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RESOURCE SYSTEMS GROUP, INC.

**MEMORANDUM**

To: Todd Presson  
From: Kenneth Kaliski, P.E., INCE Bd. Cert.  
Subject: Spruce Mountain Short Duration Repetitive Sounds  
Date: 14 July 2010

There are currently no ANSI, IEC, or other standards used to predict short-duration-repetitive-sounds (SDRS) from wind turbines. The cause of SDRS is debated, but it is likely a function of the different wind speeds at the top and bottom of the rotor (wind shear) and turbulence (Bowdler 2008, Dunbabin 1996, Oerlemans and Mendez, 2005, van den Berg 2005). The turbulence can be naturally occurring or created by wakes from upwind turbines.

Several papers have studied the theoretical effect of wind shear on the "swishing" sound from wind turbines (Lee, et al. 2009, Oerlemans and Schepers, 2009). They found that much of this amplitude modulation can be explained simply by the difference in broadband blade noise created by higher wind speeds at the top versus the bottom of the rotor rotation. Higher wind shear would result in higher amplitude modulation. This amplitude modulation is broadband and not infrasonic.

Terrain breaks up the tendency to create stable wind layers. As a result, in turbine locations such as that found at Spruce Peak, there tends to be fewer instances of excessive wind shear

To evaluate whether this area is subject to very high wind shear, we reviewed a year of data from the Spruce Mountain meteorological tower. The brown box in Figure 1 represents 90% of the hour with hub-height wind speeds of 4 m/s or greater. As shown, instances of high wind shear ( $\alpha > 0.55$ ) occur less than 5% of the time for all hours.

Excessive turbulence can increase the level of sound from a wind turbine and it may also contribute to SDRS. Turbulence may be naturally occurring, caused by thermal mixing and ground roughness, for example. Or, it can be caused by the wake from upwind turbines. To evaluate naturally occurring turbulence, we reviewed one year of meteorological data and plotted turbulence intensity for 52,560 10-minute data points. As shown, higher turbulence occurs during the day, due to higher solar radiation. Overall, 83% of the data points are below 0.20 turbulence intensity, with most of those periods above this figure occurring during the day.

Turbulence intensity is highest at the lowest wind speeds, when sound output from the wind turbines is lower. Figure 3 shows seasonal turbulence intensity from the Spruce Mountain met tower plotted against wind speed.

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Figure 1: Wind profile power law exponent by time of day for 80 meter wind speeds above 4 m/s. Boxes show 90% of data and "whiskers" are the +5% and -5% outliers

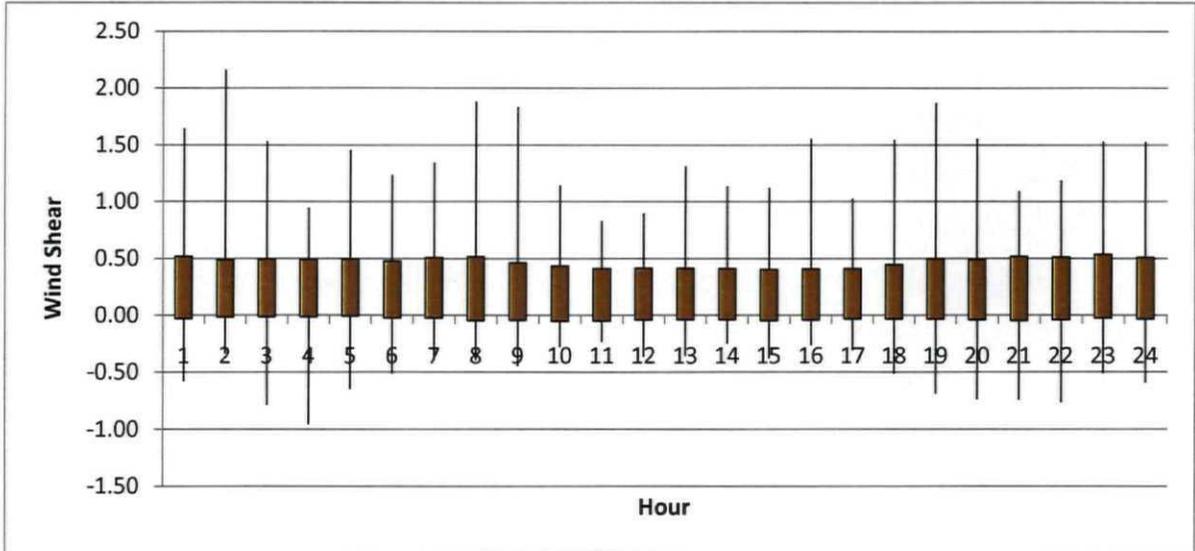


Figure 2: Turbulence intensity by wind speed. Boxes show 90% of data and "whiskers" are the +5% and -5% outliers

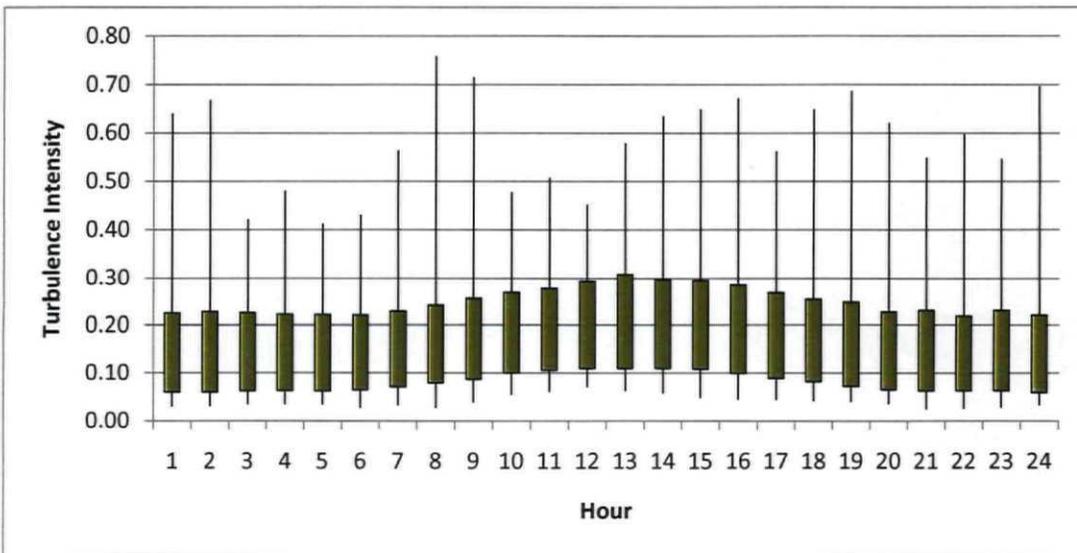
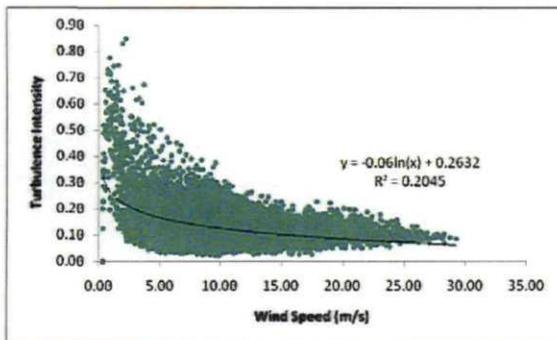


Figure 3: Turbulence Intensity by Wind Speed

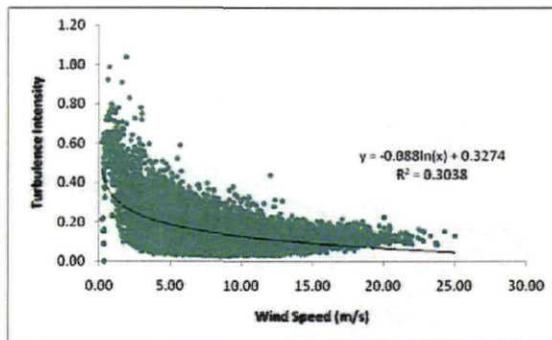
Winter 2008

Spring 2009

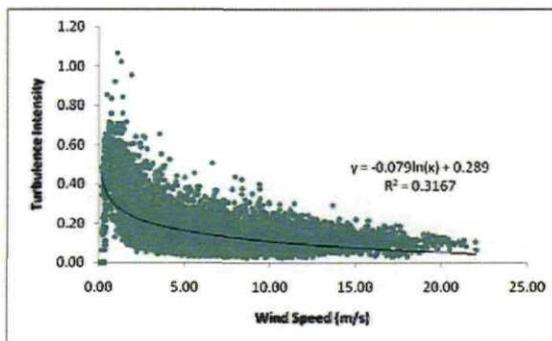
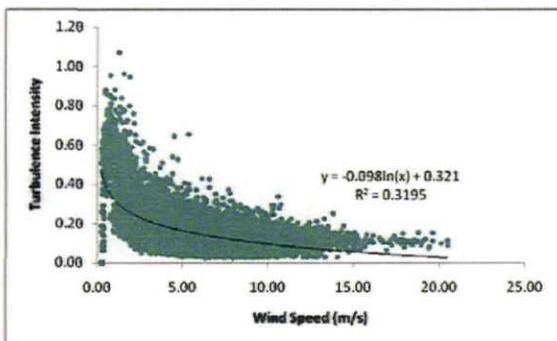




Summer 2009



Fall 2009



While it is not possible, at this time, to calculate the extent of SDRS at Spruce Mountain, the analysis shown above indicates that the site characteristics are not conducive to common occurrences of SDRS.

Inflow turbulence can also affect noise from the wind farm. I understand from you that the turbines were sited taking into account the minimization of this type of turbine wake impact.

If post-construction monitoring is required similar to the protocols from Rollins and Stetson, data will be collected to evaluate whether SDRS is occurring.

**BIBLIOGRAPHY**

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