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  RSG Noise Impact Study for Saddleback Ridge Wind Farm, (Revised March 2011)

1016

RSG INC.
ENVIRONMENT, ENERGY, & ACOUSTICS

Noise Impact Study for Saddleback Ridge Wind Farm

Carthage, Maine

October 2010
Revised March 2011

DATA ■ ANALYSIS ■ SOLUTIONS

This report is prepared by:

Resource Systems Group, Inc
55 Railroad Row
White River Junction, VT 05001

802-295-4999
info@rsginc.com
www.rsginc.com

For:

Patriot Renewables, LLC
549 South Street
Quincy, MA 02169

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1.0 INTRODUCTION

Patriot Renewables is developing a wind energy facility on the ridge of Saddleback Mountain in Carthage, Maine - the Saddleback Ridge Wind project.

This report is an update to the October 2010, "Noise Impact Study for Saddleback Ridge Wind Farm," prepared by RSG. The October 2010 report was based on a project consisting of 12 GE 2.75-100 2.75 MW turbines, with 100-meter rotors. Patriot Renewables is now proposing to use 12 GE 2.75-103 2.75 MW turbines, with 103-meter rotors. These slightly longer rotors are designed to be quieter than the 100-meter rotors. This revised noise impact study assesses the effects of the new wind turbine model on sound levels in the area surrounding the project.

The report includes:

1) A description of the project site
2) A noise primer
3) A discussion of noise issues specific to wind turbines
4) A discussion of applicable noise limits
5) The results of background sound level monitoring
6) The results of computer propagation modeling
7) A summary and conclusions

2.0 PROJECT AREA

The proposed turbines would be located in the township of Carthage in Franklin County, Maine.

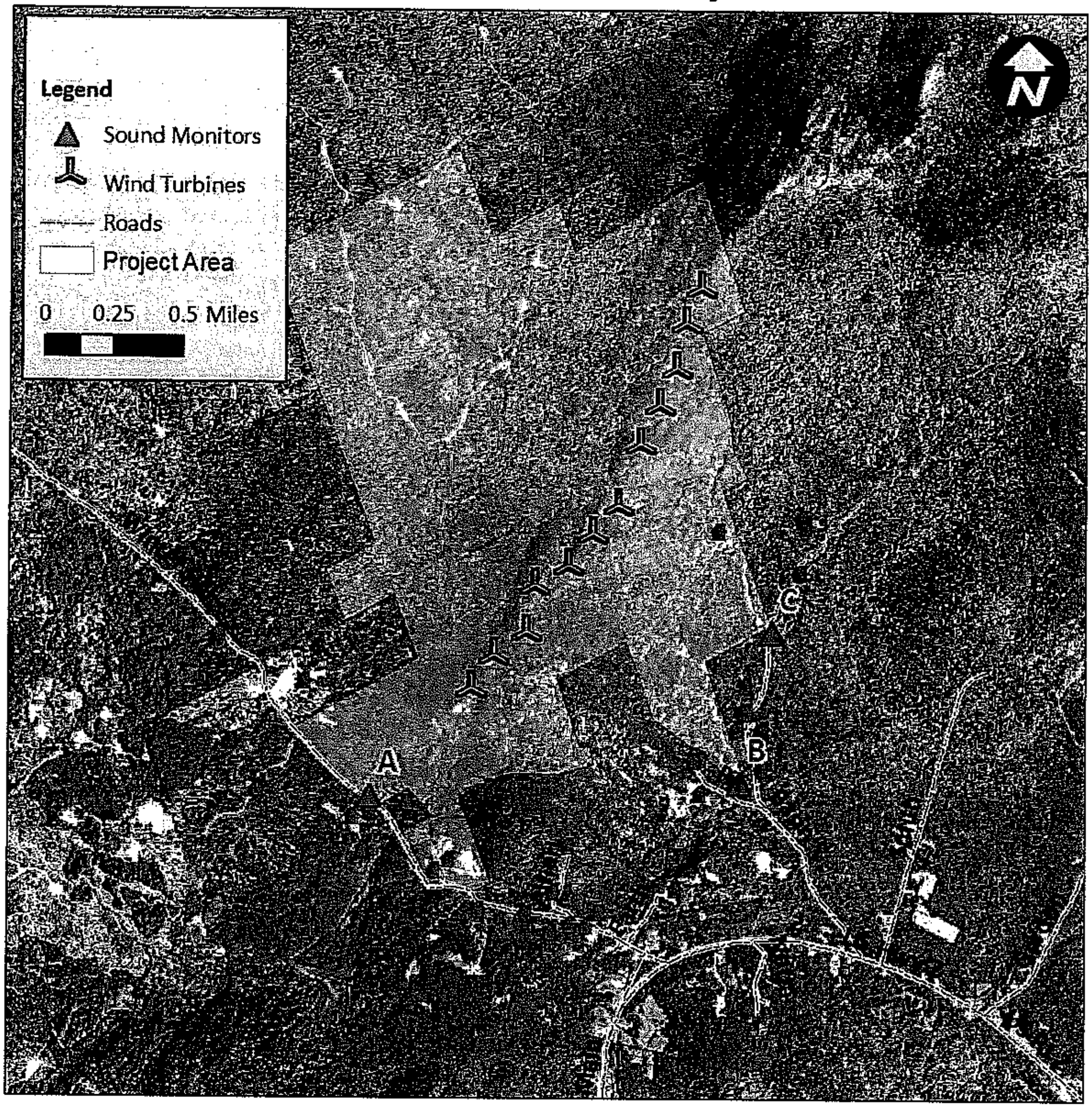
The area largely consists of forested areas, with some agricultural land. The terrain is mountainous. The project borders Winter Hill Road to the west and approaches US Route 2 to the south. The proposed turbines are located along Saddleback Ridge, which runs from the southwest portion of the project area to the northeast.

The distance between the turbines and the closest non-participating residence to the east is approximately 3,710 feet. The closest non-participating residence to the southwest of the turbine string is approximately 2,690 feet.[1]

A map of the project area is provided in Figure 1.

[1] These distances are from the residence to the nearest turbine nacelle.

Figure 1: Proposed Project Area with Wind Turbine & Ambient Sound Monitoring Locations



3.0 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.

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

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 approximate threshold of 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.

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 continuous" sound level (L_{eq}) is often used. L_{eq} averages sound pressure rather than decibels, and results in weighting the levels of 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 continuous sound level for the entire hour would be 72 dBA, compared to the arithmetic decibel average of 1.3 dB. The equivalent average sound level is often used in environmental noise analysis.

3.3 What is the Difference between Sound Pressure Levels and Sound Power Levels?

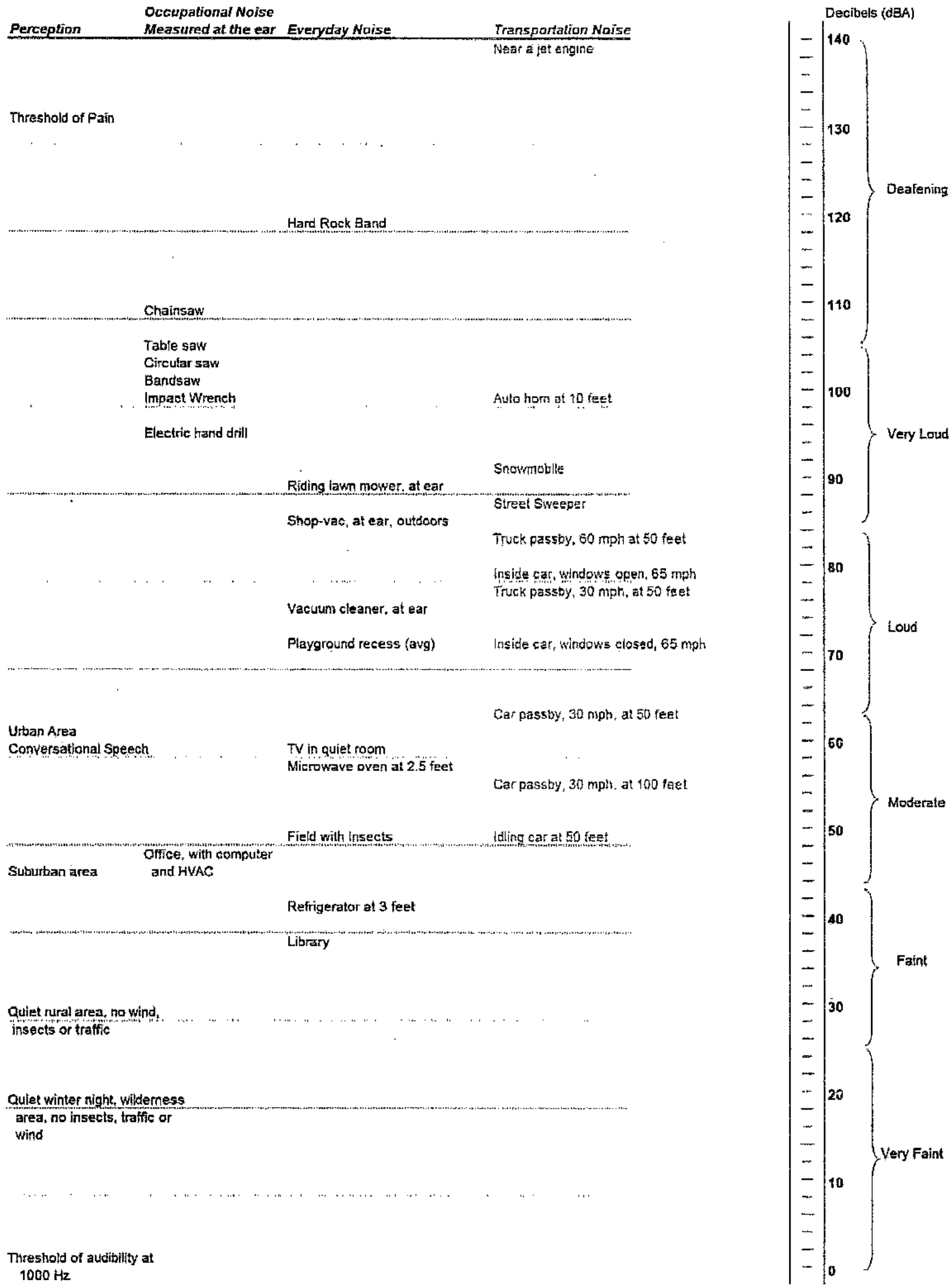
Both sound power and sound pressure levels are described in terms of decibels, but they are not the same thing. Sound power is a measure of the acoustic power emitted or radiated by a source. The sound power level of a source does not change with its surrounding conditions.

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.

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.

Figure 2: Basic Theory: Common Sounds in Decibels



3.4 How is Sound Modeled?

The decibel sound level is described 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 in sound pressure, 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 the level will decline to 60 dBA, and at 200 feet, 54 dBA, assuming no other influences. From a line source, like a gas pipeline or from closely spaced point sources, like a roadway or string of wind turbines, sound attenuates at approximately 3 dB per doubling distance. These "line sources" transition to an attenuation of 6 dB per doubling at a distance of roughly a third of the length of the line source.

Other factors, such as intervening vegetation, terrain, 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 76 dBA at 50 feet, two co-located machines would register 3 dB more, or 79 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 82 dBA and eight machines would register 85 dBA. If the two sources differ in sound level then 0 to 3 dB will be added to the higher level as shown in Table 1.

Table 1: Decibel Addition

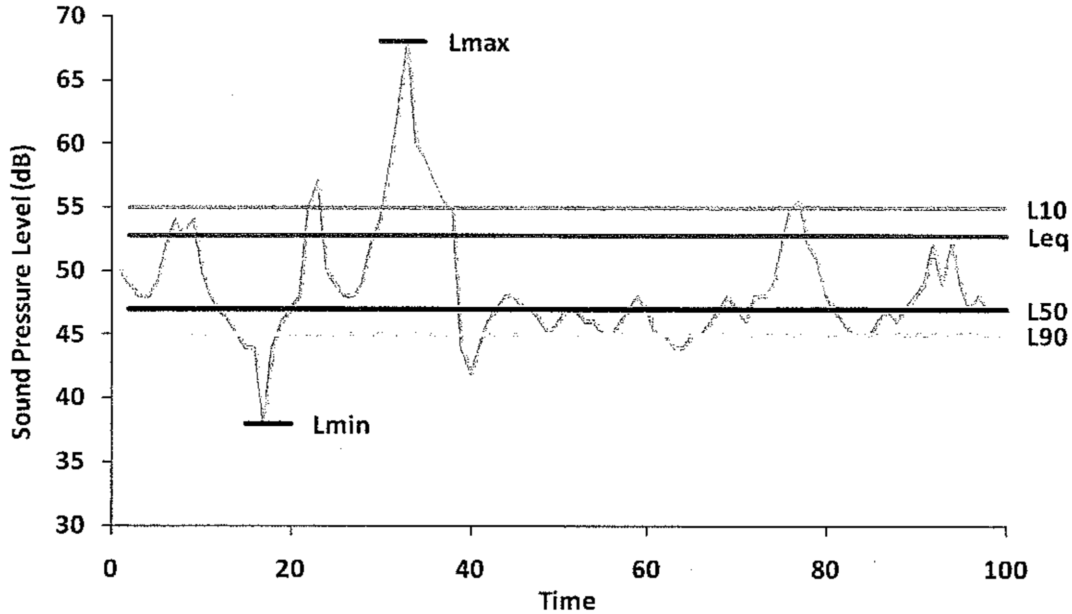
If Two Sources Differ By	Add
0-1 dB	3 dB
2-4 dB	2 dB
5-9 dB	1 dB
>9 dB	0 dB

3.5 Description of Terms

Sound can be measured in many different ways. Perhaps the simplest way is to take an instantaneous measurement, which gives the sound pressure level at an exact moment in time. The level reading could be 62 dB, but a second later it could 57 dB. Sound pressure levels are constantly changing. It is for this reason that it makes sense to describe noise and sound in terms of time.

The most common ways of describing noise over time is in terms of various statistics. Take, as an example, the sound levels measured over time shown in Figure 3. Instantaneous measurements are shown as a ragged grey line. The sound levels that occur over this time can be described verbally, but it is much easier to describe the recorded levels statistically. This is done using a variety of "levels" which are described below.

Figure 3: Example of Noise Measurement over Time and Descriptive Statistics



3.5.1 Equivalent Average Sound Level - Leq

One of the most common ways of describing noise levels is in terms of the continuous equivalent sound level (Leq). The Leq is the average of the sound pressure over an entire monitoring period and expressed as a decibel. The monitoring period could be for any amount of time. It could be one second ($Leq_{1\text{-sec}}$), one hour ($Leq_{(1)}$), or 24 hours ($Leq_{(24)}$). Because Leq describes the average pressure, loud and infrequent noises have a greater effect on the resulting level than quieter and more frequent noises. For example, in Figure 3, the median sound level is about 47 dBA, but the equivalent average sound level (Leq) is 53 dBA. Because it tends to weight the higher sound levels and is representative of sound that takes place over time, the Leq is the most commonly used descriptor in noise standards and regulations.

3.5.2 Percentile Sound Level - Ln

Ln is the sound level exceeded *n* percent of the time. This type of statistical sound level, also shown in Figure 3, gives us information about the distribution of sound levels over time. For example, the L10 is the sound level that is exceeded 10 percent of the time, while the L90 is the sound level exceeded 90% of the time. The L50 is exceeded half the time. The L90 is a residual base level which most of the sound exceeds, while the L10 is representative of the peaks and higher, but less frequent levels. When one is trying to measure a continuous sound, like a wind turbine, the L90 is often used to filter out other short-term environmental sounds that increase the level, such as dogs barking, vehicle passbys, wind gusts, and talking. That residual sound, or L90, is then the sound that is occurring in the absence of these noises.

3.5.3 Lmin and Lmax

Lmin and Lmax are simply the minimum and maximum sound level, respectively, monitored over a period of time.

4.0 NOISE STANDARDS

Saddleback Ridge falls under the planning and zoning jurisdiction of the Maine Department of Environmental Protection (DEP), which has set out its regulations for noise in Control of Noise, Chapter 375.10. Generally speaking, commercial, industrial, and other non-residential areas are subject to hourly equivalent average $Leq_{(1)}$ sound level limits of 70 dBA in the daytime (7am to 7pm) and 60 dBA during the night (7pm to 7am).

The most restrictive DEP standards apply to quiet areas where pre-development hourly sound levels are 45 dBA or less during the day and 35 dBA or less during the night. Quiet areas are subject to hourly sound level limits of 55 dBA during the day (7am to 7pm) and 45 dBA during the night (7pm to 7am). Nighttime limits also apply to protected locations within 500 feet of an existing or proposed residence (or at the residence's property line, whichever is closer). In these areas, sound levels may not exceed 45 dBA. Beyond a distance of 500 feet or on properties without a residential structure, a daytime limit of 55 dBA applies.

This project will be evaluated against the daytime and nighttime quiet area criteria, whereby maximum sound levels may not exceed 55 dBA and 45 dBA, respectively.

The DEP standards apply various penalties to the overall sound levels which exceed certain tonal and short duration repetitive sound criteria. Given the nature of the turbines proposed for this location, these penalties are not expected to be applied.

5.0 SOUND MONITORING

5.1 Soundscapes around the Project

Soundscapes are the combination of sounds that characterize a listening environment. Soundscapes can be distinguished by the types and levels of ambient sound over time. In a rural project area, differences in soundscapes are often a function of the distance from roadways of varying traffic volumes. In this area, sound level monitoring locations were chosen to represent distinctive soundscapes around the project area. These characteristic soundscapes include the:

1. Residences southwest of the project area. These residences are accessible by a dirt road or ATV trail. They lie to the southwest of the ridge line.
2. Residences southeast of the project area. These residences are closer to Route 2 and may be subject to more traffic noise. They lie to the south of the ridge line.
3. Residences east of the project area. These residences are at a higher elevation than the others and are farthest from Route 2. They lie to the east of the ridge line.

Sound level monitors were installed around these areas.

5.2 Sound Monitoring

To determine ambient sound levels in the area, RSG conducted sound level monitoring for three locations in the representative areas around the project (see Figure 1). The monitoring took place from September 14 to 21, 2010.

All sites were monitored with ANSI Type 1 Cesva SC310 sound level meters set to log 1/3 octave band sound levels every second. Each sound level meter was calibrated before and after the measurements and fitted with seven-inch diameter windscreens. The windscreens reduce the self-noise created by wind passing over the meter's microphone. Each microphone was placed approximately 1.4 meters above the ground. Table 2 shows the specifics of each measurement position and Table 3 displays summarized results from the background sound monitoring.

Table 3 displays four different sound levels: the Leq, L90, L50, and L10. The values given for each statistic correspond to the average daytime or nighttime sound levels throughout the entire monitoring period. As defined in Section 3, the Leq is the equivalent average sound level. This measure weights louder sound levels more than quieter levels because it is based on a logarithm of the squared sound pressure. The L90, L50, and L10 are the sound levels exceeded 90%, 50%, and 10% of the time, respectively. In this table, "daytime" refers to the period between 7am and 7pm and "nighttime" refers to the period between 7pm and 7am. This is in accordance with the Maine DEP regulations outlined in Section 4 of this report.

Table 2: Background Sound Monitoring Summary

Monitor	Meter	Start Time	End Time
A	Cesva SC310	9/14/10 2:00 PM	9/21/10 10:10 AM
B	Cesva SC310	9/14/10 2:30 PM	9/21/10 1:40 PM
C	Cesva SC310	9/14/10 4:20 PM	9/21/10 1:30 PM

Table 3: Background Monitoring Results Summary (dBA)

	Daytime				Nighttime			
	Leq	L90	L50	L10	Leq	L90	L50	L10
Monitor A	41	25	31	41	47	19	28	42
Monitor B	40	22	31	43	42	20	31	40
Monitor C	39	26	32	41	45	23	27	41

Figure 1 identifies the monitoring locations in reference to the project area. Each monitoring location and logged sound levels are shown in greater detail in the figures that follow.

5.2.1 Monitor A

Monitor A was located in the southwest of the project area, set back about 50 feet from Winter Hill Road. The monitor was placed 0.5 miles from the nearest proposed wind turbine and 300 feet from the nearest residential building. Its location is shown in Figure 4 and monitoring results are provided in Figure 5.

An anemometer with a temperature sensor was also placed here at a height of one meter above the ground. This equipment was damaged by a vandal on the evening of September 20th. It ceased to log data after this time.

Figure 4: Monitor A Location

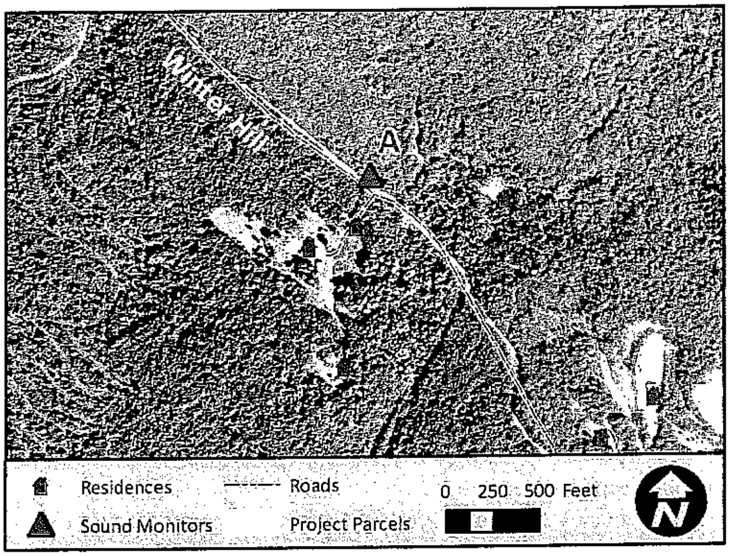
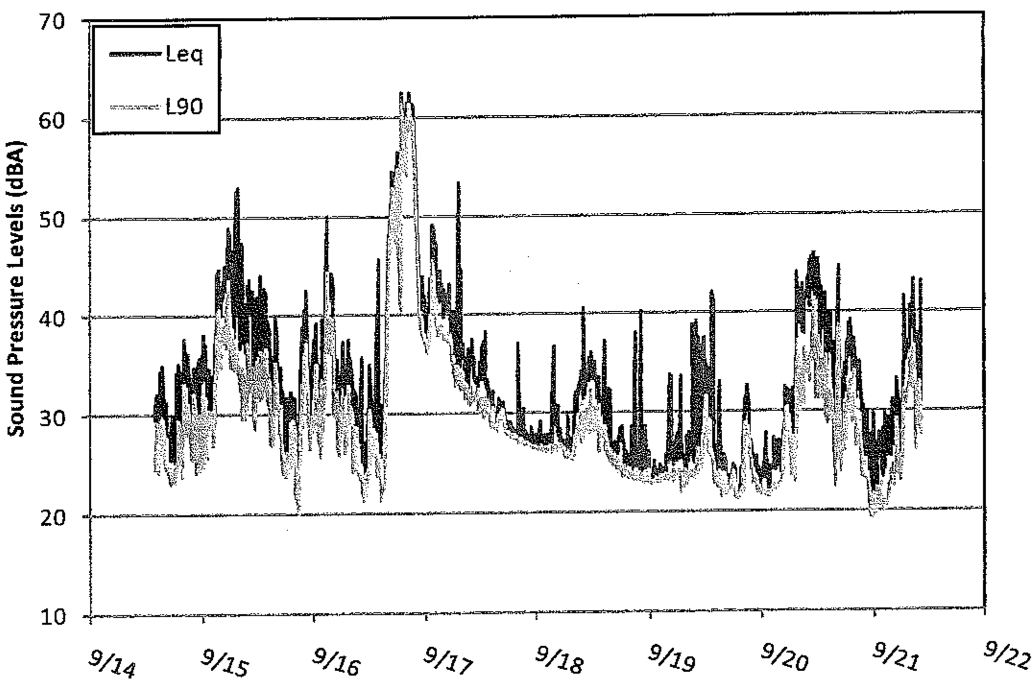


Figure 5: Monitor A Results, 10-minute Periods



5.2.2 Monitor B

Monitor B was located in the southeast of the project area, between Cliff Road and Basin Road. The monitor was placed about 250 feet from the nearest public road, 500 feet from the nearest house, and 1.0 miles from the nearest proposed wind turbine. Its location is shown in Figure 6 and monitoring results are provided in Figure 7.

Figure 6: Monitor B Location

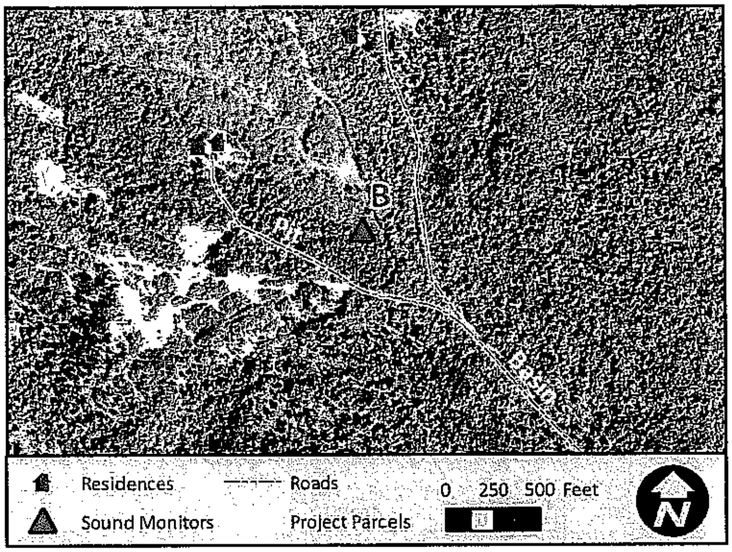
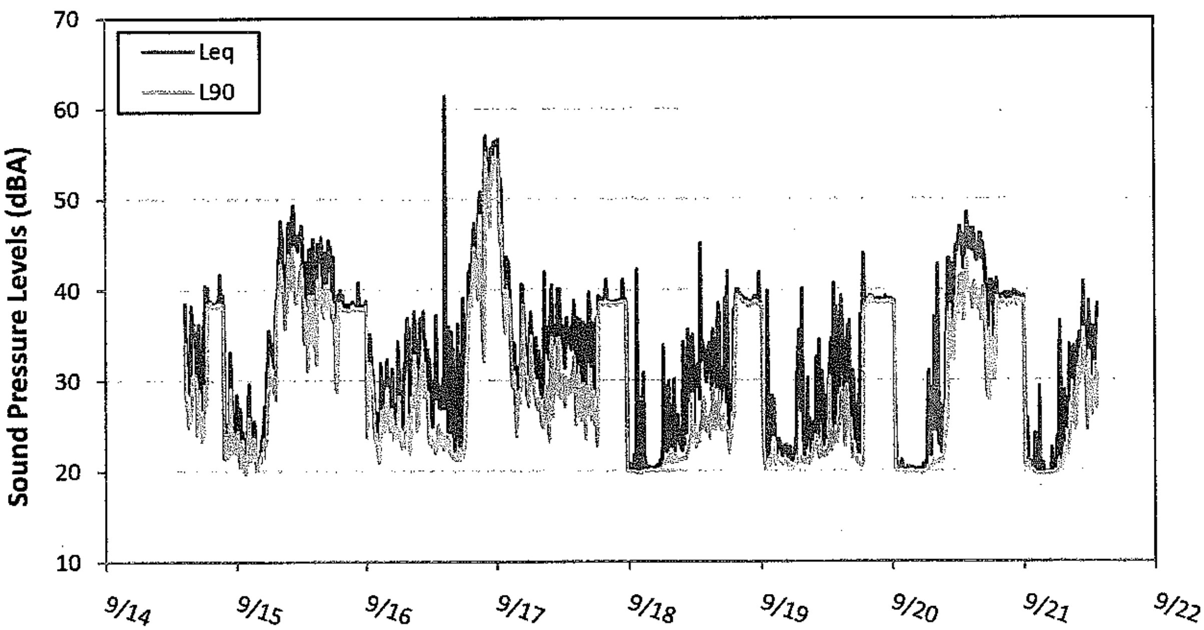


Figure 7: Monitor B Results, 10-minute Periods



5.2.3 Monitor C

Monitor C was located to the east of the project area, about 60 feet east from Basin Road. The monitor was placed 1,100 feet (0.2 miles) from the nearest residence and 0.7 miles from the nearest proposed wind turbine. An anemometer was set up at a height of one meter to record wind speeds at Monitor C. The location of the equipment is shown in Figure 8 and monitoring results are provided in Figure 9.

Figure 8: Monitor C Location

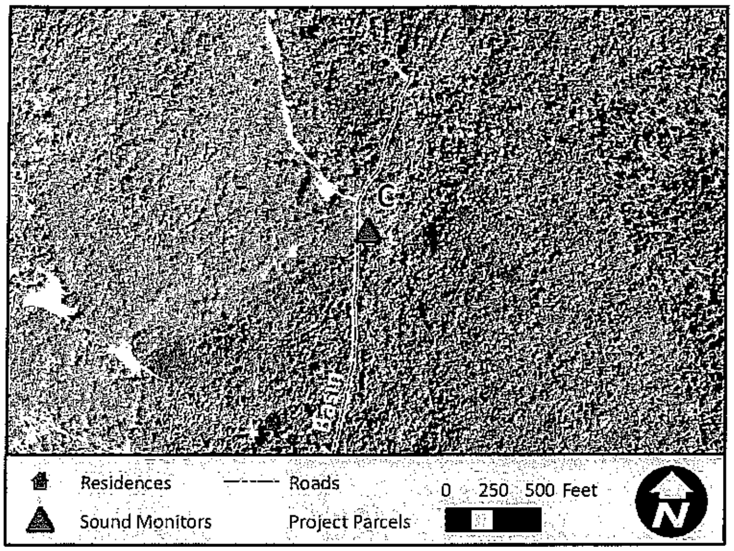
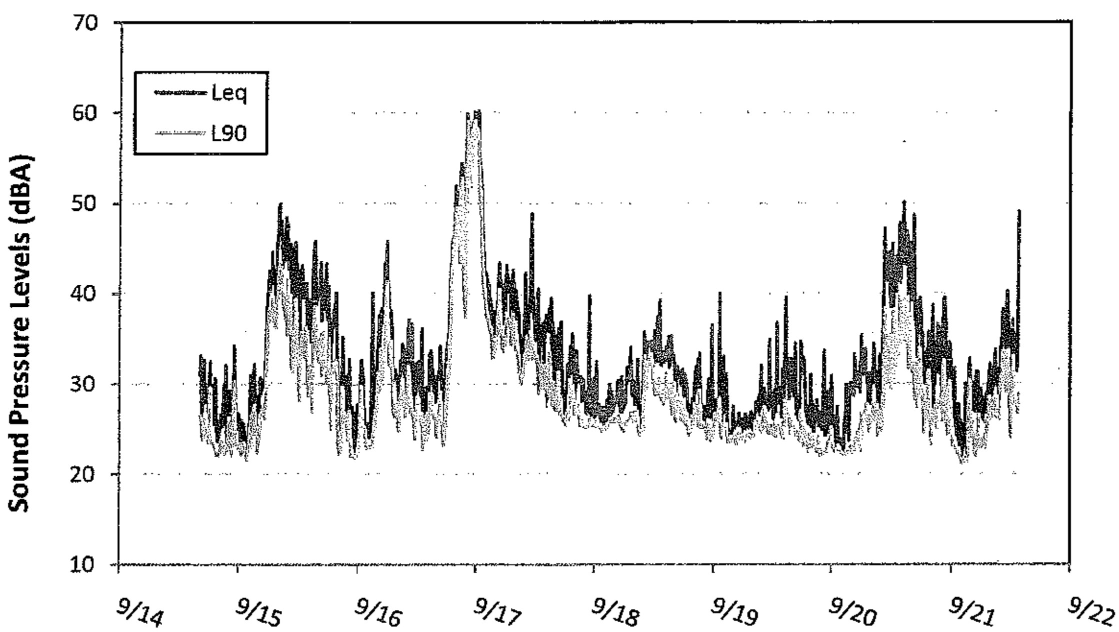


Figure 9: Monitor C Results, 10-minute Periods



6.0 METEOROLOGICAL DATA

6.1 Weather Events

RSG installed a meteorological station near both Monitor A and Monitor C. The station at Monitor A recorded wind speed, gust speed, temperature and relative humidity at 1 meter above ground throughout the monitoring period. On average, persistent calm winds were detected by this met station, and very small wind gust speeds were recorded. The average temperature during the monitoring period of met station A was 53°F, ranging from a low of 39°F to a high of 55°F. The average relative humidity was 79%.

The met station at Monitor C monitored wind speed, gust speed, and wind direction at 1 meter above ground throughout the monitoring period. Very minor wind and gust speeds were detected by this met station.

Data was also collected by the project met tower at 60 meters above ground level. The 10-minute average wind speeds collected from this station ranged from calm conditions to 17 meters/second during the monitoring period.

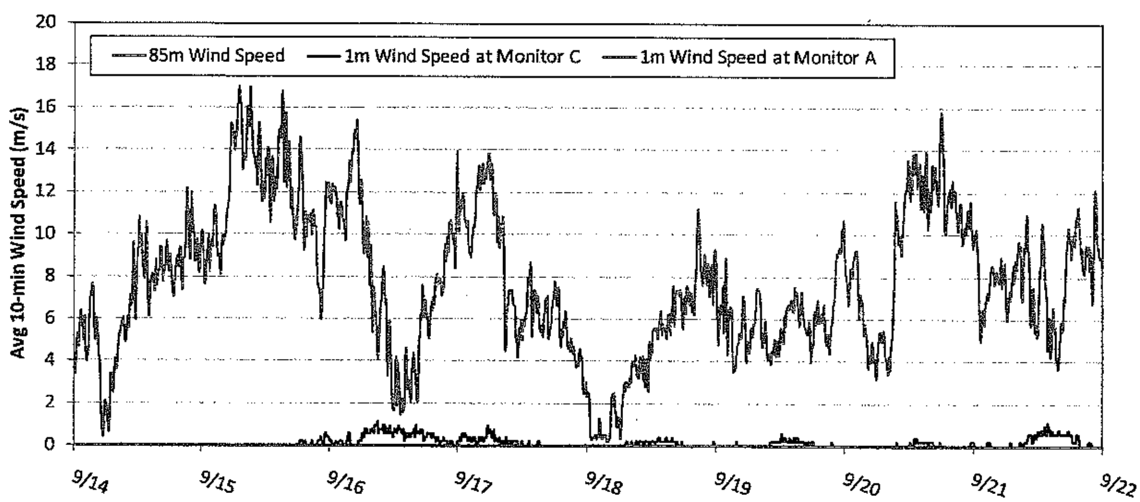
Additional meteorological data for the monitoring period was collected from WeatherUnderground.com for the nearest reporting met station, Auburn, Maine[1]. This station recorded no precipitation events during the monitoring period.

6.2 Wind Speeds

A long-term project met tower collected 10-minute average wind speeds at anemometer heights of 40 meters, 50 meters, and 60 meters. From this data, RSG determined the wind shear for each time period and used it to calculate average wind speeds at a relative elevation of 85 meters, which is the hub height of the turbines under consideration.

Figure 10 shows wind speeds during the monitoring period for the project met tower and the met stations at Monitor A and Monitor C.

Figure 10: Wind Speed (10-min Averages) at Ground Stations and Projected Hub Height from Project Met Tower



6.3 Correlation of Wind Speed and Ambient Sound Level

Wind speeds at hub height and sound pressure levels at ground-level receivers in the project area are typically correlated. The more they are correlated, the more there is a chance that the wind turbines will be masked by background sound generated by wind. Figures 11 through 13 depict the relationship between wind speed and 10-minute Leqs and L90s at each monitoring station.

[1] Auburn is located 45 miles south of Carthage

The hub-height wind speed and measured sound levels are well correlated ($p<0.05$). Monitor A and Monitor B show increases in sound level only after 4 to 6 m/s wind speeds, which indicate that masking could occur, but only at higher wind speeds.

Figure 11: Wind Speed and Sound Pressure Levels at Monitor A

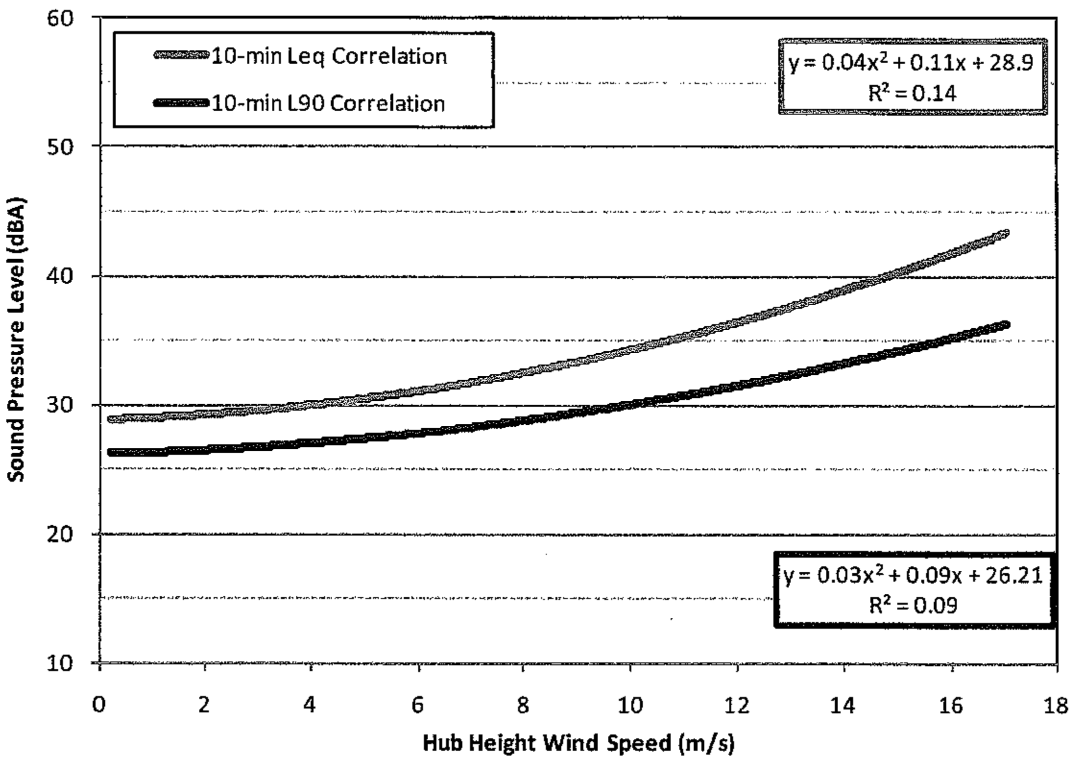


Figure 12: Wind Speed and Sound Pressure Levels at Monitor B

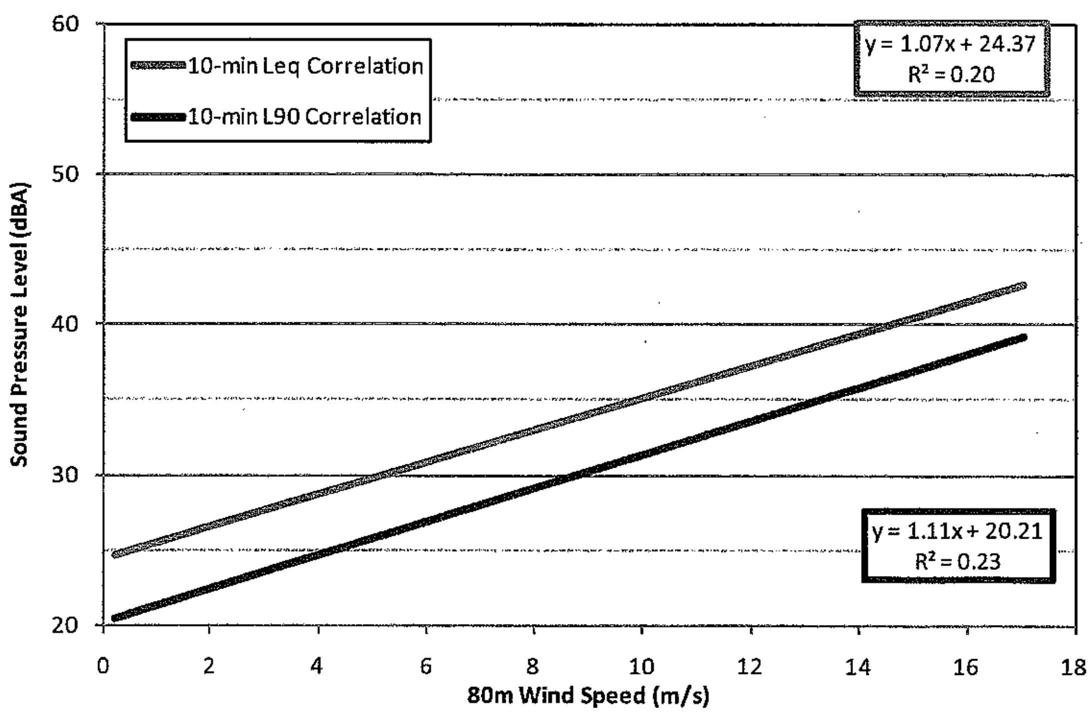
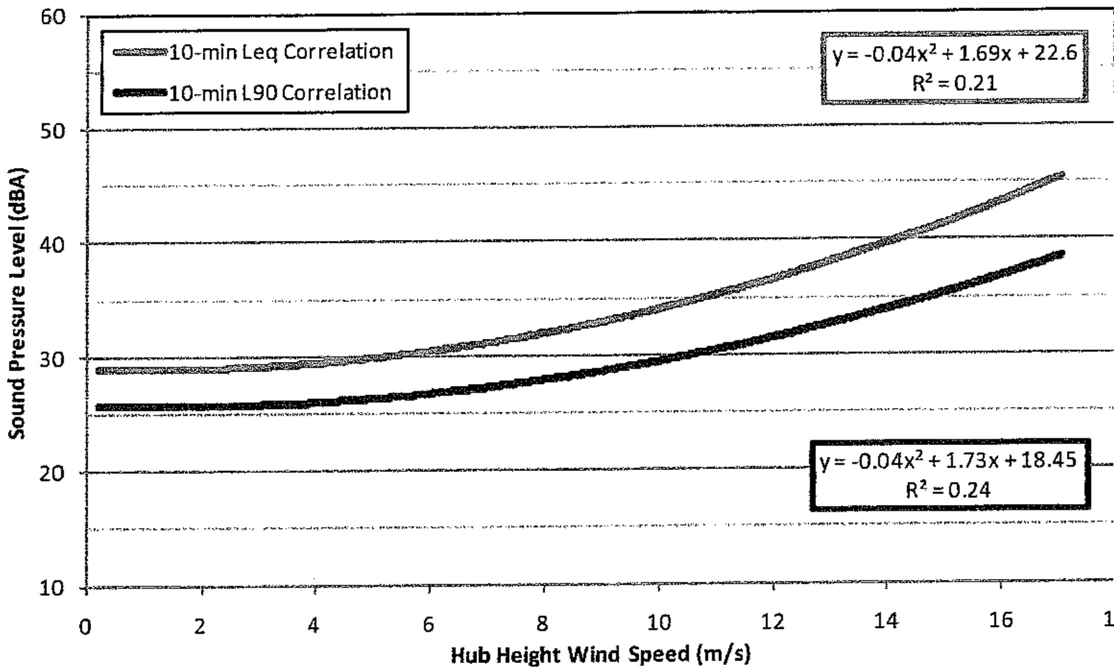


Figure 13: Wind Speed and Sound Pressure Levels at Monitor C



7.0 Sound Levels Produced by Wind Turbines

7.1 Standards Used to Measure Wind Turbine Sound Emissions

A manufacturer of a wind turbine must test its turbines using two international standards:

1. International Electrotechnical Commission standard IEC 61400-1w1:2002(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 provide sound power emission levels from a turbine, by wind speed and frequency. They also provide a confidence interval.

7.2 Manufacturer Sound Emissions Estimates

The project proposes to use 12 GE 2.75-103 2.75 MW wind turbines with a hub height of 85 meters.

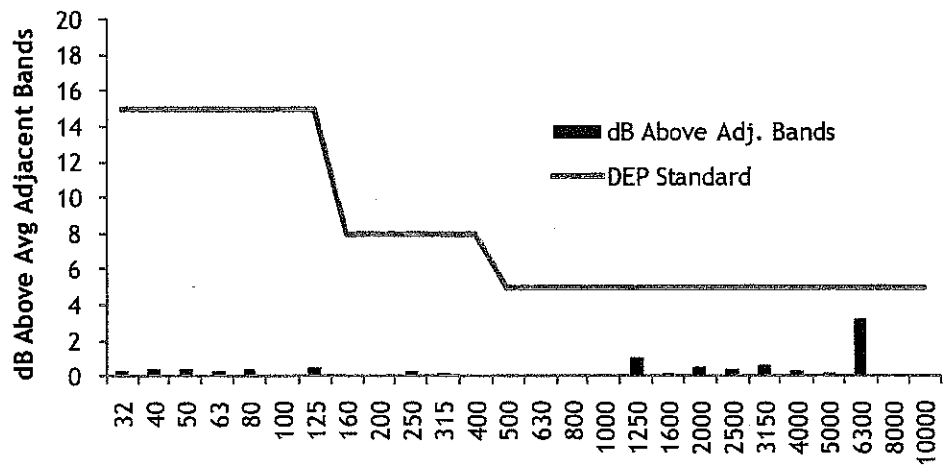
Sound emissions from a wind turbine are measured as sound *power*. This is different from the sound *pressure* that one measures on a sound level meter. Sound *power* is the acoustical energy emitted by an object, and sound *pressure* is the measured change in pressure caused by acoustic waves at an observer location.

The sound *power* level from a GE unit is 105 ± 2 dBA with wind speeds of 7 m/s and greater (10-meter anemometer height). The modeled level in this report is 107 dBA, as it includes the uncertainty factor of 2 dB. The octave band sound power levels are shown in Table 4. The maximum tonal audibility level as measured by the IEC 61400-11 methodology is less than 4 dB, irrespective of wind speed. No 1/3 octave band exceeds the arithmetic average of adjacent 1/3 octave bands by more than 3 dB, and thus the turbine has no "tonal sound" according to Maine DEP standards (Figure 14).

Table 4: GE 2.75-103 Spectral Sound Power Levels

		Octave Band Center Frequency								
10-m Height wind speed (m/s)	Nominal Sound Power (dBA)	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
7 to cut-out	105.0	82.6	92.2	96.1	97.9	98.4	99.0	96.0	87.5	71.7

Figure 14: Comparison of 1/3 Octave Band Sound Power with Maine DEP Tonal Noise Definition



8.0 SOUND FROM WIND TURBINES – SPECIAL ISSUES

8.1 Wind Turbine Noise

Wind turbines generate two principle types of noise: aerodynamic noise, produced from the flow of air around the blades, and mechanical noise, produced from mechanical and electrical components within the nacelle.

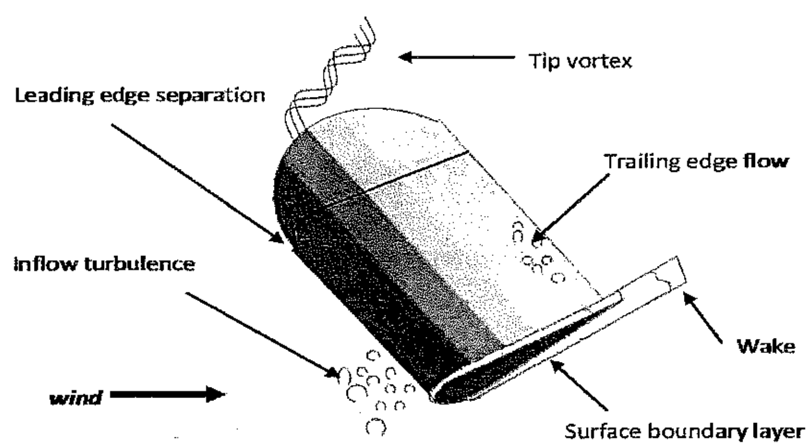
Aerodynamic noise is the primary source of noise associated with wind turbines. These acoustic emissions can be either tonal or broadband. Tonal noise occurs at discrete frequencies, whereas broadband noise is distributed with little peaking across the frequency spectrum. Low frequency aerodynamic tonal noise is typically associated with downwind rotors on horizontal axis wind turbines. In this configuration, the rotor plane is behind the tower relative to the oncoming wind. As the turbine blades rotate, each blade crosses behind the tower's aerodynamic wake and experiences brief load fluctuations. This causes short, low-frequency pulses or thumping sounds called *blade impulsive noise*. Large modern wind turbines are "upwind", where the rotor plane is upwind of the tower. As a result, this type of low frequency noise does not occur in all but the most swirling winds.

Tonal noise can also originate from unstable air flows over holes, slits, or blunt trailing edges on blades. Most modern wind turbines have upwind rotors designed to prevent blade impulsive noise. Therefore, the majority of aerodynamic noise is broadband at higher frequencies.

Wind turbines emit aerodynamic broadband noise as the spinning blades interact with atmospheric turbulence and as air flows along their surfaces. This produces a characteristic "whooshing" sound through several mechanisms (Figure 15):

- *Inflow turbulence noise* occurs when the rotor blades encounter atmospheric turbulence as they pass through the air. Uneven pressure on a rotor blade causes variations in the local angle of attack, which affects the lift and drag forces to cause aerodynamic loading fluctuations. This generates noise that varies across a wide range of frequencies but is most significant at levels below 500 Hz.
- *Trailing edge noise* is produced as boundary-layer turbulence around the airfoil passes into the wake, or trailing edge, of the blade. This noise is distributed across a wide frequency range but is most notable at high frequencies between 700 Hz and 2 kHz.
- *Tip vortex noise* occurs when tip turbulence interacts with the surface of the blade tip. While this is audible near the turbine, it tends to be a small component of the overall noise further away.
- *Stall* or *separation noise* occurs due to the interaction of turbulence with the blade surface.

Figure 15: Airflow around a Rotor Blade

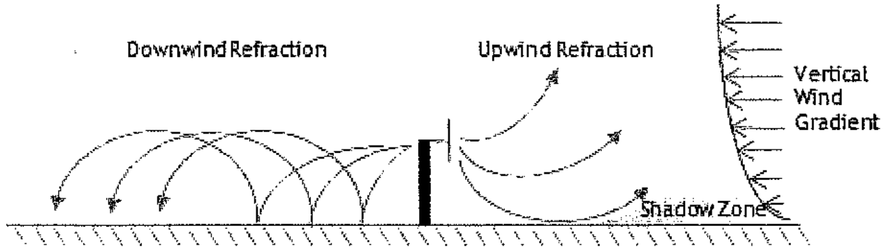


Mechanical noise tends to be tonal in nature but can also have a broadband component. Potential sources of mechanical noise include the gearbox, generator, yaw drives, cooling fans, and auxiliary equipment. These components are housed within the nacelle, whose surfaces, if untreated, radiate the resulting noise. However modern wind turbines have nacelles that are designed to reduce internal noise, and rarely is the mechanical noise a significant portion of the total noise from a wind turbine.

8.2 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 wind speed gradient), sound levels upwind from the source tend to decrease and sound levels downwind tend to increase due to the refraction, or bending, of the sound (Figure 16).

Figure 16: Schematic of the Refraction of Sound Due to Vertical Wind Gradient (Wind Shear)



With temperature lapse, when ground surface temperatures are higher than those aloft, sound will tend to refract upwards, leading to lower sound levels near the ground. The opposite is true when ground temperatures are lower than those aloft (an inversion condition).

The term "Stability Class" is used to describe how stable the atmosphere is. Unstable atmospheres can be caused by high winds and/or high solar radiation. This creates turbulence and tends to break up and dissipate sound energy. Highly stable atmospheres, which tend to occur on clear nights with low ground-level wind speeds, tend to minimize atmospheric turbulence and are generally more favorable to down-wind propagation.

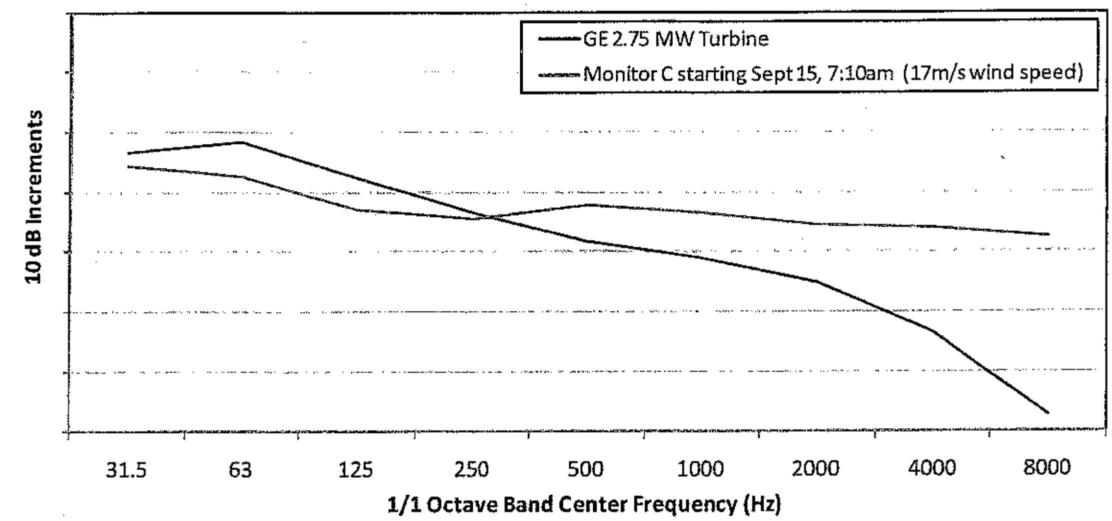
In general terms, sound propagates best under stable conditions with a strong temperature inversion. This occurs during the night and is characterized by low ground level winds.[1] Wind speeds under very stable conditions (Stability Class G) can be too low to generate electricity, therefore the turbines are not spinning, unless this inversion happens during a time with high wind shear. As a result, worst-case conditions for wind turbines tend to occur under moderate nighttime temperature inversions. Therefore, this is the default condition for modeling wind turbine sound.

8.3 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. This effect is amplified in areas covered by trees and other vegetation. The sound from a wind turbine can often be masked by wind noise at downwind receivers because the frequency spectrum from wind is very similar to the frequency spectrum from a wind turbine. Figure 17 compares the sound spectrum measured at Monitor C during a 17 m/s wind event to a GE 2.75-103 wind turbine. As shown, the shapes of the spectra are very similar at the lower frequencies. At higher frequencies, the sounds from the masking wind noise are higher than the wind turbine. As a result, the masking of turbine noise is possible at higher wind speeds.

[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.

Figure 17: Comparison of Frequency Spectra from Wind at Monitor C and a GE 2.75-103 Wind Turbine



It is important to note that while winds may be blowing at turbine height, there may be little to no wind at ground level. This is especially true during strong wind gradients (high wind shear), which mostly occur at night. This can also occur on the leeward side of ridges where the ridge blocks the wind.

Given the correlation of wind speed and background sound level at Monitors B and C (Figure 12 and 13), we would expect some masking of wind turbine sound, especially with residences on the eastern side of the project at higher wind speeds.

8.4 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. As a result, infrasound analysis is not necessary.

Low frequency sound is a component of the sound generated by wind turbines. As with infrasound, high levels of low frequency sound can induce rattling in light-weight partitions in buildings. The American National Standards Institute standard, ANSI S12.2, "Criteria for Evaluating Room Noise", recommends that levels be kept below 65 dB at 16 Hz, 65 dB at 31.5 Hz, and 70 dB at 70 Hz inside the building to prevent moderately perceptible vibration and rattles.

Low frequency sound is primarily generated by the generator and mechanical components. Much of the mechanical noise has been reduced in modern wind turbines through improved sound insulation at the hub. 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 is absorbed less by the atmosphere and ground than higher frequency sound. Our modeling took into account downward diffraction under a moderate nighttime inversion and differential atmospheric absorption of low and high frequency sound.

9.0 SOUND MODELING

9.1 Modeling Software

Modeling was completed for the project using Cadna A acoustical modeling software. Created 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 ISO 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 ... or, equivalently, 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 for omnidirectional wind, using spectral ground attenuation and a ground absorption factor of 0 (to represent hard ground). These factors are based on modeling parameters cited in "Propagation Modeling Parameters for Wind Power Projects," Sound & Vibration, December 2008. In addition, a 2 dB manufacturer's confidence interval was added to the sound power level of the wind turbines.

A 10-meter by 10-meter grid of receivers was set up in the model covering 7.2 square miles around the site. This accounts for a total of about 176,866 modeled receivers. A receiver is a point above the ground at which the computer model calculates a sound level. Separate discrete receivers were added to the model in addition to the grid to represent 33 residences in proximity to the proposed wind turbines, with an additional 9 receivers representing the worst case locations within a 500 foot radius of homes near the project (or the project property line, whichever was closer). Grid receivers were modeled at a height of 1.5 meters, discrete receivers representing homes were modeled at a height of 4.0 meters, and discrete receivers representing other locations were modeled at a height of 1.5 meters.

9.2 Modeling results

9.2.1 Overall Results

The overall modeling results under normal operating conditions are shown as a noise contour map in Figure 18. Within the figure, brown house symbols represent structures and the lines emanating from the wind turbines are color-coded noise isolines, where red represents the highest sound level and purple represents the lowest. The highest sound pressure level within 500 feet of a non-participating residence protected location is 45 dBA at Receiver B-002 (45.3 dBA at three significant digits). The sound level at that residence (Receiver 002) is 44 dBA.

Therefore, the project technically complies with DEP's nighttime noise standard of 45 dBA under normal operating conditions, because the DEP standard is given in two significant digits. To demonstrate compliance at three significant digits (45.0 dBA), model runs were conducted using a Noise Reduced Operating (NRO) mode. With NRO, turbine sound emissions are reduced primarily through slowing the blade rotational speed. Power generation is also reduced. NRO modes are specified by the level of reduced sound power. For example, a 1 dB NRO mode reduces the maximum sound power from a wind turbine by 1 dB.

Running Turbines 8 and 9 with a 1 dB and 2 dB NRO mode, respectively, and all other turbines with no NRO restriction would reduce the sound level at Receiver B-002 to 45.0 dBA. These results are shown in Figure 19.

Sound levels over 55 dBA only occur within a radius of about 120 meters (400 feet) from the wind turbines. Therefore, all daytime standards are met at protected locations in the normal operating mode.

Source information, receiver results, and modeling parameters are included in Appendix A. A discussion of model calibration and model results using G = 0.5 with a +5 dB adjustment factor are found in Appendix B.

Figure 18: Modeled Sound Pressure Levels (dBA) under Normal Operating Conditions

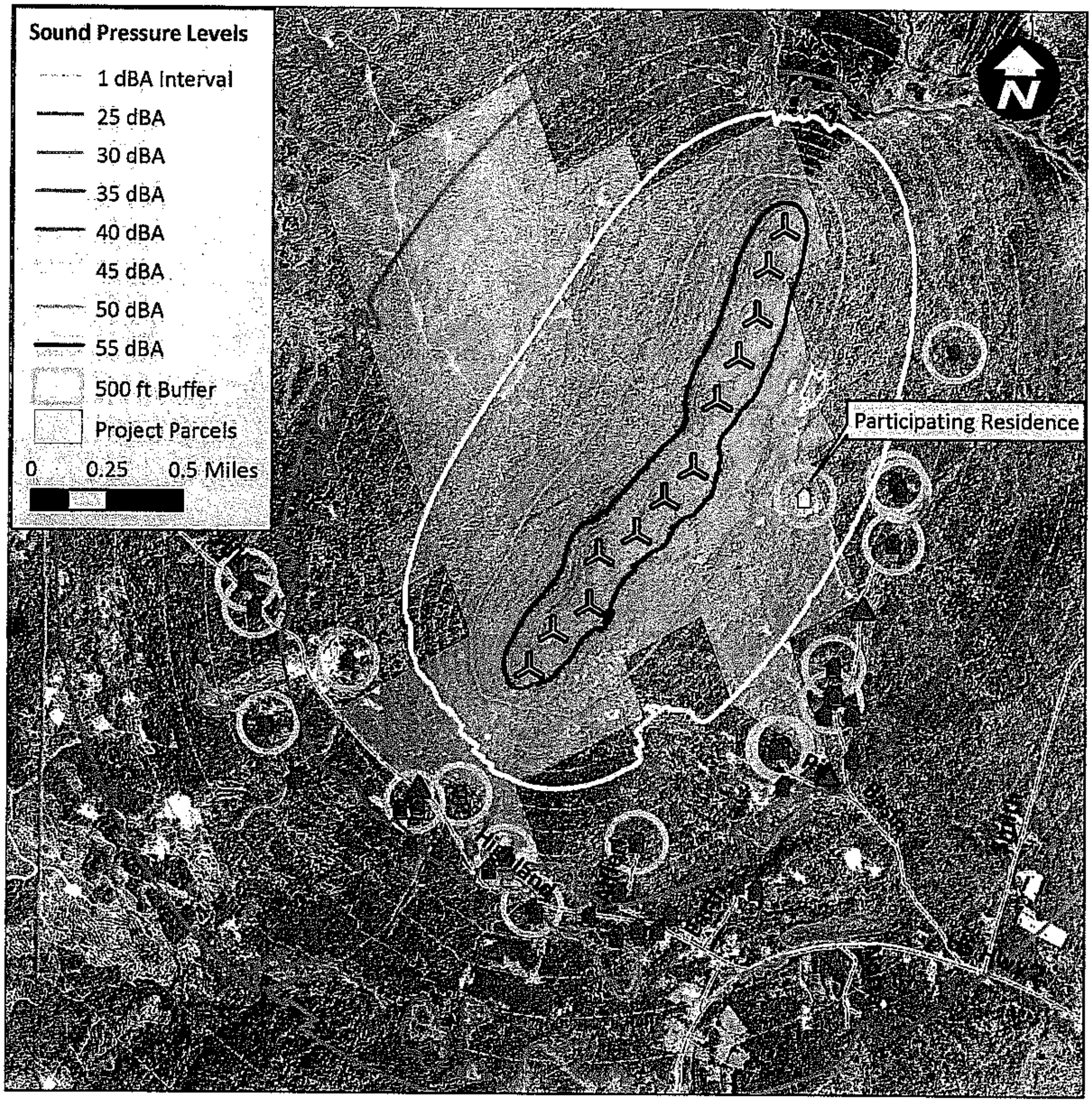
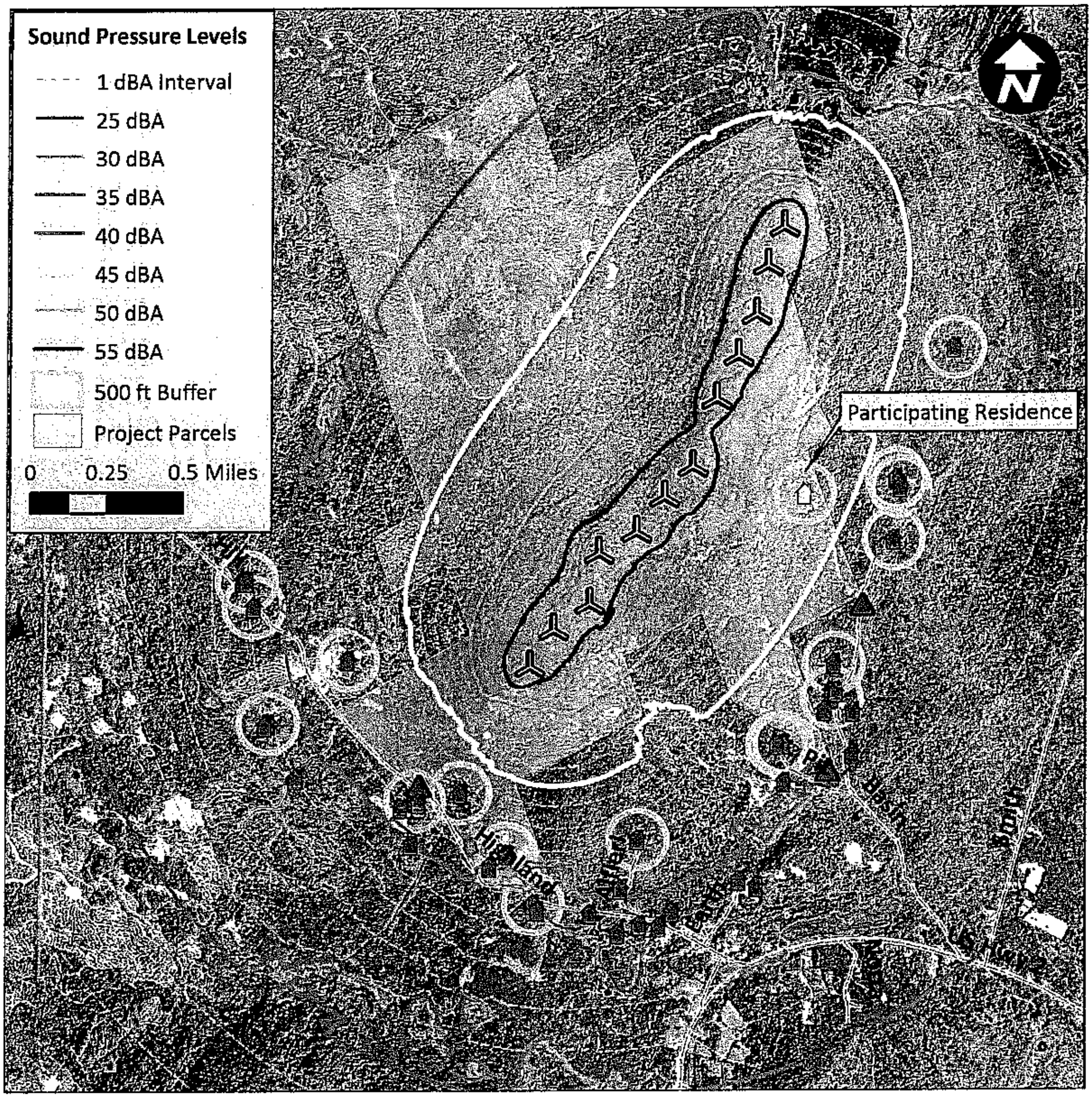


Figure 19: Modeled Sound Pressure Levels (dBA) with NRO



9.2.2 Low Frequency Sound

A criteria for noise induced building vibration at the interior or buildings can be found in ANSI S12.2-2008, "Criteria for evaluating room noise." The criteria for "moderately perceptible vibration and rattle likely" is 65 dB at 16 and 31.5 Hz, and 70 dB at 63 Hz. Of all the residences evaluated in each modeled scenario the highest sound level outside at 31.5 Hz is 64 dB and the highest sound level at 63 Hz is 60 dBA. These modeled sound levels are below the noise-induced vibration thresholds. Modeling at infrasound frequencies was not conducted, as modern wind turbines typically do not generate problematic infrasound levels.

10.0 SHORT-DURATION REPETITIVE SOUNDS

There are currently no ANSI, IEC, or other standards used to predict short-duration-repetitive-sounds (SDRS) from wind turbines. The cause of SDRS is debated, but it is likely a function of the different wind speeds at the top and bottom of the rotor (wind shear) and turbulence (Bowdler 2008, Dunbabin 1996, Oerlemans and Mendez, 2005, van den Berg 2005). The turbulence can be naturally occurring or created by wakes from upwind turbines.

Several papers have studied the theoretical effect of wind shear on the "swishing" sound from wind turbines (Lee, et al. 2009, Oerlemans and Schepers, 2009). They found that much of this amplitude modulation can be explained simply by the difference in broadband blade noise created by higher wind speeds at the top versus the bottom of the rotor rotation. Higher wind shear would result in higher amplitude modulation. This amplitude modulation is broadband and not infrasonic.

Terrain breaks up the tendency to create stable wind layers. As a result, in turbine locations such as those found along the Saddleback Ridge, there tends to be fewer instances of excessive wind shear

To evaluate whether this area is subject to very high wind shear, we reviewed a year of data from the Saddleback Ridge meteorological tower. The brown box in Figure 19 represents 90% of the hour with hub-height wind speeds of 4 m/s or greater. As shown, instances of high wind shear ($\alpha > 0.55$) occur less than 5% of the time for all hours.

Excessive turbulence can increase the level of sound from a wind turbine and it may also contribute to SDRS. Turbulence may be naturally occurring, caused by thermal mixing and ground roughness, for example. Or, it can be caused by the wake from upwind turbines. To evaluate naturally occurring turbulence, we reviewed one year of meteorological data and plotted turbulence intensity for 52,560 10-minute data points. As shown on Figure 20, higher turbulence occurs during the day, due to higher solar radiation. Overall, 76% of the data points are below 0.20 turbulence intensity, with most of those periods above this figure occurring during the day.

Turbulence intensity is highest at the lowest wind speeds, when sound output from the wind turbines is lower. Figure 21 shows seasonal turbulence intensity from the Saddleback Ridge met tower plotted against wind speed.

Figure 20: Wind profile power law exponent by time of day for 85 meter predicted wind speeds above 4 m/s. Boxes show 90% of data and "whiskers" are the +5% and -5% outliers

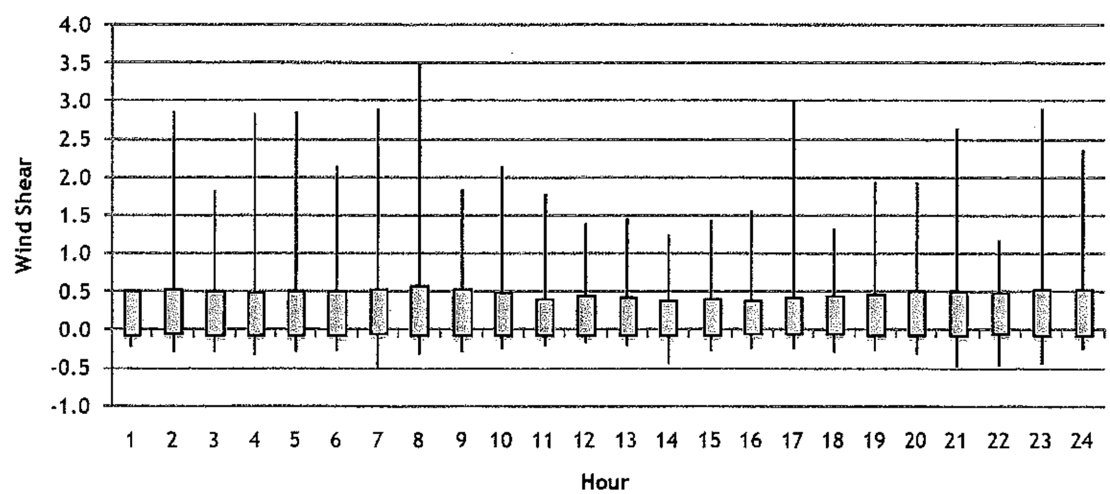


Figure 21: Turbulence intensity by wind speed. Boxes show 90% of data and "whiskers" are the +5% and -5% outliers

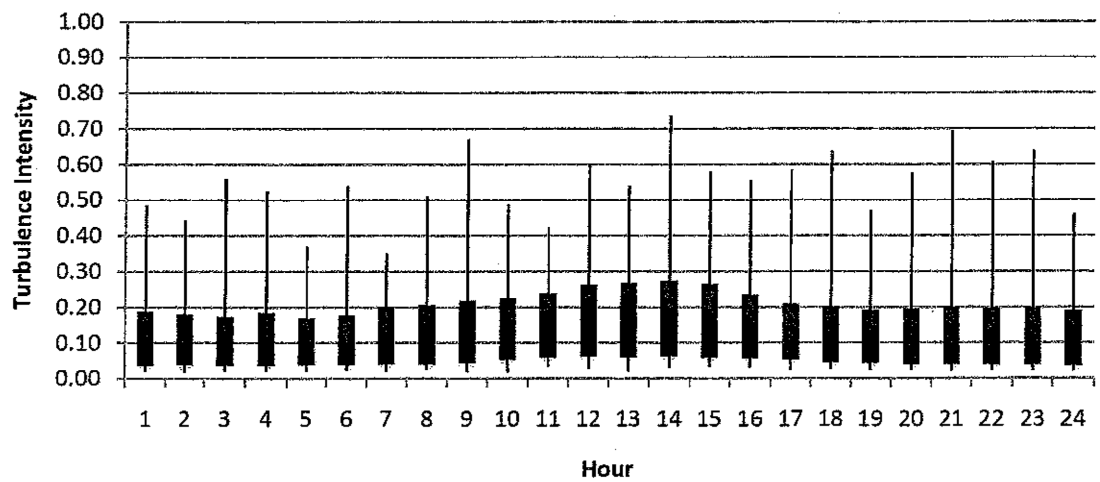
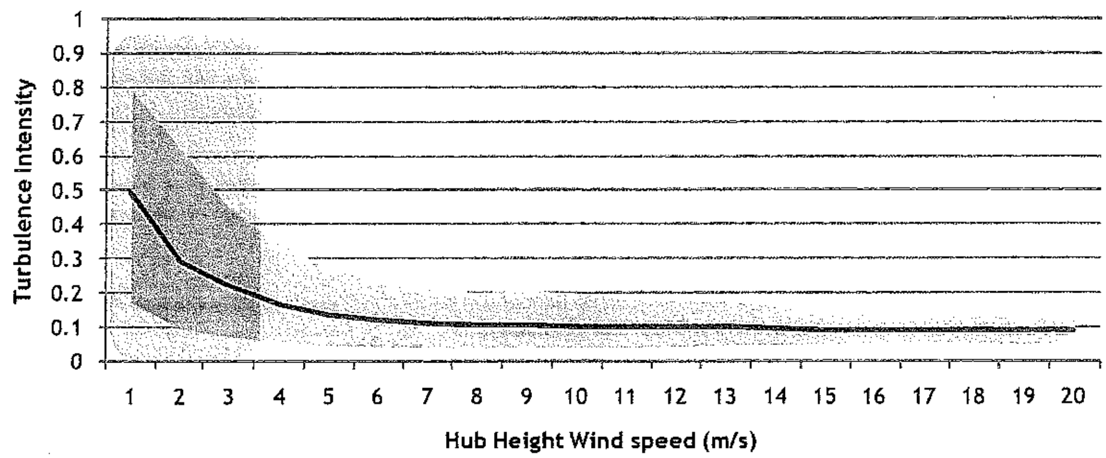


Figure 22: Turbulence Intensity by Wind Speed.

Green area bounds the 5th percentile and 95th percentile turbulence intensities by hub height wind speed. Shaded area shows wind speeds too low for turbine operation. Blue line shows the average.



While it is not possible, at this time, to calculate the extent of SDRS at Saddleback Ridge, the analysis shown above indicates that the site characteristics are not condusive to common occurences of SDRS.

Inflow turbulence between turbines in a turbine string can also affect noise from the wind farm. Proper turbine siting and operation minimizes this type of turbine wake impact.

If post-construction monitoring is required similar to the protocols from Rollins and Stetson, data will be collected to evaluate whether SDRS is occuring.

11.0 CONSTRUCTION IMPACTS

The construction of the turbines will take place primarily on the ridge line. 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 4 along with the approximate maximum sound pressure levels at 50 feet (15.2 m) and 2,445 feet (745 m). Sound levels at this distance are likely to be lower due to the presence of dense vegetation between the construction areas and the nearest residences.

Table 5: Maximum sound levels from various construction equipment

Equipment	Sound Pressure Level at 50 feet (dBA)	Sound Pressure Level at 2,445 feet (dBA)[1]
M-250 Liftcrane	82.5	43
2250 S3 Liftcrane	78	38
Excavator	83	45
Dump truck being loaded	86	49
Dump truck at 25 mph accelerating	76	37
Tractor trailer at 25 mph accelerating	80	43
Concrete truck	81	41
Bulldozer	85	45
Rock drill	100	55
Loader	80	37
Backhoe	80	38
Chipper	96	59

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.

12.0 Summary and Conclusions

Patriot Renewables proposes to construct and operate 12 GE 2.75-103 2.75 MW wind turbines in Carthage, Maine. These turbines have a nominal sound power rating of 105 dBA. The project will generate up to 33 MW of electricity.

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

1) A 45 dBA nighttime (7 pm-7 am) noise limit and a 55 dBA daytime (7 am to 7 pm) noise limit apply to the project.
2) The proposed wind turbine does not generate any tonal sound according the Maine DEP standard.
3) Sound propagation modeling was conducted using conservative assumptions, including a ground absorption factor of 0 (to represent hard ground) and a 2 dB confidence interval on top of the manufacturer's maximum sound power levels.
4) The highest modeled sound level at and within 500 feet of a non-participating residence was 44 and 45.3 dBA, respectively (Receivers 002 and B-002).

[1] Assumes hard ground around construction site, and ISO 9614-2 propagation with no vegetation reduction. Actual sound levels will likely be lower given the prevalence of dense vegetation and soft ground around the site.

5) If required by DEP for nighttime compliance, Noise Reduced Operations on Turbines 8 and 9 reduces sound levels from 45.3 dBA to 45.0 dBA at the 500 foot buffer location with the highest noise impacts from the project (Receiver B-002).[1]
6) The modeled levels of low frequency sound will not create perceptible building vibration.

The modeled results described in this report indicate the Saddleback Ridge Wind project meets the noise standards set out by the Maine Department of Environmental Protection.

[1] Sound levels would also be lower than 45.0 dBA when hub height wind speeds are below 9.1 meters/second.

APPENDIX A: MODELING INPUTS AND RESULTS

Table A1: Manufacturer Turbine Sound Power Spectrum (dBA)

Turbine Model	Octave Band Frequency (Hz)								dBA
	31.5	*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*	
GE 2.75-103*	82.6	92.2	96.1	97.9	98.4	99.0	96.0	87.5	71.7	105.0

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Table A2: Modeling Parameters

Parameter	Setting
Ground Absorption	Spectral for all sources, G=0
Atmospheric Absorption	Based on 10 Degrees Celsius, 70 % Relative Humidity
Reflections	None
Receiver Height	4 m for residences, 1.5 meters for grid and other locations

Table A3: Modeled Turbine Source Data (includes +2 dB to account for confidence interval)

Turbine ID	Modeled Sound Power Level (dBA)		Relative Turbine Height (m)	Coordinates (UTM NAD 83 Z19)		
	Day	Night		X (m)	Y (m)	Elevation (m)
1	107	107	85	390484	4939603	564
2	107	107	85	390610	4939795	579
3	107	107	85	390798	4939930	609
4	107	107	85	390849	4940197	630
5	107	107	85	391043	4940306	655
6	107	107	85	391190	4940491	650
7	107	107	85	391339	4940651	650
8	107	107	85	391463	4941004	695
9	107	107	85	391577	4941231	695
10	107	107	85	391672	4941447	686
11	107	107	85	391730	4941704	697
12	107	107	85	391818	4941907	725

Table A4: Modeled Residences and 500-foot Buffer Locations

Receiver ID	Description*	Relative Height (m)	Coordinates (UTM NAD 83 Z19)		Elevation (m)	Modeled Sound Level (dBA)**	Closest Turbine	Distance to Closest Turbine (m)***	Distance to Closest Turbine (ft)***
			X (m)	Y (m)					
001	Participating	4	391938	4940511	379	47	T07	713	2339
B 001	Participating Buffer	1.5	391783	4940550	421	48	T07	556	1824
002	Non-Participating	4	392419	4940590	341	44	T08	1133	3716
B 002	Non-Participating Buffer	1.5	392273	4940627	348	45	T08	995	3264
003	Non-Participating	4	392444	4940545	333	44	T08	1174	3851
004	Non-Participating	4	392407	4940273	307	43	T07	1213	3979
B 004	Non-Participating Buffer	1.5	392263	4940346	316	45 [44]	T07	1061	3480
005	Non-Participating	4	392094	4939622	278	43	T06	1336	4382
B 005	Non-Participating Buffer	1.5	391993	4939740	291	44	T06	1187	3893
006	Non-Participating	4	392084	4939473	266	42	T05	1416	4644
B 006	Non-Participating Buffer	1.5	391958	4939559	280	43	T05	1269	4162
007	Non-Participating	4	392107	4939470	264	42	T06	1436	4710
008	Non-Participating	4	392048	4939374	266	42	T03	1435	4707
009	Non-Participating	4	392196	4939369	255	41	T05	1565	5133
010	Non-Participating	4	392192	4939147	243	41 [40]	T03	1663	5455
011	Non-Participating	4	391828	4939202	286	42	T03	1327	4353
012	Non-Participating	4	391795	4939197	287	42	T03	1304	4277
B 012	Non-Participating Buffer	1.5	391679	4939311	299	44 [43]	T03	1149	3769
013	Non-Participating	4	391832	4939000	271	41	T03	1455	4772
014	Non-Participating	4	391687	4938452	279	39	T01	1706	5596
015	Non-Participating	4	391595	4938484	282	40 [39]	T01	1620	5314
016	Non-Participating	4	391246	4938318	314	39	T01	1532	5025
017	Non-Participating	4	391177	4938244	319	39	T01	1562	5123
018	Non-Participating	4	391074	4938252	331	39	T01	1509	4950
019	Non-Participating	4	390977	4938441	358	40	T01	1296	4251
020	Non-Participating	4	390961	4938206	341	39	T01	1509	4950
021	Non-Participating	4	390815	4938311	351	39	T01	1368	4487
022	Non-Participating	4	391063	4938700	343	42	T01	1117	3664
B 022	Non-Participating Buffer	1.5	391000	4938847	346	43	T01	966	3168
023	Non-Participating	4	390132	4938946	310	43	T01	821	2693
B 023	Non-Participating Buffer	1.5	390156	4939007	318	43	T01	759	2490
024	Participating	4	390287	4938558	349	40	T01	1106	3628

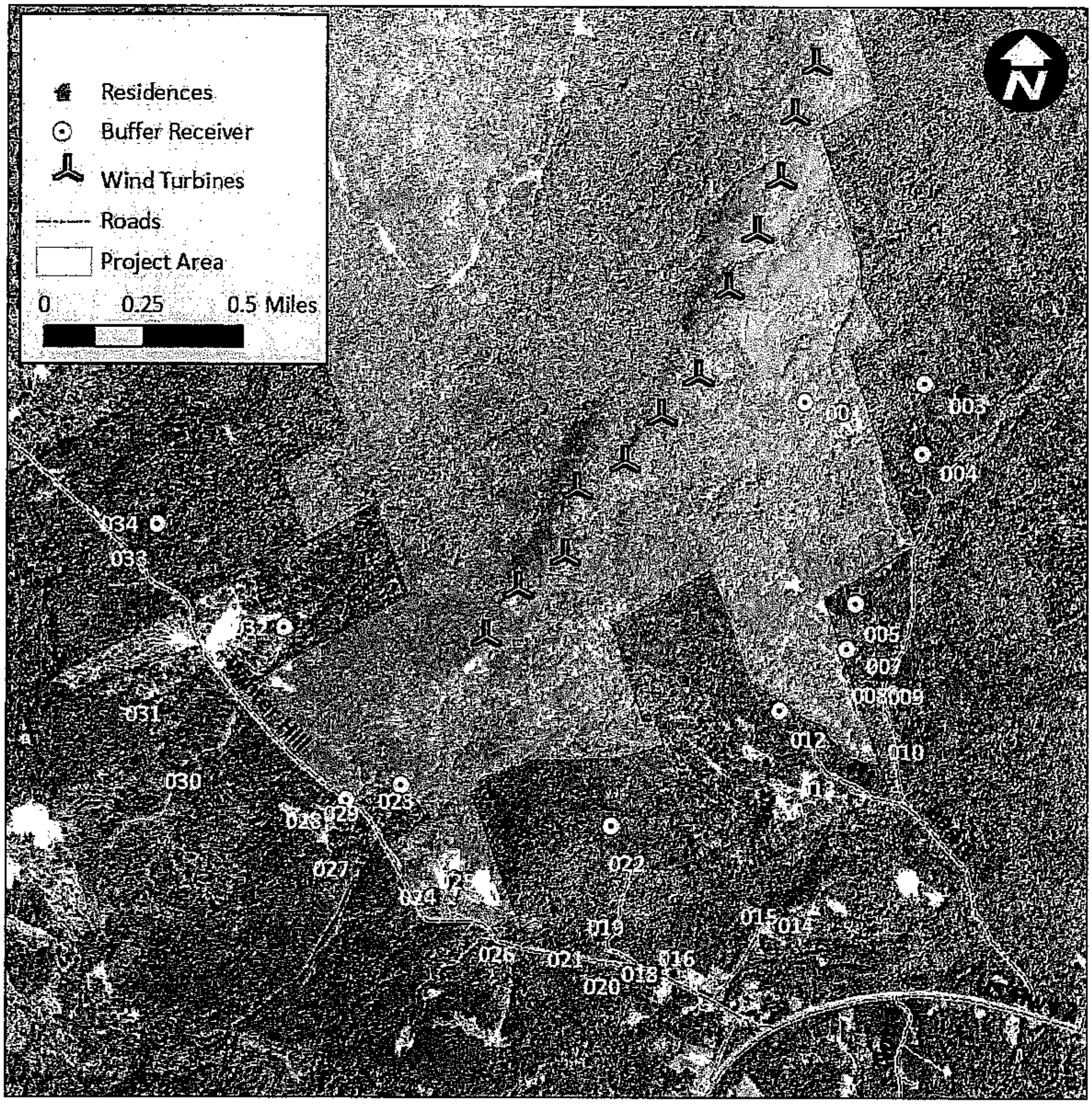
Receiver ID	Description*	Relative Height (m)	Coordinates (UTM NAD 83 Z19)		Elevation (m)	Modeled Sound Level (dBA)**	Closest Turbine	Distance to Closest Turbine (m)***	Distance to Closest Turbine (ft)***
			X (m)	Y (m)					
025	Participating	4	390372	4938626	373	41	T01	1023	3355
026	Non-Participating	4	390540	4938330	358	37	T01	1308	4290
027	Non-Participating	4	389870	4938675	304	40	T01	1166	3824
028	Non-Participating	4	389816	4938869	304	41	T01	1053	3454
029	Non-Participating	4	389908	4938895	300	41	T01	979	3211
B 029	Non-Participating Buffer	1.5	389933	4938951	297	42	T01	925	3034
030	Non-Participating	4	389259	4939023	256	39	T01	1413	4635
031	Non-Participating	4	389097	4939299	243	39	T01	1478	4848
032	Non-Participating	4	389532	4939645	269	42 [41]	T01	1028	3372
B 032	Non-Participating Buffer	1.5	389676	4939640	290	41	T01	887	2909
033	Non-Participating	4	389037	4939922	232	39	T01	1541	5054
034	Non-Participating	4	389000	4940058	234	39	T01	1608	5274
B 034	Non-Participating Buffer	1.5	389156	4940058	252	40	T01	1460	4789

* "Participating" and "Non-participating" denotes a residence location; "Buffer" is the highest level with a 500-foot buffer or the property line, whichever is closer. Buffers are shown for the closest residences to the project. Where the residences are clustered, only the closest buffer to the project is shown.

** Modeled sound levels are shown for normal and NRO modes. If the normal and NRO mode results are different, then the results for the normal operating mode is shown first with the NRO results in brackets.

*** Distances are from the receiver to the turbine nacelle and take into account elevation.

Figure A1: Receiver Locations



**Receivers 002 and 003 are in close proximity to each other and are indistinguishable from each other on this map.

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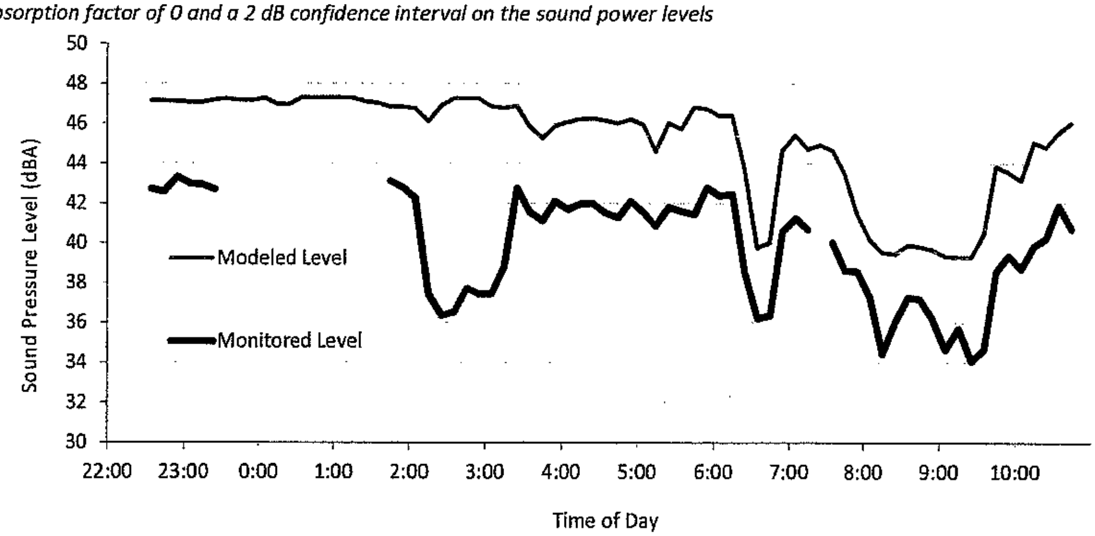
APPENDIX B: DISCUSSION OF MODELING PARAMETERS

1.1 Model Calibration

In several applications for wind projects in Maine, modeling included a ground absorption factor of 0.5 with 5 dB added to the result to account for uncertainties. The modeling in this case uses a different, but similarly conservative approach. We used a ground factor of 0 with a +2 dB correction. A ground factor of 0 represents hard non-porous ground, like pavement, over the entire modeling area. This results in a ground attenuation factor (Agr) of -3 to -4 dB, meaning, in this case, that 3 to 4 dB is added to the overall sound level, depending on frequency, source and receiver height, and propagation distance to account for ground absorption, or in this case, reflection.

We calibrated this model on actual data from an operating wind farm and published our results.[1] The chart below shows the monitored sound levels at 2,000 feet from the closest turbine and the modeled sound levels using the same parameters used in the Saddleback project. On average, the modeled level is 4.8 dB higher than the monitored level. This shows that the model methodology we are using to estimate sound levels for this wind farm has a conservative bias, which means the noise levels will have been overestimated in comparison to actual levels, as demonstrated in Figure A2.

Figure A2: Monitored vs modeled sound levels for a receiver 2,000 feet downwind of a 67-turbine wind farm using a ground absorption factor of 0 and a 2 dB confidence interval on the sound power levels



1.2 Additional calibration using Stetson data

To investigate modeling parameters further, RSG performed an additional calibration study using monitoring data from Stetson Wind, New England's largest utility-scale wind farm, located along a ridgeline in Washington County, Maine. RSG modeled Stetson Wind using the same parameters as Saddleback Ridge: G=0, spectral ground attenuation, and a +2 dB adjustment on top of the results. We compared the results to a 2009 operations compliance sound level study conducted by Resource Systems Engineering[2]. Resource Systems Engineering collected continuous sound level data over the period of 19 to 21 May 2009 at four receiver locations near the south end of the turbine string. They also collected 10-meter wind speeds and wind turbine power output levels for the duration of the monitoring period.

[1] Kaliski, K. and Duncan, D., "Propagation Modeling Parameters for Wind Power Projects," Sound & Vibration Magazine, December 2008

[2] Resource Systems Engineering, "Operations Compliance Sound Level Study," July 27, 2009

As part of their study, Resource Systems Engineering analyzed the data to find periods during the night when 10-meter wind speeds were low (at or below 6 mph) and the turbines were operating at their maximum sound power level (at or above 900 kW of power output) to conform with the approved measurement protocol. This meteorological condition represents stable meteorology with full sound power from the turbines, the assumed worst-case scenario. For the selected time periods, they compiled their data to determine the sound pressure levels at each receiver.

We compared Resource Systems Engineering's monitoring results to our modeled sound levels using G=0 and a +2 dB correction for the as-built wind farm. The results are shown in Figure A2, and demonstrate that actual monitored sound levels are at least 3 dB below RSG's modeled levels. As winds were blowing from the west and southwest during the monitoring period, Receiver 4 was directly downwind of the turbine string and is therefore the best test site in the scenario. At this location, the monitored sound levels are 4 dB below RSG's modeled levels. As a result, this calibration clearly shows that the modeling parameters used for Saddleback Wind are conservative estimates of worst-case sound levels, regardless of topography.

1.3 Modeling using G=0.5 with 5 dB added

As mentioned above, the modeling for some other projects in Maine have used a ground factor 0.5 and then added 5 dB to the results. The Resource Systems Engineering post-construction study of the Stetson Wind project found that these parameters also show a conservative bias. That is, they result in an overestimate of actual levels.

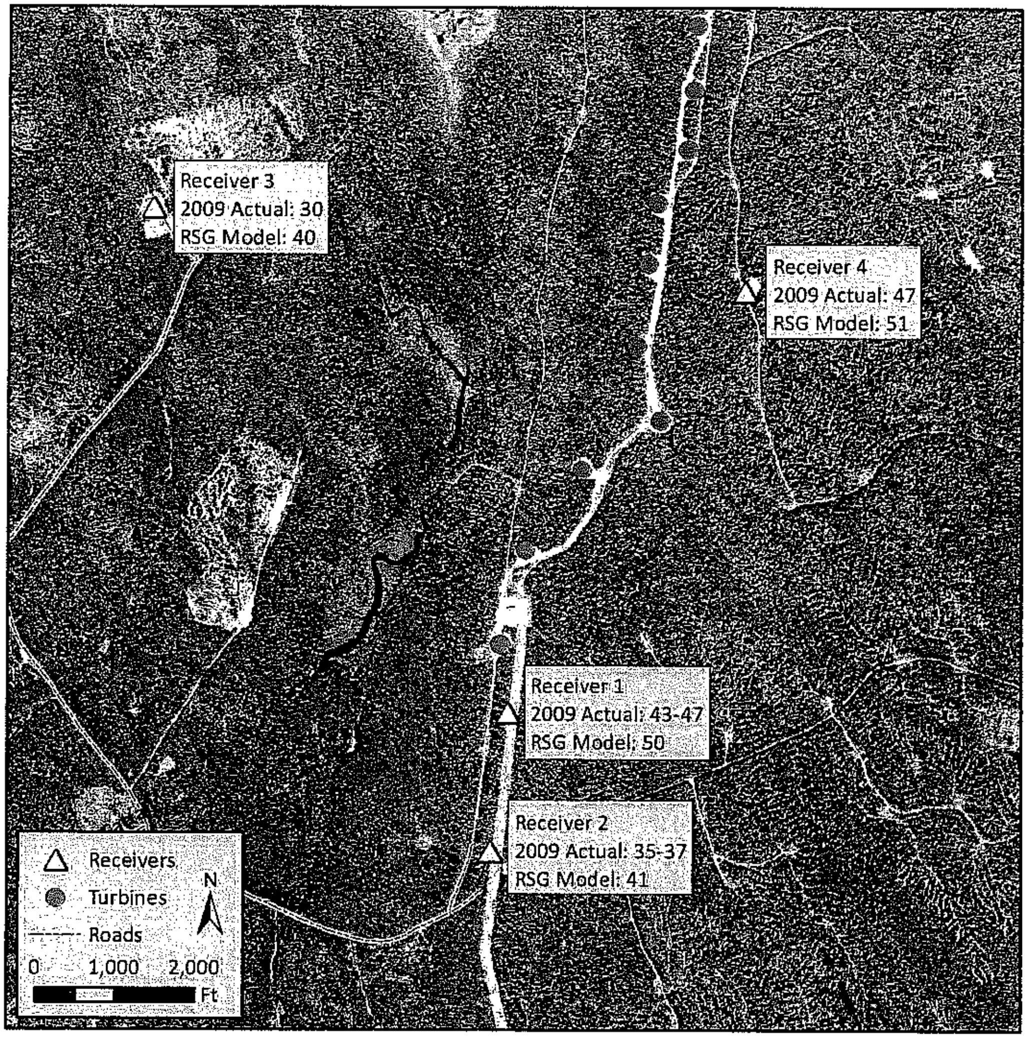
To allow a direct comparison of the modeled sound levels of Saddleback Ridge with other proejcts that use the modeling parameters noted above, we compared the modeling runs of the Saddleback Ridge project using:

A. A ground factor of G=0.5 with 5 dB added to the results, and
B. A ground factor of G=0 plus 2 dB added the the results, as used in this report.

No other changes were made to the model.

The outcome of the two methods are virtually identical. Assuming no NRO, the modeled sound level at the highest nighttime protected location is exactly the same with both methods. With an NRO of 1 and 2 dB on Turbines 8 and 9, respectively, the worst-case modeling results are 0.1 dB lower using Method A. Therefore, we come to identical conclusions and recommendations for the Saddleback Ridge project using Methods A and B.

Figure A3: Measured[3] and Modeled[4] Sound Pressure Levels (dBA) for Stetson Wind



[3] Measurements were as reported by Resource Systems Engineering, "Operations Compliance Sound Level Study," July 27, 2009

[4] RSG modeling using G=0 with 2 dB added to results