Preface

This draft regulation references many ordinances laws and regulations in effect by many cities and counties in the U. S. and other countries. Also, referenced are technical papers, reports and nationally recognized standards relating to wind turbines. These documents have been referenced to throughout this draft regulation. Many of these wind turbine noise regulations are almost identical such as those in Michigan; Eveline Township, Huron County, Lenawee Township, Montague Township, Otsego County, White River Township and Chester Township. Seven of these counties and townships all are located close to the shores of Lake Michigan or Lake Huron. In a report titled "Examples of Noise Standards and Wind Turbine noise Regulations" Carolyn Weed, Centerville Township Commercial Wind Ordinance Committee; August 7, 2006, the following comment is made.

> *With little consideration of low frequency noise standards, which vary from country to country, the inadequacy of Michigan's wind firm noise standard becomes apparent when reviewing general noise level standards for community noise and wind turbine noise that have been adopted around the world. Compare these standards with those specified in the Michigan Wind Guidelines: 55 dB(A) (or, if ambient noise is greater than 55 dB(A), ambient level plus 5 dB(A). Michigan Standards also exceed regulatory limits set in Denmark, the Netherlands, Germany and New Zealand.*

Let us now review regulations in the State of Washington where there is mountainous terrain rather than the flat terrain as in the lower peninsula of Michigan.

The State of Washington has a noise law, Chapter 173-60 WAC, titled "Maximum Environmental Noise Levels, 12/6/00. The law limits the nighttime level for residential to residential levels to 45 dB(A), 5 dB less than the Colorado Noise Law, CRS 25-12. However, for industrial to residential the nighttime limits is 60 dB(A), 10 dB higher than the Colorado Noise Law, which is zoning of the receptor independent of the zoning of the noise source. The Washington Department of Fish and Wildlife Wind Power Guidelines, April 2009 is 29 pages in length. The entire document is silent with regards to wind turbine noise.

The State of Washington Energy Facility Site Evaluation Council coordinates all evaluation and licensing steps for siting certain energy facilities in the State of Washington. Three wind turbine sites have been permitted; Desert Claim, Kititas Valley and Wild Horse. Under review is the Whistling Ridge facility.

Riverside County, California zoning ordinance 348, Section 18.41, Commercial Wind Energy Conversion Systems (WECS) Permits, (d)(12) Noise. Noise limits at the setback distances are:

Number of Turbines	Setback	Overall	Pure Tone	Low Frequency
10 or less	2000 ft.	60 dB(A)	-5 dB	75 dB(C)
More than 10	3000 ft.	60 dB(A)	-5 dB	75 dB(C)

Benton County, Indiana has two ordinances referring to Wind Energy Conversion Systems (WECS); Ordinances 2009-05-19 and 2007-0703. The first ordinance addresses setback distances and the second addresses improvement locations. Setback distances are:

Turbines – 1.0 MW or less – 1000 ft.
Turbines – 1.0 MW or greater – 1500 ft.

The following technical reports published by the Solar Energy Institute (SERI) now called the National Renewable Energy Laboratory (NREL) addresses wind turbine noise:

> SERI/TR-635-1247, Prediction of Low Frequency Sound from the MOD-1 Wind Turbine.
> From Abstract: *The purpose of this report was to determine if aerodynamic noise mechanisms are associated with the acoustic noise situation that results from the operation of the MOD-1 Wind Turbine near Boone, N.C. Acoustic measurements indicate that sound from the turbine produced structural vibrations in homes near the turbine site.*

3925 S. Kalamath St., Englewood, Colorado 80110 ● voice: 303-761-4367 ● fax: 303-761-4379

SERI/TR-635-1247, Analytical Studies and Field Measurements of Infrasound at Howard's Knob, North Carolina.
From Abstract: *This report documents the results of both a computational and field measurement effort to assess the physical parameters responsible for propagating infrasound near the MOD-1 Wind Turbine installation near Howard's Knob, N.C. The results indicate that atmospheric refraction caused by vertical wind shears is* primarily *responsible for the enhanced noise levels.*

SERI/TR-635-1166, Acoustic Noise Associated with the MOD-1 Wind Turbine: Its Source, Impact and Control.
From Abstract: *This report summarizes extensive research by staff of the Solar Energy Research Institute and its subcontractors conducted to establish the origin and possible amelioration of acoustic disturbances associated with the operation of the DOE/NASA MOD-1 wind turbine installed in 1979 near Boone, North Carolina. Results have shown that the source of this acoustic annoyance was the transient, unsteady aerodynamics lift imparted to the turbine blades as they passed through the lee wakes of the large, cylindrical tower supports. Nearby residences were annoyed by the low-frequency acoustic impulses propagated into the structures in which the complainants lived. This situation was aggravated further by a complex sound propagation process controlled by terrain and atmospheric focusing.*

Attached to this draft noise regulation is a list of the WECS by state. The documents were prepared by the American Wind Energy Association. The total number of WECS in the U. S. is about 10,137 turbines

U.K. Standards require that wind farm noise should be limited to 5 dB(A above background for both day- and night-time except in low noise environment where the day-time limit should be limited to an absolute level within the range of 35-40 dB(A). Pure tone penalties are from 2-5 dB(A).

France limits noise to 5 dB(A) above background noise during the day and 3 dB(A) above background noise at night.

South Australia EPA noise guidelines for wind turbines require the predicted A scale equivalent noise level that cannot be exceed for more than 10% of the time(i.e. $L_{Aeq.10}$) plus 5 dB(A).

Danish Guidelines for Low Frequency Noise. The Danish guideline compared to other guidelines are stricter having, first an overall usual noise limit of 30 dB(A) daytime and 25 dB(A) nighttime. For low frequency noise such as that associated with wind turbines, the limit is 20 dB(A) and about 80 dB(C). For infrasound, the limit is 85 dB(G). The dB(G) weighting does not reduce the low frequency noise as does the dB(C) weighting. Most sound level meters (SLMs) do not have a dB(G) measurement capability.

South Australia Environmental Protection Authority guidelines states: The noise guild-line set a 55 dB(A) limit and if the level exceeds 55 dB(A) then the limit shall be ambient dB(A) plus 5 dB(A). Thus, a situation could exist where the ambient was, for example 40 dB(A) and the wind farm noise exceeded 55 dB(A), then the noise limit would be 40 dB(A) plus 5 dB, making the noise limit 45 dB(A) rather than 55 dB(A). In some areas where there is little cultural activity, the ambient could be as low as 30 dB(A).

3925 S. Kalamath St., Englewood, Colorado 80110 ● voice: 303-761-4367 ● fax: 303-761-4379

NOISE MEASUREMENT METHODS

All noise shall be measured with a sound measuring system that meets the requirements set forth in ANSI S1.4-1083 for a Type 1 Sound Level Meter/Analyzer. The noise measurements shall be conducted in accordance with the requirements set forth in International Electro-mechanical Commission (IEC) Standard 61400-11, Part 11, edition 2.1 annex A.2 dated 2006 of the issue in effect at the date of approval of this regulation by the Clear Creek County Commissioners. This requirement regarding the performance specifications for acoustical instrumentation is applicable to all noise measuring, recording and analysis devices including both digital and analogue types. All instrumentation shall be calibrated annually with laboratory calibration standards having traceability to National Institute of 'Standards Technology. ANSI does not address the frequency response characteristics of sound level meters/analysis at frequencies less than 10 Hz. Therefore S1.4 should be used as a guide for methods, procedures and the performance of noise measuring instruments at frequencies less than 10 Hz.

Ambient Noise Level

The ambient noise levels (commonly referred to as baseline noise levels) shall be measured at the site property line, which abuts to the following land uses:

Residentially zones, current or planned developments
Schools
Hospitals
Public Libraries
State of Colorado Public Lands
U. S. Government Public Lands

The ambient noise level shall be measured at areas determined by the Clear Creek Planning Department and with the land owner's approval, if required. The procedures and methods in ANSI S12.9, ISO R1996 shall be used as a guideline regarding methods, procedures and reporting. The measured and recorded decibel levels shall be dB(A) and dB(C) weighting, slow response, energy equivalent (L_{eq}) for one (1) hour increments every 24-hours for a total duration of one month during summer, fall, winter and spring. The data shall include as a minimum, exceedance levels of 1%, 10%, 50%, 90% and 99% for every one hour increment. Measurement intervals may be ignored if the wind speed at the measurement site is in excess of 20 mph during any increment of time during the one-hour measurement intervals. Other disruptive events that would produce non-representative noise levels may also be excluded from the exceedance calculations but each one-hour interval must be documented as to the reason for non-inclusion of the data.

A meteorological station shall be located at the site and shall measure and record wind speed, wind direction, temperature and humidity. The meteorological data shall include one-hour time stamps so that the data can be correlated with the one-hour increment noise data.

Wind Farm Noise Emissions

Noise emission from the site shall not be greater than the dB(A) slow and dB(C) slow, one-hour energy equivalent exceedance levels.

	Hourly Exceedance Level Turbine Noise	
Exceedance Value - %	dB(A) Slow - L_{eq}	dB(C) Slow - L_{eq}
1	60	75
5	55	70
10	50	65
50	45	60
90	40	55
99	35	50

It is recommended that the noise emission levels obtained when the turbines are in operation be at the same sites as the ambient (baseline) measurement locations. Measurement intervals may be ignored and not included in the calculation of the exceedance value if the wind speed at the measurement site is in excess of 20 mph during any increment of time during the one-hour measurement interval, other disruptive events that would produce non-representative noise levels may also be excluded from the exceedance calculation but each one-hour interval most be documented as to the reason for non-inclusion of the data.

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A meteorological station shall be located and shall measure and record wind speed, wind direction, temperature and humidity. The meteorological data shall include one-hour time stamps that can be correlated with the noise data.

Pure Tones
Pure tones shall be defined using un-weighted one-third octave level as existing when the one-third octave band levels adjacent to the one-third octave band containing the tone are 5 dB or more less at frequencies greater than 500 Hz. Below 500 Hz, the differences must be 8 dB for center frequencies, 160, 200, 250. For center frequencies of 125 Hz and lower the differences must be 10 dB. If there are pure tones present as described in this section, then the audible noise standard shall be reduced by 5 dB.

Low Frequency Noise or Infrasound Noise: No low frequency noise or infrasound noise from wind turbine operations shall be created which causes the noise level at the project boundary or at a one-mile radius beyond the closest turbine, which ever is greater to exceed the following limits:

⅓ Octave Band Center Frequency (Hz)	Sound Pressure Level (L_{eq})
5	70
6.3	70
8	70
10	70
12	70
16	69
20	68
25	67
31.5	65
40	62
50	60
63	57
80	55
100	52

Impulsivity
No impulsive noise from wind turbine operations shall be created which causes the noise level at the project boundary or at a one-mile radius beyond the project boundary or noise setback boundary that exceeds the following limits as measured by either of the two following methods.

Method 1
A qualification of impulsivity can be obtained from the average of several measurements of the difference between the C-weighted “impulse hold” and maximum C-weighted “slow” sound pressure levels. The difference between the two shall be less than 20 dB.

Method 2
The impulsive character can also be displayed as a time history of the acoustical signal which has been filtered through an octave band filter set at 31.5 Hz center frequency. The filtered octave band signal shall then be converted to a root-mean-square (RMS) value, slow response, and log converted to dB. The display can be either analogue or digital. The average difference between the maximum and minimum value shall be less than 20 dB when computed as the arithmetic average of 100 differences.

Vibration
Clear Creek County Planning Department may require seismic (ground vibration) measurements at selected locations, when the site is in operation.

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Site Development (Construction)
Site development also referred to as site construction shall comply with the requirement set forth in CRS 25-12-103 (5), 80 dB(A) daytime and 75 dB(A) nighttime. These noise limits when measured at 25 ft. beyond the site property boundary include both mobile, dozers, front end loaders, haul trucks, scrapers, rock drill and temporary stationary equipment such as engine driven electric generators, rock crushers, conveyors and vibratory screens. For example, a CAT D8 dozer produces about 80 dB(A) at 100 ft. and is in compliance with the industrial zone daytime noise limit at that distance of 100 ft. The nighttime limit of 75 dB(A) would occur at a distance of about 200 ft. Once off of the site haul trucks, tractor trailers, mobile cranes etc. would be subjected to the noise limits of CRS-25-12(106) of 84 dB(A) at 50 ft.

Preemption CRS 25-12-108
Except as provided in sections 25-12-103 (12) and 25-12-110, this article shall not be construed to preempt or limit the authority of any municipality or county to adopt standards that are no less restrictive that the provisions of this article.

Wind Farm Acoustics
The noise field or collection of noise contours also called an isopleath for a single relatively small but not necessarily quiet noise source can be determined by relatively simple mathematics. The effects of topography, wind, thermal gradients and ground absorption can be included in the analysis. On the other hand when there is a multiplicity of noise sources such as a wind turbine farm, the calculations of the noise field around the wind farm is extremely difficult and subjected to large errors caused by small errors in the modeling process. For example, the difference in terrain elevation between a residence and each turbine in a wind farm can be sufficient due to refraction of the rays of noise to result in a concentration of noise at a single point (a diacoustic). For example, the noise at a residence near an operating wind farm was actually louder than the noise level close to a single turbine whilist at another nearby residence the noise was considerably lower and in agreement with analysis using un-refracted direct sound rays. To model this situation would be very expensive and of questionable validity. The simplest solution, one that could be determined by experiment, would be to shut down the turbine or turbines causing the situation of abnormal noise levels.

Noise Setbacks
The Clear Creek County Planning Development and Zoning Department may impose a noise setback that exceeds the other setbacks set forth in this regulation if the County determines that such greater setbacks are necessary to protect the public health, safety and welfare of the surrounding community. Setbacks could include State of Colorado, Clear Creek County and U. S. Government public lands. Setbacks shall include the effects of spatial variations due to turbine operational conditions.

3925 S. Kalamath St., Englewood, Colorado 80110 ● voice: 303-761-4367 ● fax: 303-761-4379