Timber Road III Wind Farm

Transmission Line and Interconnect Switchyard Acoustic Assessment

December 2015

Prepared for

TIMBER ROAD
WIND FARM

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ACRONYMS AND ABBREVIATIONS

AC	alternating current
ACSR	aluminum conductor steel reinforced
BPA	Bonneville Power Administration
CadnaA	Computer-Aided Noise Abatement Program
CAFE	Corona and Field Effects
dBA	A-weighted decibel
EPRI	Electric Power Research Institute
FHWA	Federal Highway Administration
Hz	Hertz
ISO	International Organization for Standardization
kV	kilovolt
L_{eq}	equivalent sound level
MW	megawatt
NSA	noise sensitive area
OPSB	Ohio Power Siting Board
Project	Timber Road III Wind Farm
RCNM	Roadway Construction Noise Model
ROW	right-of-way
Tetra Tech	Tetra Tech, Inc.
USGS	United States Geological Survey

1.0 INTRODUCTION

EDP Renewables North America LLC currently owns and operates the Timber Road II Wind Farm in Paulding County, Ohio, and is proposing to construct a new phase referred to as the Timber Road III Wind Farm (Project). The Project will consist of a combination of wind turbine generators, a collection substation, and a transmission line, with an anticipated power output capacity of approximately 50 megawatts (MW). This acoustic assessment addresses potential noise impacts at noise sensitive areas (NSAs; e.g., residences) associated with construction and operation of the Project transmission line.

The transmission line is rated at 138 kilovolts (kV), and will have a right-of-way of 150 feet (45.7 meters). It also has an associated interconnect switchyard. For the purposes of permitting, two transmission line routes were analyzed, the Primary and Alternative routes. All routes extend to the same locations, one end near the intersection of County Roads 33 and 124, and the other end near the intersection of County Roads 27 and 114. The length of the Primary Route is approximately 8.6 miles (13.8 kilometers), whereas the length of the Alternative Route is approximately 11.6 miles (18.7 kilometers). The interconnect switchyard is located at the intersection of County Roads 27 and 114 and the closest residence is approximately 2,800 feet (850 meters) to the west of the interconnect switchyard fenceline. The interconnect switchyard will not include any transformers but will include a three-ring breaker, which will not generate any appreciable noise.

This technical report provides an overview of the mechanisms of corona sound generation, describes applicable requirements prescribed by the Ohio Power Siting Board (OPSB), presents the acoustic modeling methodologies, and results. An assessment of construction noise is also provided.

1.1 Transmission Line Corona Noise

Transmission line noise (also called corona noise) is caused by the partial electrical breakdown of the insulating properties of air around the electrical conductors and overhead power lines. Audible noise generated by corona on transmission lines has two major components. The higher frequencies of the broadband component distinguish it from more common outdoor environmental noise. The random phase relationship of the pressure waves generated by each corona source along a transmission line results in a characteristic sound commonly described as crackling, frying, or hissing. The second component is a lower-frequency sound that is superimposed over the broadband noise. The corona discharges produce positive and negative ions that, under the influence of the alternating electric field around alternating current (AC) conductors, are alternately attracted to and repelled from the conductors. This motion establishes a sound-pressure wave having a frequency twice that of the voltage; i.e., 120 hertz (Hz) for a 60-Hz system. Higher harmonics (e.g., 240 Hz) may also be present, but they are generally of lower significance (EPRI 2005). The relative magnitude of hum and broadband noise may be different depending on weather conditions at the line. According to the Electric Power Research Institute (EPRI), when the line is wet (such as during rainy weather conditions), the broadband component typically dominates; however, under icing conditions the lower frequency components may be more prevalent.

Figure 1-1 provides a representative frequency spectrum of AC transmission-line audible noise in rain, according to EPRI. The figure presents the 120 Hz hum and less significant 240 Hz frequency content. In this plot, the noise levels at frequencies below 100 Hz are likely influenced by ambient noise at the test site. The broadband noise extends in frequency above 10 kHz; however, the rolloff of the broadband noise above 10 kHz is related to the frequency response of the microphone, and from the increasing effect of the air absorption of sound energy with increasing frequency (EPRI 2005). The higher frequency components tend to drop off much more rapidly with increased distance due to atmospheric absorption, so the lower frequency 120 and 240 Hz energy content tends to dominate. These frequencies are used as indicator markers to determine if corona noise is present.

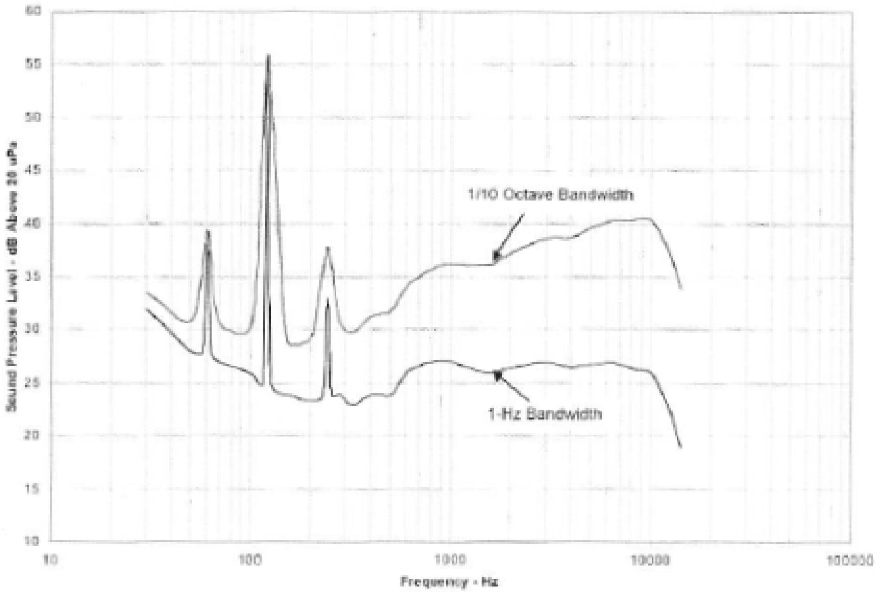


Figure 1-1. Typical Frequency Spectrum of AC Transmission-line Audible Noise in Rain

Audible noise from the Project transmission line would be expected to have a similar frequency spectrum to that indicated in Figure 1-1 when the line is wet. Corona noise levels during precipitation may vary over a wide range. During the initial stages, when the conductors are not thoroughly wet, there may be considerable fluctuation in the noise level as the precipitation intensity varies. When the conductors are thoroughly wet, the noise fluctuations will often be less significant, since even as the intensity of precipitation diminishes the conductors will still be saturated, which can result in corona discharge. Audible noise may also be present when water droplets remain on conductors after precipitation has stopped or under a light mist or heavy fog, although these conditions result in highly variable corona noise levels, dependent in part on the duration of the event. Audible noise before, during and after a rain event is shown in Figure 1-2, as presented by EPRI. The bars on the x-axis show rate of rainfall. High-humidity conditions may also result in elevated sound levels on the line, similar to those found under sustained fog conditions (see Figure 1-3, also by EPRI). In this example, fog dissipates as the sun rises in the early morning hours causing the corona noise to dissipate rapidly.

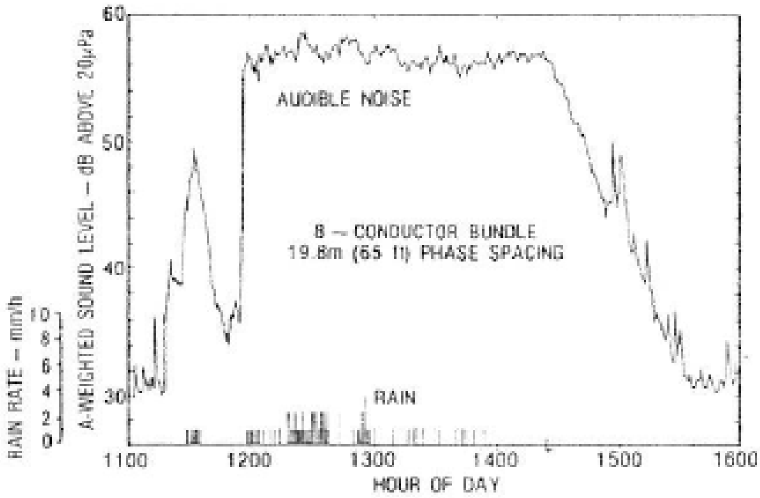


Figure 1-2. EPRI Audible Noise Before, During, and After a Rain Event

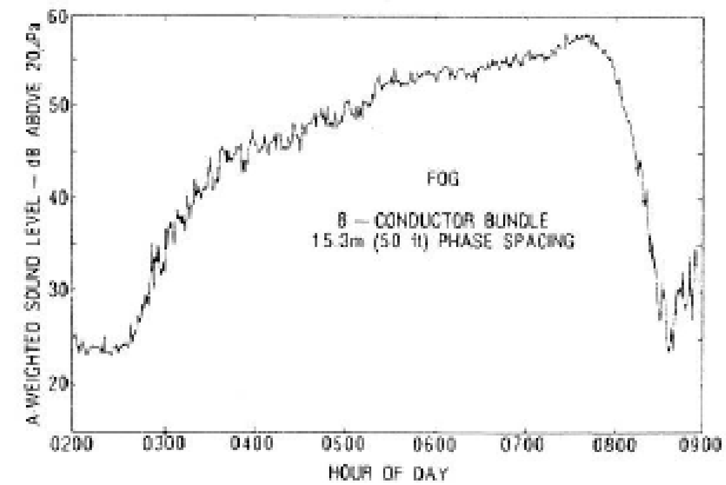


Figure 1-3. EPRI Audible Noise under Sustained Fog

2.0 NOISE REGULATIONS AND GUIDELINES

The OPSB Rule §4906-15(G)-08(A)(2) provides certification requirements for electric power, gas and natural gas transmission facilities that must be adequately addressed during both Project construction and operation. Specifically, construction noise information is only required for portions of the transmission line routes that will require more than 4 months of actual construction time to complete in residential, commercial, and other noise sensitive areas. The following information is required as part of the Project application:

> *4906-15(G)(1) Construction: To assure noise control during construction, the applicant shall estimate the nature of any intermittent, recurring, or particularly annoying sounds from the following sources:*
>
> *(a) Dynamiting or blasting activities.*
>
> *(b) Operation of earth moving and excavating equipment.*
>
> *(c) Driving of piles.*
>
> *(d) Erection of structures.*
>
> *(e) Truck traffic.*
>
> *(f) Installation of equipment.*
>
> *4906-15(G)(2) Operation and maintenance: The applicant shall estimate the effect of noise generation due to the operation or maintenance of the transmission line and associated facilities.*
>
> *4906-15(G)(3) Mitigation procedures: The applicant shall describe any equipment and procedures designed to mitigate noise emissions during both the site clearing and construction phase, and during the operation and maintenance of the facility to minimize noise impact.*

The OPSB does not prescribe numerical decibel limits within the rules; but limits were provided within the Opinion, Order and Certificate issued to the Timber Road III Wind Farm on November 18, 2010. It also gave guidance on assessment of Project noise impacts applicable at the exterior of any non-participating residences within 1 mile of the facility. The Project is not to exceed the greater of (1) the Project ambient nighttime equivalent sound level (L_{eq}; 41 A-weighted decibels [dBA]) plus 5 dBA, or (2) the validly measured ambient L_{eq} plus 5 dBA.

3.0 ACOUSTIC MODELING METHODOLOGY

The acoustic assessment of the Project transmission line involved two separate analytical methods. The Bonneville Power Administration (BPA) Corona and Field Effects (CAFE) program Version 3 was used to determine anticipated corona noise levels generated along the transmission line conductors. DataKustik's Computer-Aided Noise Abatement (CadnaA) was then used to model how sound propagates from the transmission line to the NSAs.

3.1 Modeling Input Parameter Assumptions

As mentioned previously, two transmission lines routes were analyzed, the Primary Route that is 78.6 miles (13.8 kilometers) in length and the Alternative Route that is 11.6 miles (18.7 kilometers) in length. The proposed conductor for the 138-kV transmission line structures is a 795 KCM aluminum conductor steel reinforced (ACSR) 26/7 "Drake" for the phase wires. Figure 3-1 shows the typical transmission line structure planned for the Project.

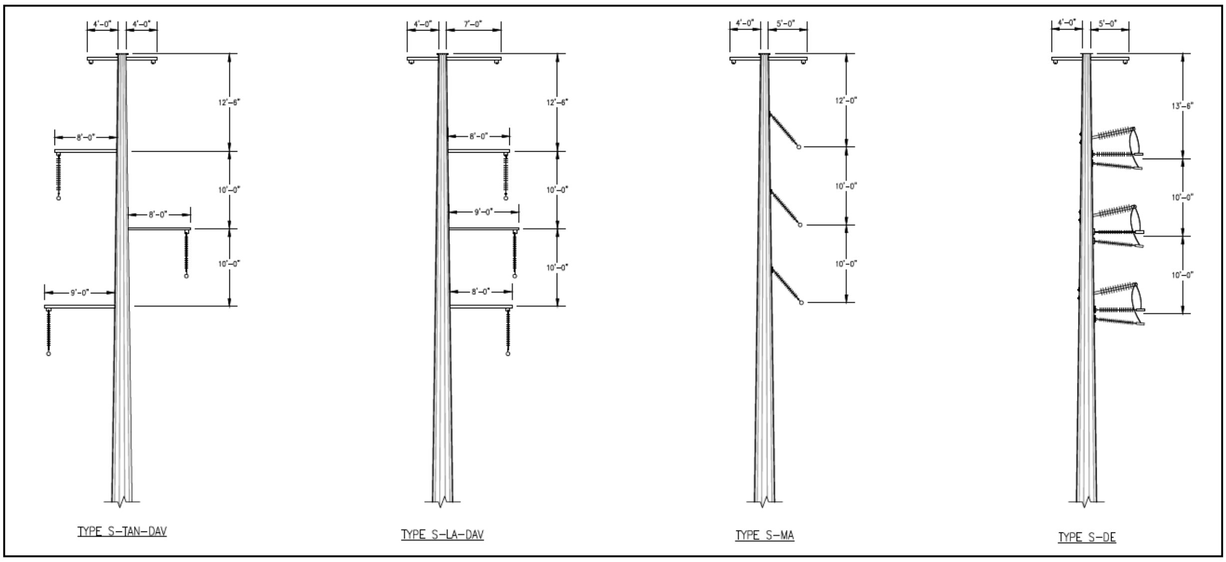


Figure 3-1 Typical 138-kV Transmission Line Type

Representative broadband and octave band center frequencies were derived using the BPA CAFE program and from standardized engineering technical guidelines, based on measurements from similar equipment types and line types operating after the burn-in period. It is expected that the transmission line installed will exhibit sound source characteristics similar to the sound data used in the acoustic modeling analysis; however, it is possible that the final values may vary. Table 3-1 further summarizes setup parameters used in the transmission line acoustic modeling analysis.

Table 3-1 Operational Acoustic Modeling Parameters

Model Input	Parameter Value
138-kV Transmission Line Source Characteristics	See Figure 4-1 for audible noise level results using the Bonneville Power Administration (BPA) Corona and Field Effects (CAFE) program.
Engineering Design	Site plans dated October 27, 2015
Terrain Parameters	U.S. Geological Survey digital elevation data
Site elevation range	735 feet (224 meters) to 748 feet (228 meters) above mean sea level
Transmission Line Source Heights	60 feet (18.3 meters)
Receiver Characteristics	5 feet (1.52 meters) above ground level
Temperature	50ºF (10ºC)
Relative Humidity	For Computer-Aided Noise Abatement (CadnaA), >90%
Meteorological Factors	CadnaA assumes moderate downwind propagation. The CAFE program assumes a wind speed of 0.5 mile per hour. For CAFE, rain rate is assumed to be 1 inch/hour
Ground Absorption	Ground absorption coefficient of 0.5, representing a semi-reflective surface.
Standards	ISO 9613-2, Acoustics – Attenuation of sound during propagation outdoors.
Search radius	8,000 meters (26,246 feet)
Noise Modeling Software	BPA CAFE program DataKustik CadnaA v 4.5.151

3.2 Corona and Field Effects Program

To support engineering design and permitting efforts for the Project, audible noise calculations were performed for the Primary and Alternative routes. Corona source noise levels were calculated using methodologies described in the BPA CAFE 3 program. Developed by the U.S. Department of Energy and the BPA, CAFE algorithms have been validated and used by engineers and scientists for many years to calculate the expected levels of audible noise produced by transmission lines. The inputs to the model included variables such as line voltage, altitude, and meteorological conditions. The BPA method of calculating audible noise from transmission lines is based on long-term statistical data collected from operating and test transmission lines. This method calculates the foul weather L_{50} noise level during rainy conditions of 1 inch per hour. Long-term measurements show that L_{50} audible noise levels occur at this rain rate (EPRI 2005). The BPA CAFE modeling for the Project's transmission line assumes this standard rain rate. Results during fair weather conditions are also estimated. Received sound levels generated by the Project at the edge of the right-of-way (ROW) during fair weather conditions would be substantially lower than during foul weather conditions.

3.3 CadnaA

DataKustik GmbH's CadnaA, a computer-aided noise abatement program (DataKustik v 4.5.151) was used for the acoustic modeling analysis of the transmission line. CadnaA is a comprehensive three-dimensional acoustic software model that conforms to the International Organization for Standardization (ISO) 9613-2 standard (ISO 1996). The engineering methods specified in this standard consist of full octave band algorithms that incorporate geometric spreading due to wave divergence, reflection from surfaces, atmospheric absorption, screening by topography and obstacles, ground effects, source directivity, heights of both sources and receptors, seasonal foliage effects, and meteorological conditions.

CadnaA allows for three types of sound sources to be introduced into the model: point, line, and area sources. Point sources can be used for small sources such as fans or for larger sources with proportioned dimensions that are located away from the relevant receptors. Line sources are used for linear sources such as transmission lines. Area sources can be vertical such as transformers or noise-radiating façades. The Project was represented as a continuous line source. The lateral attenuation from a line source of noise such as a transmission line is governed by the laws of acoustics and is due to the divergence of the sound pressure waves with increased distance from the source. The acoustic model calculations assumed corona is uniformly distributed along the conductor, with the resulting pressure wave propagating in a cylindrical fashion.

Molecular absorption of energy as the sound waves propagate through the air results in additional attenuation. Atmospheric absorption is a function of frequency, temperature, and relative humidity. The absorption effect increases with frequency. At distances farther from the transmission line, the frequency will shift towards the lower end of the spectrum as greater attenuation of the high frequency sound component will occur. Sound propagation calculations applied meteorological conditions consistent with weather conditions that typically result in greater noise production (i.e., high humidity conditions, which includes all precipitation events). CadnaA does not allow for use of a rain rate as an assumption. Accordingly, attenuation rates due to air absorption were predicted using 90 percent or greater relative humidity.

The effects of wind gradients on outdoor sound propagation can cause variations in the sound level of a distant facility. Similar effects are caused by temperature changes in the atmosphere and the resulting variation in the sound speed profile. The sound level variations caused by wind and temperature gradients are most pronounced for large separation distances. Calculations were completed for meteorological conditions corresponding to moderate downwind propagation (i.e., moderate downward refraction). This condition results in efficient outdoor sound propagation between a source and receptor and is consistent with the ISO 9613-2 standard (ISO 1996). Lower sound levels are expected in other directions dependent on wind velocities, speed, direction, and gustiness.

4.0 PROJECT OPERATING NOISE LEVELS

Received sound levels (dBA) were calculated for the Primary and Alternative transmission line and results of those analyses are presented in the following subsections.

4.1 Results

The BPA CAFE program calculated the expected audible noise levels in both foul and fair weather at the edges of the ROW. The audible noise level in fair weather at the edges of the ROW is negligible. In foul weather, the audible noise levels are approximately 16.6 dBA, increasing to an approximate maximum of 21.7 dBA directly beneath the line (Figure 4-1). As expected, audible noise levels associated with the proposed Project transmission line are very low, which is due to the low voltage of the line and the low elevation of the site. Audible noise levels would increase with increasing voltage and altitude.

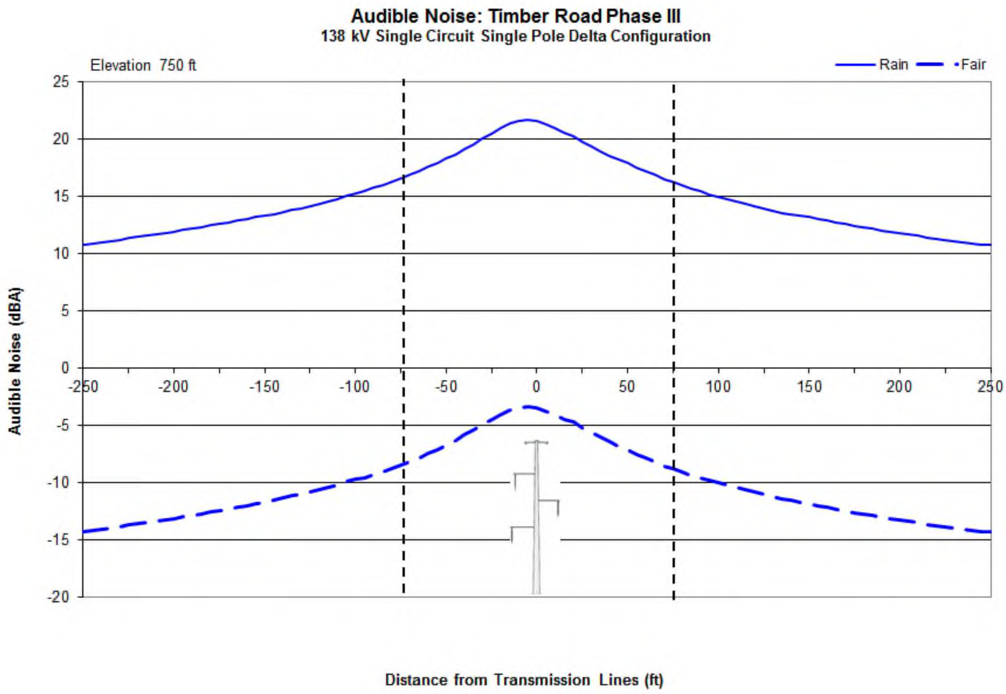
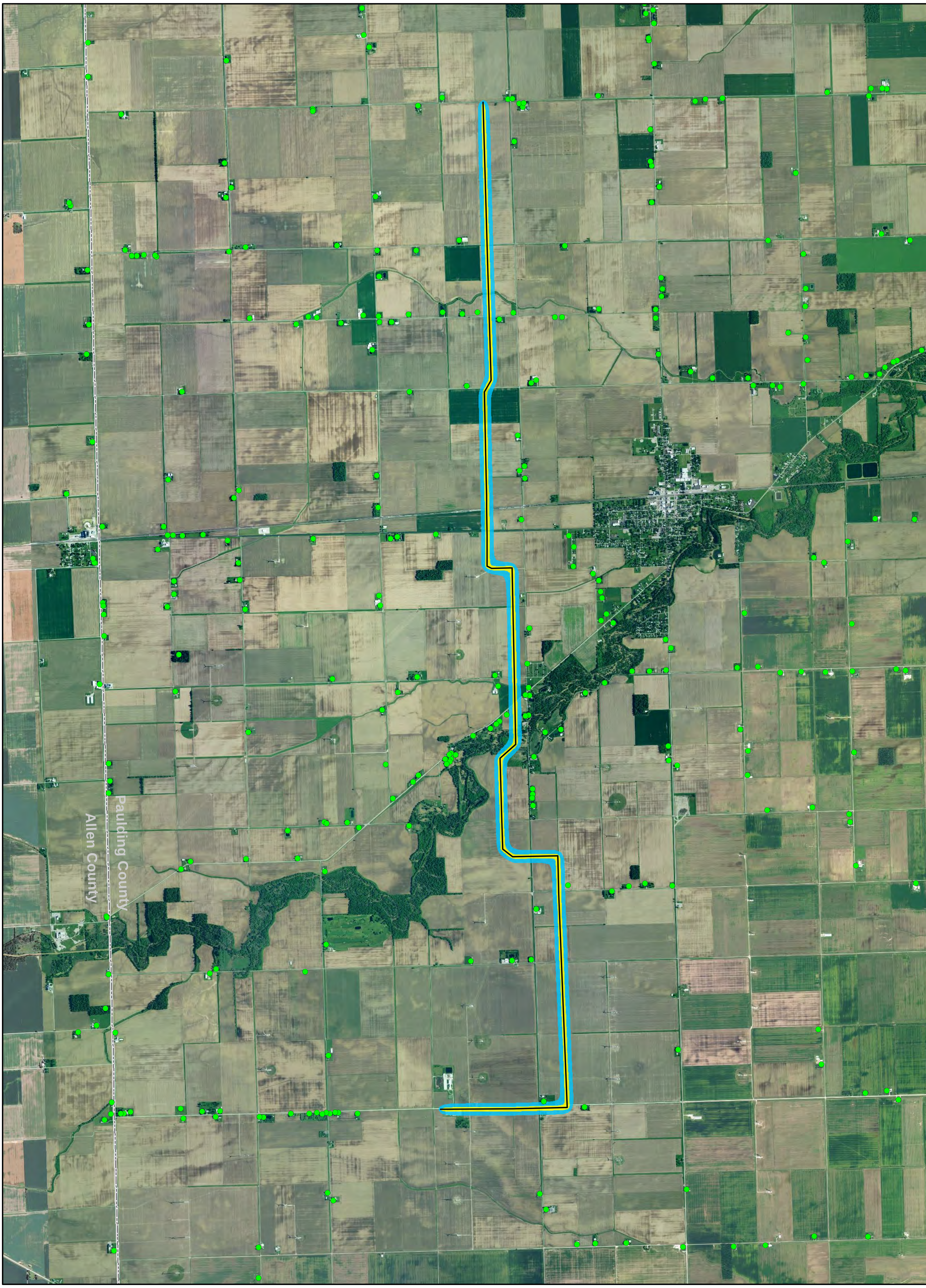


Figure 4-1 Audible Noise Profile at Midspan for proposed 138-kV Transmission Line Tower

The source characteristics from the BPA CAFE program for foul weather conditions were input into CadnaA and received sound levels were predicted at NSAs, inclusive of a 3 dBA engineering safety factor. Fair weather conditions were not modeled, since transmission line sound source levels were sufficiently low so that no impacts were expected. Maximum received sound levels at NSAs when modeling both the Primary and Alternative routes under foul weather conditions were below 25 dBA. Sound contour plots displaying Project operational sound levels in color-coded isopleths are provided for the Primary Route (Figure 4-2) and Alternative Route (Figure 4-3).



Legend

- Noise Sensitive Areas
- Primary Transmission Line

Sound Level Contour Ranges (dBA)

- 15 - 20 dBA
- 20 - 25 dBA
- > 25 dBA

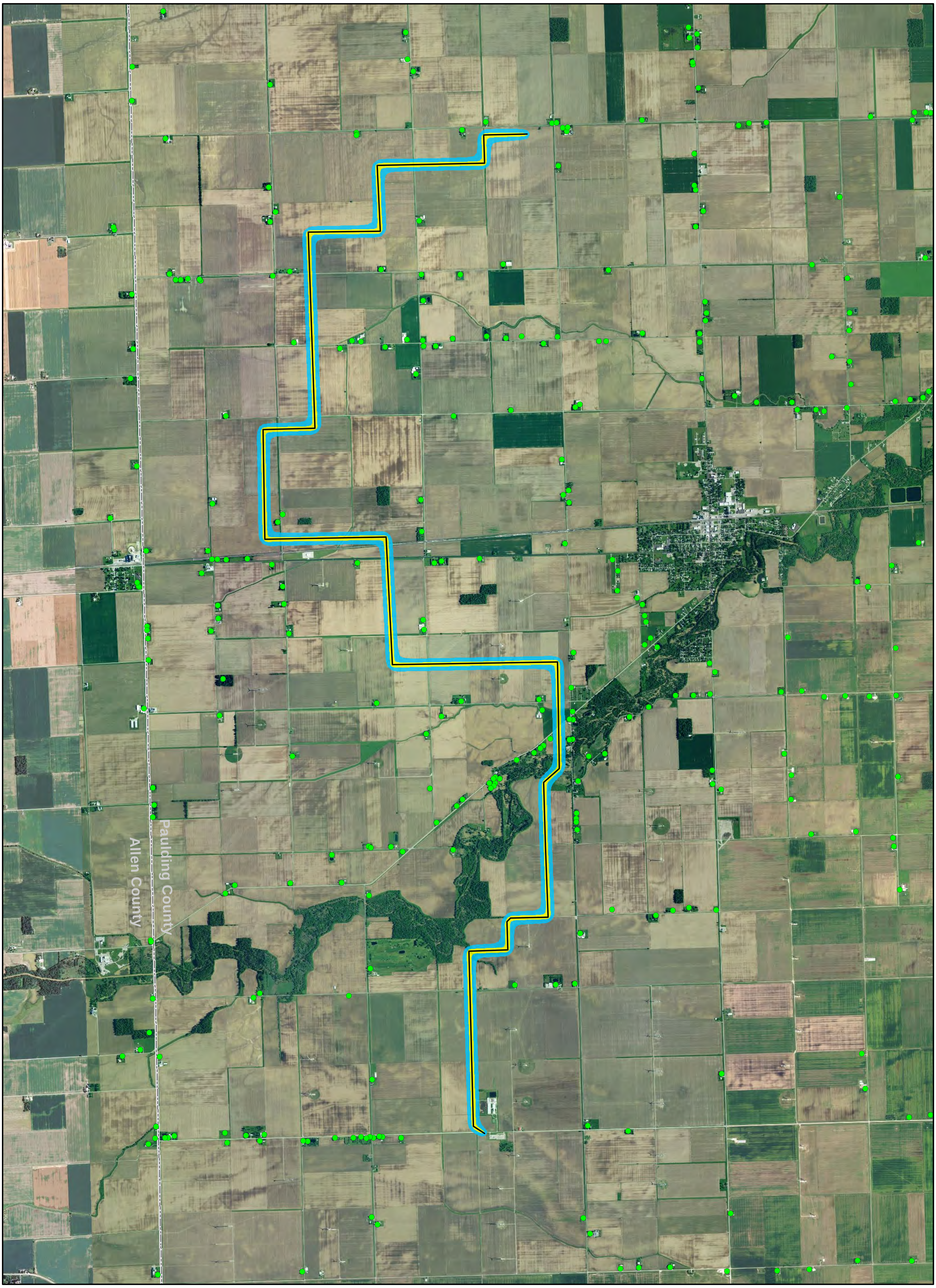
N

0 0.5 1
Miles

FIGURE 4-2
TIMBER ROAD III WIND FARM
PRIMARY TRANSMISSION LINE ROUTE
OPERATION, FOUL WEATHER

PAULDING COUNTY, OHIO

R:\PROJECTS\TIMBER_ROAD_III_5444\NOISE\TimberRd_III\TLine\Figure 4-2_Primary_Tline_Operation.mxd



Legend

- Noise Sensitive Areas
- Alternative Transmission Line

Sound Level Contour Ranges (dBA)

- 15 - 20 dBA
- 20 - 25 dBA
- > 25 dBA

N

0 0.5 1
Miles

FIGURE 4-3
TIMBER ROAD III WIND FARM
ALTERNATIVE TRANSMISSION LINE ROUTE
OPERATION, FOUL WEATHER

PAULDING COUNTY, OHIO

R:\PROJECTS\TIMBER_ROAD_III_5444\NOISE\TimberRd_III\TLine\Figure 4-3_Alternative_Tline_Operation.mxd

5.0 PROJECT CONSTRUCTION NOISE LEVELS

Transmission line construction will periodically generate audible noise levels. Additional noise sources may include commuting workers and trucks, moving material to and from the work sites. The construction equipment that will be used is similar to that used during typical public-works projects and tree service operations (e.g., road resurfacing, storm-sewer installation, natural gas line installation, tree removal, etc.). Transmission line construction will occur sequentially, moving along the length of the Project route, or in other areas such as near access roads, structure sites, conductor pulling sites, and staging and maintenance areas. Overhead line construction is typically completed in the following stages, but various construction activities may overlap, with multiple construction crews operating simultaneously:

1. **Site access and preparation**: Preparing the ROW would require the removal of trees, and may also require selective clearing of tall trees near the ROW.

2. **Installation of structure foundations**: The next step in the construction process is drilling foundations for the new transmission structures. This involves drilling large holes, which are then typically filled with concrete for the steel structure foundation.

3. **Erecting of support structures**: Once the foundation is cured, transmission structure installation can begin. The new steel poles often come in sections that are assembled on or near the foundation. Cranes or bucket trucks are used to lift the poles and set them into position on the foundations.

4. **Stringing of conductors**: With the new steel structures in place, the next step is to install the conductor wire. The wire-stringing operation requires equipment at each end of the section being strung. Wire is pulled between these "pulling sites" through stringing blocks (pulleys) at each structure. These pulling sites are set up at various intervals along the ROW, typically 1 to 3 miles apart.

Noise levels from overhead transmission line construction were evaluated using a screening-level analysis approach. The calculation methodology requires the input of the number and type of construction equipment used by phase, as well as typical noise levels associated with each piece of equipment. Construction sound source level data were obtained from the Federal Highway Administration's (FHWA) Roadway Construction Noise Model (RCNM). These data were used to determine the composite sound levels at distances of 50 feet and 1,000 feet. Table 5-1 summarizes results for the four conceptual construction phases.

Construction sound would attenuate with increased distance from the ROW. Other factors, such as vegetation, terrain, and obstacles such as buildings would also act to further limit the impact of construction noise levels, but were not considered in the analysis. Actual received sound levels would fluctuate, depending on the construction activity, equipment type, and separation distances between source and receiver. The variation in power and usage imposes additional complexity in characterizing construction noise levels, and the analysis conservatively assumes all phased construction equipment operating simultaneously. As a general construction practice, functional mufflers would be maintained on all equipment to maintain noise levels as low as reasonably achievable.

Received sound levels at NSAs from construction will depend on the type of equipment used, the mode of equipment operation, the length of time the equipment is used, the amount of equipment used simultaneously, and the distance between the sound source and NSA. All of these factors are expected to vary regularly throughout the construction period, making the calculation of a specific received sound-level value at each NSA location difficult. Work in the proximity of any single general location will likely last no more than a few days to a week as construction activities move along the corridor; therefore, no single receptor will be exposed to significant noise levels for an extended period.

Table 5-1 Summary of Transmission Line Construction Noise at Specified Reference Distances

Phase No.	Construction Phase	Example Construction Equipment	Equipment Noise Level at 15 m (50 ft.), dBA	Composite Noise Level at 15 m (50 ft), dBA	Composite L_{eq} Noise Level at 1000 feet, dBA
1	Site Access and Preparation	Bulldozer Grader Roller – Compactor Loader Water Truck Dump Truck	85 85 85 80 84 84	88	53
2	Installation of Structure Foundations	Bulldozer Loader Backhoe-Loader Forklift Mobile Crane Auger Rig Drill Rig Compressor Pump Portable Mixer Jackhammer Cement Mixer Truck Dump Truck Slurry Truck Specialty Truck Water Truck	85 80 80 80 85 85 85 80 77 82 85 85 84 78 84 84	90	56
3	Erecting of Support Structures	Forklift Mobile Crane Compressor Flatbed Truck Flatbed Truck Water Truck	80 85 80 84 84 84	86	52

Table 5-1 Summary of Transmission Line Construction Noise at Specified Reference Distances

Phase No.	Construction Phase	Example Construction Equipment	Equipment Noise Level at 15 m (50 ft.), dBA	Composite Noise Level at 15 m (50 ft), dBA	Composite L_{eq} Noise Level at 1000 feet, dBA
4	Stringing of Conductors	Tracked Dozer Backhoe-Loader Compressor Line Puller Mixed Trucks Specialty Truck Specialty Truck Water Truck	85 80 80 81 84 84 84 84	88	54

Source: Equipment Noise Levels from FHWA 2006 Construction Noise Handbook

Construction of the new interconnect switchyard would involve site clearing, grading and compaction, trenching so that cables running to the switchyard could be installed and pouring of the foundation. In addition, the equipment pad would be laid down within the fenced area and equipment would be installed. While the construction location or equipment used in a particular phase of construction may vary, it is expected that noise levels generated during switchyard construction would be similar to those generated during transmission line construction.

6.0 CONCLUSIONS

Operational sound levels of the Project 138-kV transmission line were characterized, and potential impacts were analyzed at nearby NSAs. Both the Primary and Alternative routes were analyzed using the same inputs and methodologies. Results showed that the highest predicted received sound levels at NSAs were below 25 dBA, which is well below the noise criterion prescribed by the OPSB for the Timber Road III Wind Farm, or for other well-recognized noise guidelines provided by the U.S. Environmental Protection Agency or World Health Organization. Results for the Primary and Alternative routes were comparable. Due to the low voltage of the Project transmission line, potential impacts at NSAs were expected to be minimal.

7.0 TECHNICAL REFERENCES

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