APPENDIX A

Noise Analysis

PRELIMINARY NOISE COMPLIANCE REPORT

BLAZING STAR WIND FARM

the science of insight

8.31.2016

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1.0 INTRODUCTION

Blazing Star Wind Farm, LLC has submitted a Site Permit Application (SPA) to the Minnesota Public Utilities Commission (PUC) to build a wind power generation facility in Lincoln County. The facility will involve the construction of up to 100 wind turbines for a project rating of up to 200 MW. The turbines would be installed in an area south, east, and north of Hendricks and west of US Route 75. For the SPA, RSG has performed a preliminary noise compliance assessment of the project based on the preliminary turbine layout. Included in this report are:

- A description of the project;
- A discussion of sound level standards;
- A discussion of sound issues that are particular to wind farms;
- Background sound level monitoring procedure and results;
- Sound propagation modeling procedures and results; and
- Conclusions.

Appendix A includes a primer on the science of sound, including descriptions of some of the acoustical terms used in this report.

2.0 PROJECT DESCRIPTION

Blazing Star Wind Farm will be located in Lincoln County, Minnesota. The project area is generally located to the south, east, and north of Hendricks, just south of the Lincoln/Yellow Medicine County Line, approximately four miles north of Lake Shaokatan, and two to three miles west of US Route 75. The roads and borders that envelope the project area are County Highway 20 to the north, 170th Avenue to the east, Minnesota Highway 19 to the south, and the South Dakota state line to the west. The wind project is designed to include up to 100 turbines, with hub heights between 84 and 95 meters (275 and 312 feet). A map of the site is provided in Figure 1.

The area around the project is composed primarily of agricultural land uses (primarily corn, soybean, and dairy) with farm residences. Terrain in the area is mostly flat in the southern part of the project, with more rolling terrain in the northern part of the project. The City of Hendricks is located to the west of the project, and the closest proposed turbine location to the city is approximately 2,500 feet to the northeast. Land uses within the city are primarily residential and commercial. There is a hospital on the east edge of the city as well as a worship facility. On the south edge of the city there are some grain elevators and an agricultural salvage yard.

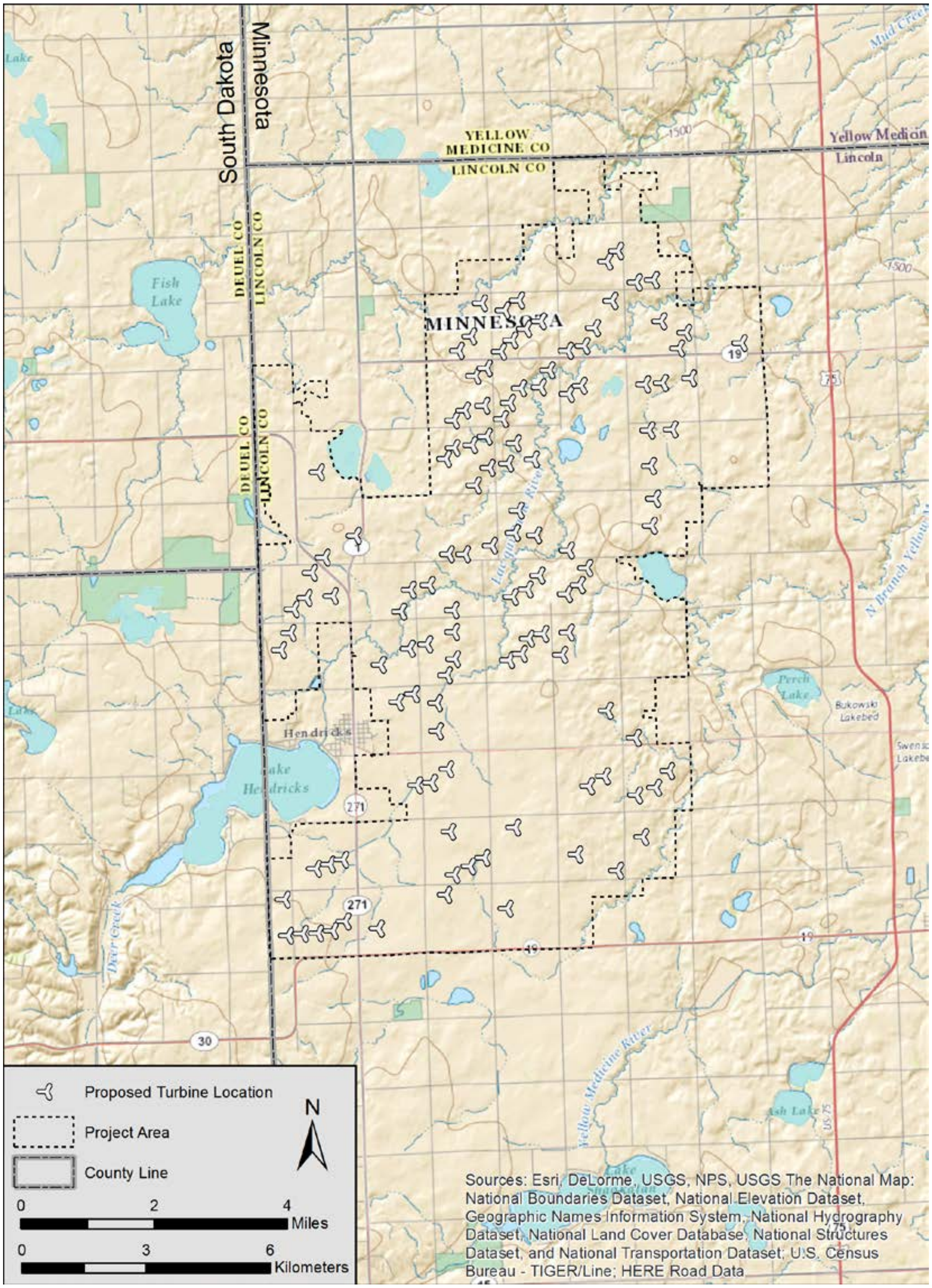

FIGURE 1: BLAZING STAR WIND FARM AREA MAP

3.0 SOUND LEVEL STANDARDS & GUIDELINES

3.1 | LOCAL STANDARDS

Locally, Lincoln County Comprehensive Development Ordinance No. 40 regulates noise from wind power in Section 9, Subdivision 700:

> "Noise regulated by Minnesota Pollution Control Agency under Chapter 7030. These rules establish the maximum night and daytime noise levels that effectively limit wind turbine noise to fifty (50) dB (A) at farm residences. However, these standards may not be sufficient for the "preservation of public health and welfare" in relation to impulsive noises. Additional local limits relative to impulsive and pure tone noises may be appropriate."

3.2 | STATE STANDARDS

Minnesota Statute §116.07 charges the Pollution Control Agency with adopting noise standards. These standards are set in Minnesota Rules Chapter 7030, for which a wind power project needs to demonstrate it will be in compliance with to receive a site permit from PUC. The Rule provides daytime and nighttime[1] sound level limits (Table 1) for a variety of land uses, which are grouped into three categories identified by a Noise Area Classification. The sensitive land uses around the Blazing Star Project area are primarily within Noise Area Classification 1 which includes residences including farm houses, and contain the most restrictive sound limits.

TABLE 1: SOUND LEVEL LIMITS (dBA) FROM MN RULES 7030.0040

Noise Area Classification	Daytime		Nighttime	
	L_{50}	L_{10}	L_{50}	L_{10}
1	60	65	50	55
2	65	70	65	70
3	75	80	75	80

The Rule says that the limits are for the "…preservation of public health and welfare" and that they are "…consistent with speech, sleep, annoyance, and hearing conservation requirements…", but that they "…do not, by themselves, identify the limiting levels of impulsive noise[2] needed for the preservation of public health and welfare."

[1] MN Rules 7030.0020 define daytime as 7:00 a.m. to 10:00 p.m. and nighttime as 10:00 p.m. to 7:00 a.m.

[2] Impulsive noise is defined in Minnesota Rules Chapter 7030.0020. Typical, wind turbine sound at the distance of a residential receiver is not considered impulsive.

4.0 WIND TURBINE ACOUSTICS – SPECIAL CONSIDERATIONS

4.1 | SOURCES OF SOUND GENERATION BY WIND TURBINES

Wind turbines generate two principle types of sound: aerodynamic, produced from the flow of air around the blades, and mechanical, produced from mechanical and electrical components within the nacelle.

Aerodynamic sound is the primary source of sound associated with wind turbines. These acoustic emissions can be either tonal or broadband. Tonal sound occurs at discrete frequencies, whereas broadband sound is distributed with little peaking across the frequency spectrum. While unusual, tonal sound can also originate from unstable air flows over holes, slits, or blunt trailing edges on blades. The majority of audible aerodynamic sound from wind turbines is broadband at the middle frequencies, roughly between 200 Hz and 1,000 Hz.

Wind turbines emit aerodynamic broadband sound as the rotating blades interact with atmospheric turbulence and as air flows along their surfaces. This produces a characteristic "whooshing" sound through several mechanisms (Figure 2):

- Inflow turbulence sound occurs when the rotor blades encounter atmospheric turbulence as they pass through the air. Uneven pressure on a rotor blade causes variations in the local angle of attack, which affects the lift and drag forces, causing aerodynamic loading fluctuations. This generates sound that varies across a wide range of frequencies but is most significant at frequencies below 500 Hz.
- Trailing edge sound is produced as boundary-layer turbulence as the air passes into the wake, or trailing edge, of the blade. This sound is distributed across a wide frequency range but is most notable at high frequencies between 700 Hz and 2 kHz.
- Tip vortex sound occurs when tip turbulence interacts with the surface of the blade tip. While this is audible near the turbine, it tends to be a small component of the overall sound further away.
- Stall or separation sound occurs due to the interaction of turbulence with the blade surface.

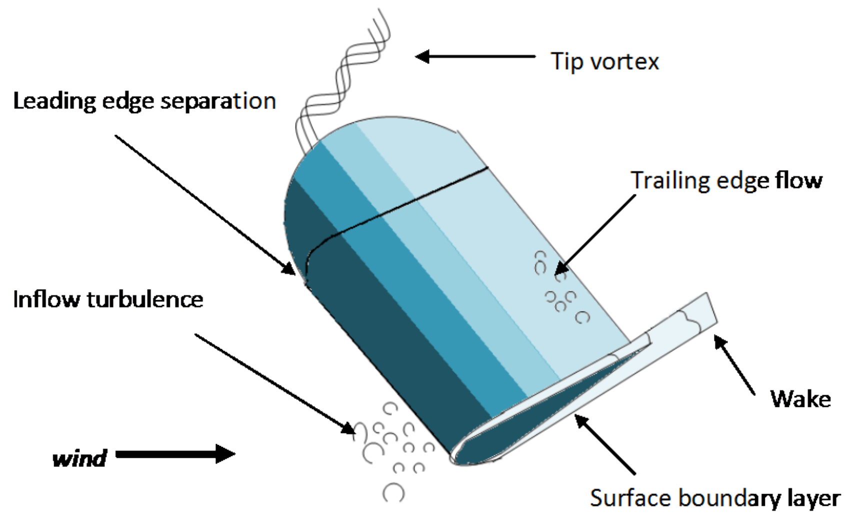

FIGURE 2: AIRFLOW AROUND A ROTOR BLADE

Mechanical sound from machinery inside the nacelle tends to be tonal in nature but can also have a broadband component. Potential sources of mechanical sound include the gearbox, generator, yaw drives, cooling fans, and auxiliary equipment. These components are housed within the nacelle, whose surfaces, if untreated, radiate the resulting sound. However modern wind turbines have nacelles that are designed to reduce the transmission of internal sound, and rarely is this a significant portion of the total wind turbine sound.

4.2 | AMPLITUDE MODULATION

Amplitude modulation (AM) is a fluctuation in sound level that occurs at the blade passage frequency. There is no consistent definition how much of a sound level fluctuation is necessary for blade swish to be considered AM. Fluctuations in individual 1/3 octave bands are typically greater. Fluctuations in individual 1/3 octave bands can sometimes synchronize and desynchronize over periods, leading to increases and decreases in magnitude of the A-weighted fluctuations. Similarly, in wind farms with multiple turbines, fluctuations can synchronize and desynchronize, leading to variations in amplitude modulation depth.[3] Most amplitude modulation is in the mid-frequencies and most overall A-weighted AM is less than 4.5 dB in depth.[4]

There are many confirmed and hypothesized causes of amplitude modulation including: blade passage in front of the tower, blade tip sound emission directivity, wind shear, inflow turbulence, and turbine blade yaw error. It has recently been noted that although wind shear can contribute to the extent of amplitude modulation, wind shear does not contribute to the existence of amplitude modulation in and of itself. Instead, there needs to be detachment of

[3] McCunney, Robert, et al. "Wind Turbines and Health: A Critical Review of the Scientific Literature." *Journal of Occupational and Environmental Medicine.* 56(11) November 2014: pp. e108-e130.
[4] RSG, et al., "Massachusetts Study on Wind Turbine Acoustics," Massachusetts Clean Energy Center and Massachusetts Department of Environmental Protection, 2016

airflow from the blades for wind shear to contribute to amplitude modulation.[5] While factors like the blade passing in front of the tower are intrinsic to wind turbine design, other factors vary with turbine design, local meteorology, topography, and turbine layout. Mountainous areas, for example, are more likely to have turbulent airflow, less likely to have high wind shear, and less likely to have turbine layouts that allow for blade passage synchronization for multiple turbines. Amplitude modulation extent varies with the relative location of a receptor to the turbine. Amplitude Modulation is usually experienced most when the receptor is between 45 and 60 degrees from the downwind or upwind position and is experienced least directly with the receptor directly upwind or downwind of the turbines.

4.3 | METEOROLOGY

Meteorological conditions can significantly affect sound propagation. The two most important conditions to consider are wind shear and temperature lapse. Wind shear is the difference in wind speeds by elevation and temperature lapse rate is the temperature gradient by elevation. In conditions with high wind shear (large wind speed gradient), sound levels upwind from the source tend to decrease and sound levels downwind tend to increase due to the refraction, or bending, of the sound (Figure 3).

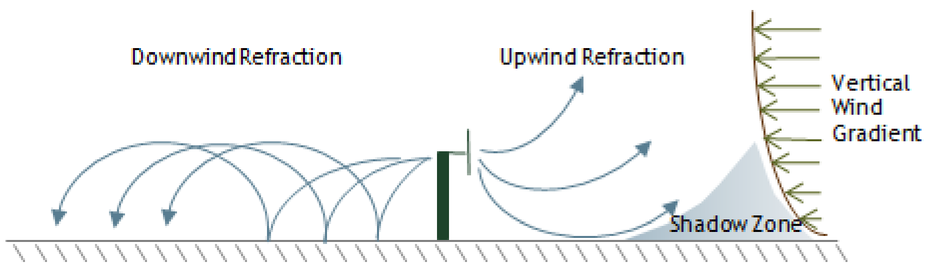

FIGURE 3: SCHEMATIC OF THE REFRACTION OF SOUND DUE TO VERTICAL WIND GRADIENT (WIND SHEAR)

With temperature lapse, when ground surface temperatures are higher than those aloft, sound will tend to refract upwards, leading to lower sound levels near the ground. The opposite is true when ground temperatures are lower than those aloft (an inversion condition).

High winds and/or high solar radiation can create turbulence which tends to break up and dissipate sound energy. Highly stable atmospheres, which tend to occur on clear nights with low ground-level wind speeds, tend to minimize atmospheric turbulence and are generally more favorable to downwind propagation.

In general terms, sound propagates along the ground best under stable conditions with a strong temperature inversion. This tends to occur during the night and is characterized by low ground level winds. As a result, worst-case conditions for wind turbines tend to occur downwind under moderate nighttime temperature inversions. Therefore, this is the default condition for modeling wind turbine sound.

[5] "Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect." *RenewableUK*. December 2013.

4.4 | MASKING

As mentioned above, sound levels from wind turbines are a function of wind speed. Background sound is also a function of wind speed, i.e., the stronger the winds, the louder the resulting background sound. This effect is amplified in areas covered by trees and other vegetation.

The sound from a wind turbine can often be masked by wind sound at downwind receptors because the frequency spectrum from wind is very similar to the frequency spectrum from a wind turbine. Figure 4 compares the shape of the sound spectrum measured during a 5 m/s wind event to that of a Acciona AW132 3.0 MW wind turbine. As shown, the shapes of the spectra are very similar at lower frequencies. At higher frequencies, the sounds from the masking wind sound are higher than the wind turbine. As a result, the masking of turbine sound occurs at higher wind speeds for some meteorological conditions. Masking will occur most, when ground wind speeds are relatively high, creating wind-caused sound such as wind blowing through the trees and interaction of wind with structures.

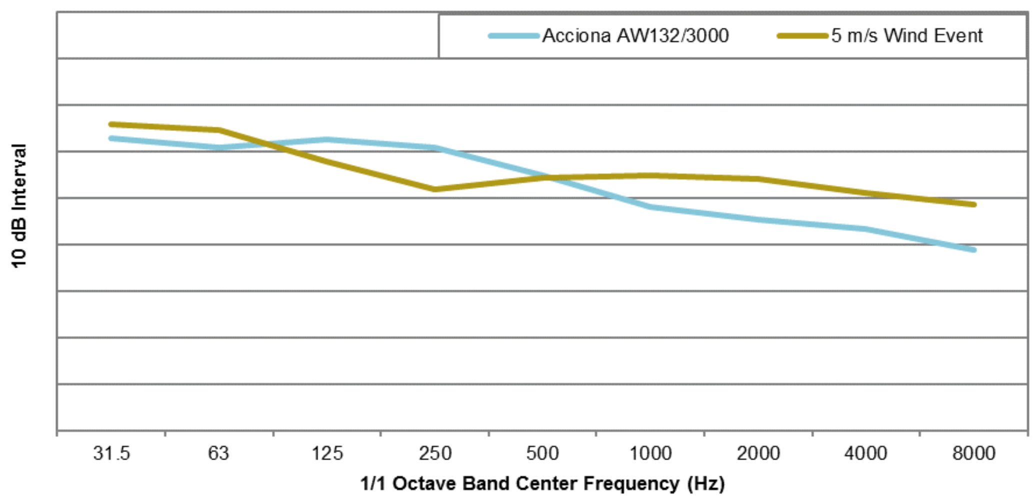

FIGURE 4: COMPARISON OF NORMALIZED FREQUENCY SPECTRA FROM THE WIND AND THE ACCIONA AW132 3 MW[6]

It is important to note that while winds may be blowing at turbine height, there may be little to no wind at ground level. This is especially true during strong wind gradients (high wind shear), which mostly occur at night. This can also occur on the leeward side of ridges where the ridge blocks the wind.

4.5 | INFRASOUND AND LOW FREQUENCY SOUND

Infrasound is sound pressure fluctuations at frequencies below about 20 Hz. Sound below this frequency is only audible at very high magnitudes. Low frequency sound is in the audible

[6] The purpose of this Figure is to show the shapes to two spectra relative to one another and not the actual sound level of the two sources of sound. The level of each source was normalized independently.

range of human hearing, that is, above 20 Hz, but below 100 to 200 Hz depending on the definition.

Low frequency aerodynamic tonal sound is typically associated with downwind rotors on horizontal axis wind turbines. In this configuration, the rotor plane is behind the tower relative to the oncoming wind. As the turbine blades rotate, each blade crosses behind the tower's aerodynamic wake and experiences brief load fluctuations. This causes short, low-frequency pulses or thumping sounds. Large modern wind turbines are "upwind", where the rotor plane is upwind of the tower. As a result, this type of low frequency sound is at a much lower magnitude with upwind turbines than downwind turbines, well below established infrasonic hearing thresholds.

Figure 5 shows the sound levels 350 meters (1,148 feet) from a wind turbine when the wind turbine was operating (T-on) and shut down (T-off) for wind speeds at hub height greater than 9 m/s. Measurements were made over approximately two weeks.[7] The red 90 dBG line is shown here as the ISO 7196:1995 perceptibility threshold. As shown, the wind turbines generated measurable infrasound, but at least 20 dB below audibility thresholds.

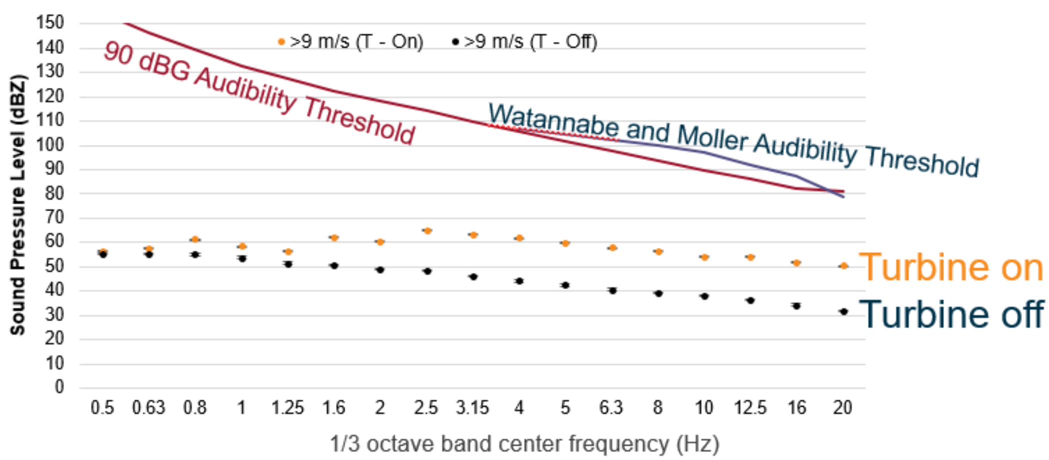

FIGURE 5: INFRASOUND FROM A WIND TURBINE AT 350 METERS (1,148 FEET) COMPARED WITH PERCEPTION THESHOLDS

Low frequency sound is primarily generated by the generator and mechanical components. Much of the mechanical sound has been reduced in modern wind turbines through improved sound insulation at the hub. Low frequency sound can also be generated by the blades at higher wind speeds when the inflow air is very turbulent. However, at these wind speeds, low frequency sound from the wind turbine blades is often masked by wind sound at the downwind receptors.

[7] RSG, et al., "Massachusetts Study on Wind Turbine Acoustics," Massachusetts Clean Energy Center and Massachusetts Department of Environmental Protection, 2016 – Graphic from RSG presentation to MassDEP WNTAG, March, 2016

Finally, low frequency sound is absorbed less by the atmosphere and ground than higher frequency sound. Our modeling takes into account frequency-specific ground attenuation and atmospheric absorption factors that takes this into account.

4.6 | USE OF SOUND LEVEL WEIGHTING NETWORKS FOR WIND TURBINE SOUND

The human ear is not equally sensitive to sound pressure levels at all frequencies and magnitudes. Some frequencies, despite being the same decibel level (that is, magnitude), seem louder than others. For example, a 500 Hz tone at 80 dB will sound louder than a 63 Hz tone at the same level. In addition, the relative loudness of these tones will change with magnitude. For example, the perceived difference in loudness between those two tones is less when both are at 110 dB than when they are at 40 dB.

To account for the difference in the perceived loudness of a sound by frequency and magnitude, acousticians apply frequency weightings to sound levels. The most common weighting scale used in environmental noise analysis is the "A-weighting", which represents the sensitivity of the human ear at lower sound pressure levels. The A-weighting is the most appropriate weighting when overall sound pressure levels are relatively low (up to about 70 dBA). The A-weighting de-emphasizes sounds at lower and very high frequencies, since the human ear is insensitive to sound at these frequencies at low magnitude. The A-weighting is indicated by "dBA" or "dB(A)".

At higher sound pressure levels (greater than approximately 70 dBA), a different weighting must be used since human hearing sensitivity does not change as much with frequency. The "C-weighting" mimics the sensitivity of the human ear for these moderate to higher sound levels (greater than approximately 70 dBA, which is higher ground based sound levels produced by wind power projects). C-weighted sound levels are indicated by "dBC" or "dB(C)".

The "Z-weighting" does not emphasize or de-emphasize sound at any frequency. "Z" weighted sound levels are sometimes labeled as "Flat" or "Linear". The difference is that the "Z-weighting" is defined as being unweighted in a specific range, whereas "Flat" or "Linear" indicate that no weighting has been used. Z-weighting or unweighted levels are typically used when reporting sound levels at individual octave bands.

The most appropriate weighting for wind turbine sound is the A-weighting, for two reasons. The first is that sound pressure levels due to wind turbine sound are typically in the appropriate range for the A-weighting at typical receiver distances (50 dBA or less). The second is that various studies of wind turbine acoustics have shown that the potential effects of wind turbine noise on people are correlated with A-weighted sound level (i.e. Pedersen et al, 2008[8]) as well as to the perceived loudness of wind turbine sound.[9,10] Other researchers

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[8] Pedersen, Eja and Waye, Kerstin. "Perception and annoyance due to wind turbine noise - a dose-response relation." Journal of the Acoustical Society of America. 116(6). pp. 3460-3470.
[9] Yokoyama S., et al. "Perception of low frequency components in wind turbine noise." Noise Control Engr. J. 62(5) 2014

found that 51% of the energy making up a C-weighted measurement of wind turbine sound is not audible. Thus, it is more difficult to relate the level of C-weighted sound to human perception. That is, two sounds may be perceived exactly alike, but there could be significant variations in the C-weighted sound level depending on the content of inaudible sound in each.[4]

[10] Yokoyama et al. "Loudness evaluation of general environmental noise containing low frequency components." Proceedings of InterNoise2013, 2013

5.0 SOUND LEVEL MONITORING PROCEDURES

Background sound level monitoring was conducted throughout the area to quantify the existing sound levels throughout the area, including the nighttime L50, and to identify existing sources of sound.

Seven locations were monitored to determine existing background sound levels, including two offsite locations (Offsite A and Offsite B), three at locations within the project area predicted to experience relatively higher levels of wind turbine sound (North, Mid, and South), a location in the Town of Hendricks (Hendricks Town), and one along the shore of Lake Hendricks (Hendricks Lake). A map of the monitor locations within the project area is shown in Figure 6.

Monitoring locations were selected per the guidance provided in the Department of Commerce, Energy Facility Permitting document, "Guidance for Large Wind Energy Conversion System Noise Study Protocol and Report", October 2012 (LWECS Guidance). The guidance recommends a minimum of three locations with in the project area, and five were used for this project. The guidance also recommends that one monitoring location be in proximity to the worst-case modeled receptor, and for this project, three monitors were installed covering the worst-case modeled areas to the north, middle, and south. Of these locations, the Mid Monitor location is modeled to be exposed to the highest sound levels.

The Hendricks Lake Monitor was positioned to capture the soundscape of the Lake Hendricks recreational area, approximately 1,000 meters (0.6 miles) just to the north of the project area and 1,300 meters (0.8 miles) north of the nearest potential turbine location. Similarly, the Hendricks Town Monitor was positioned to capture the soundscape of the town of Hendricks. The closest project boundary was approximately 680 meters (0.4 miles) to the northeast and the closest potential turbine location was approximately 880 meters (0.5 miles) to the northeast.

Two offsite monitors were located to capture background sound levels just beyond the project area. These monitors are expected to have little to no contributions of sound from the wind turbine when the project is built. The Offsite A monitor was located north of the project area while still being located within Lincoln County. The monitor was located 2,400 meters (1.5 miles) northwest of the project boundary and 4,000 meters (2.5 miles) northwest of the nearest potential turbine location. The Offsite B monitor was located south of the project area, while being removed from Lake Shaokatan to the south, U.S. Route 75 located to the east, and wind farms located to the southwest. The closest potential turbine location is located approximately 4,800 meters (3 miles) to the northwest.

Further information on the monitoring locations as well as a review of monitoring equipment and procedures is found in the following sections.

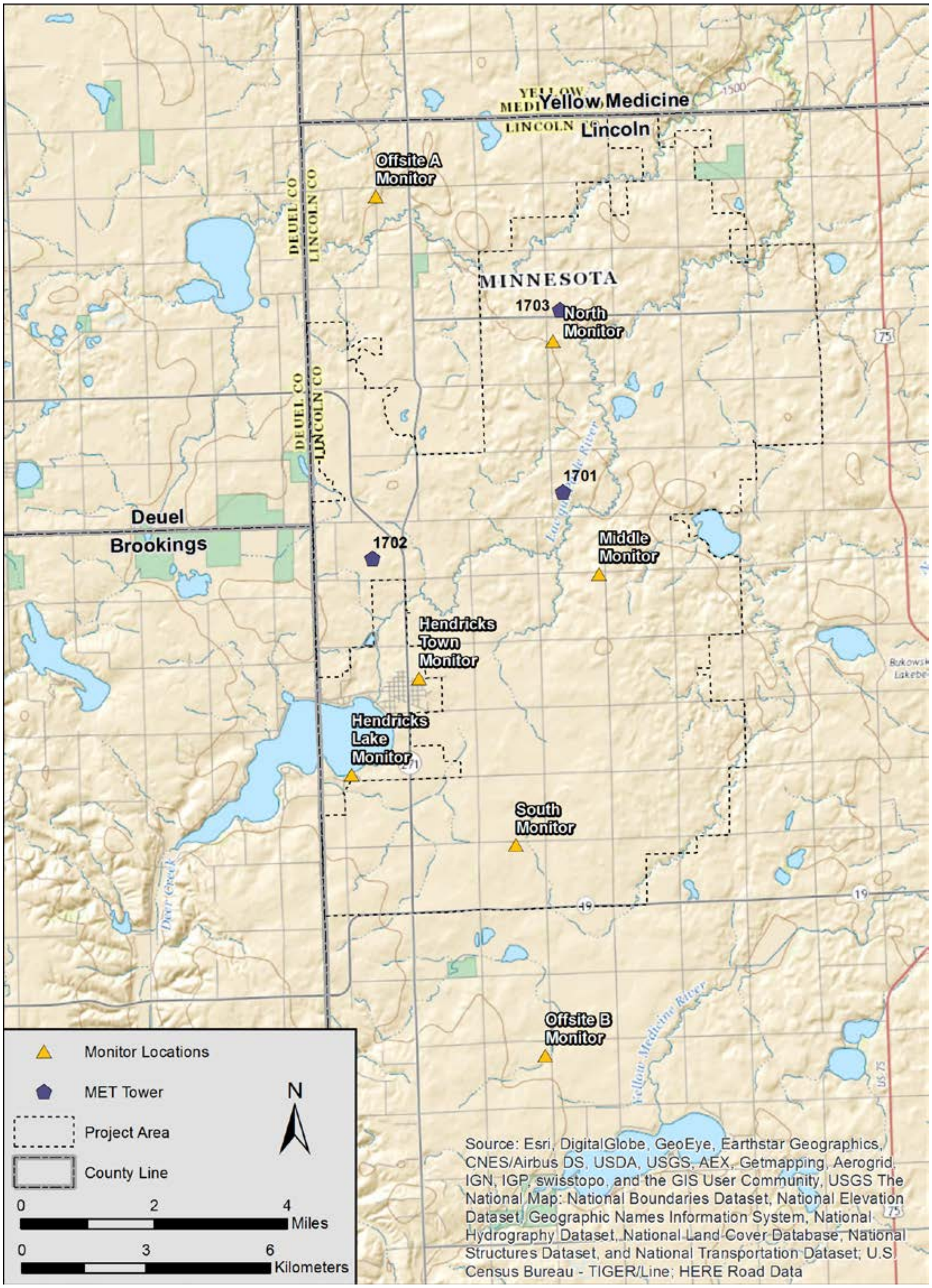

FIGURE 6: MONITORING LOCATION MAP

5.1 | EQUIPMENT

Background sound level monitoring was performed with ANSI/IEC Type 1 Cesva SC310 and Svantek SV979 sound level meters with a minimum frequency range of 20 Hz to 10 kHz. Meters were set to log, at a minimum, 1/3 octave band sound levels once each second for the entire measurement period. Sound level meter microphones were mounted on wooden stakes at a height of approximately 1.5 meters (5 feet) and covered with 180 mm (7 inch) windscreens to minimize the impact of wind distortion on measurements. Cesva SC 310 meters were connected to Edirol R-09HR or R-05 audio recorders, recording audio data at a minimum resolution of 96 kbps in the .mp3 format. Svantek SV979 sound level meters record audio internally. During this period resolution was set to 12 kHz at a 16 bit depth. Before and after the measurement periods, the meters were calibrated with either a Cesva CB-5 or Brüel and Kjær 4231 calibrator. The monitoring equipment meets LWECS Guidance.

A list of the equipment used at each monitor is shown in Table 2. At each site, an ONSET anemometer was located at microphone height and at a distance of at least 15 feet from the sound level meter. At the Offsite A, Offsite B, and Mid monitor locations, a wind direction sensor was also included in the setup. Wind data was logged at a rate of once each minute. Precipitation and temperature data were obtained from the KCNB National Weather Service weather station located at the airport in Canby, MN. Additionally, wind speeds were measured by three project met-towers at heights of 32, 47, and 60 meters (105, 154, 197 feet). Hub height wind speeds were determined from the project meteorological towers.

TABLE 2: SOUND MONITOR SPECIFICATIONS BY SITE

Monitor Location	Sound Level Meter[11]	1/3 Octave Band Frequency Range	Audio Recorder	Weather Station
North	Cesva SC310	20 Hz - 10 kHz	Edirol R-09HR	ONSET HOBO Wind Speed Sensor
Mid	Svantek SV979	3.15 Hz - 20 kHz	Internal	ONSET HOBO Wind Speed and Direction Sensors
South	Cesva SC310	10 Hz - 20 kHz	Edirol R-05	ONSET HOBO Wind Speed Sensor
Hendricks Town	Cesva SC310	10 Hz - 20 kHz	Edirol R-05	ONSET HOBO Wind Speed Sensor
Hendricks Lake	Cesva SC310	20 Hz - 10 kHz	Edirol R-05	ONSET HOBO Wind Speed Sensor
Offsite A	Svantek SV979	3.15 Hz - 20 kHz	Internal	ONSET HOBO Wind Speed and Direction Sensors
Offsite B	Svantek SV979	3.15 Hz - 20 kHz	Internal	ONSET HOBO Wind Speed and Direction Sensors

5.2 | DATA PROCESSING

After data collection, data was downloaded, processed, and summarized into 1-hour periods. For each period A-, C-, and Z-weighted equivalent average sound levels (L_{EQ}) were calculated. For A- and C-weighted sound levels, the L10, L50, and L90 statistical sound levels were also calculated.

A second set of data was also generated with periods removed from the data that either contained anomalous sound events or periods with conditions that could lead to false sound level readings.

Periods that were removed from the sound level data included:

[11] The frequency range for the Cesva SC-310 sound level meters is limited by the instrument and the range for the Svantek SV979 sound level meters is limited by the microphone.

- Wind speeds above 11 mph (5 m/s),
- Precipitation and thunderstorm events,
- Electrical interference with a nearby HAM radio signal at one site, or
- Personnel interaction with equipment.

5.3 | MONITOR LOCATION DESCRIPTIONS

NORTH MONITOR

The North Monitor was located towards the north end of the proposed project area, approximately 140 meters (460 feet) east of County Road 101 (CR-101) and 580 meters (1,900 feet) south of CSAH 19.

The monitor was on the north side of a maintained, but vacant residence with nearby farm buildings that were in use during the monitoring period. The premises were sheltered by trees on the north and west sides and by farm buildings on the east and south sides. The surrounding area is predominantly farmland, with scattered clumps of trees, a small creek to the east and a couple small ponds.

A picture of the monitoring setup is shown in Figure 7, and a map of the monitoring location is shown in Figure 8.

FIGURE 7: PHOTOGRAPH OF THE NORTH MONITOR LOOKING EASTWARD

FIGURE 8: NORTH MONITOR LOCATION AERIAL VIEW

MID MONITOR

The Mid Monitor location located approximately 35 meters (115 feet) south of 330th Street, and 150 meters (490 feet) southwest of the intersection between 330th Street and 150th Avenue.

The monitor was located on a homestead, approximately 24 meters (79 feet) east and slightly downhill of the residence, under a small clump of trees, with minimal undergrowth and surrounding grasslands.

This area is at a relatively higher elevation than most of the project and tends to be windier at the ground level. Farming takes place in the fields surrounding the homestead, but the homestead itself is not a currently active farming operation.

A picture of the monitor setup is shown in Figure 9, and a map of the monitoring location is shown in Figure 10.

FIGURE 9: PHOTOGRAPH OF THE MID MONITOR LOOKING WESTWARD

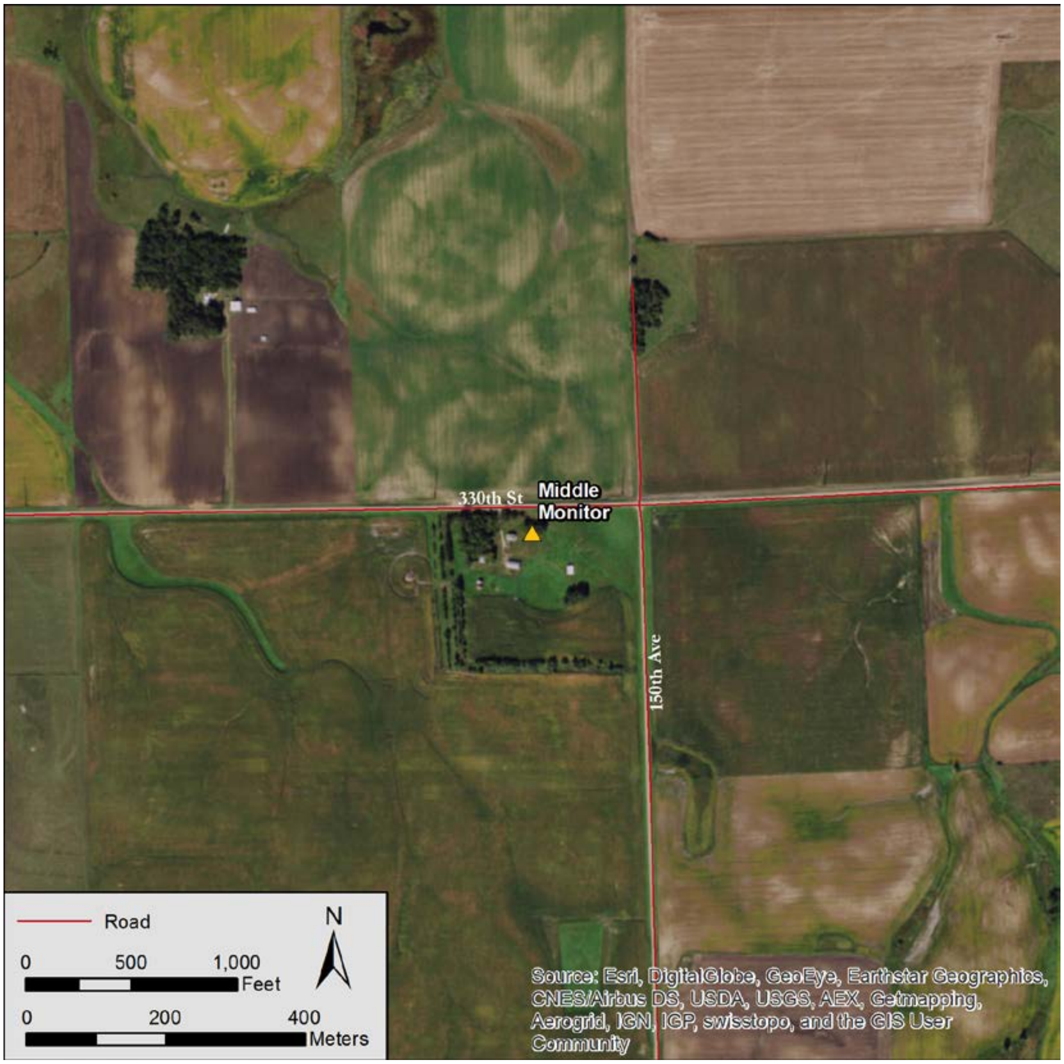

FIGURE 10: MID MONITOR LOCATION AERIAL VIEW

SOUTH MONITOR

The South Monitor was located along a row a trees that divided a homestead from the adjoining farm field to the east.

The monitor was located approximately 76 meters (250 feet) south of 290th Street, and approximately 720 meters (2,360 feet) west of County Road 101 (CR-101). A residence was located approximately 50 meters (164 feet) to the west and a larger group of trees was located approximately 65 meters (213 feet) to the west.

Farm fields surrounded the homestead and monitor location. Terrain in this part of the project is relatively flatter than to the north.

A picture of the monitoring setup is shown in Figure 11, and a map of the monitor location is shown in Figure 12.

FIGURE 11: PHOTOGRAPH OF THE SOUTH MONITOR LOOKING EASTWARD

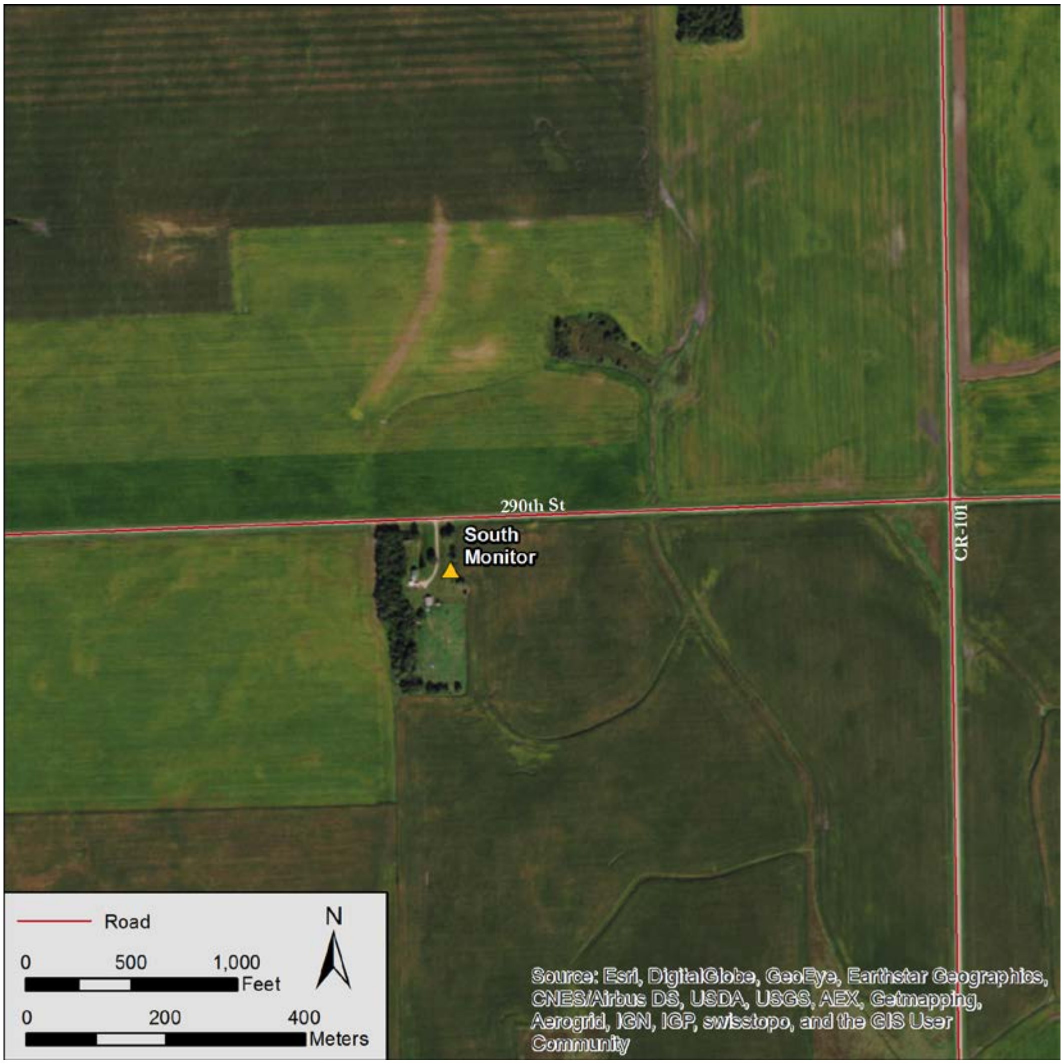

FIGURE 12: SOUTH MONITOR LOCATION AERIAL VIEW

HENDRICKS TOWN MONITOR

The Hendricks Town monitor, was located along the northeastern edge of the town of Hendricks, Minnesota. A picture of the monitoring setup is shown in Figure 13, and a map of the location is shown in Figure 14.

The monitor was located along a driveway that was adjacent to a cornfield. The cornfield was just north of the monitor, with the residences, located to the southeast and southwest. Oak Street, the closest public road was located approximately 48 meters (160 feet) to the west and East Henderson Street was located approximately 60 meters (200 feet) to the south.

Both Oak Street and East Henderson Street are quiet residential streets with low traffic volumes, typical of the town of Hendricks. The closest higher traffic volume street, North Division Street, runs through the center of Hendricks at a distance of approximately 280 meters (920 feet) to the west.

FIGURE 13: PHOTOGRAPH OF THE HENDRICKS TOWN MONITOR LOOKING WESTWARD

FIGURE 14: HENDRICKS TOWN MONITOR LOCATION AERIAL VIEW

HENDRICKS LAKE MONITOR

The Hendricks Lake Monitor was located along the southern shore of Hendricks Lake, a moderately-sized lake that straddles the border between Minnesota and South Dakota. A picture of the monitoring setup is shown in Figure 15, and a map of the monitor location is shown in Figure 16.

The monitor was located on a vacant lot, approximately 10 meters (33 feet) from the lakeshore and 95 meters (310 feet) north of CSAH 14.

This section of Hendricks Lake is primarily a recreational area, and is frequented by fishermen and boaters, particularly on the weekends. Most of the nearby residences are vacation homes. This differentiates this monitor location from all others.

FIGURE 15: PHOTOGRAPH OF THE HENDRICKS LAKE MONITOR LOOKING TO THE NORTHWEST

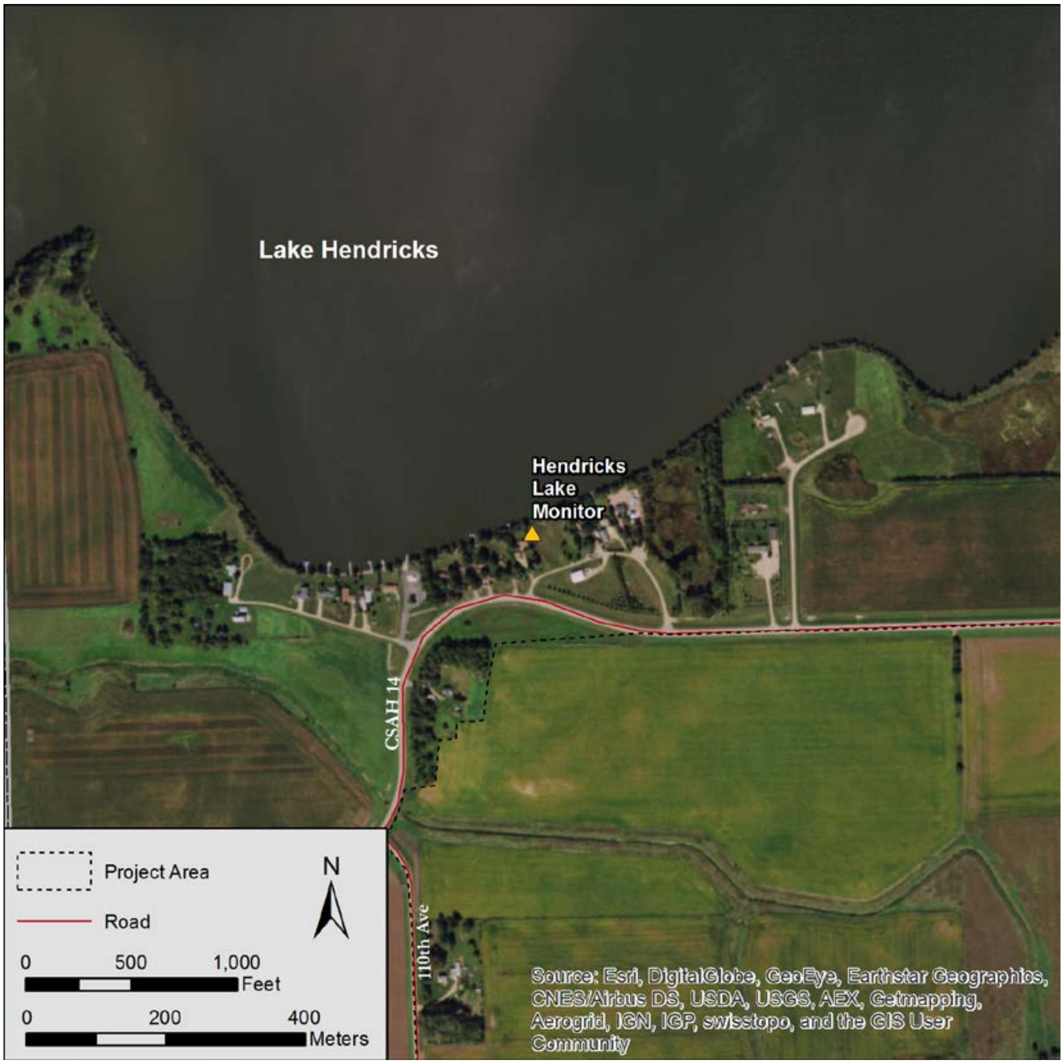

FIGURE 16: HENDRICKS LAKE MONITOR LOCATION AERIAL VIEW

OFFSITE A MONITOR

The Offsite A Monitor was located in a power line right-of-way, approximately 5 meters (16 feet) east of 115th Avenue and approximately 200 meters (660 feet) south of the intersection between County Road 139 (CR-139) and 115th Avenue.

The field to the east of the monitor was uncultivated and appeared to be wetlands. Most other land in the surrounding area was used for farming.

Terrain in this area is rolling and the monitor was located in a low lying area, surrounding by tall grass and attached to a utility pole.

The closest residence to this monitor was located approximately 270 meters (890 feet) to the west.

A map of this location is shown in Figure 18 and A picture of the monitoring setup is shown in Figure 17, and a map of this location is shown in Figure 18.

FIGURE 17: PHOTOGRAPH OF THE OFFSITE A MONITOR LOOKING NORTHWARD

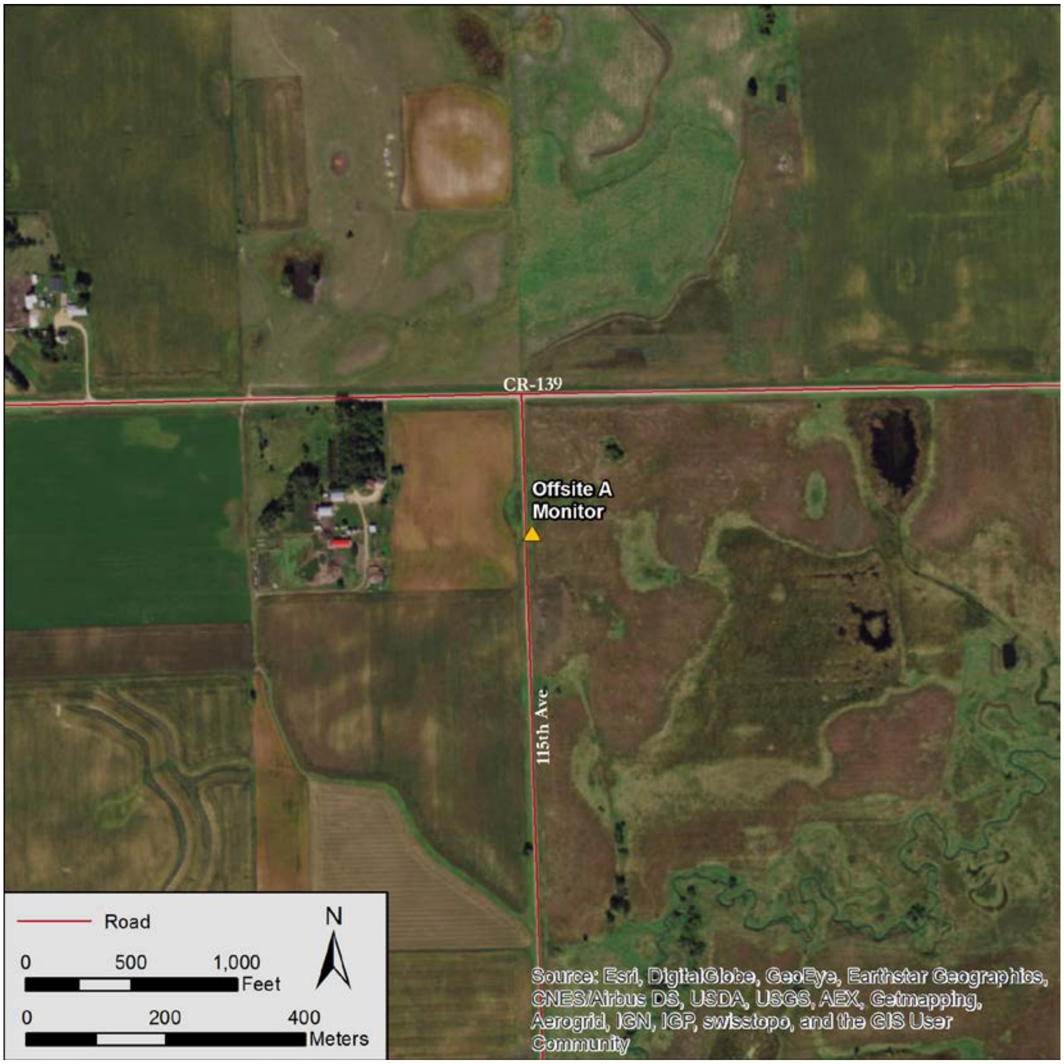

FIGURE 18: OFFSITE A MONITOR LOCATION AERIAL VIEW

OFFSITE B MONITOR

The Offsite B monitor was located south of the project area, to represent rural-residential soundscapes in this area.

The monitor was located at a homestead, approximately 145 meters (475 feet) west of CR-101 and approximately 350 meters (1,150 feet) southwest of the intersection between CR-101 and 260th Street.

The area immediately surrounding the homestead was wooded and surrounding fields were planted with corn. Terrain in this area is flat, and like the rest of the project area, is predominantly agricultural.

A picture of the monitoring setup is shown in Figure 19, and a map of the monitoring location is shown in Figure 20.

FIGURE 19: PHOTOGRAPH OF THE OFFSITE B MONITOR LOOKING NORTHWARD

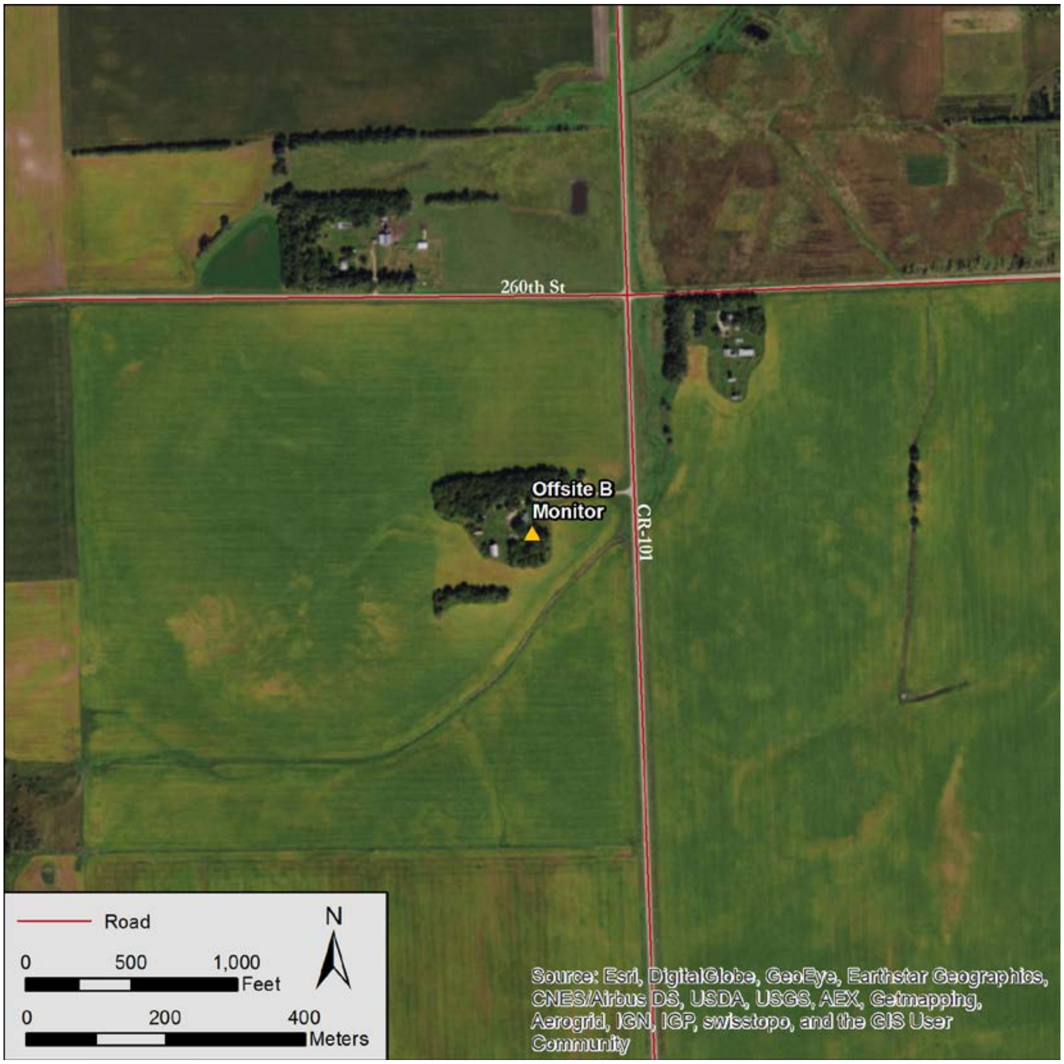

FIGURE 20: OFFSITE B MONITOR LOCATION AERIAL VIEW

6.0 SOUND LEVEL MONITORING RESULTS

For each monitor site, sound level monitoring results are presented in a single chart in this report section. Each chart contains hourly sound levels, gust wind speed measured adjacent to each microphone, "hub height" average wind speed, precipitation events, and indications of data exclusions in conformance with LWECS Guidance. Points on the sound level graph represent data summarized for a single one-hour interval. The top portion of the chart displays A-weighted sound levels, the middle portion presents C-weighted levels, and the bottom portion shows wind speeds and times when there were data exclusions. All portions of the chart exhibit day/night shading: night is defined as 20:00 to 07:00 and shaded in grey.

The specific sound level metrics reported are L_{EQ}, L_{90}, L_{50}, and L_{10}. Equivalent continuous sound levels (L_{EQ}) are the energy-average level over one hour. Tenth-percentile sound levels (L_{90}) are the statistical value above which 90% of the sound levels occurred during one hour. Fiftieth-percentile sound levels (L_{50}) represent the median sound level of that one-hour period. Ninetieth-percentile sound levels (L_{10}) are the statistical value above which 10% of the sound levels occurred during one hour. Data that were excluded from processing (e.g., due to high wind and rain periods) are included in the graphs but shown in lighter colors. Furthermore, square markers on the lower portion of the chart indicate periods for which data was excluded and designate if the period was eliminated as a result of rain, wind gusts over 11 mph, or anomalous events.

Sound level data and wind gust data presented in the charts are those measured at each corresponding site. Wind data from the monitoring location, measured at the microphone height of 1.5 meters (5 feet), are presented as the maximum gust speed occurring at any time over a 10-minute interval; they are not averaged. The average 10-minute wind speed measured at the project met-tower closest to the monitoring location is also displayed on the chart. Lastly, one-hour precipitation totals are plotted with respect to the secondary axis on the right hand side of the chart.

6.1 | RESULTS SUMMARY

EXCLUSION PERIODS

Periods were excluded at each monitor through both manual identification and automated processing. Manual processing included the review of spectrograms created from the measured one-second one-third octave band data, accompanied by audio recordings made through the sound level meter's microphone. In this way, typical sources and anomalous events were identified.

Exact rain periods were manually identified from the spectrogram to ensure that data during rain events at each monitor were excluded. Automated processing of wind speed permitted the identification of gusts above 11 mph on a one-minute basis. That is, if a gust within a specific one-minute period was measured above 11 mph, then that whole minute was eliminated.

A summary of each monitor's total runtime and the amount of time excluded from the reported sound levels for rain, wind, and anomalous events are shown in Table 3. The most time was excluded from the Mid Monitor (1.5 hours of data, or 0.57%) due to the effect of strong winds at microphone height.

TABLE 3. SUMMARY OF EXCLUSION PERIODS AT EACH MONITOR

Location	Run-Time	Exclusion Statistics							
		Rain		Wind		Anomalies		Total	
	(hr)	(hr)	(%)	(hr)	(%)	(hr)	(%)	(hr)	(%)
North Monitor	269	0.21	0.08%	0.16	0.06%	0.01	0.002%	0.37	0.14%
Mid Monitor	265	0.16	0.06%	1.30	0.49%	0.05	0.02%	1.50	0.57%
South Monitor	224	0.16	0.07%	0.04	0.02%	0.02	0.01%	0.22	0.10%
Hendricks Town	203	0.16	0.08%	0.002	0.001%	0.03	0.02%	0.20	0.10%
Hendricks Lake	269	0.18	0.07%	0.52	0.19%	0.11	0.04%	0.81	0.30%
Offsite A	261	0.22	0.08%	0.40	0.15%	0.02	0.01%	0.64	0.25%
Offsite B	285	0.13	0.05%	0.16	0.06%	0.02	0.01%	0.32	0.11%

SOUND LEVELS

The A-weighted sound levels are listed for all seven sites in Table 4 and the C-weighted sound levels are listed Table 5. The reported levels represent all valid periods, that is, all periods that were not excluded due to weather or anomalous activity, as discussed in Section 5.2. In both tables, the equivalent continuous levels (L_{EQ}) at night are less than (or equal to) daytime levels at all sites, which is typical and indicate the influence of human activity on the measured sound levels during the day. The large difference between L_{EQ} and 10th-percentile levels (L_{90}) indicate that the soundscapes are often dominated by transient or intermittent sounds (such as aircraft overflights or passing automobiles).

TABLE 4. PRECONSTRUCTION MONITORING SUMMARY (A-WEIGHTED RESULTS)

Location	Sound Level (dBA)											
	Overall				Day				Night			
	L_{EQ}	L_{90}	L_{50}	L_{10}	L_{EQ}	L_{90}	L_{50}	L_{10}	L_{EQ}	L_{90}	L_{50}	L_{10}
North Monitor	50	24	31	40	52	27	32	41	35	22	27	39
Mid Monitor	46	30	37	45	48	31	38	46	41	29	36	44
South Monitor	49	27	34	41	51	29	35	41	36	24	32	39
Hendricks Town	50	29	37	43	52	33	38	44	38	26	33	40
Hendricks Lake	50	30	38	46	52	33	40	47	40	28	34	44
Offsite A	41	25	34	42	41	25	32	39	41	25	38	44
Offsite B	51	35	40	47	53	36	41	47	42	31	37	45

TABLE 5. PRECONSTRUCTION MONITORING SUMMARY (C-WEIGHTED RESULTS)

Location	Sound Level (dBC)											
	Overall				Day				Night			
	L_{EQ}	L_{90}	L_{50}	L_{10}	L_{EQ}	L_{90}	L_{50}	L_{10}	L_{EQ}	L_{90}	L_{50}	L_{10}
North Monitor	58	31	40	48	60	35	42	50	41	29	35	46
Mid Monitor	57	38	46	58	59	41	48	60	50	34	43	52
South Monitor	57	36	44	52	59	40	45	54	47	33	41	50
Hendricks Town	59	41	48	56	61	45	50	58	49	39	44	50
Hendricks Lake	59	41	48	55	60	44	50	56	48	38	44	50
Offsite A	52	33	41	53	54	36	43	55	47	32	37	46
Offsite B	61	41	47	54	63	42	47	55	49	38	45	53

METEOROLOGY

Local meteorological data was collected from anemometers alongside the monitors, project met-towers, and the Canby Airport (station KCNB). According to the airport, local temperatures ranged from 12.5°C and 33.6°C over the duration of the monitoring period. The only registered precipitation event from KCNB was on July 23. This was a strong thunderstorm system that moved through the area. Additional short duration rain was observed at some of the monitors on July 26. Thunder, which was observed in the spectrograms, occurred on the morning of July 27th and was excluded from data processing as an anomaly.

A summary of the 1.5-meter (5-foot) wind speeds measured at each monitoring location over the deployment period at each site is provided in Table 6. The table reveals the that the Hendricks Town monitor, in particular, was relatively sheltered from direct wind speeds. The Mid Monitor was the windiest site but the Offsite B monitoring location recorded the fastest 1.5-meter (5-foot) wind gust at 24.8 mph.

TABLE 6. SUMMARY OF MEASURED 10-MINUTE 1.5-METER (5-FOOT) WIND SPEEDS

Location	Measured 1.5-meter Wind (mph)			
	10-min Wind Speed		10-min Gust Speed	
	Average	Maximum	Average	Maximum
North Monitor	0.8	8.6	3.4	16.9
Mid Monitor	3.5	12.9	7.4	22.6
South Monitor	1.7	8.6	4.4	15.2
Hendricks Town	0.3	2.6	3.2	11.3
Hendricks Lake	2.0	12.5	5.7	20.3
Offsite A	1.9	9.0	5.6	18.0
Offsite B	1.9	10.3	5.0	24.8

6.2 | MONITORING RESULTS FOR THE NORTH MONITOR

Monitoring results for the North Monitor are presented in Figure 21.

The relatively sheltered location of the monitor meant that wind-caused sound was less prevalent at this site than some other sites. Trees that contributed to this shelter were also home to biogenic sound sources, such as birds and insects. Other sound sources included vehicle passbys on CR-101 and CSAH 19, airplane overflights, farming equipment from nearby buildings and fields, and yard maintenance.

The range between maximum and minimum sound levels was generally greater for the C-weighted parameters than the A-weighted parameters, suggesting that the common sources of sound were dominated by low frequency energy.

The sound levels displayed a clear diurnal pattern, that is, sound levels rose during the day and fell at night. This observation is typical with locations that are influenced by human activity. In this case, the diurnal activity of wind was also a factor contributing to this pattern. For all but three days in the middle of the monitoring period, ground level (1.5-meter/5-foot) wind gust speeds were mild at night and picked up through the day. This trend is easily discernable with the day/night shading on the chart. The clearest exceptions to the diurnal pattern was the early morning hours of July 24 and July 26. On these mornings, measured ground level wind gusts were 5 mph and below but the average hub height wind speeds were greater than 25 mph. The apparent wind shear generated a great deal of leaf rustle.

The event that caused higher sound levels in the middle of the day on July 25th was mowing on the property where the monitor was installed. On all nights, all A-weighted metrics fell below 30 dBA. On the quietest night, July 29th, all parameters fell below 25 dBA for several hours.

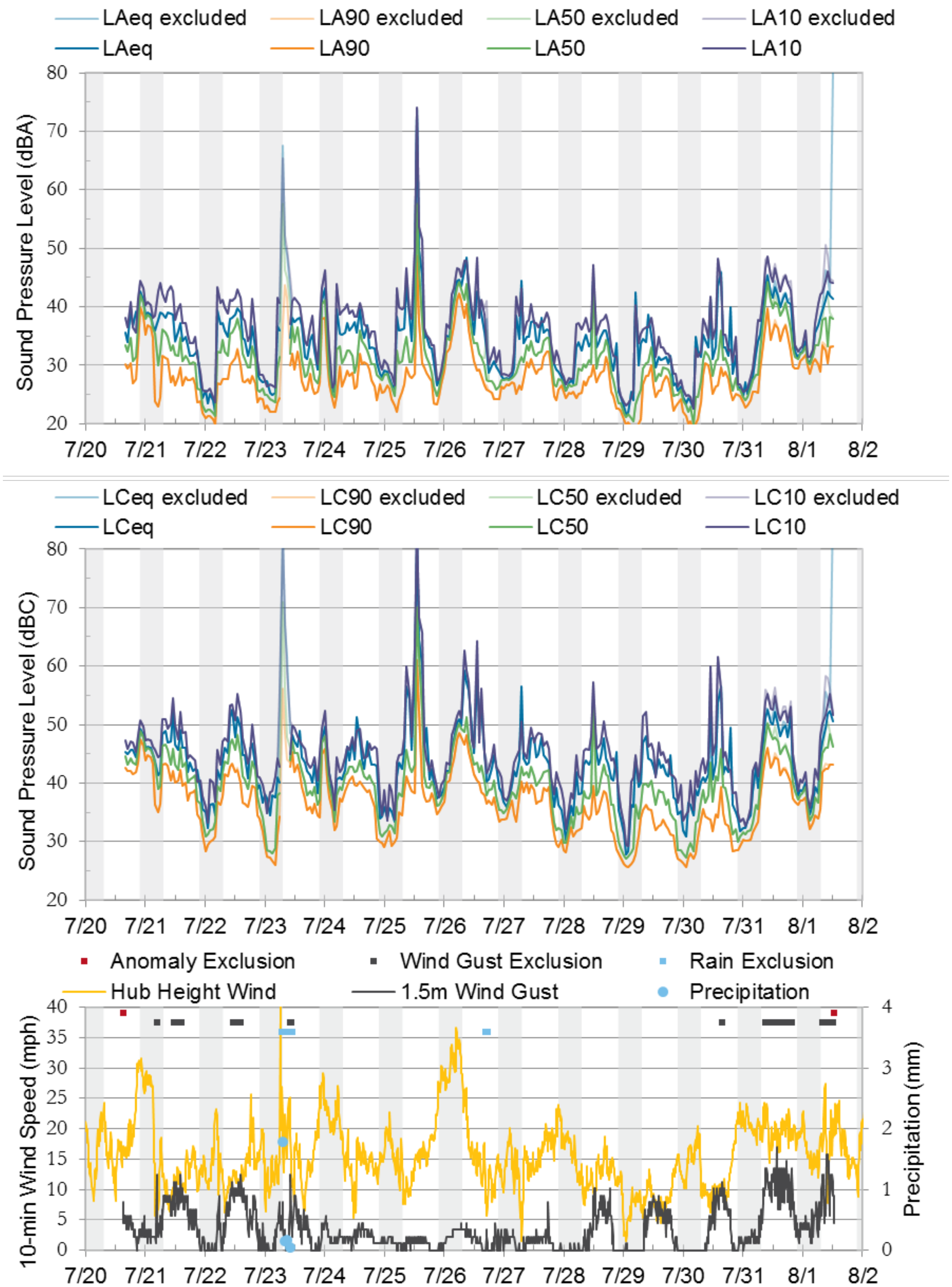

FIGURE 21. PRE-CONSTRUCTION MONITORING RESULTS AT THE NORTH MONITOR

6.3 | MONITORING RESULTS FOR THE MID MONITOR

Monitoring results for the Mid Monitor are presented in Figure 22.

The sound levels at the Mid Monitor were driven by the ground level wind speed. Due to the high elevation, lack of undergrowth, and lack of close-in farm fields, this location was more exposed to wind than others, resulting in sustained periods of wind-caused sound and wind-cause pseudosound[12]. This trend is particularly noticeable in the C-weighted portion of the chart, where strong ground level wind speeds (below 11 mph) produced a 20 dB range in the LC_{EQ}.

Biogenic sounds included insects, but few birds. Vehicle passbys were relatively high in magnitude, due to the proximity of the nearby roads. Distant farm equipment was occasionally audible. Other sound sources included airplane overflights, yard maintenance, and a window-mounted air-conditioning unit located at the nearby residence.

The louder event on July 28th was the mowing of the homestead on which the monitor was placed. The early morning hours of July 25th and July 29th were the quietest periods measured at this monitor; these were the only periods when the ground level wind gust speeds dropped to zero for several hours.

The Mid Monitor was placed in the proximity of the worst-case receptor, as identified in preliminary modeling of the project wind turbines.

Figure 23 presents the 1/3 octave band statistical sound levels for a representative wind speed at the Mid Monitor. A wind speed of 9 m/s, applied at a representative hub height of 85 meters (279 feet), was selected because it is typically the speed at which turbines begin producing maximum sound power. Only periods with this representative wind speed were used for the unweighted statistical metrics in the figure, providing a baseline for direct comparison with post-construction measurements.

[12] Wind-caused pseudosound is an measurement artifact of the wind interaction with the microphone and is not sound that would actually be experienced by a listener.

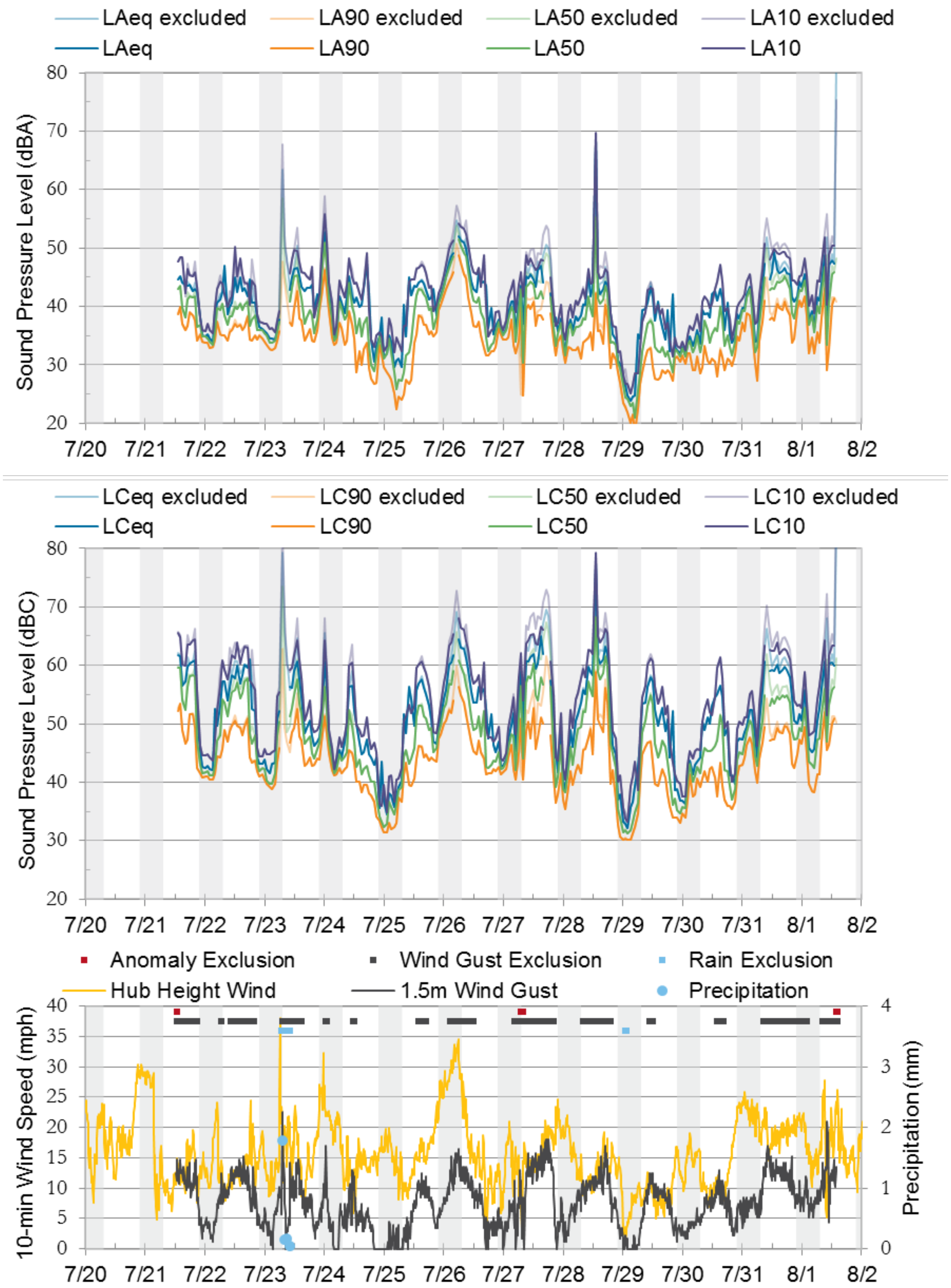

FIGURE 22. PRECONSTRUCTION MONITORING RESULTS AT THE MID MONITOR

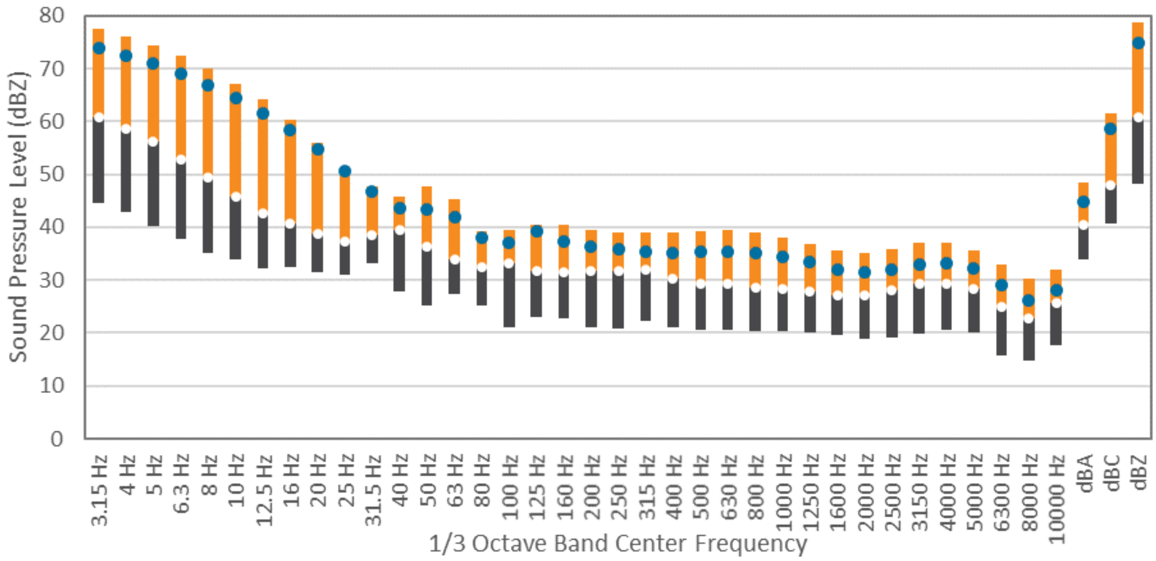

FIGURE 23: MID MONITOR - 1/3 OCTAVE BAND AND OVERALL STATISTICAL SOUND LEVELS[13] AT 9 M/S 85-METER (279-FOOT) HEIGHT WIND SPEED

6.4 | MONITORING RESULTS FOR THE SOUTH MONITOR

Monitoring results at the South Monitor are presented in Figure 24.

Although the wind's behavior generated what appears to be a diurnal pattern, distant human activity was also a contributing factor. Two Hundred Ninetieth Street, located to the north, had a relatively low traffic volume, leading to noticeable soundscape contribution from vehicle traffic during the day yet minimal impact at night. In fact, the South Monitor was one of the quieter monitoring sites at night, due to the lack of local activity during nighttime hours. Most of the sound sources at night were commercial aircraft flyovers at cruising altitude and barking dogs. Farm equipment was relatively infrequent during the monitoring period, even with farm fields surrounding the homestead. Dog barking was common due to two dogs inhabiting the site. Other sound sources that were present included birds, insects, aircraft, residents coming and going, and yard maintenance equipment.

The louder period in the middle of the day on July 25th was a result of the property, on which the monitor was placed, being mowed.

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[13] Each vertical orange and grey bar shows the Lower 10th, median, and Upper 10th percentile L_{90}, L_{50}, and L_{10}) sound level for a single 1/3 octave band. The top of the orange bar is the Upper 10th percentile sound pressure level, the white dot is the median, and the bottom of the grey bar is the lower 10th percentile sound level. The entire length of the bar indicates the middle 80th percentile of sound pressure levels. The blue dots indicate the equivalent average sound pressure level (L_{EQ}) for that 1/3 octave band. At the far right of the chart are the A-, C-, and Z-weighted overall levels. Data shown was measured during periods where the estimated 85-meter (279-foot) wind speed was at 9 meters per second, the speed where most turbine models begin producing maximum sound emissions.

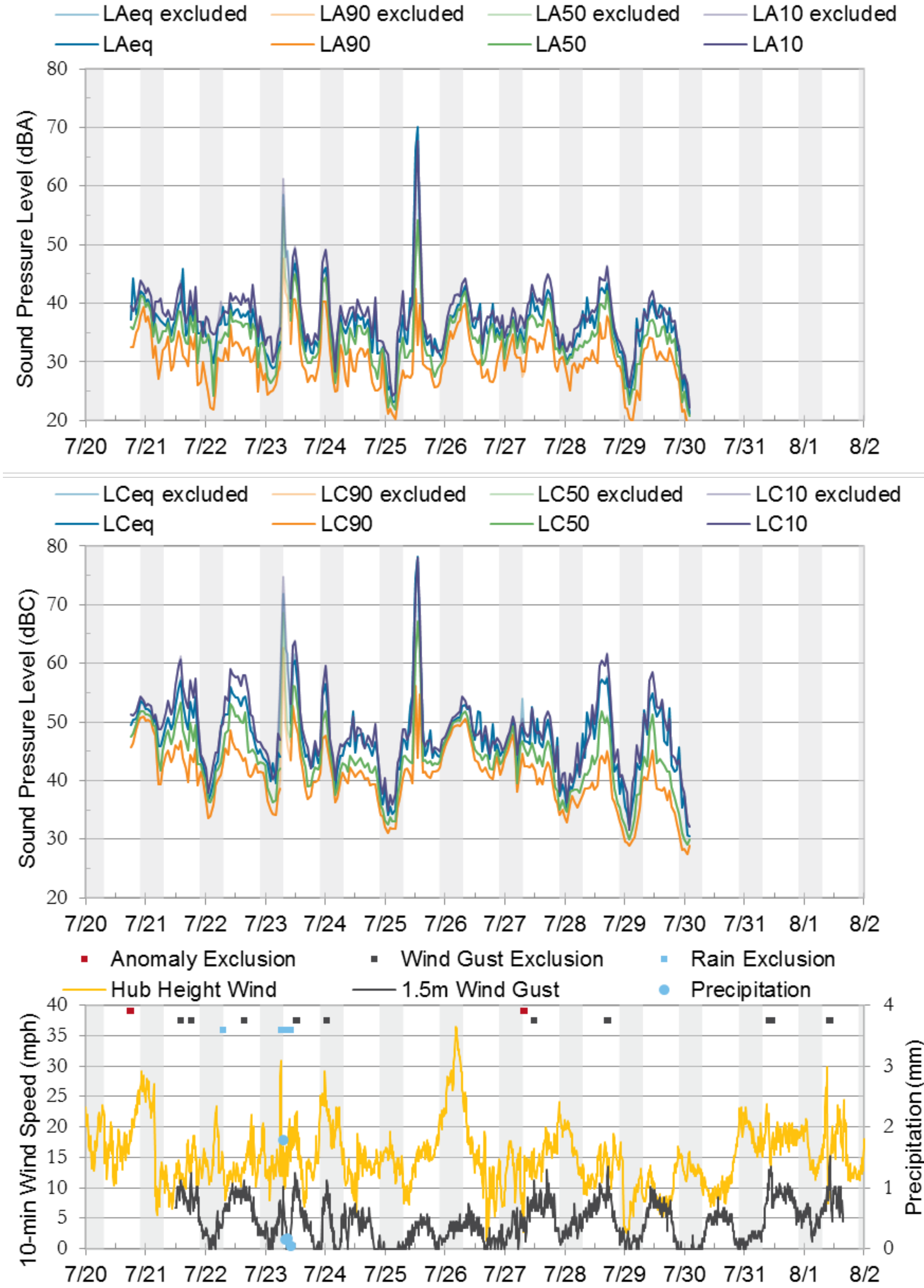

FIGURE 24. PRE-CONSTRUCTION MONITORING RESULTS FOR THE SOUTH MONITOR

6.5 | MONITORING RESULTS FOR THE HENDRICKS TOWN MONITOR

The monitoring results for the Hendricks Town Monitor are presented in Figure 25.

The site was sheltered between a mature cornfield and homes and therefore experienced very few periods of wind-generated data exclusions. The monitor revealed a soundscape typical of small rural towns; a clearly diurnal pattern emerged as a result of human activity in and around the town. Although nearby traffic noise was sparse, the proximity of the monitor to Route 271 captured much of the commuter and freight activity into and out of the town.

Biogenic sounds such as birds, insects, and the occasional dogs barking were frequently audible, as were other summer sounds typical of residential areas, such as a nearby air conditioner and other yard maintenance. Reinforcing the diurnal pattern of the sound levels were sounds representative of agricultural areas, such as crop sprayers and tractors from the farming operation directly to the north, which operated equipment during the week. Homeowner activities in the town such as lawn mowing were common during the day on the weekends. A nearby neighbor occasionally operated an All-Terrain Vehicle (ATV) or a golf cart.

Even with the activities of the town, direct ground level wind and leaf rustle were still noteworthy sources. The impact of the wind on sound levels is best observed in periods with the absence of wind: with calm winds on the two quietest evenings, A-weighted levels for all metrics remained below 30 dBA. Otherwise, the A-weighted metrics, with the exception of the L_{90}, remained above 30 dBA for most of the monitoring period.

The high levels on July 23 and July 29 were a result of the nearby mowing.

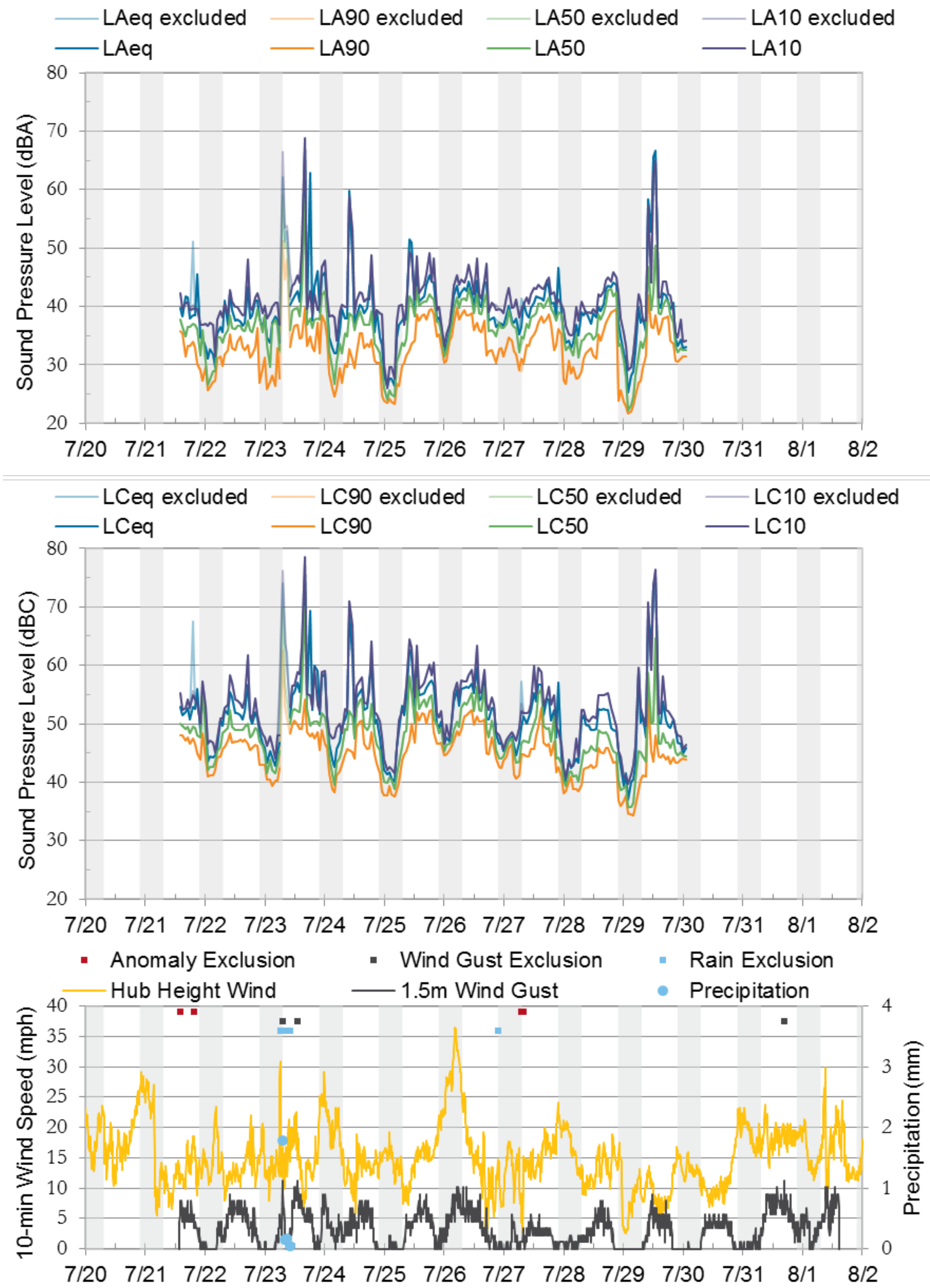

FIGURE 25. PRECONSTRUCTION MONITORING RESULTS FOR THE HENDRICKS TOWN MONITOR

6.6 | MONITORING RESULTS FOR THE HENDRICKS LAKE MONITOR

The monitoring results for the Hendricks Lake Monitor are presented in Figure 26.

The sound levels exhibited a diurnal pattern resulting from ground level wind speed fluctuations, recreational activities around the lake, and passing traffic. The soundscape at this location was different than other areas. Traffic noise from CSAH 14 is audible in the distance, and due to the curve of the road around the site, each car passby was audible for a long period of time. Farm equipment was not readily audible during the monitoring period, although there was a cultivated farm field located approximately 170 meters (560 feet) to the south. Watercraft activity on the lake was audible, as were voices from vacationers located both on and around the lake. Biogenic sound in the form of birds and insects was present.

Yard maintenance equipment was frequently audible. Mowing on the property or the adjacent property occurred on July 23, July 31, and August 1; the highest observed levels are attributed to these events. A spike in levels early in the evening on July 25th were a result of a local fireworks display.

Interference from operation of a nearby HAM radio station was observed on the morning of July 23. These periods of electrical interference were removed from the data. Just after midnight on July 25th, an animal (either a bear, pig, or dog) interfered with the microphone and this period was removed.

On most nights, besides the windy period between July 27th to 29th and August 1st, the L_{EQ}, which was mirrored closely by the L_{50}, often dropped to around 30 dBA for several hours during the night.

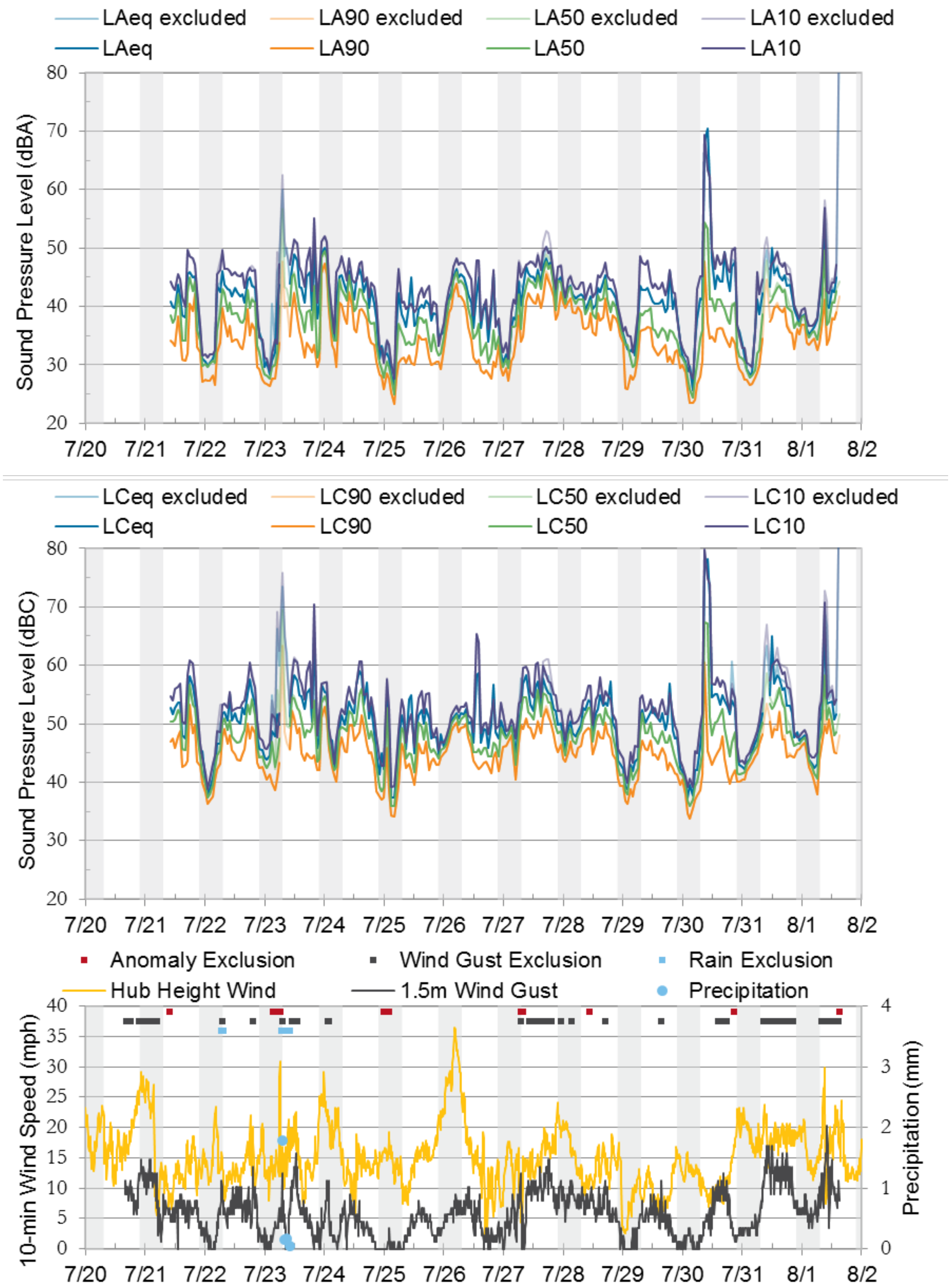

FIGURE 26. PRECONSTRUCTION MONITORING RESULTS FOR THE HENDRICKS LAKE MONITOR

6.7 | MONITORING RESULTS FOR THE OFFSITE A MONITOR

The monitoring results for the Offsite A monitor are presented in Figure 27.

Human activity was relatively distant from this monitor and mostly attributable to distant farm equipment and traffic passbys on Route 1. The typical daytime-dominated diurnal soundscape was present in the C-weighted levels, where, for the most part, sound levels were higher during the day and quieter at night. However, a strikingly different pattern emerged in the A-weighted levels. The A-weighted time history shows a consistent pattern where the first half of every night was marked with sound levels around 40 dBA; all four A-weighted sound level metrics were within a couple dB of each other, suggesting that most of the sound was the result of a consistent source. In this case, crickets that produced sound in the 10kHz 1/3-octave band and above were the source of this sound. When the crickets finished their calling in the early morning hours, sound levels dropped about 20 dBA. In the early morning hours of July 29th, after the crickets ceased, the A-weighted L_{90} reached its project low of 10 dBA. Note that the y-axes on this chart are slightly different than the other charts presented in the report as a result of this very low level.

As evidenced by the persistent crickets, the positioning of the monitor in high grass led to frequent insect and bird sound. Roads in this area, particularly 115th Avenue, were lightly traveled and car passbys were infrequent yet high in magnitude due to the proximity of the road. During the monitoring period, CR-139 was graded, which was audible during short periods. Airplane overflights were audible, particularly at night. Farm equipment in surrounding fields was occasionally audible. On an LA_{EQ} basis, this was the quietest site compared to the other monitoring locations.

Figure 28 presents overall and statistical levels for the representative hub height wind speed of 9 m/s. Spikes in the L_{EQ} in the 1/3 octave bands of 100 Hz, 4000 Hz, and 10 kHz, were due to trucks/farm equipment, birds, and the persistent nighttime crickets, respectively.

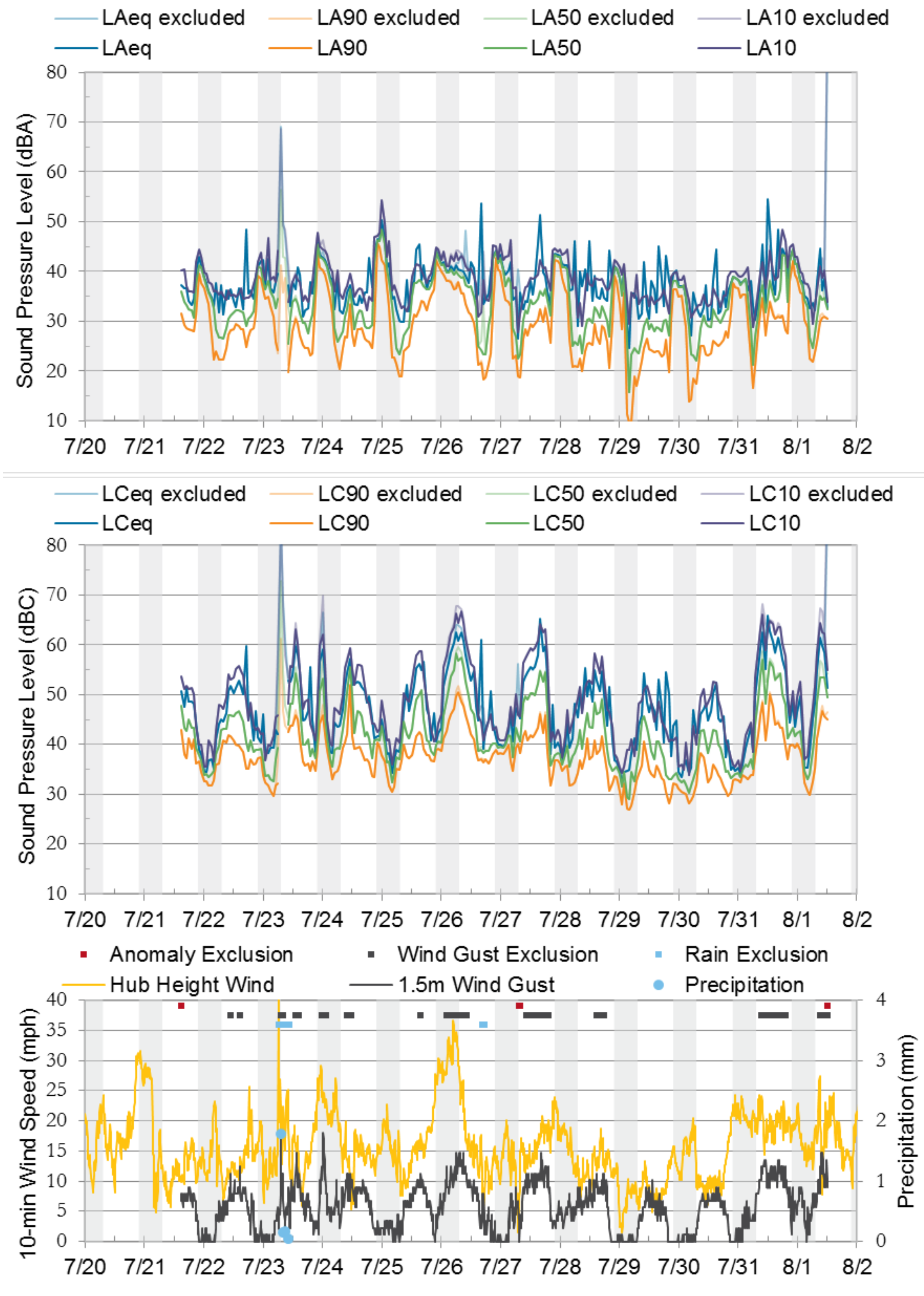

FIGURE 27. PRE-CONSTRUCTION RESULTS FOR THE OFFSITE A MONITOR

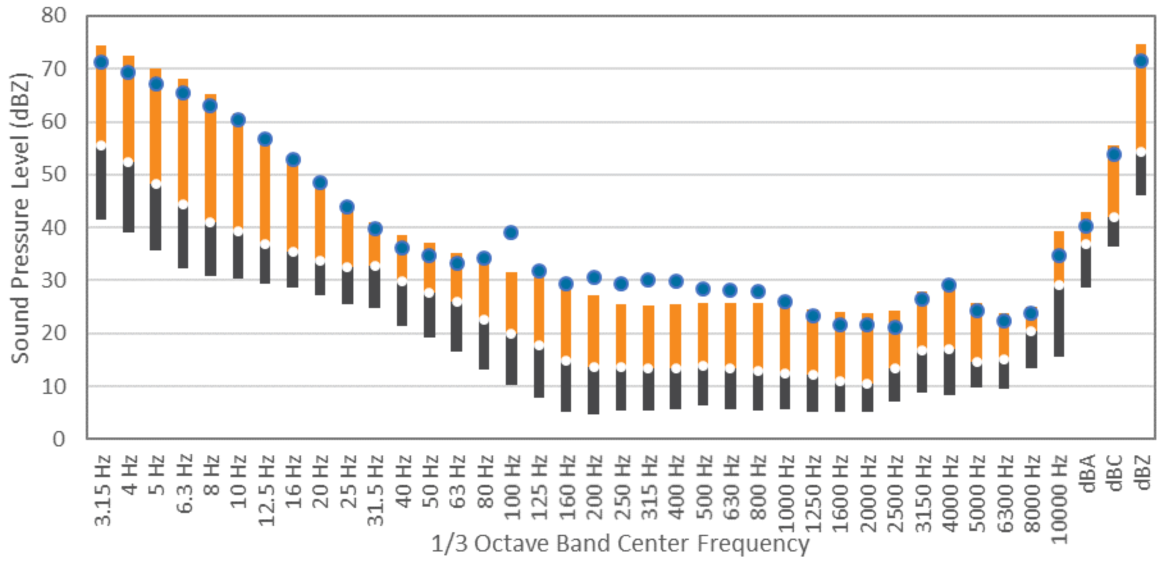

FIGURE 28: OFFSITE A - 1/3 OCTAVE BAND AND OVERALL STATISTICAL SOUND LEVELS AT 9 M/S 85-METER (279-FOOT) HEIGHT WIND SPEED

6.8 | MONITORING RESULTS FOR THE OFFSITE B MONITOR

Results for the monitoring period at the Offsite B monitor are presented in Figure 29.

The soundscape at this location was often dominated by wind-caused sound, mostly resulting from the wind's interaction with nearby trees and crops. The C-weighted L_{10} very closely followed the trend of 10-minute gust speed. Nearby vegetation also housed birds and insects that were responsible for the biogenic sound observed during monitoring. During quieter periods, a fan located at the nearby residence was audible, as was a television or radio. The early morning hours of July 29th was observed to be the quietest period at this monitor as a result of the calm winds, with all A-weighted metrics dropping below 30 dBA.

Yard maintenance activities and farm equipment were occasionally audible. Due to low overall traffic volume and distance to the roads, vehicle noise was infrequent and lower in magnitude. Airplane overflights were often masked by the fan and a railroad was occasionally audible. Lawn care of the property on which the monitor was installed took place on July 27th and July 29th.

Figure 30 displays the summary of overall and statistical levels for the representative hub height wind speed of 9 m/s. The relatively small difference between the upper 10th-precentile level and the lower 10th-percentile level means that there are few transient sounds that occurred at the monitoring location.

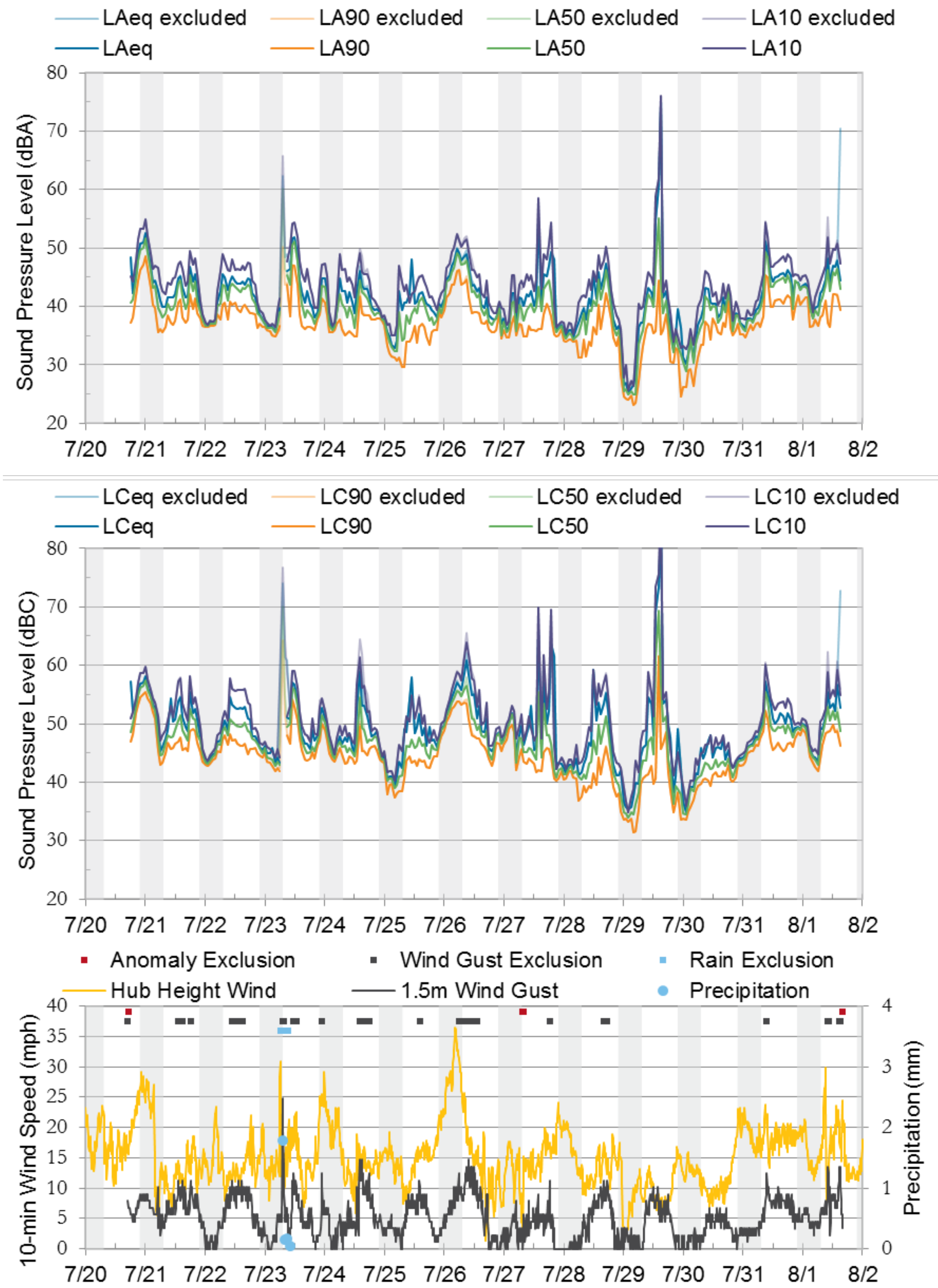

FIGURE 29. PRECONSTRUCTION RESULTS FOR THE OFFSITE B MONITOR

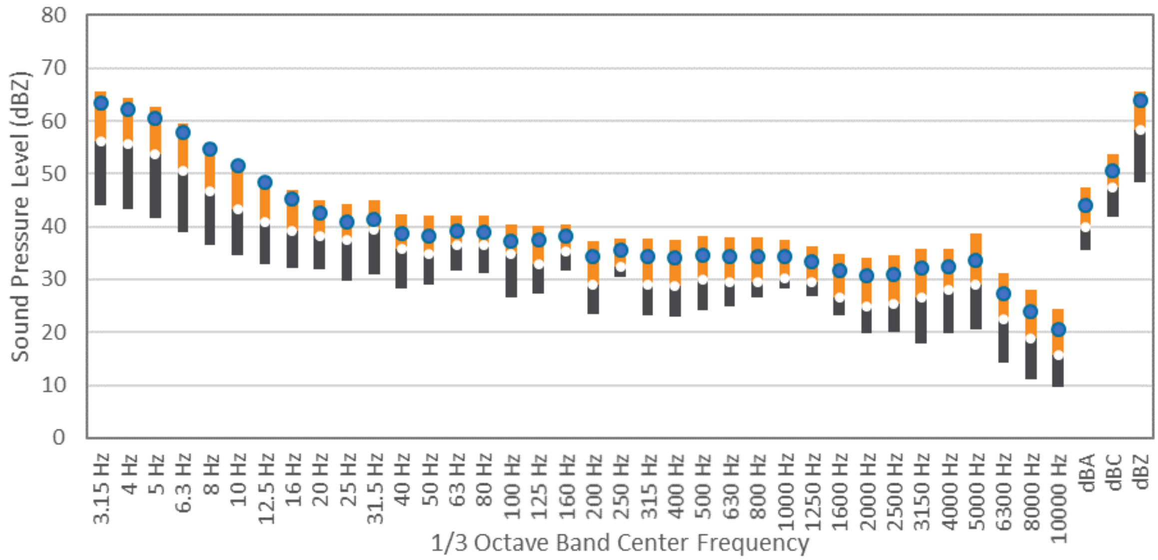

FIGURE 30: OFFSITE B - 1/3 OCTAVE BAND AND OVERALL STATISTICAL SOUND LEVELS AT 9 M/S 85-METER (279-FOOT) HEIGHT WIND SPEED

7.0 SOUND PROPAGATION MODELING PROCEDURES

Modeling for the project was in accordance with the standard ISO 9613-2, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." The ISO standard states,

> This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level … under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation … or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.

The model takes into account source sound power levels, surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain. The acoustical modeling software used here was CadnaA, from Datakustik GmbH. CadnaA is a widely accepted acoustical propagation modeling tool, used by many noise control professionals in the United States and internationally.

ISO 9613-2 also assumes downwind sound propagation between every source and every receiver, consequently, all wind directions, including the prevailing wind directions, are taken into account.

Model input parameters are listed in Appendix B including the modeled sound power spectra for each turbine model.

For this analysis, we utilized a ground absorption factor of G = 0.7, which is appropriate for comparing modeled results to the L_{50} metric used in the state standard, particularly when summing model results with the monitored L_{50} levels[14]. A 2 dB uncertainty factor was still added to the turbine sound power, except for the Acciona AW132, which specifically lists a sound power uncertainty of 1 dB.

Two distinct receiver heights are included in the analysis; different receiver heights result in different sound levels as a result of source proximity and relative exposure. Residences are modeled as discrete receivers at 4 meters (13 feet) above ground level. The 4-meter (13-foot) receiver height mimics the height of a second story window. The grid, represented in the results map figures by sound pressure level contours, is calculated at a height of 1.5 meters (5 feet), to represent one's average listening height.

[14] Generally accepted wind turbine modeling procedure calls for a ground absorption factor of G = 0.5, with a 2 dB uncertainty factor added to the manufacturer's guaranteed levels, to predict a maximum $L_{EQ(1\text{-hr})}$. In this case, the state limit utilizes an L50 metric instead of maximum $L_{EQ(1\text{-hr})}$, which means a ground factor of G=0.7 is more appropriate.

A search distance up to 8,000 meters (5 miles) allows for the contributions of distant turbines to be considered at receivers. The contribution of distant turbines will depend on the geometry and geography of the project.

Four iterations were performed using the currently proposed turbine layouts and turbine models which include the Acciona AW 132, Gamesa G126, GE 2.6-116, and the Vestas V110. The sound power spectra for each turbine is provided in Appendix B.

8.0 SOUND PROPAGATION MODELING RESULTS

8.1 | OVERALL A-WEIGHTED MODEL RESULTS

Modeling results are shown in Figure 31 for the Acciona AW 132, Figure 32 for the Gamesa G126, Figure 33 for the GE 2.3-116, and Figure 34 for the Vestas V110. Results are presented as contour lines representing 5-dB increments of calculated A-weighted sound pressure levels. Appendix C provides a list of the calculated sound pressure levels at each receiver for all four models and a map showing all receiver identification numbers for reference in the chart.

A summary of the sound propagation model results is presented in Table 7. All modeled receivers are predicted to experience sound levels below 50 dBA. The highest sound level (L50) at a non-participating residence is 47 dBA for the V110 model, and the average sound level (L50) across all non-participating residences is 37 or 38 dBA depending on the turbine model.

TABLE 7: MODEL RESULTS SUMMARY

Residence Classifiction	AW132			GE116			G126			V110		
	Avg L50 Modeled	Max L50 Modeled	Min L50 Modeled	Avg L50 Modeled	Max L50 Modeled	Min L50 Modeled	Avg L50 Modeled	Max L50 Modeled	Min L50 Modeled	Avg L50 Modeled	Max L50 Modeled	Min L50 Modeled
All	40	48	26	40	49	27	39	48	26	41	48	27
Partipating	41	48	29	42	49	28	41	48	27	43	48	30
Non-Participating	37	46	26	37	46	27	37	46	26	38	47	27

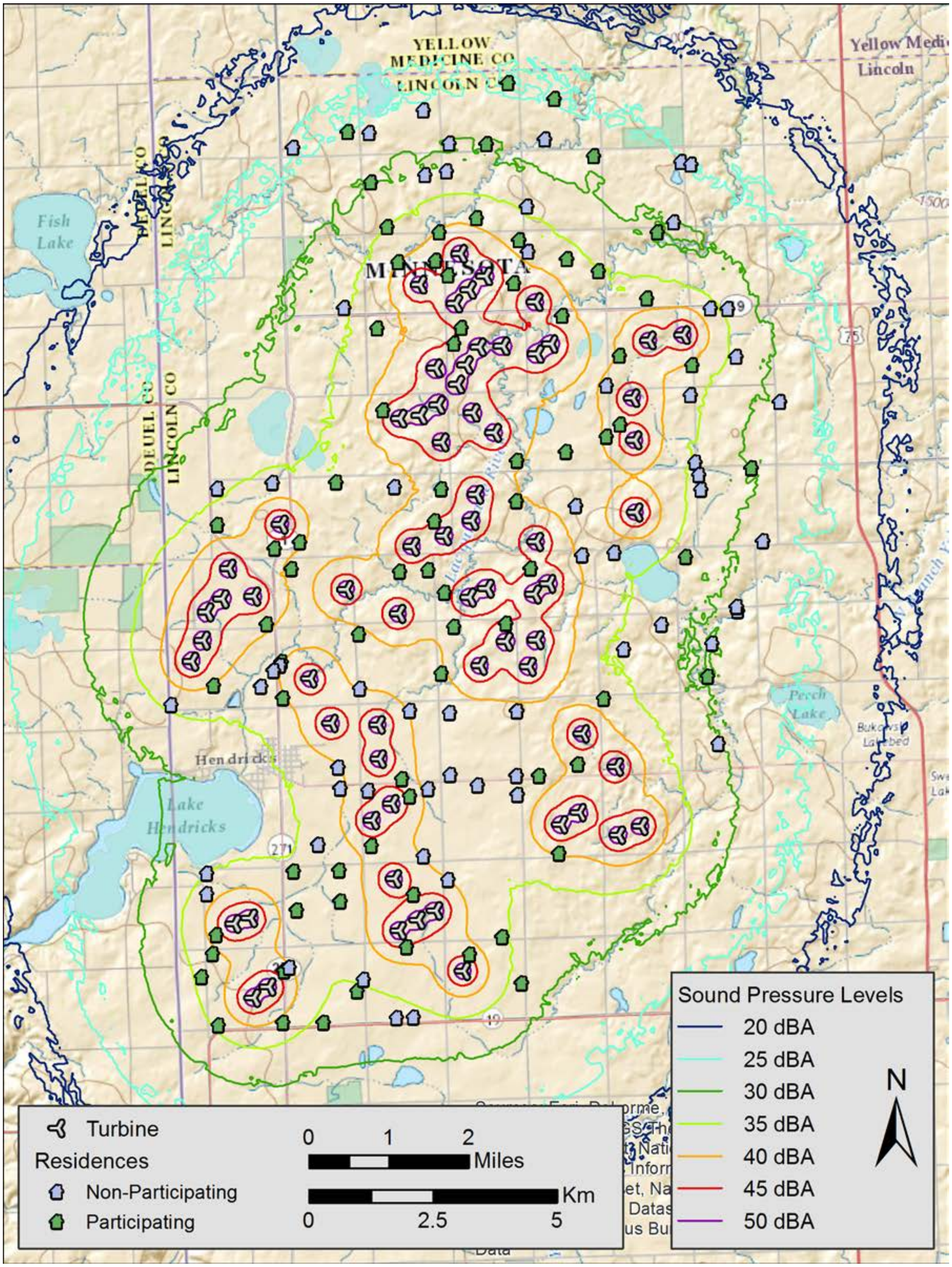

FIGURE 31: ACCIONA AW 132 3.0 MW SOUND PROPAGATION MODELING RESULTS

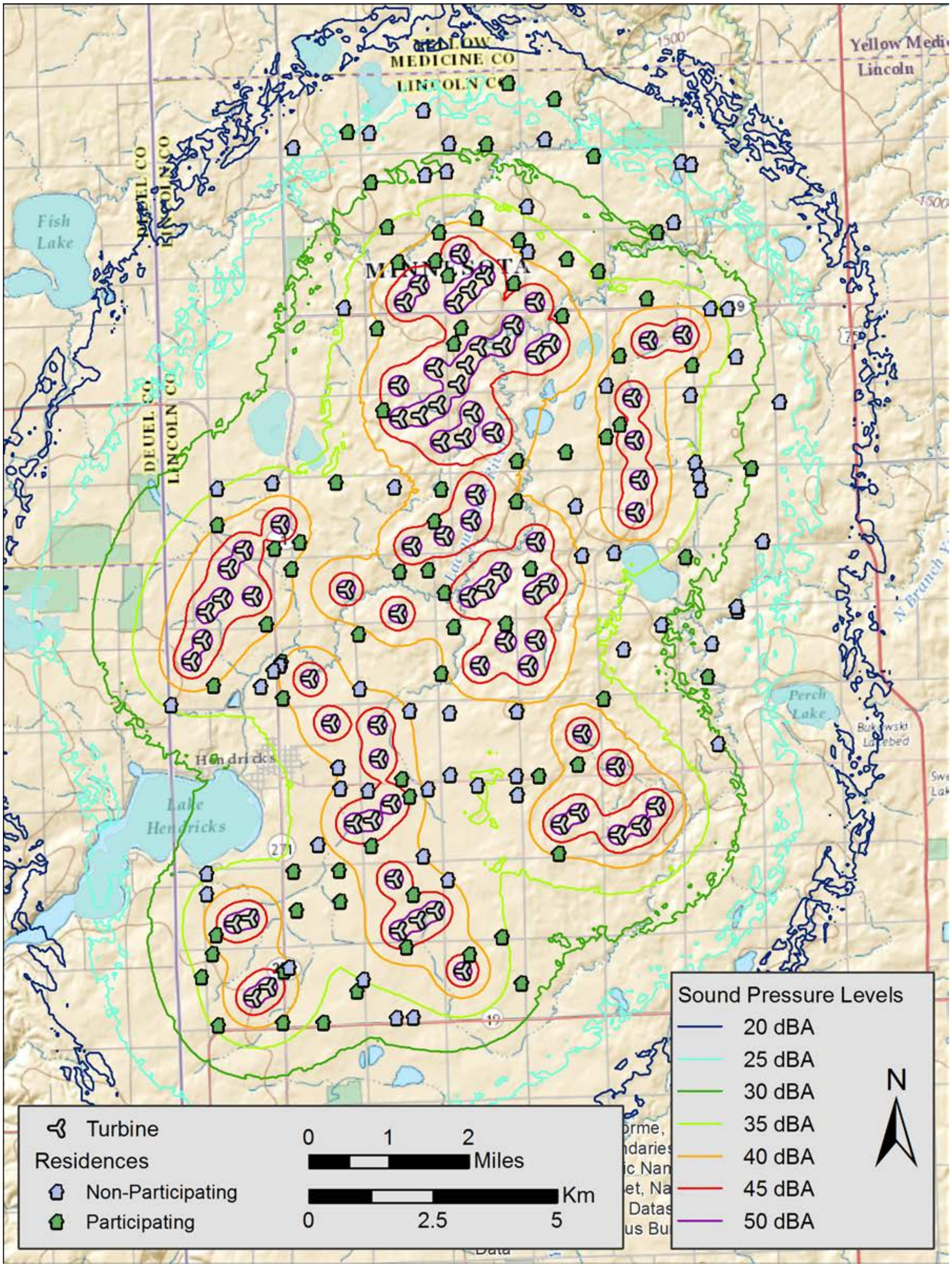

FIGURE 32: GAMESA G126 2.5 MW SOUND PROPAGATION MODELING RESULTS

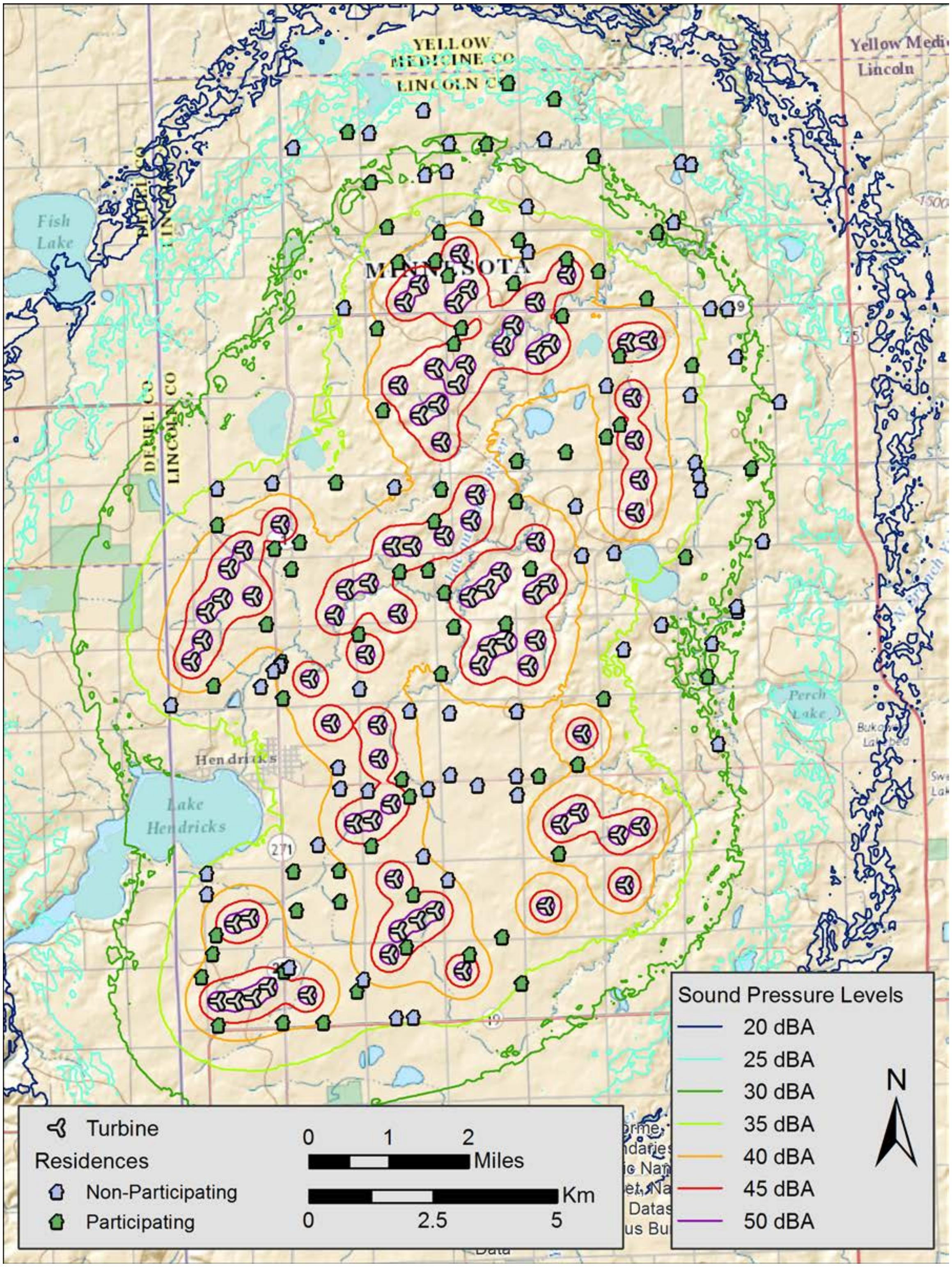

FIGURE 33: GE 2.3-116 SOUND PROPAGATION MODELING RESULTS

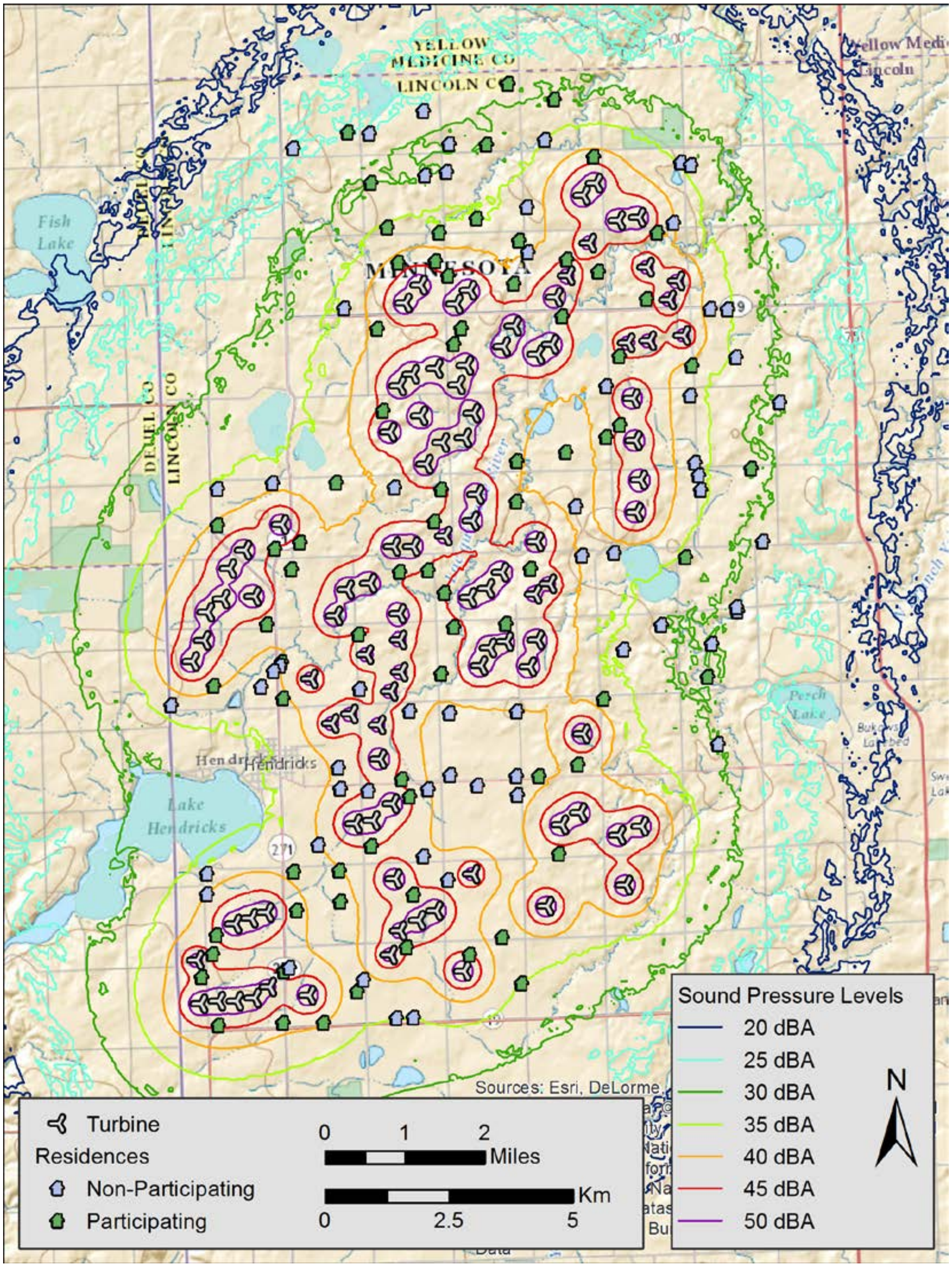

FIGURE 34: VESTAS V110 2.0 MW SOUND PROPAGATION MODELING RESULTS

8.2 | MODEL RESULTS ADDED TO BACKGROUND L50

To assess potential for compliance with state noise regulations, the model results must be summed (logarithmically) with the monitored overall nighttime L50 results to determine possible L50 levels that could occur when the project is operating. This analysis is presented in Table 8. As shown in the Table, the model results summed with the overall nighttime L50 for each monitoring location are less than 50 dBA for turbine models.

TABLE 8: MODEL RESULTS (dBA) SUMMED WITH MONITORED BACKROUND SOUND LEVELS (L50, dBA)

Scenario	Metric	Monitor Location				
		Hendricks Lake	Hendricks Town	Mid	North	South
Background Monitor Results	Overall Nighttime L50	34	33	36	27	32
	Maximum 1-hr Nighttime L50	50	43	51	44	45
	Minimum 1-hr Nightime L50	24	22	21	20	21
AW132	Modeled Sound Level	34	38	45	46	45
	Summed With Overall Nighttime L50	37	39	46	46	45
G126	Modeled Sound Level	34	38	46	47	45
	Summed With Overall Nighttime L50	37	39	46	47	45
GE 2.3-116	Modeled Sound Level	35	38	46	45	47
	Summed With Overall Nighttime L50	37	40	47	45	47
V110	Modeled Sound Level	37	38	46	46	46
	Summed With Overall Nighttime L50	38	39	46	46	46

The background L50 does and will vary from hour to hour, as shown in the monitor results in Section 6. Thus, in Appendix C, the model results are summed with a range of potential L50 values ranging from 35 dBA to 55 dBA in 5 dB increments. As previously discussed in Section 5, only periods with high wind (above 11 mph/5 m/s), precipitation, thunder, electrical interference, and personnel interaction with equipment were excluded from the monitored data. For post-construction compliance monitoring, LWECS Guidance, allows for elimination of sporadic noise such as vehicle passbys, dogs barking, and other non-turbine related extraneous sound. With all of those sources removed, the background L50s are may be lower than those reported here and in Section 6.

9.0 CONCLUSIONS

Blazing Star Wind Farm is a proposed wind power generation facility in Lincoln County, Minnesota. The facility will include up to 100 wind turbines for a project rating of up to 200 MW. In preparation for its Site Permit Application, RSG conducted a preliminary noise compliance assessment of the project. Conclusions of the assessment are as follows:

1. Background sound level monitoring periods with high wind (above 11 mph/5 m/s), precipitation, thunder, electrical interference, and personnel interaction with equipment were excluded from the monitored data.
2. Background sound levels vary some around the project site with the quietest areas on the north side of the project where the overall nighttime L50 was 27 dBA over the course of the entire monitoring period. At other locations the overall nighttime L50 was 32 to 38 dBA.
3. Minimum 1-hour nighttime L50s were between 20 and 25 dBA across the project area, while maximum 1-hour nighttime L50s had a greater range between 43 and 51 dBA.
4. With non-turbine extraneous sound sources such as, vehicle passbys and dogs barking, background sound levels may be lower than those reported here.
5. State noise regulations require that wind power generation facilities show compliance with a nighttime limit of 50 dBA (L50) and a daytime limit of 60 dBA (L50) at residences.
6. Sound propagation modeling was performed in accordance with ISO 9613-2 at over 130 discrete receivers that surround the project with spectral ground attenuation and a ground factor of G=0.7. These modeling parameters are meant to represent the L50 of the proposed facility.
7. Modeling was completed for four different turbine models: Acciona AW132, Gamesa G126, GE 2.3-116, and the Vestas V110.
8. For all turbine models, projected sound levels from the project are less than 50 dBA at all residences with the highest projected sound level (L50) at a non-participating residence of 47 dBA, and the average sound level (L50) across all non-participating residences is 37 or 38 dBA depending on the turbine model.
9. When added to the overall nighttime L50 from monitored locations, sound levels remain below 50 dBA, but the background L50 does and will vary from hour to hour, as shown in the monitor results.