BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE APPLICATION OF
CROWNED RIDGE, LLC FOR A FACILITIES PERMIT TO
CONSTRUCTION 300 MEGAWATT WIND FACILITY

Docket No. EL19-

DIRECT TESTIMONY

OF JAY HALEY

January 28, 2019

INTRODUCTION AND QUALIFICATIONS

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Jay Haley. My business address is 3100 DeMers Ave., Grand Forks, ND, 58201.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am a Partner in EAPC Wind Energy and work as a Wind Engineer.

Q. WHAT ARE YOUR RESPONSIBILITIES?

A. My responsibility was to conduct the sound and shadow flicker studies for Crowned Ridge Wind, LLC ("CRW").

Q. PLEASE DESCRIBE YOUR BACKGROUND AND QUALIFICATIONS

A. I have more than 30 years of experience in wind farm design. My experience includes financial feasibility studies, technical due diligence, wind farm design, energy assessments, visual simulations, ice throw studies, noise studies, and shadow flicker studies. I have performed more than 60 noise impact assessments and shadow flicker studies in over 15 states across the U.S. I have also worked on wind energy projects in Australia, Puerto Rico, Argentina, Chile, Uruguay and Venezuela. I am also the North and South American sales and support representative for windPRO, which is the world's leading software tool used for the design of wind farms including noise and shadow flicker studies. I have trained hundreds of engineers and environmental consultants on the proper use of windPRO with regard to wind farm design, energy assessments, visual simulations, and noise and shadow flicker studies. I have provided expert witness testimony on noise impacts, shadow flicker issues, ice throw and visual impacts in adjudicatory hearings front of local boards and in judicial proceedings.

I have a Bachelor of Science degree in Mechanical Engineering from the University of North Dakota. I am a participating member of the International Electrotechnical Commission (IEC) Technical Committee TC88, Working Group 15 as a Technical Advisor for the U.S. National Committee. The purpose of this group is to develop an International Standard for the assessment of wind resource, energy yield, and site suitability input conditions for wind power plants.

Q. HAS THIS TESTIMONY BEEN PREPARED BY YOU OR UNDER YOUR DIRECT SUPERVISION?

A. Yes.

Q. HAVE YOU PREVIOUSLY TESTIFIED BEFORE THE SOUTH DAKOTA PUBLIC UTILITIES COMMISSION?

A. No.

PURPOSE OF TESTIMONY

Q. PLEASE DESCRIBE THE PURPOSE OF YOUR TESTIMONY.

A. The purpose is to provide a description of the sound and shadow/flicker studies conducted for CRW and to set forth the results of the studies.

SOUND STUDY

Q. PLEASE DESCRIBE THE SOUND STUDY THAT WAS CONDUCTED FOR CRW.

A. Wind turbine noise can originate from a number of sources, but primarily from mechanical sound from the interaction of turbine components, and aerodynamic sound produced by the airflow over the rotor blades. In addition to the turbines, the transformer located at a wind project's substation will also emit sound.

Wind turbine sound pressure levels are measured using a sound level meter and a microphone. Sound level meters used for monitoring can pick up sounds perfectly, but the human ear is not as precise. The human ear cannot hear very low or very high frequencies. The sensitivity range of the human ear is approximately 20 to 20,000 Hz. Weighting networks are used in noise monitors in order to adjust specific frequencies in the audio spectrum to attempt to duplicate the response of the human ear.

The C-weighting network represents the actual sound pressure level that is received by the sound level meter, and does not noticeably vary in its amount of compensation throughout the audio spectrum. C-weighting is used during the calibration of sound level meters to ensure that the sound level displayed on the meter is accurate and the same as the frequency of the calibrator. The A-weighting network is then used to duplicate the sensitivity of the human ear (20-20,000 Hz).

Sounds in the environment vary with time. The two sound level metrics that are commonly reported in community noise monitoring are:

- L_{90}, which is the sound level in dBA that is exceeded 90 percent of the time during a measurement period. The L_{90} is close to the lowest sound level observed. It is essentially the same as the "residual", or ambient sound level, which is the sound level observed when there are no obvious nearby intermittent noise sources.
- L_{eq}, the equivalent level, is the level of a hypothetical steady sound that would have the same energy as the actual fluctuating sound observed. The equivalent level is designated L_{eq} and is commonly A-weighted. The equivalent level represents the time average of the fluctuating sound pressure, but because sound is represented on a logarithmic scale and the averaging is done with time-averaged mean square sound pressure values, the L_{eq} is mostly determined by occasional loud noises.

The sound levels at the base of a modern utility-scale wind turbine typically range between 55 to 60 dBA when the wind turbine is operating at full power. By comparison, a normal conversation between two people is typically 55-65 dBA when they are three feet apart. Sound levels decrease with distance. At 50 dBA it would be approximately half as loud as conversational speech, and between 30 and 40 dBA it is comparable to the ambient sound levels in a quiet rural area. A conservative prediction of sound levels associated with the Project was made using windPRO, the world's leading software tool for wind farm design, which is commonly used in the industry world-wide for sound modeling. This software incorporates the International Standard ISO 9613-2 for sound propagation (Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation).

In addition to the turbine model specifications, proposed Project layout, and the receptor locations discussed above, inputs and significant parameters employed in the model included:

- Project Layout: 284 locations were modeled (150 for Crowned Ridge and 134 for Crowned Ridge II).
- Receptor Locations: For Codington County, sound receptors were modeled as areas representing the land parcels and sound levels were calculated at the parcel boundaries. For Grant County, sound levels at receptors were modeled as discrete points at a height of 1.5 meters ("m") above ground level and 50 feet from the perimeter of the structures. Sound levels were also calculated on a 25 m x 25 m receptor grid in order to generate the sound level isolines, which are lines on a map depicting sound levels.
- Terrain Elevation: The terrain height contour elevations for the area modeled were generated from elevation information derived from the 3 m National Elevation Dataset ("NED"), developed by the U.S. Geological Survey.
- Wind Turbine Sound Levels: The expected sound power levels associated with the GE wind turbines were obtained from GE technical reports. The 1/3 octave-band sound power levels calculated for the GE 2.3-116-90 and GE 2.3-116-80 wind turbines represent the highest operational sound level emissions. In addition, all turbines were assumed to be operating simultaneously and at the design wind speed corresponding to the greatest sound level impacts, and upwind from all receptors, with an additional 2.0 dBA added to the maximum sound power level for each wind turbine.
- Ground Attenuation: Spectral ground absorption was calculated using a G-factor of 0.5, which corresponds to "mixed ground" consisting of both hard and porous ground cover. No additional attenuation due to tree shielding, air turbulence, or wind shadow effects was considered.
- Meteorological Assumptions: Meteorological conditions were selected to minimize atmospheric attenuation. The model also assumed favorable conditions for sound propagation, corresponding to a moderate, well-developed ground-based temperature inversion, as might occur on a calm, clear night.

Q. WHAT WAS THE SOUND STANDARD YOU APPLIED?

A. For Grant County, per Section 1211.04, paragraph 14 of the Grant County Zoning Ordinance 2016-01C, Grant County imposes the following requirement for wind energy facilities:

"14.) Noise. Noise level shall not exceed 45 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of existing off-site non-participating residences, businesses, buildings owned and/or maintained by a governmental entity."

"Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of participating residences, businesses, and buildings owned and/or maintained by a governmental entity."

For Codington County, per Section 5.22.03 paragraph 12 of the *Comprehensive Zoning Regulations for Codington County*, Codington County requires the following:

"Noise level shall not exceed 50 dBA, average A-weighted Sound pressure level effects at the property line of existing non-participating residences, businesses, and buildings owned and/or maintained by a governmental entity."

Q. WHAT WERE THE RESULTS OF YOUR SOUND STUDY?

A. The results of the study indicate that there were no sound pressure levels in exceedance of either of the two respective county's noise ordinances. Sound pressure levels at all non-participating occupied structures were 45 dBA or less, and 50 dBA or less at all participating occupied structures for both counties. Codington County's ordinance only requires 50 dBA or less at non-participating property lines and the highest sound pressure level was 48.8 dBA at the property line.

SHADOW/FLICKER STUDY

Q. WHAT IS SHADOW AND FLICKER AS IT RELATES TO WIND TURBINES?

A. Shadow flicker from wind turbines occurs when rotating wind turbine blades move between the sun and the observer. Shadow flicker is generally experienced in areas near wind turbines where the distance between the observer and wind turbine blade is short enough that sunlight has not been significantly diffused by the atmosphere. When the blades rotate, this shadow creates a pulsating effect, known as shadow flicker. If the blade's shadow is passing over the window of a building, it will have the effect of increasing and decreasing the light intensity in the room at a low frequency in the range of 0.5 to 1.2 Hz, hence the term "flicker." In this case, with a maximum rotational speed of 15.6 rpm for the GE 2.3-116, the frequency would be 0.78 Hz. This flickering effect can also be experienced outdoors, but the effect is typically less intense, and becomes less intense when farther from the wind turbine causing the flicker.

Q. PLEASE DESCRIBE THE SHADOW AND FLICKER STUDY THAT WAS CONDUCTED.

A. This shadow flicker analysis was performed utilizing windPRO, which is the most commonly used software world-wide for performing shadow flicker studies. It has the capability to calculate detailed shadow flicker maps across an entire area of interest or at site-specific locations using shadow receptors.

Shadow maps which indicate where the shadows will be cast and for how long, are generated using windPRO, calculating the shadow flicker in varying user-defined resolutions. Standard resolution was used for this study and represents shadow flicker being calculated every three minutes of every day over the period of an entire year over a grid with a 20 m by 20 m resolution.

In addition to generating a shadow flicker map, the amount of shadow flicker that may occur at a specific point can be calculated more precisely by placing a shadow receptor at the location of interest and essentially "recording" the shadow flicker that occurs as the relative sunrise to sunset motion of the sun is simulated throughout an entire year.

The point-specific shadow flicker calculation is run at a higher resolution as compared to the shadow flicker map calculation to utilize the highest precision available within windPRO. Shadow flicker at each shadow receptor location is calculated every minute of every day for an entire year. Shadow receptors can be configured to represent an omni-directional window of a specific size at a specific point (greenhouse mode) or a window facing a single direction of a specific size at a specific point (single direction mode). The shadow receptors used in this analysis were configured as greenhouse-mode receptors representing a 1 m x 1 m window located 1 m above ground level. This represents more of a "worst-case" scenario, and, thus, will produce more conservative results since it assumes that all windows are always in direct line of sight with the turbines and the sun.

As a part of the calculation method, windPRO must determine whether or not a turbine will be visible at the receptor locations and not blocked by local topography. It does this by performing a preliminary Zones of Visual Influence calculation, utilizing 10 m grid spacing. If a particular turbine is not visible within the 10 m x 10 m area that the shadow receptor is contained within, then that turbine is not included in the shadow flicker calculation for that receptor.

The inputs for the windPRO shadow flicker calculation include the following:

- Turbine Coordinates: The location of a wind turbine in relation to a shadow receptor is one of the most important factors in determining shadow flicker impacts. A line-of-site is required for shadow flicker to occur. The intensity of the shadow flicker is dependent upon the distance from the wind turbine and weather conditions.

- Turbine Specifications: A wind turbine's total height and rotor diameter will be included in the windPRO shadow flicker model. The taller the wind turbine, the more likely shadow flicker could have an impact on local shadow receptors as the ability to clear obstacles (such as hills or trees) is greater, although in this analysis, no credit is taken for any such blockage from trees. The larger the rotor diameter is, the wider the area where shadows will be cast. Also included with the turbine specifications are the cut-in and cut-out wind speeds within which the wind turbine is operational. If the wind speed is below the cut-in threshold or above the cut-out threshold, the turbine rotor will not be spinning and thus shadow flicker will not occur. The blade width is also taken into consideration. The wider the blade is, the farther from the wind turbine the shadow effect will persist.

- Shadow Receptor Coordinates: As with the wind turbine coordinates, the elevation, distance and orientation of a shadow receptor in relation to the wind turbines and the sun are the main factors in determining the impact of shadow flicker.

- Monthly Sunshine Probabilities: windPRO calculates sunrise and sunset times to determine the total annual hours of daylight for the modeled area. To further refine the shadow flicker calculations, the monthly probability of sunshine is included to account for cloud cover. The greater the probability of cloud cover, the less of an impact from shadow flicker. The monthly sunshine probabilities for many of the larger cities across the United States are available from the National Climatic Data Center. For this study, 18 years' worth of monthly sunshine probability data was retrieved for Huron, SD, which was the closest, most representative station, to create the long-term representative monthly sunshine probabilities.

- Joint Wind Speed and Direction Frequency Distribution: A set of long-term corrected wind distributions was provided by Crowned Ridge Wind, LLC to represent the annual wind speed and direction distribution for the project site.

This data was used to estimate the probable number of operational hours for the wind turbines from each of the 12 wind direction sectors. During operation, the wind turbine rotors will always be assumed to face into the wind and automatically orient themselves as the wind direction changes. Shadow flicker can only occur when the blades are turning and the wind turbine rotor is between the sun and the receptor. Shadow flicker is most significant when the rotor is facing the sun.

- USGS Digital Elevation Model (DEM) (height contour data): For this study, 3 m USGS NED DEMs were used to construct 10-foot interval height contour lines for the windPRO shadow flicker model. The height contour information is important to the shadow flicker calculation since it allows the model to place the wind turbines and the shadow receptors at the correct elevations. The height contour lines also allow the model to include the topography of the site when calculating the zones of visual influence surrounding the wind turbine and shadow receptor locations.

The actual calculation of potential shadow flicker at a given shadow receptor is carried out by simulating the environment near the wind turbines and the shadow receptors. The position of the sun relative to the turbine rotor disk and the resulting shadow is calculated in time steps of one minute throughout an entire year. If the shadow of the rotor disk (which in the calculation is assumed solid) at any time casts a shadow on a receptor window, then this step will be registered as one minute of shadow flicker. The calculation also requires that the sun must be at least 3.0° above the horizon in order to register shadow flicker. When the sun angle is less than 3.0°, the shadow quickly becomes too diffuse to be distinguishable since the amount of atmosphere that the light must pass through is 15 times greater than when the sun is directly overhead.

The sun's path with respect to each wind turbine location is calculated by the software to determine the paths of cast shadows for every minute of every day over a full year. The turbine runtime and direction are calculated from the site's long-term wind speed and direction distribution. The effects of cloud cover are calculated using long-term reference data (monthly sunshine probability) to arrive at the projected annual flicker time at each receptor.

Shadow flicker does not extend beyond a distance of approximately 1,700 meters from the wind turbine base, which is why all occupied structures within a conservative distance of 2 kilometer (km) from a wind turbine were included in the analysis.

Q. WHAT WAS THE SHADOW AND FLICKER STANDARD YOU APPLIED?

A. There are no federal shadow flicker regulations. There are regulations in both Codington and Grant Counties that require a limit of 30 hours of shadow flicker per year, which is the standard used in the study.

Q. WHAT WERE THE RESULTS OF YOUR SHADOW AND FLICKER STUDY?

A. Using the conservative modeling methodology which includes the use of greenhouse sensors, turbines always facing the sun, and no credit for any blockage by trees or buildings, the Project is not projected to result in shadow flicker levels above 30 hours per year at any residence, business, or building owned and/or maintained by a governmental entity.

A total of 125 existing residences within 2 km of a wind turbine were analyzed and standard resolution realistic shadow flicker maps were generated for the turbine array. The 125 shadow receptors were then modeled as greenhouse-mode receptors and the estimated shadow flicker was calculated for the array. No shadow receptors are expected to experience more than 29 hours and 50 minutes of shadow flicker per year. Therefore, CRW would be in compliance with Codington County Ordinance #68, Section 5.22.03, paragraph 13, as well as Grant County Ordinance 2016-01C, Section 1211.04, paragraph 14, both of which limit shadow flicker to 30 hours per year.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes.

STATE OF NORTH DAKOTA)
) ss
COUNTY OF GRAND FORKS)

I, Jay Haley, being duly sworn on oath, depose and state that I am the witness identified in the foregoing prepared testimony and I am familiar with its contents, and that the facts set forth are true to the best of my knowledge, information and belief.

Jay Haley
Jay Haley

Subscribed and sworn to before me this 28th day of January, 2019.

SEAL

CAROL ENGLUND
Notary Public
State of North Dakota
My Commission Expires April 11, 2023

Carol Englund
Notary Public

My Commission Expires April 11, 2023