NOISE STUDY FOR THE ANTELOPE HILLS WIND PROJECT, MERCER COUNTY, NORTH DAKOTA

Prepared for

Antelope Hills Wind Project, LLC

Prepared by

TRC Environmental Corporation
41 Spring Street
New Providence, NJ 07974

July 6, 2015

TRC

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1.0 INTRODUCTION

A noise assessment was performed for the Antelope Hills Wind Project (Project) on behalf of Antelope Hills Wind Project, LLC. The Project will be located over an approximate 57.2 square mile area in Mercer County, North Dakota. The Project will include 86 Vestas V-100 2.0-megawatt (MW) name plate capacity wind turbine generators (WTGs) and associated facilities. A total of 18 WTGs were also included in the analysis as alternate locations. The hub height for all turbines will be 80 meters. The noise assessment includes an analysis of potential noise levels due to Project operation and comparison to the North Dakota noise standard. Nearby noise sensitive areas, including all identified inhabited residences and community buildings, were identified and included in this assessment. A total of 38 structures (such as unoccupied residences, occupied residences, or residential structures) were provided to TRC and evaluated as part of this analysis.

1.1 General Information on Noise

The range of pressures that cause the vibrations that create noise is large. Noise is therefore measured on a logarithmic scale, expressed in decibels (dB). The frequency of a sound is the "pitch" (high or low). The unit for frequency is hertz (Hz). Most sounds are a composite of frequencies. The normal human ear can usually distinguish frequencies from 20 Hz (low frequency) to about 20,000 Hz (high frequency), although people are most sensitive to frequencies between 500 and 4,000 Hz. The individual frequency bands can be combined into one overall dB level.

Noise is typically measured on the A-weighted scale (dBA). The A-weighted scale was developed and has been shown to provide a good correlation with the human response to sound and is the most widely used descriptor for community noise assessments (Harris 1991). The faintest sound that can be heard by a healthy ear is about 0 dBA, while an uncomfortably loud sound is about 120 dBA. In order to provide a frame of reference, some common sound levels are listed below.

- Pile driver at 100 feet 90 to 100 dBA
- Chainsaw at 30 feet 90 dBA
- Truck at 100 feet 85 dBA
- Noisy urban environment 75 dBA
- Lawn mower at 100 feet 65 dBA
- Average speech 60 dBA
- Typical suburban daytime 50 dBA
- Quiet office 40 dBA
- Quiet suburban nighttime 35 dBA
- Quiet rural area 30 dBA

Common terms used in this noise analysis are defined below.

L_{eq} - The equivalent noise level over a specified period of time (i.e., 1-hour). It is a single value of sound that includes all of the varying sound energy in a given duration.

1.2 Applicable Noise Standards and Guidelines

1.2.1 Local Ordinances

Mercer County has a nuisance type ordinance that does not provide any numerical limitations on noise.

1.2.2 State of North Dakota

The North Dakota Public Service Commission has adopted a noise standard (Chapter 69-06-08-01(4)) specifically related to wind energy facilities that limits noise from any wind energy conversion system (WECS). WECS must not operate in a manner such that sound levels measured within 100 feet of an inhabited residence or community building are above 50 dBA. Specifically, the standard states that:

> *Additional avoidance areas for wind energy conversion facilities. A wind energy conversion facility site must not include a geographic area where, due to operation of the facility, the sound levels within one hundred feet of an inhabited residence or a community building will exceed fifty dBA [A-weighted decibels]. The sound level avoidance area criteria may be waived in writing by the owner of the occupied residence or the community building.*

The North Dakota Public Service Commission noise standard specific to WECS is the most restrictive standard, and is therefore the driving regulatory limit for the proposed Project.

2.0 OPERATION NOISE

This section describes the operational noise characteristics of WTGs, as well as the methods and results from the operational noise analysis for the Project.

2.1 Wind Turbine Noise Sources

Older wind turbine installations have been documented as generating low frequency noise problems, and complaints due to both aerodynamic noise and mechanical noise. These problems have been corrected in modern designs through the following design features (Curry & Kerlinger, L.L.C. 2004; Danish Wind Industry 2004):

- Upwind Design - older wind turbine rotors were located on the downwind side of the tower. Wind passing through the tower into the rotor created an aerodynamic wake. Modern designs locate the rotor on the upwind side of the tower, avoiding this problem.
- Streamlined monopole tower designs produce minimal disturbance in the wind field.
- Improved blade design.
- Reduced blade tip speed.
- Improved gearbox design.
- Insulated nacelles.

Aerodynamic noise is generated by wind passing over the turbine blades which, in modern turbines, creates a broadband sound similar in nature to the sound environment typical of rural areas. WTG sound levels increase somewhat with increasing wind speeds. Mechanical noise associated with modern wind turbines has been significantly reduced through improved component design and high efficiency insulation of the nacelle, which houses the gearbox and drive train.

The Project will be required to meet the North Dakota Public Service Commission noise standard, which limits wind turbine noise to no more than 50 dBA at any location within 100 feet of an inhabited residence or community building.

2.2 Modeling Methodology

The commercially available CadnaA model (DataKustik, 2006) was used for this analysis. The software takes into account spreading losses, ground and atmospheric effects, shielding from terrain, barriers and buildings, and reflections from surfaces. The software is standards-based and the International Standards Organization (ISO) 9613-2 standard was used for air absorption and other noise propagation calculations (ISO 1996). These model capabilities are especially important in an area such as the Project site, as the effects of the complex terrain can be accounted for. Site specific GIS topographic data were obtained and incorporated into the model. By default, the model assumes that all receptors are downwind of the WTGs simultaneously (a physical impossibility) thereby producing a conservative result. The following model options were selected:

- The ground absorption coefficient was selected as 0.5 where a value of 0 is a highly reflective ground surface such as pavement or calm water and 1 is a highly absorptive surface such as plowed fields and forests. A value of 1 would be more realistic for the Project area, but the value of 0.5 yields a conservative result to avoid under-predicting expected noise levels.

- Standard atmospheric conditions were selected (temperature of 50 degrees Fahrenheit and a relative humidity of 70 percent), which are favorable to the propagation of sound. This is also a conservative selection since different combinations more applicable to the site will generally produce slightly lower modeled results on the order of tenths of a decibel.

- The search radius was set to 8 kilometers. This means that the contributions of all turbines within 8 kilometers of each receptor or grid point were calculated in the total for those locations. Because of the scattering of sound in the atmosphere, particularly when it is windy, noise from any more distant turbines should not realistically have any contribution, although the model might show a slight increase.

- No credit was taken for the vegetative cover or intervening trees, which in reality will act to further reduce noise levels.

Table 1 shows the sound power level, by octave band and as an overall dBA level, of the Vestas V100-2.0 MW turbine. The overall dBA sound power levels were provided by Vestas (Vestas 2015). The octave band data were estimated based on the spectral shape of other 2.0 MW WTGs. Sound power is the total acoustic power produced by a noise source and is independent of the distance from the source. It is reported in decibels referenced to 10^{-12} watts. Provided in Table 2 is the sound power level output for the turbines at various wind speeds. As shown in the table, the maximum sound output for the turbine occurs at a hub height elevation wind speed of 9 m/s and greater. Turbine sound output does not increase with hub height winds greater than 9 m/s.

Sound power levels for wind turbines are determined in accordance with International Electrotechnical Commission (IEC) Standard 61400-11 (2012). The methodology was developed in order to provide more consistent reporting and measurement techniques to allow for better comparison between turbine manufacturers. The standard defines deviation values for the total standard deviation, a deviation for test reproducibility, and a deviation for product variation. To account for the inherent deviation associated with the IEC testing methodology, a confidence interval of k=2 dBA was reported and applied to the WTG sound power levels. The addition of this confidence interval, combined with the modeling assumptions, is expected to result in a conservative assessment of Project sound levels.

The 2 dBA k-factor was added to the maximum 105 dBA sound power level for each WTG, with the result of a 107 dBA power level per WTG being utilized in the modeling. The model was used to calculate noise levels in order to produce a noise contour map that shows expected maximum Project related noise levels over the entire area. All WTGs operating simultaneously at full load were included in the model, and all noise was assumed to emanate from the hub height (80 meters above the ground). The model grid was set to 10 feet above grade to account for two story residential structures. Noise emissions from the Project substation were not included in the model because of the large distance (0.75 miles) from any noise sensitive receptors.

The coordinates for all WTGs and all identified inhabited residences and community buildings were provided by Sun Edison.

2.3 Noise Modeling Results

The output from the model, in the form of noise contour maps of the area, is presented as Figures 1 and 2. Figure 1 shows noise contours in five dBA increments, while Figure 2 shows only the 50 dBA contour that corresponds to the North Dakota Public Service Commission noise standard limit. The WTG locations are depicted as red circles with black crosses and the occupied residences are depicted as small orange colored squares on the contour maps. The noise contour maps depict the calculated sound levels that would occur with the Project operating at full noise output conditions, with all turbines operating simultaneously. Wind turbine sound has some modulation (e.g., the sound, mainly at close in distances, will fluctuate somewhat by several decibels). The contours presented closely reflect the average, or L_{eq} sound level that would be expected.

The North Dakota Public Service Commission standard applies at distances of 100 feet from any inhabited residence or community building. Each individual receptor was therefore scrutinized to determine the highest sound level calculated at any edge of the 100 foot radius. Tables 3 and 4 provide the highest calculated sound level for each receptor. The calculated noise levels at each residence are sorted by residence identification in Table 3, and sorted by sound level in Table 4.

A review of the contour map and the data in Tables 3 and 4 reveal that the maximum calculated noise level at 100 feet for any inhabited residence or community building is 47.3 dBA, which is below the North Dakota 50 dBA standard.

The calculated Project noise levels are conservative (i.e., projected to be higher than is likely), as they are for all turbines operating at the same time under full load and include the aforementioned k-factor. Under normal conditions, the turbines will often be operating at lower speeds, or not be operating at all, and would therefore produce less noise. Also, as discussed previously, the model assumes that all receivers are downwind simultaneously. In reality, receivers will be upwind from some turbines, and downwind from others, so actual sound levels are anticipated to be lower.

3.0 CONCLUSION

TRC conducted a noise assessment of the Antelope Hills Wind Project in Mercer County, North Dakota proposed by Antelope Hills Wind Project, LLC. The assessment included a noise modeling analysis of expected maximum Project operational noise levels, and a comparison of Project noise levels against the North Dakota Public Service Commission standard.

The modeling analysis utilized the maximum sound output from the WTGs (hub height wind speeds of 9 m/s or greater), and included the addition of a 2 dBA k-factor to account for measurement uncertainty. Modeling was conducted conservatively, assuming a partially reflective ground surface, favorable sound propagation conditions of downwind/moderate atmospheric inversion, and included the contribution of noise from all WTGs within 8 kilometers of any receptor.

The noise modeling analysis revealed that maximum Project sound levels would be below the North Dakota Public Service Commission noise standard limit of 50 dBA at 100 feet from all 38 inhabited residences and community buildings. The highest sound level calculated at any receptor location is 47.3 dBA. The proposed WTG layout and selected WTG model analyzed in this study did not show any exceedances of the North Dakota Public Service Commission noise standard.

4.0 REFERENCES

Curry & Kerlinger, L.L.C. 2004. www.nationalwind.org

Danish Wind Industry. 2004. www.windpower.org

DataKustik GmbH. 2006. Computer Aided Noise Abatement Model CadnaA, Version .7. Munich, Germany.

Harris 1991. Handbook of Acoustical Measurements and Noise Control, Third Edition. McGraw-Hill, Inc.

International Electrotechnical Commission. 2012. International Electrotechnical Commission. Standard 61400-11 *Wind Turbine Generator Systems: Acoustic Noise Measurement Techniques.*

International Standards Organization. 1996. International Organization for Standardization. Standard ISO 9613-2 *Acoustics - Attenuation of Sound During Propagation Outdoors, Part 2 General Method of Calculation*. Geneva, Switzerland.

North Dakota Public Service Commission. 2013. Section 69-06-08-01(4) *Energy Conversion Facility Siting Criteria: Additional Avoidance Areas for Wind Energy Conversion Facilities. Bismarck, North Dakota.*

Vestas 2015. Performance Specification V100-2.0MW 50/60 Hz. Document No. 0051-0207-V00.

Tables

Table 1 – Vestas V100-2.0 MW Wind Turbine Sound Power Level.

Un-weighted Octave Band Sound Power Levels (dB) at Maximum Sound Output with a 2 dBA K-factor Hub Height Wind Speed ≥ 9 Meters Per Second								
Octave Band Center Frequency (Hz)								**Total dBA**
63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	
109.2	110.1	106.6	105.2	102.0	96.8	90.0	88.1	106.9

Note: Total dBA sound power level is as provided by Vestas (Vestas, 2015). Octave band data are estimated.

Table 2 – Sound Power Levels of Vestas V100-2.0 MW WTG by Wind Speed (k-Factor Not Included).

Hub Height Wind Speed (m/s)	Sound Power Level (dBA)
< 4	94
5	95
6	99
7	101
8	103
≥9	105

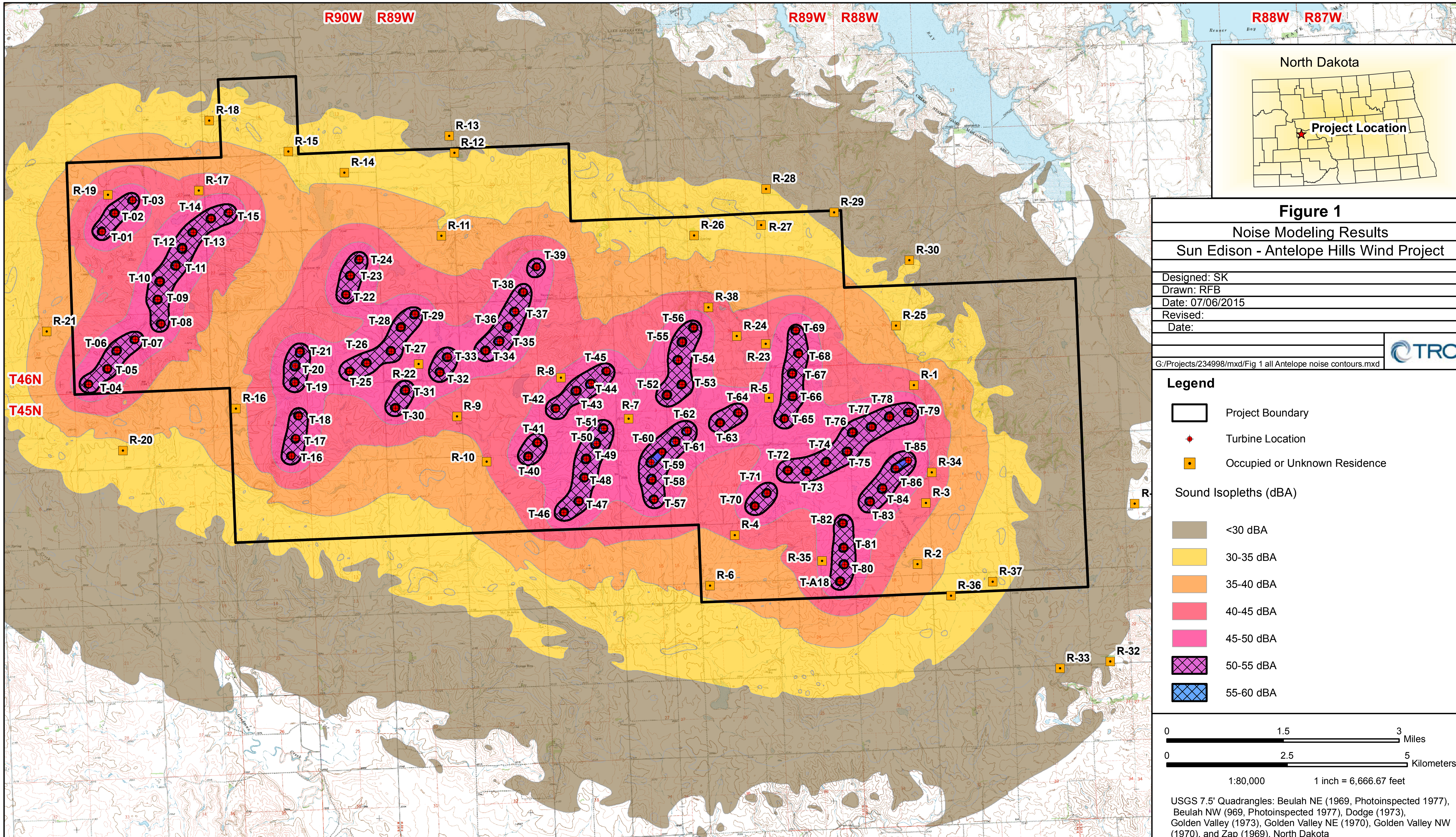
Table 3 – Noise Modeling Results at 100 Feet From Inhabited Residences or Community Buildings (Sorted by Receptor ID).

Antelope Hills Wind Noise Modeling Results (Sorted by Receptor ID)			
Inhabited Residence or Community Building ID	**Sound Level (dBA)**	**Inhabited Residence or Community Building ID**	**Sound Level (dBA)**
1	43.6	20	34.4
2	38.0	21	36.9
3	42.0	22	47.3
4	41.6	23	44.2
5	47.1	24	42.1
6	36.0	25	33.6
7	46.3	26	33.7
8	47.1	27	32.1
9	41.4	28	30.6
10	40.6	29	26.1
11	37.3	30	30.7
12	30.9	31	19.7
13	27.4	32	19.6
14	34.2	33	21.9
15	33.9	34	44.6
16	38.7	35	47.0
17	43.4	36	33.4
18	33.2	37	31.3
19	46.4	38	43.4

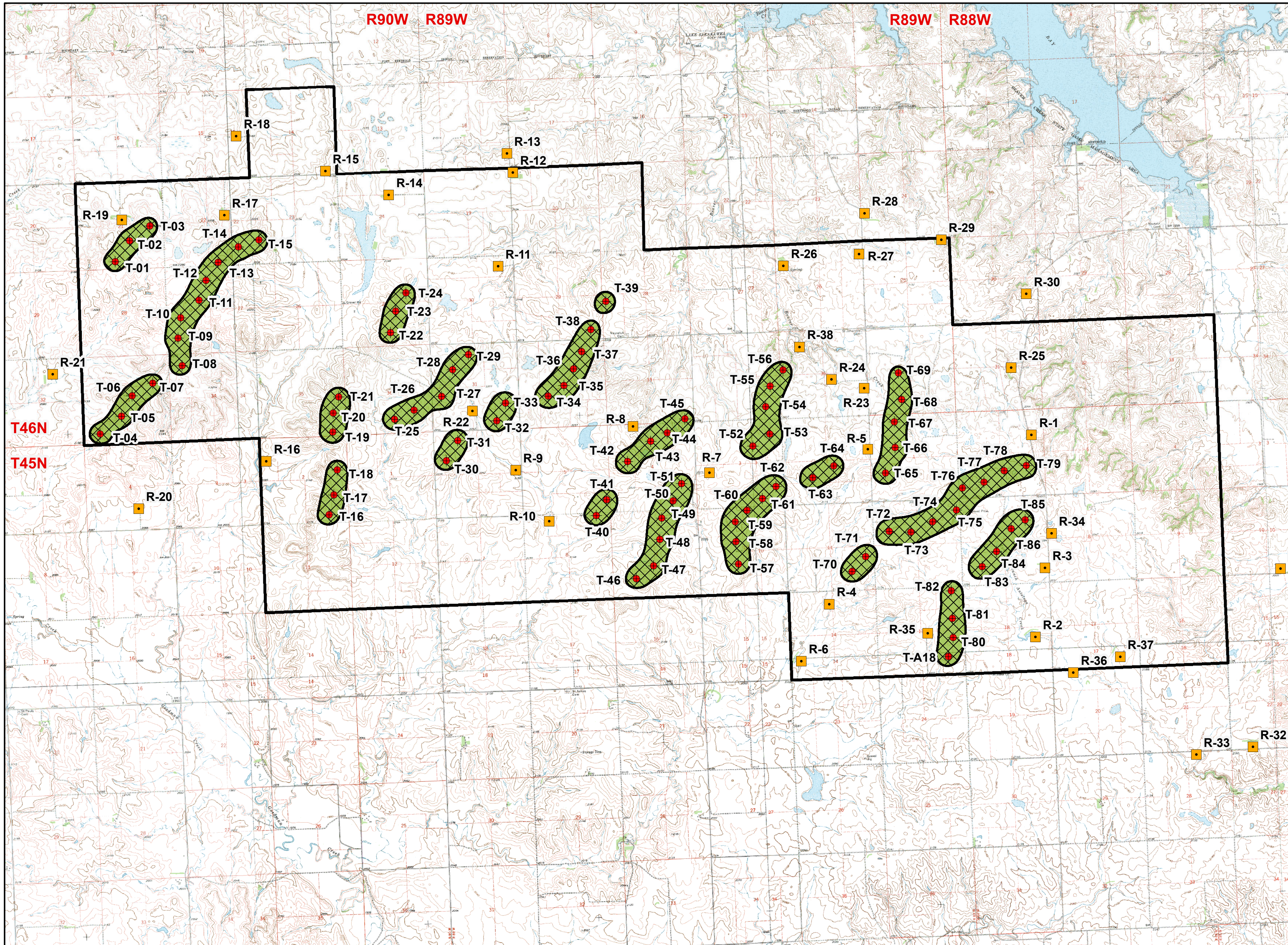
Table 4 – Noise Modeling Results at 100 Feet From Inhabited Residences or Community Buildings (Sorted by Sound Level).

Antelope Hills Wind Noise Modeling Results (Sorted by Sound Level)			
Inhabited Residence or Community Building ID	**Sound Level (dBA)**	**Inhabited Residence or Community Building ID**	**Sound Level (dBA)**
22	47.3	21	36.9
5	47.1	6	36.0
8	47.1	20	34.4
35	47.0	14	34.2
19	46.4	15	33.9
7	46.3	26	33.7
34	44.6	25	33.6
23	44.2	36	33.4
1	43.6	18	33.2
17	43.4	27	32.1
38	43.4	37	31.3
24	42.1	12	30.9
3	42.0	30	30.7
4	41.6	28	30.6
9	41.4	13	27.4
10	40.6	29	26.1
16	38.7	33	21.9
2	38.0	31	19.7
11	37.3	32	19.6

Figures



R90W
R89W
R89W
R88W
R88W
R87W
T46N
T45N
North Dakota
Project Location
Figure 1
Noise Modeling Results
Sun Edison - Antelope Hills Wind Project
Designed: SK
Drawn: RFB
Date: 07/06/2015
Revised:
Date:
G:/Projects/234998/mxd/Fig 1 all Antelope noise contours.mxd
TRC
Legend
Project Boundary
Turbine Location
Occupied or Unknown Residence
Sound Isopleths (dBA)
<30 dBA
30-35 dBA
35-40 dBA
40-45 dBA
45-50 dBA
50-55 dBA
55-60 dBA
0
1.5
3
Miles
0
2.5
5
Kilometers
1:80,000
1 inch = 6,666.67 feet
USGS 7.5' Quadrangles: Beulah NE (1969, Photoinspected 1977), Beulah NW (969, Photoinspected 1977), Dodge (1973), Golden Valley (1973), Golden Valley NE (1970), Golden Valley NW (1970), and Zap (1969), North Dakota



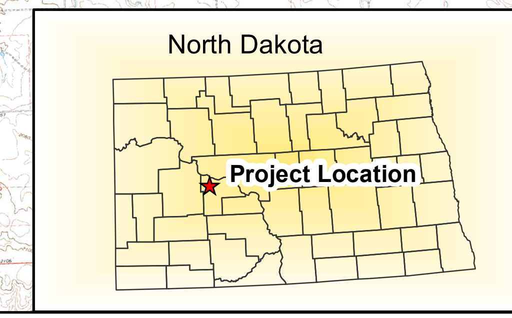


Figure 2

50 dBA Noise Contours

Sun Edison - Antelope Hills Wind Project

Designed: SK
Drawn: RFB
Date: 07/06/2015
Revised:
Date:

G:/Projects/234998/MXD/Fig 2- 50 dBA AntelopeNoise Contours.mxd

TRC

Legend

Project Boundary

Turbine Location

Occupied or Unknown Residence

Sound Isopleths (dBA)

>50 dBA

0 1.5 3 Miles

0 2.5 5 Kilometers

1:80,000 1 inch = 6,666.67 feet

USGS 7.5' Quadrangles: Beulah NE (1969, Photoinspected 1977), Beulah NW (969, Photoinspected 1977), Dodge (1973), Golden Valley (1973), Golden Valley NE (1970), Golden Valley NW (1970), and Zap (1969), North Dakota