RSG INC.
RESOURCE SYSTEMS GROUP, INC.

Noise Impact Study for:

DEERFIELD WIND, LLC

Searsburg/Readsboro, Vermont

Prepared for:

PPM Energy

28 December, 2006

55 Railroad Row, White River Junction, Vermont 05001

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1. INTRODUCTION

The Deerfield Wind Project is a proposal to construct and operate up to 24 wind turbines in Searsburg and Readsboro, Vermont. The total capacity of the system would be in the range of 30 to 45 MW with each turbine generating 1.5 to 3.0 MW.

The turbines are expected to be constructed in 2007. Since new turbine models are being constantly introduced, no one model has been selected for this project. Therefore, the approach taken for this study is to use generic wind turbine data and develop a noise standard for the project that would apply regardless of which turbine model is ultimately chosen.

This study will assess the effects of the wind turbines on noise levels in the surrounding area. The study will include:

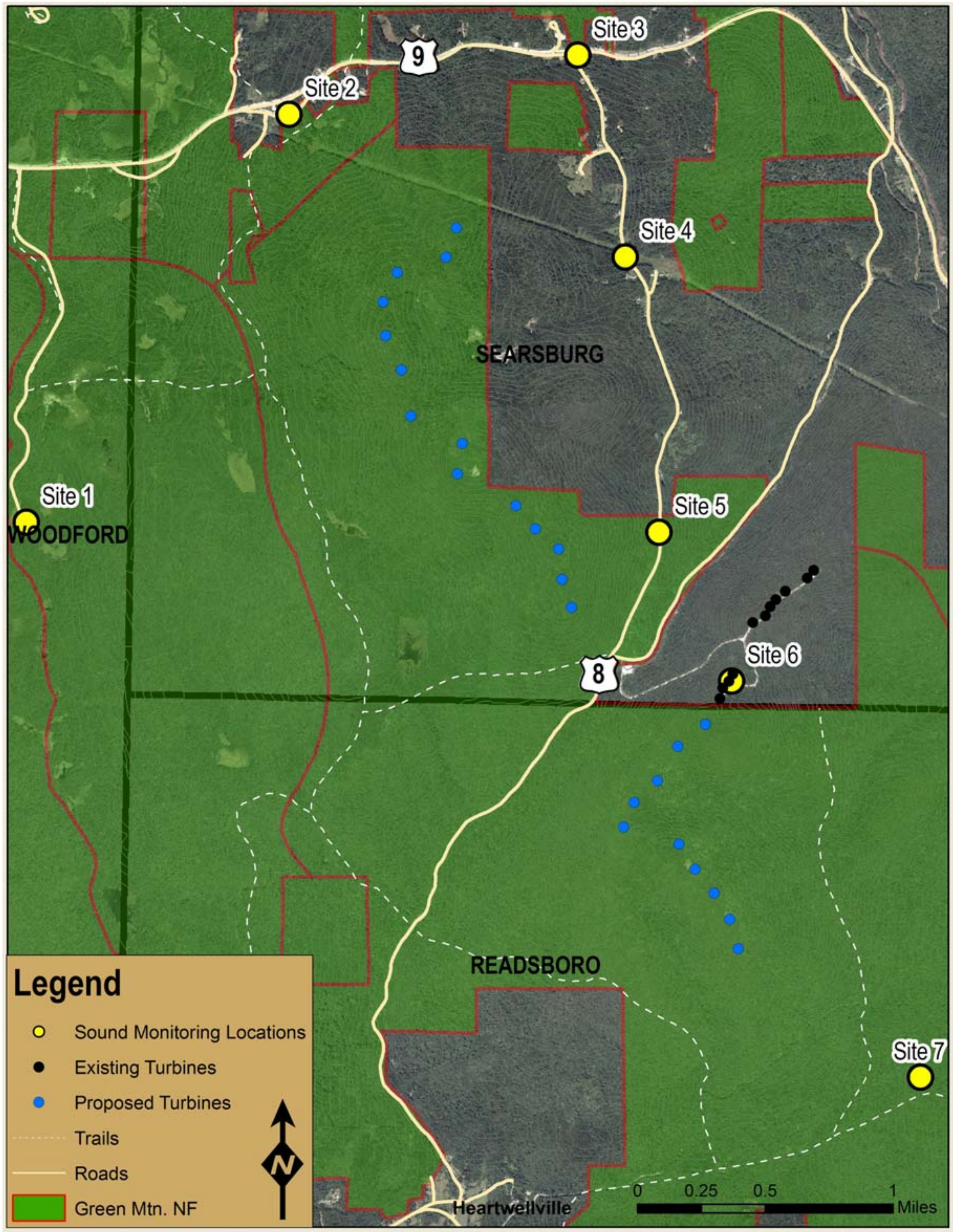
1) A description of the site
2) A discussion of noise issues specific to wind turbines
3) A discussion of noise limits and a recommendation for a standard to be used in this case
4) The results of background sound level monitoring
5) The results of computer propagation modeling of the existing and proposed turbines
6) A discussion of the results and mitigation that may be required.
7) Summary and conclusions

This study follows the procedures for modeling sound as specified in the International Standards Organization (ISO) standard ISO 9613-2, "Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation." (1996).

2. SITE DESCRIPTION

The proposed turbines are separated into two distinct "strings": East and West. The western string is located along a ridge in Searsburg, Vermont, to the west of VT Route 8. The eastern string is located in Readsboro, Vermont, along a ridge directly south of an existing string of 11 turbines installed in 1996. Figure 1 shows the location of the turbine strings with respect to the surrounding roadway network, homes, trails, and the Forest boundaries. Also shown are sites where sound monitoring stations were placed. These will be described in later sections in this report.

Figure 1: General Location Map



3. NOISE STANDARDS

3.1. LOCAL AND STATE STANDARDS

There are no quantitative noise standards in Readsboro or Searsburg. In addition, there are no state statutes or regulations that establish quantitative noise standards that would apply to this project.

3.2. SECTION 248 CERTIFICATE OF PUBLIC GOOD FOR EXISTING WIND PROJECTS

The existing Searsburg facility has a Certificate of Public Good issued by the Public Service Board (Docket 5823). While noise testimony was provided, the Board did not issue a noise standard for the project.

3.3. WORLD HEALTH ORGANIZATION

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

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

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

3.4. FEDERAL STANDARDS AND GUIDELINES

There are no federal standards that apply to wind turbines. Many federal agencies have adopted guidelines and standards that apply to other types of projects. A summary of some of these standards is shown in Table 1. Note that these standards are in terms of Leq, Ldn, or L10. The Leq is the pressure weighted average sound level, over a specified period of time. The Ldn is the A-weighted day-night Leq, where a penalty of 10 dB is applied to nighttime sound. The L10 is the 10^{th} percentile sound level. It is the level that is exceeded 10% of the time, and thus represents the higher sound levels over a period of time. For further information on the definitions of these terms, refer to attached Noise Primer.

Table 1: Summary of Federal Guidelines and Standards for Exterior Noise

Agency	Applies to	Standard (dBA)
Environmental Protection Agency	Guideline to protect public health and welfare with an adequate margin of safety	55 dB Ldn
Bureau of Land Management (BLM)	Guidelines for the development of wind turbines on federal lands managed by BLM	Refers to the EPA 55 dB Ldn guideline.
Federal Energy Regulatory Commission (FERC)	Compressor facilities under FERC jurisdiction	55 dB Ldn
Federal Highway Administration (FHWA) and Vermont Agency of Transportation (VTrans)	Federally funded highway projects. For “Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.”	57 dBA Leq or 60 dBA L10 during the peak hour of traffic. Either standard can be used, but not both.
	For “picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, hotels, motels, schools, libraries, churches, and hospitals.”	67 dBA Leq or 70 dBA L10
	For all areas	At a background Leq of 40 dBA, no more than an 18 dBA Leq increase during the peak hour
Federal Interagency Task Force	This Taskforce is set up to develop consistency of noise standards among federal agencies	55 to 65 dB Ldn for impacts on residential areas

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

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

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

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

3.5. NOISE THRESHOLD GOALS

The EPA Guidelines, the BLM PEIS, and the WHO Guidelines each provide relevant noise criteria for a project of this type. Given the scientific evidence regarding sleep disturbance and other impacts that was reviewed by WHO, we propose that the project should meet a standard of 45 dBA Leq (night)[1] averaged over the entire night and 50 dBA Leq (day) averaged over the remainder of the day. This is equivalent to a day-night average level of 52 dB Ldn. This would be applied to areas of frequent human use during the summer months, including homes, yards, and porches. This would not apply to areas that have transient uses such as driveways, trails, and parking areas. This standard is more stringent than all of the federal standards mentioned above and will be well below the level that can cause hearing impairment. This noise limit is both protective of human health and prevents any quality-of-life concerns, i.e., would not result in an undue adverse effect to the aesthetics of the area.

4. EXISTING NOISE ENVIRONMENT

4.1. NOISE ZONES AROUND THE PROJECT

There are several discrete noise zones around the project that are addressed in this report. They include:

1) The Aiken Wilderness
2) Other management areas of the Green Mountain National Forest
3) Homes along VT Route 8, which has an average daily traffic (ADT) volume of approximately 720 vehicles per day (vpd).
4) Homes along VT Route 9, which has an ADT of approximately 4,400 vpd.
5) The existing wind turbines adjacent to the proposed Eastern String.

4.2. BACKGROUND SOUND MONITORING

To determine ambient sound levels in the area, sound level monitoring was completed for two different four and five day periods. Sites 2, 4, and 7 were monitored from Friday, November 18th to Wednesday, November 23rd, 2005, and Sites 1, 3, 5, and 6 were monitored from Thursday, December 1st to Monday, December 5th, 2005.

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

All sites were monitored with ANSI Type 1 Cesva SC310 integrating sound level meters set to log average, 90th percentile, 50th percentile, and full octave band sound levels every ten seconds. Each sound level meter was calibrated before and after the measurements and fitted with windscreens. The windscreens reduce the self-noise created by wind passing over the meter's microphone. Each microphone was placed between approximately 0.8 and 1.4 meters above the ground. In each case, the ground was considered "soft", that is, it was suitable for the growth of vegetation.

Figure 2 identifies the monitoring locations in reference to the project area. Each monitoring location and hourly sound level readings are shown in greater detail in the figures that follow. A location description of each meter site is given below. This Universal Transverse Mercator (UTM) coordinates of each site is shown in Table 2. A summary of the monitoring results, including distances to the existing and proposed wind turbines is shown in Table 3. Three different levels are shown: the Leq, L90 and L50. As mentioned above, the Leq is the equivalent average sound level. This measure weights louder sounds more than quieter sounds. For example, the Leq average of 60 dB and 40 dB is 57 dB. The L50 is the fiftieth percentile level and the L90 is the ninetieth percentile level.

1) Site 1 is located at the end of George D. Aiken Wilde Road (Forest Road. 74) in Woodford. The meter was set up 20 feet east of the end of the road. Site 1 is shown in Figure 3. The sound monitoring results are shown in Figure 4 along with wind speeds as monitored at the ridgeline of wind turbines. As shown in the chart, the Leq, L50, and L90 generally follow a similar trend indicating that there is not a lot of traffic or infrequent and relatively loud events. The sound levels also tend to rise and fall along with the ridgetop wind speeds.

2) Site 2 is located 47 feet south of Old Route 9, east of Bishop Hill Road, and south of VT Route 9 in Searsburg. Site 2 is shown in Figure 5 and the monitoring results in Figure 6. The results show a more diurnal pattern in the sound levels. Levels are highest during the day and lowest during the night. This indicates that traffic patterns heavily influence noise in this area.

3) Site 3 is in the tree line between the cemetery and the intersection of VT Routes 9 and 8 in Searsburg. The meter was setup 94 feet east of Route 8 and 107 feet south of Route 9. Site 3 is shown in Figure 7 and the monitoring results are shown in Figure 8. Similar to Site 2, the results show a diurnal pattern of sound levels. However, this site also shows a rise in sound levels during the night of December 3. This night experienced very high wind speeds at the ridgeline (above 25 mph) which resulted in wind noise at this location. Note that the existing turbines are not readily audible at Site 3.

4) Site 4 is located near the transmission line that crosses VT Route 8 approximately 1.3 km (0.8 miles) south of the VT 8/VT 9 intersection in Searsburg. The meter at Site 4 was located 56 feet west of Route 8 in the woods immediately south of the transmission lines. Site 4 is shown on Figure 9 and the monitoring results are shown in Figure 10. At this site, there is a very clear difference between the Leq values, which follow a diurnal pattern, and the L90 and L50 levels which are more stable. The difference is due to relatively low traffic volumes on VT 8. That is, there are not enough vehicles on VT 8 to affect the percentile

levels, but the peaks from the vehicle passbys effect the Leq. The rise in the L50 and L90 during the night of November 23 was due to a short period of rain.

5) Site 5 is located approximately 0.5 miles north of Sleepy Hollow Road on VT Route 8 in Searsburg. The meter was setup 32 feet west of Route 8. Site 5 is shown on Figure 11 and the results of the monitoring are shown in Figure 12. The patterns of sound levels are similar to that shown at Site 4 with the L50 and L90 correlated with the ridgetop wind speed.

6) Site 6 is located south of the existing GMP turbine string. The meter at Site 6 was set up 65 feet east of the turbine shown in Figure 13. Site 6 is shown on Figure 13 and the results of the sound monitoring is shown in Figure 14. Given the close proximity of the meter to the wind turbine, we assume that all of the sound at this location is generated by the turbine. The sound levels here are closely correlated to wind speed with the exception of the evening of December 2 when the wind turbine blades were pitched back to prevent damage by high winds. Also note that the Leq, L10, and L90 are nearly identical, indicating that the sound levels during each of these hourly periods were very constant.

7) Site 7 is located on a forest trail located southeast of the existing Zond turbines in Readsboro. The meter was set up near the beginning of a trail that leads to a local topographic feature known as "The Dome". Site 7 is shown on Figure 15 and the monitoring results are shown in Figure 16. With the exception of the rainy period during the early morning of November 22, the sound levels here are closely correlated with wind speed. The sound levels are relatively low during the night, especially during calm winds.

Table 2: Universal Transverse Mercator (UTM) coordinates of monitoring sites (NAD 83, meters)

Site	Easting	Northing
Site 1	661,772	4,748,163
Site 2	665,256	4,751,123
Site 3	665,566	4,749,827
Site 4	667,436	4,744,588
Site 5	666,219	4,747,121
Site 6	665,755	4,748,100
Site 7	663,419	4,750,764

Table 3: Summary of Overall Monitoring Results by Site

Site	Distance to Existing Turbines (m)	Distance to Proposed Turbines (m)	Day			Night		
			LEQ	L50	L90	LEQ	L50	L90
Site 1	4,500	2,500	45	33	32	39	29	28
Site 2	4,350	1,150	50	45	43	46	38	37
Site 3	3,550	1,300	56	49	46	52	39	38
Site 4	2,350	1,050	56	41	40	51	41	40
Site 5	800	650	57	42	42	50	43	42
Site 6	20	300	63	56	55	62	62	61
Site 7	2,750	1,400	51	29	28	49	33	32

Figure 2: Sound Monitoring Sites in Reference to the Project Area

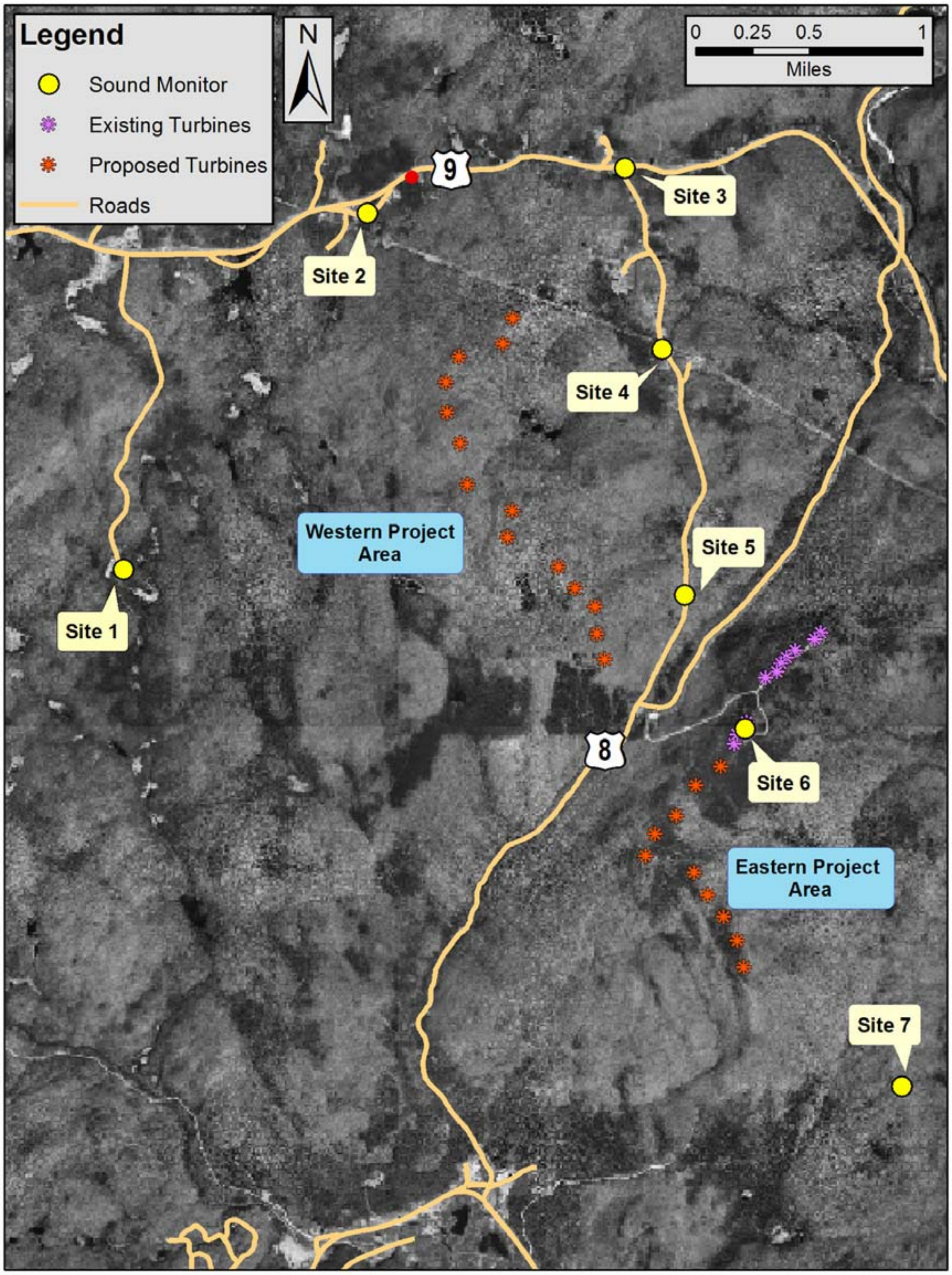


Figure 3: Monitoring Site 1

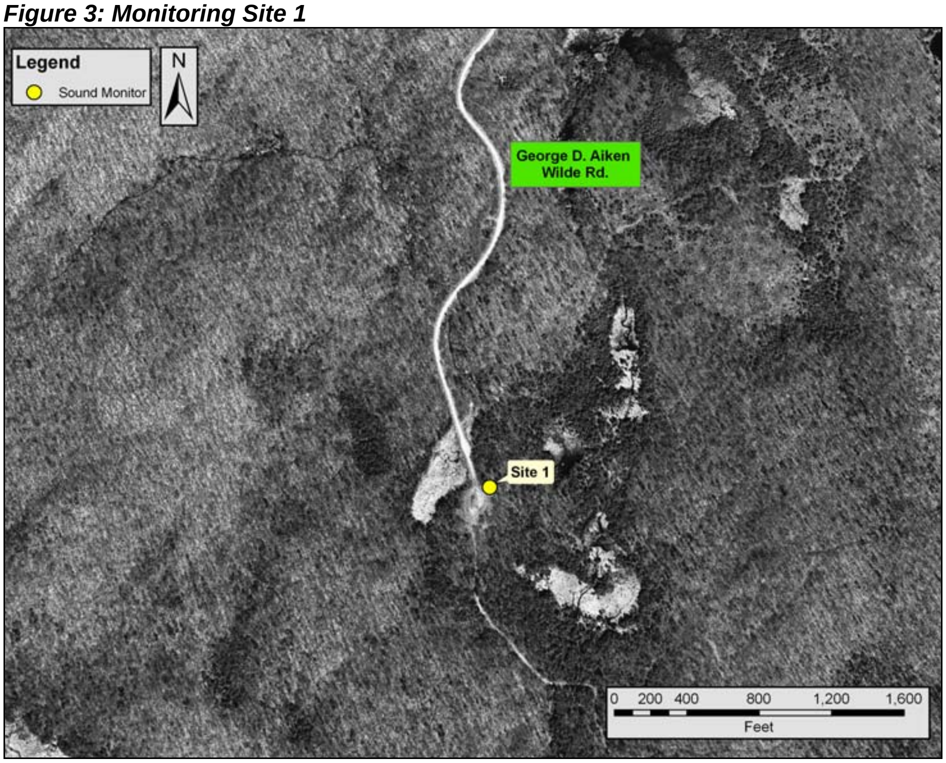


Figure 4: Hourly Sound Pressure Levels (dBA) for Site 1 and Wind Speed Data (mi/hr)

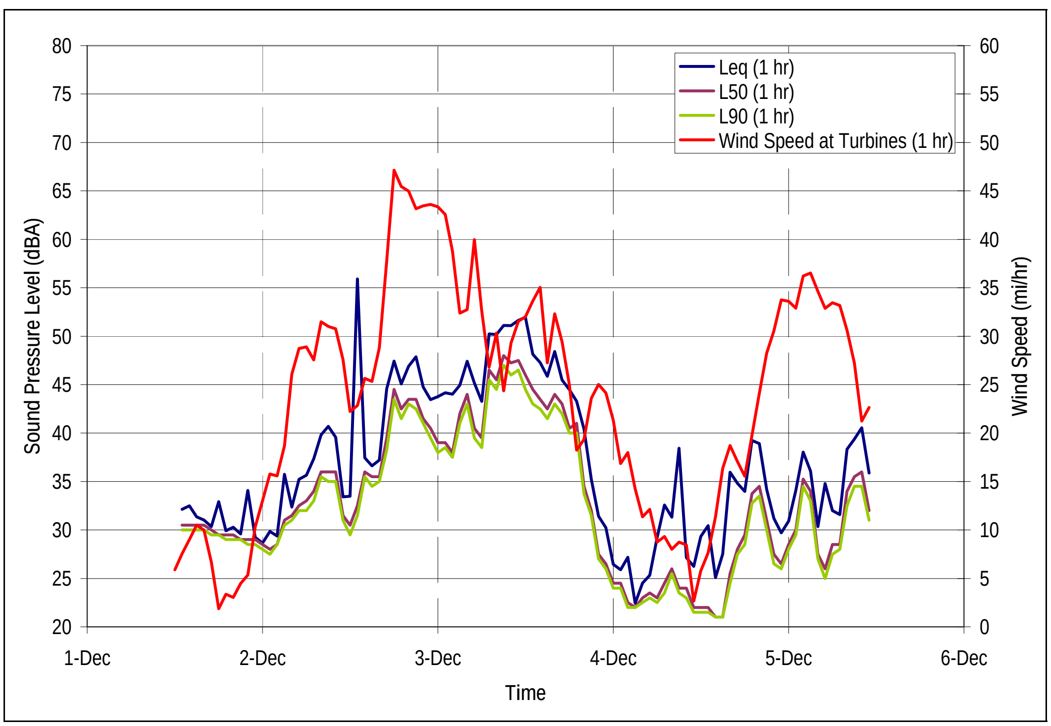


Figure 5: Monitoring Site 2

Figure 6: Hourly Sound Pressure Levels (dBA) for Site 2 and Wind Speed Data (mi/hr)

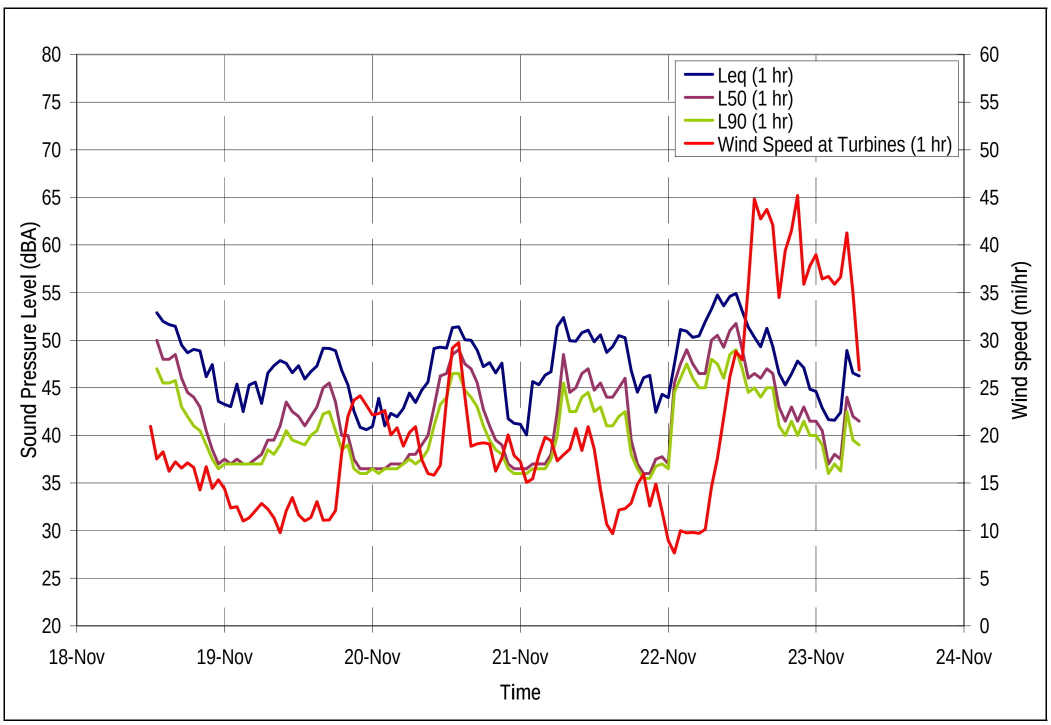


Figure 7: Monitoring Site 3

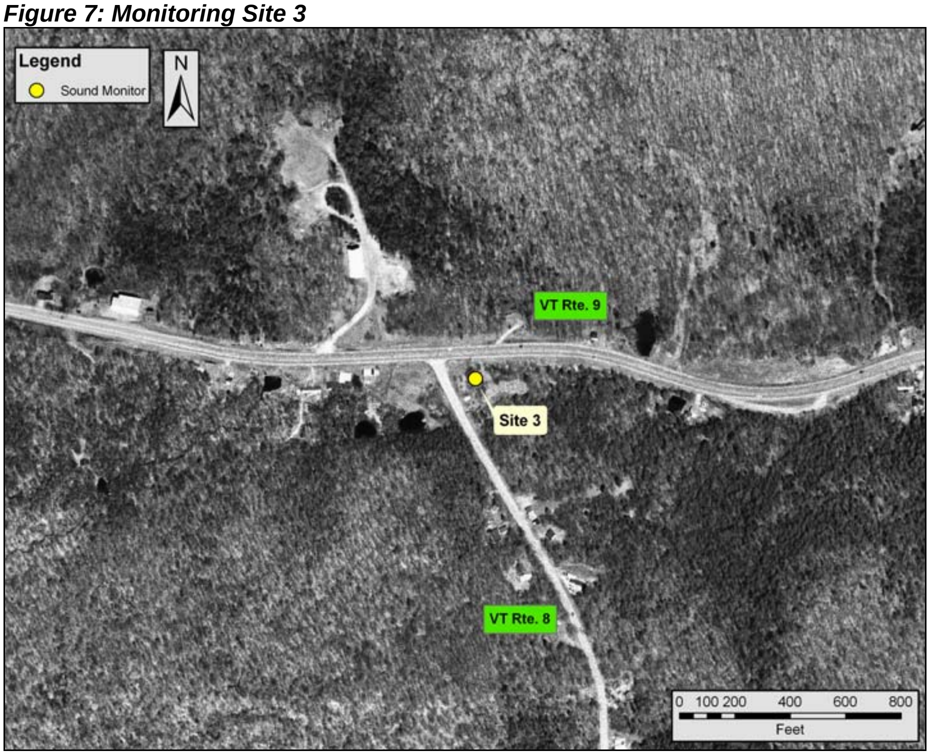


Figure 8: Hourly Sound Pressure Levels (dBA) for Site 3 and Wind Speed Data (mi/hr)

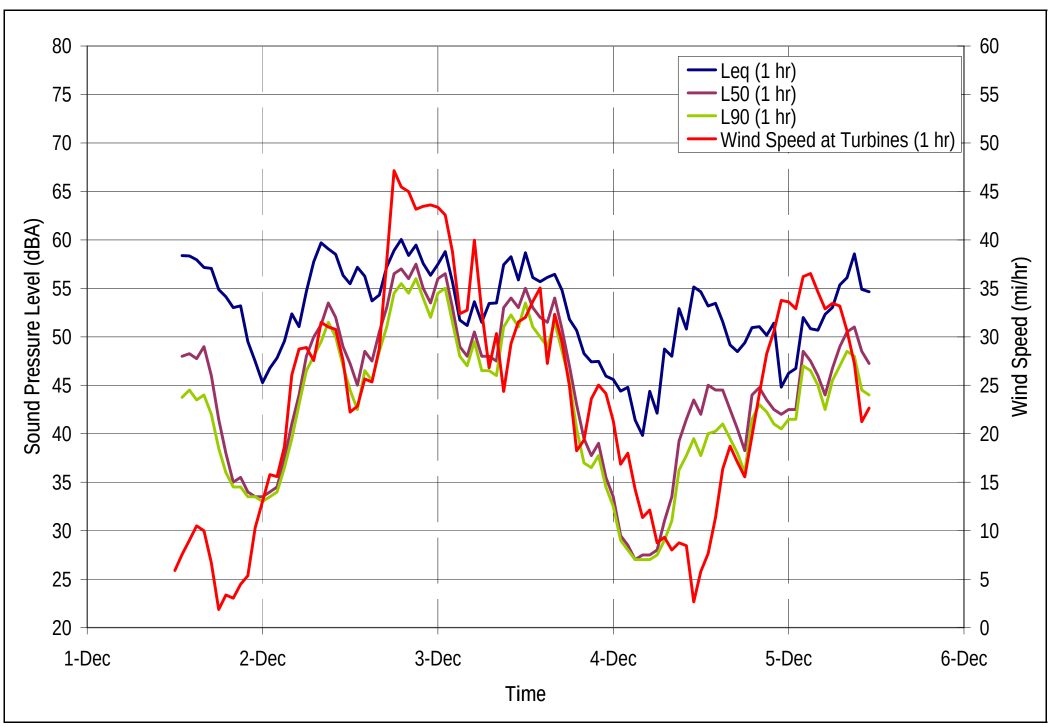


Figure 9: Monitoring Site 4

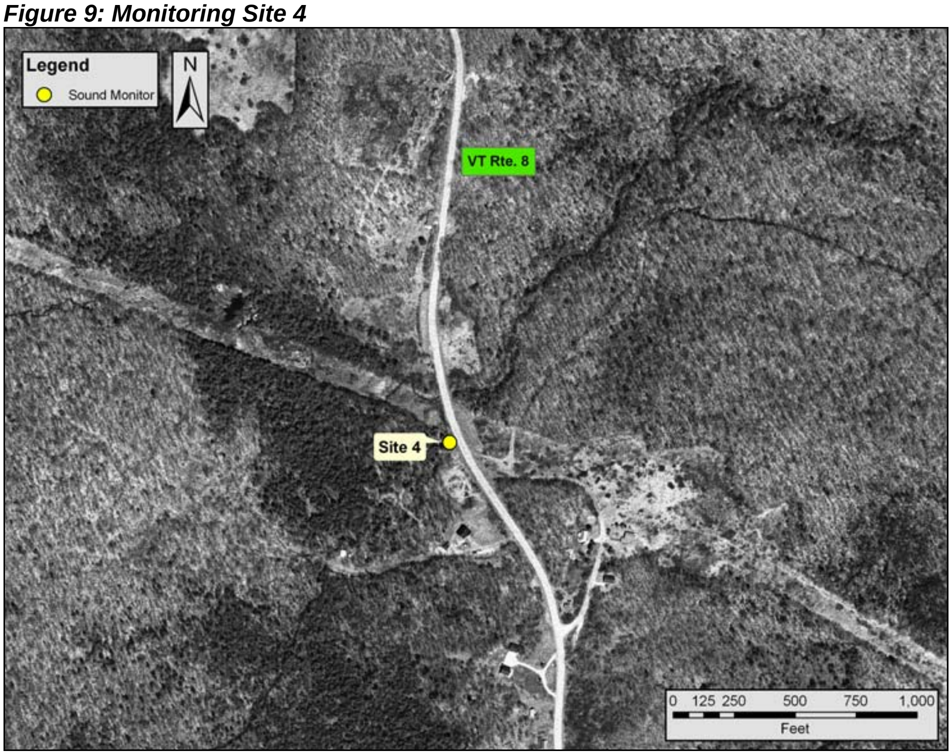


Figure 10: Hourly Sound Pressure Levels (dBA) for Site 4 and Wind Speed Data (mi/hr)

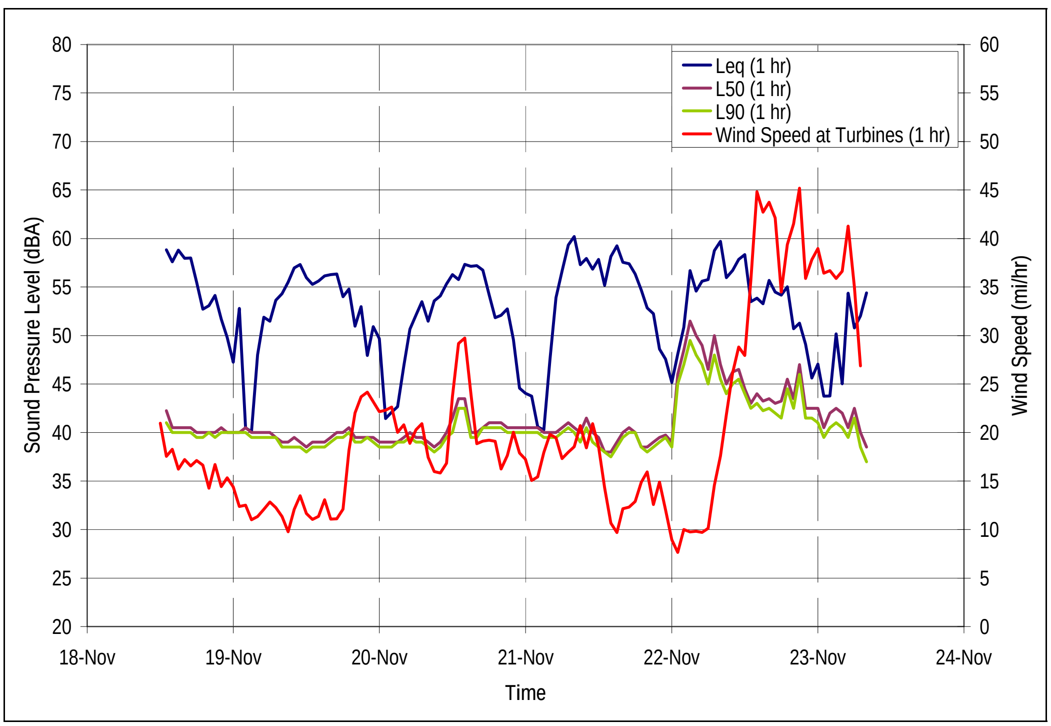


Figure 11: Monitoring Site 5

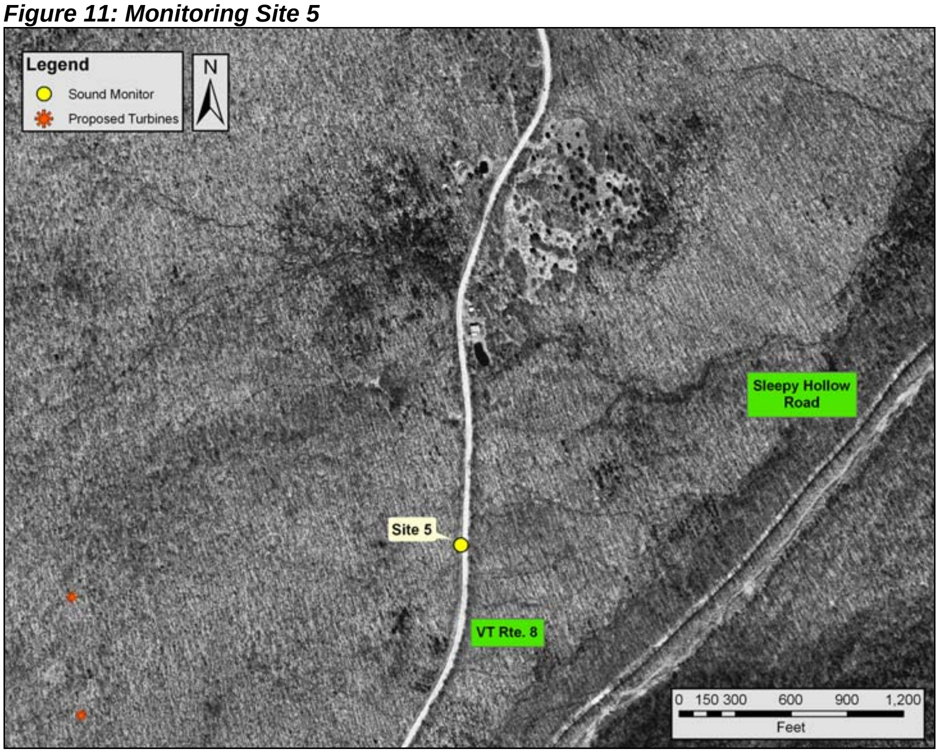


Figure 12: Hourly Sound Pressure Levels (dBA) for Site 5 and Wind Speed Data (mi/hr)

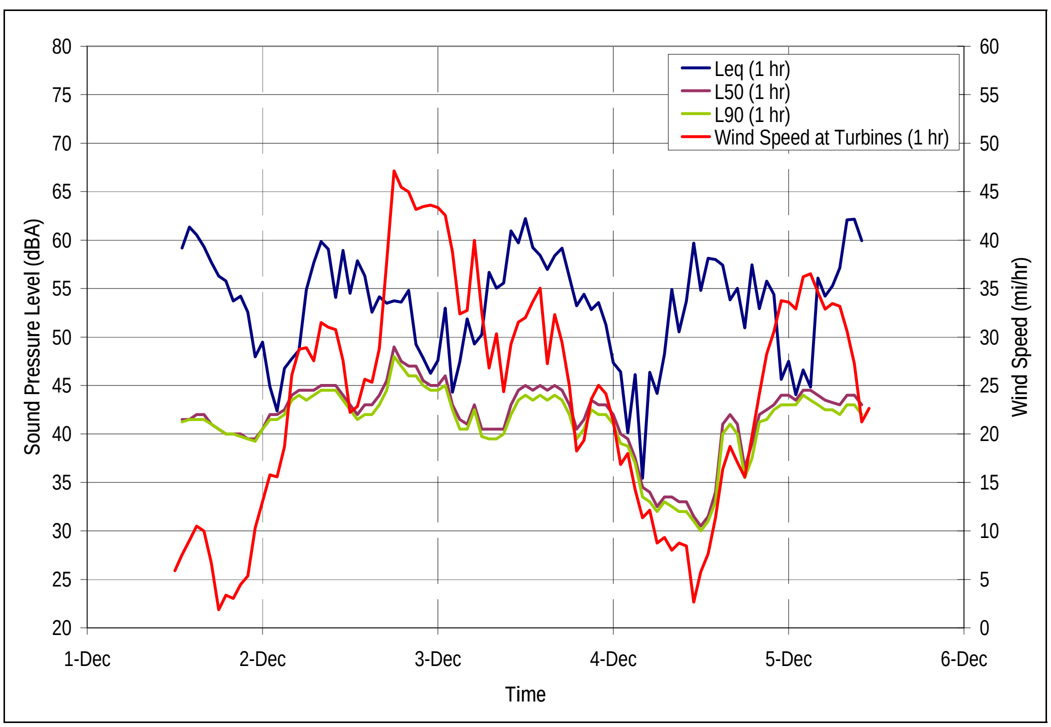


Figure 13: Monitoring Site 6

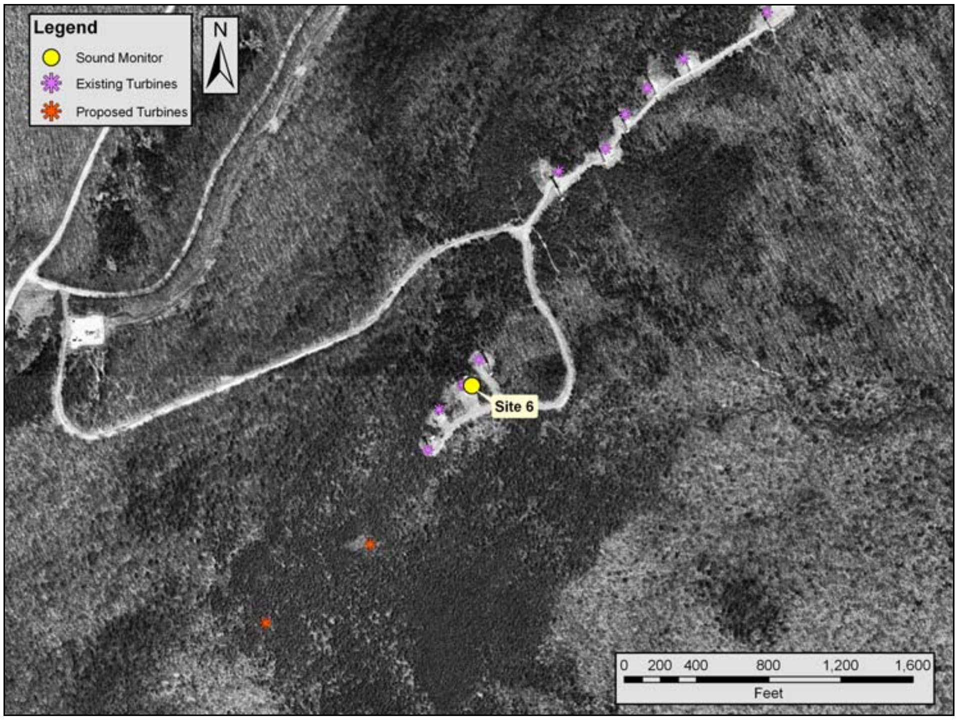


Figure 14: Hourly Sound Pressure Levels (dBA) for Site 6 and Wind Speed Data (mi/hr)

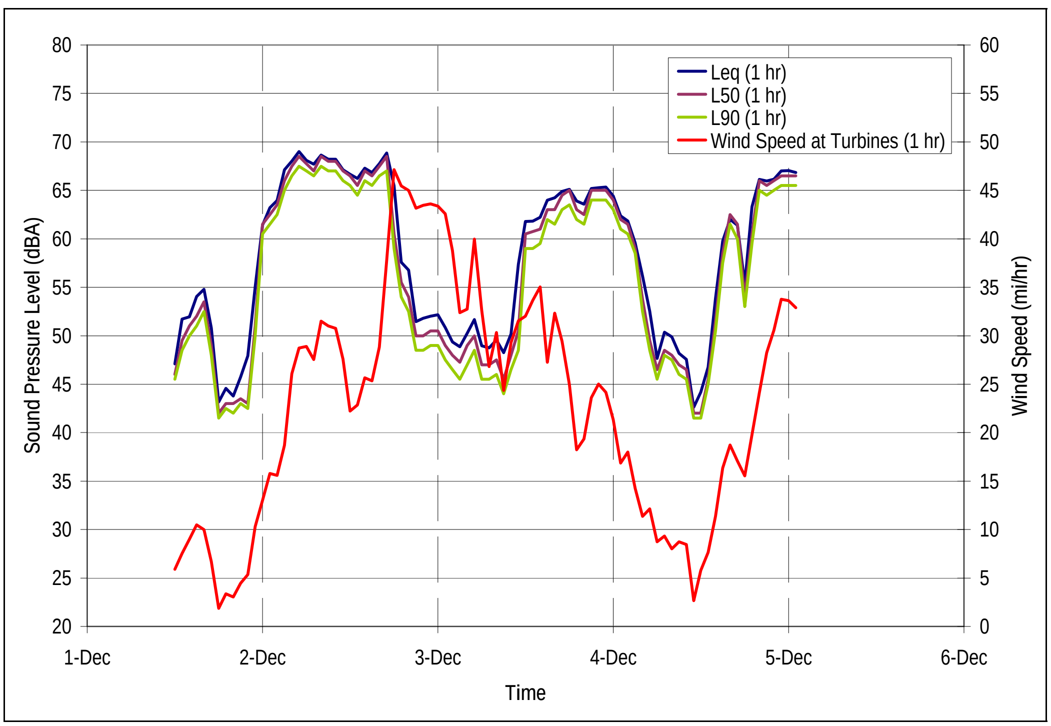


Figure 15: Monitoring Site 7

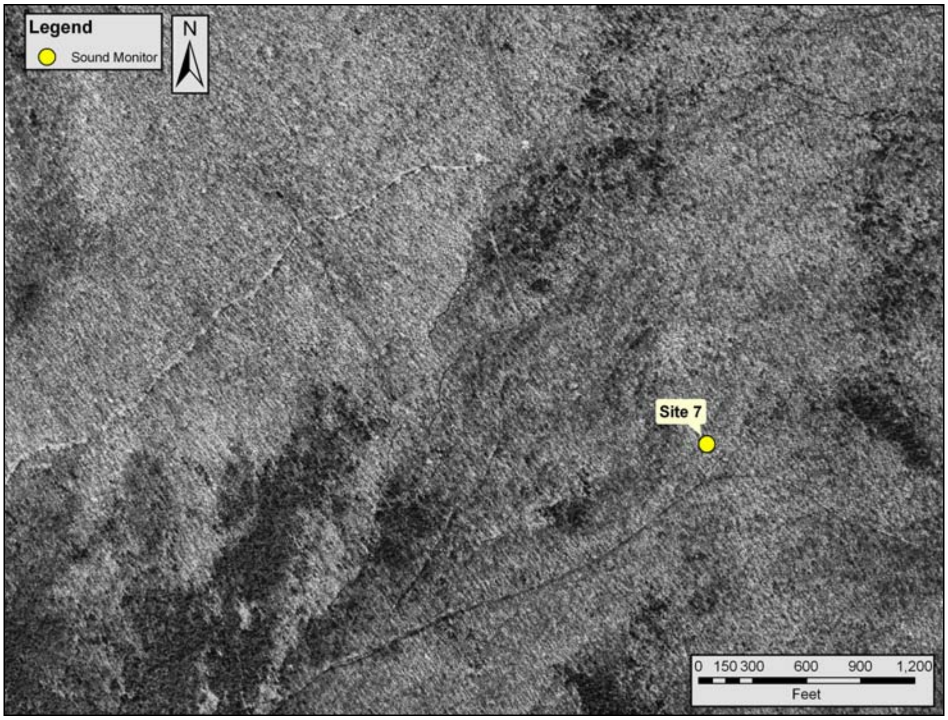
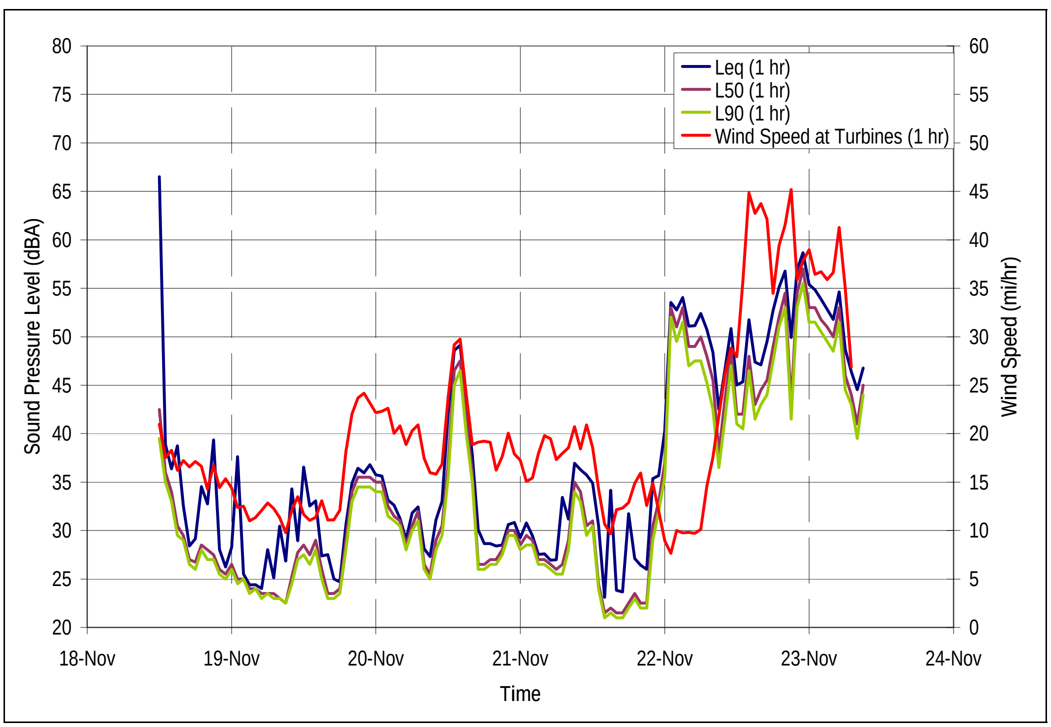


Figure 16: Hourly Sound Pressure Levels (dBA) for Site 7 and Wind Speed Data (mi/hr)



4.3. EXISTING SEARSBURG WIND PROJECT

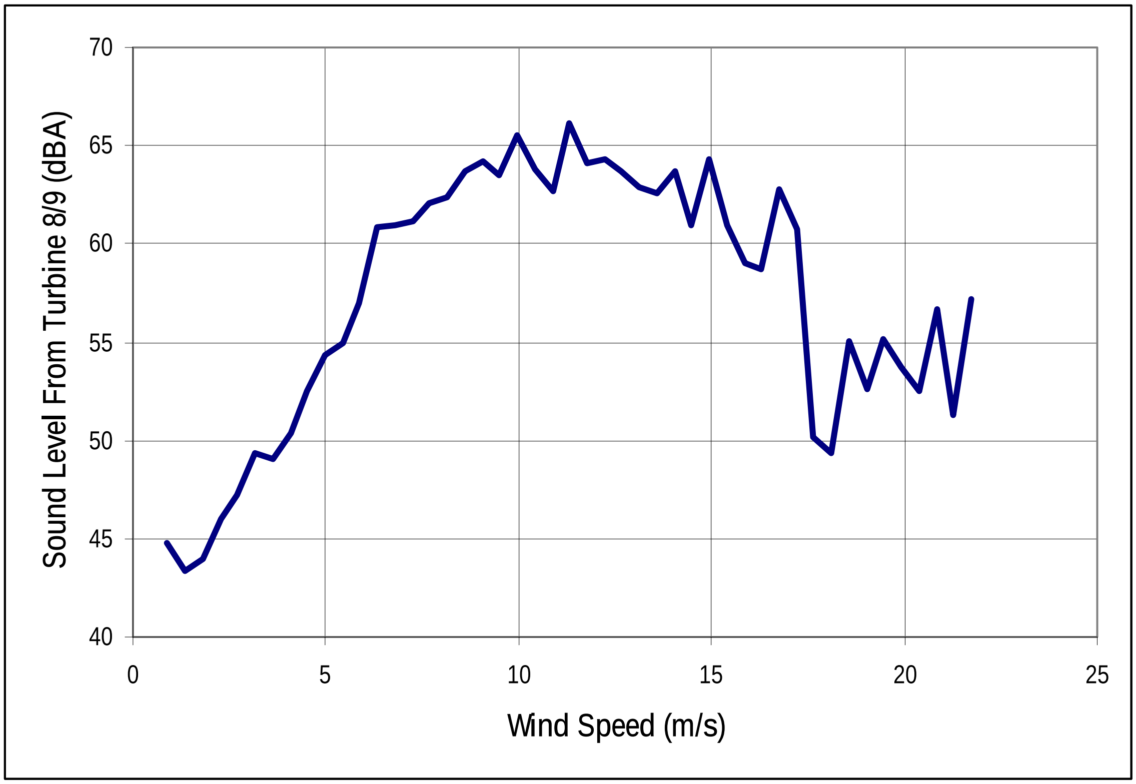
There are eleven Green Mountain Power wind turbines to the north of the Eastern String in the town of Searsburg. These wind turbines have been operating there continuously since 1996. These wind turbines are part of the background noise in a portion of the study area, so it is important to understand how they may contribute to the overall noise environment once the Deerfield project is completed.

These existing turbines were manufactured by Zond Energy Systems. They have a single rotational speed. That is, they revolve at approximately 29 rpm above a certain minimum wind speed. Each turbine begins to generate power in winds above 10 mph and its rated output of 550 kW in winds of 30-65 mph. Above about 65 mph, the turbines are programmed to shut down by either pitching their blades or yawing parallel to the wind direction. At low wind speeds, the hub will rotate at a slower rotational velocity, while the turbine is not generating any power.

This is illustrated by looking at sound level measurements taken at the existing turbines between December 1 and December 5, 2005. If we sort the results by wind speed, as shown in Figure 17, the sound emissions from the turbines gradually increase by 2.4 dBA for each meter/second (m/s) (2.2 mph) of wind speed to a maximum sound level at 10 to 11 m/s (22.4 to 24.6 mph). The sound levels are relatively constant (within about 5 dBA) between 6 and 17 m/s (13.4 and 38.0 mph). Above 17 m/s, the turbine blades have begun to pitch to prevent damage.

Since the turbine operates at a single rotational speed, sound levels from the existing Zond turbines are relatively constant. Most of the sound is created by air turbulence around the blades, the yaw motors, and the generator. In the past, malfunctions that created unusual sounds have been reported. These were fixed soon after the reports were made.

Figure 17: Sound Level 65 feet from Zond Turbines 8 and 9, as Measured 12/1 through 12/5, 2005, by Wind Speed



5. SOUND LEVELS PRODUCED BY WIND TURBINES

5.1. STANDARDS USED TO MEASURE WIND TURBINE SOUND

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

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

These standards give the sound power emission levels from a turbine, by wind speed and frequency. They also give a confidence interval. For example, a GE 1.5 MW turbine has a reference sound power level of 102.7 dBA ±2 dB at an 8 m/s (17.9 mph) hub height wind speed.

5.2. MANUFACTURER SOUND EMISSIONS ESTIMATES

A turbine manufacturer uses the above standards to provide their clients with a sound emission level and confidence intervals under typical operation. In addition to sound levels, the manufacturer publishes information quantifying pure tones, if any, from the turbines.

5.3. SOUND LEVELS USED IN MODELING

We evaluated several wind turbines for the modeling of the Deerfield Wind Project. These ranged from a GE 1.5 MW turbine to a Vestas 3.0 MW turbine. Turbines in the 1.5 to 3.0 MW rated output range vary in their sound emissions level. Data from the German Wind Energy Association indicate a range of sound power levels from about 100.5 dBA to 105 dBA for turbines of this size. We found other turbines that can have sound power levels as high as 111 dBA under certain conditions.

For the purposes of modeling, we chose the GE 1.5 MW sl turbine and a 72 meter hub height.[1] This has a sound power rating of 104 dBA at the highest wind speeds (9 m/s and above as measured at hub height). At 100 feet from the turbine base, this is roughly equivalent to a sound pressure level of 55 dBA. The sound emissions from the GE turbine drop off by about 2.5 dB for every 1 meter per second drop in wind speed.

6. SOUND FROM WIND TURBINES – SPECIAL ISSUES

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

6.1. METEOROLOGY

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

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

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[1] The sound levels from the turbines at the worst-case receivers will not change at a higher hub height such as 80 meters. This is because there is line of sight between the turbines and receivers, and no forest cover is assumed in the modeling.

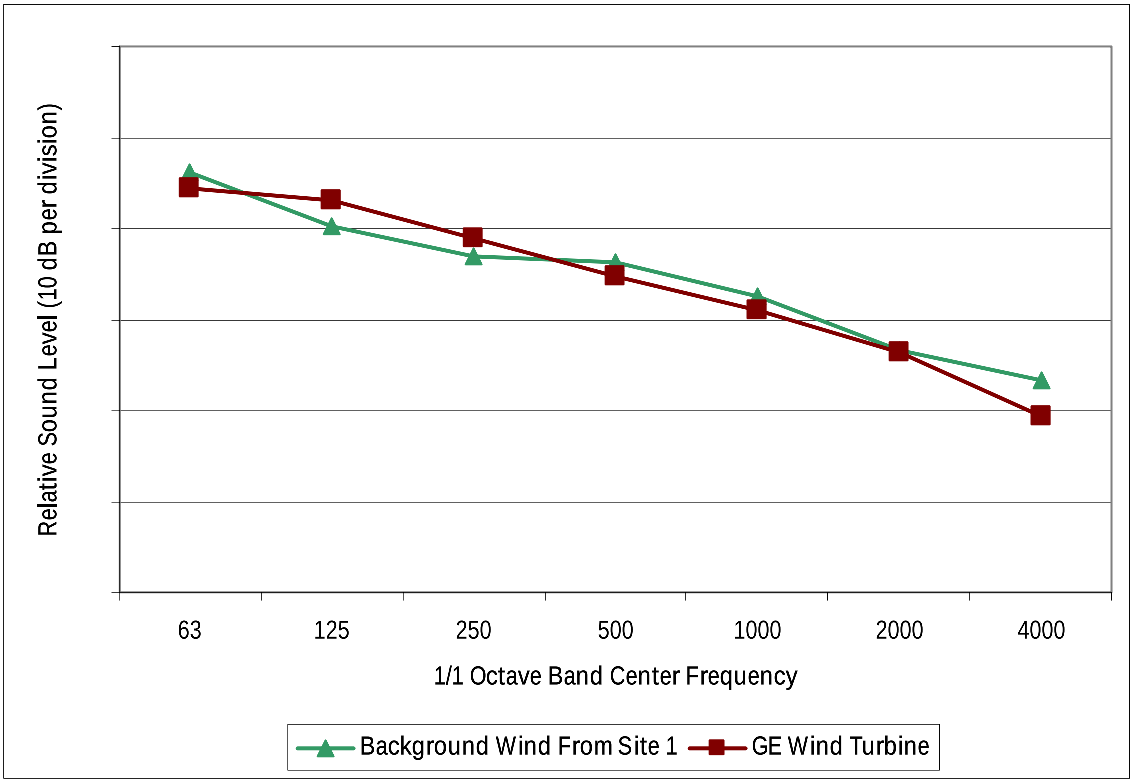
In general terms, sound propagates best under stable conditions with a strong inversion. This occurs during the night and is characterized by low winds.[1] In those situations, sound levels from wind turbines would be at their lowest. Wind speeds under very stable conditions (Stability Class G) are generally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

6.2. MASKING

As mentioned above, sound levels from wind turbines are a function of wind speed. Background sound is also a function of wind speed, i.e., the stronger the winds, the louder the resulting background sound. In areas that are covered by trees and bushes, such as is found in this region, the effect is amplified. Combined with the fact that the frequency spectrum from wind is very similar to the frequency spectra from a wind turbine, the sound from a wind turbine is easily masked by wind noise at downwind receivers. Figure 18 compares the sound spectrum measured at Site 1 during a 20 to 26 mph wind event on the ridge to the sound spectrum from a GE 1.5 MW wind turbine. As shown, the shapes of the spectra are very similar.

[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 18: Comparison of Frequency Spectra from Wind and Wind Turbine

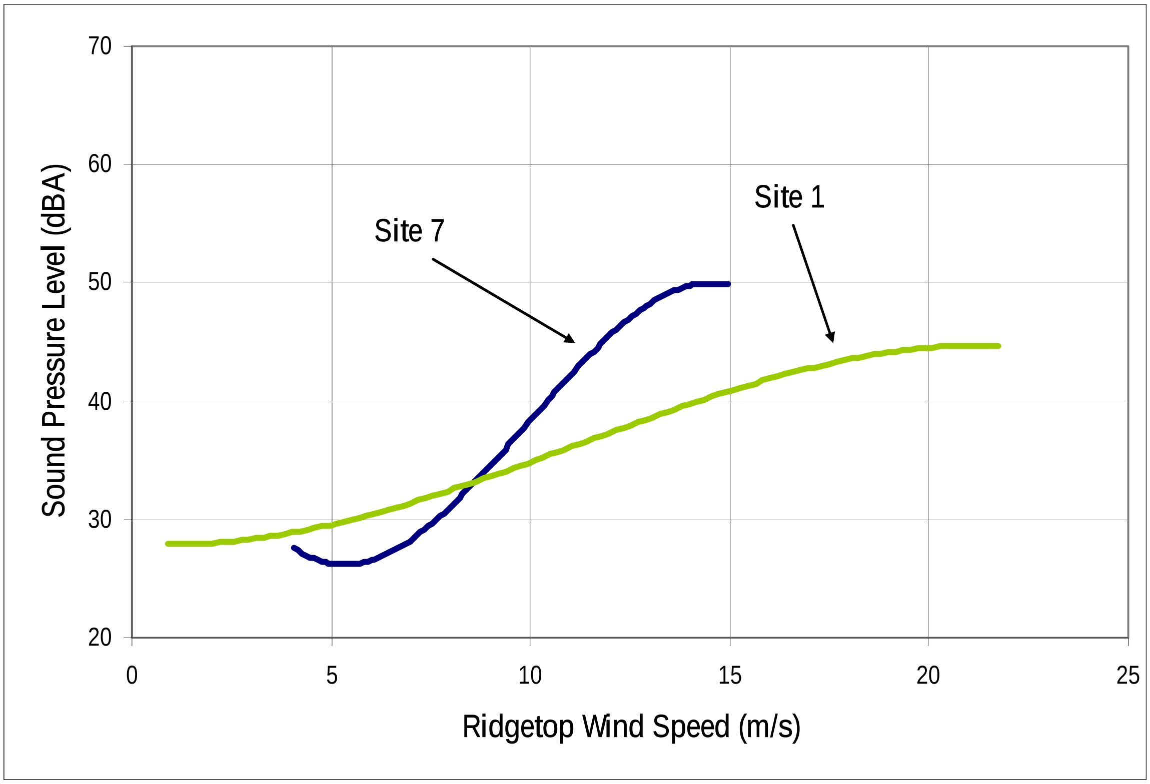


It is important to point out that while winds may be blowing on top of the ridge where the turbines are located, there may be little or no wind down in the valley. This is due to the fact that winds are lighter on the leeward side of a ridge and that the "roughness" of forest cover slows surface winds.

To confirm this, we conducted a correlation of wind speed on the ridge with sound levels at various measurement sites. We found that in each case, sound levels in the valley were correlated with wind speed on the ridge. However, we also found that ambient sound levels in the valley do not start to rise until the wind speeds on the ridge reach about 5 to 7 meter per second (Figure 19).

At the point at which winds are blowing with relatively low speeds on the ridge, but not in the valley, the wind turbines would be most audible. The turbines would be operating at low to medium speeds and will have proportionally lower sound emissions.

Figure 19: Background Sound Levels by Ridgeline Wind Speed at Sites 1 and 7



6.3. INFRASOUND AND LOW FREQUENCY SOUND

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

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

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

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

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

7. SOUND MODELING

7.1. MODELING SOFTWARE

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

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

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

A 25 meter by 25 meter grid of modeled receivers was set up covering 12,900 acres (20 square miles) around the site. A receiver is a point on the ground at which the computer model calculates a sound level. In addition, discrete receivers were placed at all residential homes using the Vermont Emergency 911 database. In an effort to be conservative, we excluded sound attenuation from forest cover. The model included the 11 existing turbines at a height of 40 meters above ground and the 24 proposed turbines at 72 meters above the ground.

Details of the modeling input assumptions are shown in Appendix A.

7.2. MODELING RESULTS

We modeled several different scenarios to quantify sound levels from the project:

1) The proposed Deerfield wind turbines only, assuming all 24 are operating at their highest rated sound power. Note that 2 dB was added to the rated sound power of 104 dBA to account for the 95% confidence interval of the manufacturers data.

2) The existing GMP wind turbines only, assuming all 11 are operating under the highest sound emissions derived from the recent monitoring data.

3) The proposed Deerfield and GMP wind turbines, all operating at the highest rated sound emission level.
4) The change in sound levels, comparing the existing condition, with the GMP turbines and background traffic, to the build condition.
5) The wind turbines operating under actual conditions monitored in the field.

7.2.1. Modeling under maximum rated sound power

As described above, we modeled the existing GMP and proposed Deerfield wind turbines using their maximum rated sound power level[1] under a moderate nighttime inversion with winds blowing from each wind turbine to each receiver.

Table 1 shows the sound powers of each that were used in the modeling with 1/1 octave band center frequencies represented. Overall, the proposed turbines from General Electric (GE) would be quieter than the turbines already installed at the GMP Searsburg facility.

Table 4: Sound Power (Lw) of Existing and Proposed Turbines Assumed in Modeling

	Sound Power Level by 1/1 Octave Band (in dB)									Total	Total
Turbine	31.5	63	125	250	500	1000	2000	4000	8000	In dB	in dBA
Existing Zond turbines	120	112	109	107	104	103	100	95.3	88.4	121	108
GE Turbine with 2 dBA addition		87.1	96.0	99.2	100.6	99.9	96.5	89.3	80.1	117	106

Four scenarios were modeled using the ISO standard and are representative of the levels that would be expected with a moderate wind blowing from the source to the receiver under a moderate nighttime temperature inversion. In the first scenario, only the proposed turbines are included. The results of this modeling are shown in Figure 20. The figure shows several discrete modeled receivers as circles colored black and yellow. These receivers include the closest homes to the project, representative residences, and backcountry areas to the west and south of the project. The blue dots in the figure are the wind turbines. The figure is color coded conforming to the modeled sound levels from the wind turbines, where red is the highest sound levels and light green is the lowest. As shown in sound level at the closest home due to the proposed Deerfield wind turbines is 41 dBA.

In the second scenario, only the existing turbines are included. The results of this modeling are shown in Figure 21. The sound level at the closest home due to the existing GMP Searsburg wind turbines is 42 dBA.

The third scenario includes both the existing and proposed turbines. As shown in Figure 22, the highest sound level modeled at a home is just under 45 dBA.

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[1] Note that there are some circumstances in the winter where ice can form on the wind turbine blades, creating higher levels of turbulence noise. These events are expected to occur only a few times during a typical winter and are of short duration.

The last scenario shows the difference between the no-build and build sound levels. As opposed to the latter three scenarios, this includes background equivalent average daily sound levels from traffic on VT Routes 8 and 9. Given that this is a 24-hour average, it implicitly and conservatively assumes that the sound levels from the wind turbines would be affected by moderate nighttime inversions over the entire period. The results are shown in Figure 23. The modeling shows that there is very little change in sound levels due to the proposed project at residences along VT 8 and VT 9.

The modeling demonstrates that the project, even when combined with the sound from the existing GMP Searsburg turbines, can meet the noise standard of 45 dBA (night) at all nearby residences during times when windows would typically be open, and under the meteorological conditions specified in the ISO 9613-2 standard.

Figure 20: Sound Levels from the Proposed Deerfield Wind Project

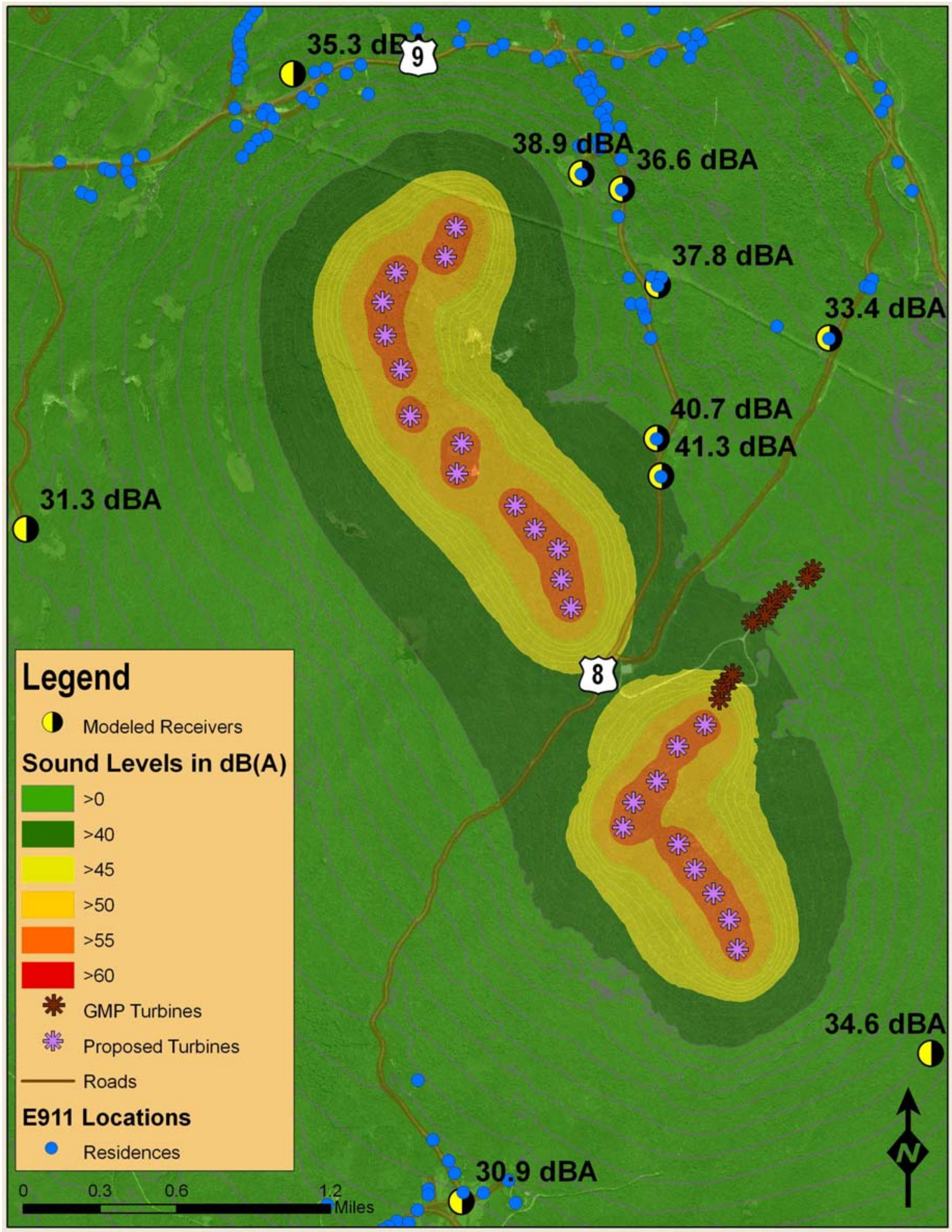


Figure 21: Sound Levels from Existing GMP Searsburg Turbines Only

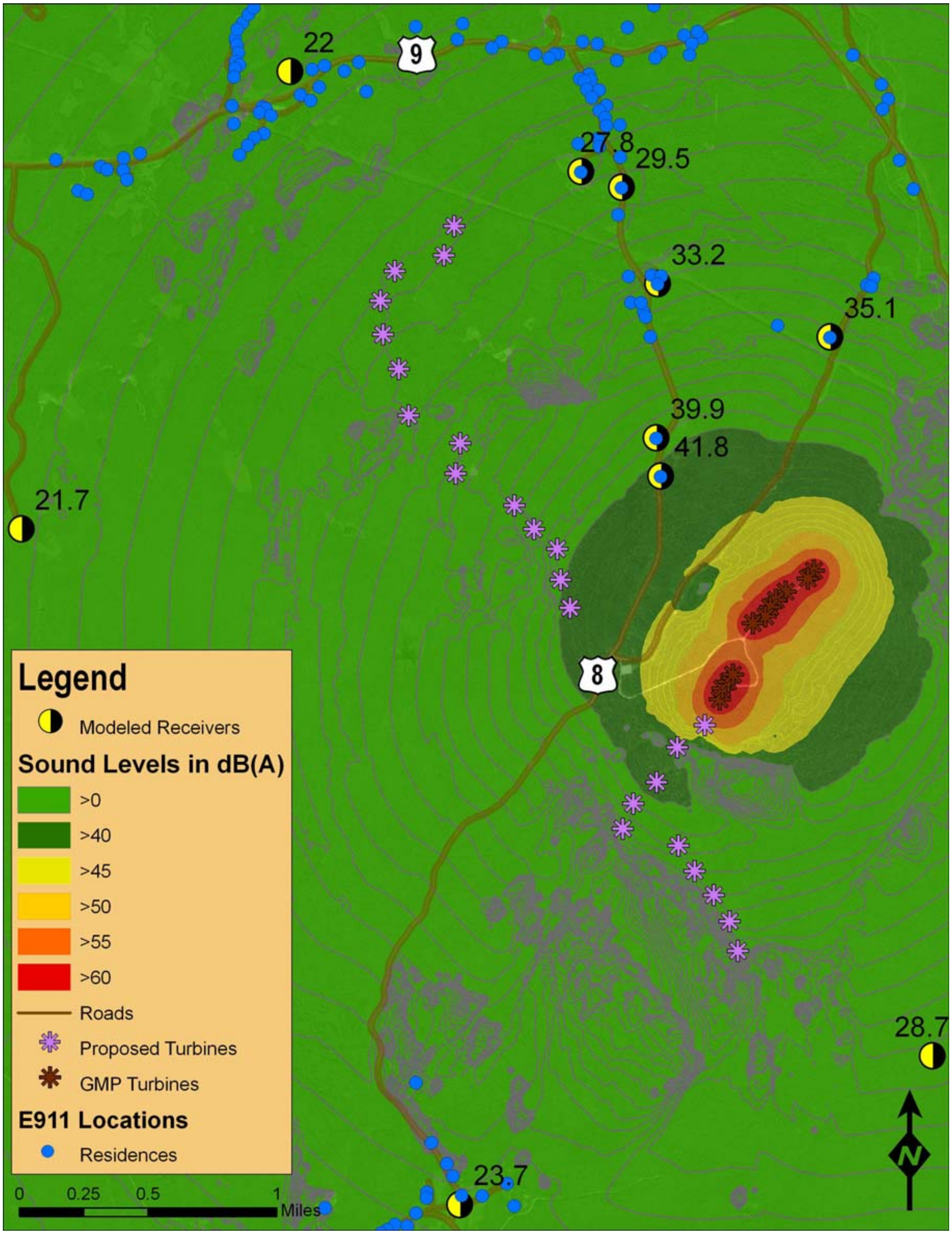


Figure 22: Sound Levels from Deerfield Wind Project and GMP Searsburg Facility Combined

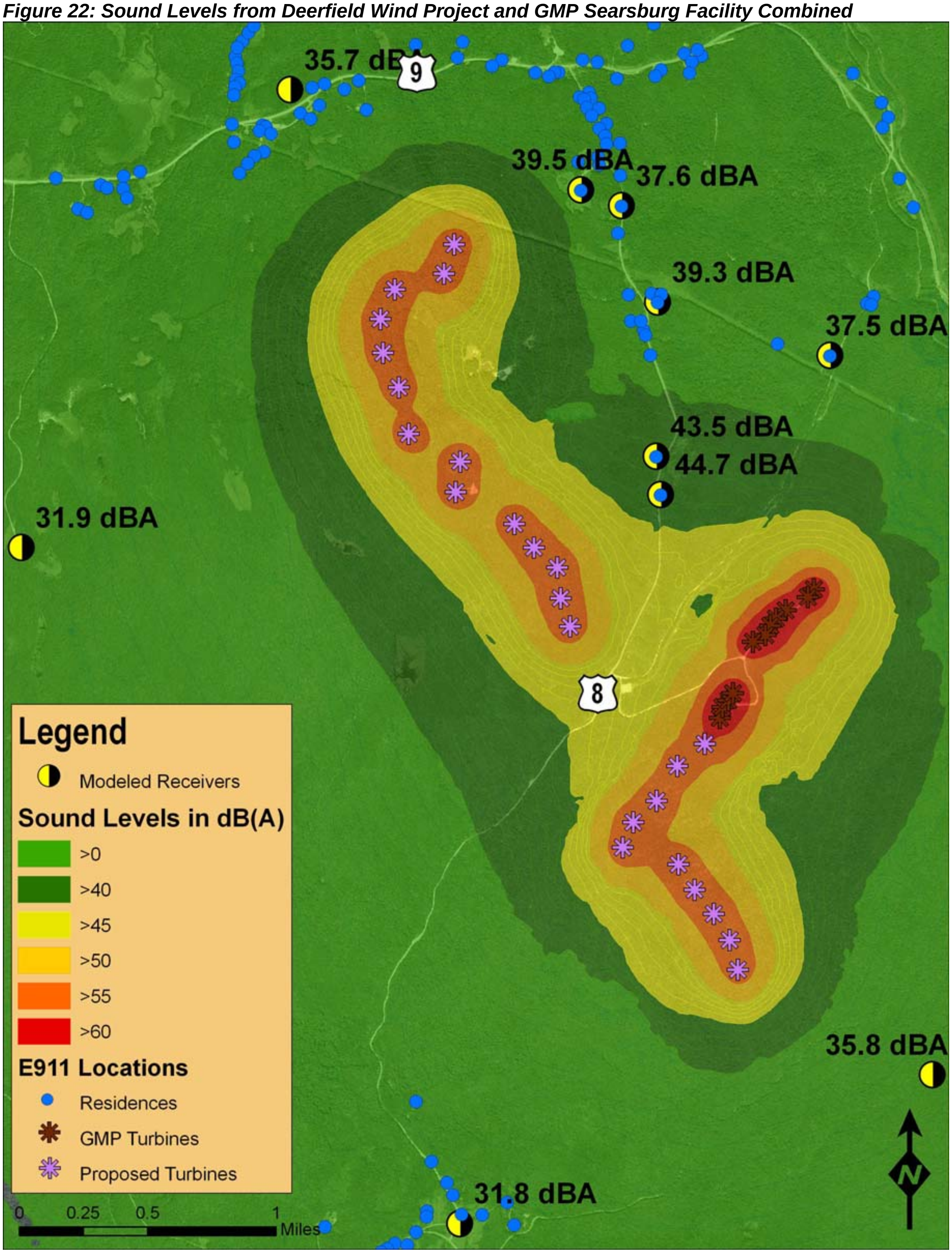
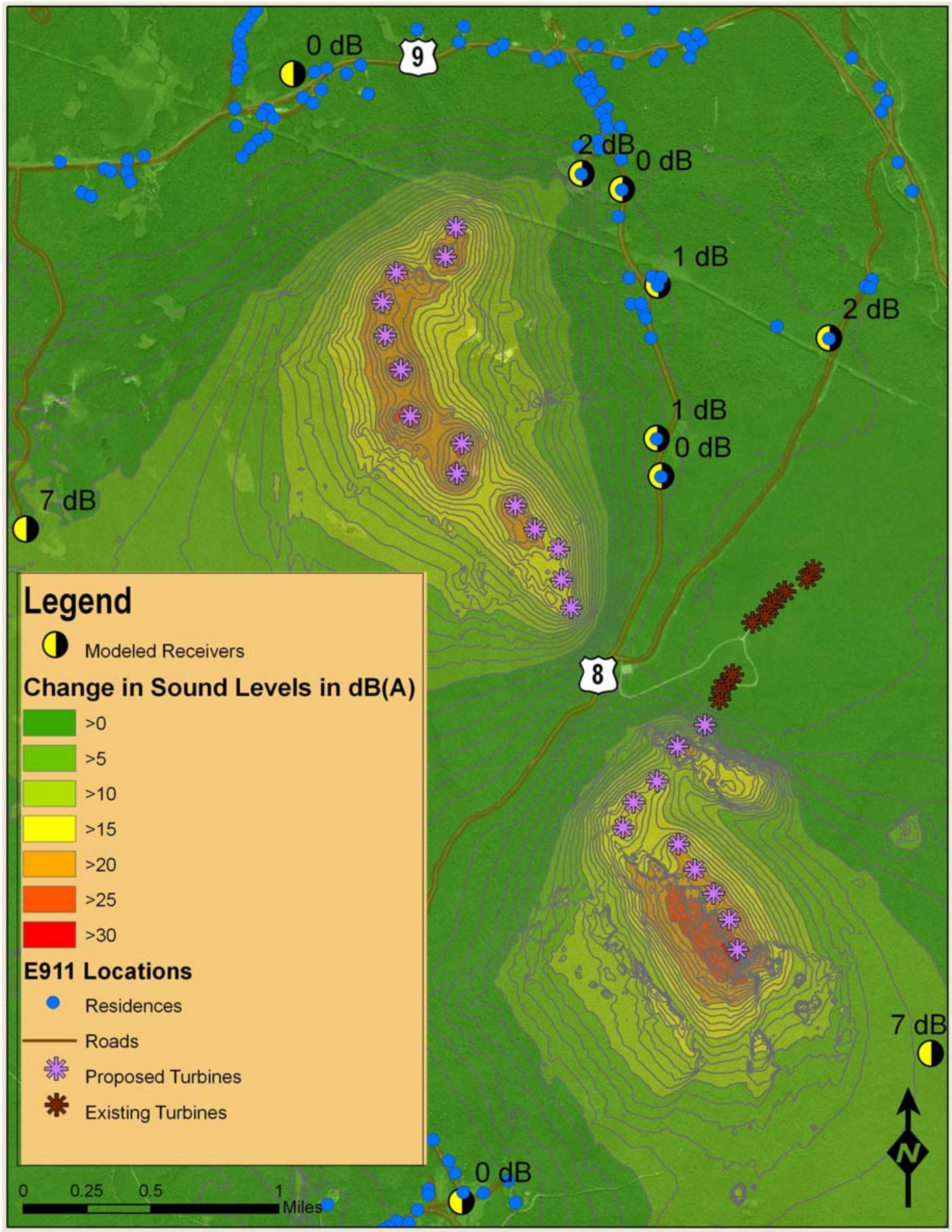


Figure 23: Difference between No Build and Build Sound Levels



7.2.2. Effect of changes to hub height

The number and location of the turbines has an effect on the sound levels experienced at each receiver. For example, for every doubling of the number of turbines, sound levels would increase by about 3 dB. For every halving, sound levels would decrease by 3 dB. For every doubling of distance between the source and receiver, sound levels would decrease by about 6 dB. Therefore, the hub height would have little impact on the modeling results given the relatively large distance between the wind turbines and the receivers.

7.2.3. Frequency analysis using one year of meteorological data

Wind turbines operate at all types of wind speeds and wind directions, not just those assumed in the ISO 9613-2 standard. The ISO standard is valid for moderate nighttime inversions, with winds blowing from the source to the receiver, and wind speeds of 1 to 4 m/s as measured up to 11 meters above the ground. The turbines will operate outside this range. That is, during the daytime, when winds are blowing away from receivers, under higher wind speeds, and under more severe inversions. Some of these factors will increase perceived noise from the wind turbines and some will decrease it.

To evaluate the likelihood of sound levels exceeding a nighttime sleep disturbance level of 45 dBA $Leq_{8)}$, we obtained one year of hourly wind speed and wind direction data from the ridgetop meteorological towers in Searsburg. We then used this data to calculate stability class for each hour and ran the Cadna A model at the receiver that has the greatest impact for stability classes, wind speeds, and wind directions that were not covered by the ISO standard, but estimated using the Concawe algorithm.[1] We then adjusted the sound output from the wind turbine based on the actual wind speed and assuming a ± 2 dB confidence interval about the rated sound power level. Finally, we estimated the sound level at this worst-case home for each hour of the year.

Assuming these conditions, our results show:

1) With the Deerfield turbines operating only, there would be no hours of the year that exceed 45 dBA
2) With the combined operation of Deerfield and GMP/Searsburg, there would be a 99% probability that any hour would be at or below 45 dBA.
3) Of the hours that would exceed 45 dBA, none would occur during warm-weather months (May to September)
3) With the combined operation, there would be no period during which the average 8-hour nighttime sound level would exceed 45 dBA.

This analysis confirms that there is a very high probability that the 45 dBA $Leq_{(8)}$ standard will not be exceeded. In fact, under the above scenario, there were no periods in which the 45 dBA $Leq_{(8)}$

[1] "The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighbouring Communities," CONCOWE Report no 4/81, May, 1981.

standard was excceded. While there is a small but finite chance nighttime hourly sound levels may exceed 45 dBA, this would not occur during warm weather months when windows are more likely to be open.

7.3. LOW FREQUENCY SOUND

At the residence with the highest overall sound levels from the turbines, the highest sound level at a frequency of 31.5 Hz is approximately 62 dB and at a frequency of 63 Hz it is approximately 54 dB.[1] (These are unweighted sound pressure levels.) These are below the *interior* sound level of 65 to 70 dB that is likely to create moderately perceptible building vibrations.

8. CONSTRUCTION IMPACTS AND OTHER NOISE SOURCES

8.1. 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 5 along with the approximate maximum sound pressure levels at 50 feet (15.2 m) and 2,600 feet (800 m). Sound levels at 2,600 feet are likely to be lower due to the presence of dense vegetation between the construction areas and the nearest residences.

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[1] GE does not report sound power levels for its turbine in the 31.5 Hz octave band. Therefore, we calculated the levels at this octave band by assuming a similar spectral shape as the Zond turbines at Searsburg. That is, on an A-weighted basis, the 31.5 Hz octave band is 5 dB less than the 63 Hz octave band as perceived at the receiver.

Table 5: Maximum Sound Levels from Various Construction Equipment

EQUIPMENT	SOUND PRESSURE LEVEL AT 50 FEET (dBA)	SOUND PRESSURE LEVEL AT 2,600 FEET (dBA)[1]
M-250 Liftcrane	82.5	42
2250 S3 Liftcrane	78	37
Excavator	83	44
Dump truck being loaded	86	49
Dump truck at 25 mph accelerating	76	37
Tractor trailer at 25 mph accelerating	80	42
Concrete truck	81	40
Bulldozer	85	44
Rock drill	100	54
Loader	80	38
Backhoe	80	39
Chipper	96	58

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 be limited to the hours of 7 am and 7 pm 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.

8.2. OTHER NOISE SOURCES

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

1) Transformers – The electrical equipment has not yet been specified. There may be a transformer at the base of each turbine, similar to the existing site. The high side voltage is likely to be 34.5 kV. At the existing GMP substation or at a new one at the northwest of the project area, there will be another 34.5 kV/69 kV transformer. Transformer noise emissions are subject to NEMA standards. The transformers at the base of the turbines will likely be inaudible outside of the project area. The noise from the step-up transformer will likely also be insignificant. However, this will be addressed as a design

[1] Assumes hard ground around construction site, and ISO 9614-2 propagation with no vegetation reduction.

detail closer to construction. That is, the transformers will be designed to meet a 45 dBA limit at the nearest residences.

2) Transmission lines – The transmission lines associated with the project are 34.5 and 69 kV. The voltage of these lines is too low to generate any significant corona noise and will likely be inaudible next to the lines.

3) Maintenance and operations – The project expects roughly two round trips each day to the Eastern and two to the Western Project Areas. The site will be accessed via a pickup truck or off-road vehicle in adverse conditions. This level of increased traffic will not create any adverse sound impacts especially considering the proximity of the nearest residences to state highways.

9. RECOMMENDATIONS

Based on the above analysis, we recommend:

1) Selecting turbines with a sound power level of 106 dBA or less or demonstrating that the final number and configuration of the turbines will not exceed 45 dBA, averaged over the night, at the nearest residence.

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

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

10. SUMMARY AND CONCLUSIONS

Wind turbines are proposed for two related sites in Searsburg and Readsboro, Vermont. The sites are adjacent to existing turbines installed in the late 1990s.

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

1) An appropriate standard to apply to this project would be the World Health Organization sleep disturbance criteria of 45 dBA averaged over the night and the WHO's moderate annoyance criteria of 50 dBA averaged over the remainder of the day, during summer months when windows are likely to be open.

2) To meet this standard, the sound power level from each wind turbine (assuming 24 turbines) would need to be at or below 106 dBA at the maximum rated capacity. However, other combinations of sound power levels, wind turbine siting and changing the number of wind turbines can also achieve the same result.

3) The levels of low frequency sound will not create perceptible building vibration.

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

5) Major construction will take place during normal business hours. Aside from road construction, these activities will take place well away from the nearest residence and thus will have a minimal impact on noise levels.

6) Other sound sources include routine maintenance and transformers at the base of the turbines and at the substation. The routine maintenance and turbine transformers will not create significant noise. Transformer noise at the substation will be treated as a design detail when final specifications are available.

As a result, the Deerfield Wind Project can be constructed in such a way as to have no impact to health and no undue adverse impact on aesthetics.

APPENDIX A

CADNA MODELING PARAMETERS

Point Sources of Noise

Name	M.	ID	Result. PWL Day (dBA)	Result. PWL Night (dBA)	Lw / Li Type	Lw / Li Value	Correction Day dB(A)	Correction Night dB(A)	Direct.	Height (m)		Coordinates X (m)	Coordinates Y (m)	Coordinates Z (m)
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666105.9	4746829	940
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666124.7	4746885	940
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666163.7	4746939	933.91
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666193.4	4746980	925.39
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666697	4747636	887.9
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666658.1	4747586	892
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666525.8	4747496	886.13
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666469.1	4747459	892
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666416.2	4747398	897.71
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666398.4	4747340	898
EXISTING	~	x	107.6	107.6	Lw	zond3	0	0	(none)	40	r	666298.5	4747295	895.06
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	666015.5	4746665	996
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665843.4	4746527	966.33
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665713.6	4746308	976.35
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665566.6	4746174	976.92
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665501.5	4746017	981.59
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665848.9	4745910	1014
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665951.8	4745750	1014
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	666070.9	4745600	1014
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	666169.8	4745435	1008
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	666221.9	4745249	983.54
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665172.2	4747402	930.22
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665113	4747578	937.12
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	665092.3	4747771	948
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664945	4747897	947.43
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664822.9	4748044	947.66
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664455.6	4748245	955.87
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664485.6	4748436	956.28
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664162.2	4748609	920.22
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664101.6	4748902	939.09
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664002.5	4749117	939.86
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	663986.8	4749330	921.56
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664075.2	4749516	917.82
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664383	4749614	903.45
PROPOSEDTURBINES	~	p	106	106	Lw	ge	2	2	(none)	72	r	664448.2	4749799	910.2

Source Sound Power

Name	ID	Type	Oktave Spectrum (dB)												Source
			Weight.	31.5	63	125	250	500	1000	2000	4000	8000	A	lin	
Searsburg Turbine-Existing	zond3	Lw		119.9	112.3	109	106.7	103.6	102.7	100.3	95.3	88.4	107.6	121.2	
GE Turbine-Proposed	ge	Lw	A		85.1	94	97.2	98.6	97.9	94.5	87.3	78.1	104	114.8	

Receivers

Name	M.	Height		Coordinates		
				X	Y	Z
		(m)		(m)	(m)	(m)
s1		1.2	r	665737.7	4748227	719.95
s2		1.2	r	665709.5	4748465	738.25
s3	+	1.2	r	665237.2	4750137	763.2
s4		1.2	r	665716.8	4749432	736.22
s5	+	1.2	r	665492.1	4750037	729.83
s6	+	1.2	r	666795.9	4749099	580.32
s7	+	1.2	r	664480.7	4743654	547.2
Site 1		1.5	r	661738.3	4747893	665.96
Site 7		1.5	r	667436	4744588	710.91
Site 2		1.5	r	663418.7	4750764	685.27

Model Parameters

Parameter	Value
Lateral Deffraction	some Obj
Ground Attenuation over Barriers	Exclude
Obst within area source	do not shield
temperature (ºC)	10
Relative Humidity (%)	70
Foliage	None
Ground Attenuation	not spectral

Roads

Name	M.	ID	Lme		Count Data		Speed Limit	Gradient
			Day	Night	DTV	Str.class.	Auto	
			(dBA)	(dBA)			(km/h)	(%)
VT9		roads	65.5	58.2	4900	Federal Road	80	0
VT8		roads	57.2	49.8	720	Federal Road	80	0

Model switches for grids shown in Figures 20 through 23

Source Name	ID Expression	Scenario		
		No Build	Build	Roads
existing turbines	x	On	On	Off
proposed turbines	p	Off	On	Off
roads	roads	Off	Off	On

Figures 20 through 23 are calculated by adding or subtracting the above Scenario grids

Figure 20 is Scenario "Build" - Scenario "No Build"
Figure 21 is Scenario "No Build"
Figure 22 is Scenario "Build"
Figure 23 is Scenario "Roads" + Scenario "Build" - Scenario "No Build"