MEMO

TO:	Ryan Pumford, NextEra Energy Resources, LLC
FROM:	Ken Kaliski, P.E., INCE Bd. Cert., RSG Richard Lampeter, Epsilon Associates
DATE:	December 22, 2016
SUBJECT:	Tuscola III modeling of L_{max} and 10-minute L_{eq}

The Almer Township ordinance does not specify a metric or averaging time for the wind turbine sound level limit. In our modeling submitted as part of Tuscola Wind III's permit application, we assumed a one-hour equivalent average sound level (L_{eq}), as this represents a relatively short-duration exposure, and can be predicted with a high degree of confidence using manufacturer sound power data (which is an L_{eq}) and the ISO 9613-2 model with appropriate adjustments.

We understand that at the last Planning Commission meeting regarding Tuscola Wind III's permit application, there were discussions about using shorter averaging times, including a 10-minute L_{eq} and a maximum instantaneous sound level (L_{max}). This memo outlines our modeling of these metrics.

10-MINUTE L_{eq}

A not-to-exceed standard using a shorter averaging time will generally result in higher sound levels. For example, take the following one-hour period consisting of six 10-minute L_{eq} sound levels during which the wind turbine was clearly discernible from ambient sound in the MassCEC study[1]: 40.9, 41.1, 42.0, 42.3, 41.8, and 41.3 dBA. The equivalent one-hour average is 41.6 dBA and the highest of these 10-minute sound levels is 42.3 dBA. The difference between the highest 10-minute L_{eq} and the one-hour L_{eq} is 0.7 dB. This trend is typical for periods of minimal background contamination.

As a result, to model the maximum 10-minute L_{eq}, we will apply an additional 1.0 dB beyond the +2.0 dB adjustment that is already included in our modeled results.

L_{MAX}

As noted above, the L_{max} is the maximum instantaneous sound level. L_{max} is typically not used to measure wind turbine sound levels for the purposes of regulation for several reasons:

[1] RSG et al, "Massachusetts Study on Wind Turbine Acoustics," Massachusetts Clean Energy Center and Massachusetts Department of Environmental Protection, 2016.

- It is not representative of long-term exposure to wind turbine sound. Rather, it is a short-term statistical anomaly that occurs 0.0000001% of a year (i.e. 1 second in a year).
- One cannot subtract background from L_{max} measured levels since the L_{max} is not an equivalent average sound level, but rather the result of a damping function applied to the measured sound levels.
- The L_{max} is highly variable as a metric that results in poor repeatability among similarly conducted measurements.
- Manufacturers of wind turbines do not report L_{max} sound power for their wind turbines – only L_{eq}.
- L_{max} is the result of many complex temporal interactions that cannot be reliably modeled, include synchronization of blade passages, angle to the turbine rotor, wind direction, turbulence, wind shear, previous sound levels, and several other factors.
- The ISO 9613-2 model forecasts equivalent average sound levels, not instantaneous L_{max}.

It should be noted that, when L_{max} is considered as a sound metric in other ordinances or guidelines not specific to wind turbine sound, the limits are typically higher than an L_{eq}. For example, the World Health Organization guidelines for sleep disturbance identify a 60 dBA L_{Fmax} limit compared to a 45 dBA $L_{eq(8\text{-hours})}$. Both metrics are measured outside the bedroom window.

Based on the factors listed above, it is very difficult to quantify the additional adjustment necessary to conduct a modeling study of L_{max} for a wind energy project. This necessitates the addition of a highly conservative adjustment factor to estimate an operational L_{max}. The MassCEC study, depending on what table is viewed and other post-construction measurements, ranges L_{Fmax}[2] values from about 6 dB to 11 dB greater than the L_{eq}, although some degree of background contamination is included in those L_{max} values. For this study, to be conservative, we are using an additional 11 dB adjustment above the +2.0 dB already modeled.[3]

MODELING RESULTS

The modeling results comparing 1-hour L_{eq}, 10-minute L_{eq}, and L_{Fmax} are shown in Figure 1. For simplicity, we only show the 45 dBA contour under each metric.

As shown, the 10-minute L_{eq} 45-dBA isoline is slightly larger than the one-hour L_{eq} isoline. The use of a 10-minute L_{eq} as the metric for the sound limit would require some additional adjustments to the NRO plan to meet a 45 dBA standard at non-participating property lines.

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[2] "F" identifies the response time: Fast.

[3] The MassCEC study has data on the L_{max} measured when wind turbines were and were not operating. Although modeling adjustment factors for L_{max} are not specifically quantified in the MassCEC study, useful tabular data are presented that support the conservative estimate in this analysis. That is, while L_{max} measurement data were reported, the MassCEC study did not calibrate models to estimate L_{max} for regulatory purposes. In fact, the MassCEC study concluded that the L_{max} metrics had the lowest predictability and repeatability of the metrics evaluated. We know of no other studies that explicitly look at what adjustment to make to the ISO 9613-2 model to account for wind turbine L_{max}.

The L_{Fmax} isolines are well outside participating properties. No turbines could be constructed on participating land in the Township using this metric.

CONCLUSIONS

A specific sound level metric is not specified in Almer Township's ordinance. The ordinance says that noise emissions from a WECS "shall not exceed" 45 dBA at a non-participating property line. But "shall not exceed" is not a metric; it simply means that, whatever metric is reasonably applied, that number shall not exceed 45 dBA. Therefore, an interpretation must be made on what is the most appropriate metric to apply to evaluate this ordinance.

For the evaluation of the 45 dBA sound level limit in Almer Township, the modeling analysis included in the application submittal assumed a one-hour L_{eq} sound metric. The L_{eq}, or the equivalent continuous sound level, is the level of a hypothetical steady sound that would have the same energy (i.e., the same time-averaged mean square sound pressure) as the actual fluctuating sound observed. While it represents the time average of the fluctuating sound pressure, the L_{eq} is mostly determined by louder noises if there are fluctuating sound levels.[4] The L_{eq} is not an arithmetic average of the sound levels.

This metric (L_{eq}) is appropriate for the evaluation of the "shall not exceed 45 dBA" section of the ordinance for the following reasons:

- Per industry standard (IEC 61400-11), sound levels provided by the manufacturer for analysis are L_{eq} sound levels.
- An L_{eq} model input results in a L_{eq} model output, so an L_{eq} limit allows for an "apples to apples" comparison.
- The L_{eq} metric is found in guidelines such as the World Health Organization's guideline values for the prevention of sleep disturbance.
- The ANSI Standard on compatible land use (ANSI/ASA S12.9-2007/Part 5) uses a metric derived from a L_{eq} for identifying compatible sound levels for different land uses.
- EPA uses a L_{eq} metric in its document entitled "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," which identified levels requisite to protect the public from adverse health and welfare effects.
- Neighboring communities, such as Akron Township, Columbia Township, and Huron County (which used ABD to help it develop its recently amended ordinance), recognize the L_{eq} as the appropriate metric for evaluating sound levels.
- In the absence of a specified metric, L_{eq} has been approved in post-construction measurement programs in nearby Fairgrove and Guilford Townships.

[4] Because sound is represented on a logarithmic scale and the averaging is done with linear mean square sound pressure values, higher sound levels are weighted more than lower sound levels. For example, if the sound level for a half hour is 20 dB and the next half hour it increases to 45 dBA, the L_{eq} for that hour would be 42 dBA.

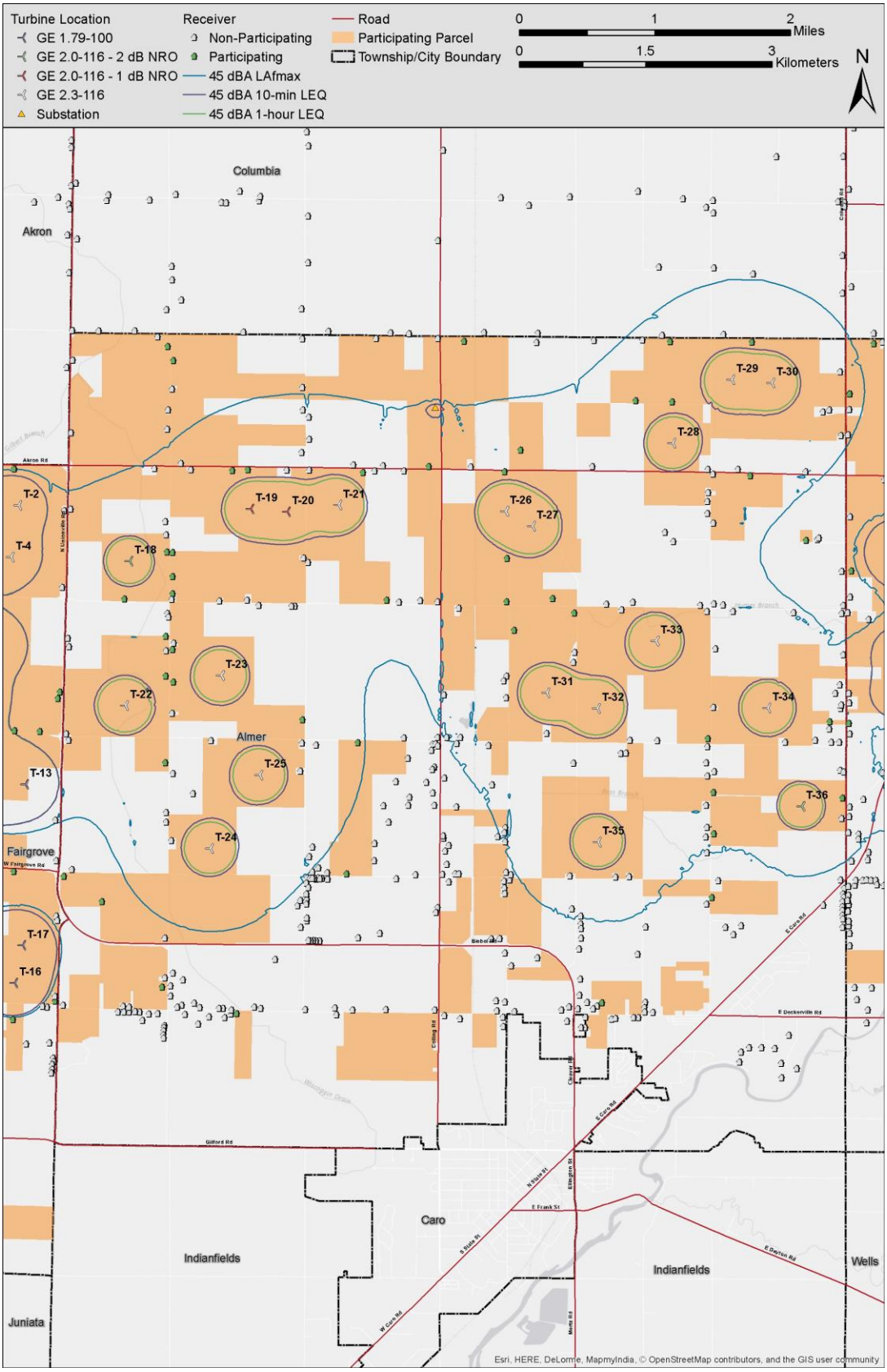

FIGURE 1: 45 dBA ISOLINES FOR MAXIMUM 1-HOUR L_{eq}, 10-MINUTE L_{eq}, AND L_{Fmax}

Evaluating a "shall not exceed" limit for a wind energy project using an L_{eq} is a common interpretation not only in Michigan as presented above but throughout the United States. For example, the South Dakota Public Utility Commission Draft Model Ordinance for Siting of Wind Energy Systems uses "…**shall not exceed** fifty-five (55) dBA, **average** A-weighted sound pressure at the perimeter of occupied residences existing at the time the permit application is filed…" [emphasis added]. Navajo County, Arizona uses "…**shall not exceed** the greater of (a) 45 dBA $\mathbf{L_{Aeq,10}}$; or, (b) the measured background, $L_{A90,10}$ plus 5 dB, as measured at the exterior at any legal residence …" [emphasis added]. The New Hampshire Site Evaluation Committee (NH SEC) imposed language that a permittee "shall not exceed" a certain sound level as a condition of approval for a wind energy project in New Hampshire. The language did not specify the metric, but sound levels from this project were evaluated using L_{eq} sound levels. This methodology was accepted by the State for the compliance evaluation.

Kerrie Standlee of ABD wrote in his December 6, 2016 memo that L_{eq} is a reasonable metric to apply in Almer Township, although he suggests using a different time interval: "While I can agree that it might be reasonable to conclude that the 45 dBA noise limit in the wind energy facility noise ordinance could be considered an L_{eq} noise metric and not an absolute maximum noise level limit, I cannot agree with the consultant that the limit could be a one-hour L_{eq} noise level limit." In addition, he states, "If the Commission decides to consider adopting a noise metric for the Tuscola Wind III project other than the maximum noise level metric, I would suggest consideration be given to adopting a 10-minute L_{eq} metric." While the modeling analysis for a 10-minute L_{eq} did not demonstrate compliance under the current layout configuration, adjustments to the layout and/or NRO modifications would likely result in a layout that could comply with a 10-minute L_{eq} interpretation of the sound provision of the ordinance.

As outlined previously in this memo, the L_{max} metric is not a typical or appropriate metric for the evaluation of a "shall not exceed" wind energy ordinance. If this interpretation is applied, no wind turbines can be constructed on the land identified as participating in the submittal based on the modeling analysis presented in this memo.