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Docket No. 7508
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RSG INC.
ENVIRONMENT, ENERGY, & ACOUSTICS

Noise Impact Study for Georgia Mountain Community Wind

Georgia and Milton, Vermont

February 2009

DATA ■ ANALYSIS ■ SOLUTIONS

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1. INTRODUCTION

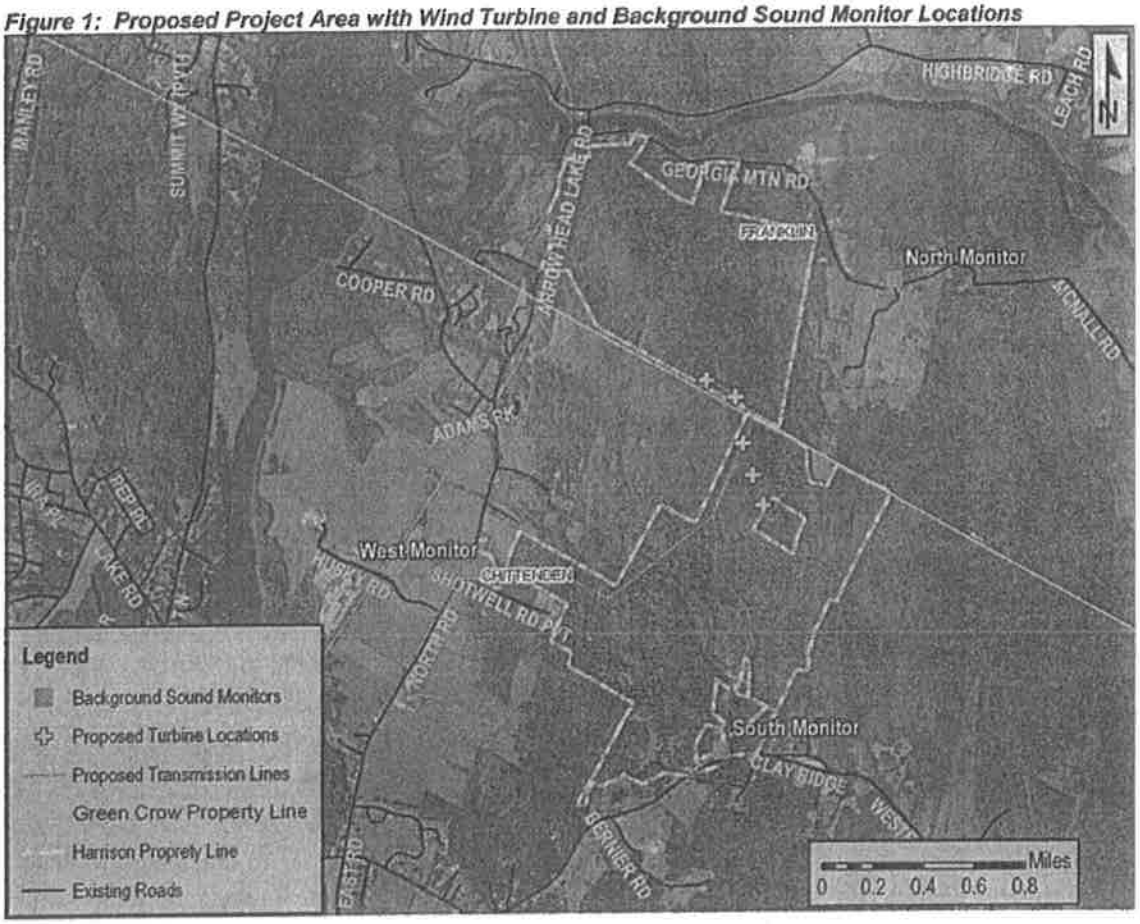
The Georgia Mountain Community Wind Project is a proposal to construct and operate up to five wind turbines on the border of Milton and Georgia, Vermont. Resource Systems Group, Inc. was retained to conduct a noise impact analysis of the project. The study assessed the effects of wind turbines on sound levels in the surrounding area. This report includes:

- A site description
- A noise primer
- A discussion of noise standards and the standard recommended for use in this case
- Background sound level monitoring results
- A discussion of noise issues specific to wind turbines
- Computer noise propagation modeling results for the proposed turbines
- Recommendations
- Summary and conclusions

2. SITE DESCRIPTION

The proposed turbines would be installed on Georgia Mountain located near Milton, Vermont. Figure 1 shows the location of five turbines and the surrounding area. Also shown are sites where sound monitoring stations were placed. These will be described in Section 5 of this report.

Figure 1: Proposed Project Area with Wind Turbine and Background Sound Monitor Locations



3. A NOISE PRIMER

3.1. WHAT IS NOISE?

Noise is defined as "a sound of any kind, especially when loud, confused, indistinct, or disagreeable."[1] Passing vehicles, a noisy refrigerator, or an air conditioning system are sources of noise which may be bothersome or cause annoyance. These sounds are a part of generally accepted everyday life, and can be measured, modeled, and, if necessary, controlled.

3.2. HOW IS SOUND DESCRIBED?

Sound is caused by variations in air pressure at a range of frequencies. Sound levels that are detectable by human hearing are defined in the decibel (dB) scale, with 0 dB being the threshold of

1 "The American Heritage Dictionary of the English Language," Houghton Mifflin Company, 1981.

human hearing, and 135 dB causing pain and permanent damage to the ear. Figure 2 shows the sound levels of typical activities that generate noise.

In addition, the decibel scale can be weighted to mimic the human perception of certain frequencies. The most common of these weighting scales is the "A" weighting, and this scale is used most frequently in environmental noise analysis. Sound levels that are weighted by the "A" scale have units of dBA or dB(A)

To account for changes over time, a weighted average sound level called the "equivalent" sound level (L_{eq}) is often used. L_{eq} averages sound pressure rather than decibels, and results in weighting loud and infrequent noises more heavily than quieter and more frequent noises. For example, a train passing by for one minute out of an hour could produce sound levels around 90 dBA while passing by, but the equivalent sound level for the entire hour would be 72 dBA. L_{eq} is also often used in environmental noise analysis. The day-night sound level (L_{dn}) is also commonly used by the U.S. Environmental Protection Agency (U.S. EPA) in referencing community noise. The L_{dn} is simply a time-weighted average, similar to L_{eq}, except that the nighttime sound levels are weighted by +10 dB.

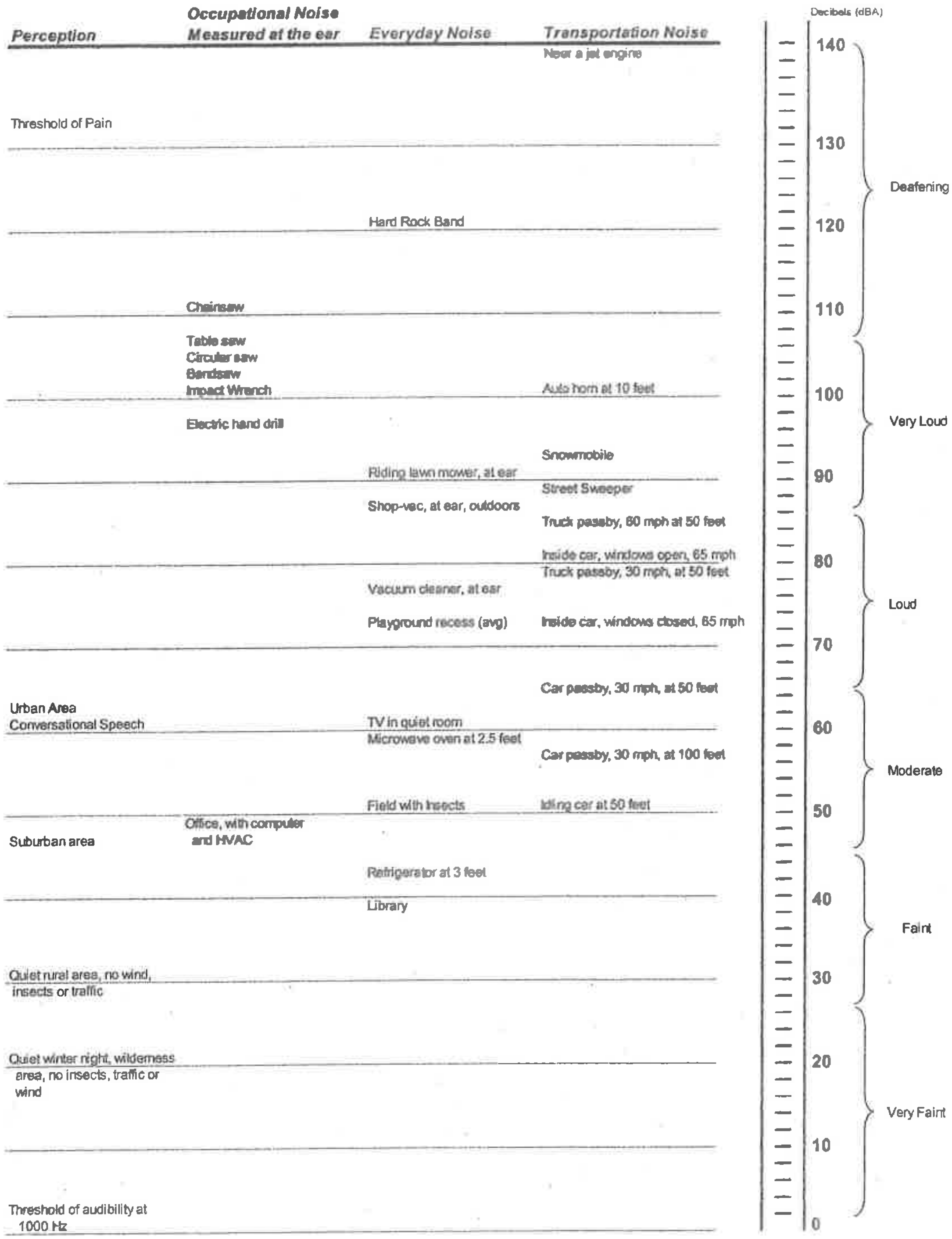
3.3. WHAT IS THE DIFFERENCE BETWEEN SOUND PRESSURE LEVELS AND SOUND POWER LEVELS?

Both sound power and sound pressure levels are described in terms of decibels, but they are not the same. Sound power is a measure of the acoustic power emitted or radiated by a source. The sound power level of a source does not change with its surrounding conditions.

Sound pressure level is observed at a specific location and is related to the difference in air pressure above or below atmospheric pressure. This fluctuation in air pressure is a result of the sound power of a source, the distance at which the sound pressure level is being observed, and the characteristics of the path and environment around the source and receiver. When one refers to sound level, they are generally speaking of the perceived level, or sound pressure level.

For example, a coffee grinder will have the same sound power whether or not it is grinding indoors or outdoors. The amount of sound the coffee grinder generates is always the same. However, if you are standing six feet away from the coffee grinder indoors, you would experience a higher sound pressure level than you would if you were six feet away from the coffee grinder outdoors in an open field. The reason for this is that the sound being emitted from the coffee grinder would bounce off walls and other surfaces indoors which would cause sound to build up and raise the sound pressure level.

Figure 2: Basic Theory: Common Sounds in Decibels



Sound power cannot be directly measured. However, since sound pressure and sound power are related, sound power can be calculated by measurements of sound pressure and sound intensity. It can be helpful to note that over soft ground outside, the sound pressure level of a small source observed 50 feet away is roughly 33 dB lower than its sound power level.

3.4. HOW IS SOUND MODELED?

The decibel sound level is on a logarithmic scale. One manifestation of this is that sound *power* increases by a factor of 10 for every 10 dB increase. However, for every 10 dB increase, we *perceive* an approximate doubling of loudness. Small changes in sound level, below 3 dB, are generally not perceptible.

For a point source, sound level diminishes or attenuates by 6 dB for every doubling of distance due to geometrical divergence. For example, if an idling truck is measured at 50 feet as 66 dBA, at 100 feet it will be heard as 60 dBA, and at 200 feet, 54 dBA. Along a road, sound is generated as a line source. Line sources attenuate their sound at 3 dB to 4.5 dB per doubling distance, depending on the sound reflectivity of the ground.

Other factors, such as intervening vegetation, walls, berms, buildings, and atmospheric absorption will also further reduce the sound level reaching the listener. In each of these, higher frequencies will attenuate faster than lower frequencies. Finally, the ground can also have an impact on sound levels. Harder ground generally increases and softer ground generally decreases the sound level at a receiver. Reflections off of buildings and walls can increase broadband sound levels by as much as 3 dB.

If we add two equal sources together, the resulting sound level will be 3 dB higher. For example, if one machine registers 86 dBA at 50 feet, two machines would register 3 dB more, or 89 dBA at that distance. In a similar manner, at a distance of 50 feet, four machines, all operating at the same place and time, would register 92 dBA and eight machines would register 95 dBA. If the two sources differ in sound level then 0-3 dB will be added to the higher level as shown in Table 1.

Table 1: Decibel Addition

If Two Sources Differ By	Add
0-1 dB	3 dB
2-4 dB	2 dB
5-9 dB	1 dB
>9 dB	0 dB

4. NOISE STANDARDS

4.1. LOCAL AND STATE STANDARDS

There are no quantitative noise standards in the Town of Milton. In the Town of Georgia's zoning regulations, Section 5090 requires the following:

"5090 PERFORMANCE STANDARDS

The following performance standards must be met in all zoning districts for all uses except residential and agricultural uses. The applicant or operator may be required to furnish engineering or testing results to prove that the proposed use will meet, or, in the case of an operating business, is meeting and will continue to meet, the performance standards. The Administrative Officer, Planning Commission, or Board of Adjustment may determine whether the proposed use or present operation meets these standards. The use must not:

5090.1 Emit noise in excess of 70 decibels at the property line or a noise which is considered offensive."

There are no state statutes or regulations that establish quantitative noise standards that would apply to this project.

4.2. WORLD HEALTH ORGANIZATION

The United Nation's World Health Organization (WHO) has published "Guidelines for Community Noise" (1999) which uses the most current research on the health impacts of noise to develop guideline sound levels for communities. The forward of the report states, "The scope of WHO's effort to derive guidelines for community noise is to consolidate actual scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professionals trying to protect people from the harmful effects of noise in non-industrial environments."

The WHO guidelines suggest a daytime and nighttime protective noise level. During the day, the levels are 55 dBA $Leq_{(16)}$, that is, an average over a 16-hour day, to protect against serious annoyance and 50 dBA $Leq_{(16)}$ to protect against moderate annoyance.

During the night, the WHO recommends limits of 45 dBA $Leq_{(8)}$ and an instantaneous maximum of 60 dBA LAfmax (fast response maximum). These are to be measured outside the bedroom window. These guidelines are based on the assumption that sound levels indoors would be reduced by 15 dBA with windows open. That is, sound level inside the bedroom that is protective of sleep is 30 dBA $Leq_{(8)}$. So long as the sound levels outside of the house remain at or below 45 dBA, sound levels in the bedroom will remain below 30 dBA. Given the climate in this region, this is essentially a summertime standard, since residents are less likely to have their windows open during other times of the year. By closing windows, an additional ~10 dB of sound attenuation will result.

Table 4.1 of the WHO's "Guidelines for Community Noise" (1999) provides guideline values for community noise in specific environments. This table is provided in Appendix A.

4.3. FEDERAL STANDARDS AND GUIDELINES

There are no federal standards that apply to wind turbines on private land. Many federal agencies have adopted guidelines and standards that apply to other types of projects. A summary of some of these standards is shown in Table 2. Note that these standards are in terms of Leq, Ldn, or L10. The

Leq is the pressure weighted average sound level, over a specified period of time. The Ldn is the A-weighted day-night Leq, where a penalty of 10 dB is applied to nighttime sound. The L10 is the 10th percentile sound level. It is the level that is exceeded 10% of the time, and thus represents the higher sound levels over a period of time.

Table 2: Summary of Federal Guidelines and Standards for Exterior Noise

Agency	Applies to	Standard (dBA)
Environmental Protection Agency	Guideline to protect public health and welfare with an adequate margin of safety	55 dB Ldn
Bureau of Land Management (BLM)	Guidelines for the development of wind turbines on federal lands managed by BLM	Refers to the EPA 55 dB Ldn guideline.
Federal Energy Regulatory Commission (FERC)	Compressor facilities under FERC jurisdiction	55 dB Ldn
Federal Highway Administration (FHWA)	Federally funded highway projects. For "Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose."	57 dBA Leq or 60 dBA L10 during the peak hour of traffic. Either standard can be used, but not both.
	For "picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, hotels, motels, schools, libraries, churches, and hospitals."	67 dBA Leq or 70 dBA L10
Federal Interagency Task Force	This Taskforce is set up to develop consistency of noise standards among federal agencies	55 to 65 dB Ldn for impacts on residential areas

The United States Department of the Interior, Bureau of Land Management (BLM) has developed a Programmatic Environmental Impact Statement (PEIS) for Wind Energy Development on BLM Lands in the Western United States. Noise is addressed in several sections of the PEIS. Several relevant points made in the PEIS are listed below:

- From Section 4.5.1: "at many wind energy project sites on BLM-administered lands, large fluctuations in broadband noise are common, and even a 10-dB increase would be unlikely to cause an adverse community response. In addition, noise containing discrete tones (tonal noise) is much more noticeable and more annoying at the same relative loudness level than other types of noise, because it stands out against background noise."

- From Section 4.5.2: "In general, background noise levels (i.e., noise from all sources not associated with a wind energy facility) are higher during the day than at night. For a typical rural environment, background noise is expected to be approximately 40 dB(A) during the day and 30 dB(A) at night (Harris 1979), or about 35 dB(A) as DNL (Miller 2002)."
- From Section 4.5.4: "The EPA guideline recommends an Ldn of 55 dB(A) to protect the public from the effect of broadband environmental noise in typically quiet outdoor and residential areas (EPA 1974). This level is not a regulatory goal but is 'intentionally conservative to protect the most sensitive portion of the American population' with 'an additional margin of safety.' For protection against hearing loss in the general population from nonimpulsive noise, the EPA guideline recommends an Leq of 70 dB(A) or less over a 40-year period."
- From Section 5.5.3.1: "aerodynamic noise is the dominant source from modern wind turbines (Fégeant 1999)."
- From Section 5.5.3.1: "Considering geometric spreading only, this results in a sound pressure level of 58 to 62 dB(A) at a distance of 50 m (164 ft) from the turbine, which is about the same level as conversational speech at a 1 m (3 ft) distance. At a receptor approximately 2,000 ft (600 m) away, the equivalent sound pressure level would be 36 to 40 dB(A) when the wind is blowing from the turbine toward the receptor. This level is typical of background levels of a rural environment (Section 4.5.2). To estimate combined noise levels from multiple turbines, the sound pressure level from each turbine should be estimated and summed. Different arrangements of multiple wind turbines (e.g., in a line along a ridge versus in clusters) would result in different noise levels; however, the resultant noise levels would not vary by more than 10 dB."
- From Section 5.5.3.1: "In general, the effects of wind speed on noise propagation would generally dominate over those of temperature gradient."
- From Section 5.5.3.1: "Wind-generated noise would increase by about 2.5 dB(A) per each 3 ft/s (1 m/s) wind speed increase (Hau 2000); the noise level of a wind turbine, however, would increase only by about 1 dB(A) per 3 ft/s (1 m/s). In general, if the background noise level exceeds the calculated noise level of a wind turbine by about 6 dB(A), the latter no longer contributes to a perceptible increase of noise. At wind speed of about 33 ft/s (10 m/s), wind-generated noise is higher than aerodynamic noise. In addition, it is difficult to measure sound from modern wind turbines above a wind speed of 26 ft/s (8 m/s) because the background wind-generated noise masks the wind turbine noise at that speed (DWIA 2003)."
- From Section 6.4.1.6: "Noise generated by turbines, substations, transmission lines, and maintenance activities during the operational phase would approach typical background levels for rural areas at distances of 2,000 ft (600 m) or less and, therefore, would not be expected to result in cumulative impacts to local residents."

These statements from the BLM's Wind Energy Development PEIS do not represent a regulatory standard itself, but they do provide some insight on how one federal agency is approaching noise generated from wind turbine projects. This project is designed to be consistent with these guidelines.

4.4. NATIONAL ACADEMY OF SCIENCES STUDY

Last year, the National Research Council of the National Academy of Sciences issued a report "Environmental Impacts of Wind-Energy Projects." This report summarized the state of understanding of wind energy projects with respect to its ecological and human impacts, the latter of which includes noise.

With respect to noise, the report concludes,

> "Noise produced by wind turbines generally is not a major concern for humans beyond a half mile or so because various measures to reduce noise have been implemented in the design of modern turbines. The mechanical sound emanating from rotating machinery can be controlled by sound-isolating techniques. Furthermore, different types of wind turbines have different noise characteristics. As mentioned earlier, modern upwind turbines are less noisy than downwind turbines. Variable-speed turbines (where rotor speeds are lower at low wind speeds) create less noise at lower wind speeds when ambient noise is also low, compared with constant-speed turbines. Direct-drive machines, which have no gearbox or high speed mechanical components, are much quieter."

The Georgia Mountain Community Wind project is proposing to use variable speed upwind turbines. The gearbox and other mechanical components include noise isolation to reduce impacts.

4.5. PUBLIC SERVICE BOARD PRECEDENTS

The only major precedent established by the Public Service Board is the Certificate of Public Good for the Sheffield Wind Project (Docket No. 7156). The noise standard for this project reads,

> 8. UPC shall construct and operate the Project so that it emits no prominent discrete tones pursuant to ANSI standards at the receptor locations, and indoor sound levels at any existing King George School structures used for residential or instruction purposes and any existing surrounding residences do not exceed 30 dBA(Leq)(1).

4.6. NOISE THRESHOLD GOALS FOR THE GEORGIA MOUNTAIN COMMUNITY WIND PROJECT

The EPA Guidelines, the BLM PEIS, and the WHO Guidelines each provide relevant noise criteria for a project of this type. Given the scientific evidence regarding sleep disturbance and other impacts that was reviewed by WHO, we propose that the project should meet a standard of 45 dBA

Leq (night)[1] averaged over the entire night outside the residence. This would not apply to areas that have transient uses such as driveways, trails, farm fields, and parking areas. This standard is more stringent than all of the federal standards mentioned above and will be well below the level that can cause hearing impairment. This noise limit is both protective of human health and prevents any quality-of-life concerns.

5. EXISTING NOISE ENVIRONMENT

Sound levels were monitored over a four-day period to determine background sound levels in the area. Monitoring started on October 18, 2008 at three sites chosen to represent different residential areas around the project. The three monitors are labeled *North*, *West*, and *South* and are shown in Figure 1.

All sites were monitored with ANSI Type I integrating sound level meters set to log sound levels every second. Each sound level meter was calibrated before and after measurements and fitted with a windscreen. Windscreens are used because they reduce the self-noise created by wind passing over the meter's microphone. Each microphone was placed between approximately 1 and 1.5 meters above the ground. In each case, the ground was considered "soft", that is, it was suitable for the growth of vegetation.

A location description of each monitoring site is provided below. The Vermont State Plane coordinates of each site are shown in Table 3 with approximate distances from the proposed turbine locations. A summary of the daytime and nighttime sound levels is provided in Table 4.

1) The North Monitor was located at the Wimble Brothers Farm at 1495 Georgia Mountain Road. It was placed approximately 110 feet north of Georgia Mountain Road. This location was chosen to represent the north section of the project area along Georgia Mountain Road. The sound monitoring results are shown in Figure 3. The dominant sources of background noise in this area are traffic on Georgia Mountain Road and farming activities.

2) The West Monitor was located on the Harrison property just north of Shotwell Road. It was placed approximately 100 feet east of North Road. This location was chosen to represent the western section of the project area along North Road. The sound monitoring results are shown in Figure 4. The dominant sources of background noise in this area are traffic on North Road and mechanical noise from the Husky facility nearby.

3) The South Monitor was located on the Harrison property just west of Ted Road. It was placed approximately 185 feet north of Westford Road. This location was chosen to represent the southern section of the project area along Westford Road. The sound monitoring results are shown in Figure 5. The dominant sources of background noise in this area are traffic on Westford Road and Ted Road.

[1] The sleep disturbance standard used here is based on a windows-open condition. During the seasons when windows are generally closed, the standard is 10 dB higher, to account for the additional attenuation of closed windows.

Table 3: VT State Plane Coordinates of Monitoring Sites and Distance to Proposed Turbines

Monitor	Easting (m)	Northing (m)	Distance to Proposed Turbines (m)	Distance to Proposed Turbines (ft)
North	455,757	241,325	1,220	4,000
West	453,097	239,548	1,880	6,170
South	454,679	238,429	1,540	5,050

Table 4: Daytime and Nightime Sound Levels (dBA) at Each Monitoring Station

Monitor	Daytime Sound Levels (dBA)				Nighttime Levels (dBA)			
	Leq	L90	L50	L10	Leq	L90	L50	L10
North	46	29	33	42	31	25	28	33
West	51	40	42	53	47	41	41	42
South	56	33	46	59	47	26	27	36

Figure 3: North Monitor Results

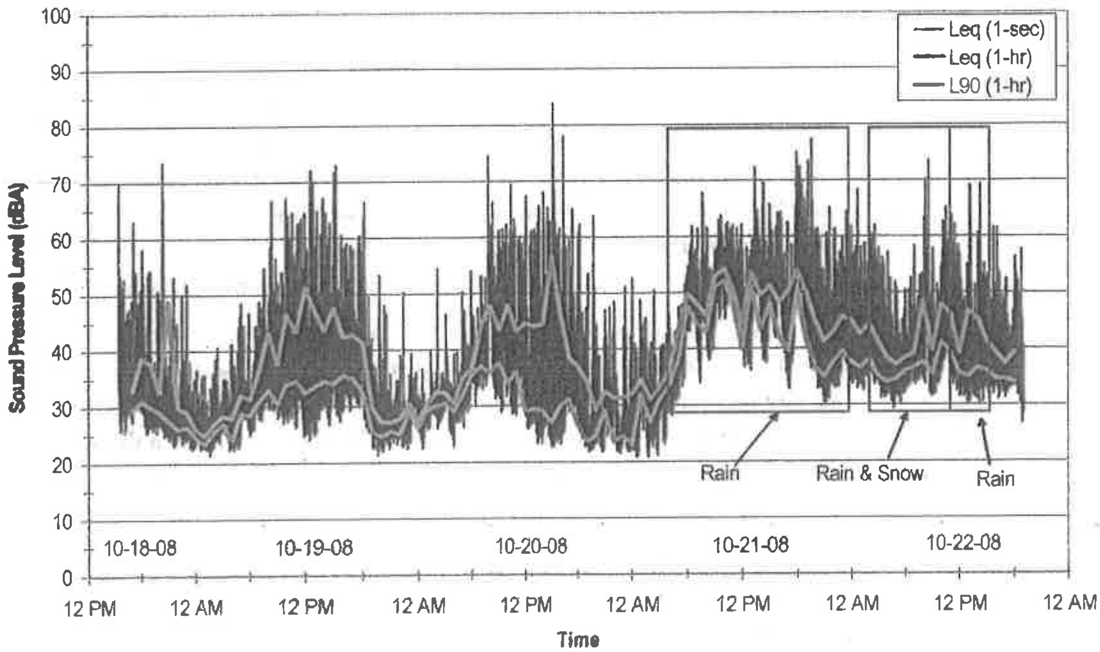


Figure 4: West Monitor Results

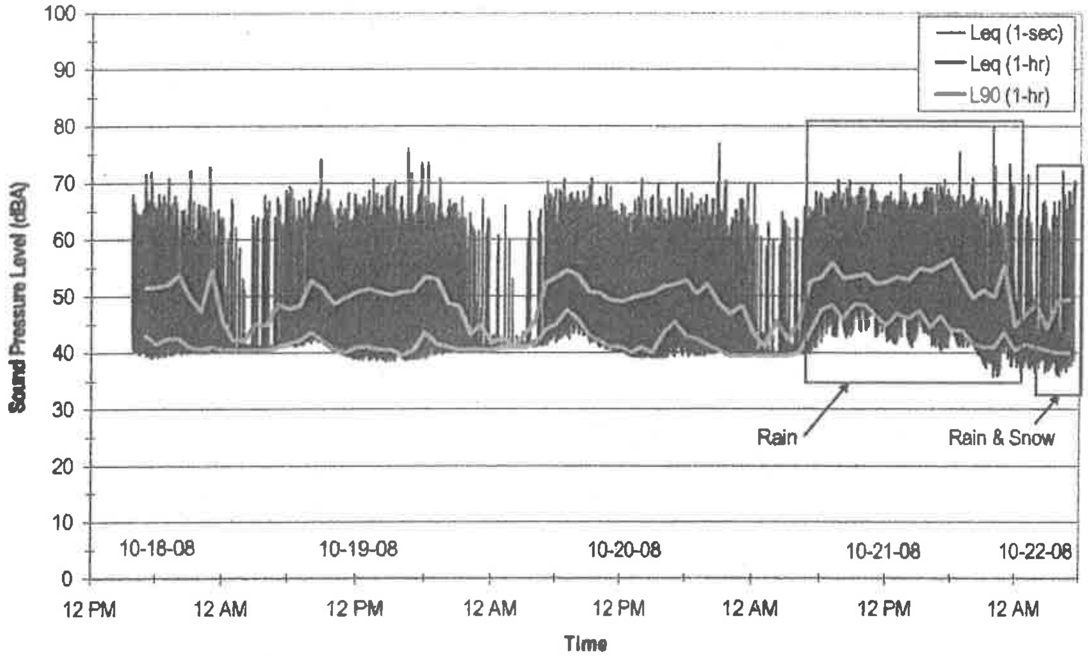
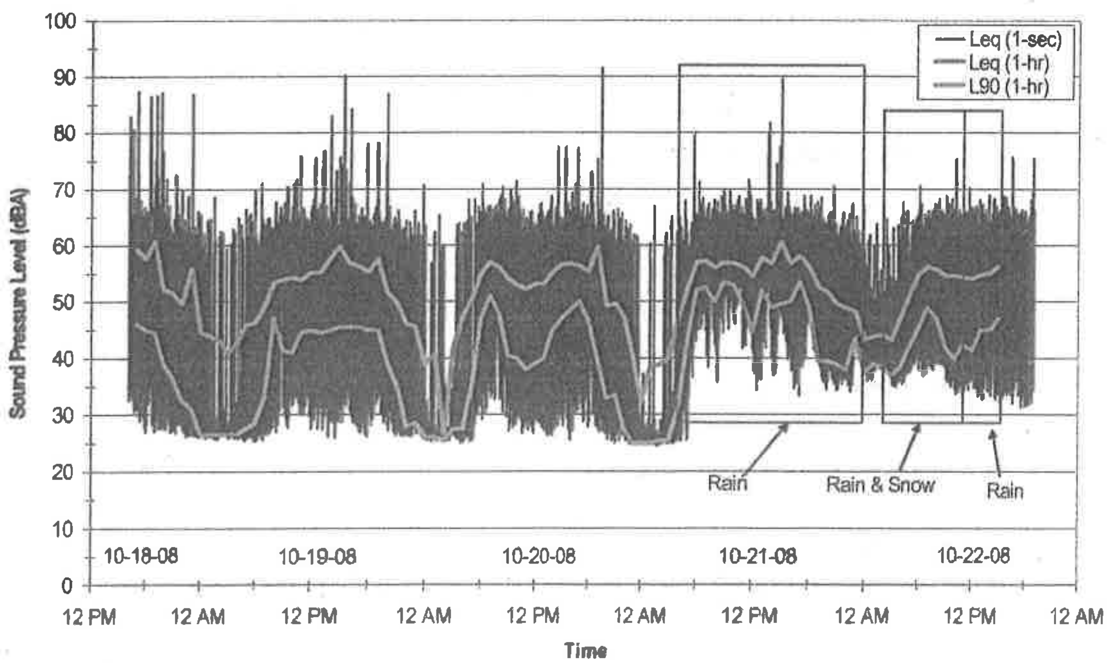


Figure 5: South Monitor Results



6. SOUND LEVELS PRODUCED BY WIND TURBINES

6.1. STANDARDS USED TO MEASURE WIND TURBINE SOUND

A manufacturer of a wind turbine must test and report its turbines' noise emissions using two international standards:

1) International Electrotechnical Commission standard IEC 61400-11:2002(E), "Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques"
2) International Electrotechnical Commission standard IEC 61400-14:2005(E), "Wind Turbine Generator Systems – Part 14: Declaration of Apparent Sound Power Level and Tonality Values"

These standards give the sound power emission levels from a turbine, by wind speed and frequency.

6.2. SOUND LEVELS USED IN MODELING

For the purposes of modeling, we used a typical wind turbine represented by GE 1.5 MW wind turbine. GE provided a mean reference sound power level of 104±2 dBA. The modeling assumes a turbine hub height of 80 meters and a maximum sound power level of 106 dBA.

Note that the sound *power* rating of a wind turbine is not the same as the sound *pressure* levels referred to earlier in this report. The sound *power* of a source is the total acoustical energy generated by a source. The sound *pressure* level of a source is the pressure measured by a sound level meter. By way of analogy, a light bulb's energy use, i.e., power, is measured in Watts, while the perceived level of light is measured in lumens. Sound power is analogous to the bulb energy use while sound pressure is analogous to lumens in this example. Both power and pressure levels are reported in decibels, so they are often confused. See Section 3.3 for more information on sound power.

7. SOUND FROM WIND TURBINES – SPECIAL ISSUES

Wind turbines are special sound generators in that their sound emissions are often masked by noise from the wind moving through trees and other vegetation, and their sound level is highly dependent on meteorological conditions. In addition, wind turbines generate lower frequency sound which tends to propagate better than higher frequency sound. These aspects are discussed below.

7.1. METEOROLOGY

Meteorological conditions can significantly affect sound propagation. The two most important conditions to consider are wind shear and temperature lapse. Wind shear is the difference in wind speeds by elevation and temperature lapse rate is the temperature gradient by elevation. In conditions with high wind shear (large gradient), sound levels upwind from the source tend to decrease and sound levels downwind tend to increase. With temperature lapse, when ground surface temperatures are higher than that aloft, sound levels on the ground will decrease. The opposite is true when ground temperatures are lower than those aloft (an inversion condition).

As a substitute for these conditions, we often use "stability class". Stability classes range from A to G, where A is a highly unstable condition (high solar radiation and high winds) and G is very stable (clear night, no wind, strong temperature inversion).

In general terms, sound tends to propagate best under stable conditions with a strong inversion. This occurs during the night and is characterized by low winds.[1] In those situations, sound levels from wind turbines would be at their lowest. Wind speeds under very stable conditions (Stability Class G) are generally too low to generate electricity and thus the wind turbines would produce little or no noise. As a result, worst-case conditions for wind turbines tend to be under moderate nighttime inversions. An analysis of wind turbine noise under stable conditions is provided later in this report.

7.2. MASKING

As mentioned above, sound levels from wind turbines are a function of wind speed. Background sound is also a function of wind speed, i.e., the stronger the winds, the louder the resulting background sound. In areas that are covered by trees and bushes, such as is found in this region, the effect is amplified. Combined with the fact that the frequency spectrum from wind is very similar to the frequency spectra from a wind turbine, the sound from a wind turbine can be masked by wind noise at downwind receivers.

It is important to point out that while winds may be blowing at the turbine hub, there may be little or no wind at downwind receivers. This is due to the fact that winds are lighter closer to the ground. At the point at which winds are blowing with relatively low speeds at the hub, but not on the ground, the wind turbines would be most audible. The turbines would be operating at low to medium speeds and will have proportionally lower sound emissions.

7.3. INFRASOUND AND LOW FREQUENCY SOUND

Infrasound is sound pressure fluctuations at frequencies below about 20 Hz. Sound below this frequency is generally not audible. Low frequency sound is in the audible range of human hearing, that is, above 20 Hz, but below 100 to 200 Hz depending on the definition.

At very high sound levels, infrasound can cause health effects and rattle light-weight building partitions. However, modern wind turbines, with the hub upwind of the tower, do not create this level of infrasound.

Low frequency sound is generated by wind turbines. As with infrasound, high levels of low frequency sound – above 65 to 70 dB at 31.5 Hz, for example - can rattle light-weight partitions in buildings. In addition, low frequency sound that is well above background sound levels at higher volumes can be more annoying than higher frequency sounds.

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[1]The amount of propagation is highly dependent on surface conditions and the frequency of the sound. Under some circumstances highly stable conditions can show lower sound levels.

Low frequency sound is primarily generated by the generator and mechanical components. Through improved sound insulation at the hub, much of the mechanical noise has been reduced in modern wind turbines. Low frequency sound can also be generated at higher wind speeds when the inflow air is very turbulent. However, at these wind speeds, low frequency sound from the wind turbine blades is often masked by wind noise at the downwind receivers.

Finally, low frequency sound propagates better than higher frequency sound and tends to diffract more in the atmosphere under inversion conditions. Our modeling takes into account nighttime inversions and the differential atmospheric absorption of low and high frequency sound.

8. SOUND MODELING

8.1. MODELING SOFTWARE

Modeling was completed for the project using Cadna A acoustical modeling software. Made by Datakustik GmbH, Cadna A is an internationally accepted acoustical model, used by many other noise control professionals in the United States and abroad. The software has a high level of reliability and follows methods specified by the International Standards Organization in their ISO 9613-2 standard, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." The standard states,

> "This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level ... under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation ... propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night."

The model takes into account source sound power levels, surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain.

While standard modeling methodology takes into account moderate nighttime inversions and moderate wind speeds, there may be meteorological conditions that result in higher levels of sound from the turbines. In particular, much higher wind speeds can account for greater downwind propagation. Adjustments can be made to take into account the more extreme conditions. For this study, we modeled the sound propagation in accordance with ISO 9613-2 with spectral ground attenuation and no ground absorption which has been found to yield the most accurate yet conservative results using standard modeling parameters.[1]

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[1] Duncan, E., and Kaliski, K., "Improving Sound Propagation Modeling for Wind Power Projects," Acoustics'08, 2008, Paris, France .

A 10 meter by 10 meter grid of modeled receivers was set up covering 36 square miles around the site. This accounts for a total of about 950,000 modeled receivers. A receiver is a point above the ground at which the computer model calculates a sound level. In addition, discrete receivers were placed at 474 residential homes. The closest homes are approximately 1,130 meters (3,700 feet) away from the nearest turbine, which is well beyond the 2,000 feet setback recommended by the BLM and discussed in Section 4.3 of this report. Details of the modeling input assumptions are shown in Appendix B.

8.2. MODELING RESULTS

As described above, we modeled the proposed wind turbines using their maximum rated sound power level.[1]

Table 5 shows the sound power of the GE 1.5 MW turbine that was used in the modeling with 1/1 octave band center frequencies represented.

Table 5: Sound Power (Lw) of Proposed Turbines Assumed in Modeling

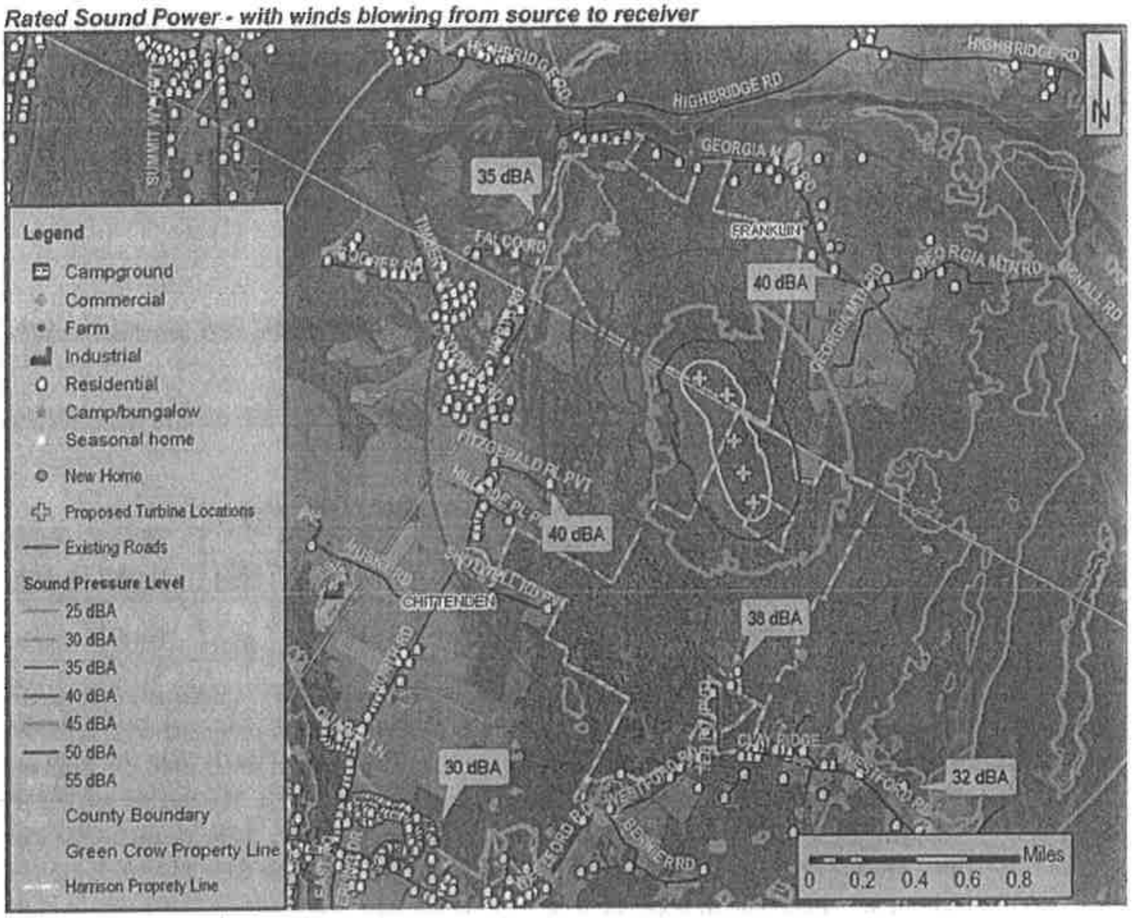
Turbine	Sound Power Level by 1/1 Octave Band (in dB)								Total in dB	Total in dBA
	63	125	250	500	1000	2000	4000	8000		
GE 1.5 MW Turbine	113.3	112.1	107.8	103.8	99.9	95.3	88.3	81.2	116.8	106.0

The results of the modeling are shown in Figure 6. The figure shows many discrete modeled receivers as orange circles. The green crosses in the figure are the proposed wind turbine locations. Noise isolines are color coded conforming to the modeled sound levels from the wind turbines, where blue is the highest sound levels and light green is the lowest. The thicker red line represents the geographic limit of a 45 dBA sound pressure level. As shown, there are no homes within the 45 dBA zone. The worst-case sound level at the nearest homes to the west and north northeast is 40 dBA. This would tend to occur on a clear or cloudy night and with winds blowing at more than 5 m/s (as measured at the sound level meter).

The modeling demonstrates that the project can meet the noise standard of 45 dBA (night) at all nearby residences during times when windows would typically be open. In addition, the Georgia Performance Standard of 70 dBA at all property lines would also be met.

[1] Note that there are some circumstances in the winter where ice can form on the wind turbine blades, creating higher levels of turbulence noise. These events are expected to occur only a few times during a typical winter and are of short duration. Note that windows are most likely to be closed during these icing events, thus reducing their noise impacts.

Figure 6: Sound Levels from the Proposed Georgia Mountain Community Wind Project at Maximum Rated Sound Power - with winds blowing from source to receiver



8.3. LOW FREQUENCY SOUND

At the residence with the highest overall sound levels from the turbines, the highest sound level at a frequency of 31.5 Hz is approximately 49 dB. (This is an unweighted sound pressure level.) This is below the *interior* sound level of 65 to 70 dB that is likely to create moderately perceptible building vibrations.

9. CONSTRUCTION IMPACTS AND OTHER NOISE SOURCES

9.1. CONSTRUCTION IMPACTS

The construction of the turbines will take place primarily at the turbine sites. While there may be activity closer to residences for road construction and utility work, such work will be of a relatively short duration.

The equipment used for the construction will be varied. Some of the louder pieces of equipment are shown in Table 6 along with the approximate maximum sound pressure levels at 15.2 m (50 feet) and 1,130 m (3,700 ft).

Table 6: Maximum Sound Levels from Various Construction Equipment

EQUIPMENT	SOUND PRESSURE LEVEL AT 15.2 m (dBA)	SOUND PRESSURE LEVEL AT 1,130 m (dBA)[1]
M-250 Liftcrane	82.5	38
2250 S3 Liftcrane	78	34
Excavator	83	41
Dump truck being loaded	86	45
Dump truck at 25 mph accelerating	76	33
Tractor trailer at 25 mph accelerating	80	39
Concrete truck	81	37
Bulldozer	85	41
Rock drill	100	49
Loader	80	33
Backhoe	80	36
Chipper	96	55

Blasting may be required. However, the amount of blasting will be limited. Blasts will be warned as per federal requirements. Blasts will be designed by a licensed blasting company and charges and delays will be set such that Bureau of Mines standards for vibration and airblast will be complied with.

Construction will take place over approximately nine months. Major construction work, such as clearing for the access roads, will occur primarily during the day, however, minor construction work may extend earlier or later.

Due to the setbacks involved and the limited duration of the activities, construction noise should not pose undue quality of life concerns.

9.2. OTHER NOISE SOURCES

There will be several minor noise sources at the site. These include:

1) Transformers – The electrical equipment has not yet been specified. There may be a transformer at the base of each turbine. Transformer noise emissions are subject to NEMA standards. The transformers at the base of the turbines are not likely to be audible outside of the project area. No step-up transformer is currently proposed.

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[1] Assumes a reduction of 6 dB per doubling of distance.

2) Transmission lines – The transmission lines associated with this project is 34 kV. The voltage of these lines is too low to generate any significant corona noise and will likely be inaudible next to the lines.

3) Maintenance and operations – The site will be accessed via a pickup truck or off-road vehicle. This level of increased traffic will not create any adverse sound impacts.

10. RECOMMENDATIONS

Based on the above analysis, we recommend:

1) Selecting turbines models and a turbine configuration that will not exceed 45 dBA outside the nearest residence, as demonstrated in this report.

2) Selecting wind turbines with no tonality or tonality within an acceptable level.

3) Providing neighbors with a site supervisor to call so as to resolve noise complaints promptly.

11. SUMMARY AND CONCLUSIONS

This report evaluated the potential noise impacts of the Georgia Community Wind project and concluded the following:

1) An appropriate standard to apply to this project would be the World Health Organization sleep disturbance criteria of 45 dBA averaged over the during summer months when windows are likely to be open.

2) Using five wind turbines with a sound power level of 106 dBA and a hub height of 80 meters, this project meets this standard by 5 dB or more during the night.

3) The sound levels from the turbines will not rise to a level that can create hearing damage, activity interference, or pose quality of life concerns.

4) The Georgia Zoning Ordinance Performance Standard of 70 dBA at the property line will be met.

As a result, the Georgia Community Wind project can be constructed in such a way as to have no undue adverse impact to health or aesthetics with respect to noise.

APPENDIX A

TABLE 4.1 OF THE WHO'S "GUIDELINES FOR COMMUNITY NOISE" (1999)

Table 4.1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30	16 8	 45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school Bedrooms, indoors	Sleep disturbance	30	sleeping -time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial, shopping and traffic areas, indoors and Outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music through headphones/ Earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3		

#1: as low as possible;

#2: peak sound pressure (not LAmax, fast), measured 100 mm from the ear;

#3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low;

#4: under headphones, adapted to free-field values

APPENDIX B

MODEL INPUT DATA

Turbine Information

Name	ID	Sound Power (dBA)	Height (m)	Coordinates X (m)	Y (m)	Z (m)
PROPOSED TURBINE_LOCATIONS_9.24.08	3	106	80	454810	240326	501
PROPOSED TURBINE_LOCATIONS_9.24.08	2	106	80	454873	240128	520
PROPOSED TURBINE_LOCATIONS_9.24.08	1	106	80	454936	239948	506
PROPOSED TURBINE_LOCATIONS_9.24.08	5	106	80	454592	240714	494
PROPOSED TURBINE_LOCATIONS_9.24.08	4	106	80	454766	240612	511

Name	1/1 Octave Band sound power levels (dBA)								
Center frequency (Hz) ->	31.5	63	125	250	500	1000	2000	4000	8000
GE Turbine	72.6	87.1	96	99.2	100.6	99.9	96.5	89.3	80.1

Modeling parameters

Parameter	Setting
Ground absorption	ISO 9613-2 Spectral, G=0
Atmospheric Absorption	Based on 10 degrees ~~F~~ C, 70% relative humidity ✓
Reflections	None
Search radius	4000 m (2.6 miles) from each source
Receiver height	4 m (13.1 ft)
Contour interval	10 m from USGS Digital elevation model