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TECHNICAL MEMORANDUM

Title:	**Updated Noise Modeling Study**
Project:	**Marble River Wind Farm**
Location:	**Clinton County, NY**
Prepared For:	**Marble River Wind Farm, LLC**
Prepared By:	**David M. Hessler, P.E.**
Revision:	**0**
Issue Date:	**July 15, 2010**
Reference No:	**TM-1762-071410-0**
Attachments:	**Plots 1, 2 and 3**

1.0 Introduction

Because of significant changes to the number and location of wind turbines within the Marble River Wind Farm that have occurred over the past several years and the planned use of a different turbine model, Hessler Associates has been asked to update the noise model for the project.

This report briefly reviews the findings of the original field survey of background sound levels carried out in late 2005, re-evaluates the nominal NYSDEC impact threshold, and compares the anticipated noise emissions from the current site plan calling for 74 Vestas V112 turbines to the previous design, from November 2007, based on 115 Suzlon S88 units.

2.0 Background Sound Level Survey - Summary

A field survey was carried out in late October of 2005 to establish the existing levels of background sound - as a function of wind speed - within the project area because the New York State Department of Environmental Conservation (NYSDEC) guidelines [1] evaluate potential noise impacts on a *relative* basis; i.e. in terms of an overall increase in sound level due to additional noise from a new project. Full details related to the specific measurement positions, instrumentation and general test methodology are contained in our Report 1762-113205-D dated March 27, 2006.

In general, hourly measurements were taken continuously over a three week period during leaf-off, cold season conditions at five positions evenly distributed over the project area. The conservative, near-minimum L90 sound levels recorded at all positions over the entire survey period are plotted in Figure 2.0.1. The L90 statistical measure is conservative in the sense that it filters out sporadic noise events and captures the quiet, momentary lulls between them thereby representing the true “background” sound level that would be consistently present and available to potentially obscure project noise.

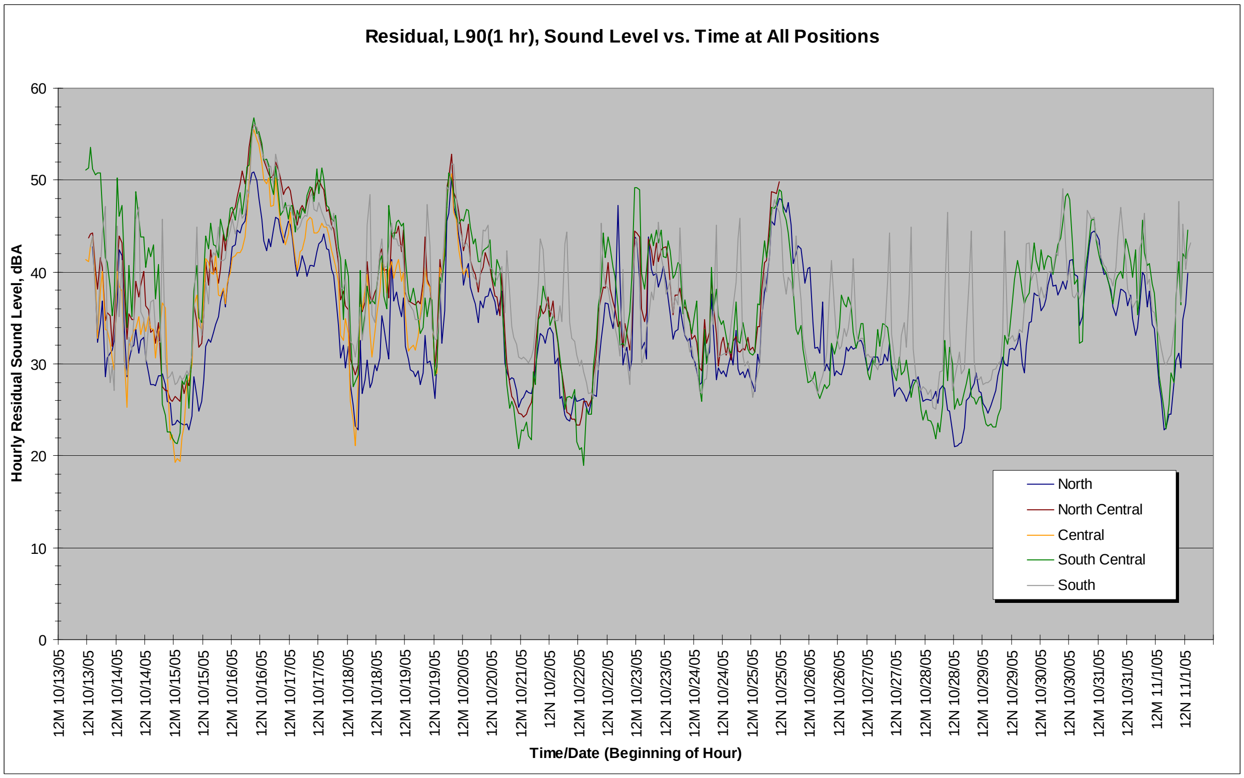


Figure 2.0.1

Figure 2.0.1 shows that the sound levels at all the positions generally follow the same temporal trends and have similar magnitudes at any given moment. The one obvious exception to this is at the South measurement station very close to Rt. 190 (Star Road) where sound levels spike around 9 a.m. and 6 p.m. nearly every day apparently to due to commuter traffic. If this position is neglected the site-wide consistency in sound levels is more clearly evident, as shown in Figure 2.0.2.

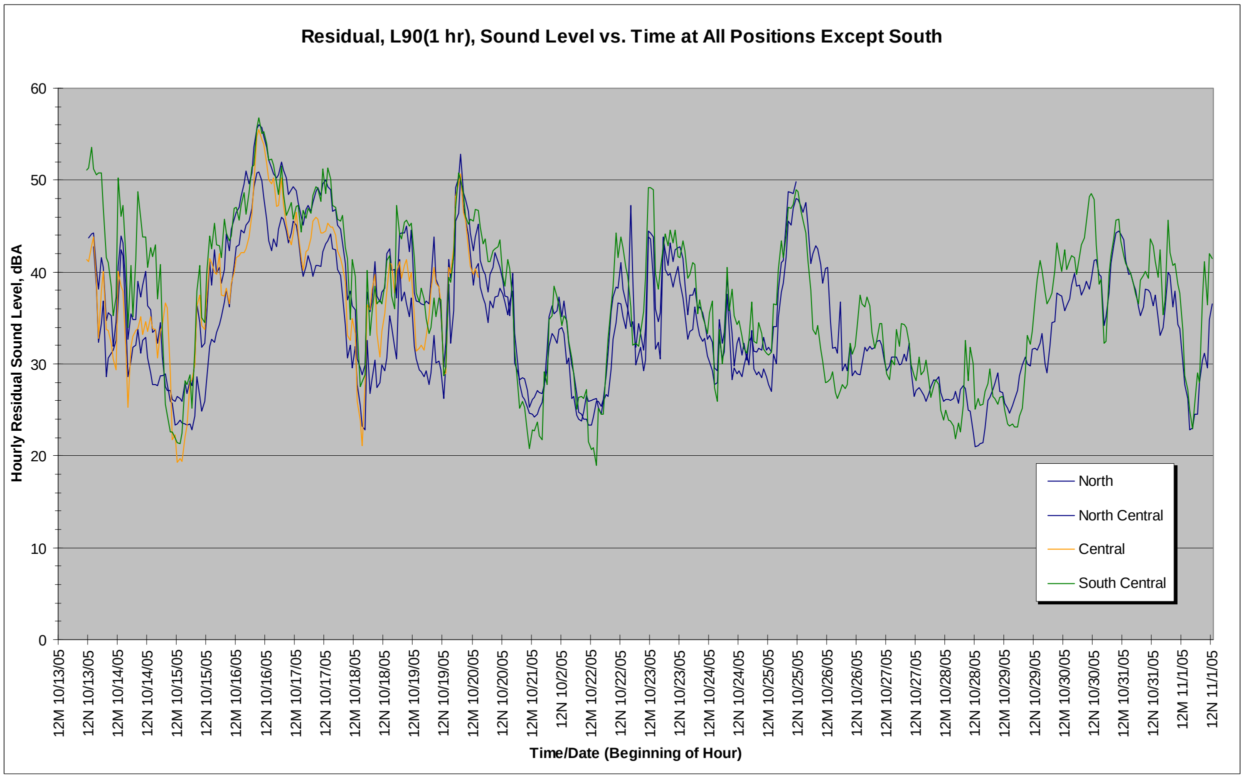


Figure 2.0.2

Since the levels at the four remaining positions intertwine and no one position is consistently higher or lower than the others, the arithmetic average can be taken to reasonably represent the likely sound level at any point within the site area. In Figure 2.0.3 this average, site-wide design L90 sound level measured essentially at ground level is compared to the wind speed measured at 80 m by an on-site met tower and subsequently normalized to a standard elevation of 10 m above ground level[1]. Thus this plot compares the near-minimum sound level that existed at ground level to the concurrent wind speed that would be experienced at turbine rotor height – and not at ground level, where the wind speed in many instances may well have been negligible.

[1] Normalization to what IEC 61400-11 [3] defines as a standard height of 10 m above ground level is necessary so that background sound levels can later be compared to turbine sound levels on a consistent basis. Turbine sound power levels are always expressed in terms of the wind speed at 10 m above grade.

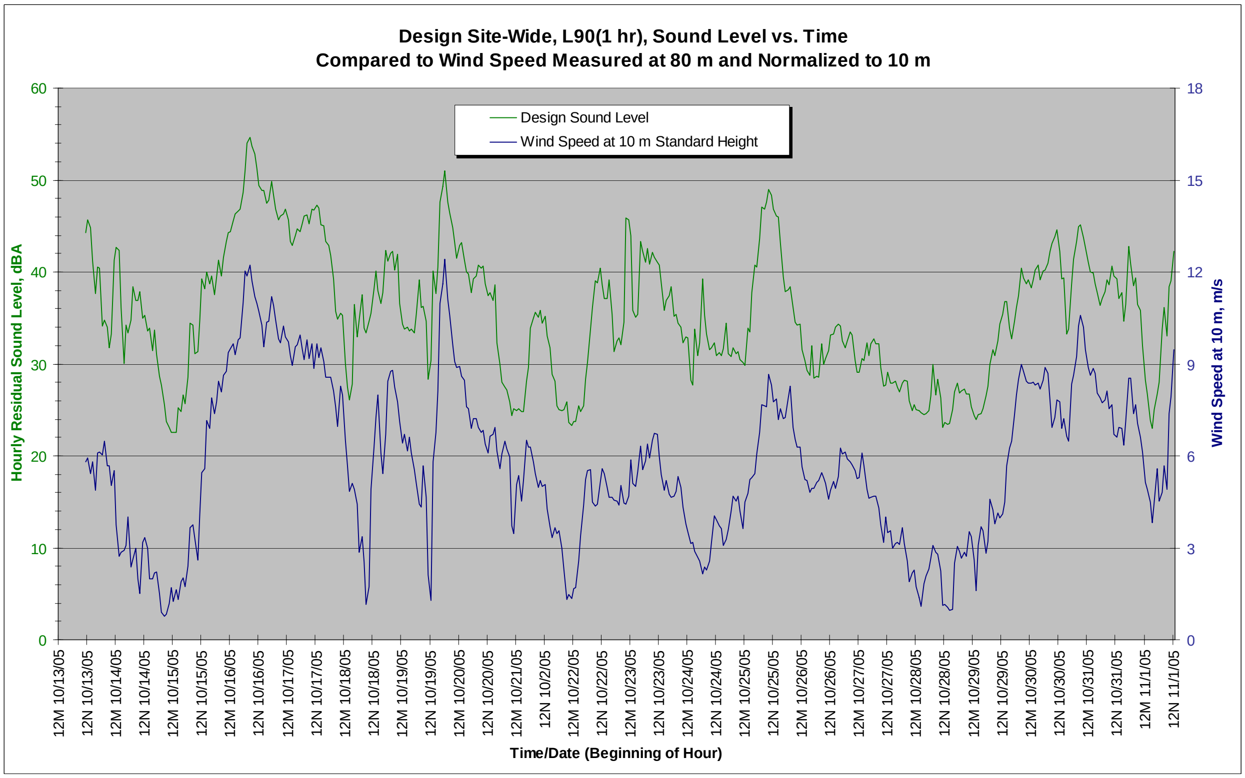


Figure 2.0.3

Figure 2.0.3 clearly shows that there is a strong relationship between the environmental sound level and wind speed. In fact, the general ambient sound level is dominated and largely controlled by wind-induced sounds, particularly during periods of moderate to high winds. The specific numerical correlation is shown in Figure 2.0.4 where the same data are plotted as a function of wind speed rather than time.

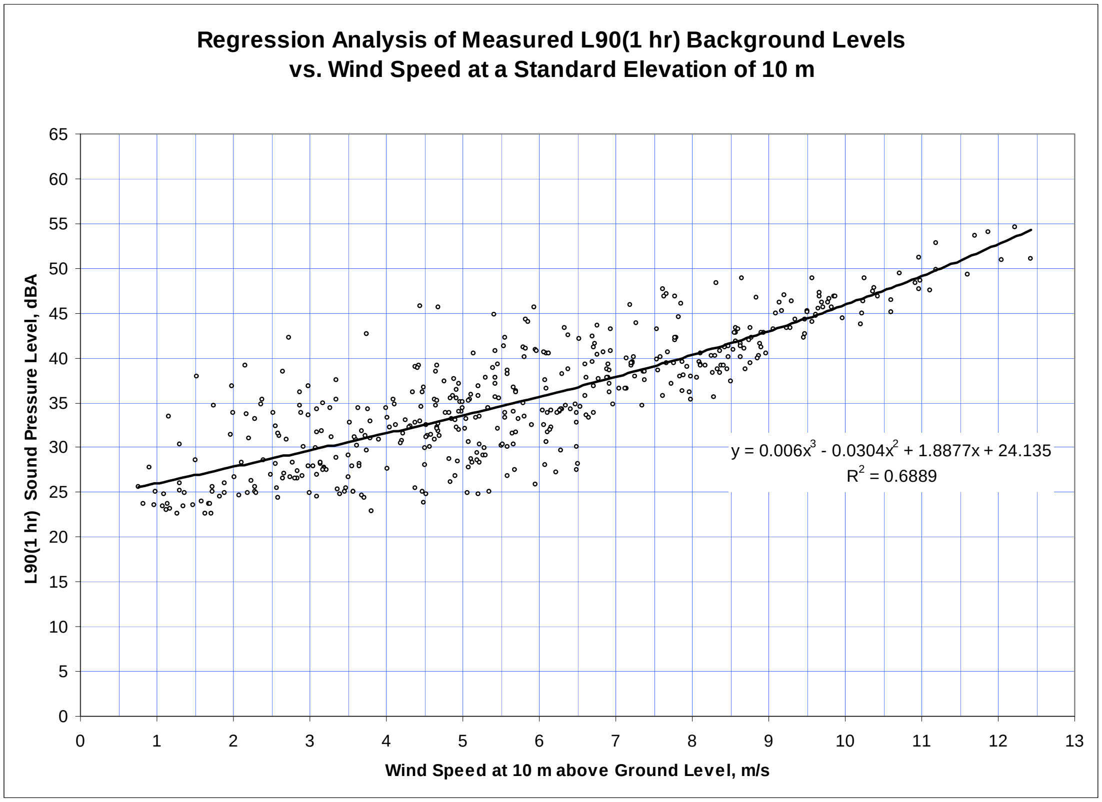


Figure 2.0.4

A definite trend towards higher sound levels with increasing wind speed is shown in Figure 2.0.4. Quiet periods are seen to occur only during fairly calm or low wind conditions when the turbines would be idle or turning only very slowly and higher sound levels exist during the windy conditions necessary for turbine operation. Recall that the wind speed in this plot is derived from measurements at 80 m (within the rotor plane) so it is directly associated with turbine operation and has nothing to do with ground level conditions. At 7 m/s, which is the point where the turbine rotors would generally first reach their maximum rotational speed and generate the maximum amount of noise, the background sound level is typically around 38 dBA (based on the mean trend line) and is essentially never below 35 dBA at that wind speed or any higher wind speed. At wind speeds above 11 m/s the background sound level (alone) can be expected to exceed the local ordinance limit of 50 dBA.

The mean background levels for wind speeds in the 3 to 12 m/s range are summarized in Table 2.0.1.

Table 2.0.1 *Measured A-Weighted Background L90(1 hr) Sound Levels as a Function of Normalized Wind Speed*

Integer Wind Speed at Standardized Height of 10 m, m/s	3	4	5	6	7	8	9	10	11	12
Mean Background Sound Level, L90, dBA	**30**	**32**	**34**	**36**	**38**	**40**	**43**	**46**	**49**	**53**

It is important to note that these results were obtained prior to the construction of the neighboring Noble Chateaugay Windpark, which closely borders the Marble River project to the west and south. Existing sound levels in the western and southern parts of the project area are likely to be somewhat higher today.

3.0 Turbine Sound Power Levels

3.1 Vestas V112

It is currently envisioned that the new Vestas V112-3.0MW wind turbine will be used for the project, whereas previously the Gamesa G87 and, more recently, the Suzlon S88 had been considered. The V112 is rated at 3 MW and has a 112 m diameter rotor. A 94 m hub height is anticipated. Because the V112 is a new model definitive sound test data are not currently available (although they are expected soon). At the present time, what is available from the manufacturer is a general technical specification [2] containing a set of overall A-weighted sound power levels at wind speeds ranging from 3 to 12 m/s, evidently measured per IEC 61400-11 [3] on a prototype since very specific wind speeds (within each bin) are associated with each sound level. It is not clear, however, whether these values are the actual measured levels or guaranteed levels incorporating an explicit design margin.

Table 3.1.1 *Preliminary Sound Power Levels for the Vestas V112 Turbine (Mode 0) as a Function of Normalized Wind Speed*

Integer Wind Speed at Standardized Height of 10 m, m/s	3	4	5	6	7	8	9	10	11	12
Sound Power Level, dBA re 1 pW	**95.0**	**97.7**	**102.5**	**105.7**	**106.5**	**106.5**	**106.5**	**106.5**	**106.5**	**106.5**

General experience with many different makes and models of wind turbines with rotors ranging from 77 to 101 m suggests that these levels are reasonable and that the actual final test results are unlikely to be significantly different. Overall sound power and frequency content varies surprisingly little with rotor size or electrical output.

Information on the frequency content and possible, but unlikely, tonal content is not currently available.

3.2 Suzlon S88

For comparison purposes the previous site plan utilizing more of the smaller Suzlon S88-2.1MW, V3 turbines needs to be modeled for this assessment. The latest noise information from Suzlon is a warranty statement [4] that gives the following sound power levels for the S88 based on a field test [5] per IEC 61400-11.

Table 3.2.1 *Warranted Sound Power Levels for the Suzlon S88-2.1MW, V3 Turbine as a Function of Normalized Wind Speed*

Integer Wind Speed at Standardized Height of 10 m, m/s	6	7	8	9
Sound Power Level, dBA re 1 pW	**104.8**	**105.5**	**106.1**	**105.2**

The performance at higher wind speeds is not given. Although IEC 61400-11 requires the reporting of sound levels for the 6 through 10 m/s wind speed bins (only), valid data for the often hard to obtain 10 m/s wind speed bin was apparently not captured during the field test.

Sound levels below 6 m/s are not given in the test report but values of 105 and 105.4 dBA re 1 pW are given in the warranty statement for the 4 and 5 m/s wind speed bins, respectively. These values appear to be grossly conservative estimates and are not considered valid since the sound levels of all similar wind turbines drop off precipitously below 6 m/s and are never higher than the 6 m/s value.

4.0 Critical Wind Speed and Design Conditions

4.1 Vestas V112 Design Sound Power Level

From the field survey it was determined that the background sound level varies with wind speed. From Table 3.1.1 above it can be seen that the turbine sound level also varies with wind speed. The two values must be compared under the same wind conditions to be meaningful. For example, it would be incorrect to compare the maximum turbine sound level, which requires relatively high winds for it to occur, to a very low background sound level that might occur on a calm night.

In terms of potential noise impacts the worst-case combination of background and turbine sound levels would occur at the wind speed where the background level is lowest relative to the turbine sound level – or, in other words, where the differential between the background level and turbine sound power level is greatest.

The following chart shows that this worst-case situation does not occur during 7 m/s wind conditions when the V112 sound level first reaches its maximum value, but rather at a somewhat lower wind speed of **6 m/s**. Under this particular wind condition the potential audibility of the turbines would be the greatest. At higher wind speeds the background level continues to rise rapidly while the turbine sound level plateaus making the project progressively less audible under higher wind conditions. At lower wind speeds the turbine sound level drops off faster than the background level.

Table 4.0.1 *Comparison of Measured Background Levels to V112 Turbine Sound Levels to Determine Critical Design Wind Speed*

Integer Wind Speed at Standardized Height of 10 m, m/s	3	4	5	6	7	8	9	10	11	12
Mean Background Sound Level, L90, dBA	**30**	**32**	**34**	**36**	**38**	**40**	**43**	**46**	**49**	**53**
Sound Power Level Vestas V112, dBA re 1 pW	**95**	**98**	**103**	**106**	**107**	**107**	**107**	**107**	**107**	**107**
Differential, dB	**65**	**66**	**69**	**70**	**69**	**66**	**64**	**61**	**57**	**54**

Consequently, the critical design wind speed for the modeling analysis for this project would be 6 m/s when the turbines would be generating a sound power level of 105.7 dBA re 1 pW.

The frequency content of the turbine sound power level is not given the technical specification for the V112 and is estimated for modeling purposes by essentially scaling up the known octave band frequency spectrum of the Vestas V90-2.0MW model as shown in Table 4.0.2. The scaling factor of 3.2 dB is simply the differential between the A-weighted sound power levels of the two models at 6 m/s.

Table 4.0.2 *Vestas V112 Octave Band Sound Power Level Frequency Spectrum for 6 m/s Wind Conditions – Estimated from the V90-2.0MW Model*

Octave Band Center Frequency, Hz	31.5	63	125	250	500	1k	2k	4k	8k	dBA
V90-2.0MW Sound Power Level at 6 m/s, dB re 1 pW	114.3	111.2	106.8	102.8	99.1	96.9	94.3	90.7	77.9	102.5
Scaling Factor*	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	
Estimated V112-3.0MW Sound Power Level Spectrum at 6 m/s, dB re 1 pW	117.5	114.4	110.0	106.0	102.3	100.1	97.5	93.9	81.1	105.7

* Differential between overall A-weighted sound levels (105.7 – 102.5 = 3.2 dB)

4.2 Suzlon S88 Design Sound Power Level

Although sound power levels over a full range of wind speeds are not available for the Suzlon S88, a similar critical wind speed analysis also points to a 6 m/s design condition as shown in Table 4.0.3.

Table 4.0.3 *Comparison of Measured Background Levels to S88 Turbine Sound Levels to Determine Critical Design Wind Speed*

Integer Wind Speed at Standardized Height of 10 m, m/s	6	7	8	9
Mean Background Sound Level, L90, dBA	**36**	**38**	**40**	**43**
S88 Sound Power Level, dBA re 1 pW	**105**	**106**	**106**	**105**
Differential, dB	**69**	**68**	**66**	**62**

In this instance the frequency spectrum for 6 m/s wind conditions is known (Table 4.0.4).

Table 4.0.4 *Suzlon S88 Octave Band Sound Power Level Frequency Spectrum for 6 m/s Wind Conditions [5]*

Octave Band Center Frequency, Hz	31.5	63	125	250	500	1k	2k	4k	8k	dBA
S88 Sound Power Level at 6 m/s, dB re 1 pW	101.2	105.3	110.7	107.6	103.0	98.1	94.5	85.2	73.0	104.8

4.3 NYSDEC Guideline Threshold

The nominal impact threshold per the NYSDEC guidelines [1] is commonly taken as an increase of 6 dBA in the overall environmental sound level due to additional noise from a new project. If the 6 dBA increase is conservatively considered a cumulative increase then the project-only sound level that would produce a 6 dBA increase would be 5 dBA above the pre-existing background level because decibels add together logarithmically rather than arithmetically. During critical (design) wind conditions at 6 m/s the mean background sound level was found to be 36 dBA; consequently, the nominal impact threshold would be a project level of **41 dBA** (36 dBA background + 41 dBA project = 42 dBA total cumulative sound level, or 6 dBA above the pre-existing level of 36 dBA). It is important to note that this threshold is a recommended design target and not a firm regulatory limit.

4.4 Regulatory Limits

Local noise ordinances in the towns of Clinton and Ellenburg have 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 place 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 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.

5.0 Modeling Methodology

Using the design sound power level spectra for the Vestas and Suzlon turbines in Tables 4.0.2 and 4.0.4 above, project sound levels were calculated using the Cadna/A®, ver. 4.035 noise modeling program developed by DataKustik, GmbH (Munich). This software enables the project and its surroundings, including terrain features, to be realistically modeled in three-dimensions. The modeling software is essentially an automated version of ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors* [6], which is the primary worldwide standard for sound propagation calculations.

Each V112 turbine is represented as a point noise source at a height of 94 m above the local ground surface. Hub height for the Suzlon units is 80 m.

A moderate ground absorption coefficient of 0.5 has been assumed in the model since all of the intervening ground between the turbines and potentially sensitive receptors consists of open fields or wooded areas, which are acoustically soft. The ground absorption coefficient (from ISO 9613) ranges from 0 for water or hard concrete surfaces to 1 for absorptive surfaces such as farm fields, woods or sand.

The sound level from each turbine is assumed to be the downwind sound level in all directions simultaneously; i.e. although physically impossible, an omni-directional wind is assumed essentially considering all possible wind directions at once. This approach has been found to correlate well with actual field measurements of operational wind projects. In general, sound radiates uniformly in all directions most of the time and directional effects (slightly louder downwind than upwind) are largely associated with brief and unusual wind conditions, such as a passing frontal system or a period of turbulent winds.

6.0 Revised Model Results

Plot 1 shows, as a baseline, the sound contours associated with the previous project design as of 2007 making use of the latest noise data available from Suzlon and setting the design conditions at a critical wind speed of 6 m/s. Because the turbine sound power level is highest relative to the background level at 6 m/s, the nominal NYSDEC impact threshold, in this case 41 dBA, is furthest from the turbines and covers the largest area. At all other wind speeds both higher and lower the potential impact region would be smaller. For example, at 8 m/s the mean background level is 40 dBA putting the NYSDEC design target at 45 dBA and making the “impact” area roughly correspond to the yellow areas in Plot 1.

Plot 2 shows, for the same critical design conditions that are depicted in Plot 1, the expected sound contours associated with the current Vestas V112 site layout, which uses fewer but more efficient turbines. A comparison between the two plots indicates that the general regions where sound level increases of 6 dBA or more are anticipated are generally similar in the southern part of the project and substantially smaller with the new layout in the northern part of the site.

In both instances, a mean project sound level of 50 dBA occurs well short of any residences, whether participating or not, indicating that the project will comply with the local ordinance limit during normal conditions. Field verification tests of similar completed projects in New York and elsewhere show that the model predictions accurately represent the mean or average sound level from the project and that the actual sound level will be within +/- 3 dBA of the predicted mean about 95% of the time. However, significant excursions above the mean have been observed to occur rarely (generally less than 1% of the time) due to unusual and unstable wind conditions; consequently, there may be brief periods when levels of more than 50 dBA occur at non-participating residences but for the vast majority of the time compliance with the 50 dBA ordinance limit can be expected.

Plot 3 shows the sound levels associated with the current site plan combined with the sound levels of the now-present Noble Chateaugay Windpark. Compared with Plot 2, it can be seen that most of the noise in the most-affected southwestern corner of the Marble River project area will be due to the Noble project. There are no homes within the yellow, higher noise area along Rt. 190 in Plot 2 where only the Marble River project is considered but there are quite a number in Plot 3 after the Noble units are added. In fact, the Noble units are so dominant in this area that the few additional Marble River units are unlikely to substantially change or affect the general sound level at the homes in this area.

7.0 Conclusions

The expected sound emissions from the Marble River Wind project have been recalculated based on the latest site plan involving 74 Vestas V112-3.0MW wind turbines and compared to the previous site layout from late 2007 using 115 Suzlon S88-2.1MW units. Both site arrangements have been evaluated under critical 6 m/s wind conditions when potential noise impacts from the project would theoretically be the greatest and both noise models have used the latest available sound data from the manufacturers. The large reduction in the number of turbines from 115 to 74 has reduced the potential noise impact footprint slightly in the southern part of the site and much more substantially in the northern part of the site. Compliance with the noise limit of 50 dBA appearing in both the Clinton and Ellenburg town wind laws continues to be expected under all normal operating conditions, although rare and brief excursions above 50 dBA at some residences cannot be ruled out.

References

1. New York State Department of Environmental Conservation, Program Policy: *Assessing and Mitigating Noise Impacts*, Feb. 2001.

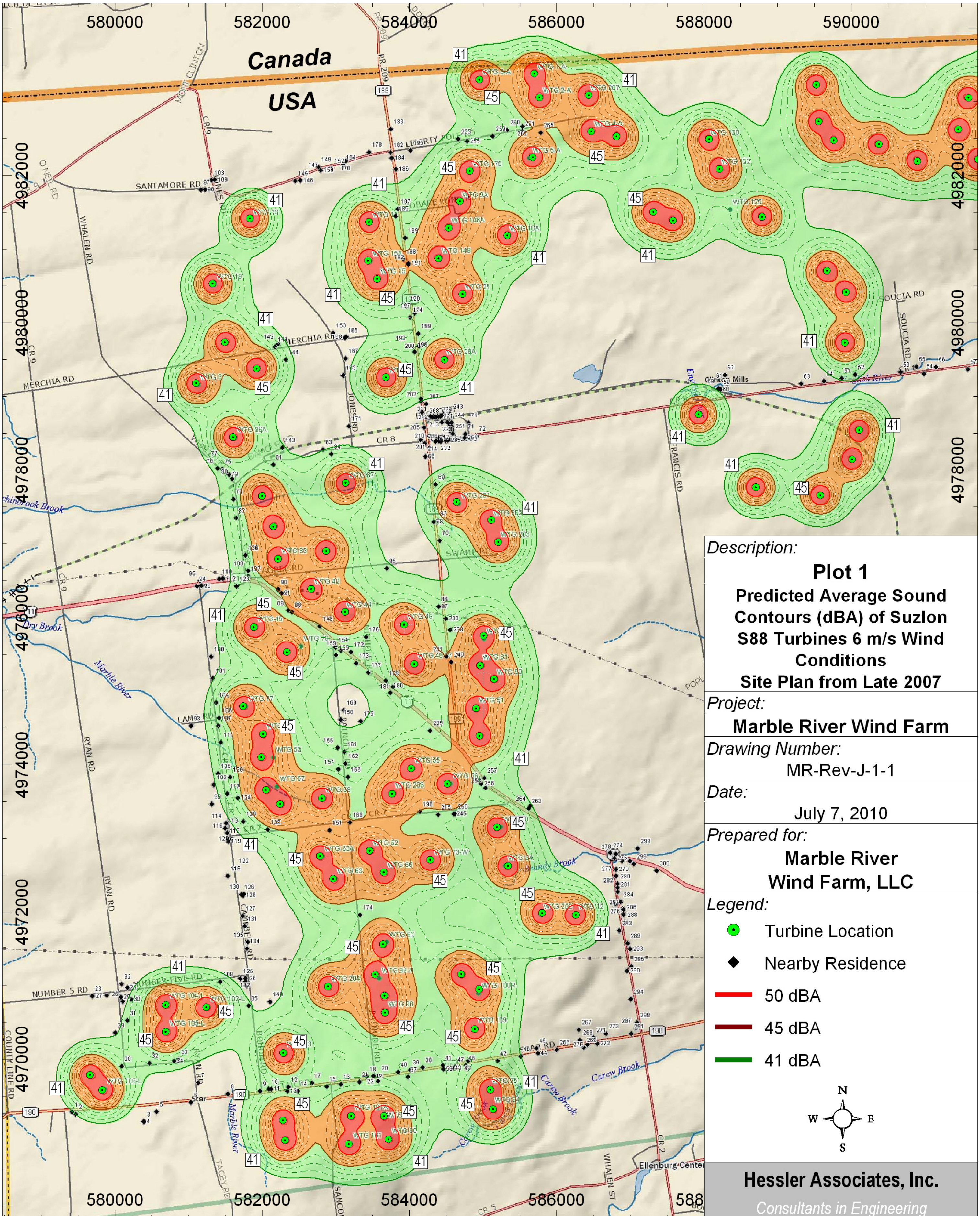
2. Vestas Wind Systems A/S, Item No. 0004-7993 V02, “General Specification V112-3.0MW IEC IIA”, Dec. 2009.

3. International Electromechanical Commission (IEC) 61400-11:2002(E) *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques*, Second Edition 2002-12.

4. Suzlon Energy A/S, “Warranted Sound Power Level S88-2.1MW, V3”, Feb. 13, 2008.

5. Suzlon Energy A/S, “1/3 Octave Band Sound Power Level S88-2.1MW, V3”, Jun. 13, 2007.

6. International Organization for Standardization, ISO 9613-2 *Acoustics – Attenuation of Sound during Propagation Outdoors*, Part 2, “A General Method of Calculation”, Geneva, 1989.



Scale in meters, units are UTM NAD83 coordinates

Description:

Plot 1

Predicted Average Sound Contours (dBA) of Suzlon S88 Turbines 6 m/s Wind Conditions Site Plan from Late 2007

Project:

Marble River Wind Farm

Drawing Number:

MR-Rev-J-1-1

Date:

July 7, 2010

Prepared for:

Marble River Wind Farm, LLC

Legend:

- Turbine Location
- Nearby Residence
- 50 dBA
- 45 dBA
- 41 dBA

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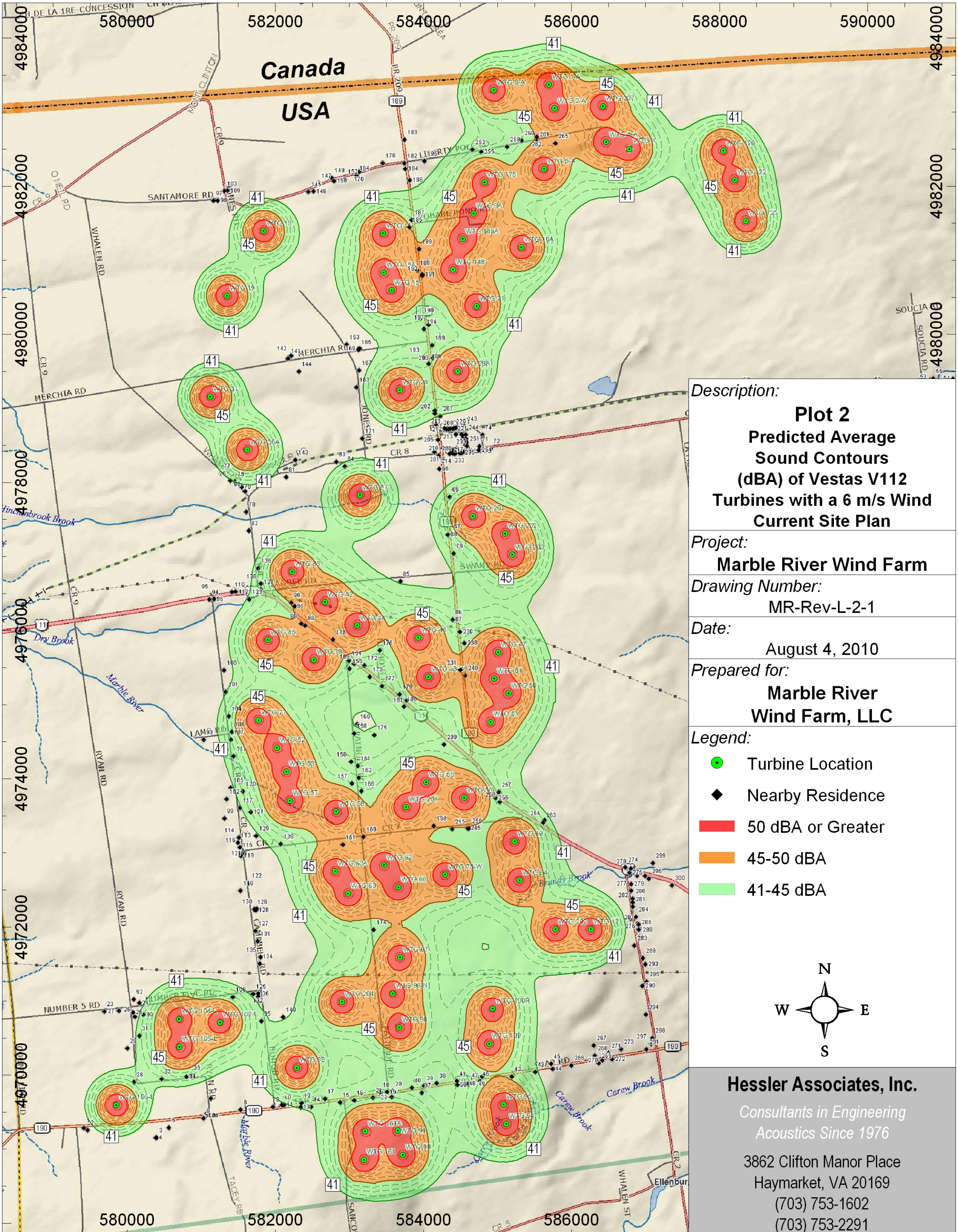

Scale in meters, units are UTM NAD83 coordinates

Description:

Plot 2
Predicted Average Sound Contours (dBA) of Vestas V112 Turbines with a 6 m/s Wind
Current Site Plan

Project:

Marble River Wind Farm

Drawing Number:

MR-Rev-L-2-1

Date:

August 4, 2010

Prepared for:

Marble River Wind Farm, LLC

Legend:

- Turbine Location
- Nearby Residence
- 50 dBA or Greater
- 45-50 dBA
- 41-45 dBA

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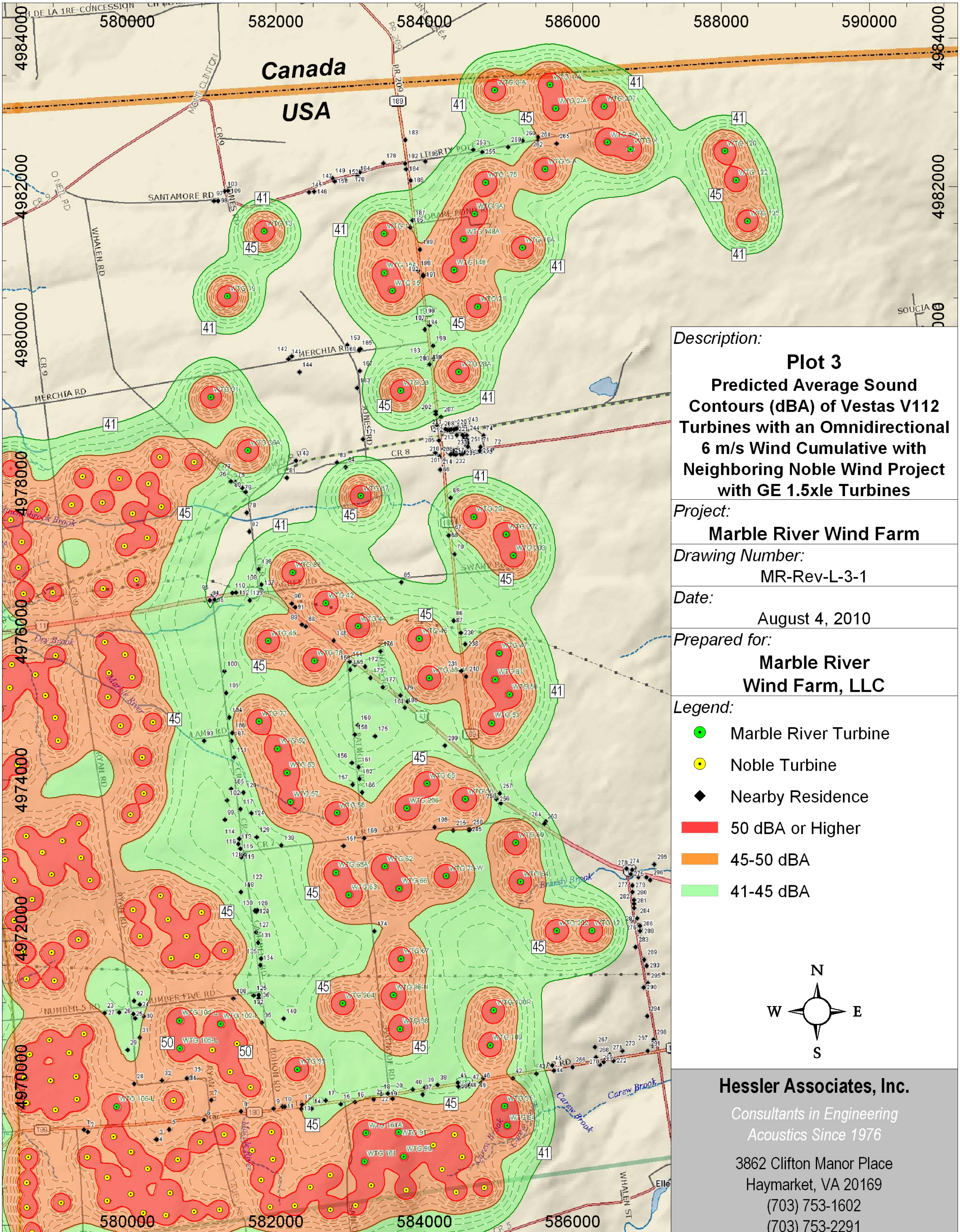

Scale in meters, units are UTM NAD83 coordinates

Description:

Plot 3

Predicted Average Sound Contours (dBA) of Vestas V112 Turbines with an Omnidirectional 6 m/s Wind Cumulative with Neighboring Noble Wind Project with GE 1.5xle Turbines

Project:

Marble River Wind Farm

Drawing Number:

MR-Rev-L-3-1

Date:

August 4, 2010

Prepared for:

Marble River Wind Farm, LLC

Legend:

- Marble River Turbine
- Noble Turbine
- Nearby Residence
- 50 dBA or Higher
- 45-50 dBA
- 41-45 dBA

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