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**REPORT NO. 1762-112305-D**

DATE OF ISSUE: MARCH 27, 2006

# ENVIRONMENTAL SOUND SURVEY AND NOISE IMPACT ASSESSMENT

## MARBLE RIVER WIND FARM PROJECT

CLINTON AND ELLENBURG, NY

PREPARED FOR:

**Marble River Wind Farm, LLC**


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# 1.0 INTRODUCTION

Hessler Associates, Inc. has been retained by Marble River Wind Farm, LLC to evaluate potential noise impacts from the proposed Marble River Wind Farm Project on residents in the vicinity of the proposed project area. At the present time approximately 109 wind turbine generators, each with a nominal output of 2 MW, are planned for installation over an area covering 19,310 acres within the towns of Clinton and Ellenburg, NY.

The study essentially consisted of two phases: a background sound level survey and a computer modeling analysis of future turbine sound levels. The field survey of existing sound levels at the site was necessary to determine how much natural masking noise there might be - as a function of wind speed - at the nearest residences to the project. The relevance of this is that high levels of background noise due to wind induced natural sounds, such as tree rustle, would reduce or preclude the audibility of the wind farm while low levels of natural noise would permit operational noise from the turbines to be more readily perceptible. For a broadband, atonal noise source, such as the proposed wind turbines, the audibility of and potential impact from the noise is a function of how much, if at all, it exceeds the pre-existing background level.

In the second phase of the project an analytical noise model of the project was developed to predict the sound level contours associated with the project over the site area and thereby determine if any nearby residents might be able to hear the turbines above the pre-existing background level and, if so, what the likelihood of an adverse impact might be.

The primary basis for evaluating potential project noise is the Program Policy *Assessing and Mitigating Noise Impacts* issued by the New York State Department of Environmental Conservation (NYCDEC), Feb. 2001. This assessment procedure is incremental in the sense that a simplified “first level noise impact evaluation” is initially carried out to determine if any residential receptors *may* experience a noticeable increase in sound level followed by a more in depth “second level noise impact evaluation” if any sensitive receptor receptors are identified as being possibly affected. The procedure essentially defines a cumulative increase in overall sound level of 6 dBA as the threshold between no significant impact and a potentially adverse impact.

# 2.0 BACKGROUND SOUND LEVEL SURVEY

## 2.1 OBJECTIVE AND MEASUREMENT QUANTITIES

The purpose of the survey was to determine what minimum environmental sound levels are consistently present and available at the nearest potentially sensitive receptors to mask or obscure potential noise from the project. A number of statistical sound levels were measured in consecutive 1 hour intervals over the entire survey. Of these, the average (Leq) and residual (L90) levels are the most meaningful.

The average, or equivalent energy sound level (Leq), is literally the average sound level over each measurement interval. While useful and informative, this measure needs to be viewed with some caution when the survey objective is to quantify the mean minimum background level - since it can, and often is, influenced by noise events that are relatively loud in magnitude but short in duration, such as a car passing close by the monitoring position. For example, one such event can significantly elevate the average level over a short to moderate integration period and yield a result that may well be unrepresentative of the quieter times during the sample.

In order to avoid this pitfall, the residual, or L90, statistical sound level is commonly used to quantify background sound levels. The L90 is the sound level exceeded during 90% of the measurement interval and has the quality of filtering out sporadic, short-duration noise events thereby capturing the quiet lulls between such events. It is this consistently present "background" level that forms a conservative basis for evaluating the audibility of a new source. If the source does not exceed this relatively low background threshold by more than about 3 to 5 dBA it is safe to say that the source will not be perceived as a noise nuisance - if it is even audible at all.

An additional factor that is important in establishing the minimum background sound level available to mask potential wind turbine noise is the natural sound generated by the wind itself. Wind turbines only operate and produce noise when the wind exceeds a minimum cut-in speed of about 4 m/s (measured at a reference elevation of 10 m above ground level). Turbine sound levels increase with wind speed up to about 8 m/s when the sound produced reaches a maximum and no longer increases with wind speed. Consequently, at moderate to high speeds when turbine noise is most significant the level of natural masking noise is normally also relatively high due to tree or grass rustle thus reducing the perceptibility of the turbines. In order to quantify this effect wind speed and direction were measured over the entire sound level survey period at a met tower near the center of the turbine array for later correlation to the sound data.

## 2.2 SITE DESCRIPTION AND MEASUREMENT POSITIONS

The proposed Marble River Wind Farm is spread out over a very large area covering almost 50 square miles between the town of Ellenburg and the Canadian border in Clinton County, NY. From a noise impact perspective the site consists of two distinct areas: the eastern half of the gross project area is forested and contains few permanent residential dwellings while the western half consists of small to moderate sized farms interspersed with individual residences on smaller tracts of land. The distribution and density of residential dwellings over the western half of the site is more or less uniform except for a small area of greater density around the locality of Churubusco.

Because there are no potentially sensitive receptors close to any of the proposed turbine locations in the eastern half of the site the field survey and subsequent analysis essentially focuses exclusively on the populated western half of the project area.

The topography of the site area and its surroundings is essentially flat, meaning that there are no significant ridges, ravines or mountains that would have a meaningful impact on sound propagation from any given turbine to any given receptor point.

In terms of vegetation, the western part of the site is comprised mostly of open farm fields and pasture lands intermixed with moderately extensive wooded areas. Some homes have several trees immediately around them but are otherwise located in generally open areas. Most of the deciduous trees had a few leaves at the beginning of the survey and were largely bare by the end of the survey.

The proposed wind turbine locations in the western half of the site are distributed in a fairly uniform manner and are interspersed among and between the residences.

Because of the homogeneous nature of the populated portion of the site, background sound level measurement locations were chosen to evenly cover and represent the entire area as shown in Figure 2.2.1 on the following page. The more usual approach of identifying and measuring at those residences closest to the project and most likely to be impacted was completely impractical at this site.

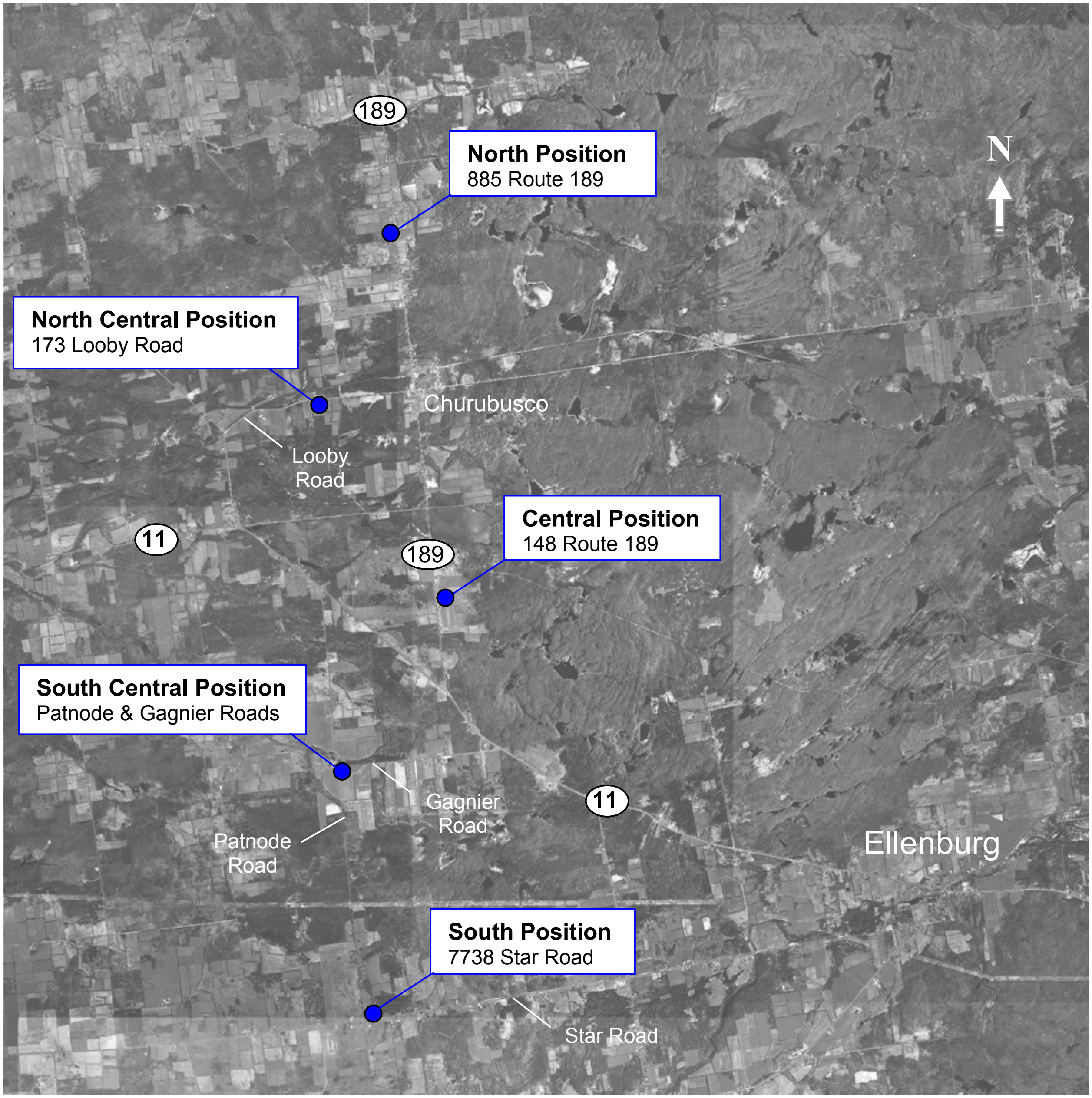


**Figure 2.2.1**
*Aerial Photograph of Site Area Showing Background Sound Level Monitoring Locations*

Each location is close to a residence considered typical for the area in terms of proximity to local roads and exposure to the prevailing sources of normal background noise, which are largely confined to wind induced sounds, farm machinery and very distant, indistinct traffic noise. The specific positions are listed below. Photographs of the locations are also shown.

**North Position (N) – 885 Route 189**
Rear yard of house between garage and trailer

**Figure 2.2.2** *North Location*

**North Central Position (NC) – 173 Looby Road**
Side yard of house near driveway. Monitors mounted on a utility pole on the edge of an open field near a few small trees.

**Figure 2.2.3** *North Central Location*

**Central Position (C) – 148 Route 189 (Clookey Farm)**
In large open field roughly 100 ft. from Churubusco 5 met tower.

**Figure 2.2.4** *Central Location*

**South Central Position (SC) – Corner of Patnode and Gagnier Roads (Buettner Farm)**
Behind house near rear deck adjacent to several trees and bushes.

**Figure 2.2.5** *South Central Monitor Location*

**South Position (S) – 7738 Star Road**
Side yard of house. Clear exposure to Star Road some 60 ft. away.

**Figure 2.2.6** *South Monitor Location*

## 2.3 INSTRUMENTATION AND SURVEY DURATION

Several types of noise monitoring equipment were used for the survey. The principal instruments, deployed at the N, C, SC and S positions were Norsonic Model 118, ANSI Type 1 precision integrating octave band analyzers, which were set to measure sound levels in full octave bands. Rion Model NL-06 and NL-32 ANSI Type 2 A-weighted sound level meters were used at the North Central position. All equipment was operated by large format 12 or 6 V batteries. Unfortunately, the Central position meter did not run beyond 3 a.m. on 10/20 due to a battery problem.

The Norsonic units were fitted with Type 1211, 90 degree incidence, environmental microphones with double windscreens. The Rion microphones were also protected from rain by waterproof double windscreens. All microphones were located on masts or booms 2 m above local ground level. The instrumentation was enclosed in plastic cases either resting on the ground or, in the case of the Rion equipment, attached to a pole.

The survey was carried out over roughly a 3 week period from October 13 to November 1, 2005.

All equipment was field calibrated at the beginning of the survey and again at the end of the survey. The maximum observed calibration drift was +1.3 dB at the North position. All other equipment showed a divergence of between 0 and 0.3 dB.

## 2.4 SURVEY WEATHER CONDITIONS

The weather conditions during the survey were not ideal with many days of overcast skies, light to moderate rain and even a significant snow event. In spite of, or perhaps because of this generally inclement weather a good sampling of wind speeds over the full range of interest were observed; i.e. from the turbine cut in speed up to the speed necessary to rotate the turbine blades at maximum rpm.

The general weather parameters of temperature and barometric pressure for the survey period, as observed in Plattsburgh, NY, are illustrated in the graphs below.

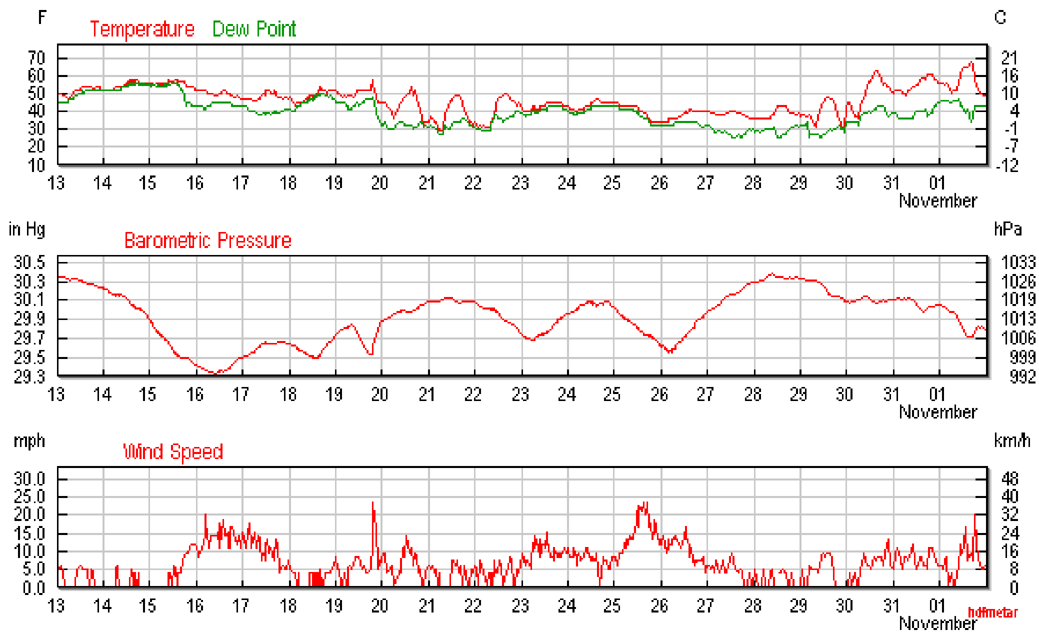


**Figure 2.4.1** *General Weather Data for the Survey Period as Observed in Plattsburgh, NY*

The specific periods of precipitation are tabulated below.

**Table 2.4.1** *Precipitation During the Survey Period (at Plattsburgh)*

| Date | Precip. Total, in. | Time(s) | Description |
|---|---|---|---|
| Oct. 13 | .23 | 7 a.m. – 8 p.m. | Lt. Rain |
| Oct. 14 | 1.17 | 3 a.m. – 4 a.m.<br>4 a.m. – 5 a.m.<br>7 a.m. – 12 m. | Lt. Rain<br>Hvy. Rain<br>Lt. Rain |
| Oct. 15 | .71 | 12 m. – 1 p.m.<br>2 p.m. – 3 p.m. | Lt. Rain<br>Hvy. Rain |
| Oct. 16 | .39 | 8 a.m. – 12 m. | Lt. Rain |
| Oct. 17 | .04 | 12 m. – 3 a.m. | Lt. Rain |
| Oct. 18 | .14 | 5 a.m. – 7 p.m. | Lt. Rain Intermittent |
| Oct. 19 | .04 | 7 p.m. – 8 p.m. | Lt. Rain |
| Oct. 20 | - | | |
| Oct. 21 | - | | |
| Oct. 22 | .18 | 8 p.m. – 12 m. | Lt. Rain |
| Oct. 23 | .71 | 12 m. – 12 m. | Lt. Rain |
| Oct. 24 | .13 | 12 m. – 3 a.m.<br>5 p.m. to 6 p.m. | Lt. Rain<br>Lt. Rain |
| Oct. 25 | 1.43 | 12 m. – 6 p.m.<br>6 p.m. – 12 m. | Lt. Rain<br>Snow |
| Oct. 26 | .21 | 12 m. – 12 n. | Snow (Total Accum. 12") |

| Date | Precip. Total, in. | Time(s) | Description |
|---|---|---|---|
| Oct. 27 | - | | |
| Oct. 28 | - | | |
| Oct. 29 | - | | |
| Oct. 30 | - | | |
| Oct. 31 | - | | |
| Nov. 1 | - | | |

The wind speed at the site itself was measured at met tower immediately adjacent to the Central monitoring location on Route 189. Figure 2.4.2 below shows the hourly average wind speeds directly measured by the mast top anemometer at an elevation of 82 m above ground level (agl) and, for reference, the calculated average wind speed per IEC Standard 61400 at the standard normalization height of 10 m.

Also shown in the figure is the effective cut-in wind speed of the wind turbines at 10 m agl. For this particular 20 day period, the turbines would be off line about 20% of the time. No credit has been taken in the acoustical assessment for this fact since, when on, the turbines may operate for extended periods of time. Nevertheless, it is a positive factor unique to wind farms that when wind conditions are calm and ambient sound levels are at their lowest level there is no potentially intruding noise - whereas with any other type of power generator the facility would normally be operating during these tranquil times.

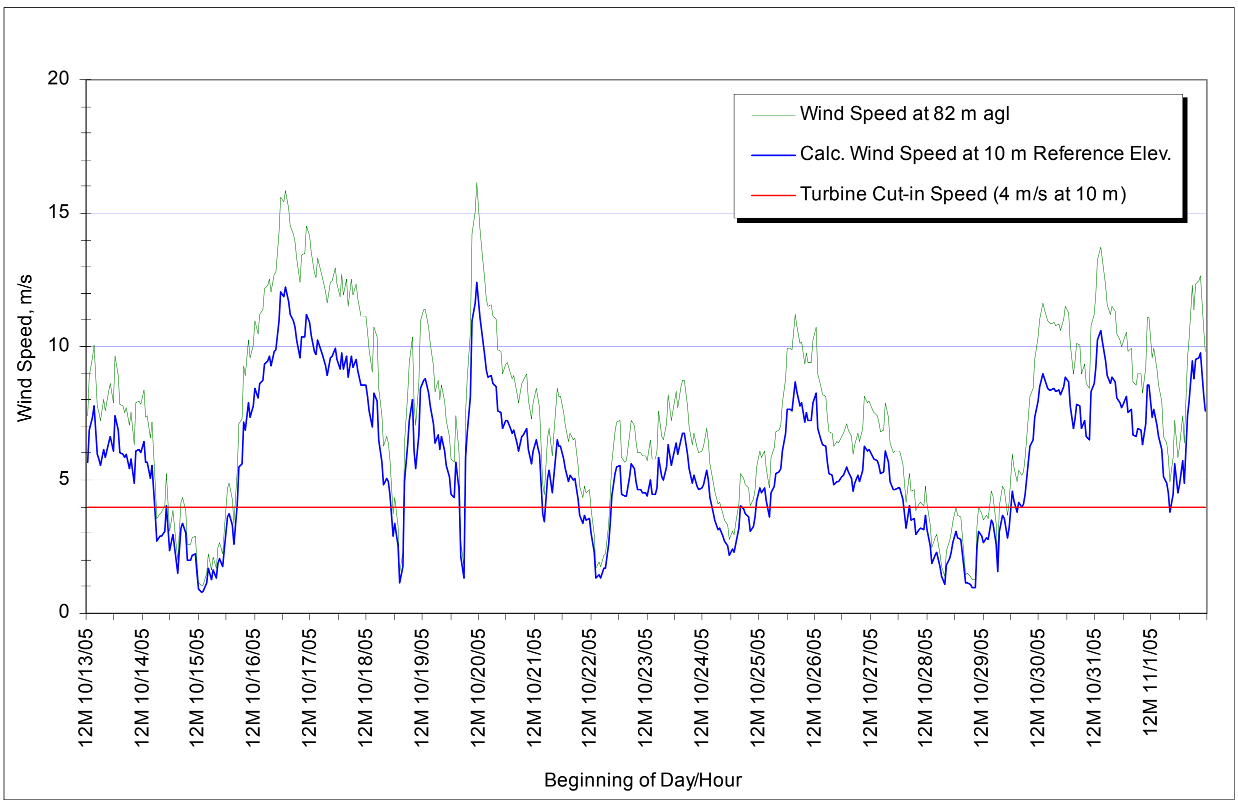


**Figure 2.4.2** *Wind Speed Measured at On-Site Met Tower (Churubusco 5)*

## 2.5 OVERALL SURVEY RESULTS

As discussed above in Section 2.1 the L90, or residual, sound level is a conservative measure of background sound levels in the sense that it filters out short-duration, sporadic noise events that cannot be relied upon to provide consistent and continual masking of potential turbine noise. This level represents the quiet lulls between all relatively short duration events, such as cars passing by or tractor activity in a neighboring field. The hourly L90 sound levels for all five positions are plotted below for the entire 20 day survey period.

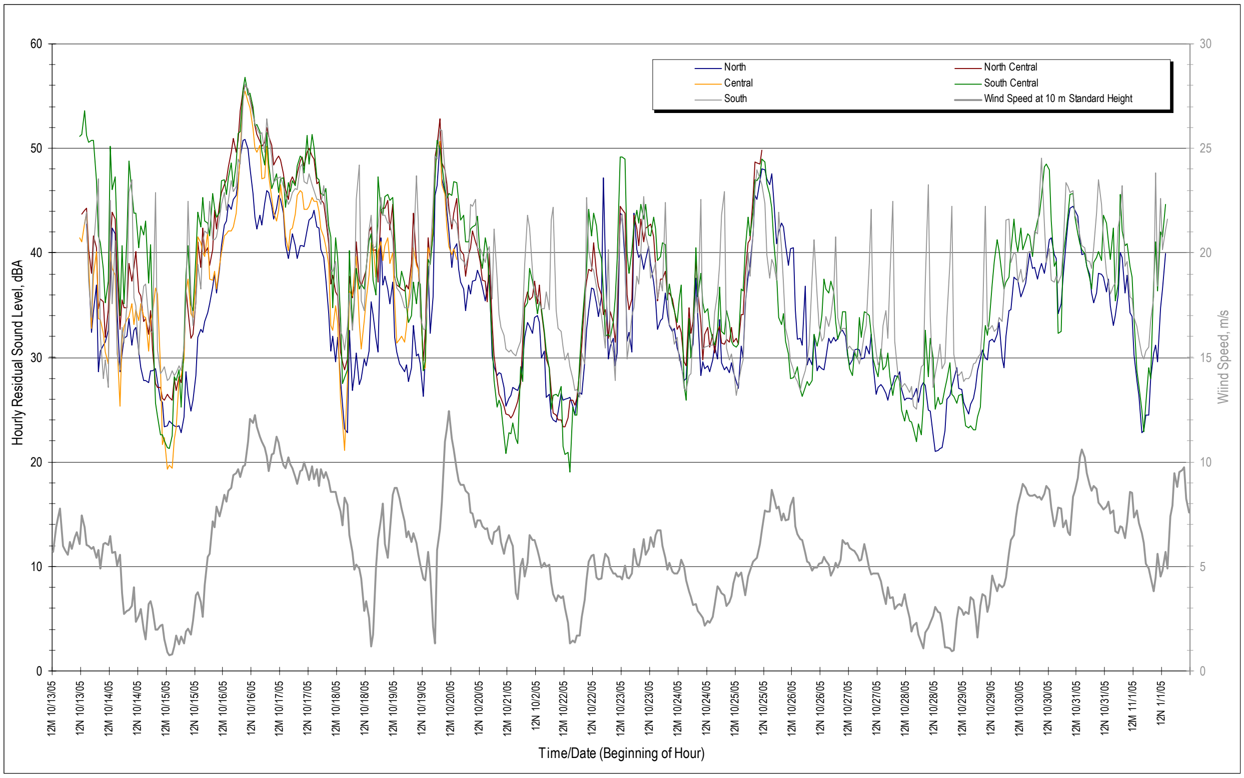


**Figure 2.5.1** *Hourly Sound Levels at All Positions vs. Wind Speed (10/13 to 11/1/05)*

What is notable about this plot is that the sound levels at all five locations, some many miles apart, are very similar and certainly follow the same overall trends, which are clearly dictated to a large extent by wind speed.

The one obvious inconsistency between the various monitoring positions is the pattern of regularly repeating spikes observed at the South position around 9 a.m. and 7 p.m. every day. These periods of elevated sound levels are associated with morning and evening traffic activity on Star Road. Between these temporary, man made peaks the natural background sound levels at the South position essentially follows those of the other locations.

Apart from the traffic noise aberration at the South location, it is not surprising that similar sound levels would exist at all the monitoring positions because the terrain and general sources of natural background noise are uniform over the area site. An area such as this that experiences homogeneous sound levels over a wide area is said to have a "macro-ambient", meaning that the sound level at any specific point can be inferred with good accuracy from levels measured elsewhere within the same macro-ambient environment.

As mentioned in passing above, the general trend in sound level at all the monitoring stations closely parallels wind speed. This indicates that the predominant sounds heard at any given location are likely to be trees rustling in the breeze or the wind blowing over grass fields. This clear dependency of background sound levels on wind speed is obviously of direct relevance to potential noise impacts from wind turbines since they only generate significant noise during periods of relatively high wind - when background levels are also high.

## 2.6 WIND SPEED AS A FUNCTION OF ELEVATION

Below about 100 m, wind speed varies with elevation above the ground due to friction with the ground surface and obstacles such as trees. Because this roughness varies from place to place measurements of wind turbine sound power levels and concurrent wind speeds carried out in accordance with IEC Standard 61400-11 (Ref. 1) are normalized to and reported at a reference height of 10 m. This enables the nominal noise level of different makes and models of wind turbines to be compared on a uniform basis. The conversion of wind speed at one elevation to the related speed at another elevation is calculated from a formula in the standard (Equation (7), Section 8), which describes a logarithmic profile. For the specific parameters relevant to this project the wind profile resulting from the Eqn.(7) is shown graphically below for an example case where the wind is normalized to a speed of 8 m/s at 10 m.

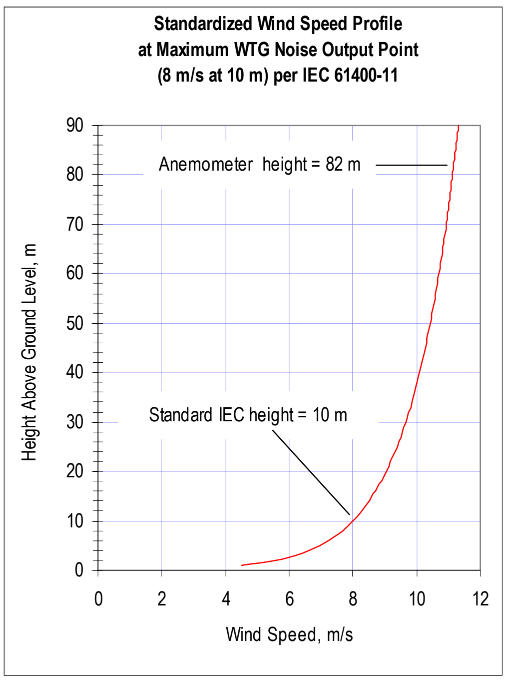


**Figure 2.6.1**

In this example, a standardized wind speed of 8 m/s at the reference height of 10 m would correspond to wind speed of just over 11 m/s at an anemometer height of 82 m. A normalized wind speed of 8 m/s at 10 m is significant in that it is the wind speed associated with maximum turbine noise. At the turbine cut in speed of 4 m/s at 10 m the shape of the profile would remain the same only the entire curve would shift 4 units to the left.

The key point to note from this is that a wind speed measured at an anemometer height of 82 m is about 3 m/s faster than the nominal wind speed at the reference height of 10 m.

## 2.7 Sound Levels as a Function of Wind Speed

From the data collected over the survey period it is possible to determine the A-weighted residual sound level that is likely to occur over all wind speeds up to about 12 m/s (as measured at the reference height of 10 m). The wind speed range of interest with respect to wind turbine noise is from the cut in speed of 4 m/s at 10 m, when the turbines just begin to operate up to about 8 m/s at 10 m when the noise level essentially levels off at a constant, maximum value after increasing from zero.

The regression plot below quantifies the relationship between wind speed normalized to the reference height of 10 m and hourly residual sound levels. Data from the South position has been excluded because it contains prominent peaks associated with local traffic that are clearly unrelated to wind effects.

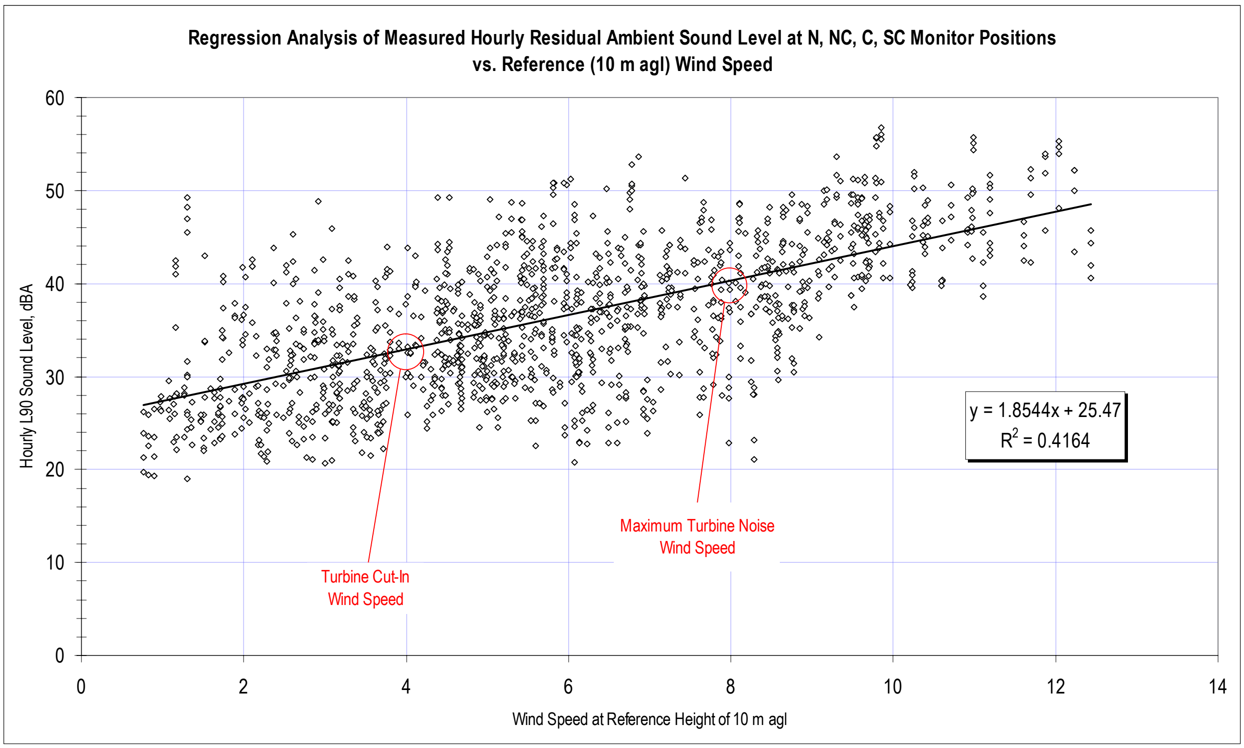


**Figure 2.7.1**

This plot illustrates a clear trend of increasing background sound levels with wind speed. Although the data may appear scattered, there is no technical reason why the regression should be more collapsed than shown because wind speed is only one parameter influencing the ambient sound level. Variations due to local and far off causes are to be expected. For example, one monitoring location might be measuring the noise of some upwind trees rustling while another might be simultaneously recording lower sound levels since the nearest trees are downwind of the measurement point.

Even with these variable considerations, a mean value for the residual ambient can be predicted with reasonable accuracy from the trend line shown at any wind speed. The key points on the line noted in red identify a background sound level of 33 dBA that is associated with the cut in speed of the turbines (4 m/s) and 40 dBA when the turbines would reach maximum power and when noise levels would reach their maximum value (8 m/s). Beyond this wind speed background noise, as can be seen in the plot, would continue to increase while turbine noise would remain constant. Consequently, during periods of very high wind turbine noise would be progressively less perceptible above natural background sounds.

From the regression chart above the following background sound levels can be expected at the following wind speeds.

**Table 2.7.1** *Measured A-Weighted Background Sound Levels as a Function of Normalized Wind Speed*

| | | | | | | |
|---|---|---|---|---|---|---|
| Integer Wind Speed at Standardized Height of 10 m, m/s | 4 | 5 | 6 | 7 | **8** | 9 |
| Background Sound Level, L90, dBA | **33** | **35** | **37** | **39** | **40** | **42** |

## 2.8 FREQUENCY CONTENT OF MEASURED BACKGROUND LEVELS

The discussions above have focused on the overall A-weighted sound level; however, the frequency content of the background sound level can also be relevant to its ability to obscure a potentially intrusive noise source. For example, if the background level consisted mostly of low frequency sounds it is unlikely to hide noise from high pitched source such as a whistle.

In order to evaluate this parameter octave band sound levels, quantifying the frequency content of the background levels, were measured along with the A-weighted sound level at four of the five positions during the survey. The frequency spectra associated with the turbine cut in wind speed of 4 m/s and maximum noise level wind speed of 8 m/s (both measured at 10 m) were developed from a number of measurements collected at all four locations under these specific wind conditions. The average spectra for the 4 and 8 m/s wind conditions are plotted in Figure 2.8.1 below.

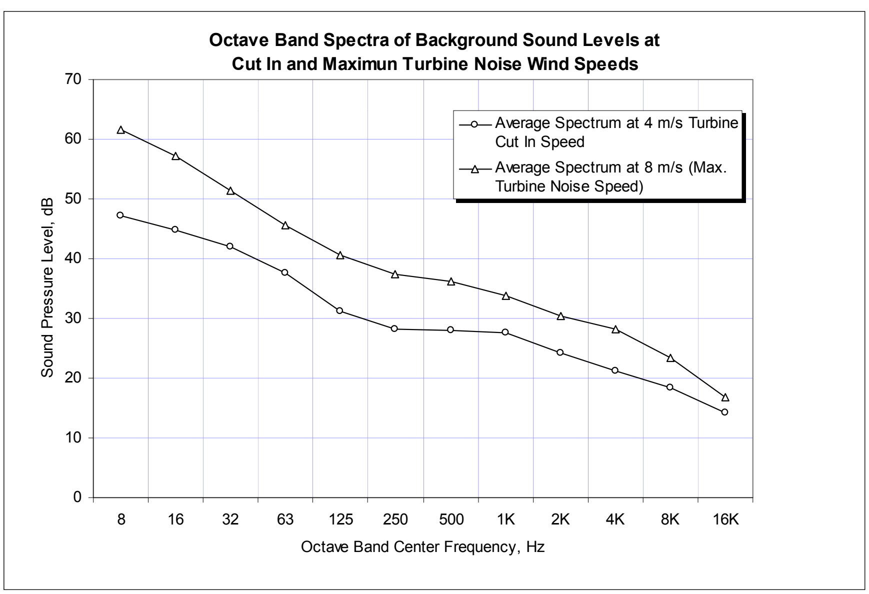


**Figure 2.8.1**

What these two spectra for relatively low and high wind conditions show is that for an open site such as this with only a few bare trees sound levels generally increase in all frequencies with increasing wind speed. The largest change - of about 10 dB - is in the lower frequencies (< 500 Hz) whereas an increase more on the order of 5 dB occurs in the higher frequencies. Experience at other sites indicates that when the trees are leafed out it is usually the mid and upper frequencies that show the greatest change.

In general, the 8 m/s spectrum illustrated in Figure 2.8.1 is similar in shape to the sound level spectrum that would be produced by a Gamesa G87 wind turbine at a fairly short distance; i.e. its sound level is highest in the lower frequencies tapering smoothly downward with increasing frequency. This similarity in shape indicates that natural wind induced sounds could provide effective masking of turbine noise depending only on the relative overall magnitude of each. As long as the turbine sound level is comparable to or less than the background level it will be difficult to perceive that the turbines are operating since their noise will not be appreciably different in character and frequency content than the background.

## 3.0 PROJECT NOISE MODELING AND IMPACT ASSESSMENT

### 3.1 ASSESSMENT CRITERIA

There are several metrics against which to compare the predicted noise from the project and thereby determine if any adverse environmental impacts might result from it. The first of these measures is a pair of local regulatory noise limits; the second is a set of noise assessment guidelines published by the New York State Department of Environmental Conservation (NYSDEC); and a third, Composite Noise Rating (CNR) method, considers the frequency content of the proposed new noise source within the context of the existing environmental setting and predicts community reaction based on a database of case histories.

#### 3.1.1 REGULATORY NOISE LIMITS

Local noise ordinances in the towns of Clinton and Ellenburg have recently been established that limit noise from any wind energy conversion facility to a maximum of 50 dBA at any "off-site", non-participating residence.

In addition, both of the ordinances places the following specific limits on tonal noise:

> In the event audible noise due to Wind Energy Facility operations contains a steady pure tone, such as a whine, screech, or hum, the standards for audible noise set forth in subparagraph A. of this subsection [50 dBA] shall be reduced by 5 dBA. A pure tone is defined to exist if the one-third (1/3) octave band sound pressure level in the band including the tone exceeds the arithmetic average of the sound pressure levels of the two contiguous one third octave bands by:
>
> 5 dB for center frequencies of 500 Hz and above
> 8 dB for center frequencies between 160 and 400 Hz
> 15 dB for center frequencies less then or equal to 125 Hz

This somewhat arcane and complex-sounding restriction essentially says that a limit of 45 dBA applies at any off-site residences if the turbine noise contains any prominent discrete tones.

There are no other overarching state or federal noise regulations that would apply to the project.

### 3.1.2 NYSDEC GUIDELINES

In the Program Policy *Assessing and Mitigating Noise Impacts* published by the New York State Department of Environmental Conservation (2001) a methodology is described for evaluating potential community impacts from any new noise source. The method is fundamentally based on the perceptibility of the new source above the existing background sound level.

It is a well-established fact for a new broadband noise source, such as a wind turbine, that a cumulative increase in the total sound level of about 5 or 6 dBA at a given point of interest is required before the new sound begins to be clearly perceptible or noticeable to most people. Cumulative increases of between 3 and 5 dBA are generally regarded as negligible or hardly audible. Lower sound levels from the new source are completely "buried" in the existing background sound level and are totally inaudible. The specific language relating to these perceptibility thresholds in the NYSDEC program policy (Section V B(7)c) is a follows:

> Increases ranging from 0-3 dB should have no appreciable effect on receptors. Increases from 3-6 dB may have potential for adverse noise impact only in cases where the most sensitive receptors are present. Sound pressure increases of more than 6 dB may require closer analysis of impact potential depending on existing SPL's [sound pressure levels] and the character of surrounding land use and receptors.

What this essentially says is that a cumulative increase in the total ambient sound level of 6 dBA or less is unlikely to constitute an adverse community impact. From a practical standpoint, because decibels add logarithmically, this threshold means that noise from the project could exceed the existing background level by up to 5 dBA. For this project, a background level of 40 dBA (during an 8 m/s wind) plus a project-only noise level of 45 dBA would equal a total cumulative level of 46 dBA – or 6 dBA above the original level.

The program policy outlines an incremental approach towards evaluating cumulative increases and potential impacts. Once the background sound level is established by means of a field survey a **First Level Noise Impact Evaluation** is carried out where noise from the future project is modeled in an extremely simple and conservative manner considering only the reduction in sound level with distance in accordance with the inverse square law. All other natural forms of sound propagation loss, such as from intervening terrain, vegetation, etc., are ignored and the ground surface is assumed to be completely reflective as though it were the surface of a large placid lake. The purpose of this analysis is to simply identify the area, defined by the 6 dBA cumulative increase contour line (45 dBA in this instance), that needs to be looked at in greater detail to see if any sensitive receptors are present.

If any residences or other potentially sensitive receptors are identified as being within the area of potential concern a **Second Level Noise Impact Evaluation** noise modeling study is carried out realistically considering all normal sound propagation loss mechanisms (in addition to pure distance losses). In this case, any receptors outside the 6 dBA cumulative increase contour are considered to have a low probability of disturbance while any receptors inside the contour might be adversely impacted and some form of mitigation should be investigated.

### 3.1.3 COMPOSITE NOISE RATING METHOD

An additional way of evaluating potential community noise impacts that also considers the frequency content of both the background and the project sound levels is the modified Composite Noise Rating (CNR) method. This method, which dates back to 1955 (Ref. 2), is based on case histories of observed reactions to new sound sources. With minor modifications it has stood the test of time and has long been used by a number of federal agencies including the EPA (Ref. 3). The procedure is somewhat archaic, making use of charts and correction factors to arrive at a final rating category for the noise in question that is then compared to a statistical plot of observed reactions. The mechanics of it are not really important but what is important is that the methodology takes into account the frequency content of the turbine noise within the context of the site ambient.

## 3.2 TURBINE NOISE LEVELS

### 3.2.1 MODEL INPUT SOUND POWER LEVEL

At the present time, two turbine models are being considered for the project: either the Model G87 or G90 produced by Gamesa Eólica. Both produce a nominal electrical output of 2 MW and are virtually identical in terms of their physical dimensions and appearance and have the same maximum rotor speed. The only substantive difference is that the G90 has a slightly larger rotor diameter of 90 m versus 87 m for the G87 allowing it to capture slightly more wind energy, thereby increasing its efficiency. A hub height of 78 m is planned regardless of which model is eventually selected.

In terms of noise emissions, Gamesa reports that the sound power level of the G90 was found to be identical to that of the G87 in a field test conducted in 2003. Both units were measured to have a maximum A-weighted sound power level of 105 dBA re 1 pW when operating at full speed, which is not particularly surprising given the fact that the units have similar dimensions and identical rotor speeds. Sound *power* level is a derived quantity based on the measured sound *pressure* level at a given distance and the effective radiating surface area of the sound wave at that point. Knowledge of the sound power level allows the sound *pressure* level of the source, the more familiar quantity perceived by the ear and measured with instruments, to be determined at any point.

More recent testing by Gamesa in 2005 (Ref. 4) indicates that a slightly higher sound power level of 106 dBA re 1 pW is associated with the G87. Since this latter study, conducted in strict accordance with IEC 61400-11 (Ref. 1), is more detailed and scientifically exhaustive in nature, its slightly higher and somewhat more conservative result was used as a basis for the noise modeling to represent either the G87 or G90.

The noise output of the Model G87/G90, as well as other similar wind turbines, varies with wind speed; consequently, the IEC test protocol requires measurements from 6 m/s – just above the cut-in wind speed of about 4 m/s when the turbine just begins to operate – up through 10 m/s when the rotational speed of the turbine becomes constant and noise levels off. From a qualitative standpoint turbine noise is zero below the cut-in wind speed, grows from a very low level to maximum noise output from about 5 to 8 m/s and then remains constant or even declines slightly at all higher wind speeds. The specific overall, A-weighted sound power levels from the latest Gamesa study at integer wind speeds ranging from 5 to 12 m/s for the G87 are tabulated below. All of these values are derived from measurements <u>downwind</u> of the turbine. Lower sound levels would exist in other directions from a typical turbine.

**Table 3.2.1.1** *Gamesa Model G87 Sound Power Levels vs. Wind Speed*

| Ref. Wind Speed Measured at 10 m, m/s | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|
| Sound Power Level, dBA re 1 pW | **101.2** | **104.7** | **106.2** | **106.4** | **106.0** | **105.4** | **105.1** | **105.2** |

What this table shows is that the maximum power level of 106.4 dBA occurs at a nominal wind speed of 8 m/s measured at a standard reference height of 10 m. The actual wind speed at a hub height of 78 m would be on the order of 11 m/s. This maximum sound power and its octave band frequency components tabulated below were used to quantify turbine noise in the model.

**Table 3.2.1.2** *Gamesa Model G87/G90 Octave Band Sound Power Level Spectrum Used for Modeling Purposes*

| Octave Band Center Frequency, Hz | 31.5 | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k | dBA |
|---|---|---|---|---|---|---|---|---|---|---|
| Sound Power Level, dB re 1 pW | **118.4** | **111.6** | **107.6** | **105.6** | **102.8** | **100.8** | **96.0** | **88.6** | **78.2** | **106.4** |

It is important to note that when the turbine first begins to operate at a wind speed of about 5 m/s the overall sound level is roughly 5 dBA lower than the maximum value reached at higher wind speeds.

### 3.2.2 TONAL NOISE

A sound from a new source containing one or more tonal components would be more readily noticed than a broadband, atonal sound with a similar overall magnitude and the likelihood of disturbance or annoyance would be significantly greater. It is for this reason that a restriction on tonal noise is included in the local noise ordinances (see Section 3.1.1 above). In these ordinances a “pure tone” is said to exist if a particular 1/3 octave band level exceeds the average of the adjoining two bands by more than the following amounts:

5 dB for center frequencies of 500 Hz and above
8 dB for center frequencies between 160 and 400 Hz
15 dB for center frequencies less then or equal to 125 Hz

The frequency dependence of this definition stems from the fact that the ear is generally more sensitive to mid and high frequencies than it is to the low frequencies. By way of background, these threshold levels for the perception of a prominent discrete tone were developed empirically by the U. S. Environmental Protection Agency and originally appeared in that agency’s “Model Community Noise Control Ordinance” (Ref. 6).

The maximum 1/3 octave band sound power level spectrum of the G87 wind turbine measured in the Ref. 4 study during an 8 m/s wind is plotted below in Figure 3.2.2.1. As can be seen, the frequency signature of this turbine is generally smooth and broadband in nature without any prominent tones or other identifiable characteristics. A slightly elevated level (96.6 dB) in the 1250 Hz band is visible but its prominence above the neighboring bands (94.6 dB at 1000 Hz and 93.0 dB at 1600 Hz) is 2.8 dB, or well below 5 dB ordinance threshold for a pure tone. It is also important to note that the slight prominence at 1250 Hz was observed at a relatively close measurement distance of 184 m (600 ft.). At greater distances this particular feature of the spectrum would become less and less pronounced. Consequently, since all of the nearest residences to proposed turbine locations are much further away than 600 ft., no tones of any significance are expected to be audible at any of the residences within the project area. Similarly, full compliance with the tonal component of the Ellenburg and Clinton town noise ordinance is also anticipated.

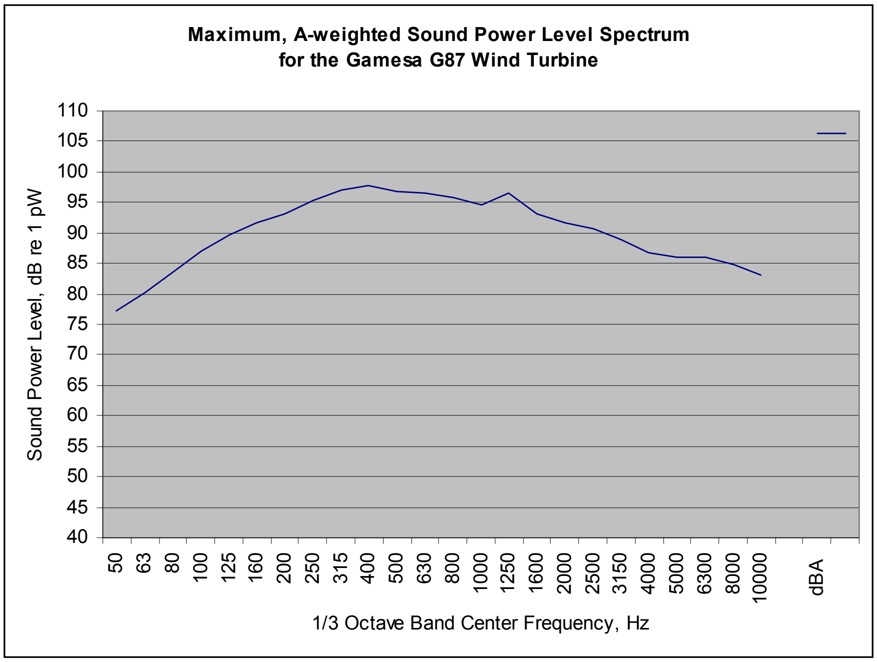


**Figure 3.2.2.1** *Detailed G87 Sound Power Level Spectrum*

## 3.3 NOISE MODELING METHODOLOGY

Using the sound power level spectrum in Table 3.2.2 above several worst-case, maximum noise level contour plots for the site were calculated using the "Cadna/A", ver. 3.5 noise modeling program developed by DataKustik, GmbH (Munich). This software enables the project and its surroundings, including terrain features, if applicable, to be realistically modeled in three-dimensions. Each turbine is represented as a point noise source at a height of 78 m above the local ground surface (design hub height).

Except for the First Level analysis where only distance is considered, a somewhat conservative ground absorption coefficient of 0.5 has been assumed in the subsequent models since all of the intervening ground between the turbines and potentially sensitive receptors essentially consists of open farm fields or pasture land with a few wooded areas. Ground absorption ranges from 0 for water or hard concrete surfaces to 1 for absorptive surfaces such as farm fields, dirt or sand. Consequently, a higher ground absorption coefficient on the order of 0.7 to 0.9 would be fully justified here; however, for conservatism the value of 0.5 has been used. In addition, any additional attenuation that might result from wooded areas has been completely neglected in all calculations.

Although wind direction effects can be modeled with this software, to be conservative the noise level from each turbine is assumed to be the downwind sound level in all directions simultaneously. In other words, although physically impossible, an omnidirectional 8 m/s wind is assumed. This approach yields a contour plot that essentially shows the maximum possible sound level at any given point and sometimes also shows levels that cannot possibly occur – such as between two or more adjacent turbines - since the wind would have to be blowing in two opposing directions at the same time. In a more realistic scenario with, for example, a wind out of the west the contour lines would occur closer to the turbines on the west side and would remain as shown on the east.

The various conservative assumptions in this modeling methodology leave some allowance for certain atmospheric conditions that are likely to occur from time to time favoring the propagation of sound relative to the ISO "standard day" default conditions (10 deg. C/70% RH) in the model. For example, the thermal profile of the lower atmosphere affects the way sound propagates over a given distance. On clear summer evenings a situation sometimes develops where the air close to the ground cools faster than the air aloft. The warmer air above causes sound waves that might otherwise travel upwards to diffract downwards allowing distant sounds to be heard when they normally wouldn't be. Of course, the opposite thermal profile - resisting the propagation of noise - also occurs with similar, if not greater frequency.

## 3.4 MODEL RESULTS – FIRST LEVEL NOISE IMPACT EVALUATION

**Plot 1** shows the project sound level contours calculated in accordance with the First Level Noise Impact Evaluation outlined in the NYSDEC Policy Program. The condition shown is for an omnidirectional 8 m/s wind, which is associated with the maximum turbine sound power level. As described above in the analysis of the background survey data (see specifically Figure 2.7.1) a residual, background sound level of 40 dBA can be expected during such a wind condition. Given this background level, the NYSDEC 6 dBA cumulative increase threshold for project noise would be 45 dBA (recall from Section 3.1.2 that a background level of 40 dBA plus a project level of 45 dBA would combine to yield a cumulative level of 46 dBA, or 6 dBA above the background level). In this case, then, the 45 dBA sound contour defines the area of concern that might be potentially impacted.

Because the site area is so large it is not possible to discern individual houses in Plot 1; however, there are a number of residences within the 45 dBA contour, particularly in the western part of the site along Route 189, Route 11, Star Road and other smaller roads.

It is very important to note that this plot is not indicative of any actual impacts but is intended to act as a kind of screen to determine if further evaluation is required. For example, if all houses were beyond the 45 dBA contour it would be immediately concluded that no impacts were associated with the project and no additional assessment work would be needed. Because there are houses inside the threshold a Second Level evaluation is required.

## 3.5 MODEL RESULTS – SECOND LEVEL NOISE IMPACT EVALUATION

The State procedure mandates that the Second Level noise model consider the actual circumstances of the site including any attenuation that might be afforded by such factors as terrain, vegetation or man made barriers. In this case, the only additional propagation loss factor that is warranted is the inclusion of ground absorption. Accordingly, the ground absorption coefficient has been changed from 0 (completely reflective) to 0.5 (moderately absorptive). The site terrain is sufficiently flat that it has no features that would appreciably influence sound propagation, so no terrain effects have been considered in the model. Additionally, wooded areas have also been neglected, even though they are fairly extensive in some areas.

The overall results of the Second Level model are attached as **Plot 2**. This plot represents a much more realistic, if still conservative view of what can be expected with all turbines operating at their maximum noise point. In contrast to the large areas and many homes encompassed by the 45 dBA contour in the First Level assessment, the more detailed Second Level contour plot shows that the areas above 45 dBA are much more localized around the turbines and are non-continuous.

**Plots 2A through 2C** are enlargements marking all of the residences that are believed to lie within the 45 dBA contour line with red boxes. No houses exist within the 45 dBA contour in the remote eastern part of the site shown in Plot 2C. In Plots 2A and 2B it can be seen that there are 22 residences where project sound levels could be in the 45 to 47 dBA range. Of these, almost all are located right on the 45 dBA line or just inside of it where turbine noise is unlikely to be prominent or particularly noticeable relative to the normal background sound level that exists under moderately windy conditions. Table 3.5.1 below lists all of the potentially affected residences.

**Table 3.5.1** *Residences within the Area that could see Project Sound Levels above 45 dBA*

| ID Number (non-consecutive) | Owner/Address/Location | Project Participant |
|---|---|---|
| 01P | Nichols, 52 Nichols Road, Clinton, NY | Yes |
| 02P | AES-EHN NyWindpower, Route 189, Churubusco, NY | Owned by Project |
| 03P | Padworski, 6649 Route 11, Clinton, NY | Yes |
| 05P | Rego, 228 Route 189, Churubusco, NY | Yes |
| 06 | Parent, 231 Whalen Road, Churubusco, NY | No |
| 07P | Buettner, Patnode & Gagnier Roads, Churubusco, NY | Yes |
| 08P | Buettner, Campbell Road, Churubusco, NY | Yes |
| 09 | Williams, 7909 Star Road, Ellenburg, NY | No |
| 11P | King, 876 Route 189, Clinton, NY | Yes |
| 12P | LeClair, 238 Liberty Pole Road, Clinton, NY | Yes |
| 13P | Damour, 37 Jones Road, Clinton, NY | Yes |
| 14 | Woods, Ellenburg Corners, Ellenburg, NY | No |
| 15 | Nichols, 6977 Route 11, Clinton, NY | No |
| 16P | Nichols, 6985 Route 11, Clinton, NY | Yes |
| 17 | Trombley, 157 Route 189, Clinton, NY | No |
| 18 | Miller, 206 Route 189, Clinton, NY | Yes |
| 21 | Alden, 32 Liberty Pole Road, Clinton, NY | Yes |
| 22 | LeClair, 238 Liberty Pole Road, Clinton, NY | Yes |
| 25 | Nichols, 6922 Route 11, Clinton, NY | No |
| 26 | Buettner, 293 Gagnier Road, Clinton, NY | Yes |
| 27 | Campbell, 327 Gagnier Road, Clinton, NY | Yes |
| 28 | Campbell, 444 Gagnier Road, Clinton, NY | No |

As can been seen, most of these homes belong to project participants.

Only four residences – 02P and 17 in Plot 2A and 12P and 22 in Plot 2B – are located in areas where their theoretical exposure is above 46 dBA. Outside of, or beyond these homes one should be able to intermittently hear sounds from the nearest turbines when the wind and atmospheric conditions favor noise propagation from the turbines towards the house; however, continuous audibility at these more distant residences seems unlikely given the conservative assumptions inherent in the model.

As an example, Receptor 02P, near the top right center of Plot 2B, could experience the illustrated sound level of 46.5 dBA (the maximum for any receptor in the project area) only if the wind were blowing from the east and the west at the same time - since it is the sum of downwind sound levels from the turbines on either side of the house (mainly units 48W, 81 and 47) that are combining to yield this sound level. In reality, when the wind is blowing from the west (the prevailing direction) noise from the closer turbines east of the house will be suppressed by the wind while the contribution from the units to the west will remain the same as predicted in the plot. The net result is that a lower overall sound level than indicated in the figure will actually occur at this particular residence under normal conditions. In addition, it should be noted that this farm is actually owned by the project.

In general, some residents in the area between the 45 and 47 dBA contours may hear the turbines at times but because of modeling conservatism, seasonal considerations discussed below, and the fact that nearly all the potentially affected homes are project participants the probability of a significant adverse impact due to noise alone is considered low. Satisfaction or dissatisfaction with these sound levels will largely be a matter of personal attitude towards the project in general.

In any event, it is clear from plots that the local ordinance limit of 50 dBA will not be exceeded at any residence.

## 3.6 Seasonal Influences on Potential Noise Impacts

Experience in conducting ambient sound level surveys at all times of year indicates that, as might be intuitively obvious, background levels are lowest in winter when the leaves are off the trees. The sound of the wind rustling through leaves or over fields of crops or grass is most prominent in the mid to high frequencies, which is the region of the audible frequency spectrum that the human ear is most sensitive to. Since the purpose of “A-weighting” is to make a measured sound level agree with normal subjective perception, the A-weighted background sound level is also usually elevated in summertime compared to the wintertime due to largely to leaf rustle.

The relevance of this to potential noise impacts from a wind farm is that relatively high levels of wind-induced background masking noise are available in summer whereas lower levels exist in winter. Consequently, the perceptibility of turbine noise, which itself is unaffected by the seasons, is lower in summer and higher in winter for an outdoor observer. However, because people are generally indoors with the windows closed in the wintertime the greater perceptibility of turbine noise in winter does not automatically mean that the likelihood of disturbance or annoyance will also increase. Inside a typical house at a typical setback distance of over a 1000 feet turbine noise is essentially inaudible so, in general, the potential for any significant noise impact from turbine operation is largely confined to the warmer months of the year when outdoor activities occur and windows might be open. Coincidentally, this is the time when background levels during windy conditions are relatively high making it more difficult to hear any turbine noise.

## 3.7 CNR Analysis

As discussed in Section 3.1.3 above, the Composite Noise Rating (CNR) method for evaluating potential noise impacts compares the background level to the predicted level of intrusive noise in terms of frequency content and other factors in order to predict community reaction.

The first step in the process is to plot the octave band frequency spectrum of the predicted project-only noise level at a point of interest against a set of curves that generally map the perceptibility of the noise as a function of frequency. For example, the human ear is much less sensitive to low frequency noise as opposed to high frequency noise. The sound level spectrum used for this purpose is the level predicted by the noise model at receptor “02P” in Plot 2B. This appears to be the closest potentially sensitive receptor to any turbine, or at least the residence with the highest expected sound level of 46.5 dBA. The following octave band frequency spectrum, due to project noise only is predicted for this location.

**Table 3.7.1** *Predicted WTG Maximum Sound Pressure Level at Receptor "04" (Plot 2B)*

| Octave Band Center Frequency, Hz | 31.5 | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k | dBA |
|---|---|---|---|---|---|---|---|---|---|---|
| Sound Pressure Level, dB | **68** | **58** | **51** | **47** | **44** | **43** | **35** | **16** | **0** | **46.5** |

This spectrum is plotted against the CNR ranking curves in Figure 3.7.1 below.

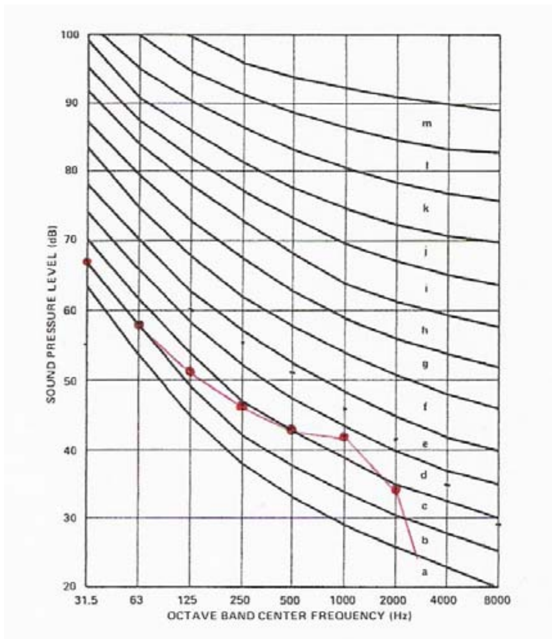


**Figure 3.7.1** *Maximum Predicted Project Sound Level Spectrum at Any Residence Plotted Against CNR Ranking Curves*

Due to the magnitude of the levels in the 500 to 2000 Hz bands this sound level falls into the "d" classification category in the CNR rating system. The highest zone into which the spectrum in question falls determines its ranking.

A second chart of curves is used as the next step to determine how well or poorly the background sound level frequency spectrum would act to mask the project sound level. A correction factor is obtained from this table that is used to adjust up or down the category ranking determined in step 1. The octave band spectrum of the residual background level measured during an 8 m/s (at 10 m) wind (from Figure 2.8.1 and tabulated below) was used for this purpose.

**Table 3.7.2** *Measured Background Level at Wind Speed Generating Maximum WTG Noise*

| Octave Band Center Frequency, Hz | 31.5 | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k | dBA |
|---|---|---|---|---|---|---|---|---|---|---|
| Sound Pressure Level, dB | **51** | **46** | **40** | **38** | **37** | **34** | **30** | **28** | **23** | **40** |

This spectrum is plotted below against the background noise correction curves and can be seen to yield a correction factor of 0, meaning that the initial classification category of "d" would remain unchanged.

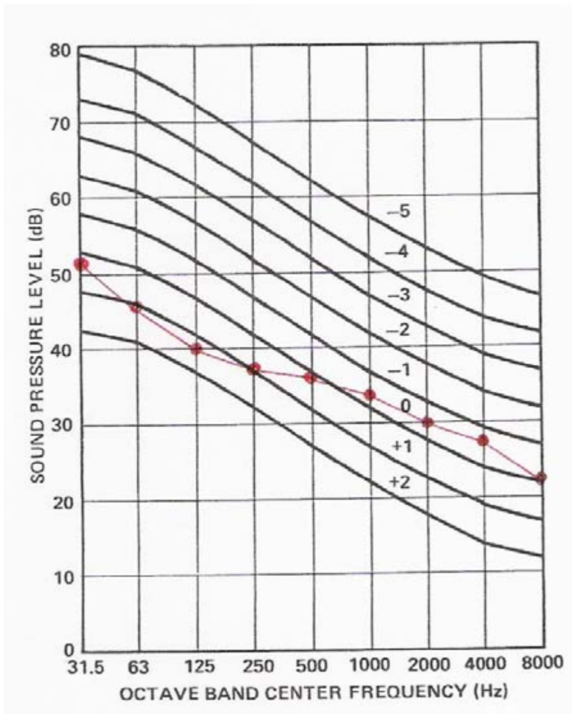


**Figure 3.7.2** *Measured L90 Background Sound Level Spectrum at During an 8 m/s Wind Plotted Against CNR Background Correction Curves*

After the background correction, a series of other corrections are possible for the temporal nature of the noise (how long it is operating on any given day, for instance), the character of the noise (low frequency, tonal, impulsive), and for previous exposure and attitude of the community. A table showing the possible adjustment factors is shown below in Figure 3.7.3.

| Correction for temporal and seasonal factors | |
|---|---|
| a. For full time operation, the total correction here is | 0 |
| b. Daytime operation only | -1 |
| Nighttime operation (10 pm to 7 am) | 0 |
| c. Winter operation only | -1 |
| Summer operation | 0 |
| d. Intermittency: Ratio of source "on" time to reference time period | |
| 1.00 - 0.57 | 0 |
| 0.56 - 0.18 | -1 |
| 0.17 - 0.06 | -2 |
| 0.05 - 0.018 | -3 |
| 0.017 - 0.0057 | -4 |
| 0.0056- 0.0018 | -5 |
| $2 \log \frac{\text{source "on" time}}{\text{reference period}} =$ | n |

| Correction for character of noise | |
|---|---|
| a. Noise is very low frequency | +1 |
| b. Noise contains tonal components | +1 |
| c. Noise is impulsive | +1 |
| **Correction for previous exposure and attitude** | |
| a. No previous exposure or some previous exposure but poor community relations | +1 |
| b. Some previous exposure and good community relations | 0 |
| c. Considerable previous exposure and good community relations | -1 |

**Figure 3.7.3** *CNR Category Correction Factors*

Assuming the turbines will operate most of the time and that operation is not dependent on time of day or the seasons, a zero correction factor can be applied for temporal or seasonal factors. This assumption is somewhat conservative because the prevalence of wind does vary to a certain extent with time of day and time of year. For example, winds are generally calmer at night and project could, at times, almost be considered a daytime only source. Additionally, in New York State the strongest winds tend to blow in the wintertime rather than the summertime.

With respect to the set of noise character corrections, a factor of +1 can be applied since, at least at close distances, the sound of a wind turbine can be considered mildly impulsive or periodic (i.e. perceived as a "woosh, woosh, woosh" sound).

Lastly, a factor of zero is considered appropriate with respect to community attitude since our understanding is that the overall state of community relations is not "poor" as would be necessary to apply a +1 factor.

In summary, all these adjustment factors, as indicated below, lead to final rating classification of "E".

**Table 3.7.3** *Summary of CNR Ratings and Adjustments*

| Description | Rating or Factor |
|---|---|
| Initial ranking category and maximum exposure point | d |
| Correction for background masking | 0 |
| Correction for temporal and seasonal factors | 0 |
| Correction for noise character | +1 |
| Correction for community attitude | 0 |
| Final Ranking | E |

The mean expected/predicted community reaction for an "E" category noise, as shown in Figure 3.7.4 below, would be "widespread complaints". This indicates that the chances of disturbance for an outdoor observer at this particular, worst-case receptor point would be fairly high – at least during wintertime conditions when the background sound level is extremely low. In the summertime, under the high wind conditions necessary to cause the turbine sound level in Table 3.7.1, a higher background level is very likely to exist that would probably alter the background correction factor from 0 to –1 or –2 and bring the final rating category down the "D" or "C". The expected reaction to noises in these categories generally ranges from "no reaction" to "sporadic complaints". Consequently, in real terms, the impact from the project is likely to be mild when people are actually outside or have their windows open and go unnoticed in the wintertime when people are inside.

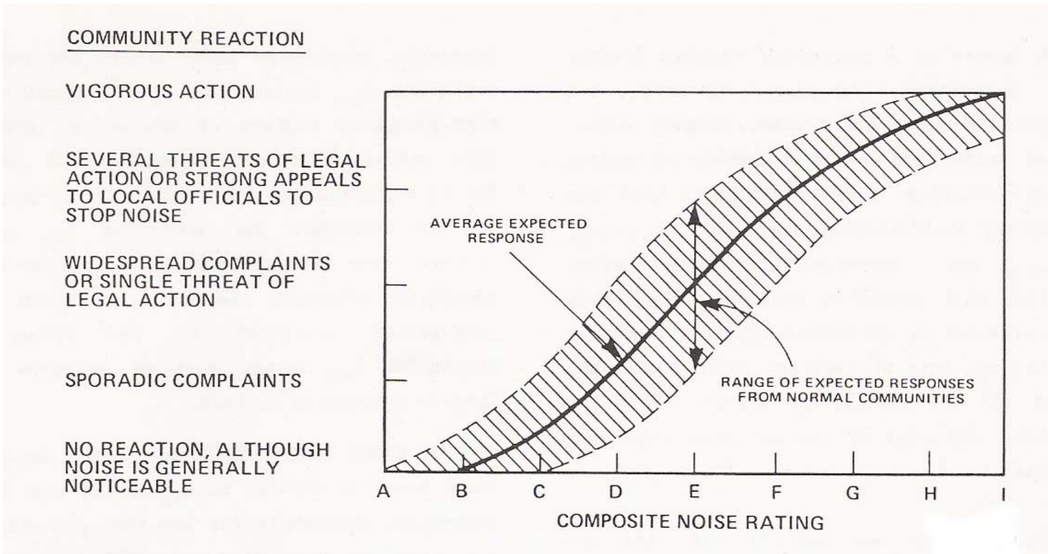


**Figure 3.7.4** *Expected Community Reaction Graph for CNR Ratings*

## 3.8 LOW FREQUENCY NOISE

Modern wind turbines of the type proposed for this project do not generate low frequency or infrasonic noise to any significant extent and no impact of any kind is expected from this. Early wind turbines with the blades downwind of the support tower were prone to producing a periodic noise each time a blade passed the tower wake but this effect no longer exists with the upwind blade arrangement used today. Concerns about excessive low frequency noise from proposed wind farms are commonly voiced but they have apparently grown out of misinformation or anecdote without any basis in fact. An interesting paper on this subject - "How the 'mythology' of infrasound and low frequency noise related to wind turbines might have developed" - by Geoff Leventhall, a highly respected acoustician in the field of low frequency noise, is attached as **Annex A**.

From a quantitative perspective, low frequency noise - best quantified in terms of C-weighted sound levels – can produce perceptible vibrations in frame structures or rattle windows if the magnitude is high enough. One of the few sources of noise that is capable of generating sufficient low frequency energy is a simple cycle gas turbine. In ANSI Standard B133.8 *Gas Turbine Installation Sound Emissions* (Ref. 5) a threshold level of 75 to 80 dBC is given as the approximate on-set point for vibrations. Our own field experience with numerous low frequency combustion turbine noise problems indicates that a lower threshold value of 70 dBC is a somewhat better indicator of the absolute minimum level that might lead to perceptible vibrations.

The maximum predicted C-weighted sound level at the receptor with the maximum predicted sound level, "04", is approximately 65 dBC – well below the threshold where any vibrations might start.

## 3.9 ASSESSMENT OF POTENTIAL NOISE IMPACTS DURING LOW WINDS

The modeling assessments above have focused on the maximum turbine noise levels and their potential impact on surrounding communities when normal environmental sound levels are elevated by the same wind necessary to drive the turbines at their full capacity. The question of turbine perceptibility during periods of low wind and reduced masking noise remains.

It was clearly determined in the field survey that the general background level over the entire site parallels wind speed - getting louder with increasing wind speed and vice versa. Over the wind speed range from 4 to 8 m/s (measured at 10 m) the sound power level of this model turbine noise increases by 5 dBA from 101 dBA at 5 m/s to a maximum value of 106 dBA at 8 m/s. Coincidentally, the background sound level was also found to increase by 5 dBA over this same wind speed range. The specific values for both the turbine and background sound levels are tabulated below (Table 3.9.1).

What this finding indicates is that when the wind speed is low, say around 5 m/s, both the noise from the turbines and the masking noise are reduced by equal amounts so the potential perceptibility of steady state turbine noise would not be any different than during the 8 m/s case previously evaluated.

The only sound that might conceivably be audible under very low wind conditions might be from the yaw motor rotating the turbine hub into the wind. No quantitative information is currently available for this noise so specific predictions cannot be made; however, it seems highly unlikely that such a noise source would be prominent or significant beyond the 1200 ft. setback distance from any residence.

**Table 3.9.1** *Measured A-Weighted Background and Turbine Sound Levels as a Function of Wind Speed*

| Integer Wind Speed at Standardized Hgt. of 10 m, m/s | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|
| Wind Speed at 48.5 m (Anemometer Hgt.), m/s | 6.5 | 7.5 | 8.5 | 9.5 | 10.5 | 11.5 |
| Gamesa G87 Sound Power Level, dBA re 1 pW (Ref. 4) | **-** | **101.2** | **104.7** | **106.2** | **106.4** | **106.0** |
| Background Sound Level, L90, dBA | **33** | **35** | **37** | **39** | **40** | **42** |

## 3.10 SUBSTATION NOISE

Noise from two large step-up transformers has been included in the overall project noise model to capture any potential noise impact from the substation. The substation is located in the southern part of the site and is noted in sound contour Plot 2A.

The sound power level used to represent the transformers, noted in Table 3.10.1 below, has been developed from many first-hand field measurements of transformers associated with 130 MW gas turbine driven generators at typical combined cycle power plants.

**Table 3.10.1** *Octave Band Sound Power Level Spectrum Used for Substation Transformer*

| Octave Band Center Frequency, Hz | 31.5 | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k | dBA |
|---|---|---|---|---|---|---|---|---|---|---|
| Sound Power Level, dB re 1 pW | **108** | **111** | **105** | **105** | **100** | **94** | **91** | **88** | **88** | **102** |

Because of its remote location a mile or more from any houses no adverse community noise impact is expected from the substation. Although essentially all transformers produce a significant tone at 120 Hz and subsequent harmonics these distinctive tonal peaks will fade out and become negligible well before reaching any homes.

## 3.11 CONSTRUCTION NOISE

Noise from construction activities associated with the project is likely to temporarily constitute a moderate unavoidable impact at some but certainly not all homes in the project area. Assessing and quantifying these impacts is difficult because construction activities will constantly be moving from place to place around the site leading to highly variable impacts with time at any given point. In general, the maximum potential impact at any single residence might be analogous to a few days to a week of repair or repaving work occurring on a nearby road. More commonly, the sounds from project construction are likely to be faintly perceived as the far off noise of diesel-powered earthmoving equipment characterized by such things as irregular engine revs, back up alarms, gravel dumping and the clanking of metal tracks.

Construction of the project is anticipated to consist of several principal activities:

- Access road construction and electrical tie-in line trenching
- Site preparation and foundation installation at each turbine site
- Material and subassembly delivery
- Erection

The individual pieces of equipment likely to used for each of these phases and their typical noise levels (from Ref. 7) are tabulated below. Also shown are the maximum total sound levels that might temporarily occur at the closest residences (roughly 1200 ft. away) and the distance from a specific construction site at which its sound would drop to 45 dBA (the nominal threshold for disturbance discussed above with respect to operational noise from the project).

**Table 3.11.1** *Construction Equipment Sound Levels by Phase*

| Equipment Description | Typ. Sound Level at 50 ft., dBA (Ref. 7) | Est. Maximum Total Level at 50 ft. per Phase, dBA* | Max. Sound Level at a Distance of 1200 ft., dBA | Distance Until Sound Level Decreases to 45 dBA, ft. |
|---|---|---|---|---|
| **Road Construction and Electrical Line Trenching** | | | | |
| Dozer, 250-700 hp | 88 | 92 | 61 | 3900 |
| Front End Loader, 300-750 hp | 88 | | | |
| Grader, 13-16 ft. blade | 85 | | | |
| Excavator | 86 | | | |
| **Foundation Work, Concrete Pouring** | | | | |
| Piling Auger | 88 | 88 | 57 | 3000 |
| Concrete Pump, 150 cu yd/hr | 84 | | | |
| **Material and Subassembly Delivery** | | | | |
| Off Hwy Hauler, 115 ton | 90 | 90 | 59 | 3400 |
| Flatbed Truck | 87 | | | |

| Equipment Description | Typ. Sound Level at 50 ft., dBA (Ref. 7) | Est. Maximum Total Level at 50 ft. per Phase, dBA* | Max. Sound Level at a Distance of 1200 ft., dBA | Distance Until Sound Level Decreases to 45 dBA, ft. |
|---|---|---|---|---|
| **Erection** | | | | |
| Mobile Crane, 75 ton | 85 | 85 | 54 | 2400 |

* Not all vehicles are likely to be in simultaneous operation. Maximum level represents the highest level realistically possible at any given time.

What the values in this table generally indicate is that, depending on the particular activity, sounds from construction equipment are likely to be significant at distances of less than 3900 to 2400 feet. In many parts of the site, such in the northeastern section, the nearest houses will, for the most part, be further than 3900 ft. and therefore they should be largely or completely unaffected by construction noise. In other places these activities will occur relatively close to existing residences and, at worst, a total sound level ranging from 54 to 61 dBA might temporarily occur over several working days or more. Such levels would not be generally regarded as acceptable on a permanent basis or outside of normal daytime working hours (when most project construction is likely to take place), but as a temporary, daytime occurrence construction noise of this magnitude may well go unnoticed by many in the project area and, after years of planning, may even be welcomed by project participants who are the closest residents to most of the turbines.

Noise from additional vehicular traffic associated with construction on area roads will not affect the actual sound level perceived at any given residence since each vehicle pass will be no louder than that of existing traffic. What will change, however, is the frequency with which vehicles will pass by. On some of the smaller side roads that normally experience very little traffic, the temporary increase in volume may be noticeable even though the number of vehicles is not expected to be very high. On the larger roads the change in traffic volume will probably be imperceptible.

## 3.12 CUMULATIVE OPERATIONAL NOISE WITH ADJACENT WIND PROJECT

This project is somewhat unique in that a wind farm project similar in scale to the Marble River Project is being planned by another developer, Noble Environmental Power (NEP), in the same area. In general, the NEP units are located to the west and south the Marble River project area. For the most part the two projects occupy contiguous areas that are separated by one or two miles but in certain areas, such as around the intersection of Route 190 (Star Road) and Bohen Road, turbines from both projects are intermingled.

In order to evaluate any potential noise impacts on residents in the area due to the cumulative noise of both projects, an additional noise model was developed showing the sound level contours due to both projects. **Plot 3** shows the sound levels out to the 45 dBA “threshold” for possible disturbance for both projects. The layout of the NEP turbines was provided to us by Marble River Wind Farm, LLC. It is our understanding that GE Model sle 1.5 MW turbines on 80 m towers are currently planned by NEP and a maximum sound power level of 104 dBA re 1 pW (General Electric’s published performance for these units) was used in the model to represent the NEP turbines.

Plot 3 shows that the two projects are sufficiently separated in most areas that they are acoustically autonomous; i.e. the sound levels produced by one project’s turbines have no appreciable affect on the sound levels near the other project’s units. Intermixture and cumulative sound levels only occur in the southern part of the project area and in one small area a couple miles west of Churubusco. These areas are shown in greater detail in **Plots 3A and 3B**.

In Plot 3A there is only one residence, Receptor 09 (7909 Star Road), that might be impacted by cumulative noise. The maximum predicted noise level from the Marble River Project alone at this residence is right on the threshold of a potentially adverse impact at 45 dBA. If a number of NEP units (shown in yellow) are erected nearby, the total sound level at this location could increase to about 47.5 dBA. In essence, the expectation of an adverse impact would go from being doubtful or borderline with only the Marble River project to being likely if the NEP project were constructed per the site plan that was made available to us.

Beyond this instance, Plots 3A and 3B show that all of the remaining receptors identified as being possibly affected by Marble River noise are not expected to see any significant difference in sound level due to the additional turbines proposed for the NEP project.

## 4.0 CONCLUSIONS

The results of a three week field survey of existing sound levels at the Marble River Wind Farm site indicate that, despite the very large size of the project area, background sound levels are remarkably homogeneous and consistent; i.e. the site area experiences a "macro-ambient" where the sound level at any particular point is similar to that at all other locations at any given time. This finding means that the potential impact at any sensitive receptor from project noise is largely a function of distance from the nearest wind turbines and that other common factors such as topography or exposure to geographically inconsistent levels of background masking noise have no relevance at this site.

In addition to being uniform in magnitude at all measurement positions, sound levels over the entire site area were also found to be dominated by wind induced noises and uniformly dependent on the speed of the wind - to the extent that the background level at any point can be predicted with reasonable accuracy for any given wind speed. At an 8 m/s wind speed, measured at the standard reference height of 10 m above ground level, the Gamesa G87 (or G90) wind turbine produces the maximum amount of noise. At this wind speed the mean background residual (L90) sound level was found to be 40 dBA under leaf-off, wintertime conditions, meaning that such a sound level is consistently present and available to mask potential turbine noise during the winter. Experience with surveys during other times of the year indicates that a significantly higher background level could be expected under windy conditions in the spring and summer due to leaf rustle.

In the New York State Department of Environmental Conservation's Program Policy *Assessing and Mitigating Noise Impacts* a cumulative increase in total sound level up to 6 dBA is characterized as having "potential for adverse noise impact only in cases where the most sensitive of receptors are present" and is suggested as a threshold for determining what areas might be adversely impacts by a new noise source and what areas should see "no appreciable effect".

An incremental noise modeling and assessment procedure is prescribed in the NYSDEC policy and was followed in the analysis. For this site a 6 dBA cumulative increase is associated with a project-only sound level of 45 dBA. A First Level modeling run indicated that there were residences close enough to proposed turbine locations that a more detailed Second Level analysis was required. This Second Level modeling study showed that while most residences were beyond the 45 dBA contour there were approximately 22 homes that could conceivably experience levels in the 45 to 48 dBA range. At face value the cumulative increases of 6 to 9 dBA implied by these predicted project sound levels would be considered an adverse impact by some; however, the likelihood of any actual disturbance is mitigated by the fact that the extremely low background level of 40 dBA from which these increases have been calculated is characteristic of wintertime conditions when people are infrequently outside. A much smaller cumulative increase and a much lower probability of the disturbance can reasonably be expected during summertime conditions when background levels are higher.

The Second Level modeling study also demonstrates that the local ordinance limits of 50 dBA at any non-participating residence in the Towns of Clinton and Ellenburg will not be exceeded. In addition, the project is expected to fully comply with the restrictions in these ordinances on tonal noises.

An analysis of potential noise impacts during low wind conditions when the background level is diminished indicates that turbine noise levels drop in parallel with the level of masking noise so that any incremental increase or impact would not be any different for a low wind situation than it is during an 8 m/s wind when the turbines generate maximum sound levels.

Lastly, a noise modeling analysis of potential cumulative noise impacts if the neighboring Noble Environmental Power wind farm project were to go forward indicated that the addition of these new turbines would not appreciably change the sound levels experienced at nearly all the residences identified as being possibly affected by Marble River noise. It was determined that only one of these residences may see a minor increase in overall noise level as a consequence of this second project.

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# First International Meeting
# on
# Wind Turbine Noise: Perspectives for Control
# Berlin 17th and 18th October 2005

## How the "mythology" of infrasound and low frequency noise related to wind turbines might have developed

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**Summary** Objections based on infrasound and low frequency noise, often raised against wind farm developments, arise largely from a misunderstanding of these topics by the general public, for whom the problem has developed through media and related exaggerations. There was a period, about 30 years ago, when each time infrasound and low frequency noise were given publicity, more and more of the "facts" were lost in a cloud of increasing embellishment.

This paper traces some of the history of interest in infrasound and low frequency noise, showing how the misunderstandings have arisen, how they have been used in the past to cause confusion in international politics and are used currently by objectors to wind turbine developments.

**Introduction** Infrasound and low frequency noise are often raised in objections to the development of wind farms. It is necessary to understand how the concerns might have arisen, so that objectors can be shown that their anxieties are likely to be without foundation. In the UK there has been misrepresentation of the facts of infrasound and low frequency noise, both by objectors and also by some of the noise consultants who support the objectors. It is necessary to re-educate the public in order to remove the misconceptions which have developed.

In the definitions of infrasound and low frequency noise, infrasound is often considered as sound at frequencies below 20 Hz.   However, from the subjective point of view,  there is no  reason for terminating a continuous process of hearing at this arbitrary frequency, so that from about 10Hz to 100Hz could be taken as the low frequency range. It may also be argued that there is no reason for terminating at 100 Hz, and the range is sometimes extended to about 200Hz.  But we have to stop somewhere.

**Atmospheric infrasound**     This is a well established discipline, studying frequencies from about one cycle in 1000 seconds up to, say, 2Hz. (Bedard and George, 2000)  These infrasounds are caused by weather variations,  meteorites, distant explosions, waves on the seashore, practically any occurrence which puts energy into the atmosphere over a relatively short period of time and any process with a low repetition rate, including pressure pulses from wind turbines.  The attenuation with distance is very low.   Monitoring of atmospheric infrasound is an essential part of ensuring the success of the Nuclear Test Ban Treaty.

Of course, it is important to realise that our evolution has been in the presence of naturally occurring atmospheric infrasound.

**The American Space Programme**     Early work on low frequency noise and its subjective effects was stimulated by the American space programme. It was known that very large launch vehicles produce their maximum noise energy in the low frequency region. Furthermore, as the vehicle accelerates, the crew compartment is subjected to boundary layer turbulence noise for about two minutes after lift off. Experiments were carried out in low frequency noise chambers on short term subjective tolerance to bands of noise at levels of 140dB to 150dB in the range up to 100Hz (Mohr et al., 1965). It was concluded that subjects who were experienced in noise exposure, and who were wearing ear protection, could tolerate both broadband and discrete frequency noise in the range 1Hz to 100Hz at sound pressure levels up to 150dB. Later work suggests that, for 24 hour exposure, levels of 120-130dB are tolerable below 20Hz  (von Gierke, 1973; von Gierke and Nixon, 1976). These limits were set to prevent direct physiological damage. It was not suggested that the exposure is pleasant, or even subjectively acceptable for anybody except those whose work requires them to be exposed to the noise.

Work was also in progress in the UK (Hood and Leventhall, 1971; Yeowart et al., 1969) and France (Gavreau, 1968; Gavreau et al., 1966) from the 1960's and in Japan and Scandinavia from the 1970's (Møller, 1980; Yamada, 1980). Japan and Scandinavia are now the main centres for work on infrasound and low frequency noise. A review of studies of low frequency noise has been given by Leventhall (Leventhall et al., 2003)

**Origins of the Mythology** The early American work was published in the middle 1960's and did not attract attention from the public, but a few years later *infrasound* entered upon its mythological phase, echoes of which still occur, currently in relation to wind turbines. The main name associated with the early phase is that of Gavreau from CNRS Marseille, whose work was in progress at the same time as that of the American space programme. (Gavreau, 1968; Gavreau et al., 1966). Infrasound from a defective industrial fan led to investigations of infrasonic problems and the design of high intensity low frequency sound sources. Gavreau made some misleading statements, which led to confusion of harmful effects of very high levels at higher frequencies with the effects of infrasound. (Note: According to the definition above, most of the sources developed by Gavreau and his colleagues were not infrasonic.) For example from the 1968 paper on "Infrasound", which was published in a "popular science" journal:

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

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

**Gavreau's progress** Gavreau initially energised his sources in a laboratory, exposing himself and his co-workers to very high levels of noise at relatively high frequencies. For example at 196Hz from a pneumatic "whistle" and 37Hz from a larger whistle. Exposure to the 196Hz source at a level of 160dB [1] led to irritation of internal organs, so that Gavreau and his colleague felt ill for some time following a five minute exposure, which is not surprising. Again from the 1968 paper:

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

196 Hz is not infrasound, but the unpleasant effects are described in a paper which is described as on "Infrasound". Internal haemorrhage is often quoted as an effect of exposure to any infrasound.

The 37Hz whistle was run at a low level, but sufficient to cause the lightweight walls of the laboratory to vibrate. (Some of Gavreau's earlier work had been in the development of pneumatic high intensity ultrasonic sources, so that he merely had to scale up the size).

Gavreau generated 7Hz with a tube of length 24m, driven by either a loudspeaker or a motor- driven piston. He suggested that 7Hz was particularly "dangerous" because the frequency coincided with alpha rhythms of the brain. He also used a tube to generate 3.5Hz, but further details were not given.

However, from the 1968 paper:

> *The effects of low frequency sound and infrasound are noxious. However, we found one exception: the intense vibration of the nasal cavities produced by our*

[1] 160dB is about 2000Pa, or 1/50 of an atmosphere, which is in the non-linear region.

> *whistle (340Hz, 155 decibels) had favourable effects! In one case, a subject recovered a sense of smell which he had lost some years back and was able to breathe more easily.*

**Infrasound and the public** By present standards, Gavreau's work was irresponsible, both in the manner in which it was carried out and in the manner in which it was described. Today, the experiments on people could lead to prosecution for negligence. Much of the paper with title of 'Infrasound' is not about infrasound. However, the work was picked up by the media and embellished further, including a statement that 7Hz was fatal. There was manipulation, sometimes willing manipulation, of scientists by the media, which was happy to describe all the sources developed by Gavreau as infrasound sources and to attribute all the adverse effects to infrasound, although they were actually due to high levels at frequencies above the infrasonic range.

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

*Onshore wind farms are a health hazard to people living near them because of the low-frequency noise that they emit, according to new medical studies.*

A French translation of this article for use by objectors' groups opens with

*De nouvelles études médicales indiquent que les éoliennes terrestres représentent un risque pour la santé des gens habitant à proximité, à cause de l'émission d'infrasons.*

The translation of *low frequency noise* into *infrasons* continues through the article.

This is not a trivial misrepresentation because, following on from Gavreau, infrasound has been connected with many misfortunes, being blamed for problems for which some other explanation had not yet been found (e.g., brain tumours, cot deaths of babies, road accidents). A selection of some UK press headlines from the early years is:

*The Silent Sound Menaces Drivers - Daily Mirror, 19th October 1969*
*Does Infrasound Make Drivers Drunk? - New Scientist,16th March 1972*
*Brain Tumours 'caused by noise' - The Times, 29th September 1973*
*Crowd Control by Light and Sound - The Guardian, 3rd October 1973*
*Danger in Unheard Car Sounds - The Observer, 21st April 1974*
*The Silent Killer All Around Us - Evening News, 25th May 1974*
*Noise is the Invisible Danger - Care on the Road (ROSPA) August 1974*

Absurd statements were made in the book 'Supernature' by Lyall Watson, first published in 1973 as 'A Natural History of the Supernatural' and which has, unfortunately, had a number of reprints and large sales. This book includes an extreme instance of the incredible nonsense which has been published about infrasound. It states that the technician who gave the first trial blast of Gavreau's whistle "fell down dead on the spot". A post mortem showed that "all his internal organs had been mashed into an amorphous jelly by the vibrations". It continues that, in a controlled experiment, all the windows were broken within a half mile of the test site and further, that two infrasonic generators "focused on a point even five miles away produce a resonance that can knock a building down as effectively as a major earthquake".

One can detect a transition from Gavreau and his colleague feeling ill after exposure to the high level of 196Hz to "fell down dead on the spot" and a further transition from laboratory walls vibrating to "can knock a building down", transitions which resulted from repeated media exaggerations over a period of five or six years.

Perhaps the singer David Bowie had read "Supernature". On the 20th September 1977, the London Evening News published an interview with him, giving his views on life, including the following:

*"He also expresses fears about America's new Neutron Bomb. 'It was developed along the lines of the French sound bomb which is capable of*

*destroying an area 25 miles around by low frequency vibration'. According to Bowie, plans for such a bomb are readily available in France and any minor power can get their hands on a copy. Low frequency sounds can be very dangerous. The 'sensurround' effect that accompanied the film 'Earthquake' was achieved by a noise level of nine cycles per second. Three cycles per second lower is stomach bleeding level. Any lower than that and you explode".*

We cannot blame the public for their anxiety about infrasound and low frequency noise when they have been exposed to statements like these. Public concern over infrasound was one of the stimuli for a growth in complaints about low frequency noise during the 1970's and 1980's and has continuing effects. It appears that concerns over infrasound and low frequency noise have found a place deep in the national psyche of a number of countries and lie waiting for a trigger to bring them to the surface. Earlier triggers have been gas pipelines and government establishments. A current trigger is wind turbines.

**Infrasonic weapons** The media follow-up of Gavreau's work led to interest in infrasonic weapons, although these have not been produced, as it is not possible to generate directional infrasound of high enough level to be effective at a distance. For example, to produce 150dB (1000W/$m^2$) at 100m distance requires a point source power of about 60MW. At 20Hz, which has a wavelength of about 17m, an efficient directional reflector, which must have dimensions of several wavelengths, is not feasible. However, during the cold war, the Conference of the Committee on Disarmament (see: www.unog.ch) , which commenced its work in Geneva in about 1960, and is believed to be still sitting, was presented with a paper from the Hungarian Peoples' Republic (Anon, 1978) which discussed infrasonic weapons and concluded:

> *"…..infrasound can become the basis of one of the dangerous types of new weapons of mass destruction…….*
> *All this leads to the unequivocal conclusion that the scope of the agreement on the prohibition of the development and manufacture of new types of weapons of mass destruction must also be extended to the military use of infrasound weapons of mass destruction……"*

An example of an infrasonic weapon was given as a jet engine attached to a long tube – reminiscent of Gavreau's 24m tube, as shown in Fig 1. Of course, the physics is at fault, because the rapid flow of the exhaust gas from the engine will prevent the development of resonance (Leventhall, 1998).

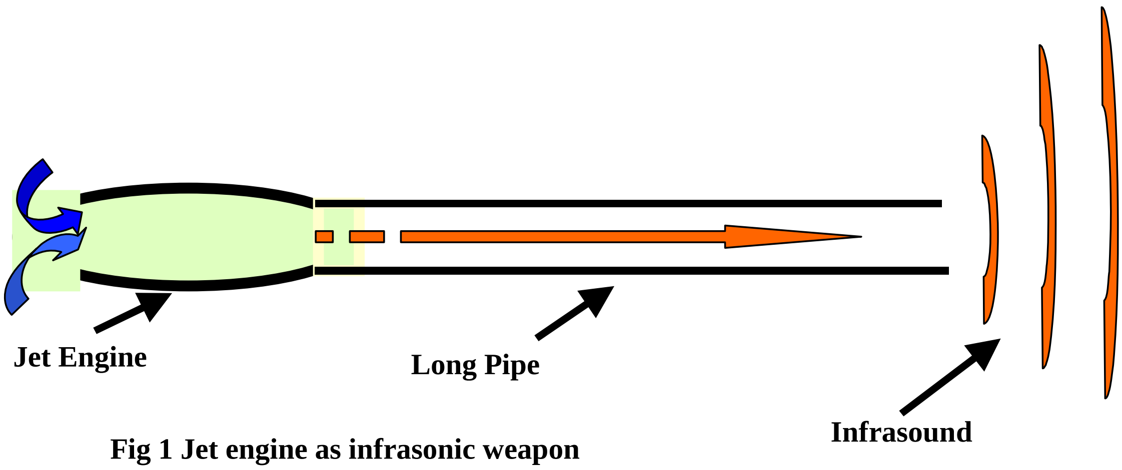
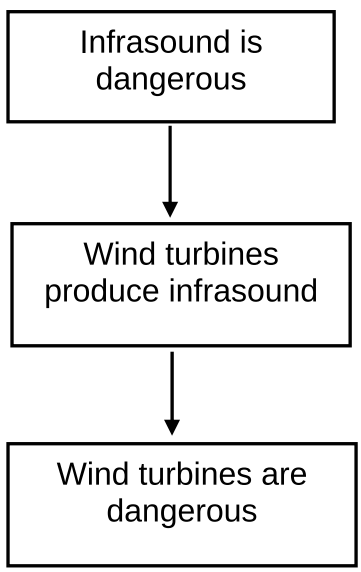



**Fig 1 Jet engine as infrasonic weapon**

However, after taking advice, the Western powers concluded that infrasonic weapons were a political distraction from the main points of the disarmament negotiations.

In relation to wind turbines, the concept that "infrasound is dangerous" has been absorbed into the minds of objectors, who take a one dimensional view of infrasound. That is, they consider only that it may be present from wind turbines and ignore the very low levels. So we have the relation:



Which objectors are pleased to believe and which they make use of in planning applications.

A recent example is from the leaflet from an objectors' group which stated:
*"wind turbines still create noise pollution, notably 'infra sound' - inaudible frequencies which nevertheless cause stress-related illness ..."*

The wind farm developers referred this statement, and others, to the UK Advertising Standards Authority, which ruled that it was misleading.

**What infrasound do we hear?** The audibility of infrasound for subjects exposed in infrasonic chambers, has been measured reliably down to 4Hz, Fig 2, is based on work by Watanabe and Møller from 4Hz and on ISO 226 from 20Hz (ISO:226, 2003; Watanabe and Møller, 1990b). The median threshold at 4Hz is 107dB, at 10Hz is 97dB and at 20Hz is 79dB. The standard deviation of the threshold measurements is about 6dB, so that a very small number of people may have 12dB or more greater sensitivity than the median.

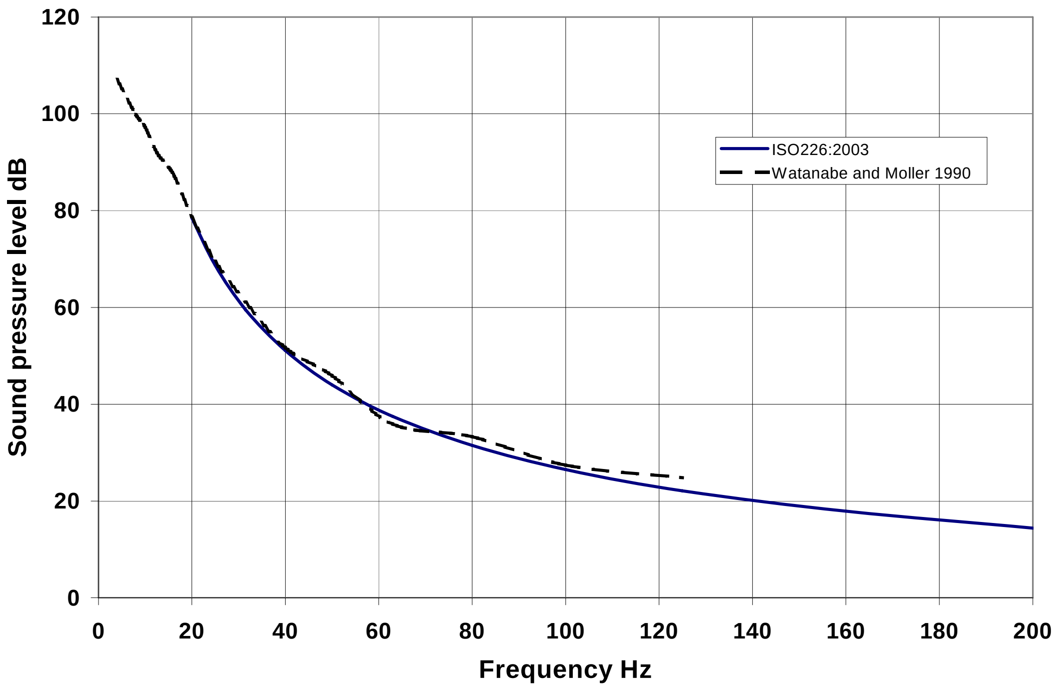



**Fig 2. Low frequency threshold**

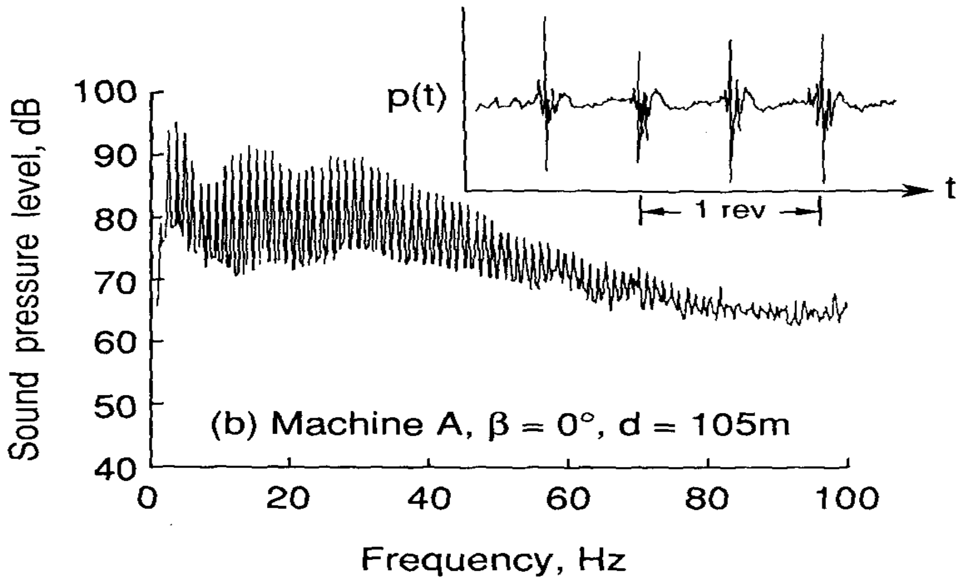
Part of the mythology is that infrasound can be felt but not heard. However, the ear is the most sensitive receptor in the body, as has been shown by threshold measurements on both normal hearing subjects and profoundly deaf subjects, which were carried out down to 8Hz (Yamada et al., 1983). If you can't hear it you can't feel it.

Gavreau (1968) used loud music to show that 7Hz infrasound could be masked by higher frequencies. Initially the sound was throbbing unpleasantly, but

> *'This musical experiment proved that this infrasound acted through the ears and not directly on the body. Furthermore, any kind of strong audible sound, by reducing the sensitivity of the ear, rendered this infrasound perfectly harmless'.*

Gavreau did not give the level of the 7Hz, but it is likely to have been at least 110 - 120dB.

**Infrasound and wind turbines** As is well known, earlier downwind turbines produced pulses at levels which caused vibration effects in light-weight buildings,




**MOD-1 Downwind 1.5MW to 2MW 61m diameter rotor BPF ~ 1Hz**

**Fig 3 Infrasound from early downwind turbine**

occurring twice a revolution from a two bladed turbine, as shown in Fig 3. (Shepherd and Hubbard, 1991)

Any slow train of pulses will analyse as infrasound. For example, pulses occurring once a second, as in Fig 3, will analyse as infrasound with a harmonic series at 1Hz intervals. But it was actually the peak pressure from the pulses which caused transient effects in the buildings, such as rattling of loose components, not the emission of a continuous infrasonic wave. These effects were heard as separate events.

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

**Low frequency noise**

There is an easy transition from infrasound to low frequency noise and much of the publicity about infrasound applies equally to low frequency noise. Sometimes the terms are used interchangeably. However, audible low frequency noise does have annoying characteristics which are not shown in conventional environmental noise measures, such as the A-weighting. This has been recognised by the World Health Organisation, which makes a number of references to low frequency noise in its publication on Community Noise (Berglund et al., 2000) with statements such as:

*It should be noted that low frequency noise, for example, from ventilation systems can disturb rest and sleep even at low sound levels*

*For noise with a large proportion of low frequency sounds a still lower guideline* (than 30dBA) *is recommended*

*When prominent low frequency components are present, noise measures based on A-weighting are inappropriate*

*Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting*

*It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health*

*The evidence on low frequency noise is sufficiently strong to warrant immediate concern*

An example of the difference between responses to low frequency noise/infrasound and other noises is in the growth of annoyance, illustrated in Fig. 4.

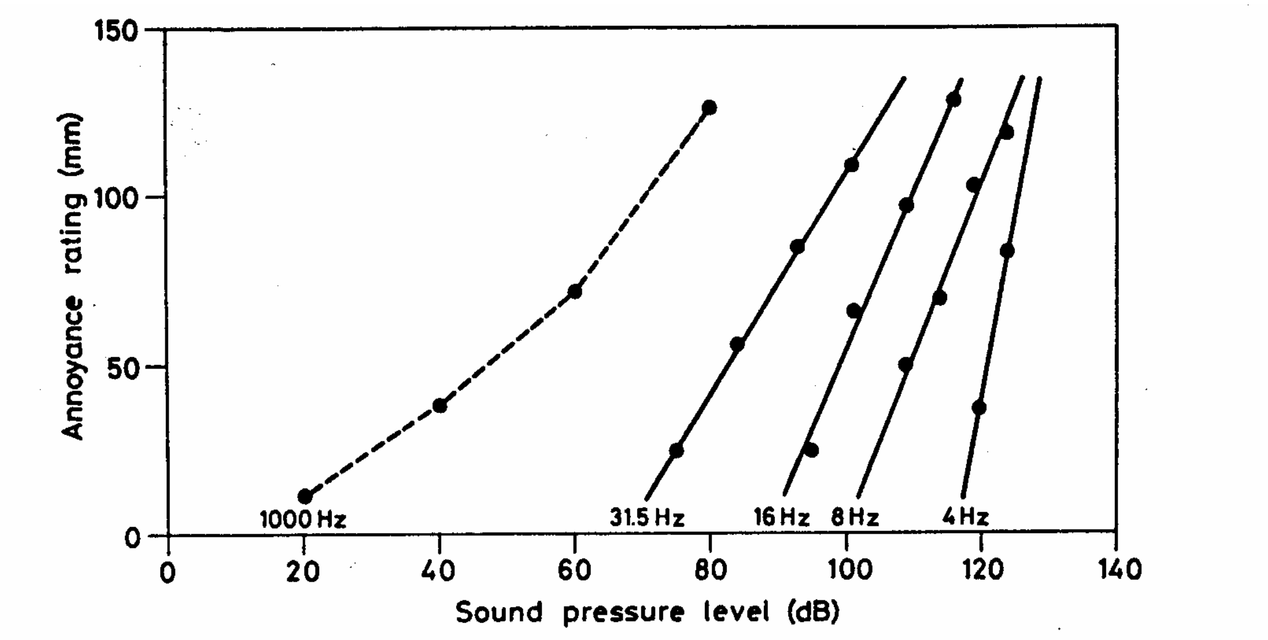



**Fig 4 Growth of annoyance at low frequencies**

Although low frequency tones require a higher level for the on-set of perception, their annoyance rating increases more rapidly with level. At 4Hz the range of annoyance is covered in a rise of about 10dB, compared with about 50dB at 1000Hz. Annoyance does not normally commence until the tone is 5 to 10dB above its threshold.

The concerns of the WHO on low frequency noise require us to look carefully at low frequency noise from wind turbines. In general, there is not a problem, although the mythology is that wind turbine noise has a substantial low frequency component.

This may be a misunderstanding of the "swish – swish - swish", at about once a second, which is typical of wind turbines. However, the swish is a modulation of a higher frequency, typically in the 500Hz to 1000Hz range, and does not contain low frequencies or infrasound. An analogy is with an amplitude modulated radio wave, which contains only the carrier and side bands, not the modulation frequency.

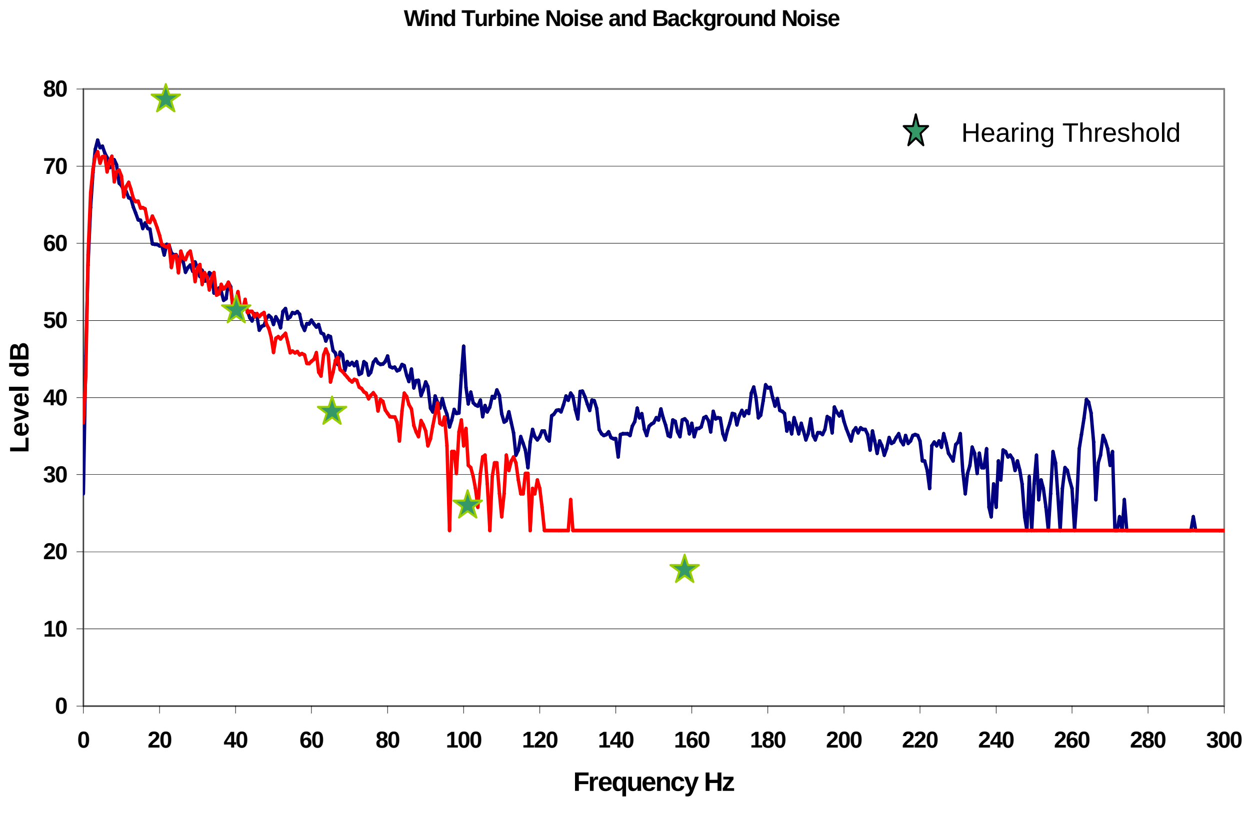



**Fig 5 Wind turbine noise —— and background noise ——**
**65m distance. wind speed at hub ~ 15m/s**

All wind turbines produce low frequencies, mainly mechanical noise, which has been reduced to low levels in modern turbines, but there are also circumstances in which turbines produce increased levels of low frequency noise. This is mainly when the inflow air to the turbine is very turbulent and there are interactions between the blade and the turbulence.

Fig 5 shows the infrasonic and low frequency noise at 65m from a 1.5MW wind turbine on a windy day. The following should be noted.

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

.

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

**Conclusions**. Specialists in noise from wind turbines have work to do in educating the public on infrasound and low frequency noise. Specifically,

- Infrasound is not a problem,
- Low frequency noise may be audible under certain conditions,
- The regular 'swish' is not low frequency noise.

Advice to objector groups in this connection could be that, by dissipating their energy on objections to infrasound and low frequency noise, they are losing credibility and, perhaps, not giving sufficient attention to other factors.

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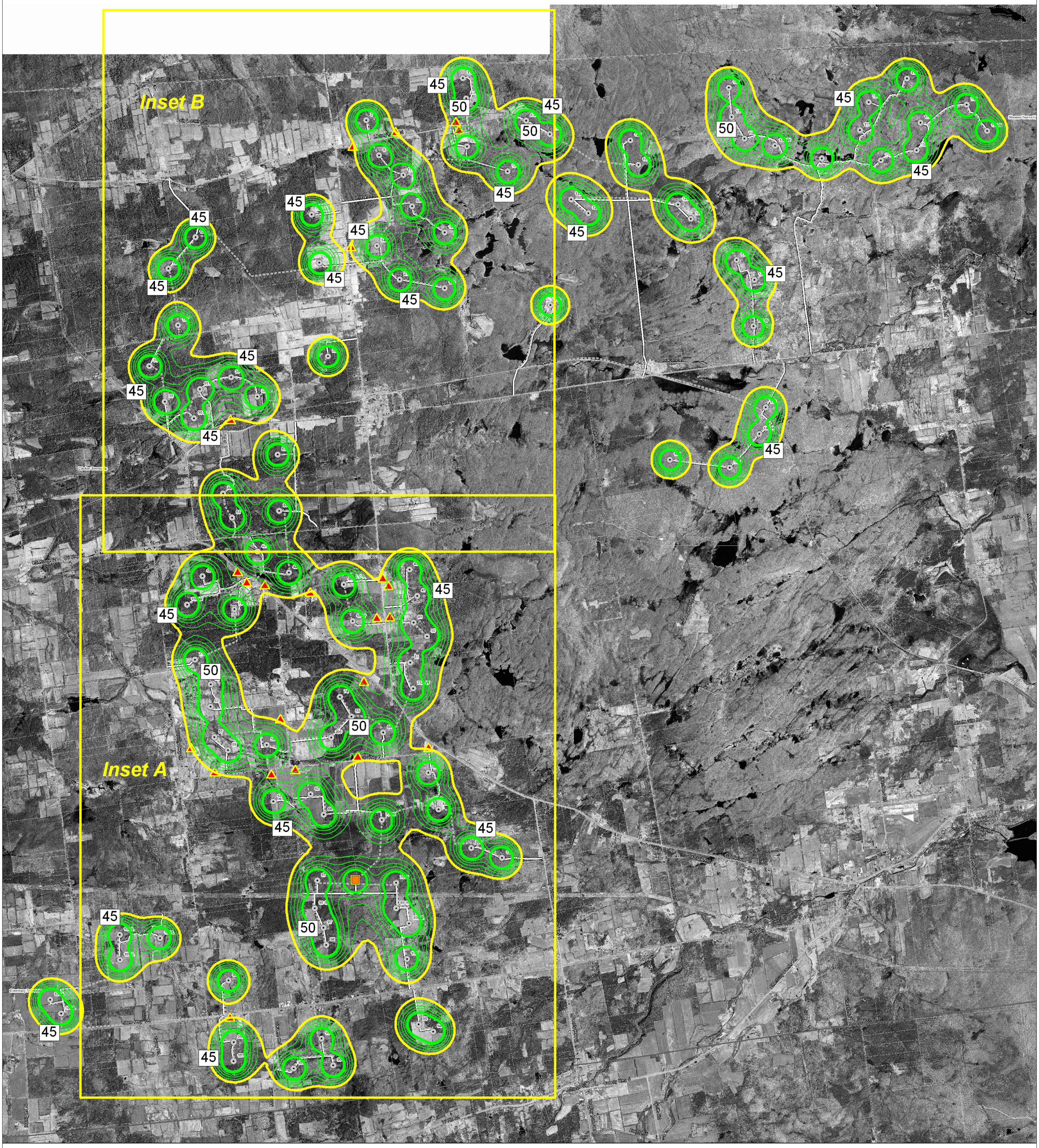


**Marble River Wind Power**
**Project Layout**

Clinton County, New York
22 December 2005

0 1,500 3,000 4,500 6,000 7,500 Feet
1 inch equals 1,500 feet

Wind Turbine
Substation
Crane Path
Buried Interconnect
Access Road
APA Blue Line
Parcel Boundary
County Boundary
Township Boundary

Prepared By:
EDR
Horizon

| *Project:* | *Description:* | *Prepared for:* |
|---|---|---|
| **Marble River Wind Farm**<br>**Plot 2** | **Maximum Wind Turbine Sound Levels (dBA)**<br>**With 8m/s Omnidirectional Wind**<br>**NYSDEC Second Level Noise Impact Assessment** | **Marble River**<br>**Wind Farm, LLC** |
| Drawing Number: MR-Rev-D-111805-2-2 | | Date: March 24, 2006 |

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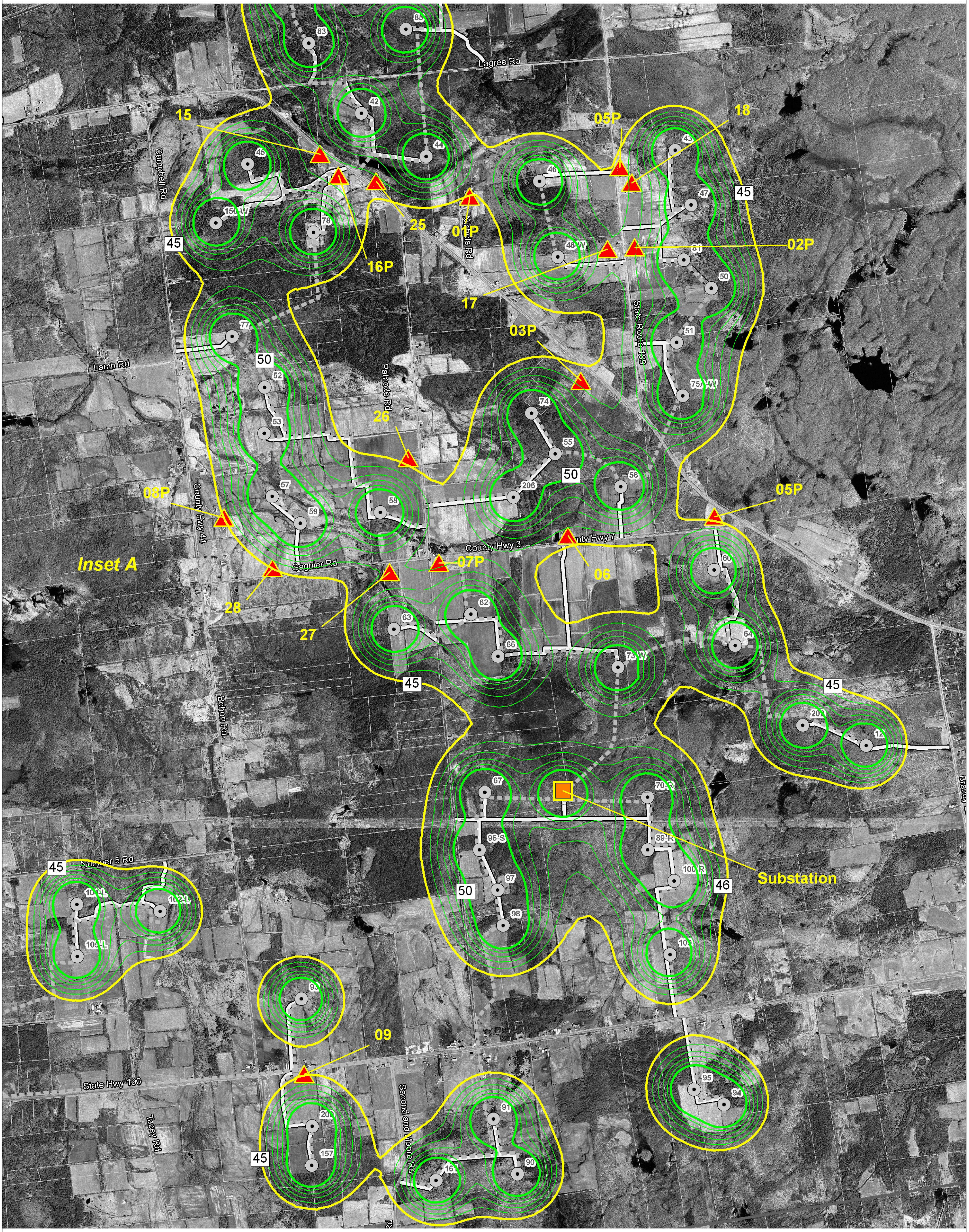


| Project: | Description: | Prepared for: |
|---|---|---|
| **Marble River Wind Farm Plot 2A** | **Maximum Wind Turbine Sound Levels (dBA) With 8m/s Omnidirectional Wind NYSDEC Second Level Noise Impact Assessment** | **Marble River Wind Farm, LLC** |
| Drawing Number: MR-Rev-D-111805-2-2 | | Date: March 24, 2006 |

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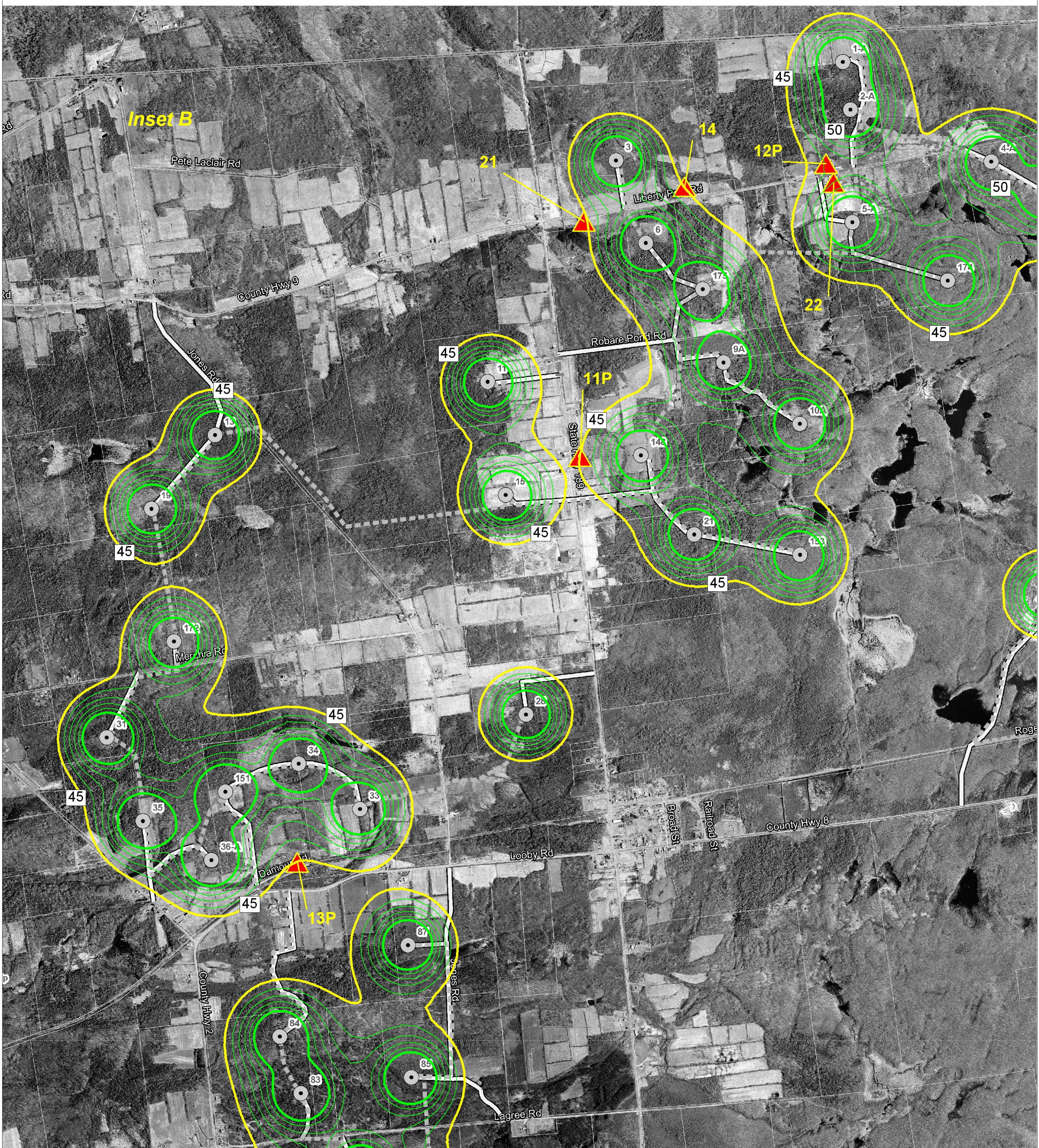


| Project: | Description: | Prepared for: |
|---|---|---|
| **Marble River Wind Farm Plot 2B** | **Maximum Wind Turbine Sound Levels (dBA) With 8m/s Omnidirectional Wind NYSDEC Second Level Noise Impact Assessment** | **Marble River Wind Farm, LLC** |
| Drawing Number: MR-Rev-D-111805-2-2 | | Date: March 24, 2006 |

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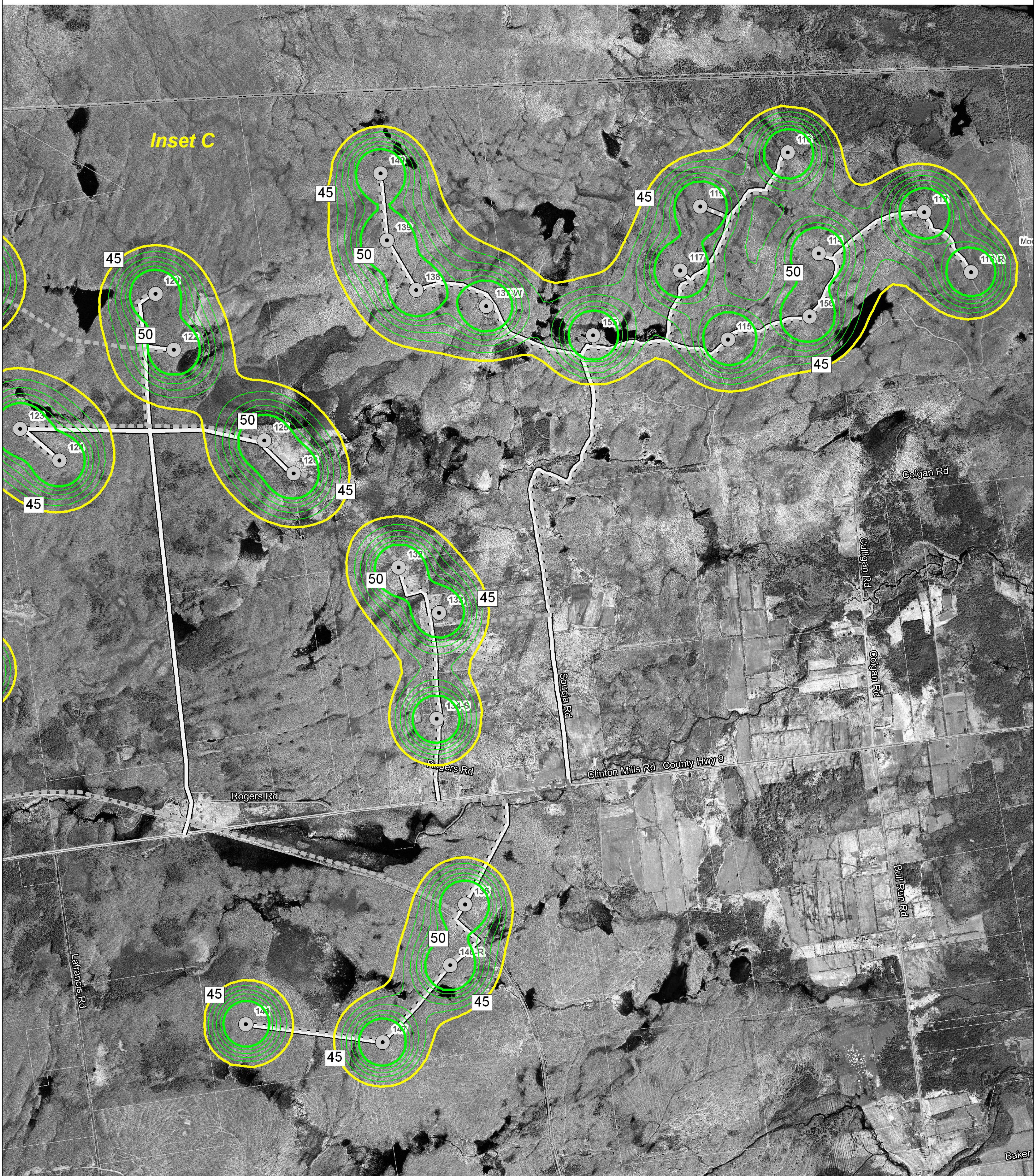


| Project: | Description: | Prepared for: |
|---|---|---|
| **Marble River Wind Farm Plot 2C** | **Maximum Wind Turbine Sound Levels (dBA) With 8m/s Omnidirectional Wind NYSDEC Second Level Noise Impact Assessment** | **Marble River Wind Farm, LLC** |
| Drawing Number: MR-Rev-B-111805-2-2 | | Date: January 26, 2006 |


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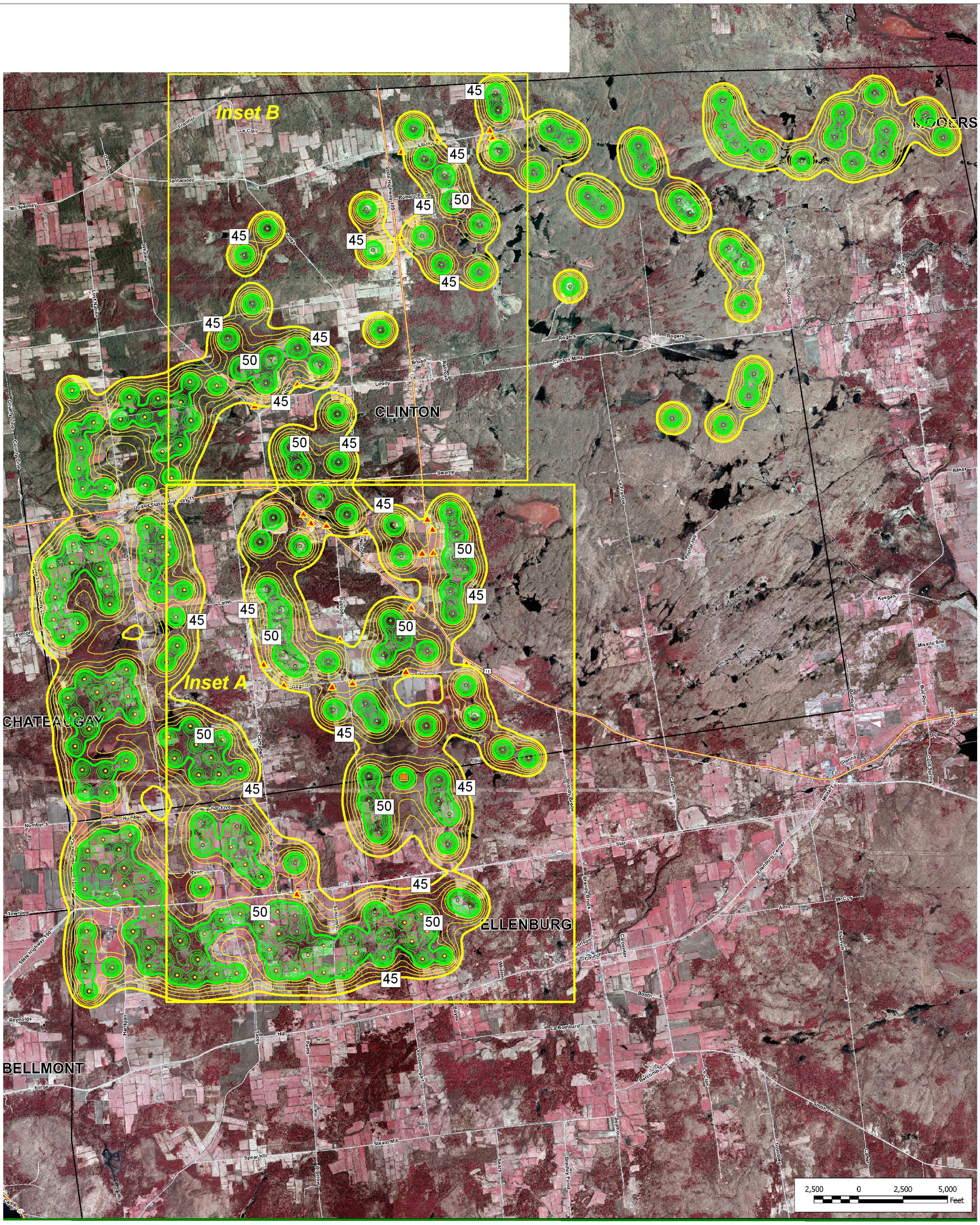


ESS Group, Inc.
Engineers
Scientists
Consultants

MARBLE RIVER WIND TURBINE PROJECT
Clinton County, New York

Scale: 1" = 2,500'

Source: 1) NYS GIS Clearinghouse, Orthos, 2003
2) Noble & Marble River, Turbine Locations, 2006

**LEGEND**

- Noble Turbines
- Marble River Turbines
- NY Town Boundaries

**Turbine Locations**

**Figure 1**

| Project: | Description: | Prepared for: |
|---|---|---|
| **Marble River Wind Farm Plot 3** | **Predicted Sound Levels (dBA) of Combined Noble and Marble River Wind Turbines with Omnidirectional Wind NYSDEC Second Level Noise Impact Assessment** | **Marble River Wind Farm, LLC** |
| Drawing Number: MR-Rev-D111805-3-1-1 | | Date: March 24, 2006 |

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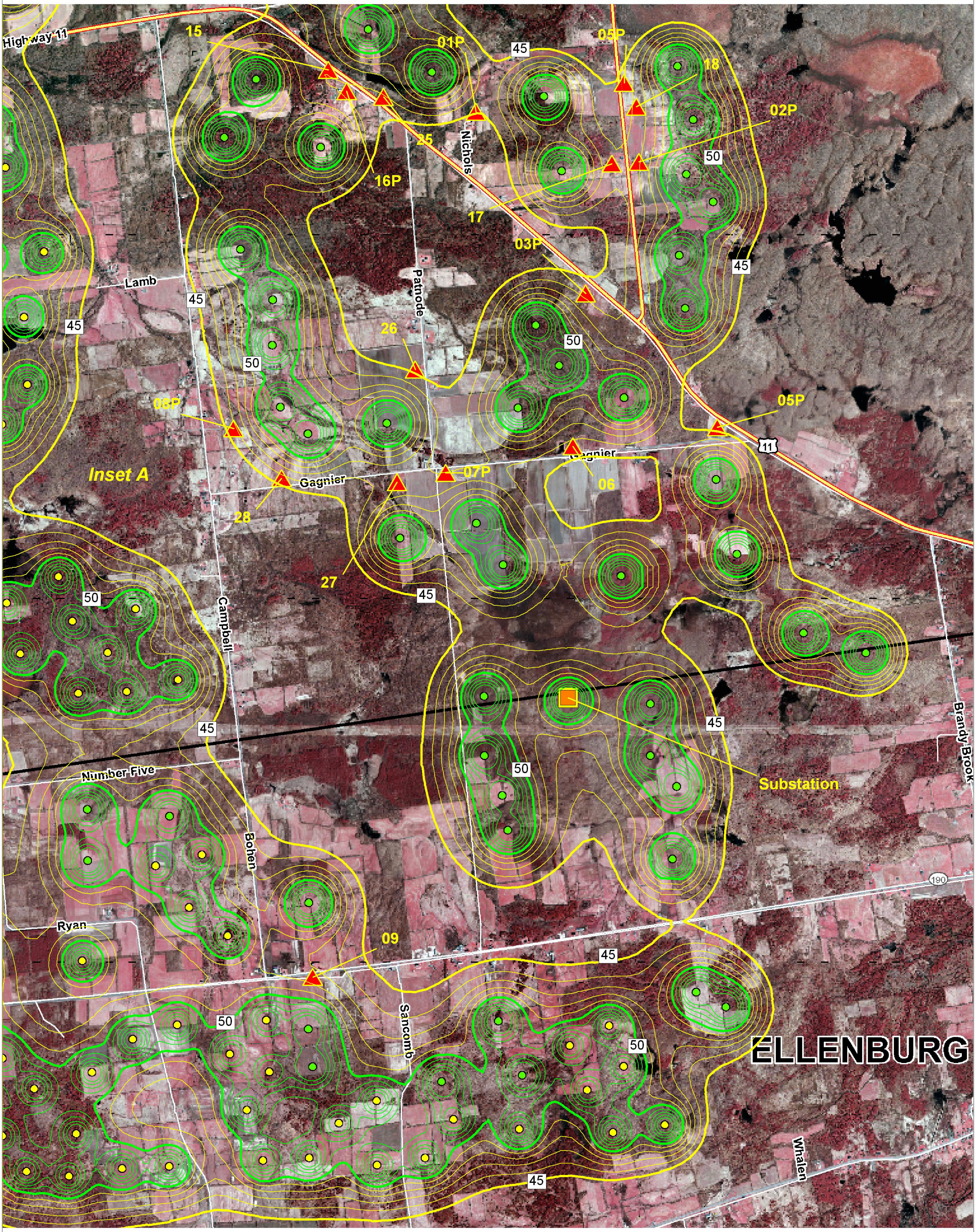


| Project: | Description: | Prepared for: |
|---|---|---|
| **Marble River Wind Farm Plot 3A** | **Predicted Sound Levels (dBA) of Combined Noble and Marble River Wind Turbines with Omnidirectional Wind NYSDEC Second Level Noise Impact Assessment** | **Marble River Wind Farm, LLC** |
| Drawing Number: MR-Rev-D111805-3-1 | | Date: March 24, 2006 |

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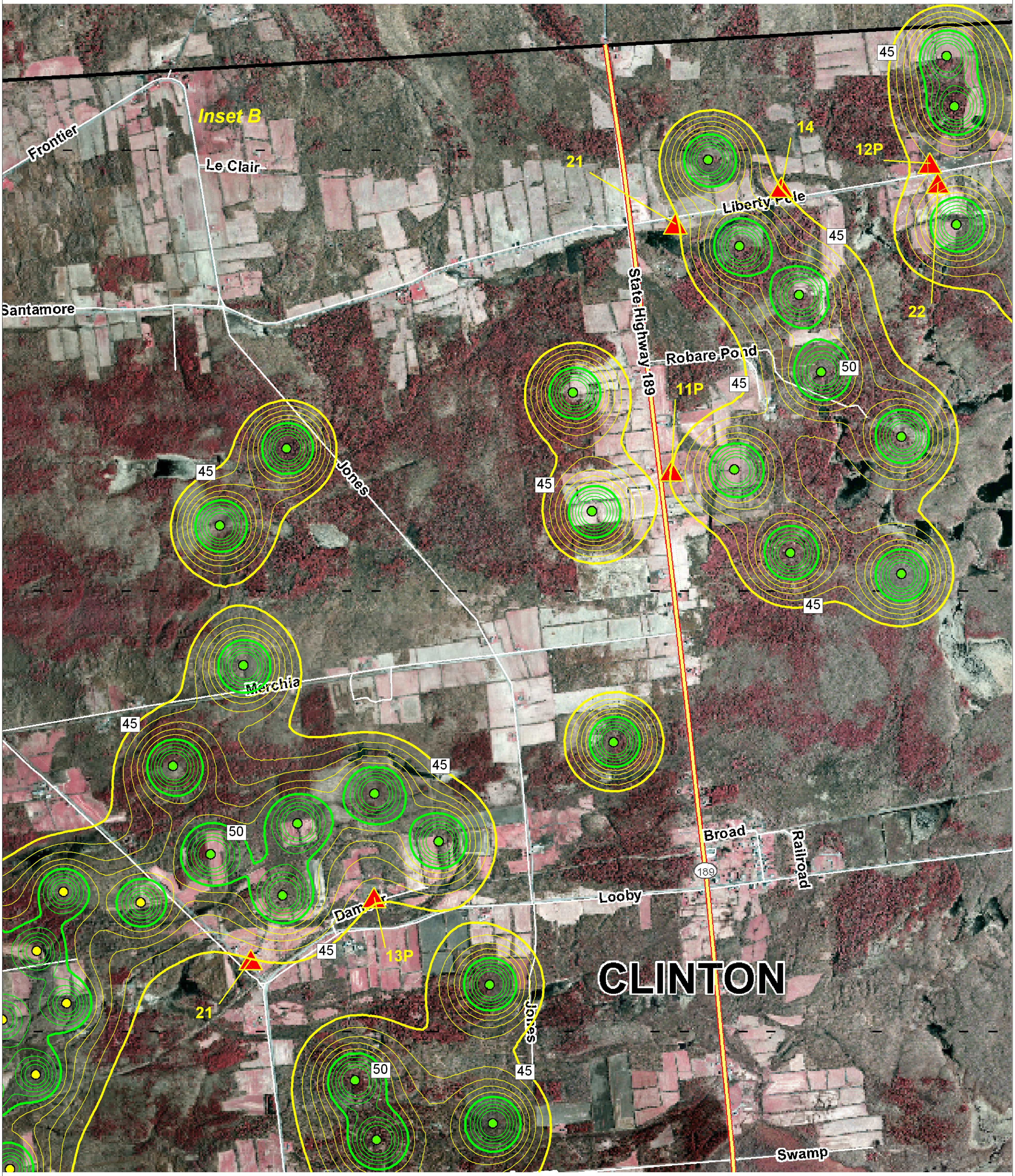


| Project: | Description: | Prepared for: |
|---|---|---|
| **Marble River Wind Farm Plot 3B** | **Predicted Sound Levels (dBA) of Combined Noble and Marble River Wind Turbines with Omnidirectional Wind NYSDEC Second Level Noise Impact Assessment** | **Marble River Wind Farm, LLC** |
| Drawing Number: MR-Rev-D111805-3-1 | | Date: March 24, 2006 |


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