Acoustic Assessment

Emmons-Logan Wind Energy Center
Emmons-Logan Wind, LLC
Emmons and Logan Counties, North Dakota

Prepared for:

Emmons-Logan Wind, LLC
700 Universe Boulevard
Juno Beach, FL 33408

Prepared by:

AECOM
401 West A Street, Suite 1200
San Diego, California 92101

November 2018

This page intentionally left blank.

EXECUTIVE SUMMARY

An acoustic assessment has been completed by AECOM for the proposed Emmons-Logan Wind Energy Center (Project) located in Emmons and Logan Counties, North Dakota. If constructed, the Project would consist of 123 wind turbine generators (WTGs) and associated access roads, underground electrical systems, collection substations, laydown yard, operations and maintenance building, meteorological evaluation towers, and concrete batch plant. For the acoustic assessment, two Project WTG layout designs were considered: one with alternates (129 WTGs), and the other without alternates (123 WTGs). The WTGs comprising these layout designs include two General Electric (GE) WTG model types, a 2.5 megawatt (MW) generator, and a 1.715 MW generator. The objective of this assessment was to determine whether nominal operations of the Project would be compliant with the applicable North Dakota Public Service Commission (Commission) 50 dBA sound limit.

WTG sound source data was obtained from GE for the proposed GE 2.5 MW and GE 1.715 MW generators. Outdoor sound propagation modeling of aggregate WTG operation sound level was performed with Datakustik CadnaA software, a commercially available computer software program that predicts sound levels near industrial sound-generating sources based on International Organization of Standardization (ISO) 9613-2 standards for outdoor sound propagation calculation (ISO 1996). This software uses industry-accepted propagation algorithms and accepts input of sound reference levels as provided by equipment manufacturers and other sources of relevant information.

Future predicted sound levels attributed to aggregate WTG operation were predicted and compared with the Commission threshold at each occupied residential land use in the Project vicinity. The results of this assessment conclude that the Project will not generate exceedances of the Commission threshold at any occupied receptor location. Thus, the Project is compliant with regulatory sound thresholds.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Emmons-Logan Wind, LLC (Emmons-Logan Wind), a wholly owned, indirect subsidiary of NextEra Energy Resources, LLC, is submitting an Application for a Certificate of Site Compatibility (Certificate) to construct and operate the Emmons-Logan Wind Energy Center (Project) in Emmons and Logan Counties, in south-central North Dakota.

The Project will have a nameplate capacity of approximately 298.1 megawatts (MW), consisting of up to 123 wind turbines using both GE 2.5 MW and GE 1.715 MW utility-grade wind turbines. In addition to the 123 primary turbines, up to seven alternative turbine locations have also been considered. The alternate turbine locations are proposed to provide siting flexibility based on on-going studies, landowner preferences, and issues identified during construction. Only 123 turbines will be constructed. AECOM has conducted the following acoustic analysis for the Project to support Emmons-Logan Wind's application for a Certificate under the North Dakota Public Service Commission.

1.1 Study Area and Existing Environment

The Emmons-Logan Wind Project Area encompasses approximately 64,563 acres between the eastern Emmons County and western Logan County. The acoustic assessment study area encompasses approximately 88,000 acres, approximately bounded on the north by 66th Street SE, on the east by 28th Avenue SE, on the south by 77th Street SE, and on the west by 10th Avenue SE. The major roadways within the Project vicinity are State Highway 34, State Highway 3, State Highway 13, and U.S. Highway 83, which generally parallel the northern, eastern, southern, and western boundaries of the study area respectively. The land uses within the study area are primarily agricultural, with rural farmstead residences and ancillary structures dispersed throughout the study area. The topography in this region is characterized by rolling grassy terrain, interspersed with natural lakes and ponds.

The sound-sensitive land uses in the area are solely rural farmstead residences. A total of 95 structures were analyzed for Project-related sound level impacts. Determination of habitation for existing structures was limited to public information and roadside surveys.

Emmons County and Logan County would generally be considered rural agricultural areas and thus would be expected to have reasonably low ambient sound levels. Existing sound sources in the area are likely dominated by distant traffic sound from the nearby arterial highways, and would also include intermittent aircraft overflights, sounds from agricultural operations, and wind-generated sounds.

1.2 Acoustical Terminology

For purposes of document brevity, AECOM assumes the reader is familiar with basic acoustical principles. Readers desiring an expanded introduction to acoustics fundamentals beyond what is presented in this section should consult industry-accepted reference texts such as *Noise & Vibration Control Engineering* (Beranek & Ver 1992) or *Engineering Noise Control* (Bies & Hansen 2003). Fundamental concepts and terms related to acoustics, as discussed in this technical report, are summarized in the following paragraphs.

Sound is a physical phenomenon consisting of minute vibrations that travel through a medium, such as air, and are sensed by the human ear. Sound is generally characterized by several variables, including frequency and intensity. Frequency describes the pitch of the sound and is measured in cycles per second or Hertz (Hz), while intensity describes the sound's loudness and is measured in decibels (dB) using a logarithmic scale.

Sound level is usually expressed by reference to a known standard. This report refers to both sound pressure level (SPL) and sound power level (PWL). In expressing sound pressure on a logarithmic scale, the sound pressure is compared to a reference value of 20 microPascals (µPa). SPL depends not only on the power of the source, but also on the distance from the source and on the acoustical characteristics of the space surrounding the source. Unlike sound pressure, which varies with distance from a source, sound power is the acoustic power of a source typically expressed in Watts. Sound power is the acoustic power radiated from a source, expressed in decibels as a sound power level (PWL) using a reference power value of 10^{-12} Watts.

Due to its definition with respect to a reference sound pressure, a sound level of 0 dB is not the complete absence of sound but instead the approximate threshold of average healthy human hearing and is barely audible under extremely quiet listening conditions. Normal speech has a sound level of approximately 60 dB. Sound levels above approximately 110 dB begin to be felt inside the human ear as discomfort and eventually pain at 120 dB and higher levels. The minimum change in the sound level of individual events that an average human ear can detect under laboratory conditions is about 1 to 2 dB. A 3 to 5 dB change, on the other hand, is readily perceived under most circumstances. A change in sound level of about 10 dB is usually perceived by the average person as a doubling (or if decreased by 10 dB, halving) of the sound's loudness, even though the actual change in sound energy is an order of magnitude.

Due to the logarithmic nature of the decibel unit, sound levels cannot be added or subtracted directly and are somewhat cumbersome to handle mathematically; however, some simple rules are useful in dealing with sound levels. First, if a sound's intensity is doubled, the sound level increases by 3 dB, regardless of the initial sound level. For example: 60 dB + 60 dB = 63 dB, and 80 dB + 80 dB = 83 dB.

Hertz is a measure of how many times each second the crest of a sound pressure wave passes a fixed point. For example, when a drummer beats a drum, the skin of the drum vibrates a number of times per second. When the drum skin vibrates 100 times per second, it generates a sound pressure wave that is oscillating at 100 Hz, and this pressure oscillation is perceived by the ear/brain as a tonal pitch of 100 Hz. Sound frequencies between 20 and 20,000 Hz are within the range of sensitivity of the best human ear.

Sound from a tuning fork contains a single frequency (a pure tone); however, most sounds one hears in the environment do not consist of a single frequency but rather a broad band of frequencies differing in sound level. The method commonly used to quantify environmental sounds consists of evaluating all frequencies of a sound according to a weighting system that represents human hearing, which is less sensitive at low frequencies and extremely high frequencies than at the mid-range frequencies. This is called "A weighting," and the decibel level measured is called the A-weighted sound level (dBA). In practice, the sound level of a source is conveniently measured using a sound level meter that includes a filter corresponding to the dBA curve of frequency-dependent adjustments.

Although dBA may adequately indicate the level of environmental sound at any instant in time, community sound levels vary continuously. Most environmental sounds include a mixture of sounds from distant sources that creates a relatively steady background sound in which no particular source is identifiable. A single descriptor called the equivalent sound level (L_{eq}) may be used to describe sound that is changing in level. L_{eq} is the energy-mean dBA during a measured time interval. It is the "equivalent" constant sound level that would have to be produced by a given source to equal the acoustic energy contained in the fluctuating sound level measured. In addition to the energy-average level, it is often desirable to know the acoustic range of the sound source being measured. This is accomplished through the maximum (L_{max}) and minimum (L_{min}) indicators that represent the root-mean-square maximum and minimum sound levels measured during the monitoring interval. The L_{min} value obtained for a particular monitoring location is often called the "acoustic floor" for that location.

2.0 REGUALTORY SETTING & ACOUSTIC IMPACT CRITERIA

A review was conducted of Federal, State, and Local laws, ordinances, regulations, and standards (LORS), applicable to sound levels generated by Project construction and operation. This review did not identify any applicable LORS at the federal level. At the state level, the State of North Dakota Public Service Commission (Commission) establishes sound limits which apply to wind energy conversion facilities within the state. No applicable LORS at the local level (participating counties/municipalities) were identified.

2.1 State of North Dakota

NDAC Section 69-06-08-01(4) reads as follows:

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

Project aerial mapping was reviewed to identify all structures, including residential and community buildings, within the Project vicinity. Sound levels produced by the Project were predicted at a distance of 100-feet from all inhabited structures and assessed for compliance against the Commission maximum sound level of 50 dBA.

2.2 County Legislation

2.2.1 Emmons County

Emmons County does not have a legislative code addressing matters related to sound; thus, sound level regulations rely on State legislation.

2.2.2 Logan County

Logan County does not have a legislative code addressing matters related to sound; thus, sound level regulations rely on State legislation.

3.0 SOUND PREDICTION METHODOLOGY & RESULTS

3.1 Review of Sound Generated by WTG Facilities

Sound generated by operation of a modern downwind-mast (i.e., the supporting tower is downstream of the spinning bladed rotor) WTG is an amalgam of the following sound sources:

- Interaction of the bladed rotor with incoming wind, and to a lesser degree the aerodynamic wake of the bladed rotor with the WTG mast; and
- The mechanical equipment housed within the nacelle just behind the WTG bladed rotor hub, which includes a gearbox, generator, and cooling fan.

For large, utility-scale WTGs currently engineered and offered by leading manufacturers, such as the 2.5 MW models considered for this Project, mechanical sounds from the nacelle tend to be much less than the dominant sound produced from aerodynamic effects resulting from rotor interaction with the incoming wind.

At rest when there is little or no wind energy to convert, a WTG produces negligible sound. As wind speeds rise up to a “cut-in” magnitude, the WTG bladed rotor begins rotation and generates power. WTG energy conversion and corresponding aerodynamic sound then increases with increasingly greater received wind speed up to a maximum rotational speed when the WTG maximum power capacity is attained. Although the WTG may experience elevated wind speeds that exceed what is necessary for this maximum power capacity, the rotor rotational speed would not increase further and thus produce an essentially constant sound power level under such elevated wind conditions.

While the WTG sound power may thus achieve a maximum level associated with full power production capacity under wind conditions that exceed those necessary for maximum blade rotation, those same elevated wind conditions are likely to produce greater outdoor background sound levels that would acoustically contribute to the ambient sound as measured and perceived at a receiver location on the ground. Although the Commission ignores this non-Project acoustical contribution to the ambient sound environment, background SPL due to steady winds traversing the Project vicinity may be estimated as follows (Hau 2000):

$$SPL_{wind} \text{ (dBA)} = 27.7 + 2.5 * V_{wind}; \text{ where } V_{wind} \text{ is in meters per second (m/s)}$$

Thus, with sustained steady winds at 4 m/s, the background SPL is likely to be as high as 38 dBA. At receiver positions sufficiently distant from Project WTGs that are exposed to high wind velocities, the background sound levels may actually be dominant and mask the Project-attributed sound contribution to the measured and perceived ambient sound level.

3.2 Modeling Software and Calculation Methods

The DataKustik CadnaA® Noise Prediction Model (Version 2018 MR1) was used to estimate the aggregate SPL from proposed Project operation layouts at the identified sound-sensitive receptors. CadnaA® is a Windows® based software program that predicts sound levels near sound sources based on ISO 9613-2 standard for outdoor sound propagation calculation. The model uses these industry-accepted propagation algorithms and accepts full-octave band (1/1) and one-third octave band (1/3) PWL (in dB re: one picoWatt) provided by the equipment manufacturer and other sources.

The software’s calculations account for classical sound wave geometric divergence, reflection off of surfaces, source directivity, meteorological effects, and attenuation factors resulting from air absorption, basic ground effects, and barrier/shielding from structures and/or topography. Topographical information was imported into the model using official United States Geological Survey (USGS) National Elevation Dataset (NED) to accurately represent existing topography in the Project area.

3.3 Modeling Input Parameters

3.3.1 Meteorological Input and Model Configuration

The sound propagation prediction model developed for this analysis assumed an outdoor air temperature of 50-degrees Fahrenheit (ºF) and a relative humidity of 70%, consistent with modeling recommendations from the Institute of Acoustics (IOA 2013).

The average ground absorption coefficient, which can range from zero (0, for acoustically reflective surfaces, such as water or pavement) to unity (1, for acoustically absorptive ground coverings, such as loose porous soils or snow), was set to an average of 0.7. This value is assigned based on the airflow resistivity of the ground in the Project vicinity, which was conservatively assumed to be between the that of “roadside dirt” and “grass, rough pasture” (Bies & Hansen 2003).

Sound attenuation due to atmospheric absorption improves with increasing acoustical frequency, and varies with temperature and moisture content. While sound attenuation due to this environmental factor is generally modest at distances less than 1,000 feet, over greater distances the result will be substantially reduced high frequency sound and the apparent preservation of low frequency sound that attenuates (due to ground and atmospheric absorption) at much lower rates.

With respect to wind speed and direction, the ISO 9613-2 standard conservatively calculates attenuation for meteorological conditions considered “favorable” to propagation: downwind (i.e., the receiver of interest is downstream of the sound-producing source). Acknowledged as a physical impossibility (i.e., because wind is experienced as having direction), this downwind assumption is considered omnidirectional by ISO 9613-2 and intended to represent most meteorological conditions experienced by the Project and its vicinity. Such conditions are assumed to be valid for study of WTG operation sound for two scenarios: 1) WTG operation under wind conditions enabling “cut-in” bladed rotor speed and at which power conversion would begin to occur; and 2) WTG operation under wind conditions at which “maximum [rotor] rotational speed” is expected along with maximum power production per tower.

3.3.2 Receiver Input

Representative receiver points were modeled at each identified residential structure in the study area. The inhabitability of structures, while noted in the results section of this report, did not preclude a prediction of sound levels at the receiver location. Receivers were modeled at a height of 4 meters (relative to ground), which could be typical of the height of a second-story listener and is recommended for wind turbine sound modeling as it reduces the influence of ground absorption factors that may be misrepresented in prediction results.

Per the Commission sound limit regulation, sound levels from Project operations are to be assessed “within 100 feet of an inhabited residence,” thus, modeled receiver locations were placed approximately 100 feet from each inhabited structure in the direction of the nearest proposed WTG. Modeled receiver locations were similarly placed near uninhabited structures.

3.3.3 Source Input

The Project plans to install GE 2.5 MW and GE 1.715 MW WTG units throughout the Project vicinity. Sources in the model were located at each discrete proposed WTG pole location as a single, omnidirectional point source, with a relative height of 80 and 90 meters (specified hub heights of the GE 2.5 MW and GE 1.715 MW WTG models, respectively). Performance specifications and proprietary sound data for the selected WTG units were provided by the manufacturer for the purpose of this study.

Tables 1 and **2** display the various A-weighted sound power level ratings for the GE 2.5 MW and GE 1.715 MW WTGs at various wind speeds.

Table 1. A-Weighted Sound Power Levels Correlated with Wind Speed – GE 1.715 MW

WTG Model	WTG Lmax Sound Power Level (PWL, dBA) at Reference Wind Speed							
GE 1.715 MW	7 m/s	7.7 m/s	8.4 m/s	9.1 m/s	9.7 m/s	11.1 m/s	12.5 m/s	14 m/s
	100.3	102.6	104.9	106.9	107.0	107.0	107.0	107.0

Table 2. A-Weighted Sound Power Levels Correlated with Wind Speed – GE 2.5 MW

WTG Model	WTG Lmax Sound Power Level (PWL, dBA) at Reference 10m Elevation Wind Speed										
GE 2.5 MW	4 m/s	5 m/s	6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	11 m/s	12 m/s	13 m/s	14 m/s
	94.5	95.4	98.3	101.7	104.7	106.5	107.0	107.0	107.0	107.0	107.0

In addition to anticipated sound levels at various wind speeds and blade types, these specifications also reported the spectral content of the WTGs in one-third octave band center frequency (OBCF) resolution. These documents report that source measurements were conducted in accordance with the International Electrotechnical Commission standard 61400-11 for acoustic measurement techniques. Specified one-third OBCF sound power levels provided by the manufacturer for both WTG models are presented in **Table 3**. Since no power level uncertainty values were provided in the manufacturer specifications, a typical +2 dB adjustment was applied across all frequency bands for each WTG source.

Table 3. WTG – Sound Power Level by One-Third Octave Band Center Frequency (1/3 OBCF)

WTG Model	Scenario	Wind Speed	One-Third OBCF, Hz (bold) and Respective A-Weighted Sound Power Level, dBA									Total PWL
GE 1.715-103 60 Hz	Cut-In	7 m/s	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	100.3
			63.5	67.9	72.0	75.3	78.2	80.7	82.6	83.9	85.0	
			200	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	
			86.3	87.7	89.3	89.9	90.4	90.2	89.4	88.8	89	
			1.6k	**2k**	**2.5k**	**3.15k**	**4k**	**5k**	**6.3k**	**8k**	**10k**	
			88.3	87.8	86.8	84.7	80.9	76.4	68.5	57.4	45.3	
	Max	9.7 m/s	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	107
			70.2	74.7	78.8	82.1	85.2	87.9	89.8	90.7	91.5	
			200	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	
			92.2	93.1	94.5	95.5	96.8	97.7	97.5	96.9	96.4	
			1.6k	**2k**	**2.5k**	**3.15k**	**4k**	**5k**	**6.3k**	**8k**	**10k**	
			95.1	94.2	93	90.9	87.1	82.2	74.8	64.4	52.3	
GE 2.5-116 60 Hz	Cut-In	4 m/s	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	94.5
			53.5	58.3	63.6	68.1	72.4	76.2	79.0	80.7	81.8	
			200	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	
			82.7	83.7	84.3	84.6	84.6	84.5	84	83.4	82.4	
			1.6k	**2k**	**2.5k**	**3.15k**	**4k**	**5k**	**6.3k**	**8k**	**10k**	
			80.6	77.7	74.9	70.3	64.6	59.7	53.5	44.6	32.7	
	Max	10 m/s	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	107
			64.9	69.4	74.5	78.8	83.0	86.8	89.6	91.4	92.9	
			200	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	
			94.1	95.5	96.6	97.3	97.5	97.5	96.9	96.3	95.2	
			1.6k	**2k**	**2.5k**	**3.15k**	**4k**	**5k**	**6.3k**	**8k**	**10k**	
			93.5	91.7	89.7	86.9	82.5	76.4	68.1	56.4	43.7	

3.3.4 Modeled Scenarios

The predictive acoustic assessment reviewed two Project WTG layouts: one with additional WTG locations (“With Alternates”), and one without the additional WTGs (“No Alternates”). Both scenarios were modeled under the following operating/meteorological conditions, deemed representative of the entire operational range of the Project:

- Cut-In, or, the minimum wind speed required to generate electricity through rotor rotation; and,
- Maximum turbine rotational speed.

3.4 Modeling Results

Each predictive operations model assumed that all WTGs would be operating concurrently at the same analyzed operation condition. Predicted levels in this section are presented in both tabulated form (**Tables 4** and **5**) and as sound level contour plots (**Figures 1** through **4**), which depict the propagation of Project operational sound upon the Project area as color-coded isopleths (Project-attributed sound level “contours,” reminiscent of topographical contours that depict equivalent grade elevation). While aggregate WTG operation sound levels may be compliant with the Commission requirements, under the right meteorological conditions, it may be possible for WTG sound to be audible at a sound-sensitive receptor.

Predicted operational sound levels associated with the “No Alternates” layout, for each of the above-mentioned operating conditions, are provided below in **Table 4**. **Figures 1** and **2**, located at the end of this section, display predicted sound level contours associated with each of these two operating conditions.

Table 4. Summary of Predicted Sound Levels, Occupied Structures, “No Alternates” Layout

Receptor ID	Nearest WTG ID	Distance to Nearest WTG (feet)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Sound Level (dBA, SPL)	
			Easting (m)	Northing (m)	Cut-In Rotation	Maximum Rotation
ARCH1a	5	9659	411785	5142245	22.3	31.6
ARCH1b	5	9829	411717	5142254	22.0	31.3
ARCH3	8	7766	414929	5142766	24.7	33.1
ARCH4a	43	5430	418988	5142322	25.3	37.0
ARCH4b	43	5522	419001	5142356	25.2	36.9
ARCH7	73	2287	426876	5142134	31.9	44.2
ARCH9a	74	2274	427843	5141969	32.8	45.1
ARCH9b	74	1900	427828	5141846	33.8	46.1
ARCH10	77	3602	429294	5142831	26.8	39.0
ARCH11	77	3894	429904	5142283	26.8	38.9
ARCH12	114	5482	432737	5141354	23.0	35.0
ARCH14	4	8917	410485	5140820	21.9	32.4
ARCH15	75	1860	428064	5140859	34.5	46.7
ARCH16a	80	1683	428652	5140340	35.8	48.2
ARCH16b	80	1581	428783	5140344	35.8	48.1
ARCH17	49	5584	422839	5139842	27.1	38.1
ARCH18	1	5925	410076	5139359	23.6	35.4
ARCH19	4	2152	411894	5139311	32.5	44.3
ARCH20a	109	2064	429679	5138898	35.3	47.5
ARCH20b	110	2142	429640	5139083	34.5	46.8
ARCH21	113	5318	432764	5138932	25.9	37.8
ARCH22	114	11289	434780	5138929	17.0	28.8
ARCH24	113	4373	432346	5138871	27.8	39.7
ARCH25	110	1634	430555	5138776	37.1	49.4
ARCH28	13	2011	413801	5138579	34.7	46.4
ARCH29	1	1545	411004	5138151	34.8	47.0
ARCH30a	1	3225	410103	5138366	27.7	39.5
ARCH30b	1	3291	410103	5138395	27.6	39.3
ARCH31	10	2372	412352	5137542	33.6	45.3
ARCH33	68	2533	424665	5137195	33.0	45.2

Receptor ID	Nearest WTG ID	Distance to Nearest WTG (feet)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Sound Level (dBA, SPL)	
			Easting (m)	Northing (m)	Cut-In Rotation	Maximum Rotation
ARCH34	123	3750	431987	5136465	29.2	41.0
ARCH35	61	1722	420620	5136706	36.3	48.6
ARCH36a	23	3245	416443	5136652	32.6	43.6
ARCH36b	23	3251	416441	5136673	32.6	43.7
ARCH37	24	1883	415730	5137365	35.6	46.7
ARCH38	11	1742	413974	5137160	37.7	49.6
ARCH39	10	2369	413130	5136498	36.0	46.7
ARCH42	57	2812	421725	5135801	30.5	42.6
ARCH45	123	4800	433245	5135583	25.0	36.8
ARCH46	123	3225	432773	5135539	27.9	39.9
ARCH47	121	1496	430976	5135014	37.0	49.2
ARCH48	117	1804	429514	5135490	37.8	49.2
ARCH49a	87	4564	424326	5134493	29.7	41.8
ARCH49b	87	4757	424357	5134592	29.8	41.8
ARCH51	55	2349	419810	5134957	33.3	45.5
ARCH52	9	2913	411670	5135816	31.9	41.8
ARCH53	29	8432	410211	5134927	25.1	34.7
ARCH54	38	1663	414817	5134470	35.7	46.6
ARCH55	92	1663	427253	5134151	35.3	47.5
ARCH57	123	7369	432544	5133295	22.5	34.0
ARCH59	85	2490	423818	5133543	32.8	45.1
ARCH60	83	5413	422245	5133554	27.1	39.2
ARCH61a	56	3540	420719	5134126	28.8	40.9
ARCH62	34	3573	411781	5134232	31.9	41.4
ARCH64	86	1654	425127	5132694	34.6	46.9
ARCH66	122	9744	431621	5132391	21.7	33.1
ARCH68	34	9495	410189	5132332	19.3	29.4
ARCH69	34	10423	410004	5132093	19.1	28.7
ARCH70	115	11585	429796	5130898	13.9	25.7
ARCH72	34	10469	412259	5130589	13.8	24.1
ARCH73	37	13107	415635	5130383	13.5	25.2
ARCH74	115	13383	428456	5130215	17.0	28.7
ARCH75	115	14347	429059	5129921	10.8	22.4
ARCH76a	81	11791	425706	5129320	16.7	28.5
ARCH76b	81	11942	425735	5129289	16.9	28.7
ARCH76c	81	11719	425646	5129295	16.8	28.6
ARCH77a	81	11063	425335	5129276	15.9	27.8
ARCH77b	81	10984	425298	5129276	17.8	29.7
ARCH77c	81	11165	425379	5129272	16.3	28.2
ARCH77d	81	11296	425370	5129215	14.2	26.1

Receptor ID	Nearest WTG ID	Distance to Nearest WTG (feet)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Sound Level (dBA, SPL)	
			Easting (m)	Northing (m)	Cut-In Rotation	Maximum Rotation
ARCH79a	81	8054	422897	5129407	18.7	30.6
ARCH79b	81	8209	422888	5129362	18.5	30.4
ARCH79c	81	7651	422891	5129532	19.4	31.3
ARCH80	50	13783	418828	5129515	10.0	21.7
ARCH81	38	15958	416281	5129699	6.3	17.9
ARCH83	81	10820	424442	5128809	13.4	25.2
ARCH84	34	7277	411560	5131845	22.5	32.7
ARCH107	1	11742	407636	5136202	13.3	25.1
ARCH108	5	12064	411018	5142525	19.3	28.3
ARCH111a	45	10656	422510	5143815	16.8	27.7
ARCH111b	45	10614	422491	5143813	15.1	26.4
ARCH111c	45	10640	422495	5143822	15.2	26.5
ARCH111d	45	10761	422499	5143862	17.4	28.4
ARCH112	72	11860	423923	5143805	14.6	26.4
ARCH115	72	10174	424678	5143820	16.1	28.0
ARCH117	72	9616	426470	5144331	18.4	30.3
ARCH119	77	9665	427940	5144650	18.5	30.4
ARCH120a	77	8668	429647	5144352	18.9	30.8
ARCH120b	77	9003	429648	5144459	18.3	30.2
ARCH120c	77	9167	429648	5144510	18.2	30.0
ARCH121a	77	8579	430637	5143711	20.0	31.9
ARCH121b	77	8652	430683	5143695	20.0	31.8
ARCH122	77	8461	430694	5143599	20.2	32.1
ARCH123	81	10056	424900	5129328	18.4	30.2
ARCH126	34	12142	412957	5130060	15.5	27.0

Predicted operational sound levels associated with the “With Alternates” layout are provided below in **Table 5**. **Figures 3** and **4**, located at the end of this section, display predicted sound level contours associated with each of the three operating conditions.

Table 5. Summary of Predicted Sound Levels, Occupied Structures, “With Alternates” Layout

Receptor ID	Nearest WTG ID	Distance to Nearest WTG (feet)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Sound Level (dBA, SPL)	
			Easting (m)	Northing (m)	Cut-In Rotation	Maximum Rotation
ARCH1a	5	9659	411785	5142245	22.3	31.6
ARCH1b	5	9829	411717	5142254	22.0	31.3
ARCH3	8	7766	414929	5142766	24.7	33.1
ARCH4a	43	5430	418988	5142322	25.3	37.0
ARCH4b	43	5522	419001	5142356	25.2	36.9
ARCH7	73	2287	426876	5142134	32.1	44.3

Receptor ID	Nearest WTG ID	Distance to Nearest WTG (feet)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Sound Level (dBA, SPL)	
			Easting (m)	Northing (m)	Cut-In Rotation	Maximum Rotation
ARCH9a	74	2274	427843	5141969	33.6	45.4
ARCH9b	74	1900	427828	5141846	34.5	46.3
ARCH10	77	3602	429294	5142831	29.8	40.1
ARCH11	Alt6	3449	429904	5142283	31.6	41.1
ARCH12	114	5482	432737	5141354	24.6	35.6
ARCH14	4	8917	410485	5140820	21.9	32.4
ARCH15	75	1860	428064	5140859	35.6	47.1
ARCH16a	80	1683	428652	5140340	38.6	49.2
ARCH16b	80	1581	428783	5140344	39.4	49.5
ARCH17	49	5584	422839	5139842	27.1	38.1
ARCH18	1	5925	410076	5139359	23.6	35.4
ARCH19	4	2152	411894	5139311	32.5	44.4
ARCH20a	109	2064	429679	5138898	36.3	47.8
ARCH20b	110	2142	429640	5139083	36.2	47.3
ARCH21	113	5318	432764	5138932	27.2	38.3
ARCH22	114	11289	434780	5138929	19.5	29.8
ARCH24	113	4373	432346	5138871	28.9	40.1
ARCH25	110	1634	430555	5138776	37.5	49.5
ARCH28	13	2011	413801	5138579	34.8	46.4
ARCH29	1	1545	411004	5138151	34.8	47.0
ARCH30a	1	3225	410103	5138366	27.7	39.5
ARCH30b	1	3291	410103	5138395	27.6	39.3
ARCH31	10	2372	412352	5137542	33.7	45.3
ARCH33	68	2533	424665	5137195	33.0	45.2
ARCH34	Alt1	2385	431987	5136465	36.4	44.8
ARCH35	61	1722	420620	5136706	36.3	48.6
ARCH36a	23	3245	416443	5136652	32.9	43.8
ARCH36b	23	3251	416441	5136673	32.9	43.8
ARCH37	24	1883	415730	5137365	35.8	46.8
ARCH38	11	1742	413974	5137160	37.8	49.6
ARCH39	10	2369	413130	5136498	36.2	46.8
ARCH42	57	2812	421725	5135801	30.5	42.6
ARCH45	Alt2	2856	433245	5135583	33.2	41.4
ARCH46	Alt2	1667	432773	5135539	38.6	46.3
ARCH47	121	1496	430976	5135014	37.4	49.4
ARCH48	117	1804	429514	5135490	37.9	49.2
ARCH49a	87	4564	424326	5134493	29.7	41.8
ARCH49b	87	4757	424357	5134592	29.8	41.8
ARCH51	55	2349	419810	5134957	33.3	45.5
ARCH52	9	2913	411670	5135816	32.0	41.9

Receptor ID	Nearest WTG ID	Distance to Nearest WTG (feet)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Sound Level (dBA, SPL)	
			Easting (m)	Northing (m)	Cut-In Rotation	Maximum Rotation
ARCH53	29	8432	410211	5134927	25.3	34.8
ARCH54	38	1663	414817	5134470	36.3	46.8
ARCH55	92	1663	427253	5134151	35.3	47.5
ARCH57	123	7369	432544	5133295	24.8	35.0
ARCH59	85	2490	423818	5133543	32.8	45.1
ARCH60	83	5413	422245	5133554	27.1	39.2
ARCH61a	56	3540	420719	5134126	28.8	40.9
ARCH62	34	3573	411781	5134232	32.0	41.4
ARCH64	86	1654	425127	5132694	34.6	46.9
ARCH66	122	9744	431621	5132391	23.0	33.6
ARCH68	34	9495	410189	5132332	19.3	29.4
ARCH69	34	10423	410004	5132093	19.1	28.7
ARCH70	115	11585	429796	5130898	13.9	25.7
ARCH72	34	10469	412259	5130589	13.8	24.1
ARCH73	37	13107	415635	5130383	13.5	25.2
ARCH74	115	13383	428456	5130215	17.0	28.7
ARCH75	115	14347	429059	5129921	10.8	22.4
ARCH76a	81	11791	425706	5129320	16.7	28.5
ARCH76b	81	11942	425735	5129289	16.9	28.7
ARCH76c	81	11719	425646	5129295	16.8	28.6
ARCH77a	81	11063	425335	5129276	15.9	27.8
ARCH77b	81	10984	425298	5129276	17.8	29.7
ARCH77c	81	11165	425379	5129272	16.3	28.2
ARCH77d	81	11296	425370	5129215	14.2	26.1
ARCH79a	81	8054	422897	5129407	18.7	30.6
ARCH79b	81	8209	422888	5129362	18.5	30.4
ARCH79c	81	7651	422891	5129532	19.4	31.3
ARCH80	50	13783	418828	5129515	10.0	21.7
ARCH81	38	15958	416281	5129699	6.3	17.9
ARCH83	81	10820	424442	5128809	13.4	25.2
ARCH84	34	7277	411560	5131845	22.6	32.7
ARCH107	1	11742	407636	5136202	13.3	25.1
ARCH108	5	12064	411018	5142525	19.3	28.3
ARCH111a	45	10656	422510	5143815	16.8	27.7
ARCH111b	45	10614	422491	5143813	15.1	26.4
ARCH111c	45	10640	422495	5143822	15.2	26.5
ARCH111d	45	10761	422499	5143862	17.4	28.4
ARCH112	72	11860	423923	5143805	14.6	26.4
ARCH115	72	10174	424678	5143820	16.1	28.0
ARCH117	72	9616	426470	5144331	19.4	30.7

Receptor ID	Nearest WTG ID	Distance to Nearest WTG (feet)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Sound Level (dBA, SPL)	
			Easting (m)	Northing (m)	Cut-In Rotation	Maximum Rotation
ARCH119	77	9665	427940	5144650	20.8	31.3
ARCH120a	77	8668	429647	5144352	21.9	32.0
ARCH120b	77	9003	429648	5144459	21.4	31.5
ARCH120c	77	9167	429648	5144510	21.3	31.3
ARCH121a	77	8579	430637	5143711	23.1	33.2
ARCH121b	77	8652	430683	5143695	23.1	33.1
ARCH122	77	8461	430694	5143599	23.4	33.4
ARCH123	81	10056	424900	5129328	18.4	30.2
ARCH126	34	12142	412957	5130060	15.5	27.0

4.0 ADDITIONAL ACOUSTIC ASSESSMENT CONSIDERATIONS

4.1 Substation Sound

There will be two substations within the Project area, one 115 kilovolt (kV) substation featuring two 60 megavolt-amperes (MVA) transformers, and one 230 kV substation featuring one 225 MVA transformer. Sound generated by the substations would be dominated by “humming” sound from the transformer(s). The Electric Power Plant Environmental Noise Guide (EPPENG) published by the Edison Electric Institute (EEI 1984) suggests OBCF sound power levels for a “quiet” transformer as shown in **Table 6**. OBCF sound power levels for a “standard” type would be 10 dB higher per octave band.

Table 6. Substation – Sound Power Level by Octave Band Center Frequency (OBCF)

Transformer Rating	OBCF A-weighted Power Level, dB									Total A-Weighted PWL, dBA
	31.5	63	125	250	500	1k	2k	4k	8k	
60 MVA[1]	82	88	90	85	85	79	74	69	62	94
225 MVA	90	96	98	93	93	87	82	77	70	102

1. Although single-unit sound power levels are presented, the following predicted operating sound levels considered a quantity of two (2) 60 MVA transformer units operating at the 115 kV station.

The 115 kV substation is located near the northeastern corner of the intersection of 72nd Street SE and 21st Avenue SE and is approximately 4,100 feet from the closest occupied receptor: ARCH33 to the north. The 230 kV substation is located near the northwestern corner of the intersection of 71st Street SE and 15th Avenue SE and is located approximately 3,000 feet from the closest occupied receptor: ARCH38 to the southwest. At these distances, both sound levels from operating “quiet” or “standard” type transformer(s) would be far less than 50 dBA and thus compliant with the Commission requirements.

At distances of no less than 560 feet from the 115 kV substation, the 50 dBA threshold would still be met with a “quiet” transformer. For a “standard” transformer, this minimum distance would be 1,620 feet. At distances of no less than 980 feet from the 230 kV substation, the 50 dBA threshold would still be met with a “quiet” transformer. For a “standard” transformer, this minimum distance would be 2,850 feet. While compliant with this assessment criterion, under the right conditions it may be possible for transformer sound to be audible at a sound-sensitive receptor.

4.2 Construction Sound

The Project will be constructed in multiple phases and will involve the development of access roads, excavation and forming of WTG foundations, site preparation for crane lifting, and WTG assembly and commission. Typical large-scale wind projects undergo the following construction phases:

1. *Site Clearing*: Predominantly characterized by establishing Project offices, equipment storage areas, and construction staging areas. Erosion and sedimentation control measures would be completed as well in preparation of initial hauling routes.
2. *Grading*: The Project area access roads will be graded and formed during this phase. Excavation would also occur at WTG locations in preparation of foundation installations in Phase 3.
3. *Foundation Work*: Foundations constructed from reinforced concrete would be constructed at each WTG location.

4. *WTG Installation*: After delivery of WTG components, a single crane will house pole segments, nacelle housing, and the rotor/propeller assembly into position, followed by commission of the WTG.

Depending on the finalized schedule and anticipated delivery of WTG components and assembly equipment, construction phases throughout the Project area may overlap, as WTGs are commonly erected in small groups or strings as site development progresses. Aside from WTG construction, additional activities would include the construction of maintenance facilities, transmission line installation, and other supporting infrastructure.

The amount of construction equipment and the number of workers in any given area of the Project area would vary, but activity would tend to be concentrated in certain areas and then move as the WTGs would be erected in a manner resembling an assembly line. These variations would also result in varying levels of construction-related sound.

Conventional construction activities at the Project site would result in a short-term, temporary increase in the ambient sound level resulting from the operation of construction equipment. The increase in sound level would primarily be experienced close to the sound source(s). The estimated magnitude of the sound effects would depend on the type of construction activity, sound level generated by construction equipment, duration of the construction, and the distance between the sound source and receiver of interest. Project construction traffic, consisting of delivery of WTG components and other materials, along public roads and Project access routes can also temporarily elevate typical roadway traffic volumes and thus increase sound levels experienced at receivers near such ground transportation routes. While most construction activities would be expected to occur during daytime hours, WTG sites can often require limited nighttime activities such as concrete pours for tower foundations.

4.3 Maintenance Sound

Upon completion and commissioning of the Project, an appropriate set of vehicles and related equipment can be expected to travel to and from, as well as within, the Project site in order to conduct regular inspections and maintenance of the WTGs and substation. Vehicles may also be involved for conducting regular security patrols of the Project site. Sound from these post-construction vehicles and activities are thus generally expected to be intermittent in nature and temporarily occurring over the life of the Project. Additionally, sound levels from such vehicles and activities are expected to be insignificant compared to expected nominal WTG operations.

5.0 CONCULSIONS

Project operational sound has been predicted and assessed against the 50 dBA Commission sound limit. The predictive operational acoustical modeling, performed with CadnaA software (and its algorithm basis per ISO 9613-2) and inclusive of conservative parameter assumptions and uncertainty corrections, demonstrates that the Project will not generate exceedances of the Commission threshold at any occupied receptor locations.

6.0 LITERATURE CITED

Beranek, L. L. and I. L. Ver, eds, 1992, Noise and Vibration Control Engineering, John Wiley & Sons, Inc., New York, NY.

Bies, D. and Hansen, C., 2003, Engineering Noise Control: Theory and Practice, Third Edition, E & FN Spon Press, New York, NY.

Edison Electric Institute (EEI), 1984, Electrical Power Plant Environmental Noise Guide, Report No. 3637, prepared by Bolt Beranek and Newman Inc.

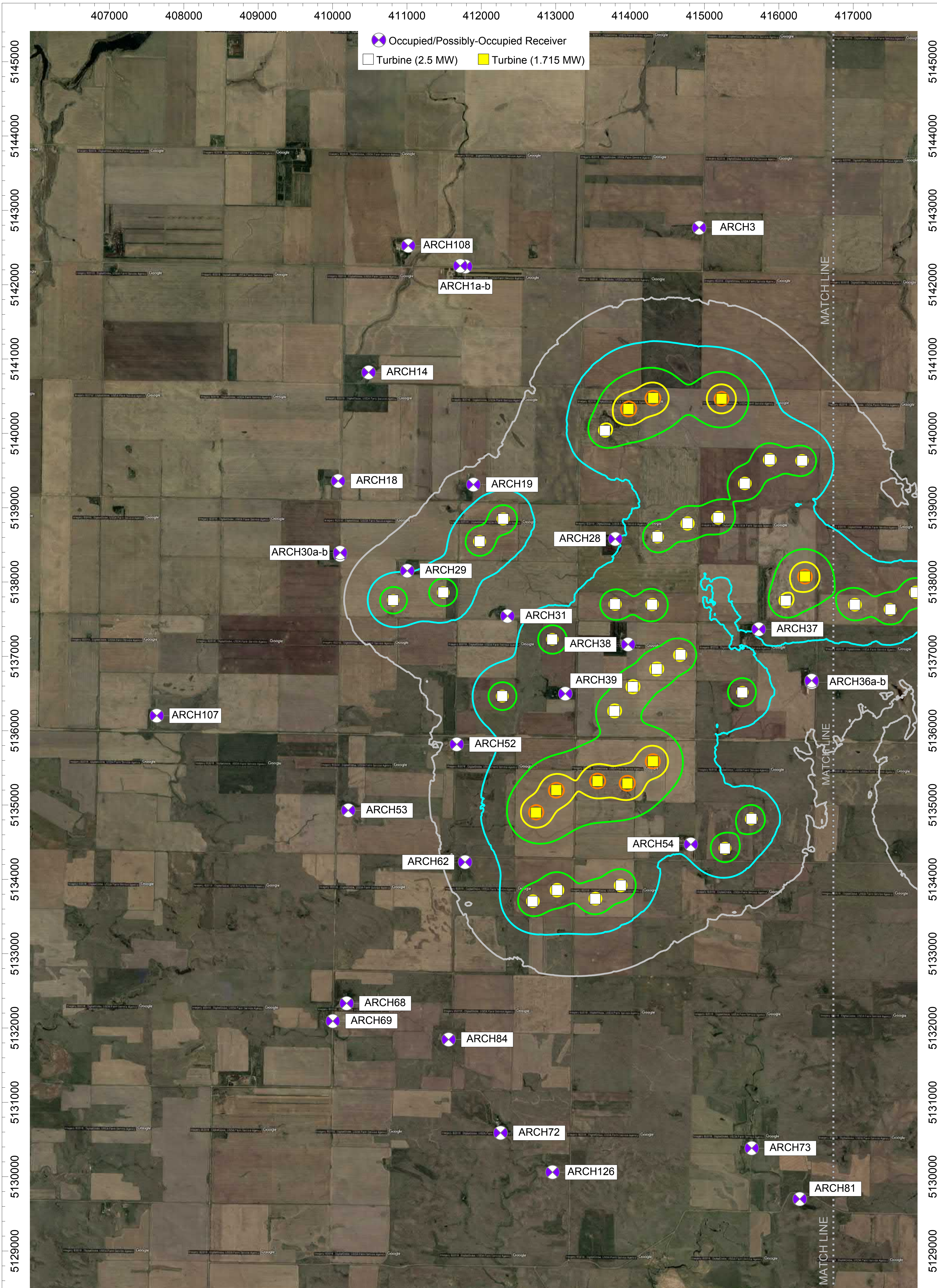
Hau, E., 2000, Wind Turbines: Fundamentals, Technologies, Application, Economics, Springer-Verlag, Berlin, Germany.

Institute of Acoustics (IOA), 2013, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise.

International Organization for Standardization (ISO), 1996, "Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation." ISO 9613-2:1996(E).

State of North Dakota, Energy conversion facility siting criteria, 69-06-08-01, North Dakota Administrative Code. Last accessed on June 19, 2017: http://www.legis.nd.gov/information/acdata/pdf/69-06-08.pdf

Figures



N

Date Created:
10/22/2018

Created by:
CK

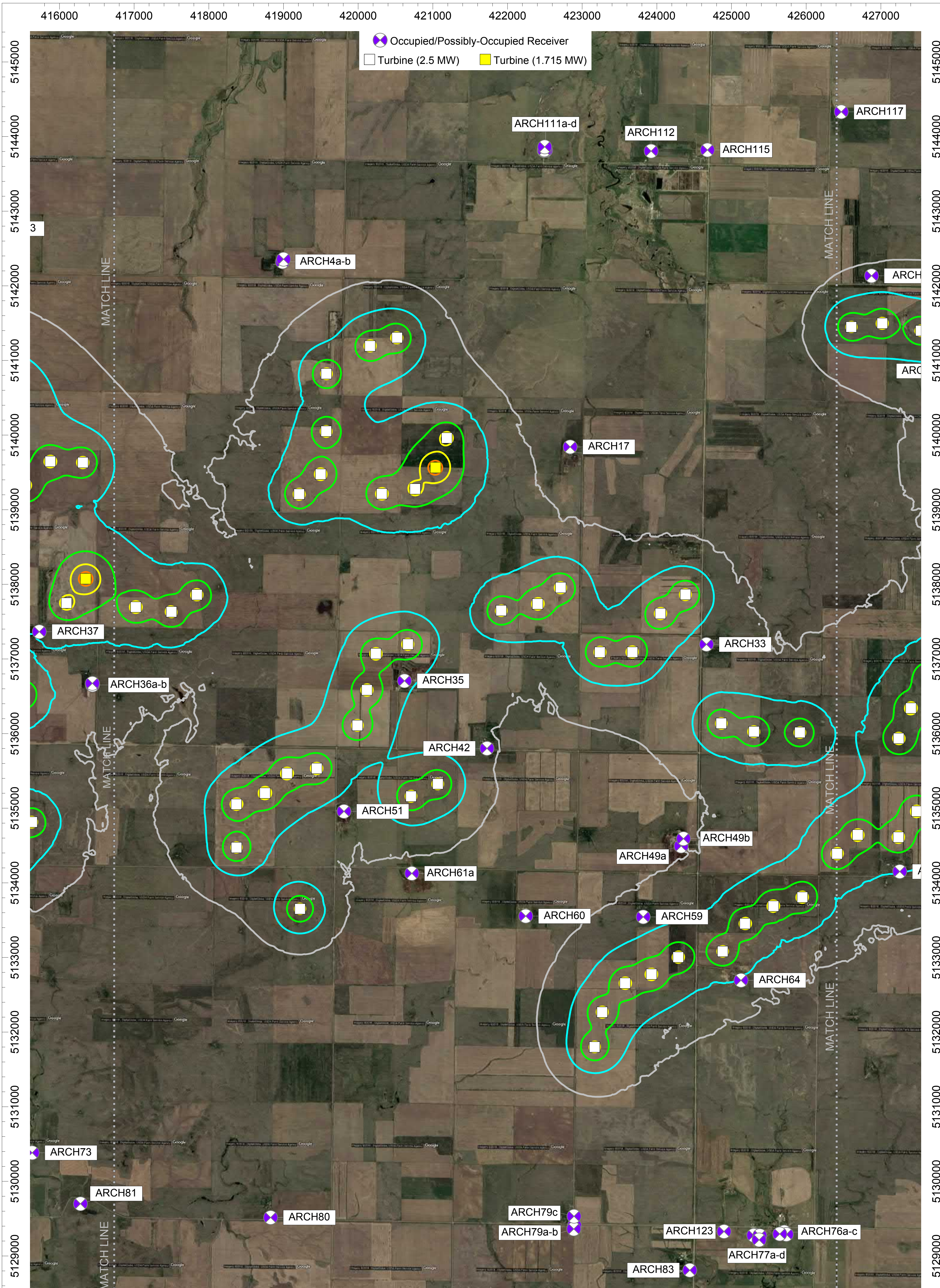
AECOM Imagine it. Delivered.
Acoustics & Noise Control Practice

Figure 1a
No Alternates
Wind Turbines at Cut-In Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

- 30 dBA
- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA



N

Date Created:
10/22/2018

Created by:
CK

AECOM Imagine it. Delivered.

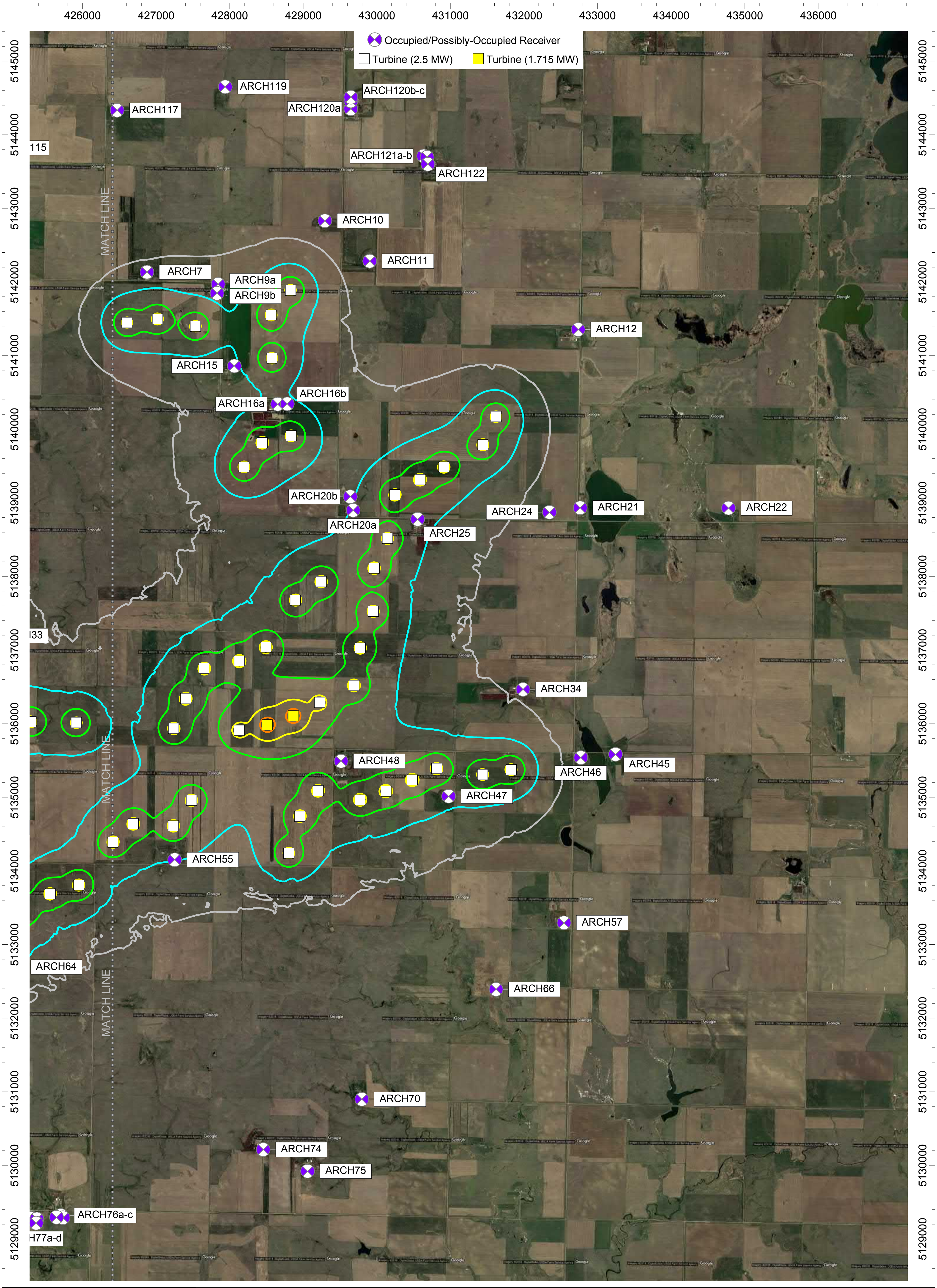
Acoustics & Noise Control Practice

Figure 1b
No Alternates
Wind Turbines at Cut-In Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

30 dBA
35 dBA
40 dBA
45 dBA
50 dBA
55 dBA



Date Created:
10/22/2018

Created by:
CK

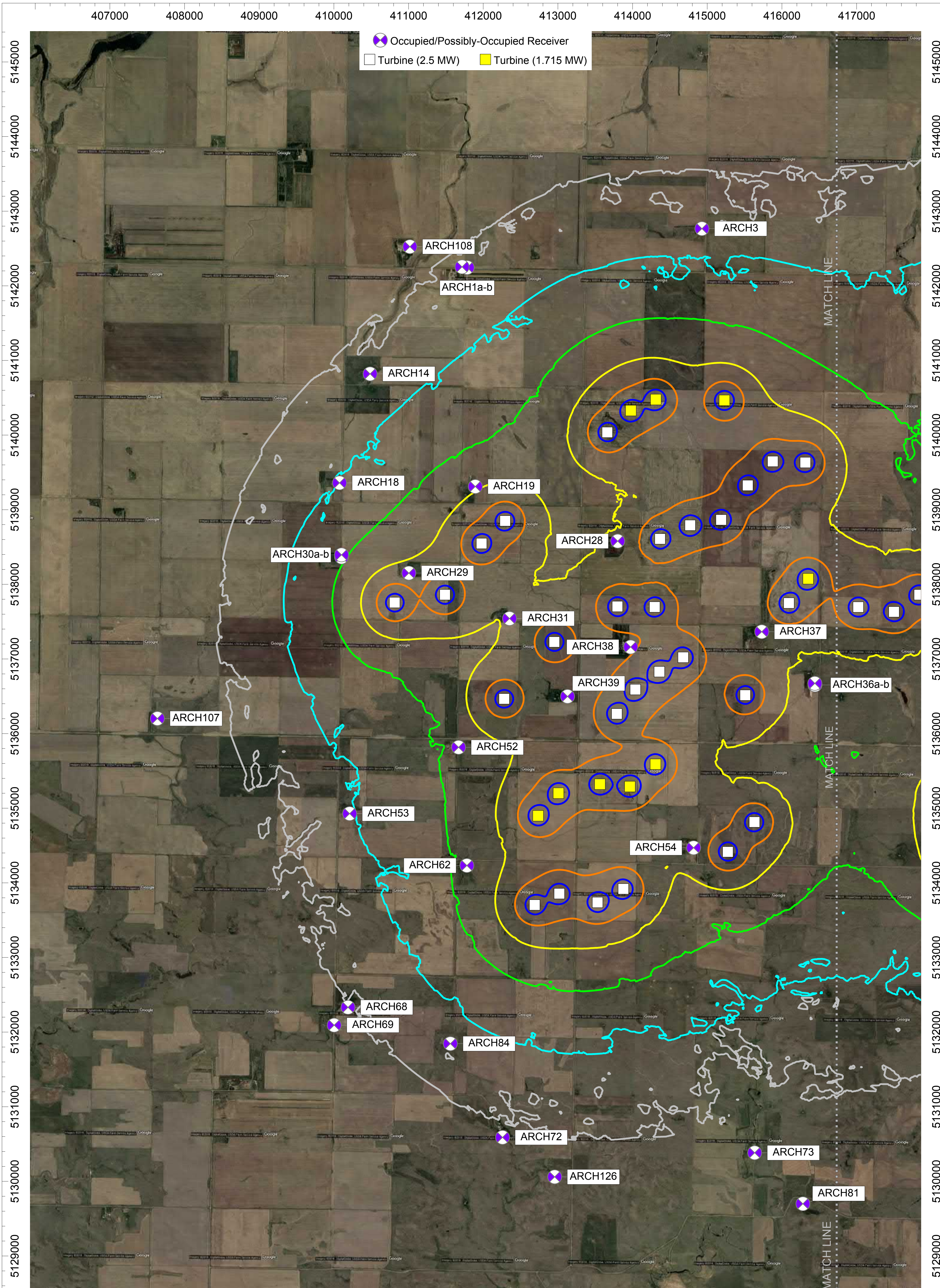
AECOM Imagine it. Delivered.
Acoustics & Noise Control Practice

Figure 1c
No Alternates
Wind Turbines at Cut-In Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

- 30 dBA
- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA



N

Date Created: 10/22/2018

Created by: CK

AECOM Imagine it. Delivered.

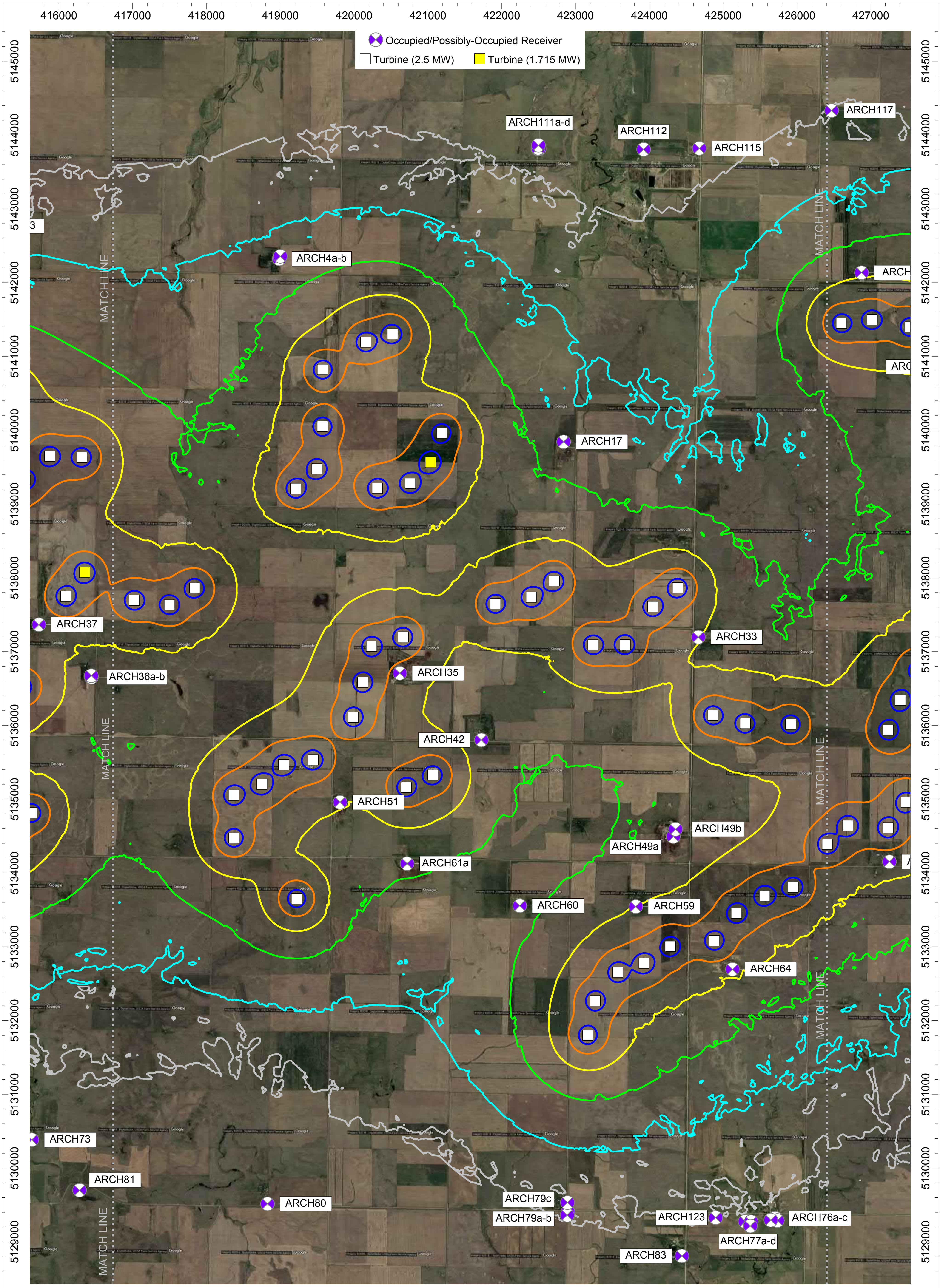
Acoustics & Noise Control Practice

Figure 2a
No Alternates
Wind Turbines at Maximum Rotational Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

- 30 dBA
- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA



N	Date Created: 10/22/2018	**Figure 2b**
	Created by: CK	**No Alternates**
		Wind Turbines at Maximum Rotational Wind Speed

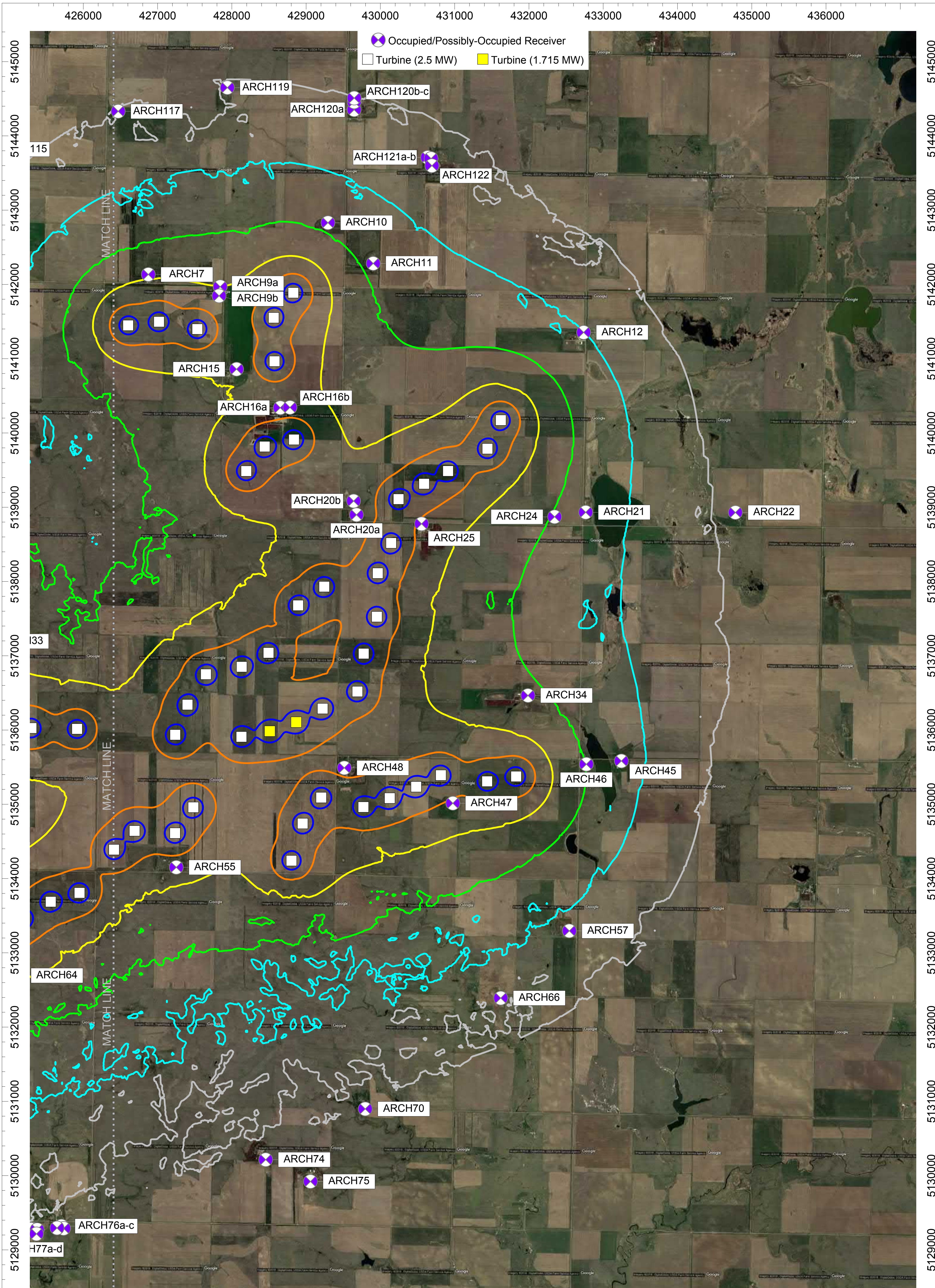
AECOM Imagine it. Delivered.

Acoustics & Noise Control Practice

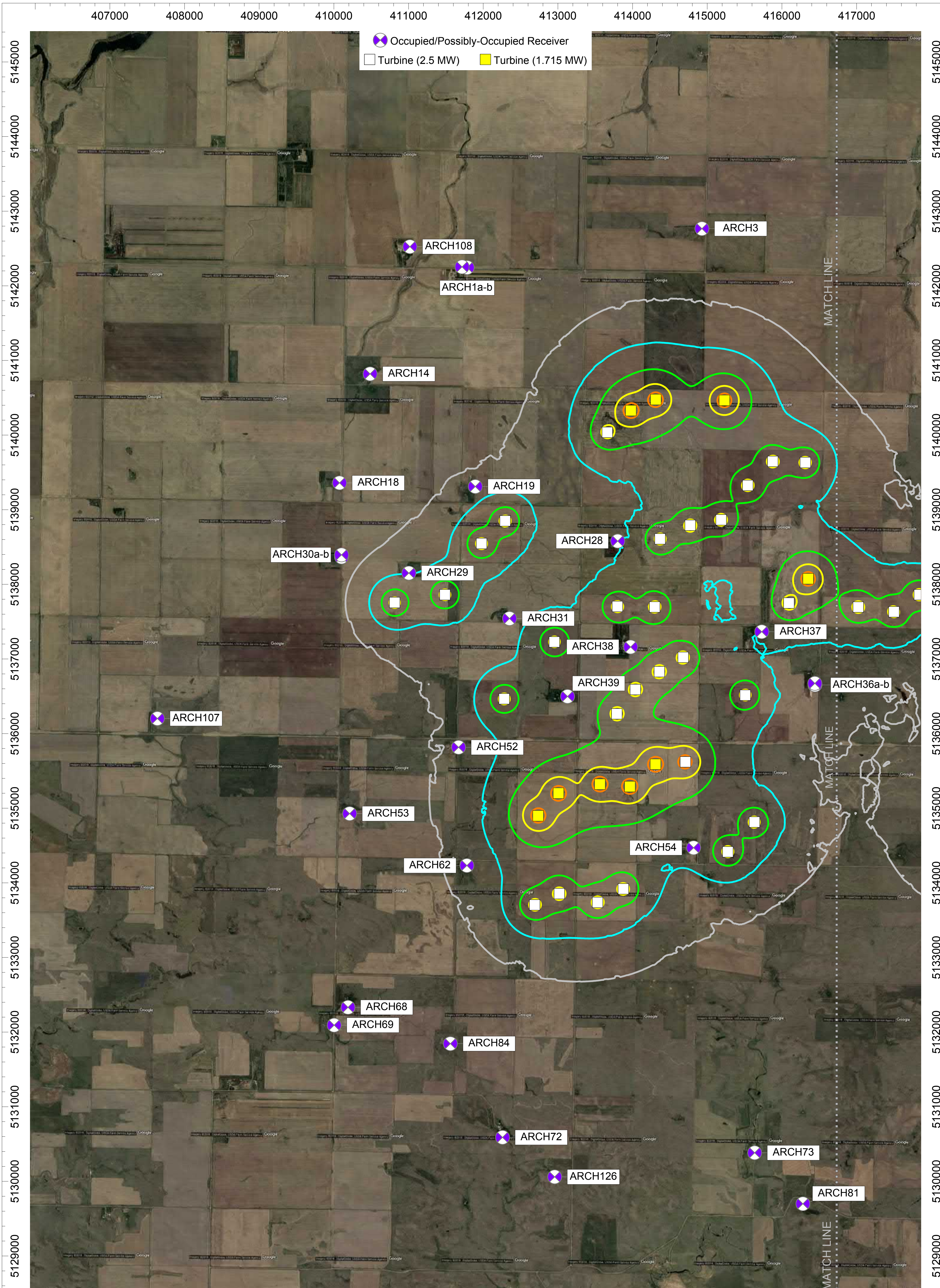
Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

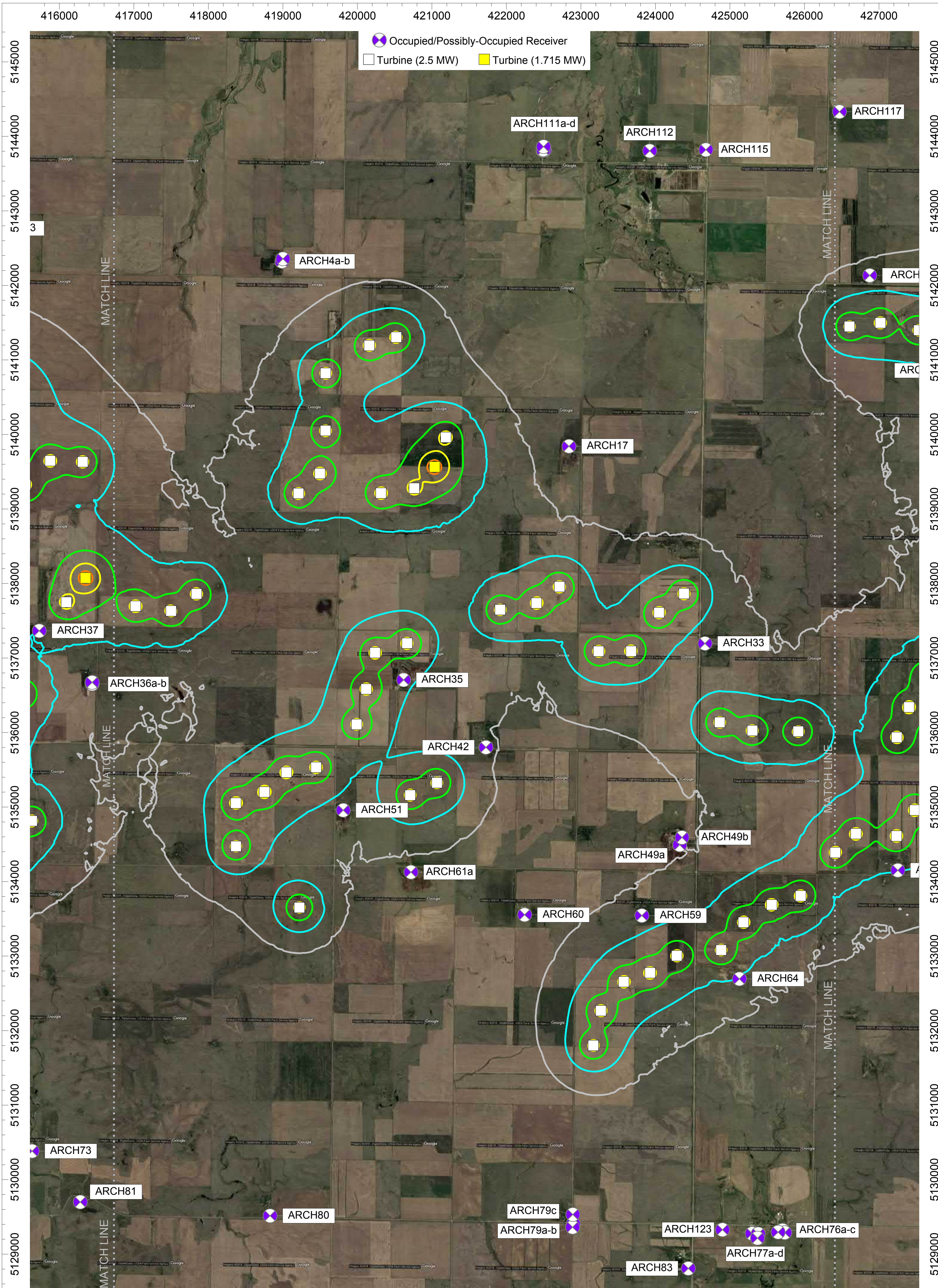
- 30 dBA
- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA



N	Date Created: 10/22/2018	Figure 2c No Alternates Wind Turbines at Maximum Rotational Wind Speed	Sound Level Contour Ranges (dBA)
	Created by: CK		30 dBA 35 dBA 40 dBA 45 dBA 50 dBA 55 dBA
AECOM Imagine it. Delivered. Acoustics & Noise Control Practice		Predicted Project Operation Sound Contours Emmons-Logan Wind Energy Center Emmons and Logan Counties, ND	



Date Created: 10/22/2018	**Figure 3a** **With Alternates** **Wind Turbines at Cut-In Wind Speed**	**Sound Level Contour Ranges (dBA)**
Created by: CK		30 dBA 35 dBA 40 dBA 45 dBA 50 dBA 55 dBA
AECOM Imagine it. Delivered. Acoustics & Noise Control Practice	**Predicted Project Operation Sound Contours** **Emmons-Logan Wind Energy Center** **Emmons and Logan Counties, ND**	



N

Date Created:
10/22/2018

Created by:
CK

AECOM Imagine it. Delivered.

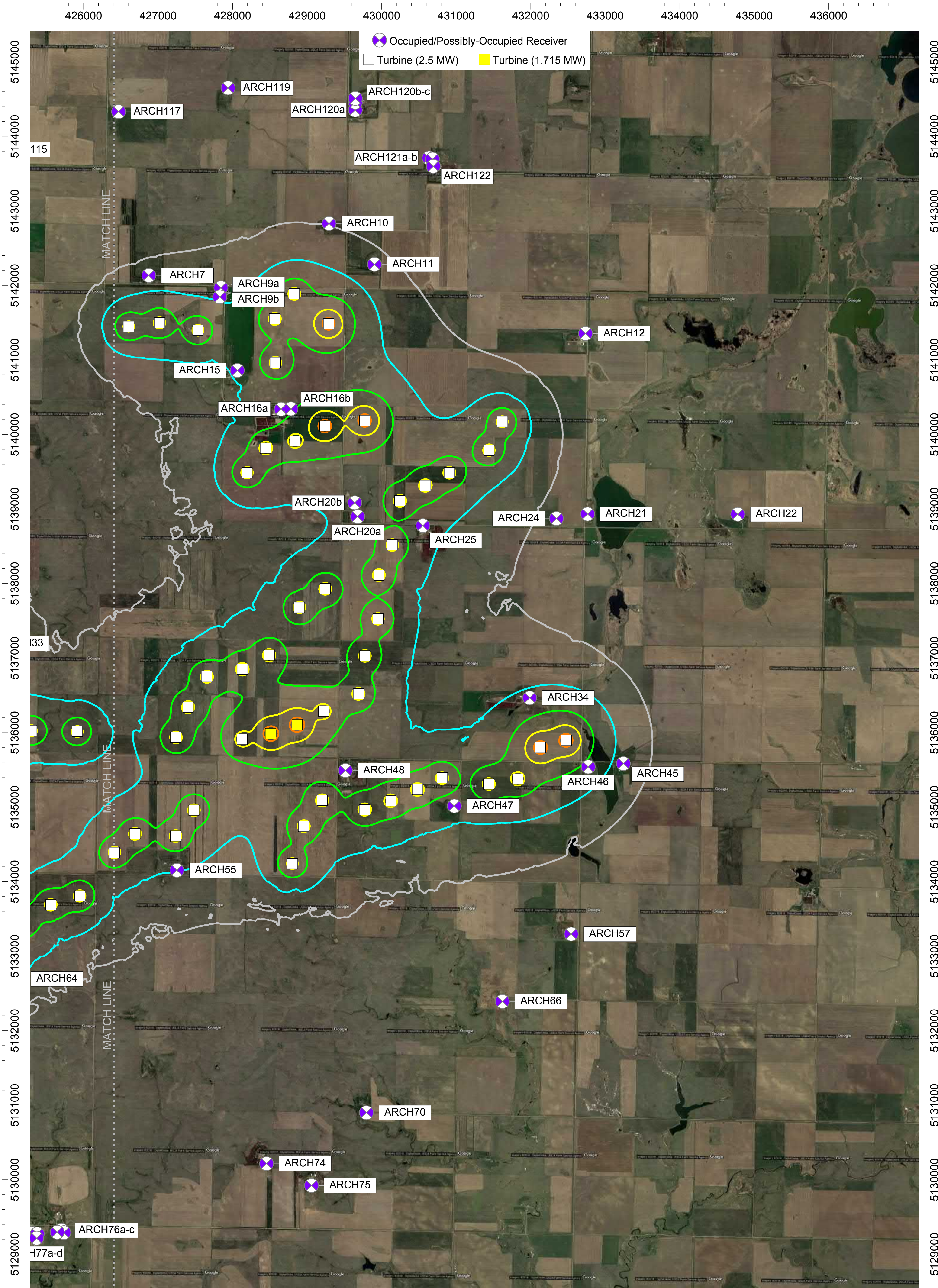
Acoustics & Noise Control Practice

Figure 3b
With Alternates
Wind Turbines at Cut-In Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

30 dBA
35 dBA
40 dBA
45 dBA
50 dBA
55 dBA



N

Date Created: 10/22/2018

Created by: CK

AECOM Imagine it. Delivered.

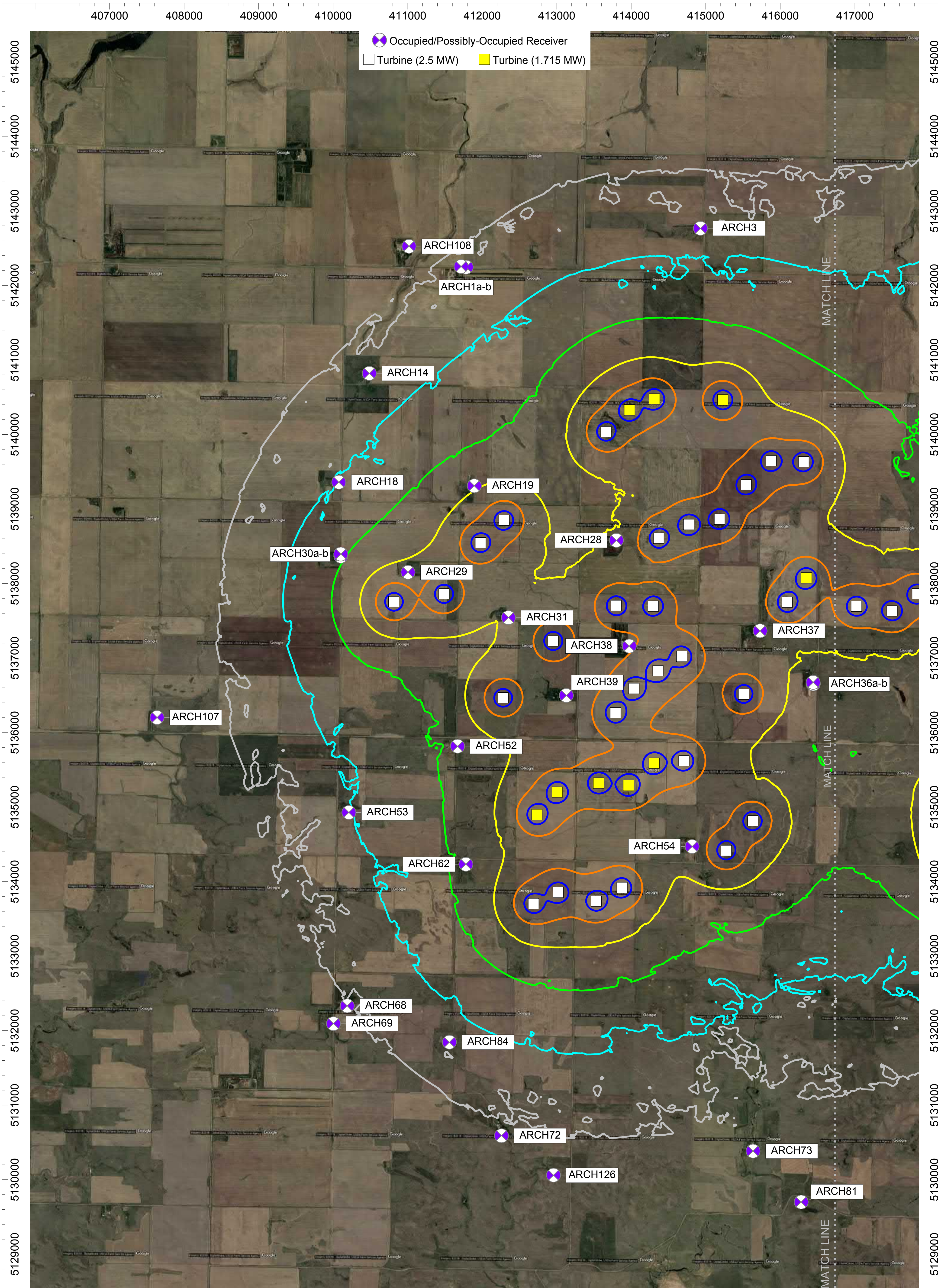
Acoustics & Noise Control Practice

Figure 3c
With Alternates
Wind Turbines at Cut-In Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

- 30 dBA
- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA



Date Created:
10/22/2018

Created by:
CK

N

AECOM Imagine it. Delivered.

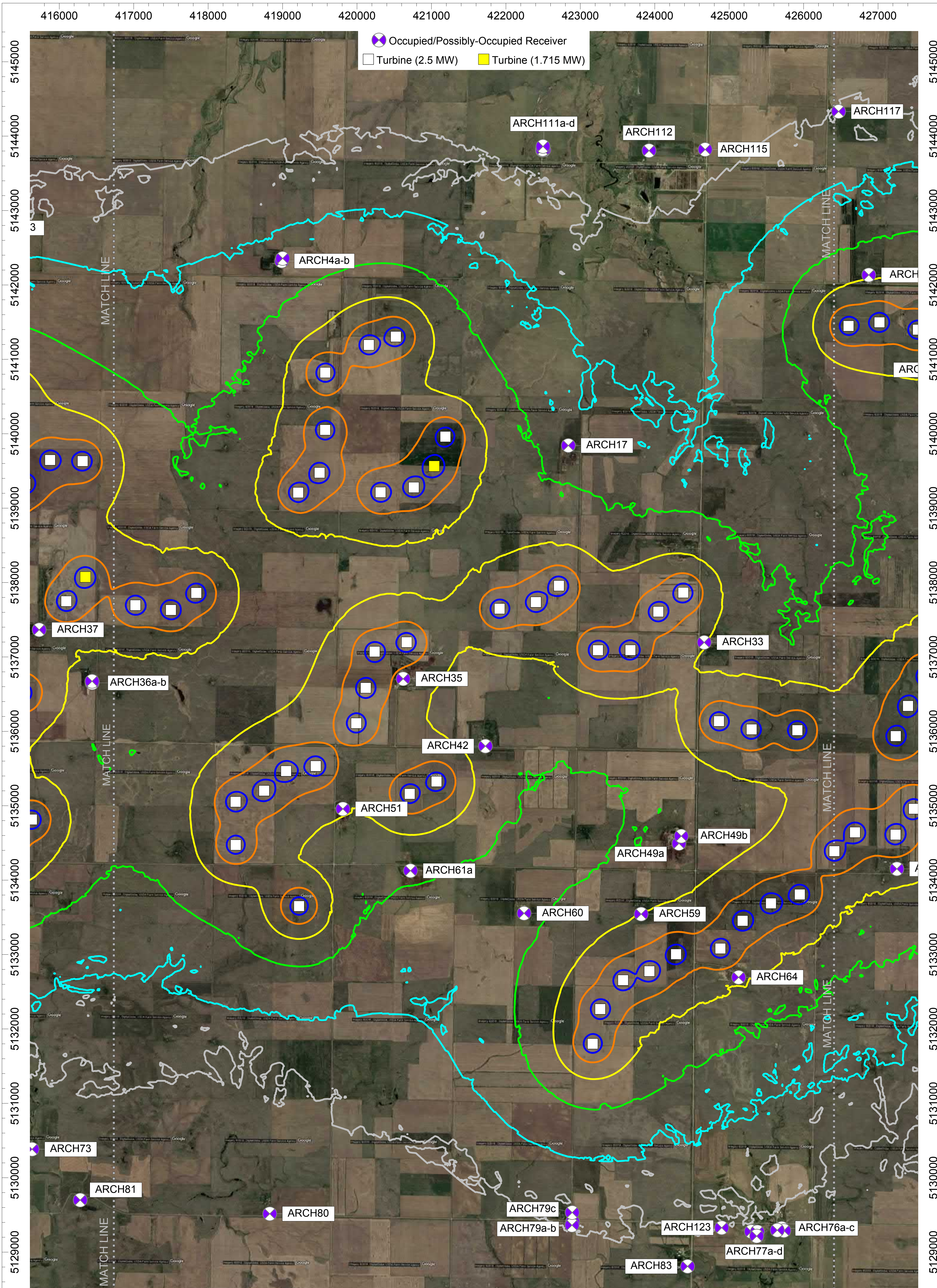
Acoustics & Noise Control Practice

Figure 4a
With Alternates
Wind Turbines at Maximum Rotational Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

- 30 dBA
- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA



N

Date Created:
10/22/2018

Created by:
CK

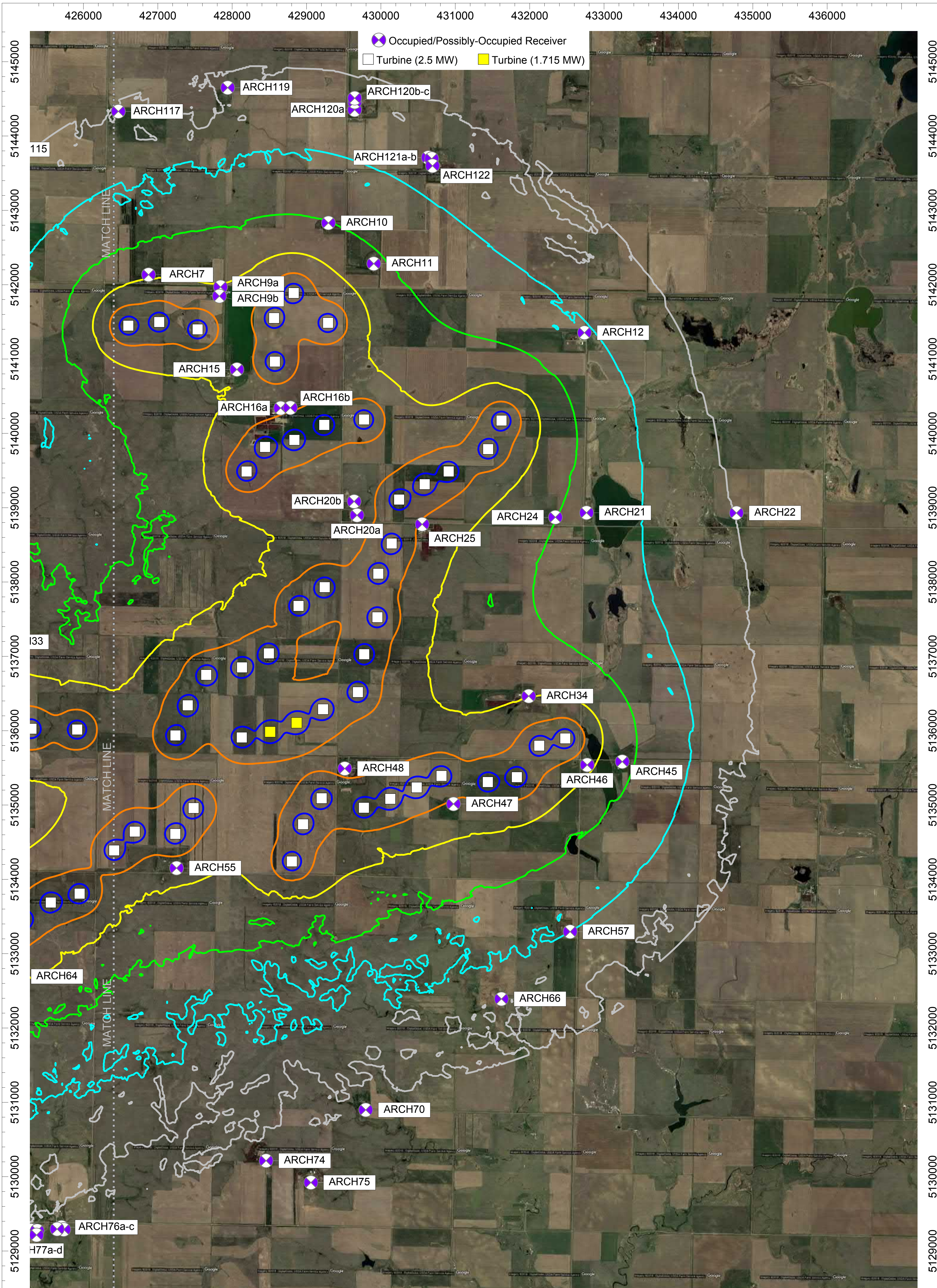
AECOM Imagine it. Delivered.
Acoustics & Noise Control Practice

Figure 4b
With Alternates
Wind Turbines at Maximum Rotational Wind Speed

Predicted Project Operation Sound Contours
Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Sound Level Contour Ranges (dBA)

- 30 dBA
- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA



N	Date Created: 10/22/2018	**Figure 4c** **With Alternates** **Wind Turbines at Maximum Rotational Wind Speed**	**Sound Level Contour Ranges (dBA)**
	Created by: CK		30 dBA 35 dBA 40 dBA 45 dBA 50 dBA 55 dBA
AECOM Imagine it. Delivered. **Acoustics & Noise Control Practice**		**Predicted Project Operation Sound Contours** **Emmons-Logan Wind Energy Center** **Emmons and Logan Counties, ND**	

Appendix A

Detailed Modeling Results

Receptor ID	Parcel of Studied Receptor	Land Status Other Parcels Owned by Landowner	Participating Landowner?	Nearest WTG ID	Distance to Nearest WTG (feet)	Receptor Coordinates (UTM Zone 14, NAD 83)		Modeled Receptor Coordinates (UTM Zone 14, NAD 83)		Predicted Operation Sound Levels (Leq, dBA) Per Scenario			
						Easting (m)	Northing (m)	Easting (m)	Northing (m)	No Alternates		With Alternates	
										Cut-In	Maximum Rotational	Cut-In	Maximum Rotational
ARCH1a	No Status	-	No	5	9659	411748	5142273	411785	5142245	22.3	31.6	22.3	31.6
ARCH1b	No Status	-	No	5	9829	411681	5142284	411717	5142254	22.0	31.3	22.0	31.3
ARCH3	No Status	NIT	No	8	7766	414922	5142811	414929	5142766	24.7	33.1	24.7	33.1
ARCH4a	NIT	-	No	43	5430	418970	5142363	418988	5142322	25.3	37.0	25.3	37.0
ARCH4b	NIT	-	No	43	5522	418976	5142395	419001	5142356	25.2	36.9	25.2	36.9
ARCH7	TAR	LSE	Yes	73	2287	426874	5142180	426876	5142134	31.9	44.2	32.1	44.3
ARCH9a	LSE	-	Yes	74	2274	427858	5142012	427843	5141969	32.8	45.1	33.6	45.4
ARCH9b	LSE	-	Yes	74	1900	427845	5141887	427828	5141846	33.8	46.1	34.5	46.3
ARCH10	LSE	-	Yes	77	3602	429319	5142869	429294	5142831	26.8	39.0	29.8	40.1
ARCH11	TAR	-	No	Alt6	3449	429934	5142318	429904	5142283	26.8	38.9	31.6	41.1
ARCH12	No Status	-	No	114	5482	432773	5141382	432737	5141354	23.0	35.0	24.6	35.6
ARCH14	No Status	LSE	Yes	4	8917	410443	5140839	410485	5140820	21.9	32.4	21.9	32.4
ARCH15	LSE	-	Yes	75	1860	428022	5140842	428064	5140859	34.5	46.7	35.6	47.1
ARCH16a	LSE	-	Yes	80	1683	428633	5140382	428652	5140340	35.8	48.2	38.6	49.2
ARCH16b	LSE	-	Yes	80	1581	428774	5140389	428783	5140344	35.8	48.1	39.4	49.5
ARCH17	LSE	-	Yes	49	5584	422884	5139836	422839	5139842	27.1	38.1	27.1	38.1
ARCH18	No Status	LSE	Yes	1	5925	410039	5139386	410076	5139359	23.6	35.4	23.6	35.4
ARCH19	No Status	-	No	4	2152	411861	5139343	411894	5139311	32.5	44.3	32.5	44.4
ARCH20a	LSE	-	Yes	109	2064	429635	5138886	429679	5138898	35.3	47.5	36.3	47.8
ARCH20b	LSE	-	Yes	110	2142	429592	5139083	429640	5139083	34.5	46.8	36.2	47.3
ARCH21	No Status	-	No	113	5318	432803	5138909	432764	5138932	25.9	37.8	27.2	38.3
ARCH22	No Status	-	No	114	11289	434822	5138912	434780	5138929	17.0	28.8	19.5	29.8
ARCH24	LSE	-	Yes	113	4373	432380	5138841	432346	5138871	27.8	39.7	28.9	40.1
ARCH25	LSE	-	Yes	110	1634	430597	5138756	430555	5138776	37.1	49.4	37.5	49.5
ARCH28	TAR	-	Yes	13	2011	413756	5138574	413801	5138579	34.7	46.4	34.8	46.4
ARCH29	LSE	-	Yes	1	1545	410988	5138194	411004	5138151	34.8	47.0	34.8	47.0
ARCH30a	No Status	-	No	1	3225	410075	5138403	410103	5138366	27.7	39.5	27.7	39.5
ARCH30b	No Status	-	No	1	3291	410068	5138425	410103	5138395	27.6	39.3	27.6	39.3
ARCH31	LSE	-	Yes	10	2372	412313	5137566	412352	5137542	33.6	45.3	33.7	45.3
ARCH33	LSE	-	Yes	68	2533	424685	5137154	424665	5137195	33.0	45.2	33.0	45.2
ARCH34	LSE	-	Yes	Alt1	2385	431973	5136509	431987	5136465	29.2	41.0	36.4	44.8
ARCH35	LSE	-	Yes	61	1722	420653	5136674	420620	5136706	36.3	48.6	36.3	48.6
ARCH36a	NIT	-	No	23	3245	416487	5136666	416443	5136652	32.6	43.6	32.9	43.8
ARCH36b	NIT	-	No	23	3251	416484	5136690	416441	5136673	32.6	43.7	32.9	43.8
ARCH37	LSE	-	Yes	24	1883	415694	5137337	415730	5137365	35.6	46.7	35.8	46.8
ARCH38	LSE	-	Yes	11	1742	413943	5137194	413974	5137160	37.7	49.6	37.8	49.6
ARCH39	LSE	-	Yes	10	2369	413090	5136520	413130	5136498	36.0	46.7	36.2	46.8

Receptor ID	Parcel of Studied Receptor	Land Status Other Parcels Owned by Landowner	Participating Landowner?	Nearest WTG ID	Distance to Nearest WTG (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Receptor Coordinates (UTM Zone 14, NAD 83) Northing (m)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83) Northing (m)	Predicted Operation Sound Levels (Leq, dBA) Per Scenario: No Alternates Cut-In	No Alternates Maximum Rotational	With Alternates Cut-In	With Alternates Maximum Rotational
ARCH42	LSE	-	Yes	57	2812	421759	5135832	421725	5135801	30.5	42.6	30.5	42.6
ARCH45	LSE	-	Yes	Alt2	2856	433280	5135553	433245	5135583	25.0	36.8	33.2	41.4
ARCH46	LSE	-	Yes	Alt2	1667	432802	5135504	432773	5135539	27.9	39.9	38.6	46.3
ARCH47	LSE	-	Yes	121	1496	430992	5134971	430976	5135014	37.0	49.2	37.4	49.4
ARCH48	NIT	LSE	Yes	117	1804	429531	5135533	429514	5135490	37.8	49.2	37.9	49.2
ARCH49a	LSE	-	Yes	87	4564	424296	5134528	424326	5134493	29.7	41.8	29.7	41.8
ARCH49b	LSE	-	Yes	87	4757	424324	5134624	424357	5134592	29.8	41.8	29.8	41.8
ARCH51	LSE	-	Yes	55	2349	419802	5134912	419810	5134957	33.3	45.5	33.3	45.5
ARCH52	No Status	PND / NIT	Yes	9	2913	411640	5135851	411670	5135816	31.9	41.8	32.0	41.9
ARCH53	No Status	-	No	29	8432	410166	5134921	410211	5134927	25.1	34.7	25.3	34.8
ARCH54	LSE	-	Yes	38	1663	414773	5134478	414817	5134470	35.7	46.6	36.3	46.8
ARCH55	LSE	-	Yes	92	1663	427252	5134105	427253	5134151	35.3	47.5	35.3	47.5
ARCH57	LSE	-	Yes	123	7369	432556	5133251	432544	5133295	22.5	34.0	24.8	35.0
ARCH59	LSE	-	Yes	85	2490	423789	5133578	423818	5133543	32.8	45.1	32.8	45.1
ARCH60	LSE	-	Yes	83	5413	422205	5133575	422245	5133554	27.1	39.2	27.1	39.2
ARCH61a	No Status	LSE	Yes	56	3540	420718	5134080	420719	5134126	28.8	40.9	28.8	40.9
ARCH62	NIT	-	No	34	3573	411735	5134229	411781	5134232	31.9	41.4	32.0	41.4
ARCH64	LSE	-	Yes	86	1654	425154	5132657	425127	5132694	34.6	46.9	34.6	46.9
ARCH66	No Status	-	No	122	9744	431631	5132346	431621	5132391	21.7	33.1	23.0	33.6
ARCH68	No Status	-	No	34	9495	410162	5132295	410189	5132332	19.3	29.4	19.3	29.4
ARCH69	No Status	-	No	34	10423	409972	5132060	410004	5132093	19.1	28.7	19.1	28.7
ARCH70	No Status	LSE	Yes	115	11585	429825	5130862	429796	5130898	13.9	25.7	13.9	25.7
ARCH72	LSE	-	Yes	34	10469	412251	5130545	412259	5130589	13.8	24.1	13.8	24.1
ARCH73	LSE	-	Yes	37	13107	415645	5130338	415635	5130383	13.5	25.2	13.5	25.2
ARCH74	LSE	-	Yes	115	13383	428480	5130176	428456	5130215	17.0	28.7	17.0	28.7
ARCH75	LSE	-	Yes	115	14347	429070	5129877	429059	5129921	10.8	22.4	10.8	22.4
ARCH76a	No Status	LSE	Yes	81	11791	425726	5129279	425706	5129320	16.7	28.5	16.7	28.5
ARCH76b	No Status	LSE	Yes	81	11942	425766	5129255	425735	5129289	16.9	28.7	16.9	28.7
ARCH76c	No Status	LSE	Yes	81	11719	425673	5129258	425646	5129295	16.8	28.6	16.8	28.6
ARCH77a	No Status	-	No	81	11063	425349	5129233	425335	5129276	15.9	27.8	15.9	27.8
ARCH77b	No Status	-	No	81	10984	425314	5129234	425298	5129276	17.8	29.7	17.8	29.7
ARCH77c	No Status	-	No	81	11165	425393	5129229	425379	5129272	16.3	28.2	16.3	28.2
ARCH77d	No Status	TAR	No	81	11296	425391	5129175	425370	5129215	14.2	26.1	14.2	26.1
ARCH79a	LSE	-	Yes	81	8054	422894	5129362	422897	5129407	18.7	30.6	18.7	30.6
ARCH79b	LSE	-	Yes	81	8209	422880	5129316	422888	5129362	18.5	30.4	18.5	30.4
ARCH79c	LSE	-	Yes	81	7651	422886	5129487	422891	5129532	19.4	31.3	19.4	31.3
ARCH80	NIT	-	No	50	13783	418813	5129471	418828	5129515	10.0	21.7	10.0	21.7

Appendix A

Detailed Modeling Results

Receptor ID	Parcel of Studied Receptor	Land Status Other Parcels Owned by Landowner	Participating Landowner?	Nearest WTG ID	Distance to Nearest WTG (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Modeled Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Operation Sound Levels (Leq, dBA) Per Scenario: No Alternates Cut-In	No Alternates Maximum Rotational	With Alternates Cut-In	With Alternates Maximum Rotational
ARCH81	No Status	-	No	38	15958	416269	5129655	416281	5129699	6.3	17.9	6.3	17.9
ARCH83	LSE	-	Yes	81	10820	424451	5128764	424442	5128809	13.4	25.2	13.4	25.2
ARCH84	No Status	NIT	No	34	7277	411554	5131800	411560	5131845	22.5	32.7	22.6	32.7
ARCH107	No Status	-	No	1	11742	407590	5136204	407636	5136202	13.3	25.1	13.3	25.1
ARCH108	No Status	-	No	5	12064	410981	5142552	411018	5142525	19.3	28.3	19.3	28.3
ARCH111a	No Status	-	No	45	10656	422531	5143856	422510	5143815	16.8	27.7	16.8	27.7
ARCH111b	No Status	-	No	45	10614	422512	5143854	422491	5143813	15.1	26.4	15.1	26.4
ARCH111c	No Status	-	No	45	10640	422510	5143865	422495	5143822	15.2	26.5	15.2	26.5
ARCH111d	No Status	-	No	45	10761	422528	5143898	422499	5143862	17.4	28.4	17.4	28.4
ARCH112	No Status	-	No	72	11860	423893	5143839	423923	5143805	14.6	26.4	14.6	26.4
ARCH115	No Status	LSE	Yes	72	10174	424647	5143854	424678	5143820	16.1	28.0	16.1	28.0
ARCH117	LSE	-	Yes	72	9616	426457	5144375	426470	5144331	18.4	30.3	19.4	30.7
ARCH119	NIT	-	No	77	9665	427937	5144695	427940	5144650	18.5	30.4	20.8	31.3
ARCH120a	No Status	-	No	77	8668	429651	5144397	429647	5144352	18.9	30.8	21.9	32.0
ARCH120b	No Status	-	No	77	9003	429656	5144503	429648	5144459	18.3	30.2	21.4	31.5
ARCH120c	No Status	-	No	77	9167	429659	5144554	429648	5144510	18.2	30.0	21.3	31.3
ARCH121a	No Status	-	No	77	8579	430675	5143737	430637	5143711	20.0	31.9	23.1	33.2
ARCH121b	No Status	-	No	77	8652	430715	5143728	430683	5143695	20.0	31.8	23.1	33.1
ARCH122	No Status	-	No	77	8461	430727	5143631	430694	5143599	20.2	32.1	23.4	33.4
ARCH123	No Status	LSE	Yes	81	10056	424913	5129284	424900	5129328	18.4	30.2	18.4	30.2
ARCH126	LSE	-	Yes	34	12142	412953	5130014	412957	5130060	15.5	27.0	15.5	27.0