60 dBA Commercial: 65 dBA Industrial: 70 dBA	Residential: 50 dBA Commercial: 55 dBA Industrial: 60 dBA	N/A (Environmental noise measurement procedure is reserved)	N/A	N/A	Noise measurement only made if a complaint is filed

Jurisdiction	Daytime Limit	Nighttime Limit	Background SPL Establishment	Wind Turbine SPL Establishment	Minimum Setback	How Impact is Assessed
Oregon	Ambient + 10 dBA		26 dBA assumed	IEC 61400-11	350m minimum, or 1000m non-consenting	
Michigan	55 dBA or $L_{90} + 5$ dBA		55 dBA assumed, not indicated for higher levels	IEC 61400, ISO 9613 (modeling)	1.5 x height of tower including blade in top position	ANSI S12.18 (post construction), ISO 9613 model
Australia	35 dBA or $L_{A90,10} + 5$ dBA		Minimum of 2000 data points of background noise and wind speed pairs with a best fit curve	IEC 61400-11, must be overlaid on graph of background sound levels	N/A	Demonstration of compliance at all relevant receivers, if compliance is not demonstrated, operation will be restricted
New Zealand	40 dBA or $L_{95} + 5$ dBA		NZS 6801 (10-14 days of continuous monitoring)	Obtained from Manufacturer	N/A	Measurements taken if necessary, to follow same procedure as background levels
UK (Britain)	$L_{90, 10min} + 5$ dBA OR 45dBA OR 35-40 dBA	43 dBA or 45 dBA	Minimum 7 days continuous 10 min interval monitoring	IEA Recommended Practice – using 8m/s at 10m height	N/A	Measurements made if complaint filed; no formal impact assessment required
Ireland	45 dBA or $L_{90} + 5$ dBA OR 35-40 dBA if $L_{90} < 35$ dBA,	43 dBA	10 minute intervals	N/A	N/A	N/A

Jurisdiction	Daytime Limit	Nighttime Limit	Background SPL Establishment	Wind Turbine SPL Establishment	Minimum Setback	How Impact is Assessed
Denmark	45 dBA in open areas 40 dBA near residential		Annex 1 of the document; requires regression analysis of min. of 10 L _{Aeq} values measured for at least one minute each over different wind speeds	EN 45000 standards or min. of 10 L _{Aeq} values measured for at least one minute each over different wind speeds – see Annex 1 of document for full procedure	N/A	- Calculations of noise level at nearest property - Measurements after operation has begun or when deemed necessary, but not more than once per year
Germany	55 dBA/50 dBA in residential areas and 45 dBA in areas with hospitals, health resorts etc.	40 dBA/35 dBA in residential areas and 35 dBA in areas with hospitals, health resorts etc.	N/A	Recommended Practice – using 10 m/s at 10m height	-	- Calculations of noise level at nearest property, using DIN ISO 9613-2.
Netherlands	50 dBA	40 dBA (night) 45 dBA (evening)	N/A	-	-	-

3.2 NORTH AMERICAN NOISE LEVEL LIMITS AS APPLIED TO WIND TURBINES

The situation in North America in terms of noise level limits for wind turbines is currently under development. Many jurisdictions are only beginning to draft standards specifically for wind turbines, and few have gone beyond the draft stage. This is true for both the United States and Canada, where wind is still a relatively under-utilized energy source. There are a number of examples of noise level limits below from the Northern U.S. States, and some Canadian provinces, and they represent the variability from one jurisdiction to the next.

3.2.1 Ontario - Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators (Reference R2)

The Ontario Ministry of the Environment has produced a document listing noise requirements for wind turbines. The document segregates development into three separate classes, the first two referring to urban environments, and the third referring to a rural environment. The sound level limits are dependent not only on their classification, but on the wind speed also. Where wind speeds are lower than 8 m/s in an urban environment, the hourly equivalent sound level from the wind turbine facility must not exceed 45 dBA or the hourly background sound level, whichever is greater. Similarly, in a rural environment where wind speed is less than 6 m/s, the hourly equivalent sound level must not exceed the greater of 40 dBA or the hourly background sound level. In the cases where the wind speeds exceed these levels, rather than a fixed limit, the sound level is permitted to be the wind induced background sound level, L_{A90} , plus 7 dBA. This is demonstrated in the Table 3.2 below.

Table 3.2. Ontario Noise Assessment Limits

Wind Speed (m/s)	4	5	6	7	8	9	10	11
Wind Turbine Noise Criterion NPC-232 (dBA) (Rural)	40	40	40	43	45	49	51	53
Wind Turbine Noise Criterion NPC-205 (dBA) - (Urban)	45	45	45	45	45	49	51	53

The noise limits apply to both daytime and nighttime periods, with the level being measured at the nearest point of reception: a location within 30 m of an existing or zoned for future dwelling. After a distance of 1000 m between the wind turbine facility and the point of reception, a detailed noise assessment is not required.

3.2.2 Alberta - EUB Directive 038 Noise Control (Reference R3)

Of all the documents reviewed, the sound level limits for wind farms are perhaps the most complicated to determine in the province of Alberta, Canada. Primarily, the permissible sound level, PSL, depends on the location of the nearest residences. If there are no dwellings within 1.5 km, the limit is a fixed 40 dBA (this corresponds to an increase over the assumed ambient sound level of 35 dBA in rural areas). However, if there are places of residence, the PSL must be determined by the following equation:

$$\text{PSL} = \text{Basic Sound Level} + \text{Daytime Adjustment} + \text{Class A Adjustment} + \text{Class B Adjustment}$$

The Basic sound level is the main component of the sound level limit and ranges from 40 dBA to 56 dBA, depending on the receiving property, and is selected from a table. The daytime adjustment allows the addition of 10 dBA to the PSL during the time period of 7 a.m. – 10 p.m. The other adjustments, Class A and Class B, require technical verification to be applied, and are only done so in specific circumstances. In order to properly determine the ambient noise level and the wind farm development's noise emissions, certain procedures must be followed which are documented in the directive. For example, the ambient sound level measurement requires continuous monitoring over a 24-hour period, 15m away from the nearest dwelling. The environmental conditions at the time of the measurements are also strictly detailed. Although their sound level limits are higher than the MOE limits, similar documentation is required, such as a noise impact assessment.

3.2.3 *British Columbia - Land Use Operational Policy: Wind Power Projects*
(Reference R4)

The British Columbia policy regulating noise from wind turbines enforces a fixed limit of 40 dBA during all hours of the day. This limit is more restrictive than in Ontario, where allowances for higher sound levels are made when the wind speed increases. This limit is to be measured at the exterior of the nearest permanently occupied residence and/or the property line of undeveloped land zoned for future residential use. The siting must conform to ISO 9613-2, which is referenced by other jurisdictions, including Ontario, for use in impact assessment. The modeling is also similar to other jurisdictions, requiring the sound power level (PWL) to be estimated for 8-10 m/s wind speeds at a 10 m height. Should the modeling demonstrate that the estimated level is close to the acceptable limit, the policy requires that a risk assessment be conducted prior to approval. Testing of the sound levels of the facility post-construction is performed if a complaint is filed.

3.2.4 *Québec - Instruction Memo 98-01 on Noise (Note: revised as of June 9, 2006)*
(Reference R5)

Quebec does not have a specific document relating only to wind turbines; the applicable paper discusses noise from all fixed sources. Different limits have been assigned based on the land use of the receiving property and the residual level of noise in the area. The location of measurement is at a distance 3 m or more from reflective structures, and 0.5 m from an open window. All sound levels averaged during a period of one hour must comply with these limits. There are two main categories of land use: sensitive zones (i.e. residential, hospitals, schools) and non-sensitive (agriculture and industrial use) zones. See table below for limits. In the case of a dwelling on agricultural land, the limits for a sensitive zone apply. For dwellings on industrial land, a 50 dBA nighttime limit and a 55 dBA daytime limit will apply. In terms of sensitive areas, the noise limits are comparable to those in Ontario, although there are different levels for day and night. However, an exception is given in the case of industrial and agricultural land, unless a dwelling exists, for the sound level limits to be much higher. The sound that is measured at the receiving property is based on an equation given in the document, accounting for the equivalent sound level of the source, and corrective factors to account for impact noise, tonal noise and

special situations. However, the length of time that applies is up to the discretion of the person performing the evaluation, and should correspond to the current practice methods. Similarly, when measuring background noise, measurements taken that cover the full reference range are favoured, but not required. Post construction, measurements must be taken to ensure the compliance of the facility with the appropriate limits.

Table 3.3 Noise Regulations in Quebec

Zone	Night	Day
I – Sensitive – Single family dwellings, schools, hospitals	40dBA	45dBA
II – Sensitive – Multi-residential and camping areas	45dBA	50dBA
III – Sensitive – Commercial use and park land	50dBA	55dBA
IV – Non-sensitive – Industrial or Agricultural	70dBA	70dBA

3.2.5 Oregon - Revising Oregon's Noise Regulations for Wind Turbines
(Reference R6)

Oregon has recently undergone a revision to its existing noise standards, which were last updated in the 1970s. There are two tests, or limits, that apply in the case of wind turbine developments, the Table 8 test (refers to Table 8 in the regulation) and the ambient degradation test. The authors of the revision have taken steps to coordinate their standard with that of the British and Australian guidelines on wind turbine noise. They have assumed a standard ambient background L_{50} of 26 dBA, although extensive documentation can be submitted for background noise greater than this level. The noise level limit is not allowed to increase the ambient noise levels by 10 dBA in any one hour, thus having an assumed limit of 36 dBA, which is lower than the MOE limits. It is also low enough to respect the WHO guidelines for indoor levels without accounting for sound reduction through walls. This limit applies to both daytime and nighttime, just like the MOE limits. However, unlike the Ontario requirements, there are also setbacks that must be adhered to; a minimum of 350 m for a consenting owner, and 1000 m between the nearest wind turbine and the property of a non-consenting owner. The methods of evaluating the sound created by the wind turbine development use the same methods that the majority of manufacturers provide to make things easier. The project must be evaluated under the maximum

sound power level conditions according to IEC 61400-11 (8 m/s at 10 m height), but no correlation between 10 m and hub height is assumed.

Table 3.4 Oregon’s Table 8 Limits, dBA

Statistical Descriptor	Daytime (7 a.m. – 10 p.m.)	Nighttime (10 p.m. – 7 a.m.)
L ₅₀	55	50
L ₁₀	60	55
L ₁	75	60

NOTE: Maximum Permissible levels for New Industrial and Commercial Noise Sources, dBA - As in Bastasch, Noise-Con 2004, originally from OAR 340-35-035.

3.2.6 Pennsylvania - Wind Farm Model Ordinance Draft 12-08-06 (Reference R7)

The draft document developed in Pennsylvania is a model document prepared for the use by different local municipalities. It is not the regulation for the entire state. Local municipalities can use the draft document to prepare their own policies and guidelines. There is only one limit in the Pennsylvania draft, which applies to both daytime and nighttime. The sound level limit is slightly unclear however, because it states that the audible sound “shall not exceed fifty (55) dBA” (note that this has been correctly recorded here, the discrepancy between the written word and the numerical value given in parentheses). This value is much higher than the value given in the MOE regulation, and also equals the WHO recommendation for serious annoyance in an outdoor setting. [See Reference R1]. There is no mention or consideration of ambient sound levels, but waivers to this sound level may be considered. It also does not mention whether this is an hourly limit or not. The point of receiving is considered to be the “exterior of any occupied building on a non-participating Landowner’s property.” There are also associated setbacks that must be followed. The distance between a wind turbine and the nearest building on the same property must be a minimum of 1.1 times the turbine height. The distance between a turbine and the nearest occupied building on a non-participating property must be at least 5 times the hub height of the turbine. These setbacks exist in response to both safety and noise related issues.

Table 3.5. Pennsylvania Draft Ordinance

Source	Receiving Property Designation					
	Residential (Class A)		Commercial (Class B)		Industrial (Class C)	
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
Class C	60 dBA	50 dBA	65 dBA	55 dBA	70 dBA	60 dBA

Note: Daytime is considered to be 7am – 10pm
Nighttime is considered to be 10pm – 7am

3.2.7 Washington - Chapter 173-60 WAC Maximum Environmental Noise Levels
(Reference R8)

In Washington State, there is no specific regulation for wind turbine noise, so sound levels must comply with the limits in the environmental noise legislation. This results in noise limits that are the highest among those reviewed here (along with Maine), much higher than the MOE limits. Noise level limits are dependant upon the designation, or class, of both the source property and the receiving property. Wind turbines, as a source, would fall under neither Class A, residential, nor Class B, commercial; therefore they would be considered Class C. The hourly sound levels must not exceed the listed measures anywhere within the property line of the neighbouring property. However, it is also mentioned that local governments should adopt their own noise policies. Chapter 173-58 WAC details the proper sound level measurement procedures to follow.

3.2.8 Michigan - Michigan Wind Energy System Siting Guidelines Draft #8
(Reference R9)

The Michigan wind energy draft is meant to apply to smaller local governments and non-urban areas that do not have other existing guidelines in place. There are different guidelines for small, on-site use wind turbines, and larger developments meant for grid energy use.

The Michigan guideline considers the measure of the ambient sound level to be L_{90} and it is assumed to be less than 55 dBA in most cases. The guidelines state that the sound level generated by the turbines should not exceed 55dBA at any property line, unless with written

consent. This level is similar to the one developed by the State of Pennsylvania (see above). During any one hour, this is not to be exceeded for more than three (3) minutes. Should the ambient sound level be greater than 55dBA, then the sound level limit is $L_{90} + 5\text{dBA}$, L_{90} as the measured ambient sound level. For demonstration of the compliance to these limits, a submission following IEC 61400 and ISO 9613 methods must be completed for project approval, and within 60 days of the project's completion, the levels must be verified to ANSI S12.18 by a professional third party. The State of Michigan is the only other jurisdiction among those reviewed that requires submission of noise impact according to ISO 9613 like the Ontario MOE requirements. However, the noise level limits are much higher than the MOE limits.

3.2.9 Maine - Chapter 375 No Adverse Environmental Effect Standard of the Site Location Law
 (Reference R10)

This is another example of a state that has written a standard for use where local governments have not written their own. Local standards take precedence over the state limits unless they contain values over 5 dBA higher for the same situation. As with the Washington sound level limits, the noise limits within this document apply to all environmental noise, including wind turbines, resulting in much higher values. The noise limits apply to new and expanding developments and are measured at the property line, but no specific information is provided on how the sound levels from wind farms are to be modeled. The limits vary based on the zoning of the receiving property or the ambient sound level, and are different for day and night. The noise limits are summarized in the Table 3.6.

Table 3.6 Regulations in Maine

Receiving Property	Daytime Sound Level Limit (7am – 7pm)	Nighttime Sound Level Limit (7pm – 7am)
Any location that is not zoned for commercial, transportation or industrial	60 dBA	50 dBA
Any location that is zoned for commercial, transportation or industrial	70 dBA	60 dBA

These limits apply unless the ambient sound level prior to development is equal to or less than 45 dBA during the daytime hours and 35 dBA during the nighttime hours, such as in a rural environment. Should this be the case, the limits are required to be 55 dBA during the day and 45 dBA during the night; a 10dBA increase, regardless of the zoning of the receiving property. There are two methods allowed to demonstrate the level of the ambient sound, by performing measurements, or, if the population within a 3000 m radius of the property is greater than 300 people, the state allows the assumption that the ambient level exceeds 45 dBA during the day and 35 dBA at night. Additionally, if it can be proven that the development will not emit sound levels greater than 50 dBA during the day and 40 dBA during the night, there is no requirement to estimate or measure the sound levels.

There are further requirements for short duration repetitive sounds and tonal sounds. There are also regulations on the personnel carrying out the measurements, the instrumentation and calibration necessary, and the location, configuration and environment conditions for the microphones, but not necessarily in the specific case of applying the measurements to wind farms.

3.2.10 New York - Power Naturally: Examples of NY Local Government Laws/ Zoning Provisions on Wind
(Reference R11)

The state of New York does not have a standard for wind turbine noise, but relies on local governments to develop their own, which many have. The town of Clinton, NY, is one such municipality, and is a good indication of what the standards in New York State are like. The limit, which applies at any time of the day, is $L_{10} \leq 50\text{dBA}$, meaning that in any one hour, 50 dBA can be equaled or exceed only ten percent of the time. The sound level is measured at the nearest residence, located off-site, which may or may not include more than one property. If the owner consents to a higher threshold of noise, a waiver can be granted allowing an increase to the noise level limit. If the ambient sound, which is defined as the highest whole number in dBA exceeded for more than 5 minutes per hour, is greater than 50 dBA, then the sound level limit is the ambient sound level plus 5dBA. These levels are higher than the MOE limits, but remain

just below the level of moderate annoyance for outdoor noise of 50dBA listed in the WHO Community Noise document.

3.3 NOISE LIMITS FROM EUROPE

Europe has long been at the forefront of developing and utilizing wind energy as an energy source. It is not surprising that they have been able to develop noise limit standards to a higher degree than North America. It does not mean that they are more complicated; in fact, they are often simpler than North American noise limits. The following are some examples of noise level limits of wind farms from European countries.

3.3.1 UK - ETSU-R-97: *The Assessment and Rating of Noise from Wind Farms* (Reference R12)

The document produced by the Working Group on Noise from Wind Farms is perhaps the most comprehensive document of all the ones reviewed here. It covers the history and philosophy of developing noise limits, as well as a thorough explanation of the current limits. The document regulates a separate limit for daytime and nighttime noise levels. These are in part based on the background noise level, $L_{A90, 10min}$, which is determined by continuous monitoring of ten minute intervals over a period of time, correlated with different average wind speeds measured over the same period. There is no distinction between zoning or the use of the receiving property as in the Ontario MOE limits.

The principle of the limits is that the wind farm noise is limited to 5 dBA above the wind dependent background noise level, subject to a minimum value at low wind speeds. During the daytime, this minimum value in low noise environments is not to be lower than a range between 35 dBA and 40 dBA, depending on the number of dwellings and the effect on the amount of energy produced. At night, this minimum value is 43dBA. Both of these limits are recommended to be increased to 45 dBA in cases where there is financial benefit to those involved. As with other standards, a 5 dB penalty is incurred if tonal characteristics occur. Should this appear to be the case, a tonal assessment must be performed, consisting of 2 minute

measurements. The document does not require an impact assessment of the development to be submitted.

3.3.2 *Ireland - Wind Energy Development Guidelines* (Reference R13)

Ireland has adopted noise limits that are similar to the UK limits for wind turbines. The daytime limit is allowed to be the maximum of 45 dBA or 5 dBA above the background level, L₉₀. However, if the current level of background noise is very low, below 30dBA, the noise level limit will fall in the range of 35 dBA to 40 dBA. The standard does not state how this limit will be determined. The nighttime limit is fixed at 43dBA. These noise levels are comparable to the Ontario MOE limits. The Irish Guidelines have no set-back limits. Instead it states and we quote, “In general noise is unlikely to be a significant problem where the distance from the nearest turbine to any noise sensitive property is more than 500 m.” [Reference R13]. The document has stated that in order to determine the ambient sound level, measurements should be taken at ten minute intervals, however, it has not dictated how the wind farm noise level should be predicted or what steps to determine the impact of the wind farm should be taken.

3.3.3 *Denmark - Document: Statutory Order From the Ministry of the Environment No. 304 of May 14, 1991, On Noise From Windmills* (Reference R14)

Denmark’s noise limits are fixed, ambient conditions having no effect, and apply to both daytime and nighttime with no distinction. This is in contrast to the MOE limits, which may depend on both the wind speed and the hourly background level; however, the actual sound level limits have a direct comparison to Ontario’s. When the wind farm is located in the open country, the outdoor sound level limit is 45 dBA at the nearest neighbouring property, considered to be any residential building other than the “private house of the windmill owner”. For wind farms closer to residential areas, the fixed limit is 40 dBA.

3.3.4 *Germany - Document: Lärm (Technische Anleitung Lärm, Germany), 1998* (Reference R15)

The German noise limits are defined in the above document and are outlined in Table 3.7 below.

Table 3.7. German Noise Regulations.

Area	Day Time	Night Time
Industrial Area	70 dBA / 65 dBA	70 dBA / 50 dBA
Mixed residential area and industry or Residential areas mixed with industry	60 dBA	45 dBA
Purely residential areas with no commercial developments	55 dBA / 50 dBA	40 dBA / 35 dBA
Areas with hospitals, health resorts etc.	45 dBA	35 dBA

Calculation of sound propagation is done according to ISO 9613-2. All calculations have to be done with a reference speed of 10 m/s at 10 m heights.

3.3.5 Netherlands: Bseluit van 18 oktober 2001, houdende regels voor voorzienen en installaties; Besluit voorzienen en installaties milieubeheer; Staatsblad van het Koninkrijk der Nederlanden 487
(Reference R16)

Noise regulations specific to wind turbines in the Netherlands were issued in 2001, but are currently under review by the Dutch authorities. The 2001 wind farm noise limits followed a wind speed dependent curve and are shown in Table 3.3.2 for night time noise limits. The limit for day time started at 50 dBA and for evening hours, the limit started at 45 dBA and increased to 50 dBA for a speed of 12 m/s.

Table 3.8. 2001 Netherlands Noise Assessment Limits – Night time.

Wind Speed at 10 m height (m/s)	1	2	3	4	5	6	7	8	9	10	11	12
Wind Turbine Noise Criterion, dBA	40	40	41	41	42	42	43	44	46	47	48	50

As noted above, the 2001 assessment process is currently under review. In the interim, the Dutch authorities use their established general limits, not specific to wind turbines, of 40 dBA (night), 45 dBA (evening) and 50 dBA (day).

3.4 WIND FARM NOISE LIMITS FROM AUSTRALIA AND NEW ZEALAND

The wind farm noise limits of these two countries relate more to those of the European countries rather than North America. They require extensive data collection for the determination of ambient sound levels, and the sound level limits themselves are among the lowest, being developed in accordance with the World Health Organization document Guidelines for Community Noise. The standards as written are much more detailed in their requirements, and thus are of great value when reviewing noise standards for wind farms.

3.4.1 Australia - Planning Bulletin 67: Guidelines for Wind Farm Development and Environmental Noise Guidelines: Wind Farms (References R17 and R18)

There are documents from both Western and Southern Australia; however, there is only one set of noise limits since the Western Australia guidelines reference the South Australian noise limits. The South Australian guidelines have elected to define fixed limits that must be followed, and are among the strictest that are reviewed here. The limit during the daytime is 35 dBA or the background noise plus 5 dBA, $L_{A90, 10} + 5$ dBA. The other jurisdiction that has a comparable noise level limit is the American state of Oregon. Both Australia and Oregon have limits that are more strict than Ontario. In order to determine the ambient levels, extensive data collection of noise levels over continuous 10-minute intervals must be examined according to a regression analysis. Wind speeds must be measured at 10m above the ground and also analyzed over the same periods. In order to determine the sound level limit compliance, the sound is measured not at the property line, but at a distance of up to 20 m away from the nearest house. In addition, demonstration is required that shows the operational sound levels do not exceed the

predetermined limits or else restrictive measures may be taken to limit the operation of the wind farm.

3.4.2 *New Zealand - NZS 6808: 1998: Acoustics – The Assessment and Measurement of Sound From Wind Turbine Generators*
(Reference R19)

New Zealand also has a fixed sound level limit, as with other countries. At any residential home, the sound level limit outside of the house must not exceed 40 dBA. This limit has been selected to achieve an indoor sound level that corresponds to the values recommended in the WHO Guidelines for Community noise. If the background noise, L_{95} , exceeds 35 dBA, then the sound level limit is permitted to be $L_{95} + 5$ dBA. These levels are higher than the strict limits of Australia and Oregon, and are comparable to the Ontario and Danish sound level limits. This limit is to apply at the property line of the nearest residential property, or the “notional boundary” if the dwelling is located on a large rural property. The standard allows the sound levels from the wind farm development to be estimated using the sound power levels supplied by the manufacturer, but for determination of the ambient sound levels, extensive data collection over a period of ten to fourteen days is required. Post-installation verification is not always required by the standard.

3.5 DISCUSSION

The assessment of wind farm noise and their impact on sensitive receptor locations as applied in different jurisdictions were described above. The main differences between the different regulations and guidelines are twofold:

- a) The acceptable noise limits; and
- b) The evaluation of receptor noise levels from the cumulative operation of the turbines in the wind farm.

The commonality among the regulations and guidelines is quite striking. All of them accept the IEC Standard 61400-11 (Reference 26) procedures to establish the sound power levels of wind turbines as well as the determination of the hub-height and/or the 10 m high wind speeds within

the operating range of the wind turbines. In addition, none of them consider the effect of atmospheric classes on night time operational character of the wind farm such as higher-than-expected wind speeds at hub-height compared to the conventional wind-shear prediction methodologies.

It is seen therefore, that the main difference between the regulations and guidelines is the noise limits and hence a comparison table is given below in Table 3.8 below. Table 3.8 summarizes only the night time noise limits. Note that direct comparisons of limits may not be appropriate as different jurisdictions have different legal, procedural and assessment frameworks.

Table 3.8. Approximate Ranking of Noise Regulations (Night time limit, dBA).

Jurisdiction	Noise Limit, dBA
Australia	35 and adjusted higher with wind speeds
Germany and Oregon, USA	35 to 36
Alberta, British Columbia, Quebec, Denmark, and Netherlands (Interim)	40
United Kingdom, Ireland, Ontario and New Zealand	40 and adjusted higher with wind speeds
New York, Maine, Pennsylvania and Washington, USA	50 and higher

3.6 SUMMARY

Regulations and guidelines from different jurisdictions in North America, Europe and Australasia were highlighted in this section. These are some of the examples of different assessments of noise impact from wind turbines and wind farms. It was shown that some jurisdictions have special legislation concerning wind turbines, while others apply general recommendations. Different descriptors such as L_{Aeq} or $L_{A90, 10 \text{ min}}$ were used to quantify wind turbine noise levels. The noise levels could be either absolute values or related to the background noise level. The background noise levels could be standardised, measured or related to ambient wind speeds. The review of the regulations and guidelines of the jurisdictions investigated showed that the Ontario, Canada assessment process is similar to other jurisdictions.

4.0 REVIEW OF AVAILABLE LITERATURE

A substantial portion of information, both scientific and non-scientific is available in the open literature. The literature review focussed mainly on the following:

- I) Metrological effects on wind turbine noise generation;
- II) Assessment procedures of wind turbine noise levels and their impact;
- III) Particular characteristics of wind farm noise; and
- IV) Human responses to wind farm noise levels.

NOTE: The literature review did not consider material that was available after June 2007.

The exact noise generation mechanisms of wind turbines and control techniques of wind farm and turbine noise were not reviewed by the current investigations. Relevant databases such as journals through ScholarsPortal, internet and conference proceedings were searched for the literature. Proceedings from a few conferences were searched also. It must be pointed out that conference papers are usually accepted without proper peer-reviews. Only a few articles were available and are listed in the main reference list. The results of the review are summarized below.

4.1 METEOROLOGICAL EFFECTS

The paper by P. Botha of New Zealand has shown the effects of weather conditions on wind speed profiles with height (Reference 22). This is the only paper, to our knowledge, that has scientifically shown variation of wind speeds with heights from measurements conducted at four sites – two (2) in New Zealand and two (2) in Australia. The measurements were conducted for a period of one year. The two Australian sites (Sites 1 and 2) were flat terrain and the two New Zealand sites (Sites 3 and 4) were complex terrain. Wind speeds were collected in 10 minutes intervals and the composite results from Reference 22 are reproduced below as Figure 6.1.

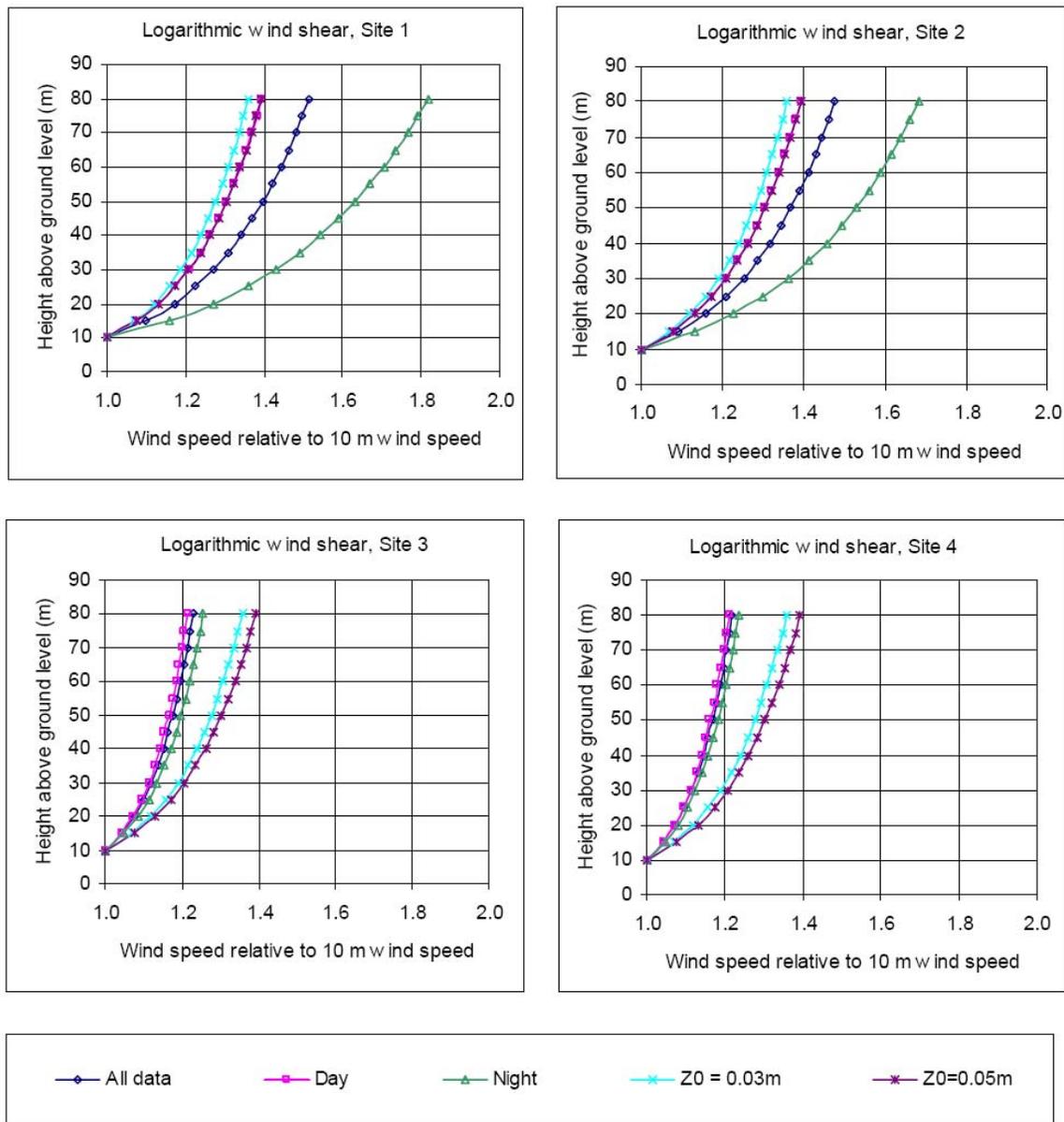


Figure 4.1. Wind speed profiles at 4 different sites

(From Reference 22 – Figure 1)

Five graphs were plotted for each site: Composite profile for all day data, profile for day data, profile for night data, IEC standard logarithmic profile with the shear coefficient from observed site conditions ($Z_0 = 0.03$) as well as the standard shear coefficient, Z_0 , of 0.05. The results do indicate that for some terrains, the hub-height wind speeds can be more at night time than during

day time when compared to the 10 m height wind speeds. However, the local conditions determine the meteorology and one cannot, as analysed by van den Berg, apply information from far-off sites to local conditions. Further, for the terrains in Australia, the Sound Power Levels at night time would be around 2 dBA more than predicted from standard procedures from day time profiles. It must also be highlighted that the measurements of Reference 22 clearly showed the wind profiles were nearly identical between day and night time for the complex terrains of New Zealand.

The main conclusions of this section are: a) wind shear is an important parameter that must be accounted for appropriately in any assessment; and b) the effect of meteorology is highly localized and strong conclusions cannot be easily transferred from site to site.

4.2 ASSESSMENT PROCEDURES OF WIND TURBINE NOISE LEVELS

Papers by Botha (Reference 22), Sloth (Reference 23) and Sondergaard (Reference 24) are examples of work undertaken to look into the assessment procedures currently applied in many jurisdictions. These three papers evaluate the application of sound power levels of wind turbines standardized to a 10 m height wind speed. The main conclusion of these papers is that the normal procedure of basing the analysis and assessment on the standardized sound power levels is not sufficient. Sloth shows a method to incorporate the relevant sound immission data with appropriate uncertainties accounted for so as to minimize noise annoyance. One such method is suggested in Appendix F. Sondergaard has also pointed out that additional research is required to account for many of these deficiencies. References 27 and 28 showed that many of the propagation models have uncertainties associated with them and can produce “less than accurate” results if local weather conditions are not properly modelled.

One of the main criticisms about noise assessment process of wind farm application is that the sound power levels of wind turbines are measured and reported following the procedures of the IEC-Standard [Reference 26]. It must be noted that the IEC 61400-11 standard for wind turbine noise is a measurement standard and is primarily intended to define how manufacturers obtain

and report the sound power from wind turbines under standardized wind shear conditions. It does not prevent one from adjusting the sound power to reflect the actual site specific wind shears obtained from testing.

4.3 PARTICULAR CHARACTERISTICS OF WIND FARM NOISE

Two main issues are usually discussed regarding the source characteristics of noise generated by wind turbines – low frequency or infra sound and the swishing (thumping) sound normally termed as the amplitude modulation phenomenon.

The measurement results from wind turbines, such as the data reported by van den Berg (Reference 1) and Howe and McCabe (Reference 28) show the absence of significant low frequency components and the same conclusion is highlighted by Regan and Casey ((Reference 25) in their primer on wind turbine noise aspects. The results of Reference 1 (van den Berg’s dissertation) show that the infra-sound levels, even if present, are well below the threshold of perception.

The nature of the amplitude modulation phenomenon and its relationship to the acoustical *beating* phenomenon was already discussed in Section 2.4. The different principles of these phenomena will not be discussed further. Due to the nature of the amplitude modulation phenomenon, the swishing or thumping exists all the time. Only van den Berg has attempted to show that the modulation gets stronger at night time. Our review of van den Berg’s work was presented in Section 2. We were unable to find other works in the literature that provide evidence for increased modulation at night time. The only effect, discussed in the next section, of the phenomenon is the modulated sound becomes audible at night time. This could be due to quieter ambient sound at night time. As Reference 18 states, “In summary, the modulation in the noise from wind turbines is not yet fully explained and will not be reduced in the near future and is therefore a factor of importance when discussing noise annoyance from wind turbines.”

Reference 30 has addressed the issues connected with modulation. One of its principal findings is and we quote, “the common cause of complaint was not associated with low-frequency noise,

but the occasional audible modulation of aerodynamic noise, especially at night. Data collected showed that the internal noise levels were insufficient to wake up residents at these three sites. However, once awoken, this noise can result in difficulties in returning to sleep.” Reference 30 does not use the term “beating” to describe the amplitude modulation that has been observed as well as measured. It has been referred to simply as “aerodynamic modulation.” Reference 30 also points out that the many mechanisms hypothesized by van den Berg (Reference 1) for the modulation behaviour are debatable. It was shown in Section 2 during the current investigation that the data provided by Reference 1 do not support its findings. Further, no support was seen for the modulation behaviour to get stronger under stable atmospheric classes at night time as postulated by van den Berg. The same points were presented in Section 2 of this report. Finally, Reference 30 discussed the many possible mechanisms that can cause the amplitude modulation as well as provided measurement results to show that modulation can produce changes in noise levels of the order of 10 dB. It concluded that detailed research is required to settle many of the unknowns that can cause the amplitude modulation.

4.4 HUMAN RESPONSES TO WIND FARM NOISE LEVELS

A considerable body of literature is available on this subject, both scientific and anecdotal. Only a few of the scientific and review articles, References 5, 12, 18, 20, and 25, are highlighted in the current study.

According to Reference 25, the only health effect of wind turbine noise is annoyance. Sheppard et al. (Reference 12) conducted a laboratory study with unbiased subjects and played different sounds including wind turbine noise at various levels. Since the study was conducted in early 80s, the old type wind turbines were included in their investigations. Their study developed a human response criterion for wind turbine generators based on receptor received noise levels and termed it ‘Perception Detection Threshold.’ The study showed that the thresholds for wind turbine noise were below the thresholds of general tones. After validating the usefulness of the response function, the following annoyance table, based on an old ISO standard, now defunct,

was recommended to evaluate the community response. The annoyance table is presented in Table 4.1 below.

**Table 4.1 Estimated Community Response to Wind Turbine Generator Noise
(From Reference 12 –Figure 12 of Reference 12, based on an ISO standard)**

Amount in dB by which the rated noise exceeds Threshold Level	Estimated Community Response	
	Category	Description
0	None	No Observed Reaction
5	Little	Sporadic Complaints
10	Medium	Widespread Complaints
15	Strong	Threats of Community Action
20	Very Strong	Vigorous Community Action

NOTE: **Rated Noise Level** – The actual noise level that would be measured at the receptor locations;

Threshold Level – The average ambient sound level that would exist in areas around the wind farm site.

A study, similar to that of Sheppard (Reference 12) is required to evaluate the detection threshold for modern wind turbines.

The annoyance study of Pedersen and Waye concluded that annoyance increases with sound levels. However, these annoyance studies have very small sample sizes and focussed on subjects living close to wind farms. No blind survey was conducted. Only 65 of the 356 respondents were exposed to noise levels of 37.5 dBA and above. The following categories – perception, dose-annoyance, sensitivity, attitude to source, visual exposure and rural setting – were included in the survey. The correlation between most of the categories and noise levels were small. The noise level and annoyance response was proportional to the exposure level. However, the sample size was too small. The subjects had prior exposure to wind turbines, making the sample biased. It must be acknowledged that the research of Pedersen and Waye has provided important insights into the human response of wind turbine noise and has considered important parameters.

However, the work of Pedersen and Waye need to be expanded to include large enough samples with unbiased subjects.

Finally, one of the arguments presented by anti-wind farm proponents is that ‘beating’ increases human annoyance. The only result that can be culled from the literature, Reference 18, is that the modulation frequencies, 0.5 to 1 Hz for wind turbines, are such that the wind turbine noise can be detected. Since major studies on wind turbine beating and human annoyance have not been conducted, major conclusions are not possible at this stage.

4.5 SUMMARY

Available literature on wind turbine noise was reviewed and the review focussed on four categories, considered important to the Ministry’s stated goals. The results of the review were presented in this section. The main findings of this section are:

- A) The local terrain conditions can influence meteorological conditions and can affect the expected noise output of the wind turbines;
- B) Assessment procedures applied in different jurisdictions are quite similar in their scope;
- C) Wind farm noise do not have significant low-frequency (infrasound) components;
- D) Further study needed in order to determine effect of modulation on human annoyance.

5.0 REVIEW OF MOE'S NOISE POLICIES AS APPLIED TO WIND FARM NOISE

The Ministry of the Environment released a guideline document, "Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators" in 2004. The above guidance document was to assist proponents of wind turbine installations in determining the list of necessary information to be submitted when applying for a Certificate of Approval (Air and Noise) under Section 9 of the *Environmental Protection Act*. A summary of these interpretations by John Kowalewski was also published in the Canadian Acoustics Journal (Reference 33). The noise guidelines in MOE publications NPC-205/NPC-232 as well as the wind generated noise levels were applied to set the noise limits. These three documents are enclosed in Appendices A, B and C.

5.1 MOE'S ASSESSMENT PROCESS

The assessment procedures of MOE are summarized below for completeness sake:

- I) All wind farm applications must obtain a Certificate of Approval from MOE. If individual wind turbines have a capacity of 2 MW or more, the project must undergo an Environmental assessment review;
- II) If there are no receptors within 1000 m of the wind farm boundary, no detailed noise assessment is necessary;
- III) The noise limits are established based on the location of the receptors in Class 1 & 2 areas and Class 3 areas.
- IV) The sound power levels of the wind turbines are to be obtained from the standard procedures contained in IEC Standard 61400-11, by applying the wind speeds at 10 m height above ground. [Reference 26].
- V) The sound pressure levels at each receptor location are to be evaluated applying the procedures of ISO 9613.

VI) The noise impact is assessed by comparing the predicted noise levels at individual receptor location with the noise limits established in Step III. The noise impact is evaluated at each wind speed over the operating range of the wind turbine specifications.

The noise limits are wind speed dependent and are summarized in Table 5.1 below.

Table 5.1 Ontario Noise Assessment Limits

Wind Speed (m/s) @ 10 m height	4	5	6	7	8	9	10	11
Wind Turbine Noise Criterion NPC-232 (dBA) (Rural) – Class 3 Areas	40	40	40	43	45	49	51	53
Wind Turbine Noise Criterion NPC-205 (dBA) (Urban) – Class 1 & 2 Areas	45	45	45	45	45	49	51	53

The MOE procedures outlined in Appendix A do not explicitly discuss the application of penalties for source character or apply particular meteorological conditions.

The MOE's assessment process is very similar to the procedures applied in the New Zealand (Reference R19), as it recognizes the usefulness of masking effects of ambient wind. The implicit assumption is that it is the ambient wind that generates the noise of wind turbines as well as background noise levels at receptor locations.

The Ministry's noise assessment guidelines for stationary sources of sound are based on the premise that noise from the stationary sources may be annoying when it is audible over and above the level of the so-called "ambient" or surrounding environmental "noise climate" at a particular location. However, audibility does not necessarily mean annoyance. Furthermore, annoyance is not the same for the entire population; people at the extreme of the statistical distribution may be annoyed at different noise levels. Such an approach was considered a 'sound' policy from the inception of the Model Municipal Noise Control by-Law issued by MOE in August 1978. The policies provide adequate protection from adverse noise pollution impacts as well as not imposing restrictive conditions on industrial noise sources. However, the MOE's

assessment, even though has provided a very simple procedure, has been very general in its overall scope. Two issues need to be resolved and are highlighted below.

5.2 PENALTY FOR SOURCE CHARACTER

The guideline document that deals with noise assessment of wind turbines, enclosed in Appendix A, does not explicitly discuss penalties for characters such as tonal components of the wind turbine noise levels, even though reference to NPC-104 is included in the interpretation document. Further, the Ministry document, NPC-205 (enclosed in Appendix C) contains guidelines for penalties, which must be used if a particular wind turbine was found to contain tonal components. The implicit assumption is that the modern up-wind wind turbines have no dominant tones in their spectrum. It must be pointed out that most of the measurement results do show that the turbine noise spectrum is devoid of dominant tones. However, MOE needs to clarify and include source character adjustments in the main body of the interpretation document and even make references to the procedures contained in the IEC Standard (Reference 26) that are used to determine the presence of tones in the noise spectrum.

5.3 METEOROLOGICAL CONDITIONS

One of the main arguments posed by van den Berg (Section 2) is that meteorological condition affect wind speed profiles with height and that the hub-height wind speed may be higher than predicted with the 10 m high wind speed being low. It was made clear in the review presented in Section 2 that the evidence presented to support these arguments were tenuous at best. However, the works of Botha (Reference 22) and Sondergaard (Reference 24) showed that local terrain conditions can dictate the wind profiles and the measurements of Reference 22 has shown that in flat terrains, the wind speed profile with height cannot be predicted accurately by standard methods such as the logarithmic shear function applied in Reference 26.

It is therefore, possible that, for a ‘worst-case scenario’, the hub-height velocities can be higher than expected thereby resulting in higher-than-expected noise levels with lower masking effect of the ambient wind at receptor locations. Some preliminary evaluations presented in Reference

32 showed that discrepancies of the order of 3 dBA are possible. Such a scenario needs to be accounted for in the Ministry's future updates of the assessment procedures. One example of a possible assessment procedure is described in Appendix F.

5.4 SUMMARY

The assessment procedures, currently, applied in the Province of Ontario by the Ministry of the Environment to evaluate wind farm noise levels were reviewed. The results showed that the procedures may have to be revised to incorporate additional factors. One possible assessment process is suggested Appendix F.

6.0 CONCLUSIONS

As part of the review process of their assessment procedures, the Ministry of the Environment for the Province of Ontario has instituted a work project with different tasks. Four individual tasks were part of the review process.

The results of each of the tasks were presented in the previous sections. The conclusions for each of the tasks were included at the end of the relevant sections. The basic conclusions are summarized below:

- A) The research work undertaken by G. P. van den Berg didn't provide scientific evidence to support the few major hypotheses postulated concerning the wind turbine noise characteristics. However, the work of other researchers showed that local terrain conditions can impact the local meteorology and thereby the resulting noise levels;
- B) Assessment procedures applied in different jurisdictions showed the current Ministry of the Environment process is similar to other jurisdiction. Further, the MOE process has provided a balanced approach between noise impact and the need for wind farms, based on currently available scientific data.
- C) Literature review showed that additional research is still required to make definitive conclusions about wind turbine noise impacts as well as human response to wind farms. In addition, detailed research on meteorological conditions, and their impact on sound generation needs to be undertaken to realise definitive conclusions;
- D) The Ministry of the Environment's procedures to assess wind farm noise levels follow a simple procedure that is sound for most situations. However, additional concerns still need to be addressed in the next round of revisions to their assessment process. These revisions may need to be addressed after the results from future research provide scientifically consistent data for effects such as meteorology, human response and turbine noise source character.

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APPENDIX A

INTERPRETATION FOR APPLYING MOE NPC TECHNICAL PUBLICATIONS TO WIND TURBINE GENERATORS

INTERPRETATION FOR APPLYING MOE NPC TECHNICAL PUBLICATIONS TO WIND TURBINE GENERATORS

Noise impacts of proposed wind turbine generators, i.e. wind turbines, are considered in the course of assessing an application for a Certificate of Approval (Air), in accordance with Section 9 of the Environmental Protection Act. The purpose of this guidance document is to assist proponents of wind turbine installations in determining what information should be submitted when applying for a Certificate of Approval (Air). It has been developed in order to provide consistency in the submissions and to streamline the review and approval process.

As a minimum, the information package must include details of the wind turbine design and operation, location of the wind turbine within the specific site and surrounding area as well as summary of compliance applicable to noise. The following defines a template for reports to be submitted to the MOE. This information is supplementary to the information in MOE Publication NPC-233, Information to be Submitted for Approval of Stationary Sources of Sound.

REFERENCES

- [1] NPC-102 - Instrumentation
- [2] NPC-103 - Procedures
- [3] NPC-104 - Sound Level Adjustments
- [4] NPC-205 - Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban)
- [5] NPC-206 - Sound Levels due to Road Traffic
- [6] NPC-232 - Sound Level Limits for Stationary Sources in Class 3 Areas (Rural)
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TECHNICAL DEFINITIONS

"Class 1 Area"

means an area with an acoustical environment typical of a major population centre, where the background noise is dominated by the urban hum.

"Class 2 Area"

means an area with an acoustical environment that has qualities representative of both Class 1 and Class 3 Areas, and in which a low ambient sound level, normally occurring only between 23:00 and 07:00 hours in Class 1 Areas, will typically be realized as early as 19:00 hours.

Other characteristics which may indicate the presence of a Class 2 Area include:

- i. absence of urban hum between 19:00 and 23:00 hours;
- ii. evening background sound level defined by natural environment and infrequent human activity; and
- iii. no clearly audible sound from stationary sources other than from those under consideration.

"Class 3 Area"

means a rural area with an acoustical environment that is dominated by natural sounds having little or no road traffic, such as the following:

- i. a small community with less than 1000 population;
- ii. agricultural area;
- iii. a rural recreational area such as a cottage or a resort area; or a wilderness area.

Point of Reception

"Point of Reception" means any point on the premises of a person within 30 m of a dwelling or a camping area, where sound or vibration originating from other than those premises is received.

For the purpose of approval of new sources, including verifying compliance with Section 9 of the Act, the Point of Reception may be located on any of the following existing or zoned for future use premises: permanent or seasonal residences, hotels/motels, nursing/retirement homes, rental residences, hospitals, camp grounds, and noise sensitive buildings such as schools and places of worship.

For equipment/facilities proposed on premises such as nursing/retirement homes, rental residences, hospitals, and schools, the Point of Reception may be located on the same premises.

NOISE LIMITS

The noise limits for a wind turbine or an array of such units (referred to as a "wind farm") are set relative to the existing MOE Noise Guidelines in NPC-205/NPC-232 as well as to the wind generated background noise. The proponents are required to demonstrate compliance with the following sound level limits:

Wind turbine installations in Class 1 & 2 Areas (Urban)

Wind speeds below 8 m/s

The lowest sound level limit at a Point of Reception in Class 1 & 2 Areas (Urban), under conditions of average wind speed up to 8 m/s (29 km/h), expressed in terms of the hourly equivalent sound level (Leq) is 45 dBA or the minimum hourly background sound level established in accordance with requirements in Publications NPC-205/NPC-233, whichever is higher.

Wind Turbine Installations in Class 3 Areas (Rural)

Wind speeds below 6 m/s

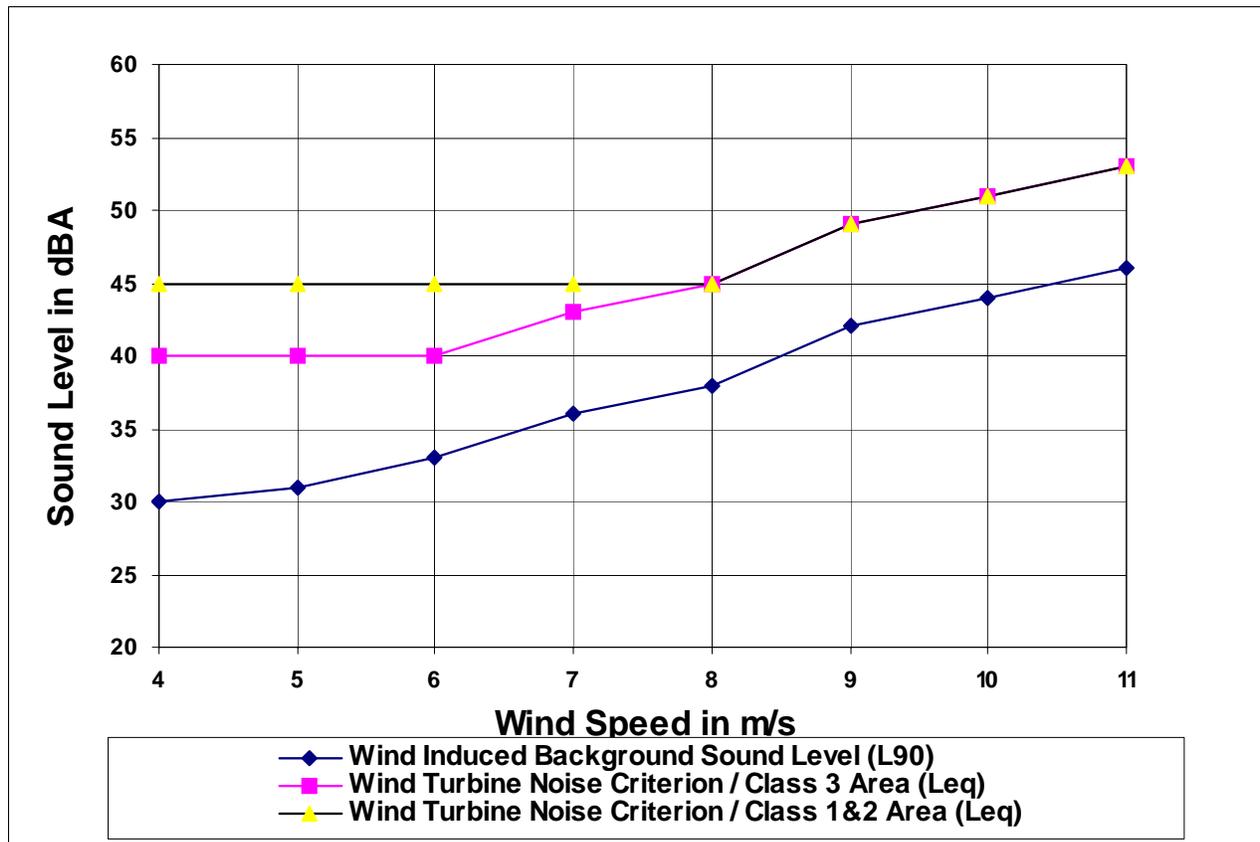
The lowest sound level limit at a Point of Reception in Class 3 Areas (Rural), under conditions of average wind speed up to 6 m/s (22 km/h), expressed in terms of the hourly equivalent energy sound level (Leq) is 40 dBA or the minimum hourly background sound level established in accordance with requirements in Publications NPC-232/NPC-233, whichever is higher.

Wind Turbine Installations in Class 1& 2 and Class 3 Areas

Wind speeds above 8 and 6 m/s respectively

The sound level limit at a Point of Reception in Class Areas 1 & 2 (Urban) or in Class 3 Areas (Rural), under conditions of average wind speed above 8 m/s and 6 m/s respectively, expressed in terms of the hourly equivalent energy sound level (Leq), is the wind induced background sound level, expressed in terms of ninetieth percentile sound level (L_{A90}) plus 7 dB, or the minimum hourly background sound level established in accordance with requirements in Publications NPC-205/NPC-232/NPC-233, whichever is higher.

A summary of the above limits is shown in figure and table below.



Wind Speed (m/s)	4	5	6	7	8	9	10	11
Wind Turbine Noise Criterion NPC-232 (dBA)	40	40	40	43	45	49	51	53
Wind Turbine Noise Criterion NPC-205 (dBA)	45	45	45	45	45	49	51	53

NOTE:

1. The measurement of wind induced background sound level is not required to establish the applicable criterion. The wind induced background sound level reference curve in the figure above was determined by correlating the ninetieth percentile sound level (L_{A90}) with the average wind speed measured at a particularly quiet site.
2. If the existing minimum hourly background sound level, established in accordance with requirements in Publications NPC-205/NPC-232/NPC-233, is selected as the sound level limit, the measurement of wind speed (for the purpose of determination of wind induced background sound level) is not required. The selected limit applies in the entire range of wind speed under consideration from 4 m/s to 11 m/s with exception of the wind turbine noise criterion values higher than the existing minimum hourly background sound level.
3. Wind Turbine Noise Criterion at wind speeds expressed as fractional values of m/s should be interpolated from the above graph.

REPORT CONTENTS AND FORMAT

The noise report must contain the required information, organized in a clear and concise manner. The report should include the following sections in the given sequence:

1. **Introduction**
Objectives of report
2. **General Description of Wind Turbine Installation Site and Surrounds**
Description of the site general environment, including: adjacent zoning, sensitive receiver locations (Points of Reception); suitable mapping of the site and surrounding area, providing elevations of source receivers and intervening structures or topography where applicable to the assessment;
3. **Description of Receptors**
Detailed acoustical description of the area surrounding the facility including: Identification of the closest and/or the critical Points of Reception, identifying noise sensitive residential or institutional uses - (industrial, commercial uses are also desirable information); Determination of the applicable minimum hourly background sound level limit at the critical Points of Reception, in accordance with NPC 205/232 and NPC-233;
4. **Description of Sources**
Description of the wind turbine (wind farm) including: manufacturer & model number; Design principle & geometric configuration (horizontal, vertical, upwind, downwind, rotor diameter and centre height, blade type, number of blades, tower height); Power train (direct from rotor to generator, indirect through gearbox); Operating details (single, twin or variable speed, power curve, generator rated power output and rotational speed); Park lay-out (for a wind farm);
5. **Wind Turbine Noise Emission Rating**
Noise emission levels in terms of sound power level of the wind turbine as a function of wind speed (determined in accordance with IEC 61400-11 method), provided by the wind turbine manufacturer;

6. Impact Assessment

Calculation of the sound pressure level at each critical Point of Reception for each wind turbine or an aggregate of units (wind farm) using ISO 9613 method.

Noise impact assessment under a “worst case scenario” at the critical Points of Reception, up to a distance of 1000 m from the wind turbine (or closest unit in a wind farm); Impact assessment is not required for Points of Reception farther than 1000 m from the wind turbine (or closest unit in a wind farm);

Comparison with the applicable noise limit;

7. Wind Turbine Summary Tables

Wind Turbine Source Summary Table and Wind Turbine Assessment Summary Table; (samples attached);

8. Conclusions and Recommendations

Summary of impacts and verification of compliance with the noise limits;

9. Appendices, etc.

Details of measurements and calculations, specifications, plans, eng. dwgs, etc.

WIND TURBINE SUMMARY TABLES

The noise report must contain Wind Turbine Summary Tables, summarising the results of the Acoustical Report and demonstrating compliance. The Wind Turbine Summary Tables must address pertinent source(s) and receptors (Points of Reception).

The information in the Wind Turbine Summary Tables must be presented in two tables:

1. Wind Turbine Source Summary Table
2. Wind Turbine Assessment Summary Table

The following examples of summary tables must be incorporated into the report:

Wind Turbine Noise Emission Summary Table
(add rows for additional sources)

	Wind Turbine ID	Max PWL at wind speed <6 m/s	PWL at selected wind speed in m/s				
			7	8	9	10	11
1	WT6000	93	97	99	100	104	106
2							
3							

Note:

1. PWL denotes Sound Power Level in dB re 10^{-12} Watt
2. Noise emissions of a wind farm are represented by a sum of PWL values for individual wind turbine units.

Wind Turbine Noise Impact Assessment Summary Table
 Identify all receptors (add rows for additional Points of Reception)

Point of Reception ID	Receptor Description	Distance to closest Wind Turbine (m)	Sound Level Limit (dBA)														Compliance with Limit (Yes/No)
			Calculated Sound Pressure Level at Receptor (dBA) at selected Wind Speed in m/s												Applicable Background Sound Level		
			at selected Wind Speed in m/s												NPC 205	NPC 232	
			6 or <	7	8	9	10	11	6 or <	7	8	9	10	11			
R1	Residence to East	100	43	44	48	50	54	56	45	45	45	49	51	53	46		No
R2	Apt. Bldg. to South	150	40	42	45	47	51	53	45	45	45	49	51	53	51		No
R3	Nursing Home to West	200	37	39	42	44	48	50	45	45	45	49	51	53	47		Yes
R4	Residence to North	260	35	38	40	42	46	48	40	43	45	49	51	53		44	Yes

Note: Values in the table which are **underlined/bold** denote an excess over the applicable limit.

APPENDIX B

NPC - 232 - SOUND LEVEL LIMITS FOR STATIONARY SOURCES IN CLASS 3 AREAS (RURAL)

**SOUND LEVEL LIMITS FOR
STATIONARY SOURCES IN
CLASS 3 AREAS (RURAL)**

PUBLICATION NPC-232

OCTOBER 1995



**Ministry
of the
Environment**

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Sound Level Limits for Stationary Sources in Class 3 Areas (Rural)

Publication NPC-232

October 1995

This Publication establishes sound level limits for stationary sources such as industrial and commercial establishments or ancillary transportation facilities, affecting points of reception in Class 3 Areas (Rural). It replaces Publication NPC-132 "Guidelines for Noise Control in Rural Areas" of the "Model Municipal Noise Control By-Law, Final Report, August 1978".

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1. SCOPE

This Publication establishes sound level limits for stationary sources of sound such as industrial and commercial establishments or ancillary transportation facilities, affecting points of reception in Class 3 Areas (Rural). The limits apply to noise complaint investigations carried out in order to determine potential violation of Section 14 of the Environmental Protection Act. The limits also apply to the assessment of planned stationary sources of sound in compliance with Section 9 of the Environmental Protection Act, and under the provisions of the Aggregate Resources Act and the Environmental Assessment Act.

This Publication does not address sound and vibration produced by blasting; blasting in quarries and surface mines is considered in Reference [7].

The Publication includes an Annex, which provides additional details, definitions and rationale for the sound level limits.

2. REFERENCES

Reference is made to the following publications:

- [1] NPC-101 - Technical Definitions
- [2] NPC-102 - Instrumentation
- [3] NPC-103 - Procedures
- [4] NPC-104 - Sound Level Adjustments
- [5] NPC-205 - Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban)
- [6] NPC-206 - Sound Levels due to Road Traffic
- [7] NPC-119 - Blasting
- [8] NPC-216 - Residential Air Conditioning Devices
- [10] NPC-233 - Information to be Submitted for Approval of Stationary Sources of Sound
- [12] ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation, Technical Document, Ontario Ministry of the Environment, ISBN 0-7729-6376, 1989

References [1] to [4] and [7] can be found in the
Model Municipal Noise Control By-Law, Ontario Ministry of the Environment, Final Report, August 1978.

2. DEFINITIONS

"Ambient sound level"
means Background sound level.

"Background sound level"
is the sound level that is present in the environment, produced by noise sources other than the source under impact assessment. Highly intrusive short duration noise caused by a source such as an aircraft fly-over or a train pass-by is excluded from the determination of the background sound level.

"Class 1 Area"
means an area with an acoustical environment typical of a major population centre, where the background noise is dominated by the urban hum.

"Class 2 Area"

means an area with an acoustical environment that has qualities representative of both Class 1 and Class 3 Areas, and in which a low ambient sound level, normally occurring only between 23:00 and 07:00 hours in Class 1 Areas, will typically be realized as early as 19:00 hours.

Other characteristics which may indicate the presence of a Class 2 Area include:

- absence of urban hum between 19:00 and 23:00 hours;
- evening background sound level defined by natural environment and infrequent human activity; and
- no clearly audible sound from stationary sources other than from those under impact assessment.

"Class 3 Area"

means a rural area with an acoustical environment that is dominated by natural sounds having little or no road traffic, such as the following:

- a small community with less than 1000 population;
- agricultural area;
- a rural recreational area such as a cottage or a resort area; or
- a wilderness area.

Other technical terms are defined in Reference [1] and in the Annex to Publication NPC-232.

3. ESTABLISHMENT OF LIMITS - OBJECTIVE

The sound level limit at a point of reception must be established based on the principle of "predictable worst case" noise impact. In general, the limit is given by the background sound level at the point of reception. The sound level limit must represent the minimum background sound level that occurs or is likely to occur during the operation of the stationary source under impact assessment.

4. BACKGROUND SOUND LEVELS OF THE NATURAL ENVIRONMENT

The One Hour Equivalent Sound Level (L_{eq}) and/or the One Hour Ninetieth Percentile Sound Level (L_{90}) of the natural environment shall be obtained by measurement performed in accordance with Section 7. The results of the measurements must not be affected by the sound of the stationary source under impact assessment.

The time interval between the background sound level measurement and the measurement of the sound level produced by the stationary source under impact assessment should be minimized as much as possible. Preferably, the two measurements should be carried out within one hour of each other.

5. SOUND LEVELS DUE TO STATIONARY SOURCES**(1) Complaint Investigation of Stationary Sources**

The One Hour Equivalent Sound Level (L_{eq}) and/or the Logarithmic Mean Impulse Sound Level (L_{LM}) produced by the stationary sources shall be obtained by measurement performed in accordance with Section 7.

(2) Approval of Stationary Sources

The One Hour Equivalent Sound Level (L_{eq}) and/or the Logarithmic Mean Impulse Sound Level (L_{LM}) produced by the stationary sources shall be obtained by measurement or prediction. The estimation of the L_{eq} and/or L_{LM} of the stationary source under impact assessment shall reflect the principle of "predictable worst case" noise impact. The "predictable worst case" noise impact occurs during the hour when the difference between the predicted sound level produced by the stationary source and the background sound level of the natural environment is at a maximum.

6. PROCEDURES

All sound level measurements of the One Hour Equivalent Sound Level (L_{eq}) and the Logarithmic Mean Impulse Sound Level (L_{LM}) shall be made in accordance with Reference [3].

All sound level measurements of the One Hour Ninetieth Percentile Sound Level (L_{90}) shall be made using a Sound Level Meter capable of measuring percentile sound levels. The meter shall meet the applicable requirements for an Integrating Sound Level Meter of Reference [2]. The measurements shall be carried out following procedures for the measurement of varying sound described in Reference [3].

Sound from existing adjacent stationary sources may be included in the determination of the background hourly sound levels L_{eq} and L_{90} , if such stationary sources are not under consideration for noise abatement by the Municipality or the Ministry of Environment and Energy.

7. SOUND LEVEL LIMITS - GENERAL

(1) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source, the sound level limit at a point of reception within 30 m of a dwelling or a camping area, expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}), is the lower of:

- the background One Hour Equivalent Sound Level (L_{eq}) obtained pursuant to Section 5; and
- the background One Hour Ninetieth Percentile Sound Level (L_{90}) plus 15 dB, i.e. $L_{90} + 15$ dB, obtained pursuant to Section 5.

(2) For sound from a stationary source, including Quasi-Steady Impulsive Sound but not including other impulsive sound, the sound level limit at a point of reception within 30 m of a dwelling or a camping area, expressed in terms of the One Hour Equivalent Sound Level (L_{eq}), is the lower of:

- the background One Hour Equivalent Sound Level (L_{eq}) obtained pursuant to Section 5; and
- the background One Hour Ninetieth Percentile Sound Level (L_{90}) plus 10 dB, i.e. $L_{90} + 10$ dB, obtained pursuant to Section 5.

8. SOUND LEVEL LIMITS - SPECIFIC IMPULSIVE SOUNDS

(1) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source which is an industrial metal working operation (including but not limited to forging, hammering, punching, stamping, cutting, forming and moulding), the sound level limit at a point of reception within 30 m of a dwelling or a camping area, expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}), is 60 dBAI, if the stationary source were operating before January 1, 1980, and otherwise is 50 dBAI.

(2) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source which is the discharge of firearms on the premises of a licensed gun club, the sound level limit at a point of reception within 30 m of a dwelling or a camping area, expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}), is:

- 70 dBAI if the gun club were operating before January 1, 1980; or
- 50 dBAI if the gun club began to operate after January 1, 1980; or
- the L_{LM} prior to expansion, alteration or conversion.

- (3) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source which is not a blasting operation in a surface mine or quarry, characterized by impulses which are so infrequent that they cannot normally be measured using the procedure for frequent impulses of Reference [3], the sound level limit at a point of reception within 30 m of a dwelling or a camping area, expressed in terms of the impulse sound level, is 100 dBAI.

9. SOUND LEVEL LIMITS - PEST CONTROL DEVICES

- (1) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a pest control device employed solely to protect growing crops, the sound level limit at a point of reception within 30 m of a dwelling or a camping area, expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}), is 70 dBAI.
- (2) For sound, including Quasi-Steady Impulsive Sound but not including other impulsive sound, from a pest control device employed solely to protect growing crops, the sound level limit at a point of reception within 30 m of a dwelling or a camping area, expressed in terms of the One Hour Equivalent Sound Level (L_{eq}), is 60 dBA.

10. PROHIBITION - PEST CONTROL DEVICES

The operation of a pest control device employed solely to protect growing crops is prohibited during the hours of darkness, sunset to sunrise.

11. PRE-EMPTION

The least restrictive sound level limit of Sections 8, 9 and 10 applies.

12. EXCLUSION

No restrictions apply to any stationary source resulting in a One Hour Equivalent Sound Level (L_{eq}) or a Logarithmic Mean Impulse Sound Level (L_{LM}), at a point of reception within 30 m of a dwelling or a camping area, lower than the minimum values for that time period, as specified in Table 232-1.

TABLE 232-1
Minimum Values of One Hour L_{eq} or L_{LM} by Time of Day

Time of Day	One Hour L_{eq} (dBA) or L_{LM} (dBAI)
0700 - 1900	45
1900 - 2300	40
2300 - 0700	40

Annex to Publication NPC-232 Sound Level Limits for Stationary Sources in Class 3 Areas (Rural)

October 1995

A.1. GENERAL

The definitions in Publication NPC-232 of a Class 3 Area (Rural), as well as Class 1 and 2 Areas (Urban), provide a broad characterization of the areas including a range of localities. In formulating the definitions, consideration was given to the fact that the terms "rural" and "urban" embody a conception of distinct types of dwelling habitat.

On one hand, the term "urban" traditionally conveys a distinct image of a concentration of people and activities in a predominantly man-made environment dominated by road traffic noise, making intensive use of the space available. On the other hand, the term "rural" brings to mind a sparse distribution of people and activities in a predominantly natural environment using land extensively (farming) or not at all (wilderness areas). In between these two categories fall areas that exhibit characteristics of both "urban" and "rural" areas, particularly at different times of the day.

It is, however, evident that not all of the environment will fit neatly into one of these categories. The predominance of road traffic in the area is a significant factor in determining rurality. For example, a residential property in an isolated recreational area, but close to a major roadway, would not be considered to be located in a Class 3 Area.

While examples of a rural setting, described in Publication NPC-232 provide some general guidelines, any classification of a point of reception as being in a Class 1, 2 or 3 Area should be made on an individual basis. The classification can, and should, utilize normally available information on zoning by-laws, official plans, and other policy statements, as well as the future character of the particular piece of land in question and the land in its vicinity.

The standard of environmental noise acceptability for a stationary source is, in general, expressed as the difference between the noise from the source and the background noise. In rural areas, this background noise is formed by natural sounds rather than man-made sounds.

The background noise may also include contributions from existing stationary sources adjacent to the stationary source under impact assessment. Contributions of these secondary stationary noise sources are considered to be a part of the existing noise environment, and may be included in the measurement of the background sound levels, provided that they are not under consideration for noise abatement by the Municipality or the Ministry of Environment and Energy.

In Class 1 and 2 Areas where the acoustical environment is governed primarily by road traffic, the background noise is best described by the energy equivalent sound level (L_{eq}). However, the background noise in Class 3 Areas is often better described in terms of the ninetieth percentile sound level (L_{90}). Therefore, Publication NPC-232 has established both the L_{90} as well as the L_{eq} of the background as the limits against which the intrusion of the source, measured in terms of the L_{eq} , is assessed.

A.2. APPLICATION

Sound level limits contained in this Publication do not apply to non-stationary noise sources nor to any equipment, apparatus or device used in agriculture for food crop seeding, chemical spraying or harvesting. In addition, several specific noise sources have been addressed in separate Publications. Limits for residential air conditioners are contained in Publication NPC-216 - Residential Air Conditioning Devices, Reference [8], and the limits for blasting operations in quarries and surface mines are contained in Publication NPC-119 - Blasting, Reference [7].

A.3. STATIONARY SOURCES

The objective of the definition of a stationary source of sound is to address sources such as industrial and commercial establishments or ancillary transportation facilities. In order to further clarify the scope of the definition, the following list identifies examples of installations, equipment, activities or facilities that are included and those that are excluded as stationary sources.

(1) Included Sources

Individual stationary sources such as:

- Heating, ventilating and air conditioning (HVAC) equipment;
- Rotating machinery;
- Impacting mechanical sources;
- Generators;
- Burners;
- Grain dryers.

Facilities, usually comprising many sources of sound. In this case, the stationary source is understood to encompass all the activities taking place within the property boundary of the facility. The following are examples of such facilities:

- Industrial facilities;
- Commercial facilities;
- Ancillary transportation facilities;
- Aggregate extraction facilities;
- Warehousing facilities;
- Maintenance and repair facilities;
- Snow disposal sites;
- Routine loading and unloading facilities (supermarkets, assembly plants, etc.).

Other sources such as:

- Car washes;
- Race tracks;
- Firearm Ranges.

(2) Excluded Sources

Specific sources or facilities:

- Construction activities;
- Transportation corridors, i.e. roadways and railways;
- Residential air conditioning devices including air conditioners and heat pumps;
- Gas stations;
- Auditory warning devices required or authorized by law or in accordance with good safety practices;
- Occasional movement of vehicles on the property such as infrequent delivery of goods to convenience stores, fast food restaurants, etc.

Other noise sources, normally addressed in a qualitative manner in municipal noise by-laws:

- The operation of auditory signalling devices, including but not limited to the ringing of bells or gongs and the blowing of horns or sirens or whistles, or the production, reproduction or amplification of any similar sounds by electronic means;
- Noise produced by animals kept as domestic pets such as dogs barking;
- Tools and devices used by occupants for domestic purposes such as domestic power tools, radios and televisions, etc., or activities associated with domestic situations such as domestic quarrels, noisy parties, etc;

Noise resulting from gathering of people at facilities such as restaurants and parks.

Activities related to essential service and maintenance of public facilities such as but not limited to roadways, parks and sewers, including snow removal, road cleaning, road repair and maintenance, lawn mowing and maintenance, sewage removal, garbage collection, etc.

A.4. PREDICTABLE WORST CASE IMPACT

The assessment of noise impact requires the determination of the "predictable worst case" impact. The "predictable worst case" impact assessment should establish the largest noise excess produced by the source over the applicable limit. The assessment should reflect a planned and predictable mode of operation of the stationary source.

It is important to emphasize that the "predictable worst case" impact does not necessarily mean that the sound level of the source is highest; it means that the excess over the limit is largest. For example, the excess over the applicable limit at night may be larger even if the day-time sound level produced by the source is higher.

A.5. DEFINITIONS

In the interpretation of Publication NPC-232, the following definitions are of particular relevance:

- Ancillary Transportation Facilities
"Ancillary transportation facilities" mean subsidiary locations where operations and activities associated with the housing of transportation equipment (or personnel) take place. Examples of ancillary transportation facilities include, but are not limited to, substations, vehicle storage and maintenance facilities, fans, fan and vent shafts, mechanical equipment plants, emergency services buildings, etc;
- Construction
"Construction" includes erection, alteration, repair, dismantling, demolition, structural maintenance, painting, moving, land clearing, earth moving, grading, excavating, the laying of pipe and conduit whether above or below ground level, street and highway building, concreting, equipment installation and alteration and the structural installation of construction components and materials in any form or for any purpose, and includes any work in connection therewith; "construction" excludes activities associated with the operation at waste and snow disposal sites;
- Construction Equipment
"Construction equipment" means any equipment or device designed and intended for use in construction, or material handling including but not limited to, air compressors, pile drivers, pneumatic or hydraulic tools, bulldozers, tractors, excavators, trenchers, cranes, derricks, loaders, scrapers, pavers, generators, off-highway haulers or trucks, ditchers, compactors and rollers, pumps, concrete mixers, graders, or other material handling equipment;
- Conveyance
"Conveyance" includes a vehicle and any other device employed to transport a person or persons or goods from place to place but does not include any such device or vehicle if operated only within the premises of a person;
- Highway
"Highway" includes a common and public highway, street, avenue, parkway, driveway, square, place, bridge, viaduct or trestle designed and intended for, or used by, the general public for the passage of vehicles;

- Motor Vehicle
"Motor vehicle" includes an automobile, motorcycle, and any other vehicle propelled or driven otherwise than by muscular power, but does not include the cars of diesel, electric or steam railways, or other motor vehicles running only upon rails, or a motorized snow vehicle, traction engine, farm tractor, self-propelled implement of husbandry or road-building machine within the meaning of the Highway Traffic Act;
- Motorized Conveyance
"Motorized conveyance" means a conveyance propelled or driven otherwise than by muscular, gravitational or wind power;
- Noise
"Noise" means unwanted sound;
- Point of Reception - Class 3 Area
"Point of reception - Class 3 Area" means a point on the premises of a person within 30 m of a dwelling or a camping area, where sound or vibration originating from other than those premises is received.

For the purpose of approval of new sources, including verifying compliance with Section 9 of the Environmental Protection Act, the point of reception may be located on any of the following existing or zoned for future use premises: permanent or seasonal residences, hotels/motels, nursing/retirement homes, rental residences, hospitals, camp grounds, and noise sensitive buildings such as schools and places of worship.

For equipment/facilities proposed on premises such as nursing/retirement homes, rental residences, hospitals, and schools, the point of reception may be located on the same premises;
- Stationary Source
"Stationary source" means a source of sound which does not normally move from place to place and includes the premises of a person as one stationary source, unless the dominant source of sound on those premises is construction or a conveyance;
- Urban Hum
means aggregate sound of many unidentifiable, mostly road traffic related noise sources.

APPENDIX C

NPC - 205 - SOUND LEVEL LIMITS FOR STATIONARY SOURCES IN CLASS 1 & 2 AREAS (URBAN)

**SOUND LEVEL LIMITS FOR
STATIONARY SOURCES IN
CLASS 1 & 2 AREAS (URBAN)**

PUBLICATION NPC-205

OCTOBER 1995



**Ministry
of the
Environment**

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Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban) Publication NPC-205

October 1995

This Publication establishes sound level limits for stationary sources such as industrial and commercial establishments or ancillary transportation facilities, affecting points of reception in Class 1 and 2 Areas (Urban). It replaces Publication NPC-105 "Stationary Sources" of the "Model Municipal Noise Control By-Law, Final Report, August 1978".

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1. SCOPE

This Publication establishes sound level limits for stationary sources such as industrial and commercial establishments or ancillary transportation facilities, affecting points of reception in Class 1 and 2 Areas (Urban). The limits apply to noise complaint investigations carried out in order to determine potential violation of Section 14 of the Environmental Protection Act. The limits also apply to the assessment of planned stationary sources of sound in compliance with Section 9 of the Environmental Protection Act, and under the provisions of the Aggregate Resources Act and the Environmental Assessment Act.

This Publication does not address sound and vibration produced by blasting; blasting in quarries and surface mines is considered in Reference [7].

The Publication includes an Annex, which provides additional details, definitions and rationale for the sound level limits.

2. REFERENCES

Reference is made to the following publications:

- [1] NPC-101 - Technical Definitions
- [2] NPC-102 - Instrumentation
- [3] NPC-103 - Procedures
- [4] NPC-104 - Sound Level Adjustments
- [6] NPC-206 - Sound Levels due to Road Traffic
- [7] NPC-119 - Blasting
- [8] NPC-216 - Residential Air Conditioning Devices
- [9] NPC-232 - Sound Level Limits for Stationary Sources in Class 3 Areas (Rural)
- [10] NPC-233 - Information to be Submitted for Approval of Stationary Sources of Sound
- [12] ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation, Technical Document, Ontario Ministry of the Environment, ISBN 0-7729-6376, 1989

References [1] to [4] and [7] can be found in the
Model Municipal Noise Control By-Law, Ontario Ministry of the Environment, Final Report, August 1978.

3. TECHNICAL DEFINITIONS

"Ambient sound level"
means Background sound level.

"Background sound level"
is the sound level that is present in the environment, produced by noise sources other than the source under impact assessment. Highly intrusive short duration noise caused by a source such as an aircraft fly-over or a train pass-by is excluded from the determination of the background sound level.

"Class 1 Area"
means an area with an acoustical environment typical of a major population centre, where the background noise is dominated by the urban hum.

"Class 2 Area"

means an area with an acoustical environment that has qualities representative of both Class 1 and Class 3 Areas, and in which a low ambient sound level, normally occurring only between 23:00 and 07:00 hours in Class 1 Areas, will typically be realized as early as 19:00 hours.

Other characteristics which may indicate the presence of a Class 2 Area include:

- absence of urban hum between 19:00 and 23:00 hours;
- evening background sound level defined by natural environment and infrequent human activity; and
- no clearly audible sound from stationary sources other than from those under impact assessment.

"Class 3 Area"

means a rural area with an acoustical environment that is dominated by natural sounds having little or no road traffic, such as the following:

- a small community with less than 1000 population;
- agricultural area;
- a rural recreational area such as a cottage or a resort area; or
- a wilderness area.

Other technical terms are defined in Reference [1] and in the Annex to Publication NPC-205.

4. ESTABLISHMENT OF LIMITS - OBJECTIVE

The sound level limit at a point of reception must be established based on the principle of "predictable worst case" noise impact. In general, the limit is given by the background sound level at the point of reception. The sound level limit must represent the minimum background sound level that occurs or is likely to occur during the operation of the stationary source under impact assessment.

5. BACKGROUND SOUND LEVELS

The time interval between the background sound level measurement and the measurement of the sound level produced by the stationary source under impact assessment should be minimized as much as possible. Preferably, the two measurements should be carried out within one hour of each other.

6. SOUND LEVELS DUE TO STATIONARY SOURCES**(1) Complaint Investigation of Stationary Sources**

The One Hour Equivalent Sound Level (L_{eq}) and/or the Logarithmic Mean Impulse Sound Level (L_{LM}) produced by the stationary sources shall be obtained by measurement performed in accordance with Section 7.

(2) Approval of Stationary Sources

The One Hour Equivalent Sound Level (L_{eq}) and/or the Logarithmic Mean Impulse Sound Level (L_{LM}) produced by the stationary sources shall be obtained by measurement or prediction. The estimation of the L_{eq} and/or L_{LM} of the stationary source under impact assessment shall reflect the principle of "predictable worst case" noise impact. The "predictable worst case" noise impact occurs during the hour when the difference between the predicted sound level produced by the stationary source and the background sound level of the natural environment is at a maximum.

7. PROCEDURES

All sound level measurements and calculations shall be made in accordance with References [3], [6] and [12].

Sound from existing adjacent stationary sources may be included in the determination of the background One Hour Equivalent Sound Level (L_{eq}) if such stationary sources of sound are not under consideration for noise abatement by the Municipality or the Ministry of Environment and Energy.

8. SOUND LEVEL LIMITS - GENERAL

- (1) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source, the sound level limit expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}) is the background One Hour Equivalent Sound Level (L_{eq}) typically caused by road traffic as obtained pursuant to Section 6 for that point of reception.
- (2) For sound from a stationary source, including Quasi-Steady Impulsive Sound but not including other impulsive sound, the sound level limit expressed in terms of the One Hour Equivalent Sound Level (L_{eq}) is the background One Hour Equivalent Sound Level (L_{eq}) typically caused by road traffic as obtained pursuant to Section 6 for that point of reception.

9. SOUND LEVEL LIMITS - SPECIFIC IMPULSIVE SOUNDS

- (1) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source which is an industrial metal working operation (including but not limited to forging, hammering, punching, stamping, cutting, forming and moulding), the sound level limit at a point of reception expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}) is 60 dBAI, if the stationary source were operating before January 1, 1980, and otherwise is 50 dBAI.
- (2) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source which is the discharge of firearms on the premises of a licensed gun club, the sound level limit at a point of reception expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}) is:
 - 70 dBAI if the gun club were operating before January 1, 1980; or
 - 50 dBAI if the gun club began to operate after January 1, 1980; or
 - the L_{LM} prior to expansion, alteration or conversion.
- (3) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a stationary source which is not a blasting operation in a surface mine or quarry, characterized by impulses which are so infrequent that they cannot normally be measured using the procedure for frequent impulses of Reference [3] the sound level limit at a point of reception expressed in terms of the impulse sound level is 100 dBAI.

10. SOUND LEVEL LIMITS - PEST CONTROL DEVICES

- (1) For impulsive sound, other than Quasi-Steady Impulsive Sound, from a pest control device employed solely to protect growing crops, the sound level limit at a point of reception expressed in terms of the Logarithmic Mean Impulse Sound Level (L_{LM}) is 70 dBAI.
- (2) For sound, including Quasi-Steady Impulsive Sound but not including other impulsive sound, from a pest control device employed solely to protect growing crops, the sound level limit at a point of reception expressed in terms of the One Hour Equivalent Sound Level (L_{eq}) is 60 dBA.

11. PROHIBITION - PEST CONTROL DEVICES

The operation of a pest control device employed solely to protect growing crops outdoors during the hours of darkness, sunset to sunrise, is prohibited.

12. PRE-EMPTION

The least restrictive sound level limit of Sections 8, 9 and 10 applies.

13. EXCLUSION

No restrictions apply to a stationary source resulting in a One Hour Equivalent Sound Level (L_{eq}) or a Logarithmic Mean Impulse Sound Level (L_{LM}) lower than the minimum values for that time period specified in Table 205-1.

TABLE 205-1
Minimum Values of One Hour L_{eq} or L_{LM} by Time of Day

Time of Day	One Hour L_{eq} (dBA) or L_{LM} (dBAI)	
	Class 1 Area	Class 2 Area
0700 - 1900	50	50
1900 - 2300	47	45
2300 - 0700	45	45

Annex to Publication NPC-205

Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban)

October 1995

A.1. GENERAL

In general, noises are annoying because they are heard over and above the level of the so-called "background" or surrounding environmental noise climate at a particular location. The standard for environmental noise acceptability of stationary sources is therefore expressed as the difference between noise from the source and the background noise.

The background noise is essentially made up of the road traffic noise which creates an "urban hum". It may also include contributions from existing industry or commercial activity adjacent to the stationary source under investigation. Contributions of these secondary noise sources are considered to be a part of urban hum and may be included in the measurements or calculation of the background sound levels, provided that they are not under consideration for noise abatement by the Municipality or the Ministry of Environment and Energy.

The sound level limits specified in Section 8 of Publication NPC-205 represent the general limitation on noise produced by stationary sources. Some noises, however, are annoying no matter where or in what kind of environment they exist. High level impulsive noises represent a special category and, consequently, are restricted by an absolute limitation. Sections 9 and 10 of this Publication provide criteria of acceptability for specific impulsive noise sources.

A.2. APPLICATION

The limits presented in Publication NPC-205 are designed for the control of noise from sources located in industrial, commercial or residential areas. The limits apply to points of reception located in Class 1 and Class 2 Areas.

Sound level limits contained in Publication NPC-205 do not apply to the excluded noise sources listed in Section A.3.(2) and neither do they apply to any equipment, apparatus or device used in agriculture for food crop seeding, chemical spraying or harvesting. In addition, several specific noise sources have been addressed in separate Publications. Limits for residential air conditioners are contained in Publication NPC-216 - Residential Air Conditioning Devices, Reference [8] and the limits for blasting operations in quarries and surface mines are contained in Publication NPC-119 - Blasting, Reference [7].

A.3. STATIONARY SOURCES

The objective of the definition of a stationary source of sound is to address sources such as industrial and commercial establishments or ancillary transportation facilities. In order to further clarify the scope of the definition, the following list identifies examples of installations, equipment, activities or facilities that are included and those that are excluded as stationary sources.

(1) Included Sources

Individual stationary sources such as:

- Heating, ventilating and air conditioning (HVAC) equipment;
- Rotating machinery;
- Impacting mechanical sources;
- Generators;
- Burners;
- Grain dryers.

Facilities, usually comprising many sources of sound. In this case, the stationary source is understood to encompass all the activities taking place within the property boundary of the facility. The following are examples of such facilities:

- Industrial facilities;
- Commercial facilities;
- Ancillary transportation facilities;
- Aggregate extraction facilities;
- Warehousing facilities;
- Maintenance and repair facilities;
- Snow disposal sites;
- Routine loading and unloading facilities (supermarkets, assembly plants, etc.).

Other sources such as:

- Car washes;
- Race tracks;
- Firearm Ranges.

(2) Excluded Sources

Specific sources or facilities:

- Construction activities;
- Transportation corridors, i.e. roadways and railways;
- Residential air conditioning devices including air conditioners and heat pumps;
- Gas stations;
- Auditory warning devices required or authorized by law or in accordance with good safety practices;
- Occasional movement of vehicles on the property such as infrequent delivery of goods to convenience stores, fast food restaurants, etc.

Other noise sources, normally addressed in a qualitative manner in municipal noise by-laws:

- The operation of auditory signalling devices, including but not limited to the ringing of bells or gongs and the blowing of horns or sirens or whistles, or the production, reproduction or amplification of any similar sounds by electronic means;
- Noise produced by animals kept as domestic pets such as dogs barking;
- Tools and devices used by occupants for domestic purposes such as domestic power tools, radios and televisions, etc., or activities associated with domestic situations such as domestic quarrels, noisy parties, etc.;
- Noise resulting from gathering of people at facilities such as restaurants and parks.

Activities related to essential service and maintenance of public facilities such as but not limited to roadways, parks and sewers, including snow removal, road cleaning, road repair and maintenance, lawn mowing and maintenance, sewage removal, garbage collection, etc.

A.4. PREDICTABLE WORST CASE IMPACT

The assessment of noise impact requires the determination of the "predictable worst case" impact. The "predictable worst case" impact assessment should establish the largest noise excess produced by the source over the applicable limit. The assessment should reflect a planned and predictable mode of operation of the stationary source.

It is important to emphasize that the "predictable worst case" impact does not necessarily mean that the sound level of the source is highest; it means that the excess over the limit is largest. For example, the excess over the applicable limit at night may be larger even if the day-time sound level produced by the source is higher.

A.5. DEFINITIONS

In the interpretation of Publication NPC-205, the following definitions are of particular relevance:

- Ancillary Transportation Facilities
"Ancillary transportation facilities" mean subsidiary locations where operations and activities associated with the housing of transportation equipment (or personnel) take place. Examples of ancillary transportation facilities include, but are not limited to, substations, vehicle storage and maintenance facilities, fans, fan and vent shafts, mechanical equipment plants, emergency services buildings, etc;
- Construction
"Construction" includes erection, alteration, repair, dismantling, demolition, structural maintenance, painting, moving, land clearing, earth moving, grading, excavating, the laying of pipe and conduit whether above or below ground level, street and highway building, concreting, equipment installation and alteration and the structural installation of construction components and materials in any form or for any purpose, and includes any work in connection therewith; "construction" excludes activities associated with the operation at waste and snow disposal sites;
- Construction Equipment
"Construction equipment" means any equipment or device designed and intended for use in construction, or material handling including but not limited to, air compressors, pile drivers, pneumatic or hydraulic tools, bulldozers, tractors, excavators, trenchers, cranes, derricks, loaders, scrapers, pavers, generators, off-highway haulers or trucks, ditchers, compactors and rollers, pumps, concrete mixers, graders, or other material handling equipment;
- Conveyance
"Conveyance" includes a vehicle and any other device employed to transport a person or persons or goods from place to place but does not include any such device or vehicle if operated only within the premises of a person;
- Highway
"Highway" includes a common and public highway, street, avenue, parkway, driveway, square, place, bridge, viaduct or trestle designed and intended for, or used by, the general public for the passage of vehicles;
- Motor Vehicle
"Motor vehicle" includes an automobile, motorcycle, and any other vehicle propelled or driven otherwise than by muscular power, but does not include the cars of diesel, electric or steam railways, or other motor vehicles running only upon rails, or a motorized snow vehicle, traction engine, farm tractor, self-propelled implement of husbandry or road-building machine within the meaning of the Highway Traffic Act;
- Motorized Conveyance
"Motorized conveyance" means a conveyance propelled or driven otherwise than by muscular, gravitational or wind power;
- Noise
"Noise" means unwanted sound;
- Point of Reception
"Point of reception" means any point on the premises of a person where sound or vibration originating from other than those premises is received.

For the purpose of approval of new sources, including verifying compliance with Section 9 of the Environmental Protection Act, the point of reception may be located on any of the following existing or zoned for future use premises: permanent or seasonal residences, hotels/motels, nursing/retirement homes, rental residences, hospitals, camp grounds, and noise sensitive buildings such as schools and places of worship.

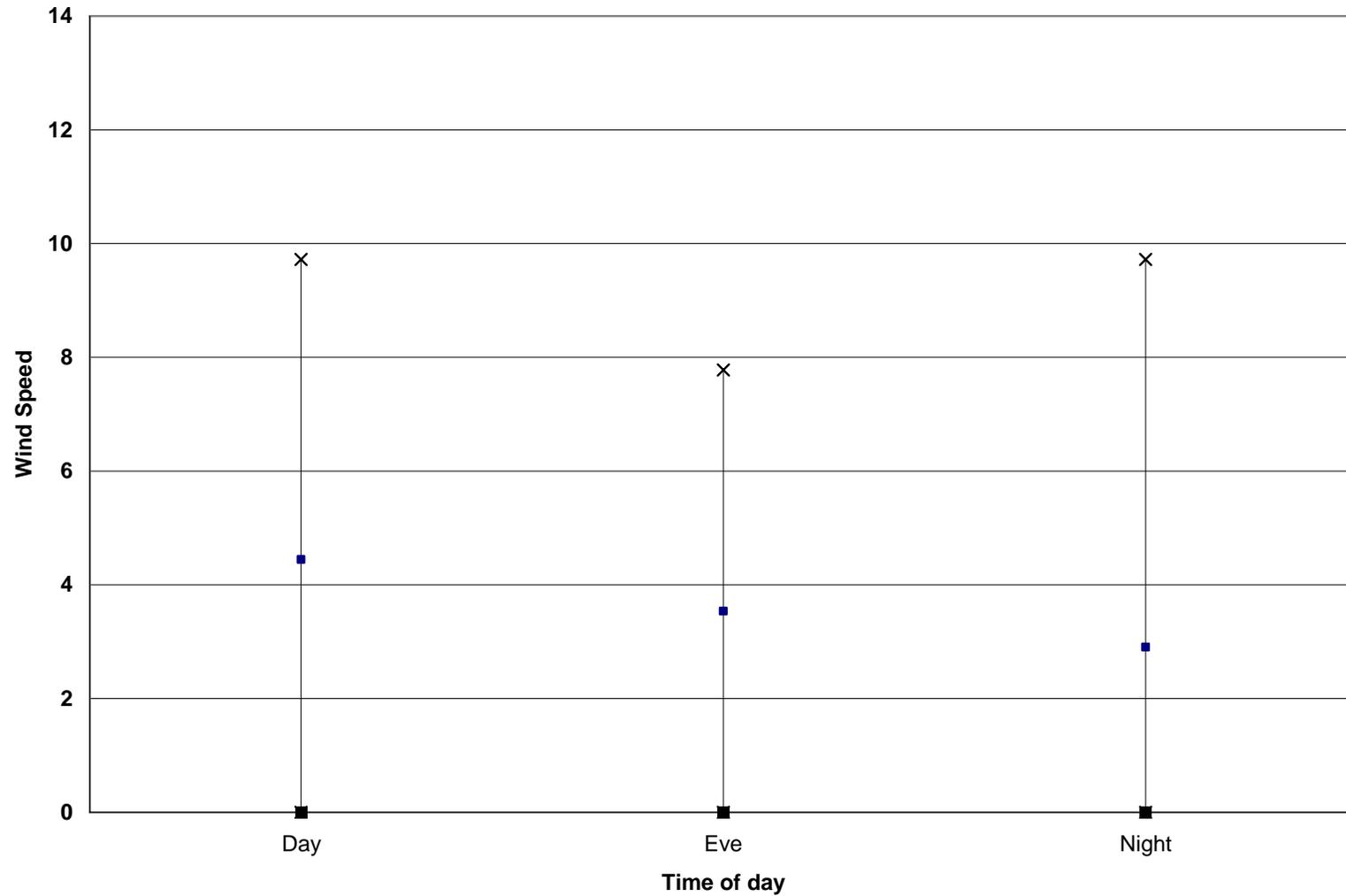
For equipment/facilities proposed on premises such as nursing/retirement homes, rental residences, hospitals, and schools, the point of reception may be located on the same premises;

- Stationary Source
"Stationary source" means a source of sound which does not normally move from place to place and includes the premises of a person as one stationary source, unless the dominant source of sound on those premises is construction or a conveyance;
- Urban Hum
means aggregate sound of many unidentifiable, mostly road traffic related noise sources.

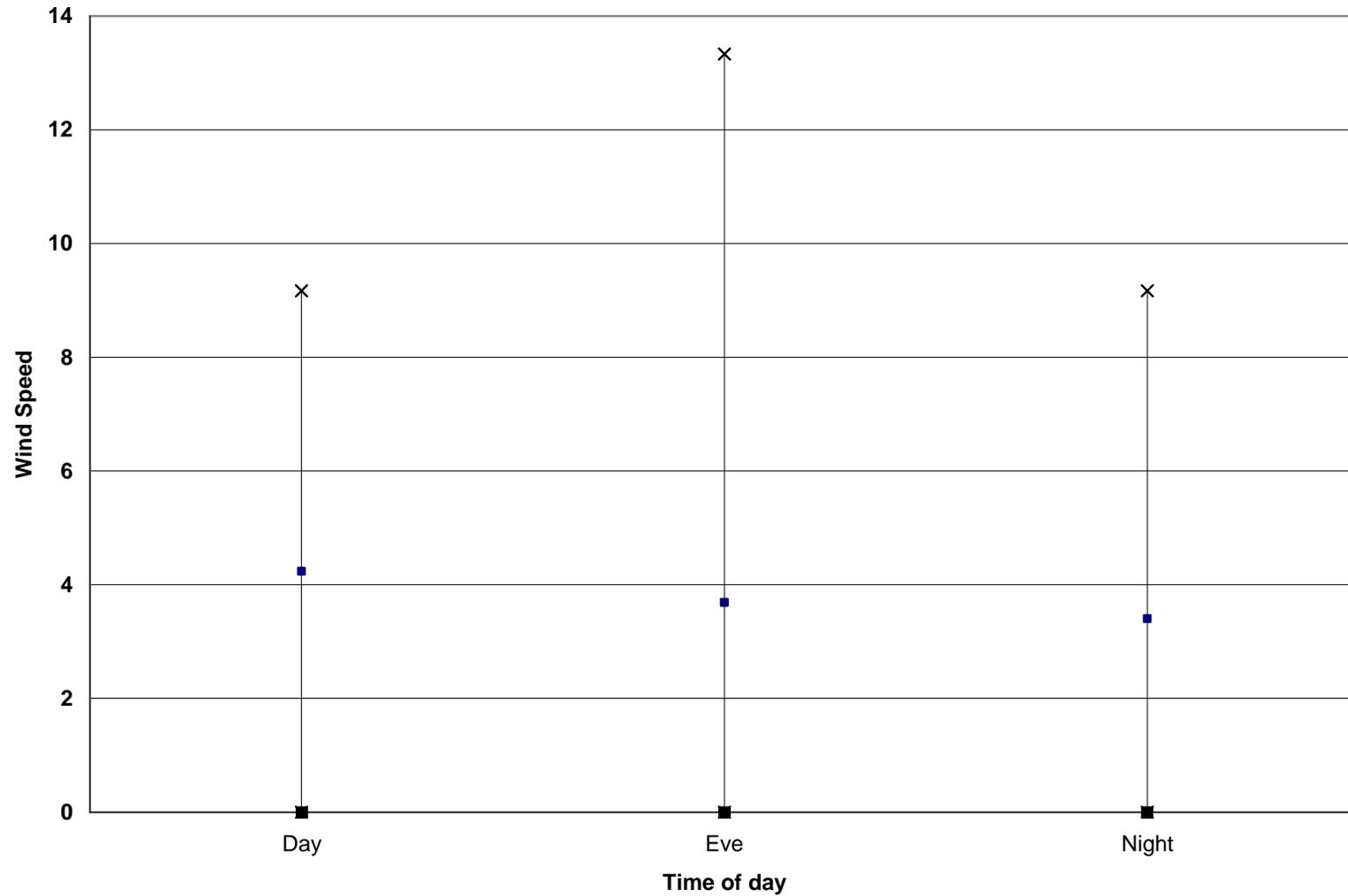
APPENDIX D

WEATHER DATA (GODERICH STATION) - WIND POWER OUTPUT DATA (KINGSBRIDGE WIND FARMS) FOR JUNE, JULY & AUGUST 2006

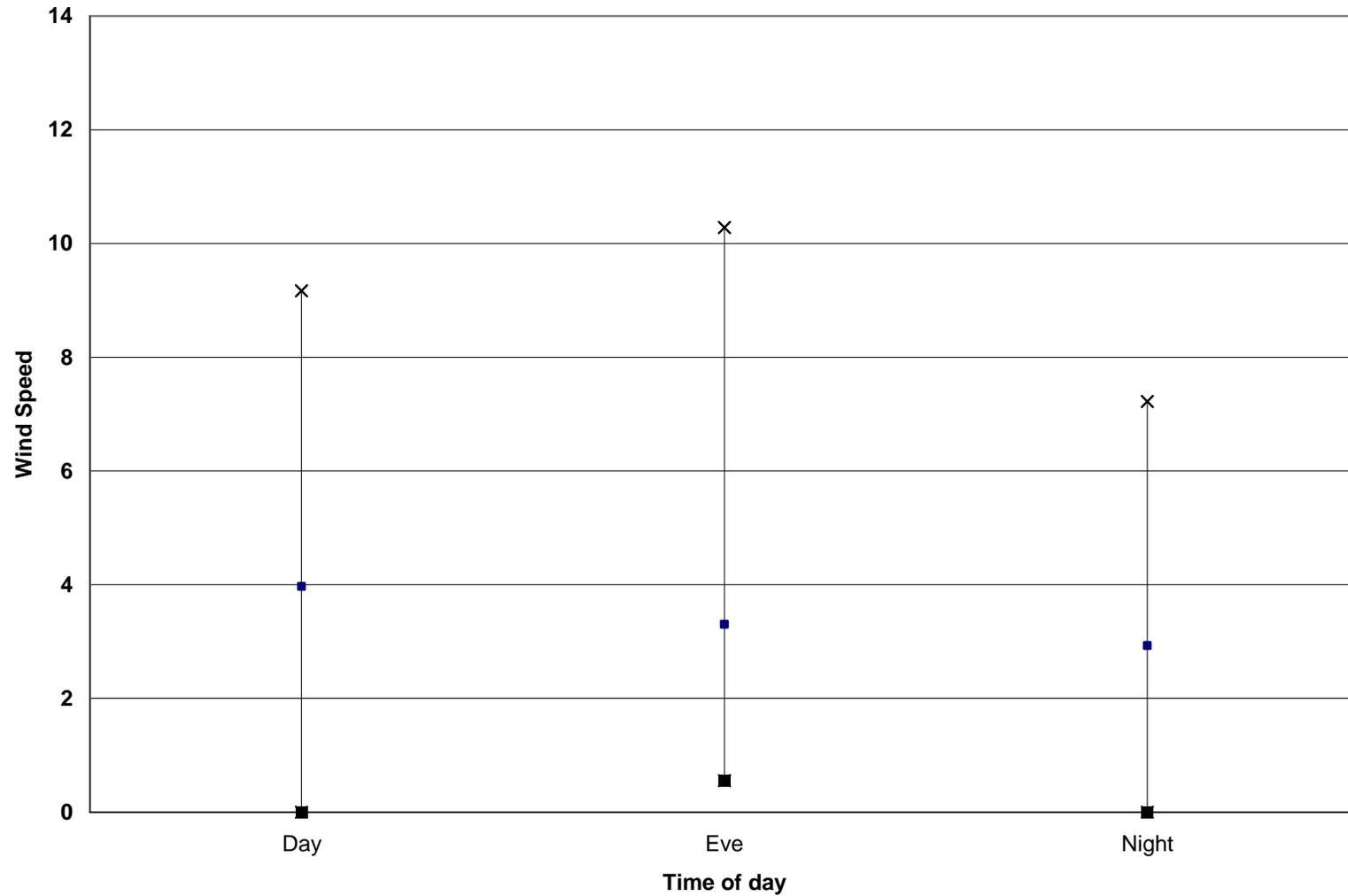
June (Wind Speed vs. time of day)



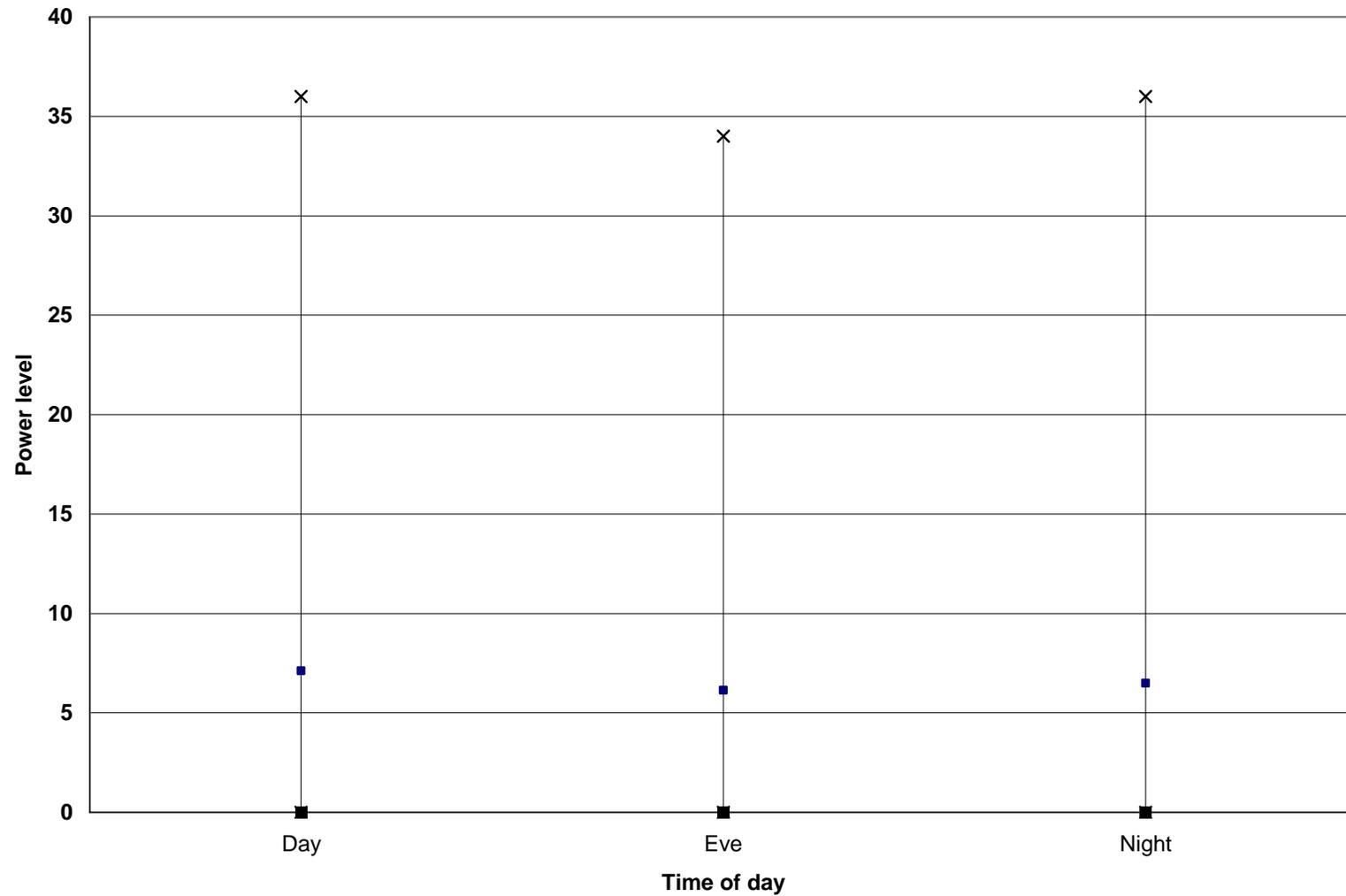
July (Wind Speed vs. time of day)



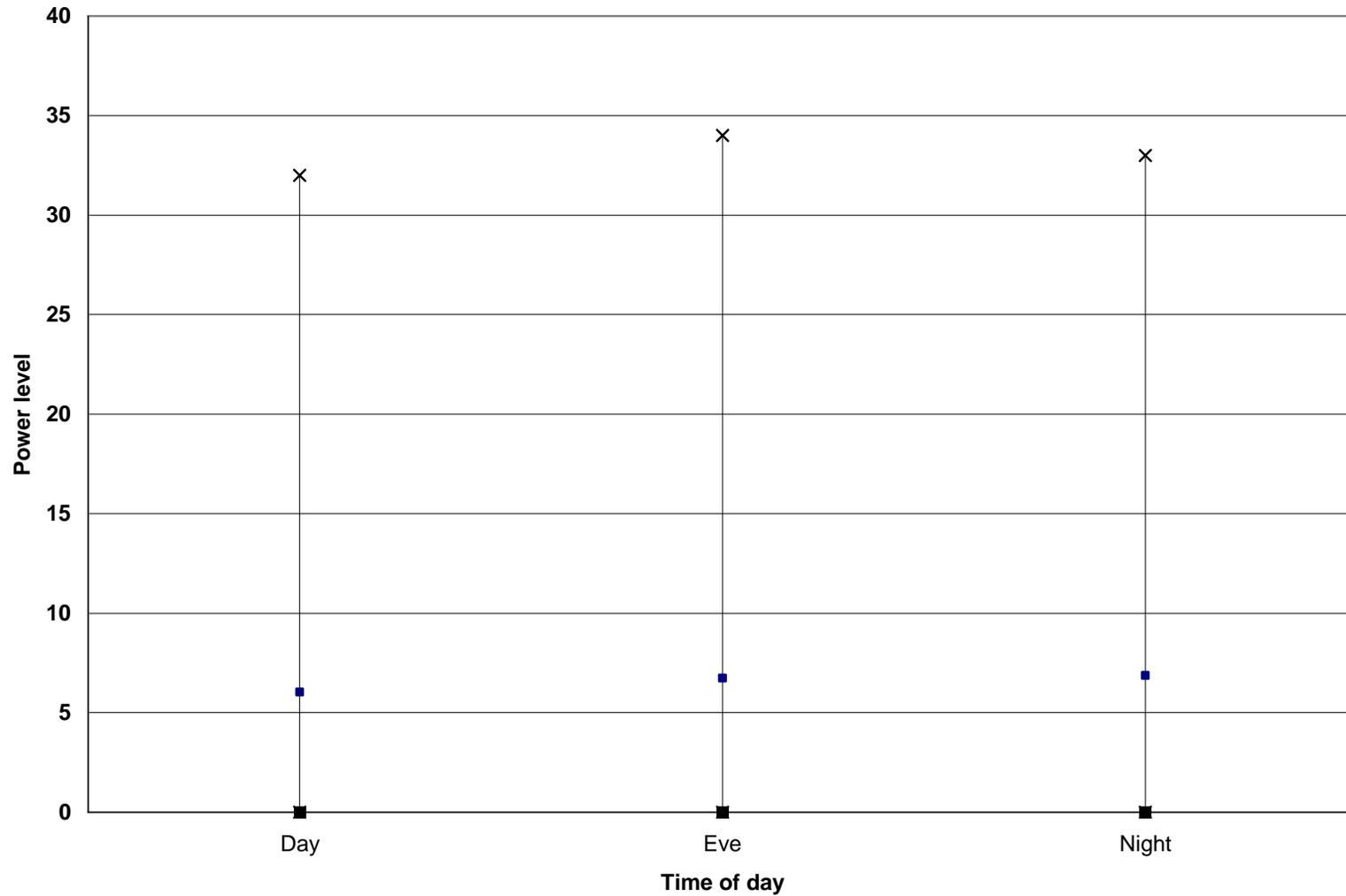
August (wind spd vs. time of day)



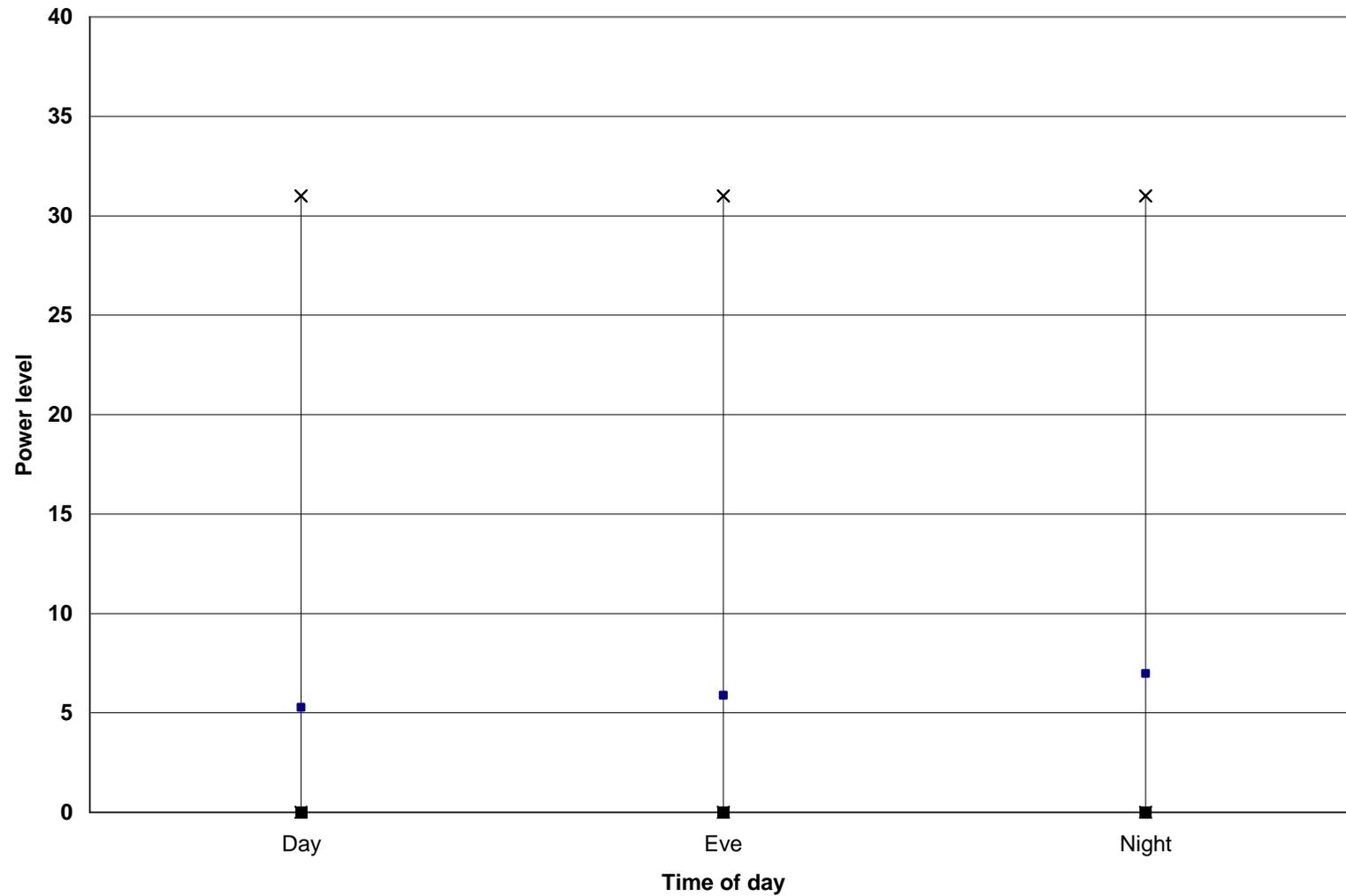
June (Pwr vs. time of day)



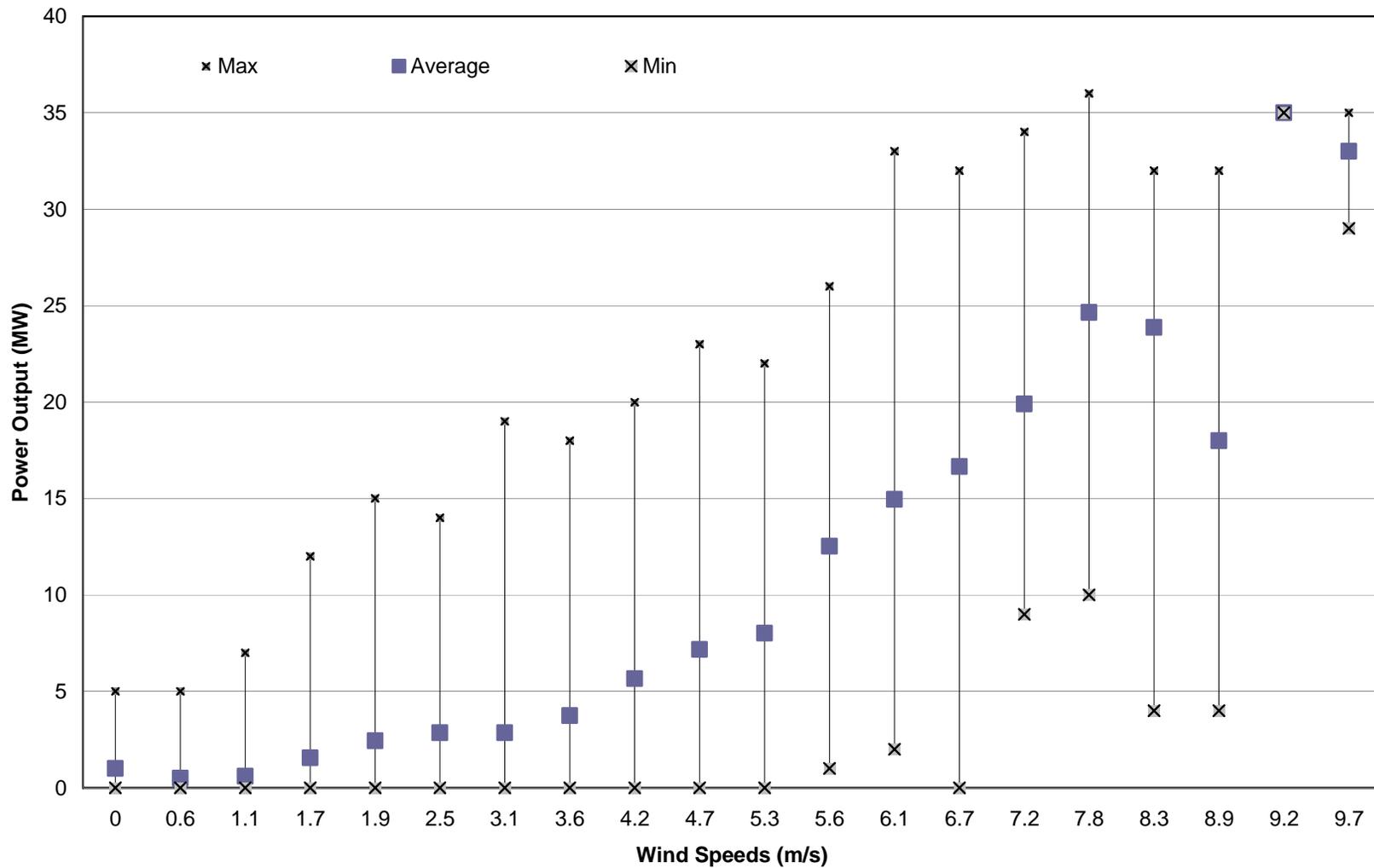
July (Pwr vs. time of day)



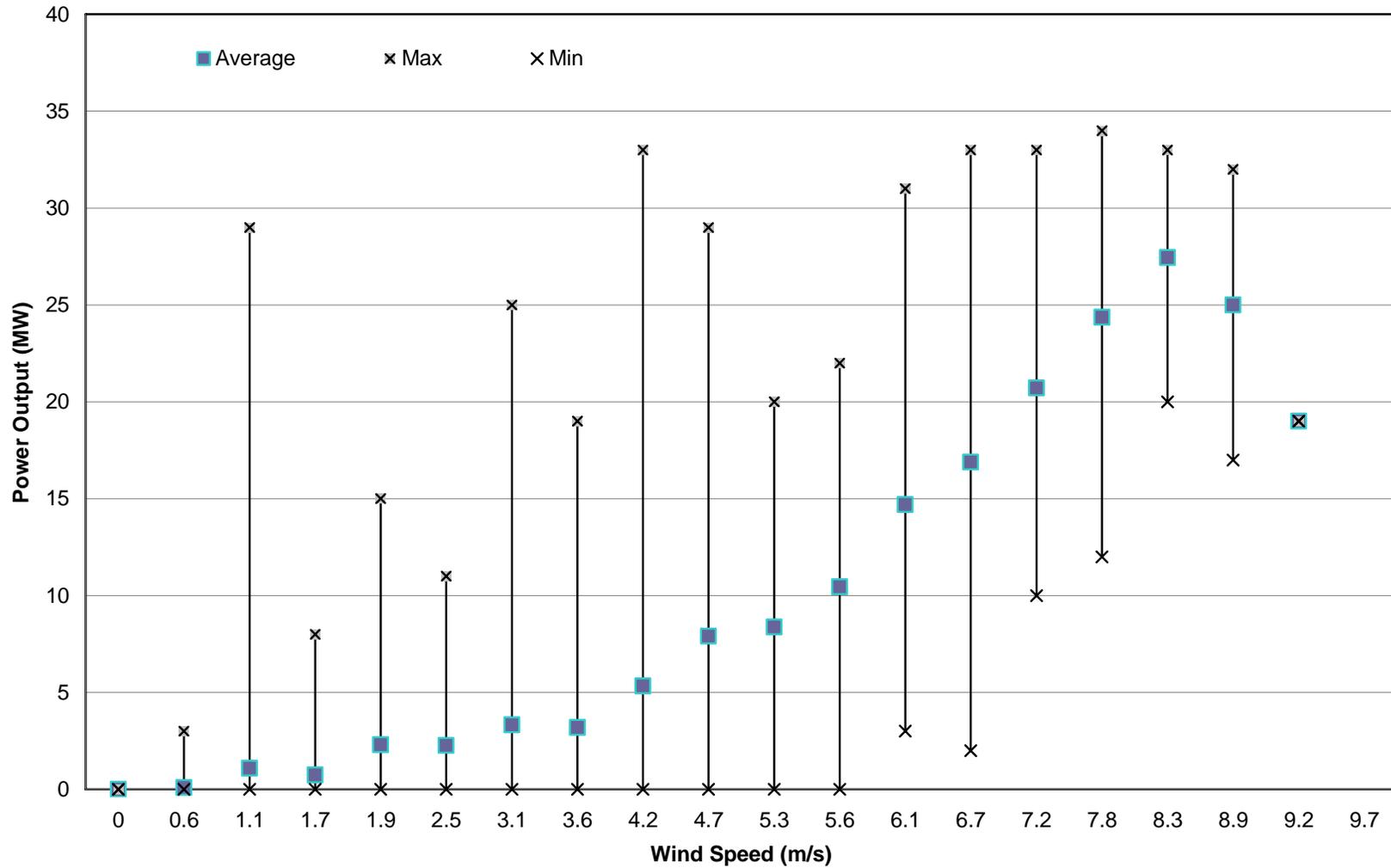
August (Pwr vs. time of day)



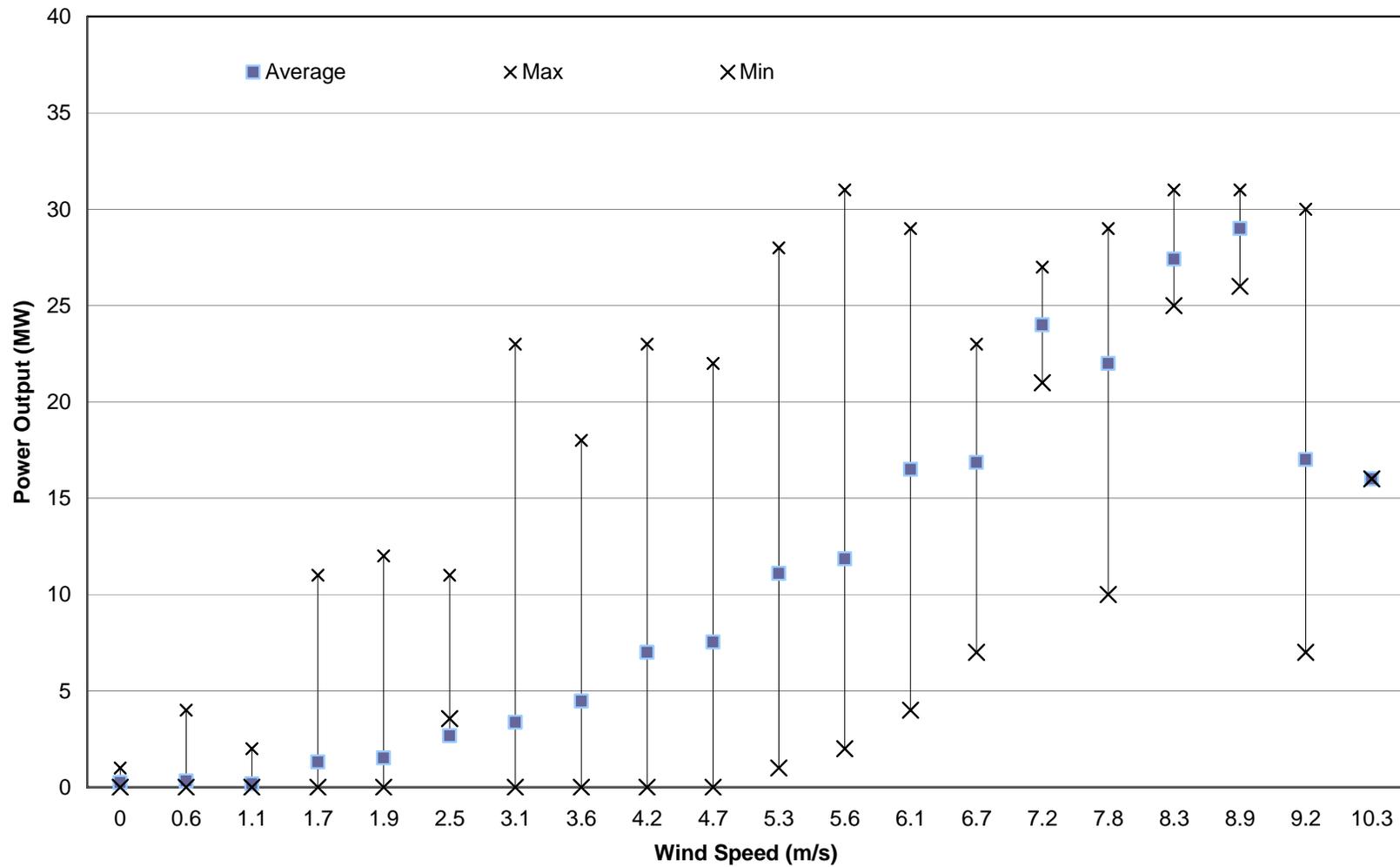
Power Output vs. Wind Speeds for June



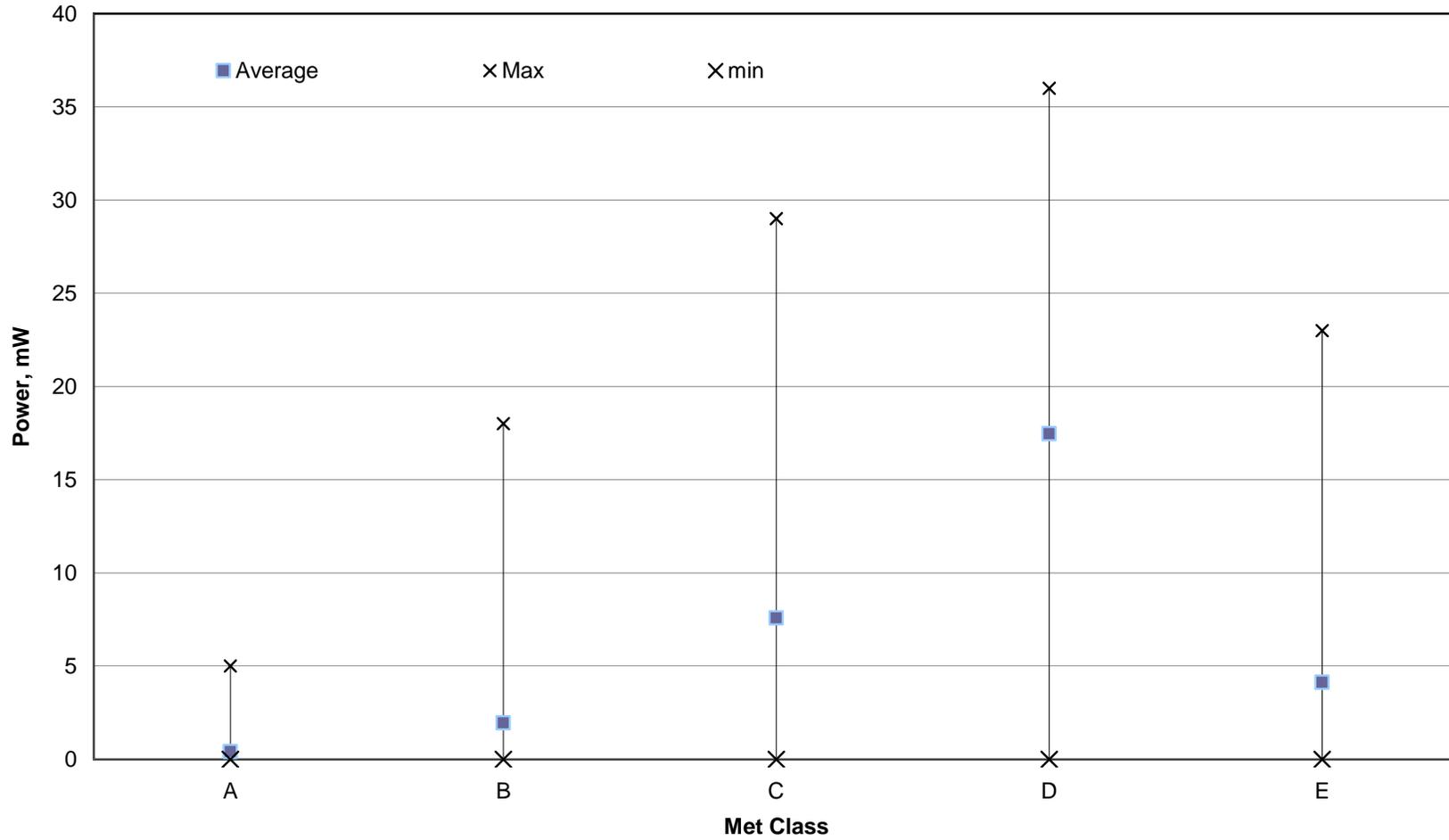
Max, Average and Min Power output for Month of July



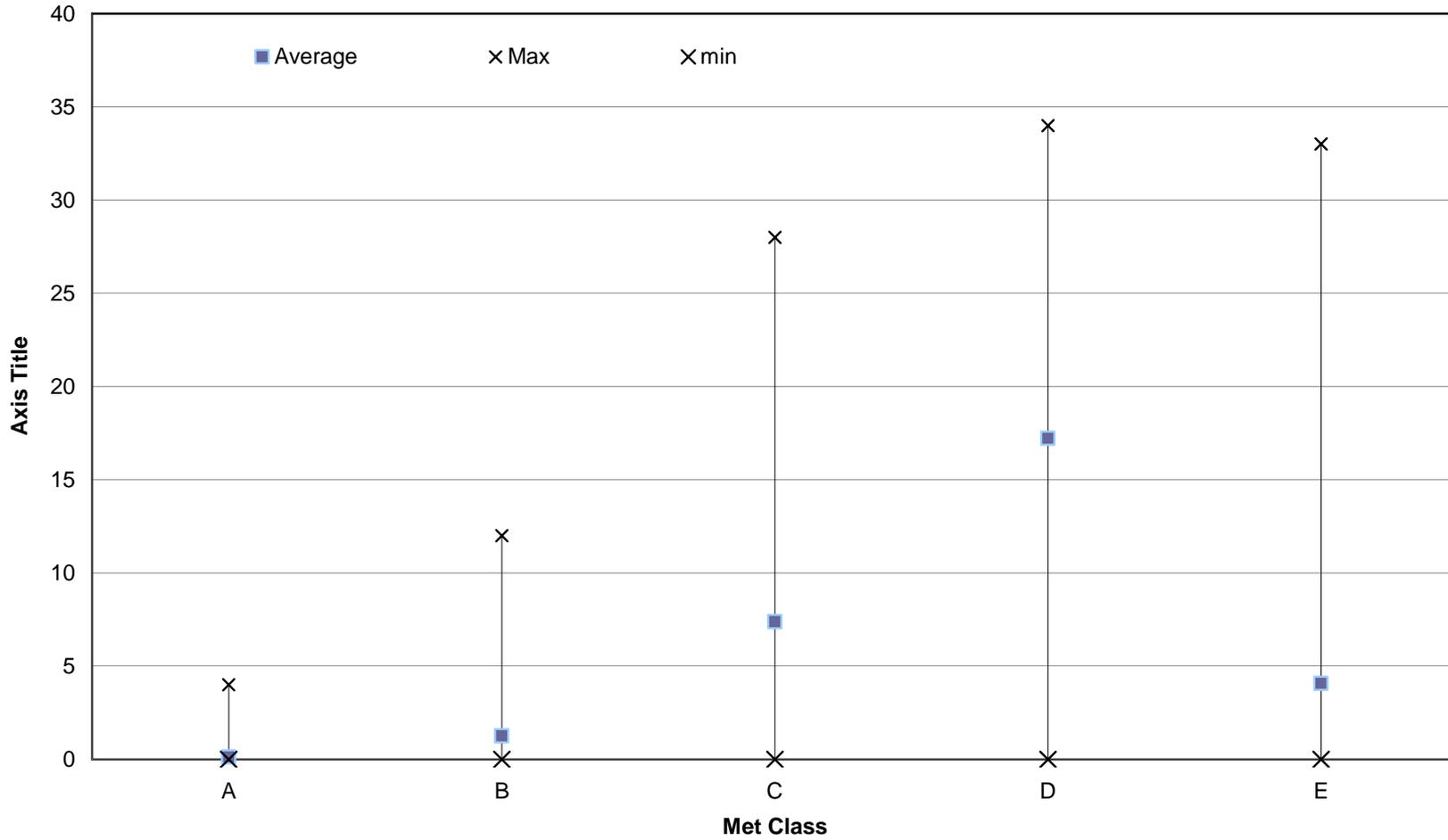
Max, Average and Min Power output for Month of August



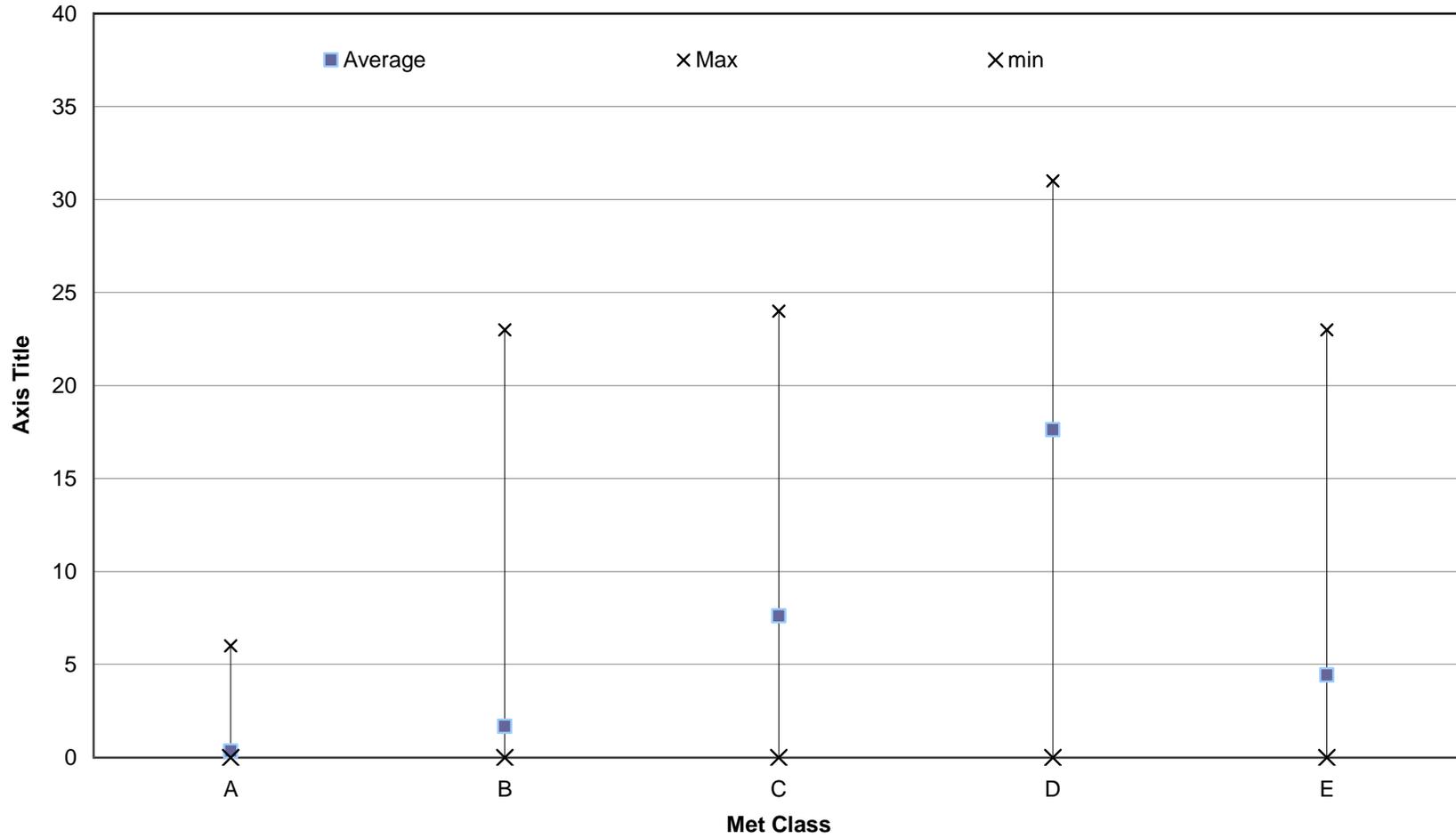
Max, Average and Min Power output for Month of June vs. Class



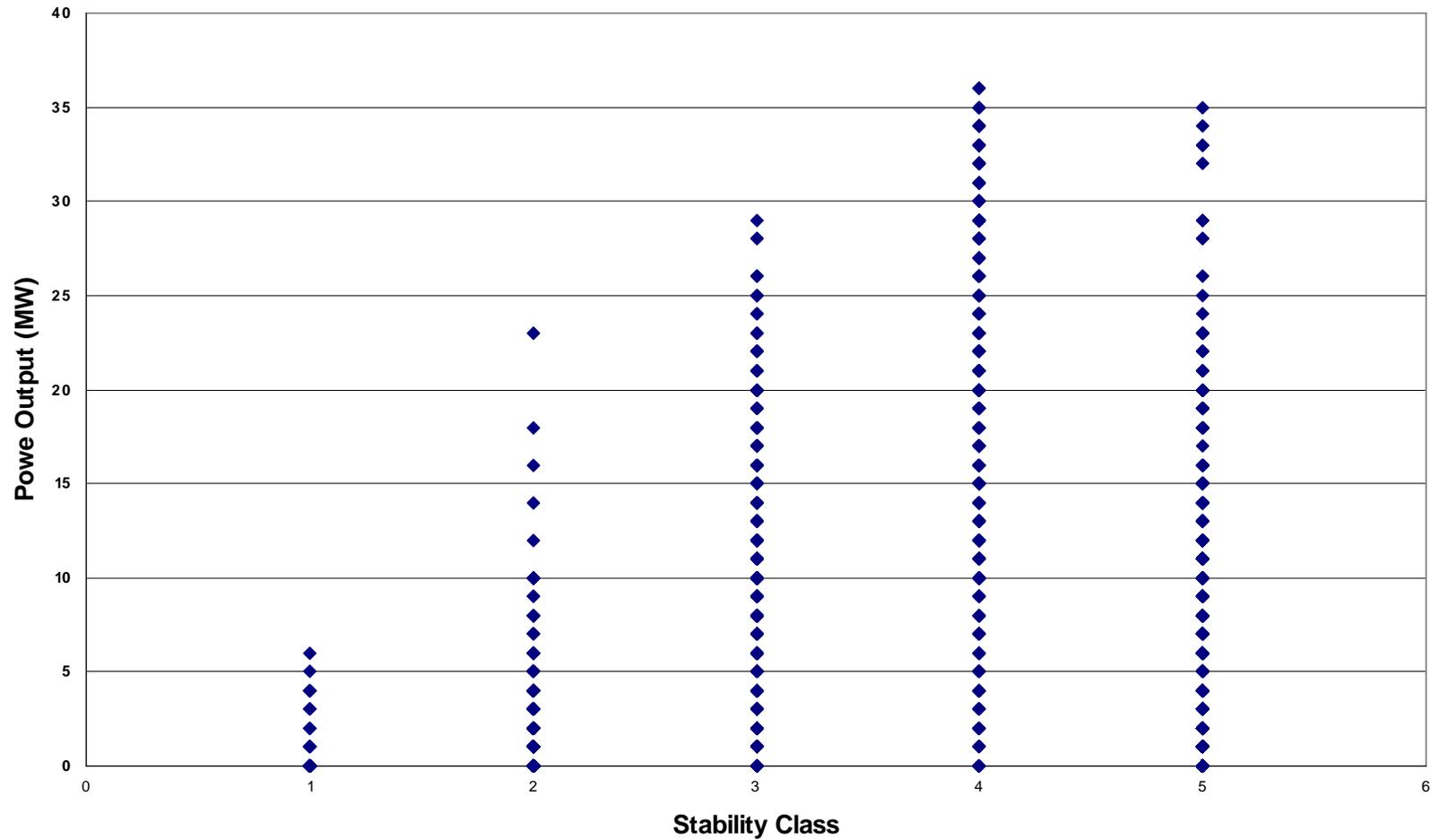
Max, Average and Min Power output for Month of July vs. Class

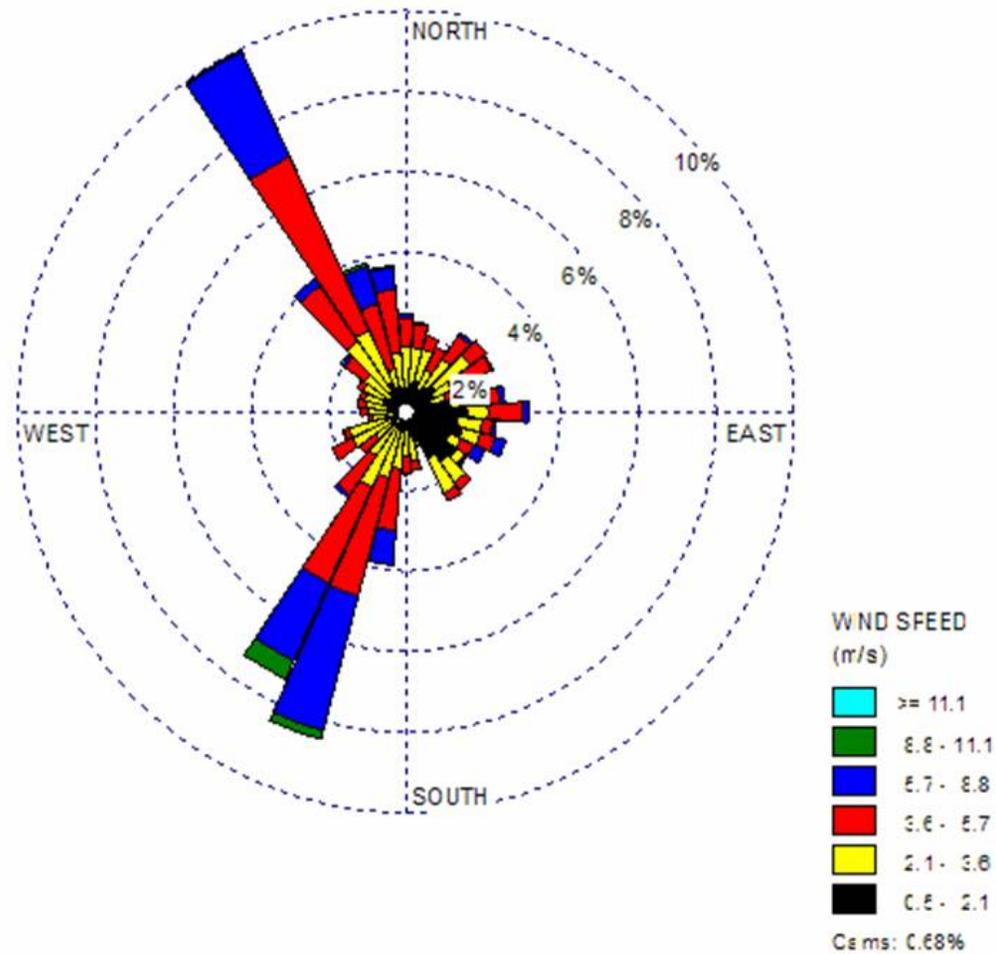


Max, Average and Min Power output for Month of August vs. Class



Power Output vs. Stability class for all three months





Windrose data for Goderich Station for June, July and August 2006 combined.

APPENDIX E

THE BEATING PHENOMENON

E1. Background

One of the main source characteristics that has been attributed to wind turbine noise is they produce swishing sound. Alternate terminologies used for the swishing sound are; beating, thumping, hammer etc. etc. by people being exposed to the wind turbine noise.

G. P. van den berg in his doctoral dissertation, Chapter V-Page 61 (Reference 1) states, “Atmospheric stability is not only relevant for wind turbine sound *levels*, as we saw in he preceding chapter, but also for the *character* of the sound. In conditions where the atmosphere is stable, distant wind turbines can produce a beating or thumping sound that is not apparent in daytime.”

A brief introduction is given in this appendix on the beating phenomenon in acoustics. Some salient points such as ‘tuning process in music’ as well as ‘the subjective reaction’ to beating are also highlighted. Clarification for beating in wind turbine noise is also given in this appendix and attempts will also be made to distinguish the ‘swishing’ phenomenon from ‘the beating’ phenomenon.

Two references are used extensively while preparing this appendix and are:

- E1) *Fundamentals of Acoustics* by L. E. Kinsler and A. R. Frey, Second Edition, John Wiley & Sons, Inc. 1962. ISBN 0 471 46049 5; and
- E2) *Musical Acoustics – An Introduction* by D. E. Hall, Wadsworth Publishing Co. 1980. ISBN 0-534-00758-9.

E2. Beats

A simple scientific definition of ‘Beating’ is: “the linear combination of two simple harmonic vibrations of nearly the same frequency results in the *phenomenon of beats*.”

Without any loss of generality, each of the vibrating wave can be represented by,

$$\text{Wave}_1 = A_1 \sin (f_1 t) \quad \text{and} \quad \text{Wave}_2 = A_2 \sin (f_2 t) \quad (\text{E1})$$

Where, A_1 and A_2 are amplitudes of the two waves and f_1 and f_2 are the frequencies of the two the two waves. When the two waves are summed together, (i.e.) played together, the resulting vibration can be regarded as approximately simple harmonic, with a frequency that lies somewhere between f_1 and f_2 and the amplitude varying slowly at a frequency of $(f_1 - f_2)$ and we have assumed that f_1 is larger than f_2 . The amplitude of the combined wave will ‘wax’ and ‘wane’ between the two limits $(A_1 + A_2)$ and $(A_1 - A_2)$.

In the case of sound waves, the simultaneous sounding of two pure tones of slightly different frequency, the above variation in amplitude results in a rhythmic pulsing of the loudness of the sound which occurs at a rate corresponding to the difference in frequency, $(f_1 - f_2)$, of the two sounds and is known as *beating*. Audible beats are heard whenever two sound of nearly the same frequency strike the ear, and when the frequency of each component is within the audible range. If the frequency difference is small, about 10 or less cycles per sec, the resulting sound waxes and wanes at this rate, with an apparent pitch corresponding to the average frequency. If, on the other hand, their frequency difference is about 200 cycles per sec or more, a combination tone may be observed whose frequency is equal to the difference between that of the two sounds. For intermediate frequency differences, the sound has a rough and discordant character.

A graphical representation of the onset and disappearance of the *beating* phenomenon is highlighted through a series of plots generated from two sounds and are shown in Figures E1 through E7 below.

Figure E1. The Beat Phenomenon

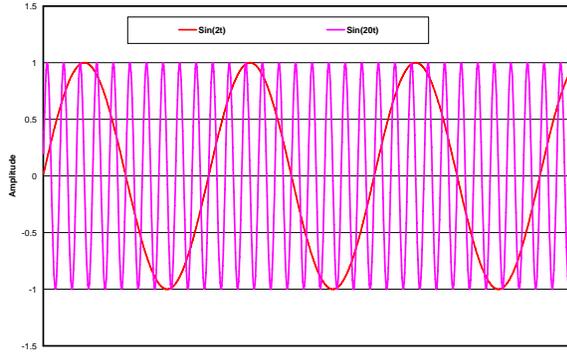


Figure E4. The Beat Phenomenon

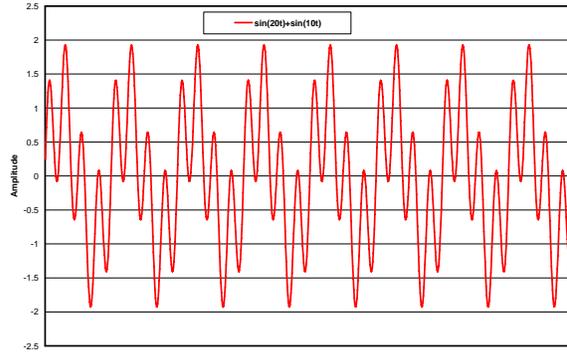


Figure E2. The Beat Phenomenon

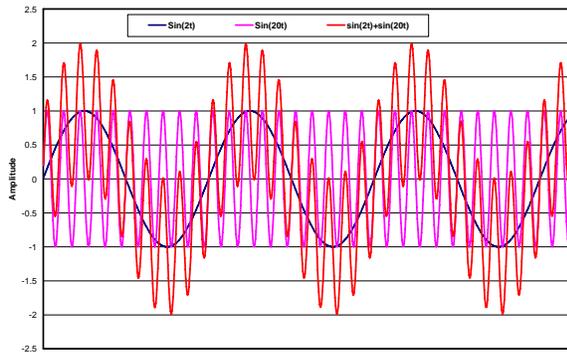


Figure E5. The Beat Phenomenon

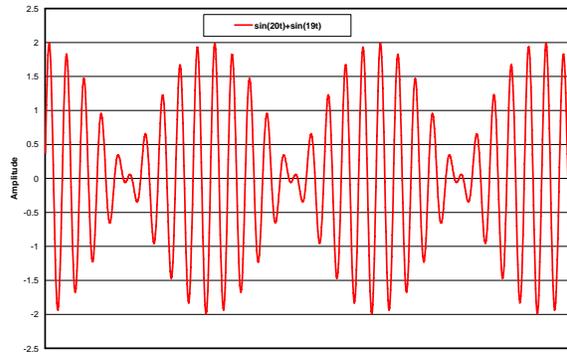


Figure E3. The Beat Phenomenon

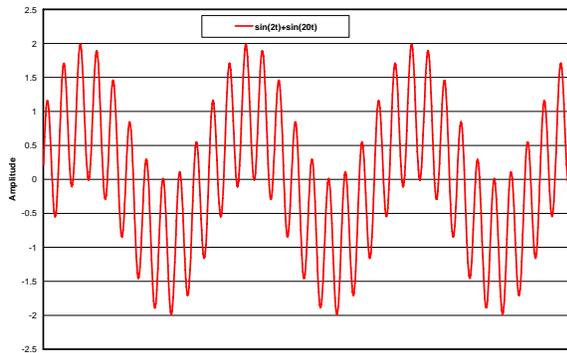
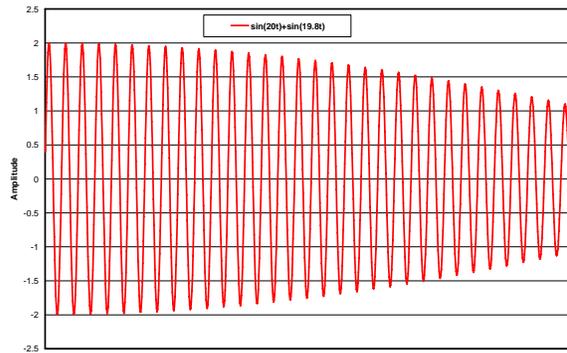


Figure E6. The Beat Phenomenon



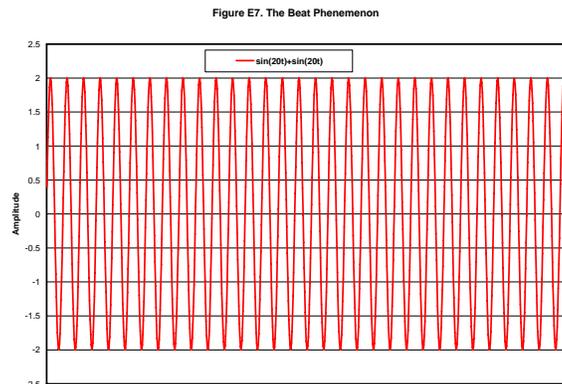


Figure E1 shows two simple sound waves at frequencies of 2 and 20 cycles per second, with their sum shown in Figure E2. One can see frequencies 2 and 20 as well as the beat frequency of 18. The *beat* is not as pronounced since the beat rate is close to the frequency of one of the two sounds as seen in Figure E3. The difference in the two frequencies is 10 in the ‘beating’ shown in Figure E4. The true ‘beating’ is not clear in Figure E4 since the beating rate is 10. Figures E5 and E6 show true *beat*. The amplitude is changing between 0 and 1 at a beat rate of 1 and 0.2.

E3. Subjective Response

If the sounds are within audible range, the resulting sound is heard as a single sound whose loudness varies smoothly and rhythmically at the beat rate, and it is said that the sounds *beat* with each other. Actually, the beating phenomenon is used by musical instrument tuners to tune, precisely by observing the beating and adjust for “zero” beat.

The main subjective effect of the ‘beating phenomenon’ is that the resulting sound appears harsh and discordant. The level of such a response is based on the beat rate as well as the level of the sound. At low levels of the sound, say less than 50 to 60 dB, the only effect is that waxing and waning of the sound.

APPENDIX F

AN ASSESSMENT PROCEDURE

F1. Background

One of the main concerns with the assessment procedures used by different jurisdictions, except New Zealand, is that the effects of meteorological conditions were not appropriately accounted for. Even the New Zealand approach accounts for the effect of wind shear by applying the wind speed data at each site, measured at the hub-height.

It was stated earlier that the current procedures in Ontario are very simple to apply and were similar to other jurisdiction in Europe. The procedure does not require the establishment of ambient sound levels at affected receptor locations before the installation of the wind farm. Neither is there a requirement to incorporate the prevailing meteorological conditions at the proposed wind farm site. Below is an example of one possible assessment process that could address the above concerns. Additional research and analysis would be required in order to develop an appropriate assessment process.

- i. Following the standard procedures used in New Zealand, the ambient sound levels are to be monitored for a pre-set time, say for a month, at salient points of reception. The data should be collected in intervals of 10 minutes so as to be able to evaluate statistically valid analysis;
- ii. The prevailing weather conditions, wind speed, direction, stability class are also measured at the wind farm site for the same duration and time intervals;
- iii. The meteorological data is collected at a minimum of two heights (say 10 m and at hub-height);
- iv. The analysis would involve correlation between wind profiles, determination of shear coefficients (similar to the schemes reported in Reference 22), support for the argument of hub-height wind speeds;
- v. The noise prediction models, for the proposed wind farm, will include the effect of dominant scenarios of meteorological conditions and evaluate the potential range of noise levels;

-
- vi. One would then assign suitable assessment conditions, based on appropriate statistical parameters, for the range of noise levels that can be expected at the salient points of receptions. Some preliminary concepts of this are:
 - a) Establish the noise levels at all salient receptor locations by applying the current MOE procedures;
 - b) Establish the expected increase in turbine sound power levels, by using the measured Meteorological (MET) data, and re-evaluate the noise levels at all the receptor locations;
 - c) Establish the dominant wind direction from the MET data and its percentage of occurrence. Most of the commercially available propagation models are able to incorporate basic MET data. Using the wind direction data, re-evaluate the noise levels at all salient receptor locations;
 - d) The results of Steps (a) thru' (c) would aid in setting up statistical analysis of noise levels, its variability and the number of affected residents. Average conclusions about the noise impact and potential mitigation methods if necessary can be established.

 - vii. Compliance of the wind farm site and potential adverse noise effects, based on acceptable annoyance criterion, can thus be included in the impact analysis to determine the suitability of the wind farm proposal.

The above process is one possible suggestion of the ways in which the current procedures can be revised to incorporate local meteorological conditions at the proposed wind farm sites.

INFRASOUND FROM WIND TURBINES – FACT, FICTION OR DECEPTION

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ABSTRACT

Infrasound is discussed in terms of what it actually is, how the media has dealt with it and what those with limited knowledge say about it. The perception of infrasound occurs at levels higher than the levels produced by wind turbines and there is now agreement amongst acousticians that infrasound from wind turbines is not a problem. Statements on infrasound from objectors are considered and it is shown how these may have caused avoidable distress to residents near wind turbines and also diverted attention from the main noise source, which is the repeating sound of the blades interacting with the tower. This is the noise which requires attention, both to reduce it and to develop optimum assessment methods

RÉSUMÉ

L'infrason est discuté en termes de ce qu'il est réellement, son traitement dans les médias et par ceux avec des connaissances limitée à son sujet. La perception de l'infrason est qu'il existe à des niveaux plus hauts que ceux produits par des éoliennes, mais il y a maintenant accord parmi les acousticiens que l'infrason des éoliennes n'est pas un problème. Des rapports sur l'infrason par des protestataires sont considérés et on montre comment ceux-ci ont pu causer de la détresse évitable aux résidents près des éoliennes et également diverter l'attention de la source principale de bruit: le son répétitif de l'interaction des lames avec la tour. C'est ce bruit qui exige de l'attention, pour le réduire et pour développer des méthodes optimales d'évaluation.

1. INFRASOUND

A definition of infrasound is: Acoustic oscillations whose frequency is below the low frequency limit of audible sound (about 16Hz). (IEC 1994)

This definition is incorrect, as sound remains audible at frequencies well below 16Hz. For example, measurements of hearing threshold have been made down to 4Hz for exposure in an acoustic chamber (Watanabe and Møller 1990b) and down to 1.5 Hz for earphone listening (Yeowart, Bryan et al. 1967)

The limit of 16Hz, or more commonly considered as 20Hz, arises from the lower frequency limit of the standardized equal loudness hearing contours measured in units of phons, which is a difficult measurement at low frequencies, not from the lower limit of hearing.

2. THE AUDIBILITY OF INFRASOUND

Hearing sensation does not suddenly cease at 20Hz when the frequency is reduced from 21Hz to 19Hz, but continues from 20Hz down to very low frequencies of several Hertz. It is not possible to define an inaudible infrasound range and an audible audio range as separate regions, unless the infrasound range is limited to naturally occurring infrasound of very low frequencies. The range from about 10Hz to 100Hz can be

considered as the low frequency region, with possible extensions by an octave at each end of this range, giving 5Hz to 200Hz. There is a very fuzzy boundary between infrasound and low frequency noise, which often causes confusion.

Hearing thresholds in the infrasonic and low frequency region are shown in Fig 1. The solid line above 20Hz is the low frequency end of the ISO standard threshold (ISO:226 2003). The dashed curve, 4Hz to 125Hz, is from Watanabe and Møller (Watanabe and Møller 1990b). There is good correspondence between the two threshold measurements in the overlap region.

The slope of the hearing threshold reduces below about 15Hz from approximately 20dB/octave above 15 Hz to about 12dB/octave below. (Yeowart, Bryan et al. 1967). The common assumption that "infrasound" is inaudible is incorrect, arising from an unfortunate choice of descriptor. "Real" infrasound, at levels and frequencies below audibility are largely natural phenomena, although human activities, such as explosions, also produce infrasound. Microphone arrays for the detection of airborne infrasound are a component of the monitoring for the Nuclear Test Ban Treaty

The median hearing threshold is not a simple delineation between "Can hear - Can't hear", but the threshold is rather variable between individuals, depending on their genetics, prior noise exposure and age (ISO7029 2000). The standard deviation of threshold measurements is typically about 6dB.

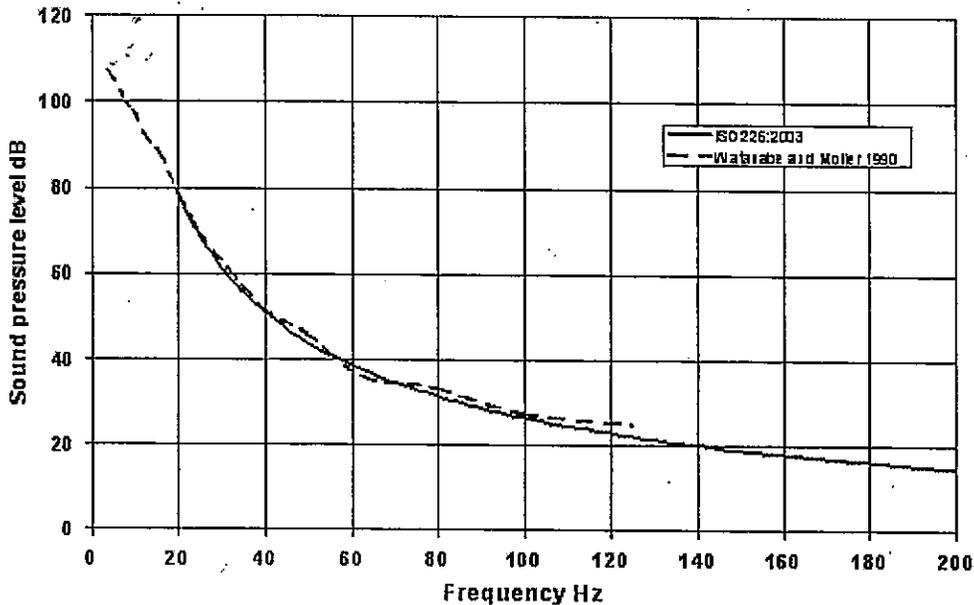


Figure 1. Infrasonic and low frequency threshold

Therefore, it is most unlikely that anyone will be able to hear sound at any frequency which is more than, say, 20dB below its median threshold.

The false concept that infrasound is inaudible, when coupled with the many common misconceptions about its subjective effects, has spawned concerns, particularly expressed in popular publications, which are best described as mythology, rather than fact.

A report reviewing low frequency noise (Leventhall, Benton et al. 2003) is available on the internet.

High levels at very low frequencies: These may result in aural pain, which is not a hearing sensation, but arises from displacements of the middle ear system beyond its comfortable limits. Persons with both hearing ability and hearing loss, and with normal middle ears, exhibit aural pain at a similar stimulus level, which is at about 165dB at 2Hz, reducing to 145dB at 20Hz. Static pressure produces pain at 175 -180dB, whilst eardrum rupture occurs at 185 -190dB (von Gierke and Nixon 1976). A pressure of 5×10^4 Pa, which is about half atmospheric pressure, falls in the 185 -190dB range. A child on a swing experiences infrasound at a level of around 110dB and frequency 0.5Hz, depending on the suspended length and the change in height during the swing.

Natural infrasound: We are enveloped in naturally occurring infrasound, which is in the range from about 0.01 Hz to 2Hz and is at inaudible levels. The lower limit of one cycle in a hundred seconds separates infrasound, as a propagating wave, from all but the fastest fluctuations in barometric pressure. There are many natural sources of infrasound, including meteors, volcanic eruptions, ocean waves, wind and any effect which leads to slow oscillations of the air. Man made sources include explosions, large combustion processes, slow speed fans and machinery. Much natural infrasound is lower

in frequency than 1 Hz and below the hearing threshold. (Berdard and George 2000). Our evolution has been in the presence of natural infrasound.

Alternative receptors: The question arises of whether there is a hierarchy of receptors, of which the ear is the most sensitive except at the lower frequencies, when other receptors may come into prominence. Several vibration and contact detectors reside in the skin, covering different frequency ranges (Johnson 2001). The Pacinian corpuscles are the most sensitive, with a threshold displacement of about 0.002mm in the region of 200Hz. Their sensitivity into lower frequencies reduces at approximately 50dB per decade from the maximum sensitivity.

The threshold displacement of 0.002mm at 200Hz is similar to the particle displacement in air of a 200Hz sound wave of 94dB (1 Pa) pressure. Since the particle displacement in a sound wave of fixed pressure doubles as the frequency is halved (20dB per decade) inaudible sound waves will not excite these subcutaneous receptors.

There is no reliable evidence that infrasound at levels below its hearing threshold has an adverse effect on the body (Berglund and Lindvall 1995). A recent French study of wind turbine noise confirms that infrasound from wind turbines is not a problem. (Chouard 2006)

Body vibrations: It is known that high levels of low frequency noise excite body vibrations (Leventhall, Benton et al. 2003). The most prominent body response is a chest resonance vibration in the region of 50Hz to 80Hz, occurring at levels above about 80dB, which are audible in this frequency range. The low frequency perception thresholds of normal hearing and profoundly deaf subjects have also been investigated (Yamada, Ikuji et al. 1983), when it was shown that the profoundly deaf subjects perceived noise through their body

only at levels which were in excess of normal thresholds. The threshold of sensation of the deaf subjects was 40-50dB above the hearing threshold of those with normal hearing up to a frequency of 63Hz and greater at higher frequencies. For example about 100dB greater at 1 kHz, at which level perception was by the subjects' residual hearing. Deaf subjects experienced chest vibration in the same frequency range as normal hearing subjects.

The much repeated statement that "infrasound can be felt but not heard" is not supported by these measurements. The erroneous thought processes which led to this confusion are possibly:

Infrasound causes body vibrations - (correct at very high levels)

But infrasound is inaudible - (not correct at very high levels)

Therefore infrasound can be felt but not heard - (not correct)

neglecting that the levels to produce body vibrations are well above the hearing threshold. But, as will be shown later, infrasound is not a problem for modern wind turbines.

The dimensions of noise: Noise is multidimensional. A one dimensional view of noise is the A-weighting, which considers only levels and neglects frequencies. Another one-dimensional view is to consider only frequencies and neglect levels. Developing the dimensions further, two dimensions include both frequency and level (the spectrum), three dimensions adds in the time variations of the noise, whilst higher dimensions include subjective response.

Many lay people take the one dimensional view of infrasound, which is based on frequency alone. They express concern at the presence of any infrasound, irrespective of its level. This is a significant failure of understanding.

Public Perceptions: The Public has been misled by the media about infrasound, resulting in needless fears and anxieties, which possibly arise from confusion of the work on subjective effects, which has been carried out at high, audible levels with the popular mindset that infrasound is inaudible. There have also been misunderstandings fostered in publications and popular science books, considered later.

Early work on low frequency noise and its subjective effects was stimulated by the American space program. Launch vehicles produce high noise levels with maximum energy in the low frequency region. Furthermore, as the vehicle accelerates, the crew compartment is subjected to boundary layer turbulence noise for about two minutes after lift-off. Experiments were carried out in low frequency noise chambers on short term subjective tolerance to bands of noise at very high levels of 140 to 150dB, in the frequency range up to 100Hz (Mohr, Cole et al. 1965). It was concluded that the subjects, who were experienced in noise exposure and who were wearing ear protection, could tolerate both broadband and discrete frequency noise in the range

1 Hz to 100Hz at sound pressure levels up to 150dB. Later work suggests that, for 24 hour exposure, levels of 120-130dB are tolerable below 20Hz. These limits were set to prevent direct physiological damage, not for comfort. (Mohr, Cole et al. 1965; Westin 1975; von Gierke and Nixon 1976).

The American work did not attract media attention, but in the late 1960's two papers from France led to much publicity and speculative exaggerations. (Gavreau, Condat et al. 1966; Gavreau 1968). Although both papers carry "infrasound" in their titles, there is very little on frequencies below 20Hz (Leventhall 2005). Some rather casual and irresponsible experiments of the "try it and see" variety were carried out on exposure of the laboratory staff, primarily using high intensity pneumatic sources at frequencies mainly at the upper end of the low frequency range, or above. For example, 196Hz at 160dB sound level and 340Hz at 155dB sound level. A high intensity whistle at 2600Hz is also included in the "infrasound" papers:

Infrasounds are not difficult to study but they are potentially harmful. For example one of my colleagues, R Levavasseur, who designed a powerful emitter known as the 'Levavasseur whistle' is now a victim of his own inventiveness. One of his larger whistles emitting at 2600Hz had an acoustic power of 1 kW. ... This proved sufficient to make him a lifelong invalid. (Gavreau 1968)

Of course, 2600Hz is not infrasound, but the misleading implication is that infrasound caused injury to Levavasseur. A point source of sound of power 1 kW will produce a sound level of about 140dB at 1 m, which is a very undesirable exposure at 2600Hz.

Referring to the exposure of 160dB at 196Hz:

...after the test we became aware of a painful 'resonance' within our bodies - everything inside us seemed to vibrate when we spoke or moved. What had happened was that this sound at 160 decibels..... acting directly on the body produced intense friction between internal organs, resulting in severe irritation of the nerve endings. Presumably if the test had lasted longer than five minutes, internal haemorrhage would have occurred. (Gavreau 1968)

96 Hz is not infrasound, but the unpleasant effects at 160dB are described in a paper which is said to be about "Infrasound". Internal haemorrhage is often quoted as an effect of exposure to infrasound. Exposure levels were not given for frequencies of 37Hz and 7Hz, although the 7Hz caused subjective disturbance and vibrations of the laboratory walls. Unfortunately, these papers by Gavreau were seized upon by the press and presented to claim that infrasound was dangerous. For example "The silent killer all around us", London Evening News, 25 May 1974. When work by other investigators detected moderate levels of infrasound in, for example, road vehicles, the press was delighted, leading to "The silent sound menaces drivers" - Daily Mirror, 19 October 1969.

"Danger in unheard car sounds" The Observer, 21 April 1974.

The most deplorable example, in a book which claimed to have checked its sources, was in "Supernature" by Lyall Watson (Coronet 1973). In this it is claimed that the technician who gave one of Gavreau's high power infrasound sources its trial run "fell down dead on the spot" and that two infrasonic generators "focused on a point even five miles away produce a resonance that can knock a building down as effectively as a major earthquake".

These fictitious statements are, of course, totally incorrect but are clear contributors to some of the unfounded concerns which the public feels about infrasound. One can detect a transition from Gavreau and his colleague feeling ill after exposure to the high level of 196Hz to "fell down dead on the spot" and a further transition from laboratory walls vibrating to "can knock a building down", transitions which resulted from repeated media exaggerations over a period of five or six years.

The misunderstanding between infrasound and low frequency noise continues to the present day. A newspaper article on low frequency noise from wind turbines (Miller 24 January 2004), opens with:

Onshore wind farms are a health hazard to people living near them because of the low-frequency noise that they emit, according to new medical studies. A French translation of this article for use by objectors' groups opens with:

De nouvelles etudes medicales indiquent que les eoliennes terrestres representent un risque pour la sante des gens habitant a proximite, a cause d'emission d'infrasons.

The translation of low frequency noise into infrasons continues through the article. This is not a trivial misrepresentation because, following on from Gavreau, infrasound

has been connected with many misfortunes, being blamed for problems for which some other explanation had not yet been found e.g., brain tumours, cot deaths of babies, road accidents.

Infrasound, and its companion low frequency noise, now occupy a special position in the national psyche of a number of countries, where they lie in wait for an activating trigger to re-generate concerns of effects on health. Earlier triggers have been defence establishments and gas pipelines. A current trigger is wind turbines.

3 INFRASOUND AND LOW FREQUENCY NOISE FROM WIND TURBINES

Early designs of downwind turbines produced pressure pulses at about once per second, which were high enough to cause vibrations in lightweight buildings nearby. (Shepherd and Hubbard 1991). A series of pulses occurring at one per second analyses into a harmonic series in the infrasound region, which is the origin of the link between wind turbines and infrasound. One could discuss whether the Fourier time-frequency duality is misleading on this point, since it was the effects of peaks of the pulses which caused the building vibration, not a continuous infrasonic wave. Similar vibration would have occurred with a faster stream of pulses, with the limiting condition that the pulse repetition rate was lower than the period of the vibration.

Modern up-wind turbines produce pulses which also analyse as infrasound, but at low levels, typically 50 to 70dB, well below the hearing threshold. Infrasound can be neglected in the assessment of the noise of modern wind turbines (Jakobsen 2004)

Fig 2 shows the infrasonic and low frequency noise at 65m from a 1.5MW wind turbine on a windy day. The fol-

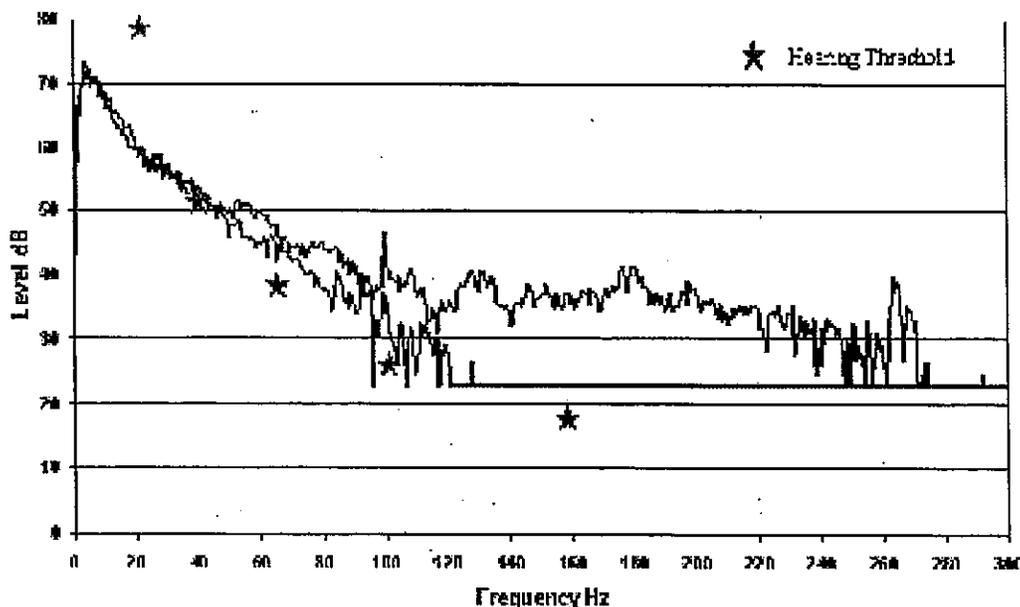


Figure 2. Spectrum of a modern upwind wind turbine - Upper trace Wind Turbine Noise. Lower trace Background noise.

lowing should be noted.

- The fall off below about 5Hz is an instrument effect. The background noise actually increases down to the frequencies of atmospheric pressure variations .
- Frequencies below 40Hz cannot be distinguished from background noise due to wind.
- The wind turbine noise and background noise separate above about 40Hz and both rise above the median hearing threshold.
- The measurements were taken at 65m. Levels are likely to be about 15dB lower at normal separation distances

On the occasions, such as unusually turbulent inflow conditions, when low frequency noise is produced by wind turbines, it may not be perceived as a noise, but rather as an unidentified adverse component in the environment, which disappears if the turbines stop, or if the inflow conditions change. This is because we are not accustomed to listening to low levels of broad band low frequency noise and, initially, do not always recognise it as a "noise", but more as a "disturbance" in the environment. An analogy is with air-conditioning rumble noise, which is noticed when it stops.

What Objectors Say Objectors have eagerly grasped the media hype on infrasound and low frequency noise and used it to engender concerns about wind turbine developments. In this they have, possibly, done a disservice to the communities they were established to help, through raising false concerns and diverting attention from more important aspects of the development. Two examples are as follows.

In the UK there is an Advertising Standards Authority(ASA), to which deceptive adverts can be referred for assessment. An objectors' group (Ochils Environmental Protection Group) issued a leaflet "FACTS ABOUT WIND POWER", containing a number of assertions including:

... wind turbines still create noise pollution, notably 'in-

fra sound' - inaudible frequencies which nevertheless cause stress-related illness ..."

In their Judgment (April 02, 2004), the ASA concluded that the objectors had not produced evidence to substantiate their claim.

In the USA, a high profile objector (Nina Pierpont of Malone NY) placed an advertisement in a local paper, consisting entirely of selected quotations from a previously published technical paper by van den Berg (Van den Berg 2004). However the comment "[i.e. infrasonic]", as shown in Fig 3, was added in the first line of the first quotation in a manner which might mislead naive readers into believing that it was part of the original.

The van den Berg paper was based on A-weighted measurements and had no connection with infrasound. So, not only is the advertisement displaying the advertiser's self deception, but this has also been propagated to others who have read it. To mistakenly connect the noise to infrasound, which has unpleasant associations is, however, a way to gather support. (When a person has adopted a particular mindset, new information is processed to support that mindset. We all do this.)

It takes little technical knowledge to be aware that a modulated high frequency wave does not contain the modulation components. For example, an amplitude modulated radio wave contains the carrier wave and sidebands, which are close in frequency to the carrier. The fluctuations of wind turbine noise (swish - swish) are a very low frequency modulation of the aerodynamic noise, which is typically in the region of 500 - 1000Hz. The modulation occurs from a change in radiation characteristics as the blade passes the tower, but the modulating frequencies do not have an independent and separate existence.

The comment, [i.e. infrasonic], added into Fig 3 gives incorrect information. Claims of infrasound are irrelevant and possibly harmful, should they lead to unnecessary fears.

PAID ADVERTISEMENT

Wind Turbines & Infrasound: What the latest research says

"At night the wind turbines cause a low pitched thumping [i.e., infrasonic] sound superimposed on a broadband 'noisy' sound, the 'thumps' occurring at the rate at which blades pass a turbine tower.... The number and severity of noise complaints near the wind park are at least in part explained by the two main findings of this study: actual sound levels are considerably higher than predicted, and wind turbines can produce sound with an impulsive character."

-- Professor Frits G.P. van den Berg, University of Groningen, the Netherlands, November 2004 (see excerpts from research articles, below)

Figure 3 Part of an advertisement placed by an objector in the Malone (NY) Telegram, 25th February 2005.

It has been shown that fear of a noise source, for example that aircraft might crash, increases the extra annoyance of a person with a high fear of a crash by up to 19dB DNL equivalent, compared with a person who has no fear (Miedema and Vos 1999).

Fear of a source is not the same as fear of the noise itself, but it is understandable that those who fear the effects of a noise upon their health will be less tolerant of the noise than those who do not fear it. We can only speculate upon the harm which objectors might have done by, for example, taking a one dimensional view of infrasound and publicising the subjective effects of high levels of both infrasound and low frequency noise in a manner which implies that the effects may also be caused by the low levels produced by wind turbines.

4 WIND TURBINE NOISE

It has been shown above that there is insignificant infrasound from wind turbines and that there is normally little low frequency noise. Turbulent air inflow conditions cause enhanced levels of low frequency noise, which may be disturbing, but the overriding noise from wind turbines is the fluctuating audible swish, mistakenly referred to as "infrasound" or "low frequency noise". Objectors uninformed and mistaken use of these terms (as in Fig 3), which have acquired a number of anxiety-producing connotations, has led to unnecessary fears and to unnecessary costs, such as for re-measuring what was already known, in order to assuage complaints.

Attention should be focused on the audio frequency fluctuating swish, which some people may well find to be very disturbing and stressful, depending on its level. The usual equivalent level measurements and analyses are incomplete, as these measurements are taken over a time period which is much longer than the fluctuation period and information on the fluctuations is lost. A time varying sound is more annoying than a steady sound of the same average level and this is accounted for by reducing the permitted level of wind turbine noise. However, more work is required to ensure that the optimum levels have been set.

5 CONCLUSIONS

- Infrasound from wind turbines is below the audible threshold and of no consequence.
- Low frequency noise is normally not a problem, except under conditions of unusually turbulent inflow air.
- The problem noise from wind turbines is the fluctuating swish. This may be mistakenly referred to as infrasound by those with a limited knowledge of acoustics, but it is entirely in the normal audio range and is typically 500Hz to 1000Hz. It is difficult to have a useful discourse with objectors whilst they continue to use acoustical terms incorrectly. This is unfortunate, as there are wind turbine installations which may have noise problems.
- It is the swish noise on which attention should be focused, in order to reduce it and to obtain a proper estimate of its

effects. It will then be the responsibility of legislators to fix the criterion levels, However, although the needs of sensitive persons may influence decisions, limits are not normally set to satisfy the most sensitive.

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