Submission to the Colorado Oil and Gas Conservation Commission's
Multi-stakeholder Committee on Noise

PROPOSED OPTIONS FOR REGULATING NOISE FROM OIL AND GAS FACILTIES IN COLORADO

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OGAP/SJCA Proposal

I. Industry shall ensure that noise from new oil and gas properties does not exceed 1 dBA over ambient, measured at a 300 or 350-foot radius (this is up for discussion) from the source(s). **(See Attachment 1)** Furthermore, at no point outside the 300 or 350-foot radius shall the noise from an oil and gas property cause an increase in noise of more than 1 dB(A) above ambient. **(See Attachment 2)**

In the event that there is an existing "receptor" within the 300 or 350-foot radius, oil and gas operators shall not exceed 1 dB(A) above ambient at the property line of the receptor.

Under no circumstances shall noise from oil and gas facilities exceed allowable levels as outlined in the Colorado nuisance statute.

II. For existing oil and gas operations, noise levels shall not exceed 45 dBA at 300 or 350 feet from the oil and gas property. **(See Attachment 3)**

Alternatively, oil and gas operators may apply the 1 dBA over ambient standards, if they choose to shut down their operations to determine the ambient noise level.

III. If complaints from neighbors are received, operators shall conduct an analysis of the noise to determine the presence of:

1) Tonal components
2) Low frequency noise
3) Impulsive characteristics
4) Intermittent noise characteristics

If, by the following methods **(See Attachment 4)** there are tonal components, significant low frequency noise, impulsive noise, or intermittent noise, the operator shall utilize best available control technologies to remove the offensive noise.

IV. Drilling, Completion and Re-working. We would like to see a requirement to limit these activities to daytime hours; and also, require the use of best available sound abatement technologies in sensitive areas or when complaints are received. **(See Attachment 5)**

V. COGCC acknowledges the special nature of noise impacts from facility-related heavy truck traffic and vibration impact from energy facility operations. Industry is expected to take every reasonable measure to avoid or minimize the impact of heavy truck traffic or vibration concerns in an area. **(See Attachment 5)**

ATTACHMENT 1: RATIONALE FOR THE 1 DBA OVER AMBIENT STANDARD

> ***If the intruding noise is of a different character than the background noise (e.g., the whine of a new turbine superimposed onto rural background noise) then the intruding noise could be easily discernible even if it adds less than 1 dBA to the background noise level.***[1]

Applying a standard of 1 dBA over ambient ensures that quiet areas remain quiet. It also allows higher noise limits for areas that have a higher background noise level (e.g., industrial areas or high traffic areas).

Example of use of this standard

The City of Farmington, NM, uses the 1 dBA over ambient as a standard for all wells constructed within city limits. This standard is included in the conditions of approval for well permits.

Page 4 and 5 of this attachment are copies of two recent gas well applications in Farmington. The applications were approved with conditions that:

The ambient sound levels from the subject property shall not be increased more than 1 dB(A) when measured at 300 feet.

Note that the 1 dB(A) over ambient applies not only to "single family residential districts," but also to "light industrial districts."

Furthermore, note that one of the Commissioners approving the conditions of approval is the president of Merrion Oil and Gas, and president of the New Mexico Independent Petroleum Producers Association. Mr. Merrion did not oppose the requirement that oil and gas operations not exceed 1 dB(A) over ambient. Thus, it is reasonable to assume that industry acknowledges the ability to meet the 1 dB(A) over ambient standard.

<u>Measuring Ambient Sound Levels</u>

In Alberta, the Energy and Utilities Board has defined the ambient sound level (ASL) as the average sound environment in a given area. The EUB has outlined procedures for measuring ASL.[2] This involves performing an ambient sound monitoring survey. The intent of an ambient sound survey is to determine the ambient sound level **<u>without</u>** any energy-related industrial component. Therefore, for existing facilities, the sound survey must be conducted with all the facilities shut down.

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[1] Council and Bonneville Power Administration February, 2002. *Wallula Power Project Draft Environmental Impact Statement*. Section 3.9: Noise. P. 3.9-1. (http://www.efsec.wa.gov/wallula/eis/DEIS/walluladeis.html)

[2] Alberta Energy and Utilities Board (EUB). November, 1999. *Noise Control Directive User Guide*. (Guide 38), pp. 18 and 30.

An ambient sound monitoring survey consists of a 24-hour continuous sound monitoring survey, with measured ASLs presented for the daytime and nighttime periods, conducted 15 m from the nearest or most impacted dwelling unit and under representative conditions.

- The 15-m requirement may be altered if it is physically impossible or acoustically illogical.
- Another measurement location may be chosen if the affected dwelling unit is not an appropriate location.

In Alberta, the opportunity to perform a 24-hour ambient sound monitoring study exists both prior to the approval of an application or once a facility is in place.

ATTACHMENT 2: RATIONALE FOR WHY NOISE FROM OIL AND GAS PROPERTIES SHOULD NOT EXCEED 1 DBA ABOVE AMBIENT ANYWHERE BEYOND THE MEASUREMENT POINT/RADIUS.

> ***. . .many factors affect the noise level, and measurement results can vary by tens of decibels for the very same noise source.**[3]*

Noise measured close to the noise source may not be quieter or less annoying that noise measured at a great distance from the source. There are a number of factors that affect the propagation of noise. The most important include:[4]

- Type of source (point or line)
- Distance from source
- Obstacles such as barriers and buildings (low frequency noises are difficult to reduce using barriers)
- Atmospheric absorption
- Wind
- Temperature and temperature gradient
- Humidity
- Precipitation
- Reflections
- Ground absorption

It is important to understand that the above factors can work to increase or decrease noise levels. For example, at short distances (up to 160 feet) the wind has a minor influence on the measured sound level. *For longer distances, the wind effect becomes appreciably greater.*[5] Also, at distances greater than 1000 feet from a noise source, noise can increase on the downwind side by as much as 20 dB,[6] while on the upwind side, levels can drop by over 20 dB, depending on wind speed and distance.[7]

Other things to consider include the fact that while barriers may act to reduce high frequency noise, low frequency noise is difficult to reduce using obstacles or barriers.[8] For example, for people inside buildings with windows closed, mid-to-high frequencies are attenuated to a much greater extent than low frequencies. Also, resonance can be set up inside a room, causing nodes (quiet points) and antinodes (loud points).

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[3] Breul and Kjaer. 2000. *Environmental Noise Handbook,* p. 16. (http://www.macavsat.org/pdf_files/misc_reports/bk.pdf)
[4] Breul and Kjaer. 2000. pp. 16-22.
[5] Breul and Kjaer. 2000. p. 20.
[6] McGregor, S. (Engineering Dynamics). 1998. *Compression Facility Noise Guidelines for Colorado Oil and Gas Commission.* p. 10.
[7] Breul and Kjaer. 2000. p. 20.
[8] Breul and Kjaer. 2000. p. 18.

Consequently, there may be elevated levels of low frequency noise at certain points within a room.[9]

Additionally, while mid and high frequency noise is attenuated by soft ground surfaces and the atmosphere, these factors do not tend to reduce low frequency noise as much as high frequency noise.[10] This means that as sound travels, its frequency content is altered, and low frequencies tend to become more prominent at greater distances.[11]

Example of noise propagation from a compressor station

The recording of compressor station noise at the Lindauer residence is an excellent example of how noise is not necessarily quieter or any less annoying as one moves away from a source. The noise measured in an upstairs room in the Lindauer residence, located 2,500 feet north of the compressor facility, was as loud as the noise measured 250 south of the facility. (Exhibit – recording of compressor noise)

According to a letter from Sid Lindauer,[12] a noise consulting company measured compressor noise at his home. The company measured sound frequencies ranging from 6 to 20,000 Hz, and measurements occurred over a period of three days. The consultants determined that most of the noise problems from the compressor station came from low frequency tones. This is not surprising. As mentioned above, low frequency sound is not attenuated as much as high frequency sound, and as sound travels over large distances (e.g., 2500 feet) a higher proportion of low frequency sound remains.

The problems experienced with low frequency compressor noise at the Lindauer residence highlight the importance of ensuring that low frequency noise is addressed in the noise rule (Section III of OGAP's proposed rule), and that consideration be given to noise that travels great distances.

Measurement of noise

If the standard for noise is set at a fixed distance from an oil and gas property (e.g., noise levels cannot exceed 40 dB at 300 feet from the oil or gas property), it is important to include a statement that ensures that the noise levels cannot be any louder that the noise standard at any point or radius beyond the measurement location.

This, combined with a test for low frequency noise, will ensure that receptors located outside of the radius are also protected by the noise standard.

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[9] Casella Stanger. 2001. *Low Frequency Noise.* (Technical research support for U.K. Department for Environment, Food and Rural Affairs Noise Programme). p. 4. (http://www.scotland.gov.uk/library3/environment/lfn-00.asp)

[10] Breul and Kjaer. 2000. p. 19.

[11] Casella Stanger. 2001. p. 4.

[12] Letter from Sid Lindauer to Russell George, Executive Directors of the Colorado Department of Natural Resources. Dec. 11, 2004. Re: Information gathering meetings on COGCC Noise Abatement Rules.

ATTACHMENT 3: RATIONALE FOR A 45 DBA LEVEL

> ***Measurable effects of noise on sleep begin at LAeq levels of about 30 dB… when noise is continuous, the equivalent sound pressure level should not exceed 30 dB(A) indoors, if negative effects on sleep are to be avoided. For noise with a large proportion of low frequency sound a still lower guideline is recommended.***[13]
>
> ~ *Guidelines for Community Noise,* World Health Organization

The World Health Organization recommends a 16-hour daytime LEQ of 55 dBA and a 45 dBA nighttime LEQ to prevent "serious annoyance," and a daytime LEQ of 50 dBA and a nighttime LEQ of 40 dBA to prevent "annoyance."[14]

For existing operations, we are not asking that the oil and gas industry meet the 1 dBA over ambient standard (although operators may choose to do so, e.g., if they are in areas with high ambient environmental noise). We are suggesting that existing operation at minimum reduce noise levels to meet a 45 dBA standard, which should prevent serious annoyance in the community.

45 dBA Leq (nighttime) is standard for many jurisdictions; even those with oil and gas operations. For example:

World Bank
For on shore sites, the maximum acceptable noise levels recorded at receptors or the edges of a property boundary, and on an average hourly basis are 55 dB(A) and 45 dB(A) for day and night, respectively. These levels apply to residential, educational and institutional areas.[15]

Sacramento County, CA
Sacramento County is a significant producer of dry natural gas in California.[16] The allowable noise level, according to the Sacramento County General Plan,

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[13] Berglund, B., Lindvall, T. and Schwela, D. 1999. *Guidelines for Community Noise*. World Health Organization. p. xii.
[14] Berglund, B., Lindvall, T. and Schwela, D. 1999. *Guidelines for Community Noise*. World Health Organization. p. xiv.
[15] World Bank Group. 1998. *Pollution prevention and abatement handbook 1998: toward cleaner production.* (http://ifcln1.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/gui_onshore_WB/$FILE/onshore_PPAH.pdf)
[16] California Department of Conservation. January 28, 2003. *California Crude Oil Production Drop Continues-- Natural Gas Production Rises Again.* (http://www.consrv.ca.gov/index/news/2003%20News%20Releases/NR2002-02_OilandGasReport.htm)

Noise Element, is 50 dBA L50 (daytime) and 45 dBA L50 (nighttime), measured at residential properties.[17]

45 dBA is achievable

45 dBA is achievable at 300 feet and even 100 feet from the source. On a recent tour of wells in Farmington, NM, led by Curt Weitkunat, Associate Planner with the City of Farmington, OGAP conducted sound measurements. The following chart summarizes the readings recorded at several sites.

Note that at the sites where the compressors and pump jacks have full sound abatement (Tiger #9, Federal A #3, Federal Gas Com E #1&2, and Possible Dream #1) the noise levels measured at 300 feet are at or below 45 dBA. This is even true when external noises, such as traffic and construction noise, are present. In the cases where the noise at 300 feet exceeds 45 dBA, the compressors and pump jacks only have partial sound abatement.

Noise Levels Measured at Gas Wells in Farmington, NM (January 7, 2005)

Well Name	**dBA**			**Comments**
	~100 ft	**~200 ft**	**~300 ft**	
Tiger #9	46	42	**41**	• Abated compressor and pumpjack • Air traffic noise at 300 feet
Tiger #15	54	51.5	48.5	• Abated compressor and **partially abated pumpjack** • Air traffic noise at 300 feet
Federal A #3	44	41	**39**	• Abated compressor, no pumpjack on site
Federal Gas Com E#1 & 2	44	44	**42**	• Abated compressor and pumpjack • Traffic noise at 200 and 300 feet
San Juan Fed FC #1	76	65.5	62	• **Partially abated compressor** • Measurements taken on side without sound barrier
‘’ ‘’	61.8	55.5	52.5	• **Partially abated compressor** • Measurements taken on side with partial sound barriers – windy
Possible Dream #1, Height #1	48.5	47	**45**	• Abated compressor; pumpjack not abated. • Construction noise present, especially at 200 and 300 feet

ATCO Noise Management in Canada has been able to achieve noise abatement on compressors and gas transmission facilities down to 33 dBA at 300 feet. Without acoustical treatment, these compressor stations would generate noise levels ranging from 100 - 140 dBA (for the human ear, the threshold of pain is pegged at 120 dBA, which is equivalent to the sound of a jet aircraft at takeoff).

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[17] Planning and Community Development Department General and Advanced Planning Section, County of Sacramento, CA. *Noise Element Of The1993 County Of Sacramento General Plan.* 1993. p. 6. (http://www.saccounty.net/general-plan/gp-home.html)

The examples below, and other examples, can be found at:
http://www.atconoise.com/mediaroom/mediaroom_tech_history.htm

TransCanada Pipeline expansion across Canada, 1992

Acoustic buildings to deaden the noise at two of its compressor stations were used on two new compressor stations in noise sensitive areas.

- "Near several cottage communities, we had to build stations with noise levels as low as technically feasible. This meant **achieving levels of 33 dbA for each station component**, such as the gas turbines and compressors."

Iroquois Gas Transmission's Wright and Croghan, New York, stations.

- **Achieved design goals of 42 dB and 40 dB at 300 feet**
- treated each significant noise source: gas turbines and compressors, exhaust and intake, oil cooler, cooling and ventilation fans
- built the compressor stations to look like barns to fit in with rural countryside

TransCanada Pipeline, 1993 (Dryden, Smooth Rock Falls and Barrie, Ontario)

- **Three stations met noise levels of 33 dBA at 300 feet**
- Noise sources consisted of a gas generator and power turbine (was producing noise at 90 dBA at 1 meter) and two centrifugal compressors (was 105 dBA at 1 meter), as well as gas generator air inlets, turbine exhausts and lube oil coolers

TransCanada Pipeline expanded gas transmission network by 13 units in 1997

- reduced noise from 105 dBA to **36 dBA at 300 feet**, and 39-44 dBA at the remaining 11 stations
- "one stations runs so quietly that a nearby resident asked when it'd be operational"

ATTACHMENT 4: RATIONALE FOR ASSESSING PENALTIES FOR DETERMINING TONAL, LOW FREQUENCY, FLUCTUATING AND IMPULSIVE NOISE CHARACTERISTICS.

> ***It is widely acknowledged that noise measurements based on the A-weighted frequencies (dBA or LAeq) do not adequately characterize most noise environments and do not adequately assess the health impacts of noise on human well-being.***[18,19,20]

Certain noise characteristics can greatly increase the annoyance factor and the health impacts associated with noise. These factors include: 1) tonality; 2) presence of low frequencies; 3) fluctuating or intermittent sounds; and 4) impulsive sounds.

1. Tonal Noise

> ***Noise with distinct tones, for example, noise from fans, compressors, or saws, is generally far more annoying than other types of noise. This annoyance factor is not taken into account in a broadband measurement. A spectral analysis may be needed to assess annoyance.***[21]
>
> ~ *Environmental Noise Handbook*, Breul and Kjaer

> ***Most energy industry facilities typically exhibit either a tonal or impulse/impact component. Examples of tonal components are transformer hum, sirens, and piping noise.***[22]
>
> ***~ Noise Control Directive User Guide*, Alberta Energy and Utilities Board**

Tones are noises with a narrow sound frequency composition (e.g., the whine of an electrical motor). Annoying tones can be created in numerous ways: machinery with rotating parts such as motors, gearboxes, fans and pumps often create tones. Unbalance or repeated impacts cause vibration that, transmitted through surfaces into the air, can be heard as tones. Pulsating flows of liquids or gases can also create tones, caused by combustion processes or flow restrictions.

Tones can be identified subjectively by listening. Regulations, however, often require an

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[18] Breul and Kjaer. 2000. *Environmental Noise Handbook,* p. 25. (http://www.macavsat.org/pdf_files/misc_reports/bk.pdf)

[19] Berglund, B., Lindvall, T. and Schwela, D. 1999. *Guidelines for Community Noise*. World Health Organization. p. xiii. (http://www.who.int/docstore/peh/noise/Commnoise2.htm)

[20] Leventhall, G. 2003. *A Review of Published Research on Low Frequency Noise and its Effects.* Prepared for Department for Environmental Foods and Rural Affairs. (United Kingdom). p. 11.

[21] Breul and Kjaer. 2000, p. 25.

[22] Alberta Energy and Utilities Board (EUB). November, 1999. *Noise Control Directive User Guide*. (Guide 38). p. 67.

objective measurement of tonal content as well.[23] In such cases, frequency analysis, where a noise signal is electronically separated into various frequency bands (e.g., octave bands or third-octave bands[24]) may be employed. The tonal audibility or annoyance factor is then calculated by comparing the tone level to the level of the surrounding spectral components.[25]

Measuring tonal noise using 1/3-octave band frequency analysis

Germany (DIN 45680 method)[26]

In Germany, there is an assumption that the great majority of low frequency noise problems from industrial sources are tonal. (See low frequency noise, below). For tonal frequencies, the allowable noise limit is less than for non-tonal noises.

If the level in a particular third-octave band is 5 dB or more above the level in the two neighboring bands, the noise is described as tonal. This is similar to a standard for tonality set by the ISO (1987).[27]

Alberta Energy and Utilities Board (EUB)[28]

In Alberta, if no tonal noise is present, oil and gas operators are allowed to emit noise at 5 dBA above the basic allowable noise level.

The test for the presence of tonal components consists of two parts.

1) The sound pressure level of any one of the slow-response, A-weighted, 1/3-octave bands between 20 and 16 000 Hz is 10 dBA or more than the sound pressure level of at least one of the adjacent bands within two 1/3-octave bandwidths. In addition, there must be a minimum of a 5 dBA drop from the band containing the tone within two bandwidths on the opposite side.
2) The tonal component must be a pronounced peak clearly obvious within the spectrum.

Figure 1 (below) shows some examples of tonal components:

250 Hz: There is a qualifying tonal here because to the left of 250 bar there is a drop of 11 dBA within 2 bandwidths. On the opposite side, there is a drop of 6 dBA. Also, the tone at 250 Hz is pronounced within the spectrum.

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[23] Breul and Kjaer. 2000, p. 25.

[24] **Octave Bands.** The center frequencies of these bands are: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000 and 16000 Hz. **Third-octave bands:** A more detailed analysis can be obtained using bands more narrow than octaves. If an octave is split into three parts, each of these parts is called a *1/3-octave band*. Narrower bands may be determined using the Fast Fourier Transform (FFT) method.

[25] Note: the duration of the tone should also be documented according to Breul and Kjaer, p. 15.

[26] Leventhall, G. 2003. p. 69.

[27] International Standard ISO 199602:1987. Cited by the Ireland Environmental Protection Agency. (http://www.epa.ie/Noise/)

[28] Alberta Energy and Utilities Board (EUB). November, 1999. *Noise Control Directive User Guide*. (Guide 38). p. 28.

2000 Hz: This is also tonal, as there are drops of more than 10 dBA within two bandwidths on the left side, and more than 5 dBA within two bandwidths to the right.

630 Hz: The sound measurement at this frequency meets part of the test. It is pronounced within the spectrum, and there is a 5 dBA difference within 2 bandwidths to the right of 630 Hz. It does not, however, meet the full test because there is no corresponding drop of at least 10 dBA within one or two bandwidths on the other side.

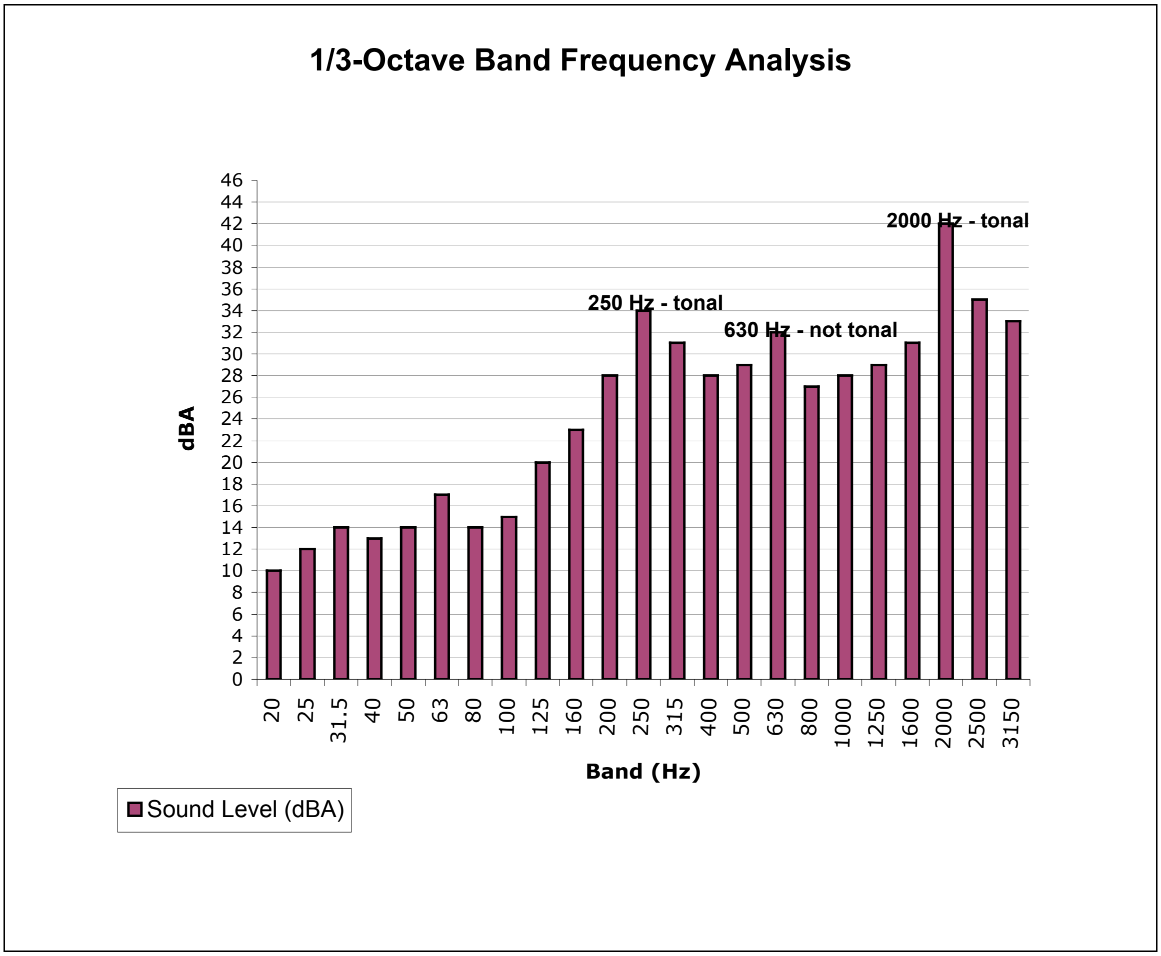

Figure 1. 1/3-Octave Band Frequency Analysis

Oregon Noise Control Regulations[29]

Oregon requires the use of octave bands to determine audible discrete tones from industrial noise "when the Director has reasonable cause to believe that the requirements of [the Oregon Noise Control Regulations] do not adequately protect the health, safety or welfare of the public." The *Oregon Noise Control Regulations* outline a procedure for determining whether or not the noise contains tonal components.

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[29] Oregon Administrative Rules, Chapter 340, Division 35, *Noise Control Regulations*. 340-35-035 (1)(f).

<u>Penalties for tonal noise</u>

In some jurisdictions, when noise has an obvious tonal content, a "penalty" or correction may be used to account for the additional annoyance.[30] The penalty for tones varies between 0 dB (no penalty) and 6 dB.[31] This penalty is added to the measured dB level before the measured dB level is compared to the acceptable dB noise levels.

For example, if the noise from a compressor is measured as 40 dBA, but it is determined that the noise has tonal components, a penalty of 6 dBA would result in a level of 46 dBA. If the noise standard is 45 dBA, the noise from the compressor would be out of compliance.

2. Low Frequency Noise

> ***A large proportion of low-frequency components in noise may increase considerably the adverse effects on health.***
>
> ***. . .low frequency noise. . . can disturb rest and sleep even at low sound levels.***
>
> ***The evidence on low frequency noise is sufficiently strong to warrant immediate concern.***
>
> ~ *Guidelines for Community Noise,* World Health Organization

Low frequency noise does not have a consistent definition, but it is commonly defined as noise that has a frequency between 20 and 100 - 150 Hz. Noise at levels below 20 Hz is referred to as infrasound.

Depending on the actual conditions, many types of noise can be regarded as low frequency noise:[32]

- Low frequency noise and infrasound are produced by machinery, both rotational and reciprocating, and all forms of transport and turbulence. Typical sources include pumps, compressors, diesel engines, aircraft and fans.
- Combustion turbines are capable of producing high levels of low frequency noise. This noise is generated by the exhaust gas.[33]
- The firing rate of many diesel engines is usually below 100 Hz, so road traffic noise can be regarded as low frequency. Similar considerations can be made for engines or compressors in industries or co-production plants.
- Burners can emit broadband low frequency flame roar.

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[30] ISO , 1987. *Acoustics – Description and measurement of environmental noise – Part 3: Application to noise limits.* International Standard ISO 1996-3:1987(E), International Organization for Standardization, Geneva, Switzerland. <u>*Cited in*</u> Berglund, B., Lindvall, T. and Schwela, D. 1999.
[31] Breul and Kjaer. 2000, p. 31.
[32] *Laboratory Evaluation of Annoyance of Low Frequency Noise*., by Torben Poulsen,and Frank Rysgaard, 2002. Prepared for the Danish Environmental Protection Agency.
[33] defined as frequencies less than 64 Hz. Walulla Power Project DEIS. P. 3.9-3. Feb. 2002.

- Structure borne noise, originating in vibration, is also of low frequency, as is neighbor noise heard through a wall, since the wall blocks higher frequencies more than lower ones.
- Low frequency noise can be noise or vibration from traffic or from industries, totally or partly transmitted through the ground as vibration and reradiated from the floor or the walls in the dwelling.[34]

Low frequency noise creates a large potential for community annoyance. It is most often experienced inside of homes and buildings where resonance amplifies the sound. (See Attachment 2) It is a general observation that indoor noise is perceived as more 'low-frequency-like' than the same noise heard out of doors.[35]

Also, low frequency noise can be a factor at much greater distances than audible noise sources. A case study in Northern Carolina near a wind turbine documented low frequency noise problems at residences located more than 1/2 mile from the turbine.[36]

Health effects of low frequency noise

It is well established that the annoyance due to a given noise source is perceived very differently from person to person. For many humans, their ears are not very sensitive to low levels of low frequency sound. At low frequencies, however, noise may not be perceived as sound but rather is "felt" as a vibration or pressure sensation.[37]

For those who are sensitive to low frequency sound the effects can be dramatic. Complainants often describe the noise as:[38]

- Humming
- Rumbling
- Constant and unpleasant
- Pressure in ears
- Affects whole body
- Sounds like large, idling engine
- Coming from far away

Researchers who conducted field measurements and laboratory studies of people who complained of low frequency noise in their homes concluded the following:[39]

- The problems arose in quiet rural or suburban environments
- The noise was often close to inaudibility and heard by a minority of people

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[34] Poulsen, Torben and Rysgaard, Frank. 2002. *Laboratory Evaluation of Annoyance of Low Frequency Noise*. Prepared for the Danish Environmental Protection Agency. Working Report No. 1. p. 14.

[35] *Laboratory Evaluation of Annoyance of Low Frequency Noise*., by Torben Poulsen,and Frank Rysgaard, 2002. Prepared for the Danish Environmental Protection Agency.

[36] Solar Energy Research Institute(SERI). 1985. Acoustic Noise Associated with the MOD-1 Wind Turbine: Its Source, Impact and Control. Colorado: SERI, U.S. Department of Energy.

[37] Breul and Kjaer. 2000, p. 15; and Casella Stanger. 2001. *Low Frequency Noise.* (Technical research support for U.K. Department for Environment, Food and Rural Affairs Noise Programme). p. 4.

[38] Moller and Lydolf, 2002. Based on a Denmark survey of people complaining of low frequency noise. *Cited in* Leventhall, G. 2003, p. 48,

[39] Vasudevan, R. N., and Gordon, C. G. 1977. "Experimental study of annoyance due to low frequency environmental noise," *Applied Acoustics.* Vol. 10, pp. 57-69. *Cited in* Leventhall, G. 2003, p. 36.

- The noise was typically audible indoors and not outdoors
- The noise was more audible at night than day
- The noise had a throbbing and rumbly characteristic
- The complainants had normal hearing

In an epidemiological survey of sufferers from low frequency noise, the following health effects were documented:[40]

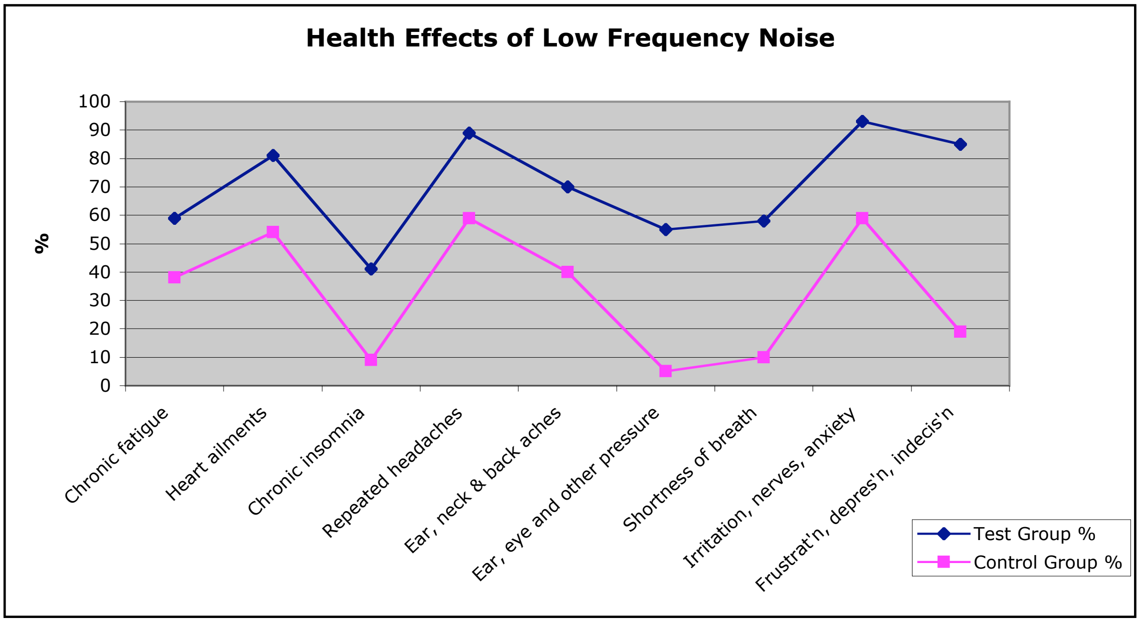

Figure 2. Health effects of low frequency noise.

The above health effects were felt by people experiencing low frequency noise in their homes. The New Mexico Game and Fish states that even for human beings in a recreational setting, low frequency noise has been shown to cause stress reactions including raised blood pressure and increased muscle tension.[41]

Measuring low frequency noise

When prominent low-frequency noise components are present, noise measurements based on A-weighting are inappropriate.[42] A-weighting has the effect of reducing measured levels of low and very high frequencies (see Figure 3), but has less filtering effect on most mid-range sound frequencies where speech and communication are important.[43]

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[40] Mirowska, M., and Mroz, E. 2000. "Effect of low frequency noise at low levels on human health in light of questionnaire investigation," *Proc Inter-Noise 2000, 5, 2809 - 2812*. Cited in Leventhall. 2003. p. 49.

[41] Federal Energy Regulatory Commission. http://216.239.57.104/search?q=cache:05wK5TjE1tMJ:www.ferc.gov/whats-new/comm-meet/072804/C-2.pdf+compressor+station+low+frequency+ferc&hl=en

[42] Berglund, B., Lindvall, T. and Schwela, D. 1999. p. xiii.

[43] Leventhall, G. 2003. p. 10.

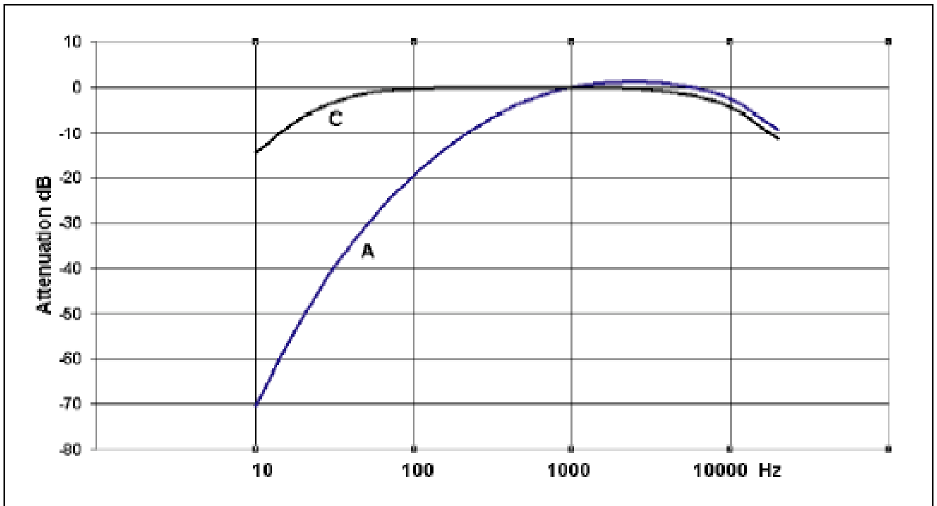

Figure 3. Sound level meter weighting curves - A and C.[44]

Berglund et al (1996) have suggested that, "Since A-weighting under-estimates he sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting." The Danish government does not recommend using the C-weighted noise level to assess low frequency noise, however, because "there is a poor relationship between the C-weighting function and the shape of the equal-loudness contours at low frequencies and low levels.[45]

In assessing low frequency noise the following steps have been used in some jurisdictions:

Step 1: Is (dBC – dBA) > x ?

The difference between dBC and dBA provides crude information about the presence of low frequency components in noise. Research suggests that when the difference (x) is great enough, that further investigation or action related to low frequency noise is warranted.

- In Germany, x > 20 dB is used as an initial indication of the presence of low frequency noise, and the need to conduct further investigations.[46]
- If x > 10 dB it is recommended by the World Health Organization that a frequency analysis of the noise be performed.[47]
- Kjellberg and co-workers (1997) have suggested that when x > 15 dB, an addition of 6 dB to the measured A-weighted level is a simple procedure for addressing the annoyance.[48]

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[44] Leventhall, G. 2003. p. 11.
[45] Danish Environmental Protection Agency. 2002. *Danish Guidelines on Environmental Low Frequency Noise, Infrasound and Vibration.* (http://www.mst.dk/transportuk/02030000.htm#vibration)
[46] Leventhall, G. 2003. p. 69.
[47] Berglund, B., Lindvall, T. and Schwela, D. 1999. *Guidelines for Community Noise*. World Health Organization. p. xiii.
[48] Kjellberg, A., Tesarz, M., Holberg, K., and Landström, U. (1997). "Evaluation of frequency-weighted sound level measurements for prediction of low-frequency noise annoyance." *Environment International. Vol.* 23, pp. 519-527. Cited in Leventall, G. 2003, p. 34.

Step 2: Conduct frequency analysis of low frequency noise and compare to criteria.

There are numerous methods for determining the significance of low frequency noise. Over the past 25 years, many European countries (Sweden, the Netherlands, Germany, Denmark) have developed national criteria for environmental low frequency noise. According to Leventhall (2003), the move to develop criteria was driven by specific problems, "particularly gas turbine installations, which radiate high levels of low frequency noise from their discharge."[49]

In Sweden and Germany, low frequency noise may be considered a nuisance if its level exceeds a criterion in any third-octave band.

Table 1. Hearing Thresholds and Allowable dB Levels for Low Frequency Noise

Frequency 1/3 Octave Band (Hz)	**ISO 226 [50] Hearing Threshold (dB)**	**Sweden allowable dB levels**	**Germany Hearing Threshold (dB)**	**Germany daytime allowable dB levels (tonal noises)**	**Germany nighttime allowable dB levels (tonal noises)**
8	--		103	108	103
10	--		95	100	95
12.5	--		87	92	87
16	--		79	84	79
20	74.3		71	76	71
25	65		63	68	63
31.5	56.3	56	55.5	60.5	55.5
40	48.4	49	48	53	48
50	41.7	43	40.5	45.5	40.5
63	35.5	41.5	33.5	38.5	33.5
80	29.8	40	28	38	33
100	25.1	38	23.5	38.5	33.5
125	20.7	36			
160	16.8	34			
200	13.8	32			

Denmark has take a slightly different approach than Germany and Sweden, by outlining criteria for infrasound, low frequency noise and audible noise.

- **Infrasound (L_{pG}):** The Danish EPA assumes that infrasound only slightly above the hearing threshold may be annoying. The average hearing threshold for infrasound corresponds to tones each having a G-weighted level of about L_{pG} = 96 dB. An environmentally acceptable infrasound level must be below the hearing threshold. The Danish EPA assumes that an individual's hearing threshold might be 10 dB lower than the average threshold, so the agency's recommended limit for environmental infrasound is L_{pG} = 85 dB.
- **Low Frequency Noise ($L_{pA,LF}$):** As seen on the chart below, the recommended limits for low frequency noise are 5-15 dB lower than the usual audible noise limits. Low frequency noise is assessed using a set of criteria which are separate from the

[49] Leventhall, G. 2003. p. 64.
[50] This International Standard specifies combinations of sound pressure levels and frequencies of pure continuous tones that are perceived as equally loud by human listeners. (http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=34222&scopelist=)

criteria used with the overall "A" weighted noise level. To avoid possible underestimation of the frequency range, 16 – 20 Hz, the "A" weighting is used down to 10 Hz. Due to the excessive tolerances at low frequencies on the "A" weighting filter in the instrumentation standard (IEC 651), the "A" weighted level of the low frequency noise cannot be measured using a normal sound level meter supplied with a low-pass filter. The level must instead be synthesized from a narrowband frequency analysis by the addition of the nominal weighting function.[51]

- **Higher Frequency Noise (L_{pA}):** the normal A-weighting (dBA) is used for higher frequencies.

Table 2. Danish Noise Limits (Low Frequency and Audible Noise)

		Low frequency noise ($L_{pA,LF}$)	**Infrasound (L_{pG})**	**Usual/audible noise limit, (L_{pA})**
Rooms in dwellings, including childcare institutions, etc.	evening / night (6 p.m.–7 a.m.)	20 dB	85 dB	30 dB / 25 dB
	day (7 a.m.–6 p.m.)	25 dB	85 dB	30 dB
Offices, classrooms and other noise-sensitive rooms		30 dB	85 dB	40 dB
Other rooms in enterprises		35 dB	90 dB	50 dB

In the operation of the Danish limits, the noise is measured over at 10-minute period and a 5 dB penalty is added for impulsive noise.

Although Denmark imposes a penalty for impulses, which are the main complaint of many sufferers,[52] none of the methods assess fluctuations. Broner and Leventhall (1983) suggest a penalty of 3 dB for noise that is fluctuating.[53]

In the United States, a standard for low frequency noise from wind turbines has been developed for the U.S. Department of Energy.[54] Also, some counties in northern Michigan have developed ordinances that reference low frequency noise as a separate than other noise issues.[55]

Measurement positions

A-weighted levels for assessment of environmental noise are normally taken outside a residential property. This is not possible for low frequency noise because of the disturbance caused by even light winds, and because an outdoor measurement will not take into account re-radiated, structure-borne noise. Additionally, it is a common observation that low frequency noise is considered more annoying indoors.[56]

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[51] Danish Environmental Protection Agency. 2002. *Danish Guidelines On Environmental Low Frequency Noise, Infrasound And Vibration.* (http://www.mst.dk/transportuk/02030000.htm#vibration)
[52] Leventhall, G. 2003, p. 72.
[53] Leventhall, G. 2003, p. 66.
[54] Kelley, N.D. 1987. *A Proposed Metric for Assessing the Potential of Community Annoyance from Wind Turbine Low-Frequency Noise Emissions.* Colorado: SERI, U.S. Dept.of Energy.
[55] Otsego County Planning Commission. 2004. *Land Use Issues of Wind Turbine Generator Sites. Section 3.* "Low frequency noise." (http://www.msue.msu.edu/cdnr/otsegowindlf**noise**.pdf)
[56] *Danish Guidelines On Environmental Low Frequency Noise, Infrasound And Vibration.*

3. Fluctuating or Intermittent Noise

> ***Fluctuating noises may be far more annoying than predicted by average sound levels.***[57]

Oil and gas pump jacks can create intermittent noises. Pump jacks may operate and automatically shut off for specific periods of time. When improperly maintained, pump jacks can develop rubbing noises or squeaking noises.

Regular variations of sound pressure levels with time have been found to increase the annoying aspects of the noise. Research suggests that variations at about 4 per second are most disturbing (Zwicker 1989). Noises with very rapid onsets could also be more disturbing than indicated by their LAeq,T (Berry 1995; Kerry et al. 1997). [58]

When machinery operates in cycles, or when single vehicles pass by, the noise level increases and decreases rapidly. For each cycle of a machinery noise source, the noise level can be measured just as for continuous noise. However, the cycle duration must be noted. A single machinery cycle or a passing vehicle is called an event.

Measuring fluctuating and intermittent noise

Sound level meters average noise readings over a period of time. This period is typically longer than the period of fluctuating or intermittent noises, which leads to a loss of information. *It underemphasizes the significance of fluctuating noises*.[59]

For intermittent noise, it is necessary to take into account both the maximum sound pressure level and the number of noise events.[60]

To measure the noise of an event, the Sound Exposure Level is measured, combining level and duration into a single descriptor. The maximum sound pressure level may also be used. A number of similar events can be measured to establish a reliable average.[61]

Penalties for fluctuating and intermittent noise

As mentioned above, when dealing with low frequency noise, Broner and Leventhall (1983) suggest a penalty of 3 dB for noise that is fluctuating.[62]

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[57] Leventhall, G. 2003, *p*. 36.
[58] Berglund, B., Lindvall, T. and Schwela, D. 1999.
[59] Wallula Power Project DEIS. Feb. 2002. Section 3.9: Noise, p. 3.9-1. (http://www.efsec.wa.gov/wallula/eis/DEIS/3.9Noise.pdf)
[60] Berglund, B., Lindvall, T. and Schwela, D. 1999. p. xii.
[61] Breul and Kjaer. 2000. *Environmental Noise Handbook,* p. 14.
[62] Broner, N., and Leventhall, H. G. 1983. "Low frequency noise annoyance assessment by Low Frequency Noise Rating (LFNR) Curves," *Journal of Low Frequency Noise and Vibration* Vol.2, pp. 20-28. Cited in Leventhall, G. 2003, p. 66.

4. Impulsive Noise

> ***Impulsive noise. . . is brief and abrupt, and its startling effect causes greater annoyance than would be expected from a simple measurement of sound pressure level.*[63]**
>
> ~ *Environmental Noise Handbook,* Breul and Kjaer

Impulsive sounds, such as gun shots, hammer blows, explosions of fireworks or other blasts, are sounds that significantly exceed the background sound pressure level for a very short duration. Examples of impulsive noise in the oil and gas industry could include venting and flaring, pipe-on-pipe impacts due to unloading pipe at a well site, and pile driving.

Measuring Impulsive Noise

Typically each impulse lasts less than one second. Measurements with a sound meter set to 'Fast' response do not accurately represent impulsive sounds. To cope with this, a third time constant called **I** (for impulse) has been developed. The time constant of I is 35 milliseconds, which is sufficiently short to permit detection and display of transient (rapidly changing) noise in a way resembling the human perception of sound.[64]

In Alberta, Canada, measurements of the A-weighted impulse response setting sound level measurement and the A-weighted slow-response setting sound level are taken. If the difference is 10 dBA or less, the impulsive sound is not deemed significant.[65]

Penalties for Impulses

The maximum penalty for impulsiveness varies from country to country, and both subjective (based on the type of source, using a list enumerating noise sources such as hammering, explosives, etc.).and objective methods are used to determine the penalty.

In Denmark, a 5 dB penalty is added for impulsive noise,[66] while in France a penalty of 3, 5 or 10 dB is assessed, depending on the duration of the impulsive noise.[67]

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[63] Breul and Kjaer. 2000, p. 14.
[64] http://www.norsonic.com/web_pages/sound_level_assessment.html
[65] Alberta Energy and Utilities Board (EUB). November, 1999. *Noise Control Directive User Guide*. (Guide 38). p. 64.
[66] Leventhall, G. 2003, p. 72.
[67] Breul and Kjaer. 2000, p. 32.

ATTACHMENT 5: RATIONALE FOR ADDRESSING NOISE AND VIBRATION FROM ALL OIL AND GAS STAGES

Alberta, Canada is a major oil- and gas-producing region in North America. For the past few decades, Alberta has been and continues to be experiencing an increase in energy development. In the late 1990s, it was recognized that conflicts related to noise were arising between surface owners and oil and gas operations. Consequently, in 1999 the Alberta Energy and Utilities Board (EUB) established a Noise Control Directive.[68]

Along with the directive, the EUB created a Noise Control Directive User Guide, which is available on the EUB web site: http://www.**eub**.gov.ab.ca/bbs/products/**guide**s/g38.pdf

Page 2 of this attachment (an excerpt from EUB User Guide) outlines the history of the directive, and the application of the directive to pre-existing operations.

Page 3 of this attachment (also an excerpt from EUB User Guide) addresses issues related to drilling noise, and noise from heavy traffic, as well as vibrations from energy facilities.

Vibration

> ***Low frequency noise can couple with wood frame walls and windows to cause a mild but perceptible vibration. While these sound levels are virtually inaudible, the vibration may cause an adverse reaction to facility noise.***[69]

As mentioned in Attachment 4, low frequency noise is often perceived as a pressure sensation or vibration. Sometimes low frequency noise seems more like vibration than noise and it can cause structural vibration.[70]

Regulating Vibration

Vibrations in the environment are usually considered annoying at a level that is just slightly above the sensation threshold. This assumption forms the basis of the Danish guidelines on vibration. The Danish guidelines outline vibration measurement and assessment methods, and recommended vibration limits. The guidelines are available at: http://www.mst.dk/transportuk/02030000.htm#Noise%20measuring%20method

The Alberta Energy and Utilities Board does not have specific regulations governing vibration, but does acknowledge that is may be an issue, and states that if complaints

[68] Alberta Energy and Utilities Board (EUB). November, 1999. *Noise Control Directive User Guide*.
[69] Wallula Power Plant DEIS. February 2002 Section 3.9: Noise. P. 3.9-3
[70] Casella Stanger. 2001. *Low Frequency Noise.* (Technical research support for U.K. Department for Environment, Food and Rural Affairs Noise Programme). p. 4.

are received industry may be required to carry out corrective actions. (See page 3 of this Attachment)