RSG INC.
ENVIRONMENT, ENERGY, & ACOUSTICS

Allegheny Ridge Wind Farm

Sound Monitoring Study

Prepared for:
Juniata Township

May 2009

DATA ■ ANALYSIS ■ Solutions

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1.0 INTRODUCTION

Allegheny Ridge Wind Farm is located in Blair and Cambria counties in Pennsylvania. Part of the wind farm lies in Juniata Township where some residents have complained about noise from the nearby wind turbines. Resource Systems Group, Inc. (RSG) has been retained by Juniata Township to objectively evaluate the sound levels from the wind farm and the complaints of the residents.

This report provides the results of the sound monitoring study. The study includes:

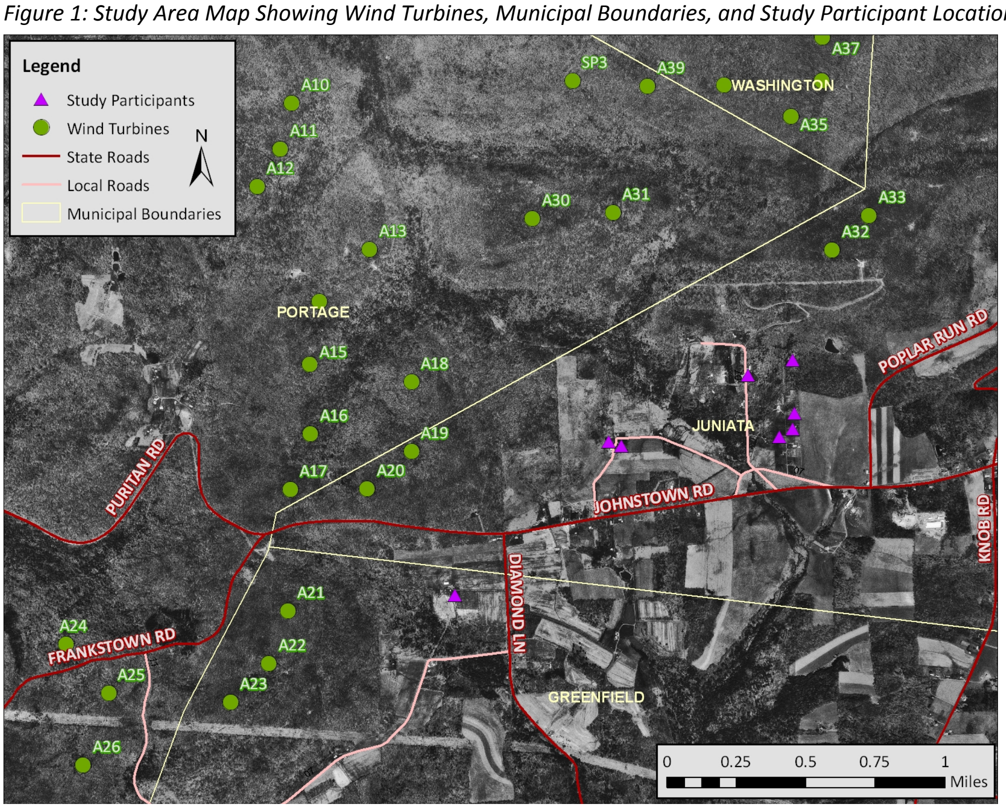
- A residence noise log which asked for information about noise timing, characterization, and weather.
- Two seven day periods of long-term sound level monitoring at a total of five residences.
- Short-term monitoring when study participants registered a complaint during the first long-term monitoring period.

2.0 STUDY AREA

The study area is located on Johnstown Road (PA 164) near intersection of Juniata, Greenfield, and Portage Townships. Washington Township is also close by. The area is primarily rural with hilly to mountainous terrain and is mostly vegetated with deciduous and coniferous forest.

There are a total of 24 Gamesa 2-MW wind turbines within 1.5 miles of the study area and four of the turbines are located in Juniata Township. Not all of the turbines are in a line of site to all of the residences in the study area. Many of the site lines are shielded by the hilly terrain and forest. Figure 1provides an overview of the study area.

Figure 1: Study Area Map Showing Wind Turbines, Municipal Boundaries, and Study Participant Locations



3.0 NOISE STANDARD

The standard for this project is defined in the Development Agreement and Permit between Juniata Township and the Allegheny Ridge Wind Farm. The document states:

> *"Allegheny Wind shall make a good faith effort to maintain a noise level attributable to the wind turbine generators of not more than 45 dBA within a reasonable margin of error as measured at existing Non-Participating residences;"*

A limit of 45 dBA is consistent with World Health Organization (WHO) guidelines and standards often applied to similar wind power projects.

4.0 RESIDENCE NOISE LOG RESULTS

4.1 Noise Log Description

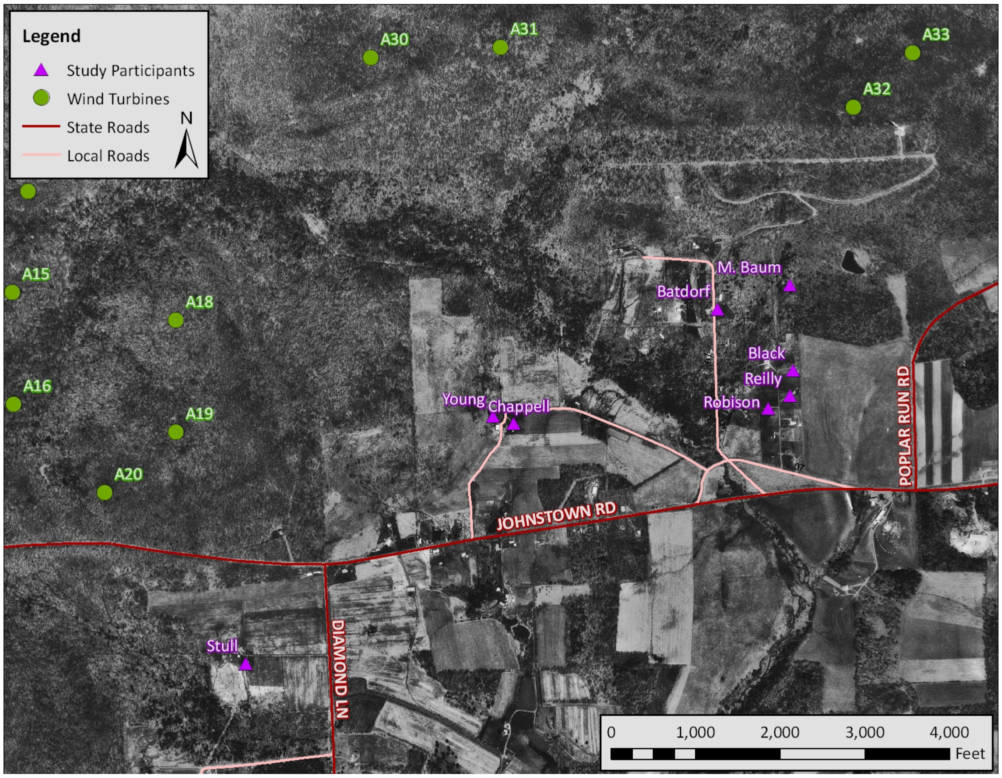
Residents were asked to participate in the study by completing noise logs for a period of time during the summer of 2008 and a short period of time in December 2008. The primary purpose of the logs was to determine what meteorological conditions resulted in high sound levels from the wind turbines. The log results also helped to qualitatively characterize the noise that residents were hearing.

Myrle and Brian Baum served as the residents' representative for the study. A total of 20 sets of paper logs with postage paid envelopes were sent to Brian for distribution. In addition, a website was made available to residents as an alternative to filling out the paper logs. A copy of the paper log is provided in Appendix A.

4.2 Summer Noise Log

Eight residences responded with at least one observation from June 5 to August 18, 2008. All but four observations were via the paper logs. The eight residences are shown in Figure 2.

Figure 2: Map of Noise Log Participants



The detailed results of the summer noise log were provided to Juniata Township, Myrle Baum, and Babcock and Brown in a memo on October 15, 2008. The results memo is provided in Appendix A. In total, there were 86 variables that were studied to determine what conditions resulted in what study participants rated as loud. The variables that were used came from the noise logs, airport met data, and turbine data.

The statistical analysis of the variables and loudness ratings resulted in conclusions that increasing wind speed, temperature, and humidity increased the odds of observing loud periods. Conversely, partly cloudy days were less likely than clear days to occur with loud periods.

4.3 Winter Noise Log

Winter noise logs were distributed in the same manner as the summer noise logs. The log sheets were the same except that residents were asked to complete the log every day from December 11 to December 31, 2008. Only four residences submitted winter logs: Reilly, M. Baum, Chappell, and Stull. Due to the small sample and the sporadic reporting for the winter noise logs no conclusions could be drawn from the data.

5.0 Long-Term Sound Level Monitoring

Long-term sound level monitoring was conducted over a period of seven days on two different occasions. Winter sound level monitoring was conducted from February 11 to February 18, 2009 and spring sound level monitoring was conducted from April 22 to April 29, 2009.

5.1 Equipment Description

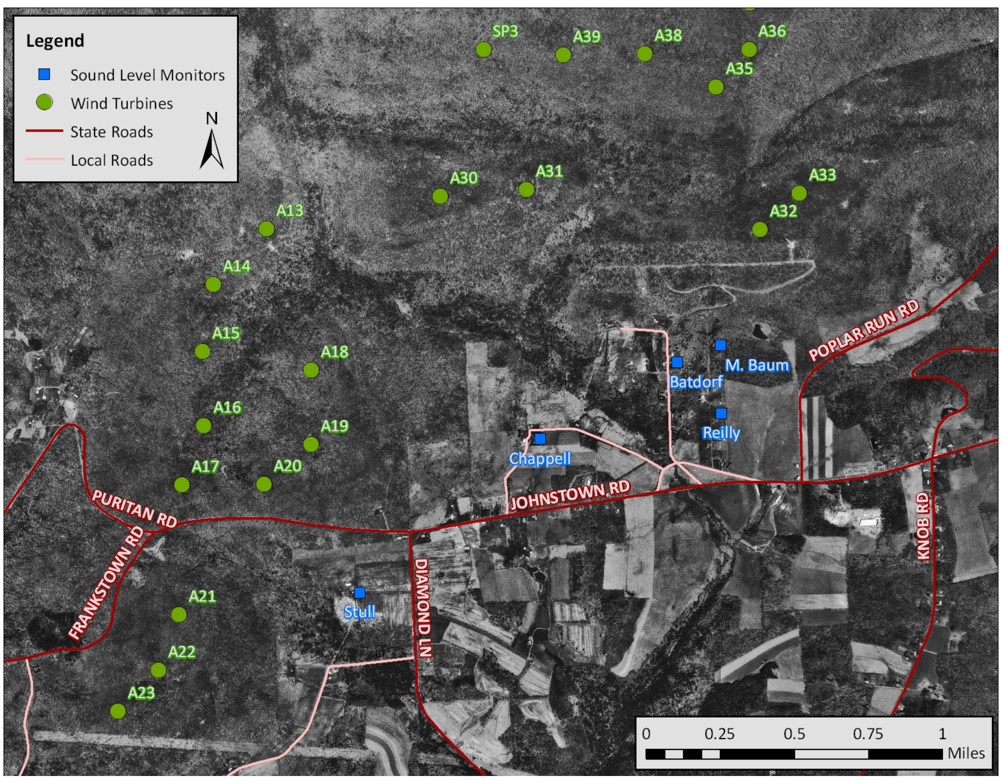
Two types of sound monitoring installations were used for long-term sound level monitoring. One type of setup was composed of a Type 2 Rion NL-22 sound level meter with built-in audio recording capability. Another type was composed of a Type 1 Cesva SC 310 sound level meter which was equipped with an external Edirol R-09 audio recorder. All sound level monitors were configured to log equivalent sound pressure levels and other statistical parameters (90^{th} percentile levels, 50^{th} percentile levels, etc) for every 10 minute period. A Bruel & Kjaer Model 4231 calibrator was used to calibrate all equipment to a 94 dB tone before and after monitoring.

All equipment was enclosed in a waterproof case. Microphones were covered with seven inch diameter water-resistant windscreens. All microphones were installed at approximately 1.2 meters above the ground surface.

5.2 Sound Monitoring Locations

Long term sound level monitoring stations were installed at five locations. The residences were chosen from the group that participated in the noise logs and were spread throughout the study area. An overview map of the five locations is shown in Figure 3. Each location is described in further detail below.

Figure 3: Map of Long-term Noise Monitor Locations



- Reilly: The Reilly monitor was located east of Dodson Drive at the Reilly residence. The monitoring station was setup north of the home with proper distances from buildings on the site to avoid reflections. The area around the Reilly monitor can be characterized as lawn and open field. For the winter monitoring period, a Rion sound level monitor with audio recording capability and a weather station were installed at the site. For the spring monitoring period a Cesva sound level monitor with an Edirol sound recorder and a weather station were installed at the site. This site is approximately 3,340 feet from the closest turbine (A32).

Figure 4: Picture of the Reilly Monitor Looking Southwest towards the House

- <u>M. Baum</u>: The M. Baum Monitor was located east of Dodson Drive at the Baum residence. The monitoring station was setup northeast of the home with proper distances from buildings on the site to avoid reflections. The area around the M.Baum monitor can be characterized as heavily wooded. For both the winter and spring monitoring periods, a Cesva sound level monitor and an Edirol sound recorder were installed at the site. This site is approximately 2,180 feet from the closest turbine (A32).

Figure 5: Picture of the M. Baum Monitor Looking Southwest towards the House

- <u>Batdorf</u>: The Batdorf Monitor was located east of Coppock Road at the Batdorf residence. The monitoring station was setup in the corner of the back yard northeast of the home with proper distances from buildings on the site to avoid reflections. The area around the Batdorf monitor can be characterized as an open lawn surrounded by heavily wooded areas. For the winter monitoring period, a Cesva sound level monitor and an Edirol sound recorder were installed at the site. For the spring monitoring period a Rion sound level monitor with audio recording capability was installed at the site. This site is approximately 2,775 feet from the closest turbine (A32).

Figure 6: Picture of the Batdorf Monitor Looking Southwest towards the House

- Chappell: The Chappell Monitor was located south of Chappell Road at the Chappell residence. The monitoring station was setup southeast of the home with proper distances from buildings on the site to avoid reflections. The area around the Chappell monitor can be characterized as an open lawn and fields with wooded hills rising to the west. For the winter monitoring period, a Rion sound level monitor with audio recording capability was installed at the site. For the spring monitoring periods, a Cesva sound level monitor and an Edirol sound recorder were installed at the site. This site is approximately 4,080 feet from the closest turbine (A19).

Figure 7: Picture of the Chappell Monitor Looking Northwest towards the House

- Stull: The Stull Monitor was located west of Diamond Lane at the Stull residence. The monitoring station was setup north of the home with proper distances from buildings on the site to avoid reflections. The area around the Stull monitor can be characterized as an open lawn and fields with wooded hills rising to the west and north. There are also several farm structures on site. For the winter monitoring period, a Cesva sound level monitor with an Edirol sound recorder, and a weather station were installed at the site. For the spring monitoring period, a Rion sound level monitor with audio recording capability and a weather station were installed at the site. This site is approximately 2,575 feet from the closest turbine (A20).

Figure 8: View from the Stull Monitor Looking North towards Turbine A20

5.3 Weather Conditions

Weather stations were set up at two of the sound monitoring locations (Reilly and Stull) for both the winter and spring monitoring periods. For the winter monitoring period the weather stations were set up on February 12, 2009, and for the spring monitoring period the weather stations were set up on April 22, 2009. The Reilly station logged wind speed, wind direction, temperature and relative humidity data every 10 minutes. The Stull station logged wind speed data every 10 minutes.

The anemometers were installed at approximately the same height as the sound monitor microphones (1.2 meters), but were on separate stakes and located 20 to 100 feet from the sound monitors. The temperature and relative humidity sensors at the Reilly stations were installed directly below the anemometer at approximately 0.8 meters.

5.3.1 Weather during the Winter Monitoring Period

During the winter monitoring period, the wind at the Reilly station was considerably greater than the Stull station by typically 2 to 7 mph. This is likely due to the fact that winds were primarily out of the west, and the Stull property is somewhat guarded at ground level from the hills directly to the west of the house. The Reilly property is much more open to the west.

The average wind speed and wind gust speed for the Reilly station in 10 minute intervals are provided in Figure 9. The same data is provided for the Stull station in Figure 10. Temperature and relative humidity data from the Reilly station are provided in Figure 11.

Figure 9: Average Wind Speed and Gust Speed (10-min, mph) at the Reilly Station for the Winter Monitoring Period

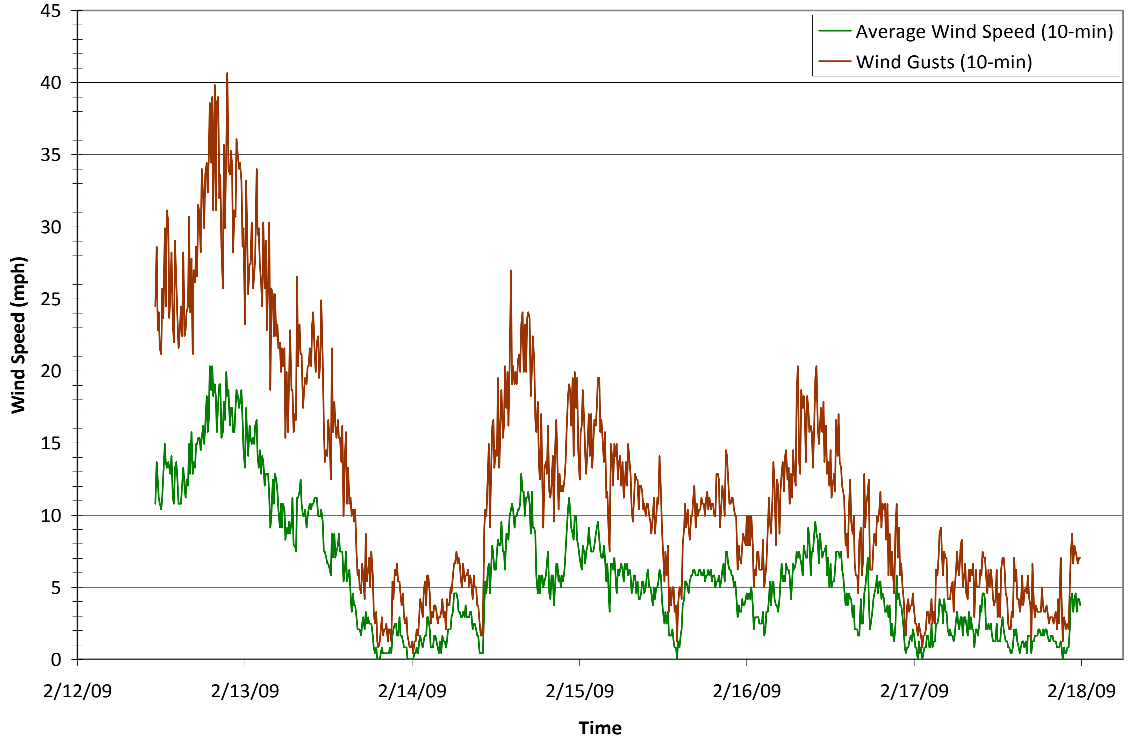


Figure 10: Average Wind Speed and Gust Speed (10-min, mph) at the Stull Station for the Winter Monitoring Period

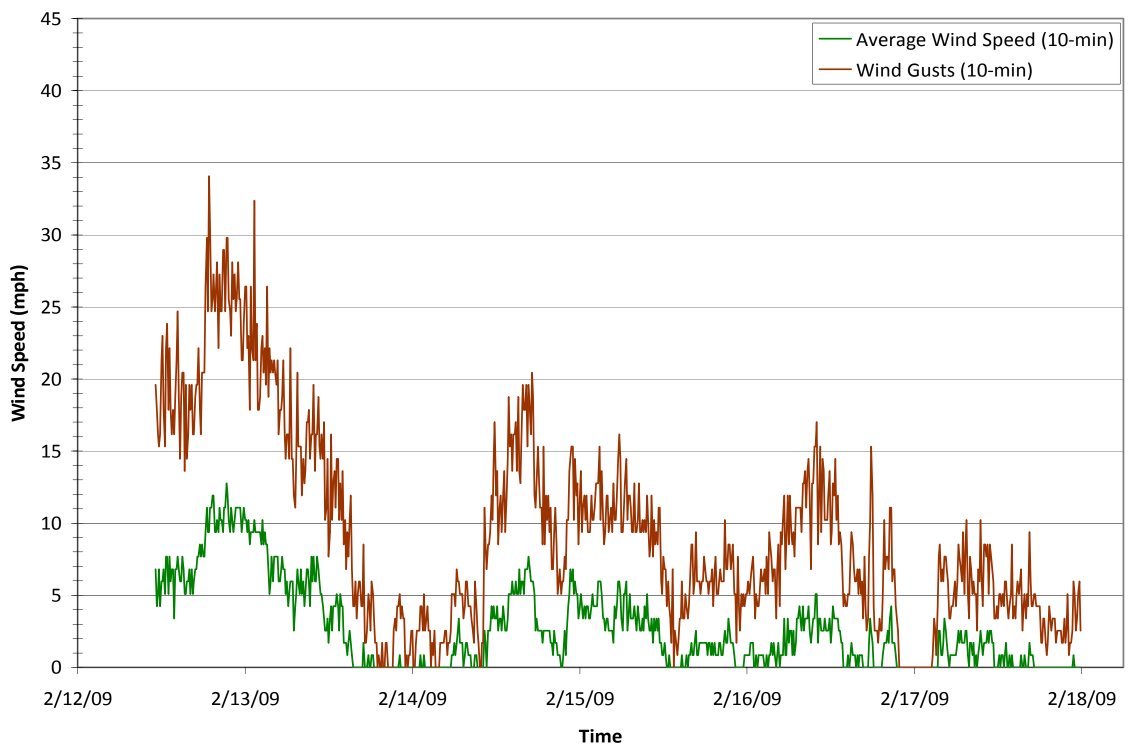
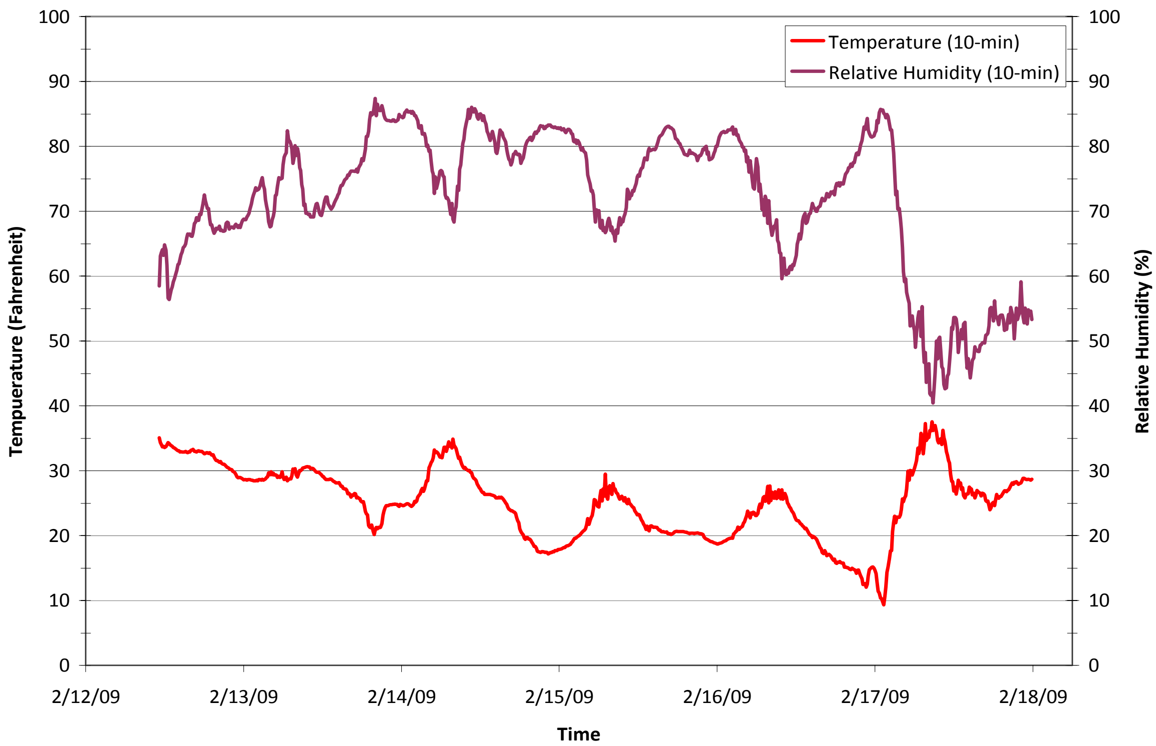


Figure 11: Temperature and Relative Humidity (10-min, ˚F, %) at the Reilly Station for the Winter Monitoring Period



While it was in the 50's on February 11 when the sound monitors were installed, temperatures were generally between 17 and 38˚F most of the monitoring period. Temperatures did drop below 14˚F for a short period over the night of February 16. Sound levels monitored during periods below 14˚F should be disregarded as it is outside the limit of our equipment specifications.

Winds were above five meters per second (approximately 11 mph) from midday on February 12th to the early morning on February 13th. Sound levels monitored above this wind speed should be disregarded as it exceeds the limit specified in ANSI S12.18.

The cloud coverage much of the week was generally overcast with some short periods of sun and some light intermittent snow flurries. In general, the weather was adequate for sound monitoring except for times noted above when there were high wind or low temperature limitations.

5.3.2 Weather during the Spring Monitoring Period

During the spring monitoring period, low temperatures and high winds were not an issue with sound monitoring. Winds were out of the west and generally ranged from 0 to 10 mph with some gusts that were significantly higher. Unfortunately the weather data that was collected is limited. The Reilly station ran for one and a half days before losing power, and while the Stull station was set up, there was no data on the data logger.

The average wind speed and wind gust speed for the Reilly station in 10 minute intervals are provided in Figure 12. Temperature and relative humidity data are provided in Figure 13.

Figure 12: Average Wind Speed and Gust Speed (10-min, mph) at the Reilly Station for the Spring Monitoring Period

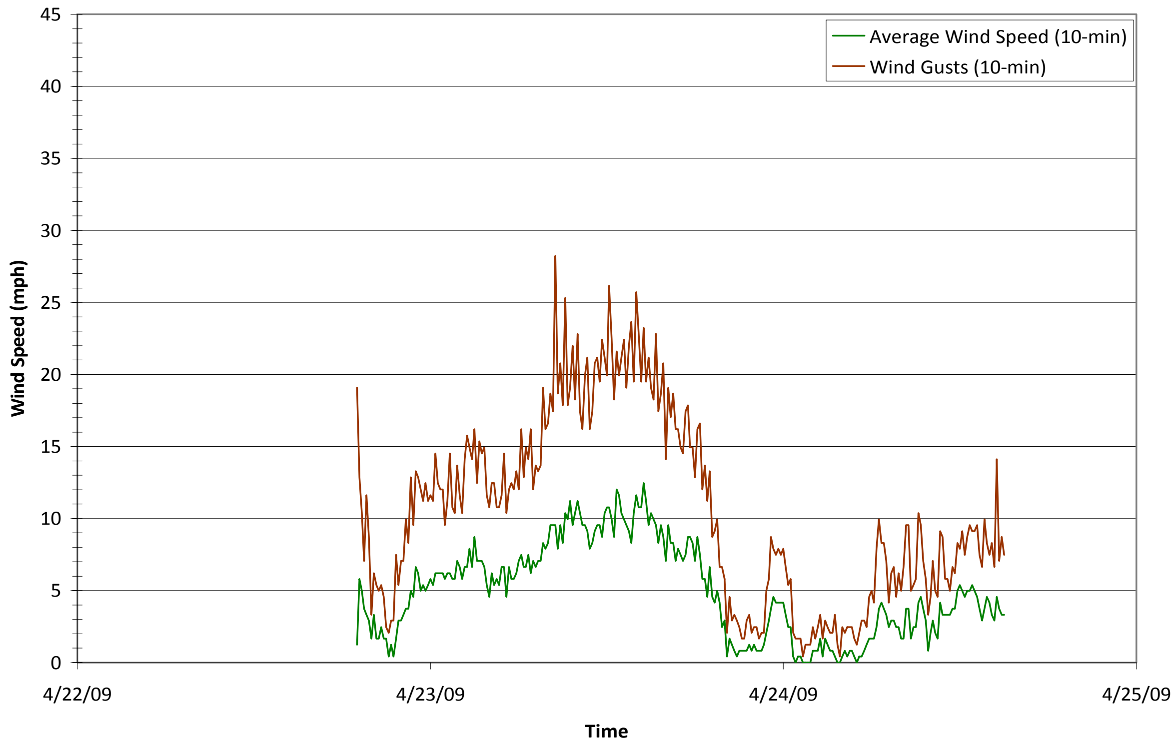
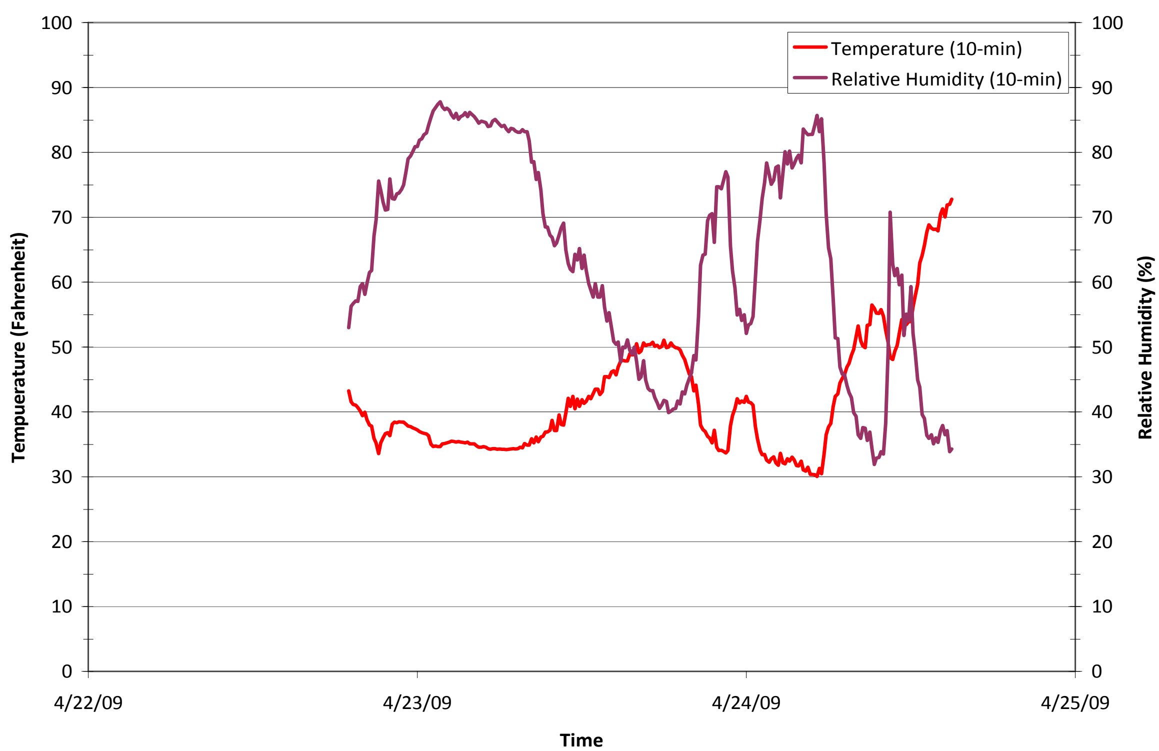


Figure 13: Temperature and Relative Humidity (10-min, ˚F, %) at the Reilly Station for the Spring Monitoring Period



5.4 Sound Level Monitoring Results

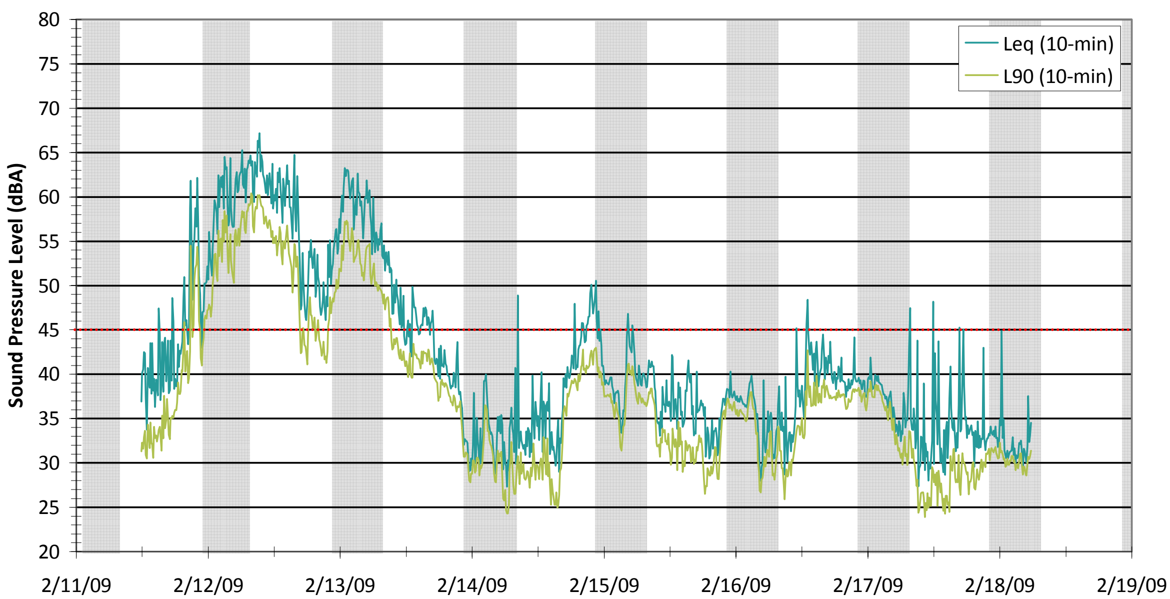
Sound level monitoring results are provided in Figures 14 through 23. For each monitor, the winter results are provided in the first figure and the spring results are provided in the second figure. Each figure shows the 10-minute L90 and Leq. The charts are shaded to show daytime and nighttime periods.

Since wind turbines are a relatively constant source of sound when compared to time varying sounds of birds, vehicle traffic, and wind gusts, turbine sound is essentially the remaining or residual sound after these short-term events are removed. The L90 provides good representation of this residual level as it is the level exceeded 90 percent of the time, while the Leq tends to weight the louder and more infrequent events. Therefore, the analysis for this study focuses on the L90 results to assess turbine sound impacts.

5.4.1 Reilly Monitor

For the winter monitoring period, sound pressure levels at the Reilly Monitor over the course of the week ranged from 24 dBA when there were no winds and the closest turbines were not operating, to approximately 60 dBA when there were high winds on February 12th. Nearly all of the sound levels on February 12th should be disregarded because of accuracy issues due to wind-induced noise over the microphone windscreen. When winds were below five meters per second[1] at the microphone, ninetieth percentile sound levels did not exceeded 45 dBA once during the monitoring period. This is shown in Figure 14 with most of the green L90 line below the red 45 dBA limit line.

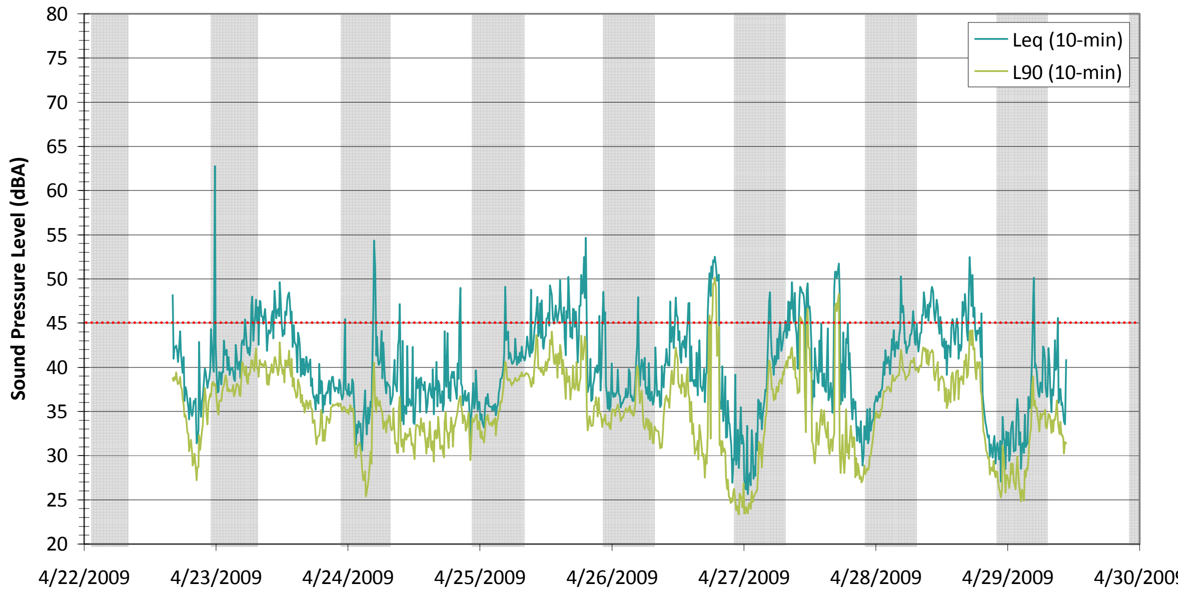
Figure 14: Winter Monitoring Results at the Reilly Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



For the spring monitoring period, sound pressure levels ranged from 23 dBA to 50 dBA. Only on three occasions did the ninetieth percentile sound levels exceed 45 dBA and review of the audio recordings indicates that all three occasions were due to a lawn mower and other unidentifiable mechanical noises. The spring monitoring results are provided in Figure 15.

[1] ANSI S12.18, "Procedures for Outdoor Measurement of Sound Pressure Level," states that "no sound level measurement shall be made when the average wind velocity exceeds 5 m/s" when measured at a height of 1.8 to 2.2 meters above the ground.

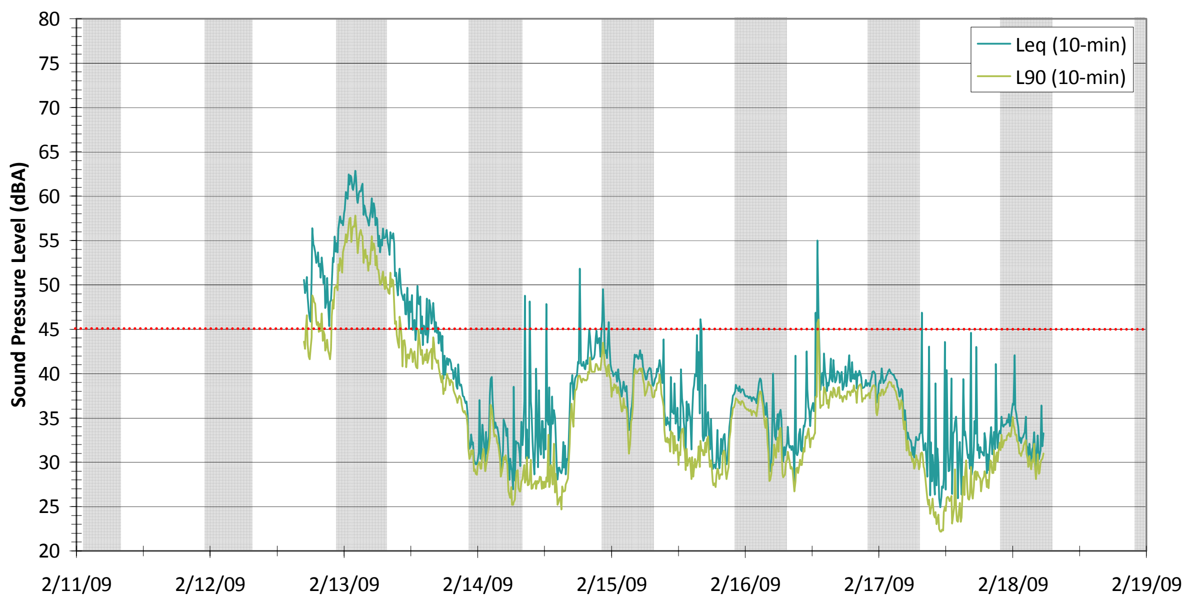
Figure 15: Spring Monitoring Results at the Reilly Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



5.4.2 M. Baum Monitor

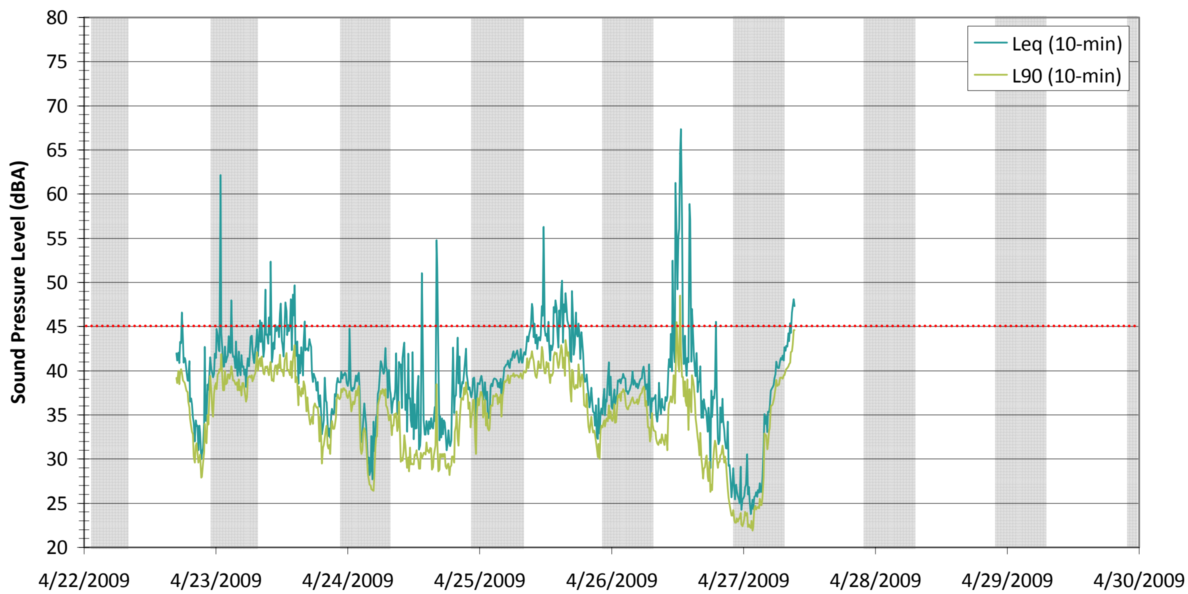
For the winter monitoring period, sound pressure levels at the M. Baum Monitor ranged from 22 dBA when there were only light winds and the closest turbines were not operating, to 58 dBA when there were high winds at ground level which causes wind-induced noise over the microphone windscreen. When winds were below five meters per second at the microphone, ninetieth percentile sound levels exceeded 45 dBA 0.3% of the monitoring time. This is shown in Figure 16 with most of the green L90 line below the red 45 dBA limit line.

Figure 16: Winter Monitoring Results at the M. Baum Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



During the spring monitoring period, the M. Baum Monitor had a power failure four and a half days into the monitoring period. During those four and a half days, sound pressure levels ranged from 22 dBA to 49 dBA. There was one occasion at which the ninetieth percentile sound levels exceeded 45 dBA. Audio recordings confirmed that this one occasion was due to lawn mower noise. The spring monitoring results are provided in Figure 17. Mr. Baum described the noise as especially bad over the first few days of the spring monitoring period. This description may explain why the nighttime levels on April 23, 24, 25, and 26 are notably higher than that on the night of April 27. Despite being higher, sound levels are still below 45 dBA.

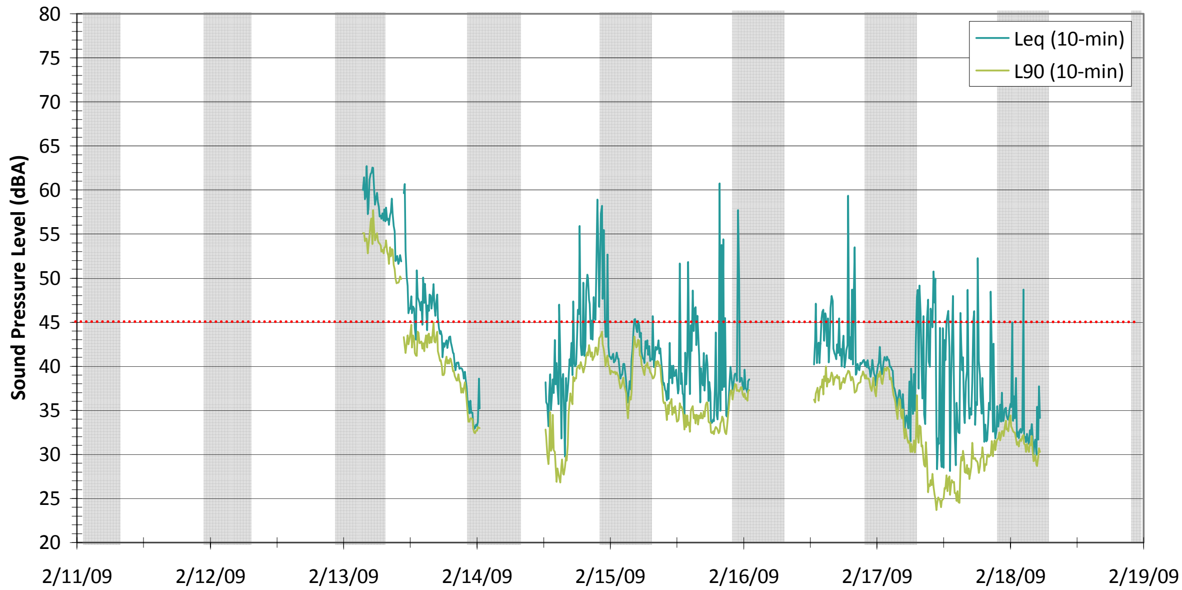
Figure 17: Spring Monitoring Results at the M. Baum Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



5.4.3 Batdorf Monitor

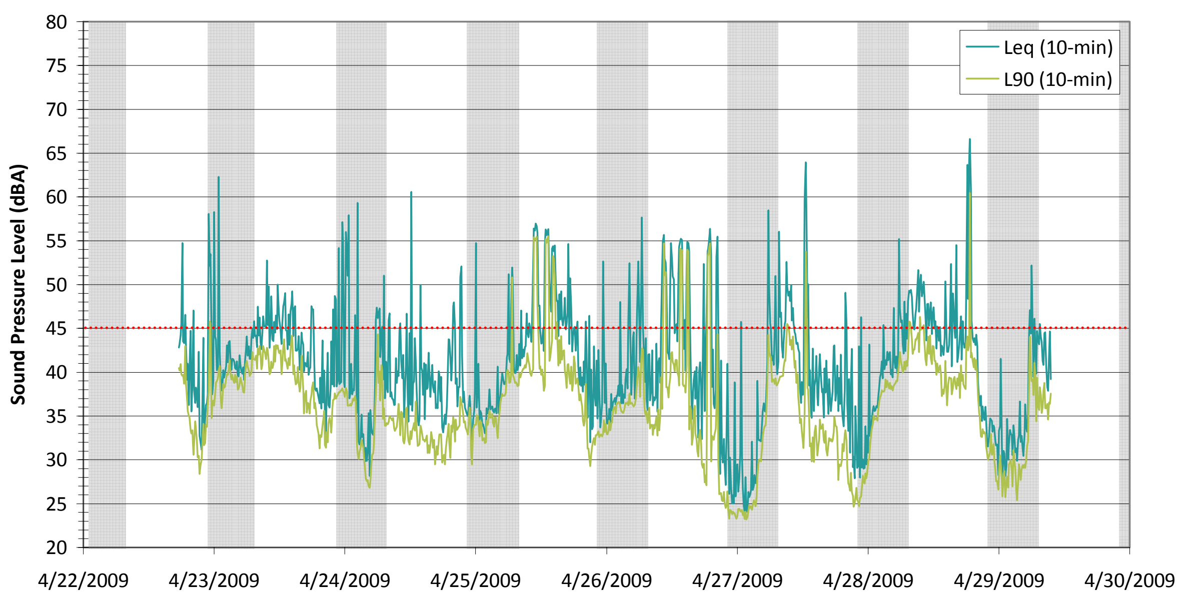
For the winter monitoring period sound pressure levels at the Batdorf Monitor ranged from 24 dBA when there were only light winds and the closest turbines were not operating, to 58 dBA when there were high winds at ground level which causes wind-induced noise over the microphone windscreen. When winds were below five meters per second at the microphone, ninetieth percentile sound levels exceeded 45 dBA 0.5% of the monitoring time. This is shown in Figure 18 with most of the green L90 line below the red 45 dBA limit line.

Figure 18: Winter Monitoring Results at the Batdorf Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



For the spring monitoring period, sound pressure levels ranged from 23 dBA to 60 dBA. There were 13 occasions in which the ninetieth percentile sound levels exceeded 45 dBA. Audio recordings confirmed that all of these occasions were due to lawn mower noise, engine noise, and dogs barking. The spring monitoring results are provided in Figure 19.

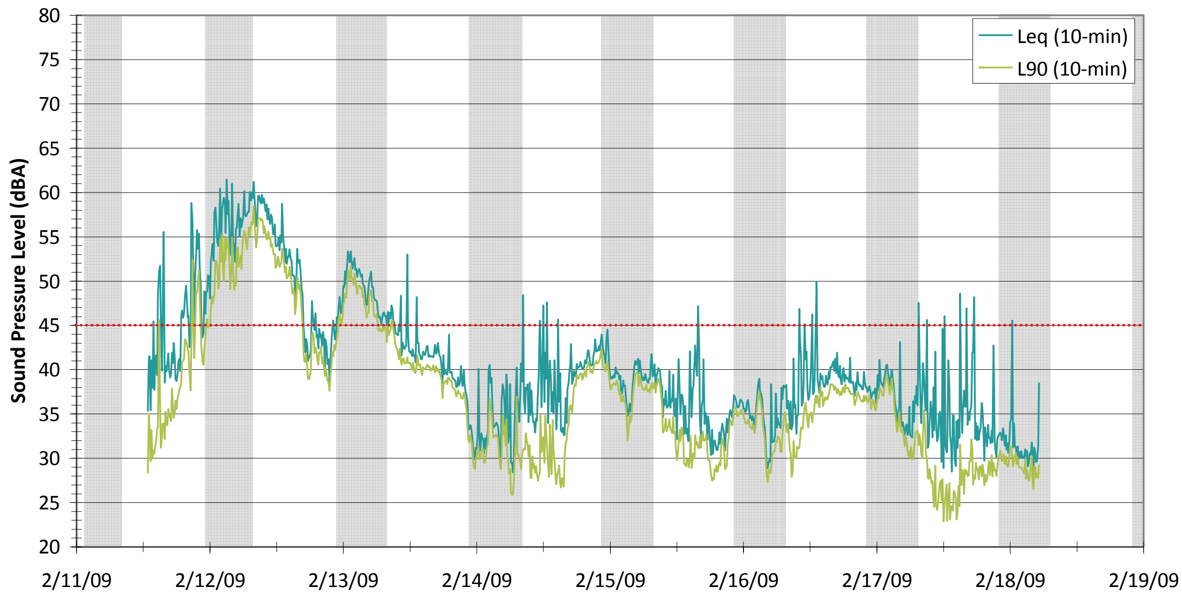
Figure 19: Spring Monitoring Results at the Batdorf Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



5.4.4 Chappell Monitor

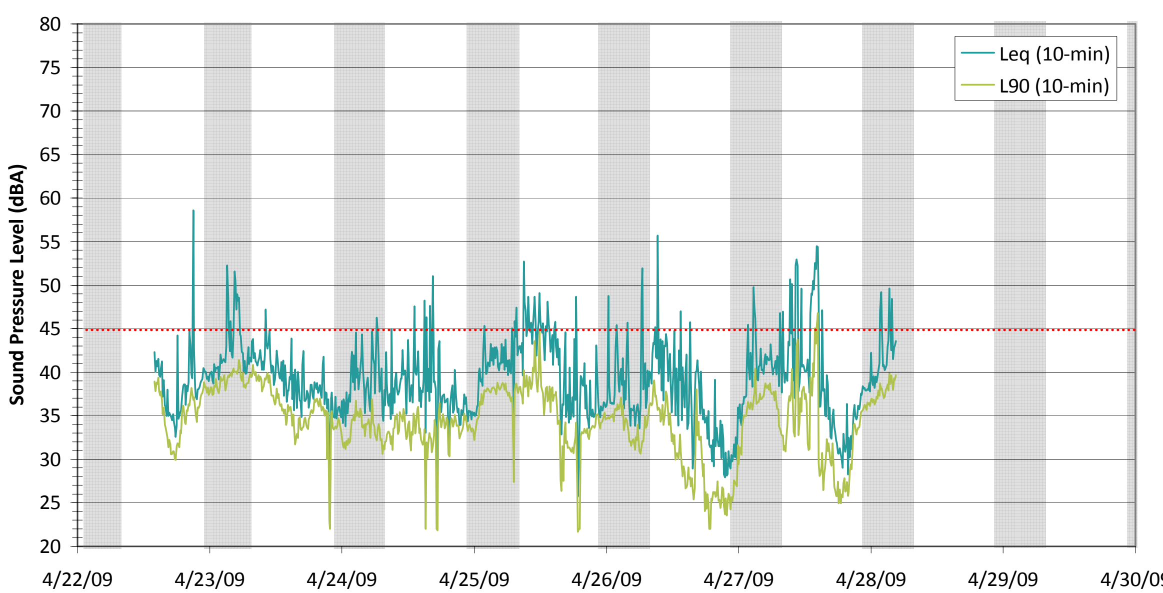
For the winter monitoring period sound pressure levels at the Chappell Monitor ranged from 23 dBA when there were only light winds and the closest turbines were not operating, to 58 dBA when there were high winds at ground level which causes wind-induced noise over the microphone windscreen. When winds were below five meters per second at the microphone, ninetieth percentile sound levels did not exceeded 45 dBA once during the monitoring period. This is shown in Figure 20 with most of the green L90 line below the red 45 dBA limit line.

Figure 20: Winter Monitoring Results at the Chappell Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



For the spring monitoring period, sound pressure levels ranged from 22 dBA to 47 dBA. There was one occasion in which the ninetieth percentile sound levels exceeded 45 dBA. Audio recordings confirmed that this occurrence was due to noise from farm equipment. The spring monitoring results are provided in Figure 21.

Figure 21: Spring Monitoring Results at the Chappell Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



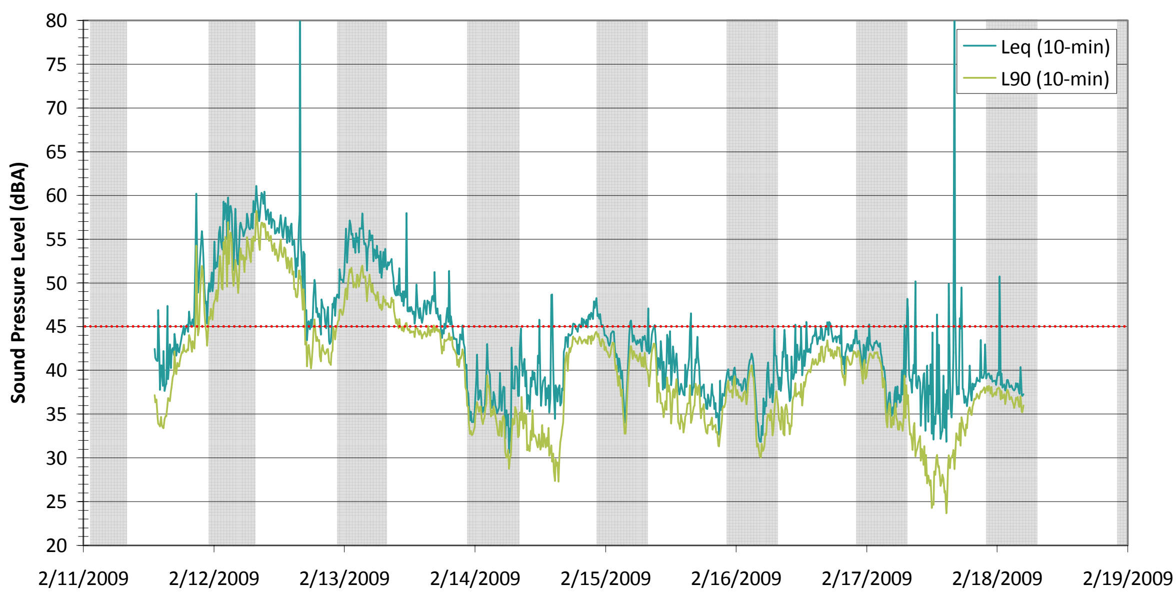
5.4.5 Stull Monitor

For the winter monitoring period, sound pressure levels at the Stull Monitor ranged from 24 dBA when there were only light winds and the closest turbines were not operating, to 58 dBA when there were high winds at ground level which caused wind-induced noise over the microphone windscreen. When winds were below five meters per second at the microphone, ninetieth percentile sound levels exceeded 45 dBA 7.9% of the monitoring time.

Most of the cases within the 7.9% occur between 10:50 PM on February 12 and 9:30 AM on February 13. While the 10 minute average wind speed during this time was typically below 5 meters per second, wind gusts were significantly higher between 8 and 14 meters per second. A review of audio files recorded during this time period indicates that much of the noise comes from wind-induced foliage noise. As described further in the short-term monitoring summary, when winds are moderately high like they were from February 11 to the 13, much of the higher noise levels (levels exceeding 45 dBA) at the Stull residence are due to the wind blowing in the trees on the property and on the ridges that rise up to the north and west of the property. In addition, only some of the turbines were operating from 10:50 PM on February 12 to 9:30 AM on February 13. An analysis of the five nearest wind turbines during this time period indicated that Turbine 17 operated 0% of the time, Turbine 19 operated 43% of the time, Turbine 20 operated 100% of the time, Turbine 21 operated 100% of the time, and Turbine 22 operated 16% of the time.

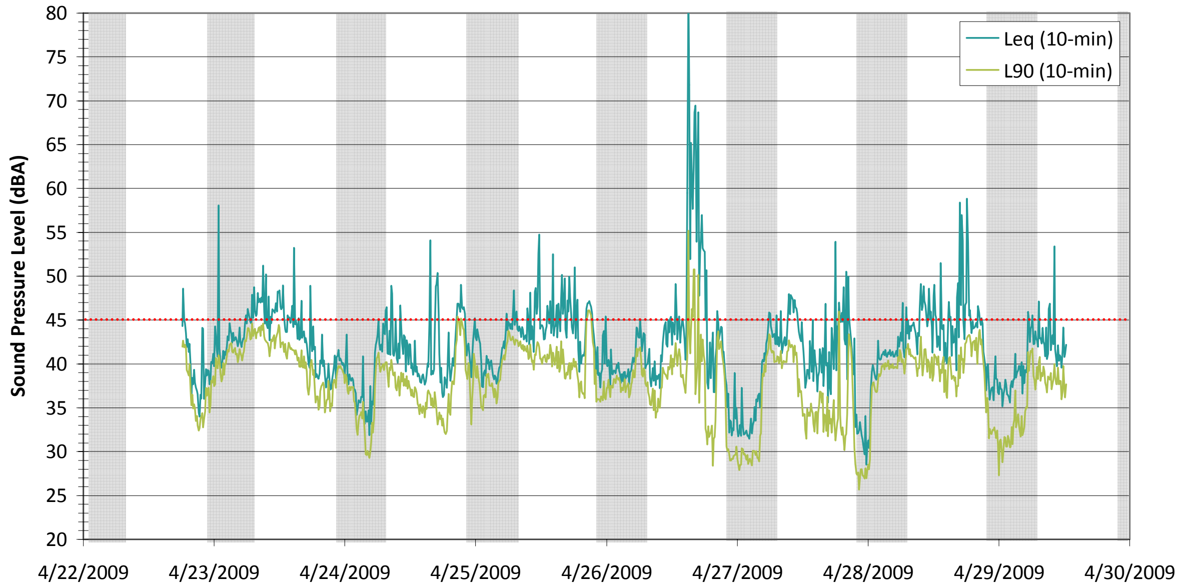
The winter monitoring results for the Stull Monitor are provided in Figure 22.

Figure 22: Winter Monitoring Results at the Stull Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



For the spring monitoring period, sound pressure levels at the Stull monitor ranged from 26 to 55 dBA. There were 3 occasions in which the ninetieth percentile sound levels exceeded 45 dBA. Audio recordings confirmed that this all of these occasions were due to insect noise, lawn mower noise, and engine. The spring monitoring results are provided in Figure 23.

Figure 23: Spring Monitoring Results at the Stull Monitor - Ten Minute Leq and L90 with a 45 dBA Limit Line



6.0 Short-Term Sound Level Monitoring

During the winter monitoring period, each resident that had a monitor placed on the property was instructed to phone a designated RSG representative who was in the area and "on-call" during the entire monitoring period if they perceived noise from the wind turbines to be especially loud. The purpose of the on-call visits was to take sound level measurements, make observations, and if sound levels merited, have the turbines temporarily shut down to take background sound level measurements.

At each on-call visit, sound level monitoring was conducted for approximately 10 minutes. Observations were made for some time prior to, during, and after monitoring. The sound level meter used during each visit was a Type I Cesva SC310 with a seven inch diameter water resistant windscreen over the microphone. The microphone was placed at approximately five feet above the ground at each location. Audio recordings (available upon request) were also taken using an Edirol R4 digital recorder which received a signal through the sound level meter audio jack. The sound level meter was calibrated to a 94 dB tone before and after each measurement.

A total of four on-call visits were requested and made. The time and location of the visits were:

- the Stull residence on February 11 at 10:10 PM
- the M. Baum residence on February 13 at 8:30 PM
- the M. Baum residence on February 14 at 7:10 PM
- the Reilly residence on February 16 at 9:05 PM

6.1 First On-Call Visit, February 11 at the Stull Residence

The first on-call visit was to the Stull residence on February 11 at approximately 10:10 PM. Mrs. Stull called the RSG representative to let him know that Mr. Stull said that the turbines were very loud at their home. Mrs. Stull was not home at the time, and Mr. Stull had just left the house.

During the monitoring period winds were from the west at 4 to 12 miles per hour with gusts as high as 20 miles per hour at the microphone. The temperature was approximately 50˚F. The monitoring results for the first on-call visit are provided in Figure 24.

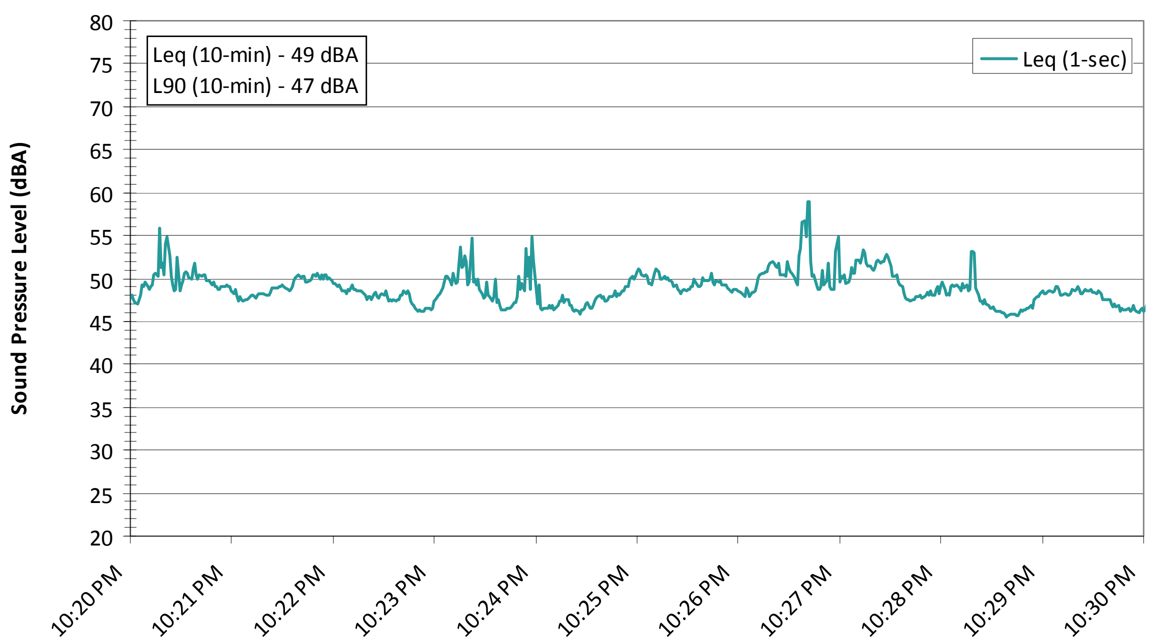
During the first on-call visit, one-second equivalent sound pressure levels generally ranged between 46 and 48 dBA, When the winds were higher, the one-second equivalent sound pressure levels ranged between 48 and 52 dBA. The ninetieth percentile sound level over the ten minute period was 47 dBA. Since this level exceeds 45 dBA, a turbine shutdown may have been merited, but the turbine shutdown protocol was not put into place by the wind farm operator until February 12.

The following observations were made during the visit:

- Most of the visible turbines were operating
- With the winds so high, much of the noise sound seemed to be coming from wind through the tall evergreens on the Stull property.
- A constant low frequency noise was heard from the ridge to the north across PA Rte. 164 from areas of the ridge where turbines are located and areas of the ridge where turbines are not located. It sounded as though this was being generated by the wind blowing through the forest on the ridge which had deciduous trees with no leaves and some evergreen foliage.
- A siren was heard off in the distance.
- When the winds were lower and sound levels were between 44 and 45 dBA, the low frequency noise from the ridge ceased, and a swooshing sound was heard from the wind turbines.
- Some noise was produced by the flag waving on the flagpole at the Stull property.

It should be noted that a voluntary site visit was conducted the following morning on February 12 when none of the wind turbines were in operation due to high winds. During the voluntary visit to the Stull residence, the same constant low frequency noise was heard as the night before, and it seemed to be generated by wind blowing through the forest on the ridges surrounding the property to the north and west.

Figure 24: Monitoring Results from the First On-Call Visit at the Stull Residence on February 11, 2009



6.2 Second On-Call Visit, February 13 at the Baum Residence

The second on-call visit was to the M. Baum residence on February 13 at approximately 8:30 PM. Mr. Baum called the RSG representative to let him know the turbines were loud.

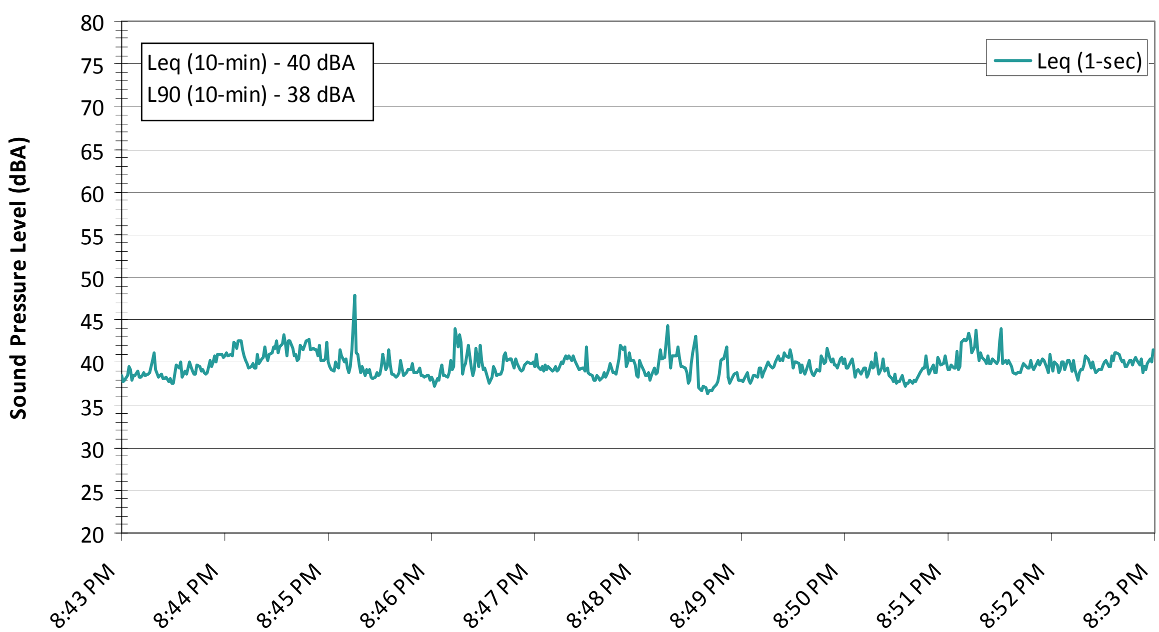
During the monitoring period winds were from the west, but there was little to no wind at the microphone. The temperature was approximately 42˚F. The monitoring results for the second on-call visit are provided in Figure 25.

During the second on-call visit, one-second equivalent sound pressure levels were generally around 39 dBA with some higher levels around 42 dBA. The ninetieth percentile sound level over the ten minute period was 38 dBA.

The following observations were made during the visit:

- Swooshing noise from the wind turbines was certainly audible.
- It sounded as though most of the turbine generated noise was coming from the direction of turbine A31.
- When a distinguishable noise came from the direction of turbine A32, it sounded more fluttery and high frequency in tone than a typical swooshing sound.

Figure 25: Monitoring Results from the Second On-Call Visit at the M. Baum Residence on February 13, 2009



6.3 Third On-Call Visit, February 14 at the Baum Residence

The third on-call visit was to the M. Baum residence on February 14 at approximately 7:10 PM. Mr. Baum called the RSG representative to let him know the turbines were loud.

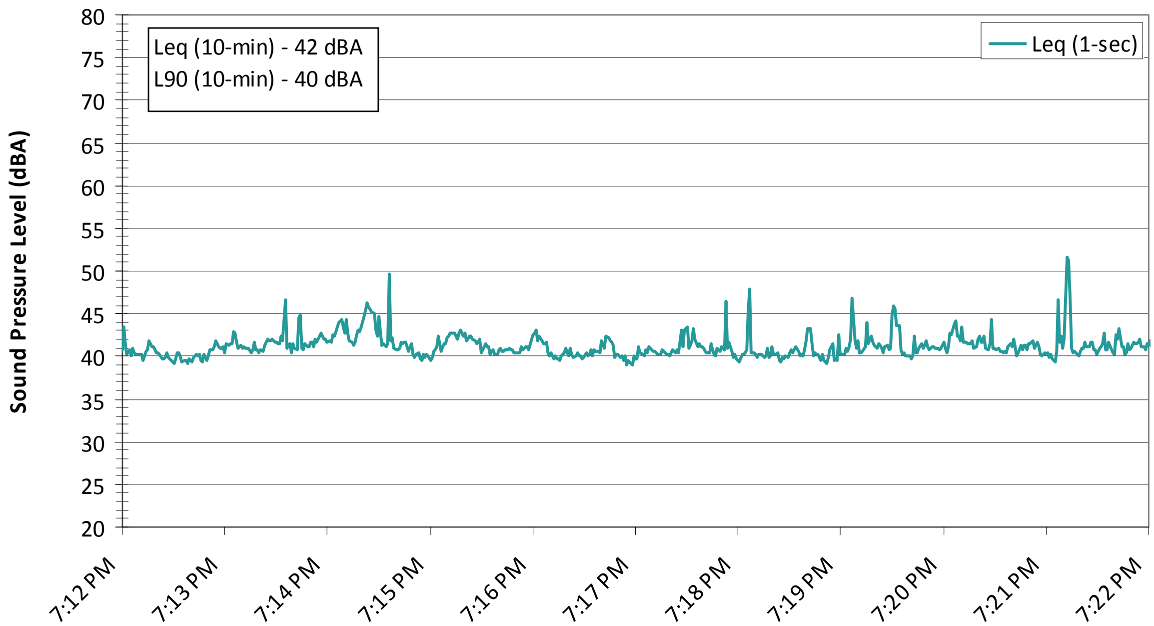
During the monitoring period winds were between 0 and 1 mile per hour at the microphone and the direction was indiscernible. The temperature was approximately 28˚F and there was light fresh snow on the ground. The monitoring results for the third on-call visit are provided in Figure 26.

During the third on-call visit, one-second equivalent sound pressure levels were generally between 39 and 43 dBA. The ninetieth percentile sound level over the ten minute period was 40 dBA.

The following observations were made during the visit:

- Swooshing noise could be heard from three to four wind turbines.
- Noise from the direction of turbine A32, sounded like a high frequency hiss-swoosh at times.

Figure 26: Monitoring Results from the Third On-Call Visit at the M. Baum Residence on February 14, 2009



6.4 Fourth On-Call Visit, February 16 at the Reilly Residence

The fourth on-call visit was to the Reilly residence on February 16 at approximately 9:05 PM. Mr. Reilly called the RSG representative to let him know the turbines were louder than normal.

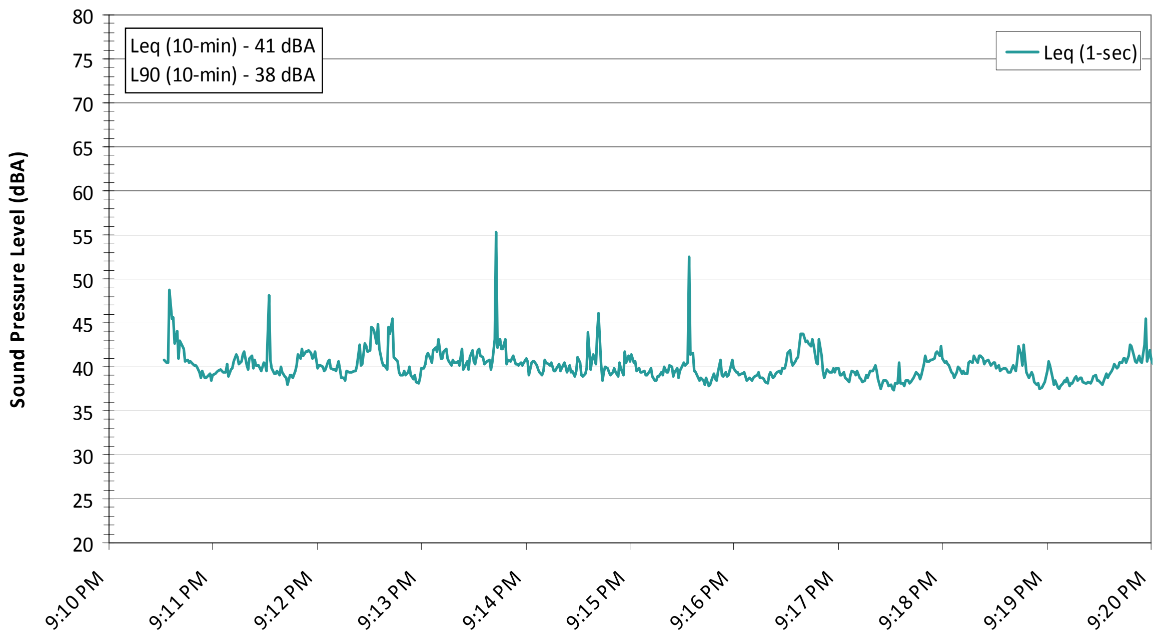
During the monitoring period winds were between 0 and 3 miles per hour at the microphone and the direction was from the northwest. The temperature was approximately 21˚F. The monitoring results for the fourth on-call visit are provided in Figure 27.

During the fourth on-call visit, one-second equivalent sound pressure levels were generally between 39 and 42 dBA. The ninetieth percentile sound level over the ten minute period was 38 dBA.

The following observations were made during the visit:

- Swooshing sound coming form turbines A30, A31, A32, and A33.
- At times the swooshing sound, had a notable low frequency component to it.

Figure 27: Monitoring Results from the Fourth On-Call Visit at the Reilly Residence on February 16, 2009



To investigate the low frequency component of the swooshing further, a voluntary visit was made to the Batdorf residence after the on-call visit at the Reilly residence. One second equivalent sound pressure levels were around 40 dBA and 55 dBC. It was noted during the voluntary visit by the RSG representative that the low frequency component of the swooshing sound seems much louder than the sound level meter was registering and could be described as highly annoying.

To illustrate the difference between the low frequency swooshing components heard on February 16 and a more normal low frequency swooshing component, two different sound files were analyzed using a spectrogram. A spectrogram is a colored graph of the sound that was recorded that shows both the frequency and the relative level of the sound. Time is represented on the horizontal axis in seconds, frequency is represented on the vertical axis in hertz, and the relative level of the sound is represented by the color scale. Blue shades are lower levels and yellows and red shades are higher levels.

The spectrogram of a normal swooshing sound that wind turbines make is shown in Figure 28 and the spectrogram of the swooshing sound that was experienced at the Reilly residence on February 16 is shown in Figure 29. The spacing of the vertical red lines represent the beating of the swooshing sound. The lower half of the graphs represents the sound at low frequencies between 0 and 30 Hz. The upper half of the graph extends up to 200 Hz. The graphs are not calibrated to so the actual numbers on the color scale are not accurate, but it does show the relative level difference between frequencies.

Figure 28: Spectrogram of Typical Swooshing Noise Created by Wind Turbines

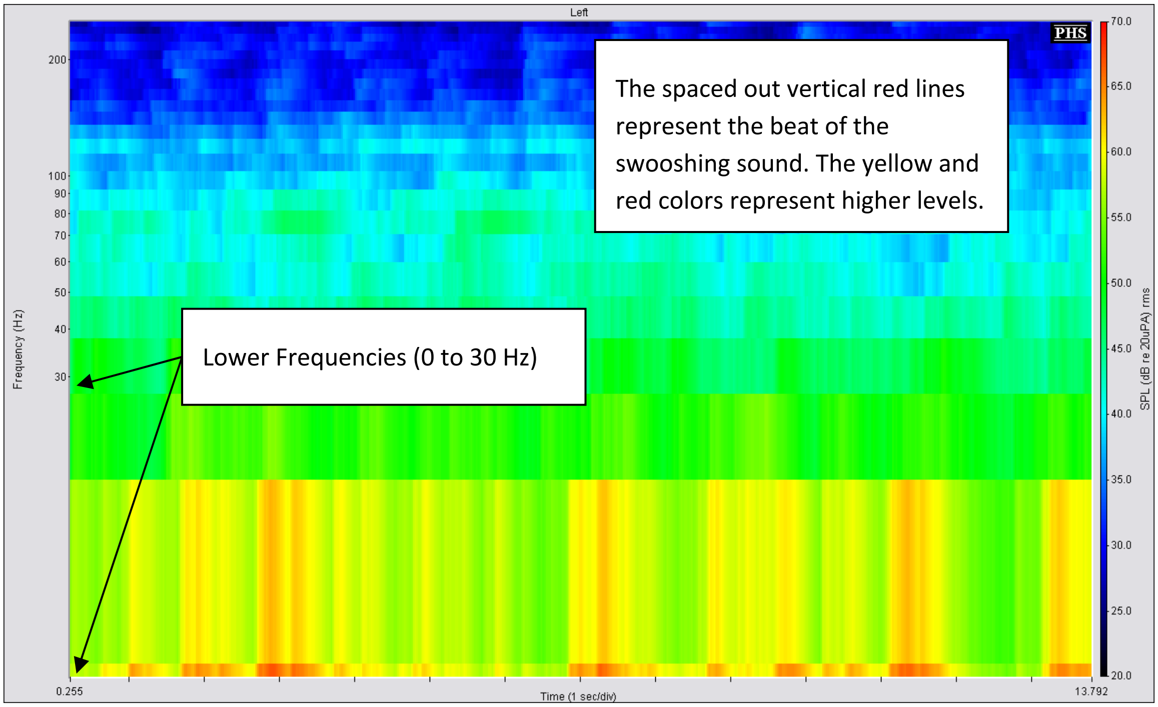
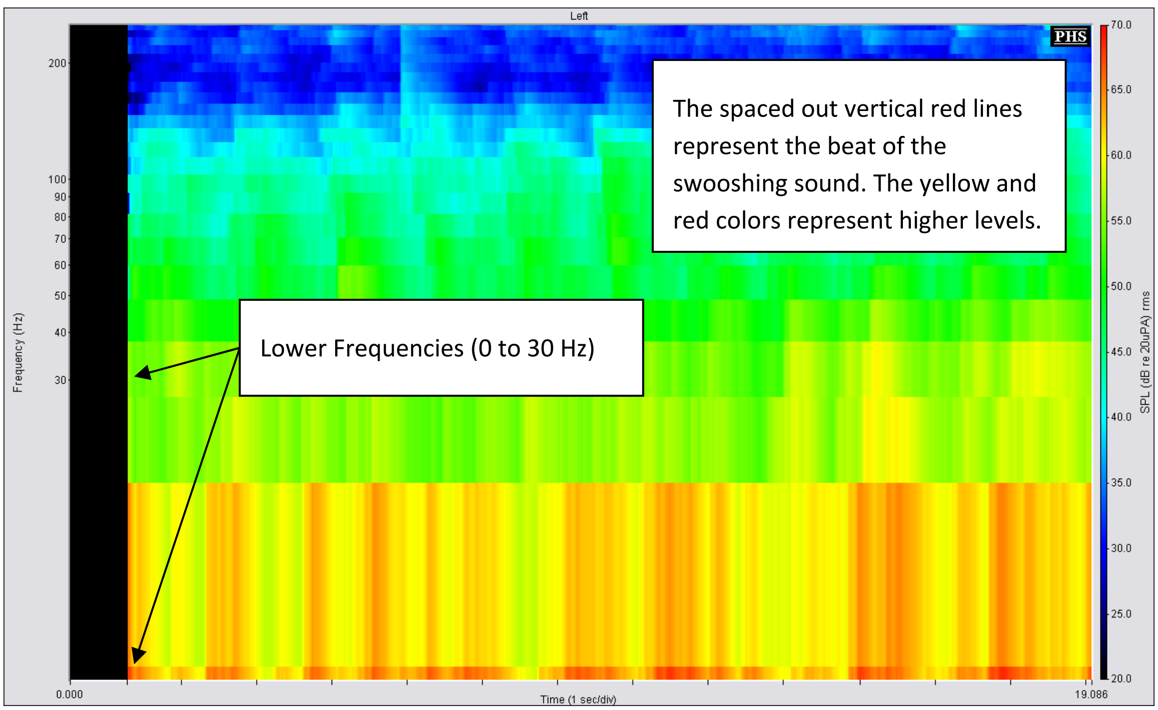


Figure 29: Spectrogram of the Swooshing Noise Produced at the Reilly Residence on February 16



7.0 Discussion and Conclusions

Extensive sound level monitoring has been conducted at five locations throughout the Allegheny Ridge Wind Farm area along PA Rte. 164 in Juniata Township. Long-term monitoring was conducted for one week in February and one week in April of 2009. In addition, during the February monitoring period, noise study participants had the opportunity to call an RSG representative to conduct short-term sound level monitoring and make observations at their property when they perceived the noise from the wind farm to be especially loud.

The results from both the February and April monitoring periods indicate that sound pressure levels from the wind farm did not exceed 45 dBA at any of the five noise study participant's properties.

It should be noted that while the 45 dBA was not exceeded, noise from the wind turbines audible. Audibility alone is not a criterion within the applicable noise standard for the Allegheny Ridge Wind Farm.

It should also be noted that during the on-call site visits completed during the February monitoring period, atypical wind turbine noise with sound levels which do not exceed the noise standard was experienced by the RSG representative. Specifically, there were two occurrences:

1. A fluttery, high frequency sound was heard from the direction of turbine A32 on the nights of February 13 and 14.
2. A highly annoying and perceived high level low frequency swoosh was heard from the direction of turbine A31 on the night of February 16.

Some residents expressed concerns during the course of this study that the wind farm operators may have changed the turbine operations during the winter monitoring period to make the turbines quieter. To assess this concern, RSG obtained turbine operational data from the wind farm operator for the time during the monitoring period and time outside of the monitoring period. Our statistical analysis of the operational data does not indicate that the turbine operations were modified during the winter monitoring period. A more detailed summary of this statistical analysis can be made available as a report addendum, if requested.

Our conclusions are as follows:

1. During the two weeks of monitoring for this study, sound pressure levels from the wind farm did not exceed 45 dBA at any of the five noise study participant's properties.
2. Some atypical and reportedly more annoying noise from the wind farm was experienced by an RSG representative during the February monitoring period. Since residents have complained about noise from the wind farm, these atypical noise issues should be investigated by the wind farm. Specifically the wind farm should try to determine the cause of the atypical noise issue and take action to mitigate the impact of these occurrences.

APPENDIX A

Noise Log Results Memo

RESOURCE SYSTEMS GROUP, INC.

MEMORANDUM

To: Michael Routch
Myrle Baum
David Smith
From: Kenneth Kaliski, P.E., INCE Bd. Cert.
Kevin Hathaway
Subject: Residence noise log results
Date: 15 October 2008

INTRODUCTION

This memo summarizes the results of resident noise logs between June 5 and August 18, 2008. The purpose of the logs was to determine what meteorological conditions resulted in high sound levels from the wind turbines at the Allegheny Ridge Wind Farm.

SUMMARY STATISTICS

20 sets of paper logs with postage paid envelopes were sent to Brian for distribution. In addition, a website was made available to residents as an alternative to filling out the paper logs. A copy of the paper log is shown in Appendix A.

Eight residences responded with at least one observation. In total, 384 observations were recorded. All but four observations were via the paper logs. The eight residences are shown in Figure 1. A summary of the reported loudness, with 5 being the loudest, is shown in Table 1. (Note the residents were asked to report when the turbines were loud, and did not report each day).

Pressure and temperature data was not available from the met tower during the monitoring period. Therefore, hourly met data from the Johnstown Airport was obtained and added to the data set. A summary of this data is shown in Tables 3 and 4.

Wind speed, wind direction, power output, and RPM data for the 27 closest turbines were provided by the Allegheny Ridge Wind Farm. These were also added to the data set.

The met data during each logged event was averaged over a four hour period to allow for the fact that events lasted for some finite period of time.

In total, we had 86 variables to work with, including the logs, airport met data, and turbine data. The entire data set, excluding the confidential turbine data, is attached to this email as a Microsoft Excel file.

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TEL 802.295.4999 ▪ FAX 802.295.1006 ▪ www.rsginc.com

Figure 1: Location of Respondents

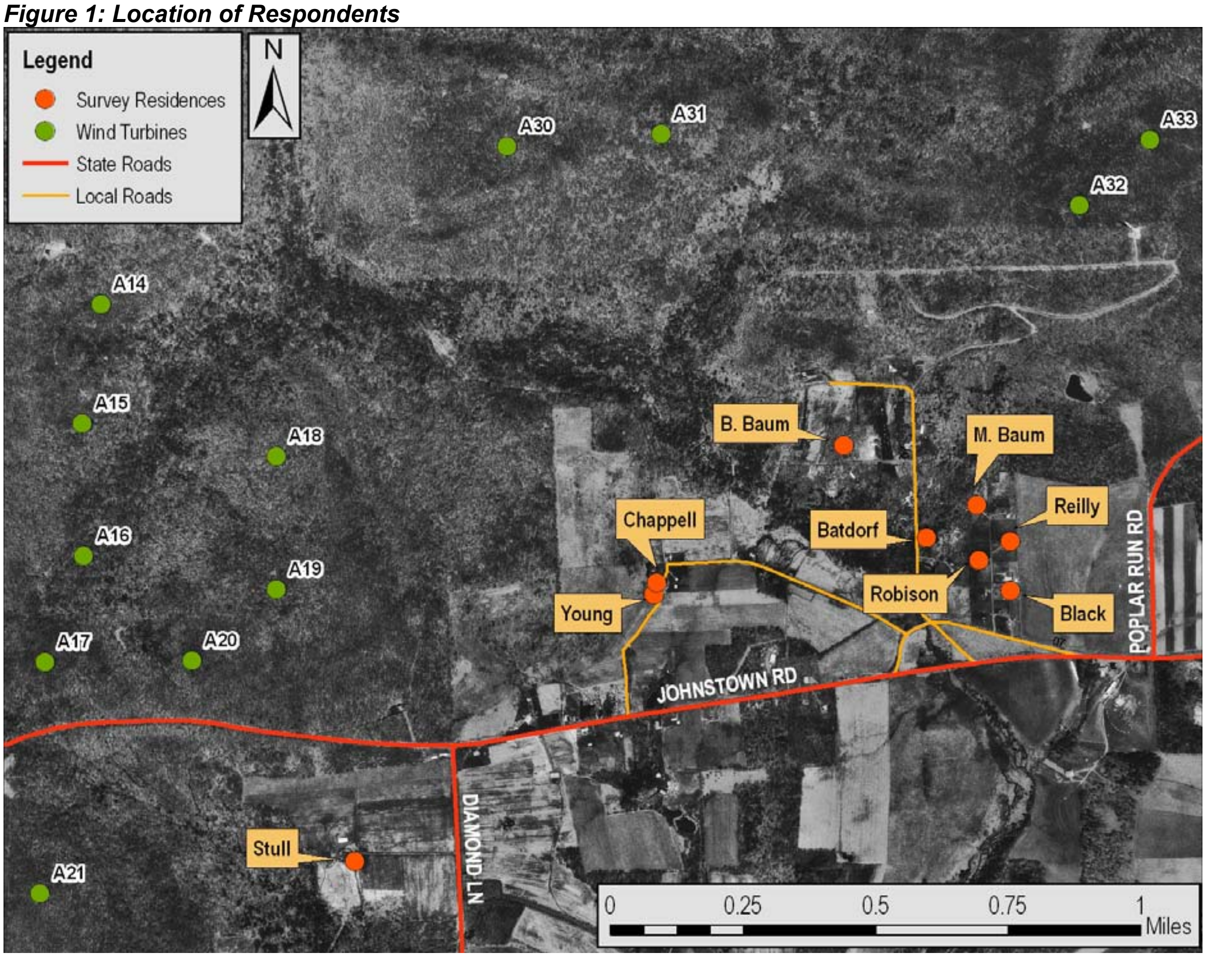


Table 1: Summary Statistics of Reported Turbine Loudness (5 being the loudest)

Loudness Rating	Frequency	Percent
1	78	20.31
2	79	20.57
3	143	37.24
4	60	15.63
5	24	6.25
Total	384	100

8 residents responded; it could be interesting to know how the 384 were distributed. Average would be 48 each, so a pretty good range; more likely is a few with even more than this, and a few with just a few reports (the latter may be less reliable in terms of understanding the distribution)

"asked to report when turbines were loud", so that implies ALL of these are times of relative loudness?? or did fuller respondents report quiet times?

Table 2: Summary Statistics of Airport Meteorological Data

variable	mean	St dev	median	min	max
temp	70	7	71	52	85
dew pt	58	6	61	42	66
humidity	69	14	66	37	94
pressure	30	0	30	30	30
visibility	9	2	10	0	10
wind speed	8	3	8	4	20

Table 3: Summary Statistics of Frequency of Rising and Falling Air Pressure

	Frequency	Percent	Cumulative percent
Falling	180	49	49
Stable	23	6	55
Rising	164	45	100
Total	367	100	

STATISTICAL MODELING

Our primary aim was to determine which meteorological conditions were most strongly associated with a neighbor recording a "4" or "5" on the survey's loud rating scale (referred hereafter as a *loud period*). These responses represent the most problematic conditions and were the focus of our modeling effort. To do this, binary logistic regression (generalized linear model with logit link and binomial distribution) was employed to estimate the odds of observing loud periods relative to other periods (1, 2 or 3 on the loud rating scale). Logistic regression is statistical modeling approach used to describe the relationship of one or more explanatory variables (X_1, X_2, … X_k) to a dichotomous outcome variable, Y. Equation 1 describes this formula:

$$E(Y) = \Pr(Y = 1) = \frac{1}{1 + \exp\left[-\left(\beta_o + \sum_{j=1}^{k} \beta_j X_j\right)\right]} \quad (1)$$

The model is fitted to the data being studied using maximum likelihood[1]. In our case, we wish to test the strength that several meteorological conditions are associated with our loud period outcome, Y. Consistent with outdoor acoustical theory, we tested wind speed, temperature, humidity, and cloud cover. All four variables were significantly associated with our outcome. Conversely, other attributes such as atmospheric pressure and wind direction provided no significant explanatory power with this sampling dataset. The model was fit using STATA 9.0 (College Station, TX). The resulting statistical table below shows the results of our analysis.

Table 1: Results from Logistic Regression

Logistic regression

Number of obs = 363
LR chi2(6) = 47.17
Prob > chi2 = 0.000

Log likelihood (null) = -187.58155
Log likelihood (full) = -163.99891

	Loud Period	Odds Ratio	SE	z	P>z	[95% Conf.	Interval]
	Wind Speed	1.21	0.07	3.33	0.001	1.08	- 1.35
relative to clear skies*	*i.Partly Cloudy*	0.27	0.09	-4.09	0.000	0.15	- 0.51
relative to clear skies*	*i.Mostly Cloudy*	0.78	0.30	-0.63	0.526	0.37	- 1.66
relative to clear skies*	*i.Full Clouds*	1.80	1.33	0.8	0.424	0.42	- 7.66
	Temp (F)	1.10	0.03	3.36	0.001	1.04	- 1.17
	Humidity	1.05	0.02	3.09	0.002	1.02	- 1.08

**The cloudiness variable was modeled using reference-cell coded indicator variables*

Statistical Table Explained

LRchi2(6): The Chi-square statistic with 6 degrees of freedom for the likelihood ratio test.

Calculated by $LRchi2 = -2logL_{null} - (-2logL_{reduced}) = (-2)*(-187.58) - (-2)*(-163.99)$

Prob>chi2: The probability of observing a LR chi-squared statistic this large by chance. Tells us our model is significantly better than no model at all (null model).

Odds Ratio: Odds ratios describe the relative odds of observing a loud period compared to the other period described by respondents. If an odds ratio is greater than 1 (and significant at 5% type I error, $p<0.05$), we conclude that variable increases the odds of a loud period. Alternatively, an odd ratio less than 1 tells us a variable is associated with decreased odds of a loud period.

SE: standard error of the estimate

[1] Kleinbaum, Kupper, Muller, and Nizam. *Applied Regression and Other Multivariable Methods: Ch 23, Logistic Regression Analysis*, 3rd Ed. Duxbury Press, Pacific Grove, CA. 1998.

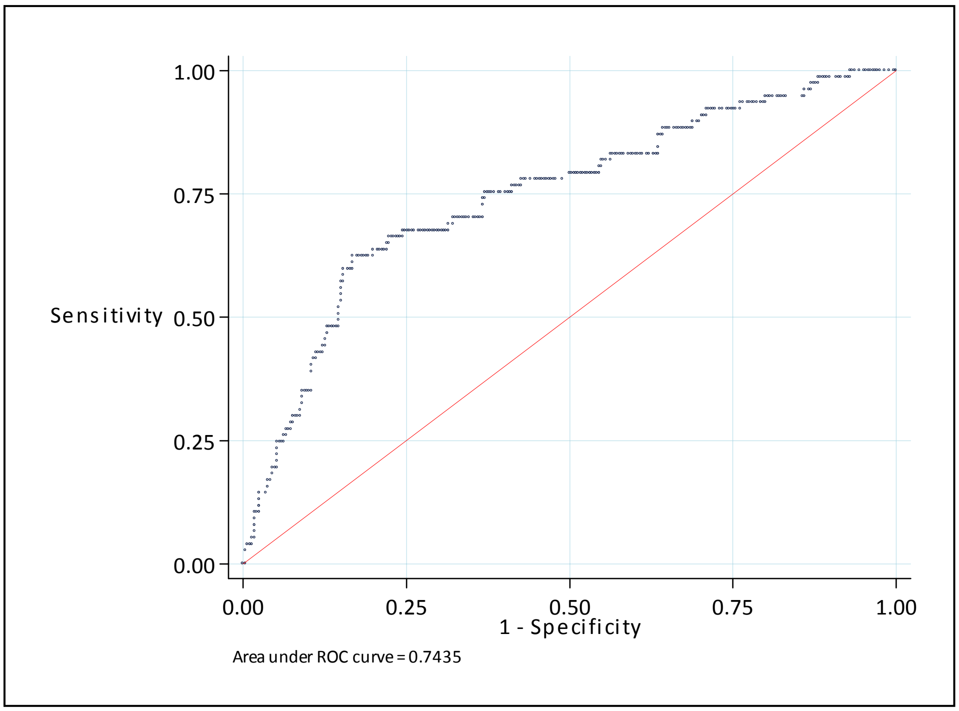
Z: The Z test statistic indicating the number of standard deviates the estimate is from the expected value (null hypothesis that the variable's odds ratio is 1).

P>z: The probability that we would observe a z statistic this large by chance alone. E.g. 0.001 indicates that only 1 in 1000 samples would provide an effect this large by chance.

95% Confidence Intervals: Indicate that if we repeated this sampling 100 times and constructed 100 confidence intervals for some variable X, 95 of them would contain the true value we are estimating.

Logistic regression produces a useful summary estimator known as an *odds ratio*. From this table, we conclude that increasing wind speed, temperature, and humidity increased the odds of observing loud periods. Conversely, partly cloudy days were less likely than clear days to occur with loud periods. More specifically, a 1 meter per second increase in wind speed will increase our odds by 21% (1.21, 95% CI 1.08-1.35) of observing a loud period. Similar inferences can be made for the other estimates.

Figure2: ROC Plot for Logistic Model



Logistic model explanatory power can be graphically summarized using an ROC (receiver operating curve) figure (Figure 0-1). An area of 0.5 (red line) would indicate the model provides no useful power. Here we see a value of 0.74, considered to provide reasonable predictive ability by statisticians (sensitivity indicates the ability of a test, or model, to correctly detect true-positives and specificity indicates the model's detection of true-negatives).

We conducted a number of other tests, but found that other combinations of variables did not increase the likelihood of loud events, or that the events were not predictable, and therefore not useful for the purpose of predicting events.

CONCLUSIONS

In finding a period of time to monitor the wind farm, we will be looking for an extended period with higher temperatures, moderate to high winds, higher-than-average humidity, and clear or overcast skies.

To get a good distribution of monitoring sites, we recommend placing sound level meters at Stull, Chappell, Brian Baum, and either at Myrle Baum, Reilly, or Black.

APPENDIX A

RESIDENT LOG

Comments

Instructions: Please make notes about the type of noise you are experiencing for each event. Also, note the incident number and date that each of your notes correspond with.

Example:

Incident 1, July 2, 2008 - The sound from the wind turbines lasted for about 10 minutes and had a "swooshing" sound to it.

RSG INC.
RESOURCE SYSTEMS GROUP, INC.

Allegheny Ridge Wind Farm Survey

Thank you for participating in the Allegheny Ridge Wind Farm Noise Survey. Your input is valuable and will be used to study the acoustical environment around the wind farm. Specifically, you will be providing information that will help determine the conditions when noise from the wind farm is most apparent.

Whenever you think the noise from the wind farm is loud, you should log the incident on this form. Reporting an incident will only take a minute. Over the next several months, please continue to use this log sheet whenever you notice noise from the wind farm. We appreciate your help - please contact us if you have any questions.

If you have any questions, please call Ken Kaliski or Eddie Duncan at:

Resource Systems Group
Phone: 802-295-4999

Name:

Address:

City:

State: Zip:

Phone Number:

Email Address:

Describe the land around your home:

- ☐ Just Lawn and/or low lying gardens
- ☐ Lawn with a couple trees and/or taller bushes
- ☐ Lawn with several trees and/or taller bushes
- ☐ Forested

RSG INC.
RESOURCE SYSTEMS GROUP, INC.

Allegheny Ridge Wind Farm Survey

	Incident 1 Date: ______	Incident 2 Date: ______	Incident 3 Date: ______	Incident 4 Date: ______	Incident 5 Date: ______	Incident 6 Date: ______	Incident 7 Date: ______
1) On a scale from 1 to 5, how loud was the noise from the wind turbines? (1 being not loud at all, and 5 being extremely loud)	☐ 1 (Not loud at all) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (Extremely Loud)	☐ 1 (Not loud at all) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (Extremely Loud)	☐ 1 (Not loud at all) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (Extremely Loud)	☐ 1 (Not loud at all) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (Extremely Loud)	☐ 1 (Not loud at all) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (Extremely Loud)	☐ 1 (Not loud at all) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (Extremely Loud)	☐ 1 (Not loud at all) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (Extremely Loud)
2) Were you at home when you heard the noise from the wind turbines? If no, where were you?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
3) Were you indoors or outdoors when you heard the noise from the wind turbines?	☐ Indoors ☐ Outdoors	☐ Indoors ☐ Outdoors	☐ Indoors ☐ Outdoors	☐ Indoors ☐ Outdoors	☐ Indoors ☐ Outdoors	☐ Indoors ☐ Outdoors	☐ Indoors ☐ Outdoors
4) How windy was it when you heard the wind turbines: calm, breezy, breezy with strong gusts, or very windy?	☐ Calm ☐ Breezy ☐ Breezy with strong gusts ☐ Very Windy	☐ Calm ☐ Breezy ☐ Breezy with strong gusts ☐ Very Windy	☐ Calm ☐ Breezy ☐ Breezy with strong gusts ☐ Very Windy	☐ Calm ☐ Breezy ☐ Breezy with strong gusts ☐ Very Windy	☐ Calm ☐ Breezy ☐ Breezy with strong gusts ☐ Very Windy	☐ Calm ☐ Breezy ☐ Breezy with strong gusts ☐ Very Windy	☐ Calm ☐ Breezy ☐ Breezy with strong gusts ☐ Very Windy
5) What direction was the wind coming from when you heard the noise from the wind turbines: North, Northeast, East, Southeast, South, Southwest, West, Northwest?	☐ North ☐ Northeast ☐ East ☐ Southeast ☐ South ☐ Southwest ☐ West ☐ Northwest	☐ North ☐ Northeast ☐ East ☐ Southeast ☐ South ☐ Southwest ☐ West ☐ Northwest	☐ North ☐ Northeast ☐ East ☐ Southeast ☐ South ☐ Southwest ☐ West ☐ Northwest	☐ North ☐ Northeast ☐ East ☐ Southeast ☐ South ☐ Southwest ☐ West ☐ Northwest	☐ North ☐ Northeast ☐ East ☐ Southeast ☐ South ☐ Southwest ☐ West ☐ Northwest	☐ North ☐ Northeast ☐ East ☐ Southeast ☐ South ☐ Southwest ☐ West ☐ Northwest	☐ North ☐ Northeast ☐ East ☐ Southeast ☐ South ☐ Southwest ☐ West ☐ Northwest
6) What time of day did this noise event occur? If it stopped, when did it end?	Start: ______ End: ______	Start: ______ End: ______	Start: ______ End: ______	Start: ______ End: ______	Start: ______ End: ______	Start: ______ End: ______	Start: ______ End: ______
7) When you heard the noise from the wind turbines was the sky: clear, partly cloudy, mostly cloudy, or full cloud coverage?	☐ Clear ☐ Partly cloudy ☐ Mostly Cloudy ☐ Full Cloud Coverage	☐ Clear ☐ Partly cloudy ☐ Mostly Cloudy ☐ Full Cloud Coverage	☐ Clear ☐ Partly cloudy ☐ Mostly Cloudy ☐ Full Cloud Coverage	☐ Clear ☐ Partly cloudy ☐ Mostly Cloudy ☐ Full Cloud Coverage	☐ Clear ☐ Partly cloudy ☐ Mostly Cloudy ☐ Full Cloud Coverage	☐ Clear ☐ Partly cloudy ☐ Mostly Cloudy ☐ Full Cloud Coverage	☐ Clear ☐ Partly cloudy ☐ Mostly Cloudy ☐ Full Cloud Coverage

Please write comments on the back of this form and once this form is filled, please continue on to another log form. Thank you.